Psychology

FOUNDATIONS AND FRONTIERS

Douglas A. Bernstein

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For Doris

To the memory of our beloved friend and co-author,
Alison Clarke-Stewart

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PREFACE

Psychology is a rich and varied science, covering the breadth and depth of human behavior—everything from fleeting reflexes to enduring memories, from falling asleep to falling in love. In my experience, most students enter the introductory course thinking that psychology concerns itself mainly with personality, psychological testing, mental disorders, psychotherapy, and other aspects of clinical psychology. Many of these students are surprised, then, when they find themselves reading about such topics as the structure of the brain, optical illusions, the effect of jet lag on athletic performance, AIDS and the immune system, and prenatal risk factors, to name just a few. Yet these are all topics under the umbrella that is psychology.

For all its diversity, psychology is also a remarkably integrated discipline whose subfields are linked through common interests and related research questions. As a psychologist and scholar, I created this new version of my introductory psychology textbook to portray the wide range of topics that make up the science of psychology. As a teacher, I focused on the essentials of the discipline—the core concepts of psychology that I hope will be especially accessible and interesting to students. And as the new title suggests, I have tried to describe the research foundations that have made psychological science what it is today, as well as the research frontiers that will be expanding the psychological science of tomorrow. I also tried to present all of this material through an integrated, active pedagogical system designed to help students get the most out of the text.

In the process, I remained dedicated to presenting a textbook that not only is clear and enjoyable to read but that also provides features to support the learning process in all students, regardless of their academic background. Specifically, I set these goals:

- To focus on topics that represent the full range of psychology, from cell to society, without overwhelming the reader with details.
- To provide many active learning exercises that invite students to work with the book's material in ways that can help them understand and remember it.
- To help students develop their ability to think critically and scientifically by examining the ways that psychologists have solved (or are trying to solve) fascinating puzzles of behavior and mental processes.
- To explain the content of psychology with an emphasis on the doing of psychology, grounding all discussions in current and classic research studies. (I help students appreciate the importance of research by exploring one study in detail in a special feature in each chapter.)

My discussion of research in psychology is also designed to remind students that although in some ways "people are people wherever you go," sociocultural factors—including gender, ethnicity, cultural background, and geography—often shape human behavior and mental processes. I repeatedly point out, therefore, that psychological research on the thinking styles, perceptual habits, psychological disorders, social pressures, and other phenomena seen in North America or Europe, for example, may or may not apply to other cultures, or even to subcultures within Western countries.

Rather than isolating discussion of sociocultural material in boxed features, I have woven it into every chapter so that students will encounter it repeatedly as they read. I introduce the importance of sociocultural factors in Chapter 1 and continue to reinforce it through coverage of such topics as the impact of culture and experience on perception (Chapter 4), classrooms across cultures (Chapter 5), ethnic differences in IQ (Chapter 8), social and cultural factors in sexuality (Chapter 10), gender differences in stress responses (Chapter 12), personality, culture, and human development (Chapter 11), gender and cultural differences in depression and suicide (Chapter 14), and cultural factors in aggression (Chapter 16), to cite just a few examples.

What's New in *Foundations and Frontiers*?

In creating *Psychology: Foundations and Frontiers*, I have sought to update, upgrade, and combine all the best features of my two previous introductory psychology textbooks. I hope that the result of my effort is a book that offers even more of what psychology faculty and their students want and need.

Organization

Designed for presentation in a single academic term, the book's chapter organization is similar but not identical to that found in both the brief and full-length versions that it replaces. There are eighteen chapters, including two formerly optional ones on industrial/organizational psychology and neuropsychology. The order of the chapters reflects the way I have always taught my introductory course, but I know that your preference for chapter sequencing may not match mine. Accordingly, you will find that each of the chapters works as a freestanding unit so that you may assign them in whatever order you wish. For example, many instructors prefer to teach the material on human development relatively late in the course, which is why it appears as Chapter 11. However, that chapter can be just as comfortably assigned earlier in the course.

An Emphasis on Active Learning

The emphasis on active learning in my earlier textbooks proved popular with faculty and students, so I have continued to emphasize it in the new book. You will find two kinds of "Try This" features throughout the book.

TRY THIS

- First, dozens of figure and photo captions help students understand and remember a psychological principle or phenomenon by suggesting ways they can demonstrate it for themselves. In the memory chapter, for example, a photo caption suggests that students show the photo to a friend and then ask questions about it to illustrate the operation of constructive memory. These captions are all identified with a Try This symbol.
- Second, I have placed Try This symbols in page margins at even more places where active learning opportunities occur in the narrative. At these points, I ask students to stop reading and try doing something to illustrate or highlight the psychological principle or phenomenon under discussion. For example, in the sensation and perception chapter, I ask the student to focus attention on various targets as a way of appreciating the difference between overt and covert attention shifts.

Active Review

My efforts to promote active learning can also be seen in two other elements of the book:

- A Linkages diagram at the end of each chapter is designed to help students understand and appreciate the ways that the chapter they have just read relates to other subfields of psychology.
- Twenty-item multiple-choice self-tests at the end of each chapter are focused on the applications as well as the definitions of principles, concepts, and phenomena.

Updated Content

As always, I have tried to present the latest as well as the most established results of basic and applied research on topics that are both important in psychological science and of high interest to students. Here is a chapter-by-chapter summary of just some the new or updated material you will find in this new book:

Chapter 1 (Introduction):

- Latest figures on employment settings for psychologists
- Latest figures on graduate degrees in psychology earned by men, women, and members of ethnic minority groups

Chapter 2 (Research Methods in Psychology):

- Latest research methods used to evaluate claims for the effectiveness of eye movement desensitization and reprocessing (EMDR) therapy

Chapter 3 (Biological Aspects of Psychology):

- New information on epigenetic influences in understanding the interacting roles of heredity and environment
- Updated research on stem cells and nerve growth factors and their uses in repairing brain damage
- Latest information on techniques for studying the brain, including commercial and forensic uses
- Latest information on electrical synapses
- Latest information on the use of electrical stimulation as therapy for brain damage
- Information about how experience can change the structure of the brain
- Latest information about adolescent brain development and behavior
- Latest information on optogenetics

Chapter 4 (Sensation and Perception):

- New information about age-related decreases in visual acuity
- New Try This exercise to help illustrate the trichromatic theory of color vision
- New information about loss of olfaction as an early indicator of neurological disorder
- Latest information about research on pheromones in humans
- Latest information about research on acupuncture
- New information about benign paroxysmal positional vertigo
- New information about the sense of equilibrium and astronautics
- Expanded information about the effects of motivation on top-down processing
- Updated and expanded information about the effects of cell phones, texting, personal music players, and laptop computer use on attention—especially drivers and pedestrians
- New Try This exercise on touch sensations

Chapter 5 (Learning):

- Latest information about the mechanisms of classical conditioning
- Latest information about the effects of reinforcers in the brain
- Updated information on applications of operant conditioning
- Updated information on the biological basis of observational learning

- Latest research on the impact of violent television and video games
- Updated information on active learning methods in the classroom
- Latest research about e-media for delivery of college class materials
- Updated information on classrooms across cultures

Chapter 6 (Memory):

- Updated information about scents as memory cues
- Updated information about false memories and eyewitness testimony
- Latest research on the biological basis of memory

Chapter 7 (Thought and Language):

- Updated information on judge and jury decision making
- New section on building effective problem solving skills
- Latest information on advances in artificial intelligence
- Latest information about creativity and its biological roots
- New information about effects of physical environment on creative thinking
- Latest information on decision making in risky situations
- Updated information on group problem solving and decision making
- Latest information about bilingualism and long-term effects on cognition

Chapter 8 (Intelligence):

- Updated information on extraneous influences on intelligence test results
- New research on stereotype threat
- Updated information on the interaction of environmental and genetic factors in intelligence, and on group differences in IQ

Chapter 9 (Consciousness):

- Revised information on the number and labels for stages of sleep
- Updated information about nonconscious and unconscious mental processes
- Updated information about sleep disorders and treating sleep disorders
- New information about the functions of REM sleep and its effect on creativity
- New information about effects of sleep deprivation to reduce impact of trauma
- Latest information about chronotypes, and the "clock genes" that seem to drive them
- Updated information about applications of hypnosis and effects of meditation
- Updated information about neural effects of drugs, including epigenetic effects
- Latest information about the long-term effects of caffeine, nicotine, and opiates
- Latest information on the debate over medical uses of marijuana

Chapter 10 (Motivation and Emotion):

- New information about how eating habits have changed over centuries
- New Try This exercise to illustrate the facial feedback hypothesis
- Latest information on lie detection
- New section on intrinsic and extrinsic sources of motivation
- Updated information about hormonal influences on eating behavior
- Updated information about neurotransmitters and eating behavior
- Latest figures on obesity and new material on its causes and on prevention efforts
- Updated material on anorexia nervosa and bulimia
- Updated information about gender differences in sexuality
- Latest information about well-being and its relation to achievement
- New coverage of the conceptual act model of emotion
- New research on situational factors in reading facial expressions

Chapter 11 (Human Development):

- Updated information about behavioral genetics, genetic influences on development, and the influence of environmental factors on genetic expression
- Updated information on the effects of electronic and social media on infant, child, and adolescent development
- Updated information about midlife transition and the "sandwich generation"
- New and updated information about intellectual abilities in late adulthood, including risk factors and protective or mediating influences
- Updated information about the impact of alcohol, nicotine, and other toxins on infant development

- Latest information about infant thinking and behavior during the sensorimotor stage
- Latest information about influences of nature and the environment on children's brain development
- Updated information about culture and cognitive development
- Updated information about poverty as a developmental danger
- Updated information on long-term effects of early attachment styles
- Updated information about parenting styles and their effects on child development
- Updated information on the development of infants' theory of mind
- Updated statistics on adolescent sexuality and teenage pregnancy
- Updated information about emotional development during emerging adulthood
- New and updated information about longevity

Chapter 12 (Health, Stress, and Coping):

- New information about the long-term effects of stressors early in life
- New statistics on worldwide deaths due to health-damaging behaviors
- Updated information about the cognitive effects of stressors on decision making and problem solving
- Updated information about posttraumatic stress disorder (PTSD)
- New information about the relationship among socioeconomic status, lack of control, and premature death in lower socioeconomic groups
- Updated information about associations between social networks and happiness
- Updated information about personality and resistance to stress
- Updated information about identifying people at elevated risk for health problems
- Updated information about health beliefs and efforts to change them

Chapter 13 (Personality):

- New information about empirical research on psychodynamic theory
- Updated information about applications and biological basis of Five Factor Theory of personality
- New research on Gray's reinforcement sensitivity theory
- Updated information on personality research in nonhumans
- Updated information about the influence of genetics and epigenetics on personality traits
- Updated information about situational factors and the expression of personality traits
- Updated information about the possible impact of early attachment style in childhood and adulthood
- Updated information about the behavioral correlates of internal versus external locus of control
- Updated information about the effects of self-efficacy on achievement and well-being
- New information about the impact of positive psychology in personality
- Updated information about culture and personality
- Updated information about the latest edition of the Minnesota Multiphasic Personality Inventory (MMPI-2 RF)

Chapter 14 (Psychological Disorders):

- Updated information on the incidence of psychological disorders
- Presentation of the new DSM-5 and the forthcoming ICD-11, and information about debates surrounding the changes made in DSM-5
- Updated information on diagnostic reliability and validity
- Updated information about bias in psychological diagnosis
- Updated coverage of causes of psychological disorders, including epigenetics
- New information about the effects of the media-driven attitudes on people's understanding and response to psychological disorders
- Updated information about culture-specific disorders
- Inclusion of *cyberchondria,* a term similar to "medical students' syndrome"
- Updated information about somatic symptom disorders and dissociative disorders
- Updated statistics about the incidence of, and risk factors for, suicide
- Updated information about hallucinations in schizophrenia
- Updated statistics about the incidence of autistic spectrum disorders
- Updated information about mental illness and the law

Chapter 15 (Treatment of Psychological Disorders):

- Updated information about the prevalence of psychological treatments in adults and children in the United States
- Updated information about research on the effectiveness of psychotherapy
- New and updated information about the evolution of evidence-based practice and empirically supported therapies
- Updated information about cultural diversity training for therapists
- Updated information about therapeutic effects of repetitive transcranial magnetic stimulation (rTMS) therapy, deep brain stimulation, and optogenic stimulation
- Updated information about effectiveness, side effects, and costs and benefits of antidepressant drugs
- Updated information about human diversity and drug treatments
- Updated information about the effectiveness of psychoactive medications for mental disorders and their value in combination with psychotherapy
- Updated information about community psychology
- New and updated information about self-help and Internet-based therapy efforts

Chapter 16 (Social Psychology):

- New Try This exercises on attitude similarity and helping behavior
- New information about factors contributing to, or mediating, feelings of empathy
- New information about how social media affect feelings of attraction
- Updated information about terror management theory
- Updated information about the speed, strength, and accuracy of first impressions and factors that influence them
- Updated information about prejudice and its possible causes
- Updated information on the contact hypothesis and the mere-exposure effect in reducing prejudice
- Updated information on factors that contribute to attraction
- Updated information on gender and conformity
- Updated statistics about aggressive behavior in the United States
- Updated information about the possible biological and social factors in aggression
- New information on neuroimaging studies in social psychology

Chapter 17 (Industrial and Organizational Psychology):

- Expanded history of industrial and organizational psychology
- Updated employment statistics for industrial and organizational psychologists
- Updated information about factors that influence job satisfaction
- Updated statistics about workplace violence
- Updated information about leader and follower behaviors
- Updated information about leader-member exchange (LMX) theory

Chapter 18 (Neuropsychology):

- Updated information about how the interconnections of modules in the brain contribute to specific abilities and behaviors
- Updated information about the effects of strokes and the latest rehabilitation approaches
- Updated information about traumatic brain injuries and memory loss
- New information about traumatic brain injuries in sports
- Updated information about consciousness disturbances
- Updated information about brain activity and prosopagnosia
- Updated information about language disorders and frontotemporal degeneration
- Updated statistics about dementia
- New and updated information about the causes and symptoms of Alzheimer's disease
- Latest information about treatments for Alzheimer's disease

Special Features

Several special features of *Foundations and Frontiers* are designed to promote efficient learning and mastery of the material. These include, in each chapter, an integrated pedagogical system as well as sections on Thinking Critically, Focus on Research Methods, and Linkages.

An Integrated Pedagogical System

An integrated pedagogical system is designed to help students get the most out of their reading. Based on the PQ4R study system (discussed in Chapter 6, Memory), learning aids in each chapter include the following elements.

Preview Section To help students survey and question the material, each chapter opens with an outline and a brief preview statement. A question related to the key topic of each main section of the chapter appears at the beginning of each of those main sections, and these questions appear again at the end of the chapter, where they help to organize the chapter summary.

Margin Glossary Key terms are defined in the margin of the page where they appear, reinforcing core concepts without interrupting the flow of reading. All key terms match those in the American Psychological Association's *Thesaurus of Psychological Index Terms* (11th ed.) and in the *APA Dictionary of Psychology*. I believe that using key terms from these sources will help students do their own research by making it easier for them to use key-term searches in the field's most popular databases (PsycINFO & PsycARTICLES). Using these key terms will also improve students' abilities to transfer terms learned in introductory courses to their work in advanced courses. (I have also revised many of the phonetic guides to make it even easier for students to correctly pronounce unfamiliar key terms as well as other terms whose pronunciation is not immediately obvious.)

Instructional Captions Captions for all figures, tables, photographs, and cartoons reiterate core concepts and help students learn to interpret visual information. And, as mentioned earlier, many of these captions prompt students to engage in various kinds of active learning experiences.

In Review Charts In Review study charts summarize information in a convenient tabular format. I have placed two or three In Review charts strategically in each chapter to help students synthesize and assimilate large chunks of information—for example, on drug effects, key elements in personality theories, and stress responses and mediators. Fill-in-the-blank self-testing items at the bottom of each In Review chart further aid student learning and review of the chapter material. The answer key for these items can be found at the back of the book.

Active Review As mentioned earlier, the Active Review section at the end of each chapter includes

- A Linkages diagram containing questions that illustrate three of the ways that material in each chapter is connected to other chapters in the book.
- A chapter summary organized around major topic headings and the related preview questions. The summary is presented in short, easy-to-read paragraphs that focus on the topics introduced by chapter subheadings.
- A twenty-item multiple-choice test designed to help students assess their understanding of the chapter's key points prior to taking quizzes and exams.

Thinking Critically

A special Thinking Critically section in each chapter helps students hone their skills in this vital area. My approach centers on describing research on psychological phenomena in a way that reveals the logic of the scientific method, identifies possible flaws in design or interpretation, and leaves room for more questions and further research. In other words, as an author-teacher, I try to model critical thinking processes for my readers. The Thinking Critically sections are designed to make these processes more explicit and accessible by providing readers with a framework for analyzing evidence before drawing conclusions. The framework is built around five questions that the reader should find useful in analyzing not only published psychological research, but other forms of communication as well, including political speeches, advertising claims, and appeals for contributions. These five questions first appear in Chapter 1, where I introduce the importance of critical thinking, and they are repeated in every chapter's Thinking Critically section.

1. What am I being asked to believe or accept?
2. What evidence is available to support the assertion?
3. Are there alternative ways of interpreting the evidence?
4. What additional evidence would help evaluate the alternatives?
5. What conclusions are most reasonable?

Using this simple yet powerful framework, I explore issues such as subliminal persuasion, recovered memories, and the origins of sexual orientation, to name just a few. Page xv includes a complete list of the Thinking Critically features.

Focus on Research Methods

Psychological scientists have helped us better understand behavior and mental processes through their commitment to empirical research. They have posed vital questions about psychological phenomena and have designed research that can answer (or at least illuminate) those questions. In Chapter 2, I introduce readers to the methods of scientific research and to basic research designs in psychology. Every subsequent chapter features a Focus on Research Methods section that highlights a particular research study to help students appreciate the value of research and the creativity with which psychologists have conducted it. Like the Thinking Critically sections, the Focus on Research Methods features are organized around five questions designed to help readers organize their thinking about research questions and research results.

1. What was the researcher's question?
2. How did the researcher answer the question?
3. What did the researcher find?
4. What do the results mean?
5. What do we still need to know?

These Focus on Research Methods sections help students see how psychologists have used experiments, correlational studies, surveys, observations, and other designs to explore phenomena such as learned helplessness, infant cognition, evolutionary theories of helping, and human sexual behavior. A full list of the Focus on Research features appears on page xv.

Linkages

In my experience, introductory psychology students are better able to appreciate the scope of our discipline when they look at it not as a laundry list of separate topics but as an interrelated set of subfields, each of which contributes to—and benefits from—the work being done in all the others. To help students see these relationships, I have built into the book an integrating tool called Linkages. There are two elements in the Linkages program.

- ***Linkages diagrams*** At the end of each chapter is a Linkages diagram, which presents a set of questions that illustrate three of the ways that material in the chapter is related to other chapters in the book. For example, the Linkages diagram in Chapter 3, "Biological Aspects of Psychology," contains questions that show how biological psychology is related to consciousness ("Does the brain shut down when I sleep?"), human development ("How do our brains change over a lifetime?"), and treatment of psychological disorders ("How do drugs help people diagnosed with schizophrenia?"). These diagrams are designed to help students keep in mind how the content of each chapter fits into psychology as a whole. To introduce the concept of Linkages, the diagram in Chapter 1 appears within the body of the chapter.
- ***Linkages sections*** One of the questions in each chapter's Linkages diagram reminds the student of the chapter's discussion of that question in a special section entitled, appropriately enough, Linkages (see page xv for a complete list of Linkages sections).

These elements combine with the text narrative to highlight the network of relationships among psychology's subfields. This Linkages program is designed to help students see the "big picture" of psychology, no matter how many chapters their instructor assigns or in what sequence.

Teaching and Learning Support Package

Many useful instructional and pedagogical materials have been developed to support this textbook and the introductory course. These are designed to enhance and maximize the teaching and learning experience.

MindTap for *Psychology: Foundations and Frontiers*

MindTap for *Psychology: Foundations and Frontiers* engages and empowers students to produce their best work—consistently. By seamlessly integrating course material with videos, activities, apps, and much more, MindTap creates a unique learning path that fosters increased comprehension and efficiency.

For students:

- MindTap delivers real-world relevance with activities and assignments that help students build critical thinking and analytic skills that will transfer to other courses and their professional lives.
- MindTap helps students stay organized and efficient with a single destination that reflects what's important to the instructor, along with the tools students need to master the content.
- MindTap empowers and motivates students with information that shows where they stand at all times—both individually and compared to the highest performers in class.

Additionally, for instructors, MindTap allows you to:

- Control what content students see and when they see it with a learning path that can be used as-is or matched to your syllabus exactly.
- Create a unique learning path of relevant readings and multimedia and activities that move students up the learning taxonomy from basic knowledge and comprehension to analysis, application, and critical thinking.
- Integrate your own content into the MindTap Reader using your own documents or pulling from sources like RSS feeds, YouTube videos, websites, Googledocs, and more.
- Use powerful analytics and reports that provide a snapshot of class progress, time in course, engagement, and completion.

Available Supplements

Cengage Learning Testing, powered by Cognero

Cengage Learning Testing Powered by Cognero® is a flexible, online system that allows you to: import, edit, and manipulate content from the text's test bank or elsewhere, including your own favorite test questions; create multiple test versions in an instant; and deliver tests from your LMS, your classroom, or wherever you want.

Online Instructor's Manual

The instructor's manual (IM) contains a variety of resources to aid instructors in preparing and presenting text material in a manner that meets their personal preferences and course needs. It presents suggestions and resources to enhance and facilitate learning.

Online PowerPoints

These vibrant, Microsoft PowerPoint lecture slides provide concept coverage to assist you with your lecture.

Acknowledgments

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Doug Bernstein

Introducing Psychology

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Preview

All of the following people hold truly interesting jobs. What do you think they studied to qualify for those jobs? See if you can correctly match each person in the left column with their field of study from the right column.

People	Fields of Study
Anne Marie Apanovitch works for a major drug company and determines which of their marketing strategies are most effective in promoting sales.	Engineering
Rebecca Snyder studies the giant pandas at Zoo Atlanta in an effort to promote captive breeding and ultimately increase the wild population of this endangered species.	Criminal Justice
Michael Moon's job at a software company is to find new ways to make websites easier for consumers to use.	Advertising
Sharon Lundgren, founder of Lundgren Trial Consulting, Inc., prepares witnesses to testify in court and teaches attorneys how to present evidence in the most convincing ways.	Psychology
Evan Byrne investigates the role of memory lapses, fatigue, errors, and other human factors in causing airplane crashes for the U.S. National Transportation Safety Board.	Computer Science
Captain Karen Orts, chief of mental health services at a U.S. Air Force base, provides psychotherapy to military personnel suffering combat-related stress disorders, and teaches leadership courses to commissioned and noncommissioned officers.	Zoology

Because Captain Orts offers psychotherapy, you probably guessed that she is a psychologist, but what academic field did you associate with Rebecca Snyder, who studies giant pandas? It would have been perfectly reasonable to assume that she is a zoologist, but she, too, is a psychologist. So is Evan Byrne, whose work on website design might suggest that he was a computer science major. And although Sharon Lundgren spends her time working with witnesses and conducting mock trials, she is a psychologist, not a lawyer. The fact is that *all* these people are psychologists! They may not all fit your ideas of what psychologists do, but as you will see in this chapter and throughout this book, psychology is much broader and more diverse than you may have expected. Reading this book will give you a fuller understanding of psychology, and we hope that you will find our field as fascinating as we do!

This chapter begins our exploration of psychology with a brief look at some of its interrelated specialty areas, or *subfields*. We then tell the story of how psychology came to be and review several theories and approaches that guide psychologists in their work. We also point out how the activities of psychologists in virtually every subfield are affected by human diversity, especially by age, gender, ethnicity, and other individual characteristics encountered in today's multicultural societies.

THE WORLD OF PSYCHOLOGY: AN OVERVIEW

What is psychology and how did it grow?

Psychology is the science that studies behavior and mental processes and seeks to apply that study in the service of human welfare. It is a science that covers a lot of territory, as illustrated by the vastly different jobs that occupy the six psychologists we described. They are all psychologists because they are all involved in studying, predicting, improving, or explaining some aspect of behavior and mental processes. Some of the world's half-million

Psychology The science of behavior and mental processes.

psychologists focus on what can go wrong in behavior and mental processes—psychological disorders, problems in childhood development, stress-related illnesses, and the like—while others study what goes right. They explore, for example, the factors that lead people to be happy and satisfied with their lives, to achieve at a high level, to be creative, to help others, and to develop their full potential as human beings. This focus on what goes right, on the things that make life most worth living, has become known as **positive psychology** (e.g., Wood & Tarrier, 2010; Waterman, 2013), and you will see many examples of it in the research described throughout this book.

TRY THIS

To appreciate how many things come under the umbrella of *behavior and mental processes*, think for a moment about how you would answer the question, Who are you? Would you answer by describing your personality, the sharpness of your vision or hearing, your interests and goals, your job skills and accomplishments, your IQ, your cultural background, or your social skills? Perhaps you would describe a physical or psychological problem that bothers you. You could list these and dozens of other things about yourself, and every one of them would reflect some aspect of what psychologists mean by behavior and mental processes. When psychologists focus their work on particular aspects of behavior and mental processes, they enter one of psychology's many subfields. Let's take a quick look at the typical interests and activities of psychologists in these subfields now; we will focus on many of them in more detail in later chapters.

Subfields of Psychology

When psychologists choose to focus their attention on certain aspects of behavior and mental processes, they enter one of psychology's subfields. Let's take a quick look at the typical interests and activities of psychologists in each subfield. We will describe their work in more detail in later chapters.

Biological Psychology

Biological psychologists, also called *physiological psychologists*, study how the brain and the body's biological processes affect, and are affected by, behavior and mental processes. Have you ever had the odd feeling that a new experience, such as entering a new house, has actually happened to you before? Biological psychologists studying this illusion of *déjà vu* (French for "already seen") suggest that it may be due to a temporary malfunction in the brain's ability to combine incoming information from the senses, creating the impression of two "copies" of a single event (Brown, 2004). In the chapter on biological aspects of psychology, we describe biological psychologists' research on many other topics, such as how your brain controls your movements and speech and what organs help you cope with stress and fight disease.

Cognitive Psychology

TRY THIS Stop reading for a moment and look left and right. Your ability to follow this suggestion, to recognize whatever you saw, and to understand the words you are reading right now are the result of mental, or *cognitive*, abilities. Those abilities allow you to receive information from the outside world, understand it, and act on it. **Cognitive psychologists** (some of whom prefer to be called *experimental psychologists*) study mental abilities such as sensation and perception, learning and memory, thinking, consciousness, intelligence, and creativity. Cognitive psychologists have found, for example, that we don't just receive incoming information—we mentally change it. Notice that the drawing in Figure 1.1 stays physically the same, but two different versions emerge, depending on which of its features *you* emphasize.

Applications of cognitive psychologists' research are all around you. The work of those whose special interest is **engineering psychology**—also known as *human factors*—has helped designers create computer keyboards, mobile phones, MP3 players, websites, aircraft instrument panels, automobile navigation systems, nuclear power plant controls,

positive psychology A field of research that focuses on people's positive experiences and characteristics, such as happiness, optimism, and resilience.

biological psychologists Psychologists who analyze the biological factors influencing behavior and mental processes. Also called *physiological psychologists.*

cognitive psychologists Psychologists who study the mental processes underlying judgment, decision making, problem solving, imagining, and other aspects of human thought or cognition. Also called *experimental psychologists.*

engineering psychology A field in which psychologists study human factors in the use of equipment and help designers create better versions of that equipment.

and even TV remotes that are more logical, easier to use, and less likely to cause errors. You will read more about human factors research and many other aspects of cognitive psychology in several chapters of this book.

Developmental Psychology

Developmental psychologists describe how behavior and mental processes change from birth through old age and try to understand the causes and effects of those changes (see Figure 1.2). Their research on the development of memory and other mental abilities, for example, is used by judges and attorneys in deciding how old a child has to be in order to serve as a reliable witness in court or to be able to choose in a responsible way which divorcing parent to live with. The chapter on human development describes other research by developmental psychologists and how it is being applied in areas such as parenting, evaluating day care, and preserving mental capacity in elderly people.

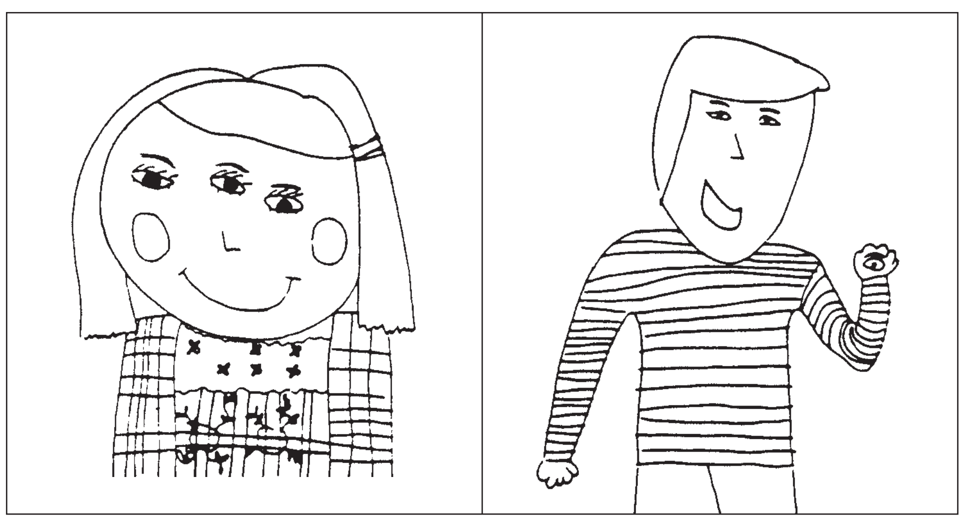
Personality Psychology

Personality psychologists study individuality—the unique features that characterize each of us. Using personality tests, some of these psychologists seek to describe how your own combination of personality traits, like your fingerprints, differs from everyone else's in terms of traits such as openness to experience, emotionality, reliability, agreeableness, and sociability. Others study the combinations of personality traits that are associated with the appearance of ethnic prejudice, depression, bullying, or vulnerability to stress-related health problems. And personality psychologists interested in positive psychology are trying to identify and understand the human strengths that help people to remain optimistic, even in the face of stress or tragedy, and to find happiness in their lives (Snyder & Lopez, 2009).

FIGURE 1.1
Husband and Father-in-Law

This figure is called "Husband and Father-in-Law" (Botwinick, 1961) because you can see an old man or a young man, depending on how you mentally organize its features. The elderly father-in-law faces to your right and is turned slightly toward you. He has a large nose, and the dark areas represent his coat pulled up to his protruding chin. However, the tip of his nose can also be seen as the tip of a younger man's chin; the younger man is in profile, also looking to your right, but away from you. The old man's mouth is the young man's neckband. Both men are wearing a broad-brimmed hat.

From American Journal of Psychology. *Copyright 1961 by the Board of Trustees of the University of Illinois. Used with permission of the University of Illinois Press.*



Drawing by a nine-year-old **(A)**

Drawing by an eleven-year-old **(B)**

FIGURE 1.2
Where Would You Put a Third Eye?

In a study of how thinking develops, children were asked to show where they would place a third eye if they could have one. Nine-year-old children, who were still in an early stage of mental development, drew the extra eye between their existing eyes, "as a spare." Having developed more advanced thinking abilities, eleven-year-olds drew the third eye in more creative places, such as the palm of their hand "so I can see around corners."

From Shaffer, Developmental psychology: Theory, research and applications. *Copyright © 1985 Wadsworth, a part of Cengage Learning Inc. Reproduced by permission. www.cengage.com/permissions*

developmental psychologists Psychologists who seek to understand, describe, and explore how behavior and mental processes change over a lifetime.

personality psychologists Psychologists who study the characteristics that make individuals similar to or different from one another.

Getting Ready for Surgery

Health psychologists have learned that when patients are mentally prepared for a surgical procedure, they are less stressed by it and recover more rapidly. Their research is now routinely applied in hospitals through programs in which children and adults are given more information about what to expect before, during, and after their operations.

Dorothy Littell Greco/The Image Works

Clinical, Counseling, Community, and Health Psychology

Clinical psychologists and **counseling psychologists** conduct research on the causes and treatment of mental disorders and offer services to help troubled people overcome those disorders. Their research is improving our understanding of the genetic and environmental forces that shape disorders ranging from anxiety and depression to schizophrenia and autism, and it is providing guidance to therapists about which treatment methods are likely to be most effective with each category of disorder.

Community psychologists work to ensure that psychological services reach the homeless and others who need help but tend not to seek it. They also try to prevent psychological disorders by promoting people's resilience and other personal strengths and by working with community leaders and neighborhood organizations to improve local schools and reduce the crime, poverty, and other stressful conditions that often lead to psychological disorders.

Health psychologists study the relationship between behaviors such as smoking or lack of exercise and the likelihood of suffering heart disease, stroke, cancer, or other health problems. They also explore the impact that illnesses such as diabetes, cancer, or multiple sclerosis can have on people's behavior, thinking, emotions, and family relationships. Their research is applied in programs that help people to cope effectively with illness, as well as to reduce the risk of cancer, heart disease, and stroke by changing the behaviors that put them at risk.

Generally, clinical psychologists have Ph.D. degrees in psychology; counseling, community, and health psychologists have either a Ph.D. or a master's degree in psychology. All of these psychologists differ from *psychiatrists*, who are medical doctors specializing in abnormal behavior (psychiatry). You can read more about the work of clinical, counseling, community, and health psychologists in the chapters on health, stress, and coping; psychological disorders; and treatment of psychological disorders.

Educational and School Psychology

Educational psychologists conduct research and develop theories about teaching and learning. The results of their work are applied in programs designed to improve teacher training, refine school curricula, reduce dropout rates, and help students learn more efficiently and remember what they learn. For example, they have supported

clinical and counseling psychologists Psychologists who seek to assess, understand, and change abnormal behavior.

community psychologists Psychologists who work to obtain psychological services for people in need of help and to prevent psychological disorders by working for changes in social systems.

health psychologists Psychologists who study the effects of behavior and mental processes on health and illness and vice versa.

educational psychologists Psychologists who study methods by which instructors teach and students learn and who apply their results to improving those methods.

Got a Match?

Some commercial matchmaking services apply social psychologists' research on interpersonal attraction in an effort to pair up people whose characteristics are most likely to be compatible.

Jeff Morgan 03 / Alamy

the use of the "jigsaw" technique, a type of classroom activity (described in the social psychology chapter) in which children from various ethnic groups must work together to complete a task or solve a problem. These cooperative experiences appear to promote learning, generate mutual respect, and reduce intergroup prejudice (Aronson, 2004).

School psychologists once specialized in IQ testing, diagnosing learning disabilities and other academic problems, and setting up programs to improve students' achievement and satisfaction in school. Today, however, they are also involved in activities such as preventing bullying, early detection of students' mental health problems, and crisis intervention following school violence.

Social Psychology

Social psychologists study the ways that people think about others and how people influence one another. Their research on persuasion has been applied to the creation of safe-sex advertising campaigns designed to stop the spread of AIDS. Social psychologists also explore how peer pressure affects us, what determines whom we like (or even love), and why and how prejudice forms. They have found, for example, that although we may pride ourselves on not being prejudiced, we may actually hold unconscious negative beliefs about certain groups that affect the way we relate to people in those groups. The chapter on social psychology describes these and many other examples of this area of research.

Industrial and Organizational Psychology

Industrial and organizational psychologists conduct research on leadership, stress, competition, pay scales, and other factors that affect the efficiency, productivity, and satisfaction of people in the workplace. They also explore topics such as worker motivation, work team cooperation, conflict resolution procedures, and employee selection methods. Learning more about how businesses and industrial organizations work—or fail to work—allows industrial and organizational psychologists to make evidence-based recommendations for helping them work better. Today, companies all over the world are applying research from industrial and organizational psychology to

school psychologists Psychologists who test IQs, diagnose students' academic problems, and set up programs to improve students' achievement.

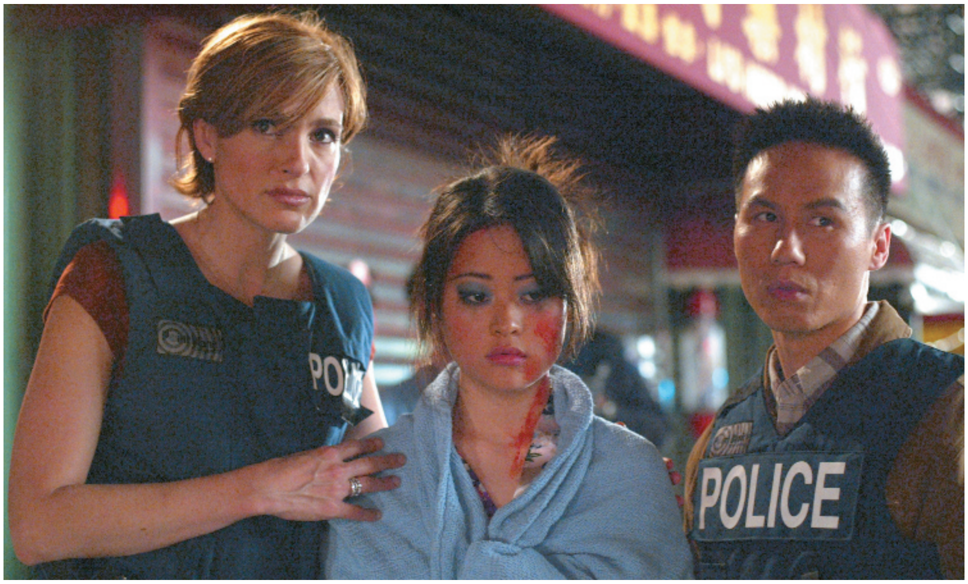
social psychologists Psychologists who study how people influence one another's behavior and mental processes, individually and in groups.

industrial and organizational psychologists Psychologists who study ways to improve efficiency, productivity, and satisfaction among workers and the organizations that employ them.

Forensic Psychology

Forensic psychologists may assist police and other agencies in profiling criminals, evaluating the mental competence of defendants, participating in jury selection, and performing many other tasks related to psychology and the law. Actor B. D. Wong's performance as forensic psychiatrist Dr. George Huang on *Law and Order: SVU* was so accurate that the Media Psychology division of the American Psychological Association gave the show its 2004 Golden Psi award for excellence in the fictional portrayal of mental health professionals.

Will Hart/NBC/Photofest



promote the development of *positive organizational behavior*. The results include more effective employee training programs, ambitious but realistic goal-setting procedures, fair and reasonable evaluation tools, and incentive systems that motivate and reward outstanding performance.

Quantitative Psychology

Quantitative psychologists develop and use statistical tools to analyze vast amounts of data collected by their colleagues in all of psychology's subfields. These tools help evaluate the quality of psychological tests, tracing the relationships between childhood experiences and adult behaviors, and even estimating the relative contributions of heredity and environment in shaping intelligence. To what extent are people born smart—or not so smart—and to what extent are their mental abilities created by their environments? This is one of the hottest topics in psychology today, and quantitative psychologists are right in the middle of it.

Other Subfields

Our list of psychology's subfields is still not complete. There are **sport psychologists**, who use visualization and relaxation training programs, for example, to help athletes reduce excessive anxiety, focus attention, and make other changes that let them perform at their best. **Forensic psychologists** assist in jury selection, evaluate defendants' mental competence to stand trial, and deal with other issues involving psychology and the law. And **environmental psychologists** study the effects of the environment on people's behavior and mental processes. The results of their research are applied by architects and interior designers as they plan or remodel residence halls, shopping malls, auditoriums, hospitals, prisons, offices, and other spaces to make them more comfortable and functional for the people who will occupy them. There are also neuropsychologists, military psychologists, consumer psychologists, rehabilitation psychologists, and more.

Further information about the subfields we have mentioned—and some that we haven't—is available on the websites of the American Psychological Association and the Association for Psychological Science.

Where do the psychologists in all these subfields work? Table 1.1 contains a summary of where the approximately 172,000 psychologists in the United States find employment, as well as the kinds of things they typically do in each setting.

quantitative psychologists Psychologists who develop and use statistical tools to analyze research data.

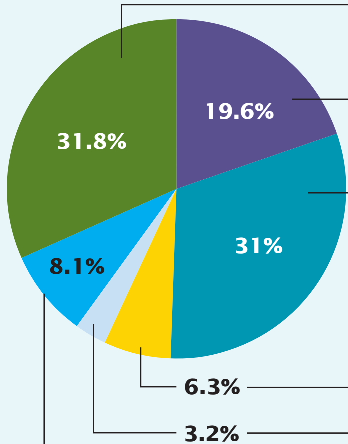
sport psychologists Psychologists who explore the relationships between athletic performance and such psychological variables as motivation and emotion.

forensic psychologists Psychologists who assist in jury selection, evaluate defendants' mental competence to stand trial, and deal with other issues involving psychology and the law.

environmental psychologists Psychologists who study the effects of the physical environment on behavior and mental processes.

TABLE 1.1 TYPICAL ACTIVITIES AND WORK SETTINGS FOR PSYCHOLOGISTS

The fact that psychologists can work in such a wide variety of settings and do so many interesting—and often well-paying—jobs helps account for the popularity of psychology as an undergraduate major (Goldstein, 2010; Dillow & Hoffman, 2008; National Center for Education Statistics, 2014). Psychology courses also provide excellent background for students planning to enter medicine, law, business, and many other fields.



Work Setting	Typical Activities
Colleges, universities, and professional schools	Teaching, research, and writing, often in collaboration with colleagues from other disciplines
Mental health facilities (e.g., hospitals, clinics, counseling centers)	Testing and treatment of children and adults
Private practice (alone or in a group of psychologists)	Testing and treatment of children and adults; consultation to business and other organizations
Business, government, and organizations	Testing potential employees; assessing employee satisfaction; identifying and resolving conflicts; improving leadership skills; offering stress management and other employee assistance programs; improving equipment design to maximize productivity and prevent accidents
Schools (including those for intellectually disabled and emotionally disturbed children)	Testing mental abilities and other characteristics; identifying problem children; consulting with parents; designing and implementing programs to improve academic performance
Other	Teaching prison inmates; research in private institutes; advising legislators on educational, research, or public policy; administering research funds; research on effectiveness of military personnel; and so on

Source: Employment characteristics of APA members by Membership status, 2012.

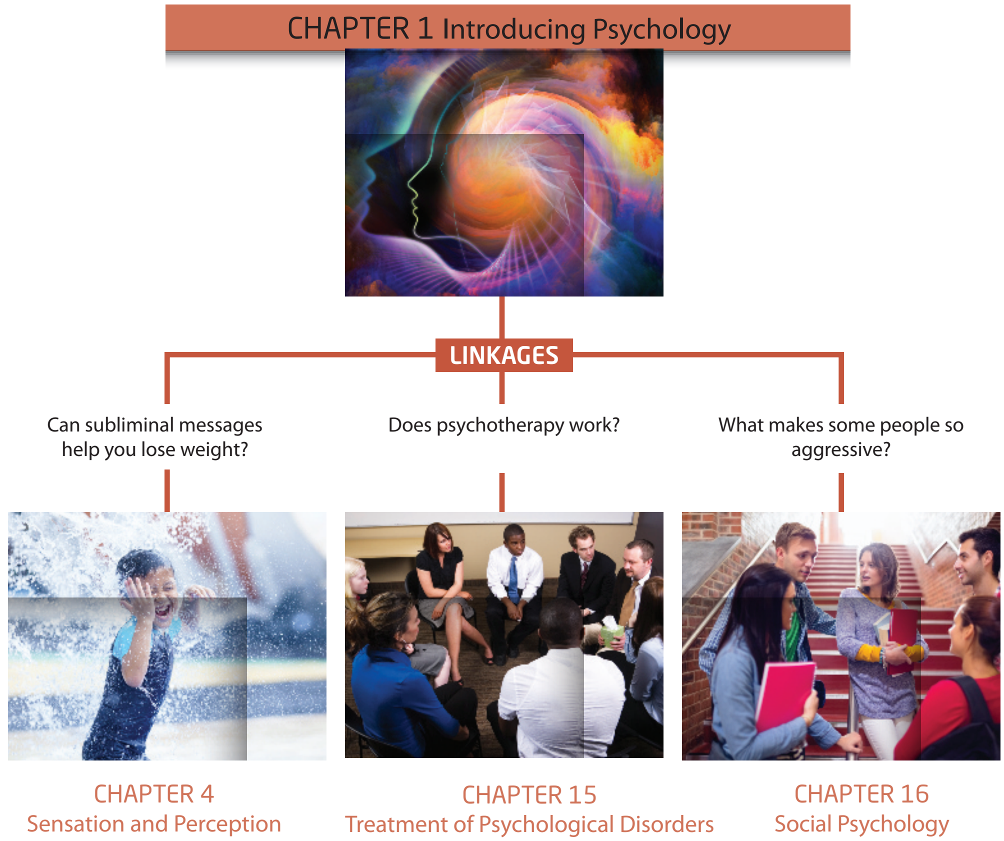
Linkages Within Psychology and Beyond

We have listed psychology's subfields as though they were separate, but they often overlap, and so do the activities of the psychologists working in them. When developmental psychologists study the changes that take place in children's thinking skills, for example, their research is linked to the research of cognitive psychologists. Similarly, biological psychologists have one foot in clinical psychology when they look at how chemicals in the brain affect the symptoms of depression. And when social psychologists apply their research on cooperation to promote group learning activities in the classroom, they are linking up with educational psychology. Even when psychologists work mainly in one subfield, they are still likely to draw on, and contribute to, knowledge in other subfields.

So to understand psychology as a whole, you must understand the linkages between its subfields. In this book, to help you recognize these linkages, we highlight three of them in a Linkages diagram at the end of each chapter—similar to the one shown here. Each linkage is represented by a question that connects two subfields, and the chapter given is where you can read more about each question (look for "Linkages" symbols in those chapters). We pay particular attention to one of the questions in each diagram by discussing it in a special Linkages section. If you follow the linkages in these diagrams, you will see more clearly how psychology's many subfields are interconnected. You find this kind of detective work to be interesting, and it will lead you to see many other linkages that we did not mention. Tracing linkages might even improve your grade in the course, because it is often easier to remember material in one topic by relating it to linked material in other topics.

LINKAGES

If you follow the many linkages among psychology's subfields as you read this book, you will come away not only with threads of knowledge about each subfield but also with an appreciation of the fabric of psychology as a whole. We discuss one linkage in detail in each chapter in a special Linkages section.



Links to Other Fields

Just as psychology's subfields are linked to one another, psychology itself is linked to many other fields. Some of these linkages are based on interests that psychologists share with researchers from other disciplines. For example, psychologists work with computer scientists to create artificial intelligence systems that can recognize voices, solve problems, and make decisions in ways that will equal or exceed human capabilities (Haynes, Cohen, & Ritter, 2009; Wang, 2007). Psychologists collaborate with specialists in neuroanatomy, neurophysiology, neurochemistry, genetics, and other disciplines in the field known as **neuroscience**. The goal of this multidisciplinary research enterprise is to examine the structure and function of the nervous system in animals and humans at levels ranging from the individual cell to overt behavior.

Many of the links between psychology and other disciplines appear when research conducted in one field is applied in the other. For example, biological psychologists are learning about the brain with scanning devices developed by computer scientists, physicists, and engineers. Physicians and economists are using research by psychologists to better understand the thought processes that influence (good and bad) decisions about caring for patients and choosing investments. In fact, psychologist Daniel Kahneman won a Nobel Prize in economics for his work in this area. Other psychologists' research on memory has influenced how lineups and "mug shot" photos are displayed to eyewitnesses attempting to identify criminals, how attorneys question eyewitnesses in court, and how lawyers and judges question witnesses and instruct juries. And psychologists' studies of the effect of aging and brain disorders on people's vision, hearing, and mental abilities shape doctors' recommendations about whether and when elderly patients should stop driving cars. This book is filled with more examples of how psychological theories and research have been applied to health care, law, business, engineering, architecture, aviation, and sports, to name just a few.

neuroscience The scientific study of all levels of the nervous system, including neuroanatomy, neurochemistry, neurology, neurophysiology, and neuropharmacology.

Linking Psychology and Law

Cognitive psychologists' research on the quirks of human memory has led to revised guidelines for police and prosecutors when dealing with crime witnesses (U.S. Department of Justice, 1999). These guidelines warn that asking witnesses leading questions (e.g., "Do you remember seeing a gun?") can distort their memories and that false accusations are less likely if witnesses are told that the real criminal might not be in a lineup or in a group of photos (Doyle, 2005).

Masterfile

Research: The Foundation of Psychology

The knowledge that psychologists share across subfields and with other disciplines stems from the research they conduct on many aspects of behavior and mental processes. For example, rather than just speculating about why some people eat too much or too little, psychologists look for answers by using the methods of science. This means that they perform experiments and other scientific procedures to systematically gather and analyze information about behavior and mental processes and then base their conclusions—and their next questions—on the results of those procedures.

The rules and methods of science that guide psychologists in their research are summarized in the chapter on research in psychology. We have placed that chapter early in the book to highlight the fact that without scientific research methods and the foundation of evidence they provide, psychologists' statements and recommendations about behavior and mental processes would carry no more weight than those of astrologers, psychics, or tabloid journalists. Accordingly, we will be relying on the results of scientific research when we tell you what psychology has discovered so far about behavior and mental processes and also when we evaluate their efforts to apply that knowledge to improve the quality of human life.

A Brief History of Psychology

How did scientific research in psychology get started? Psychology is a relatively new discipline, but its roots can be traced through centuries, especially in the history of philosophy. Since at least the time of Socrates, Plato, and Aristotle in ancient Greece, philosophers had been debating psychological topics, such as "What is the nature of the mind and the soul?," "What is the relationship between the mind and the body?," and "Are we born with a certain amount of knowledge, or do we have to learn everything for ourselves?" They even debated whether it is possible to study such things scientifically.

The philosophical view known as *empiricism* was very important to the development of scientific psychology. Beginning in the 1600s, proponents of empiricism—especially the British philosophers John Locke, George Berkeley, and David Hume—challenged the long-accepted claim that we are born with knowledge about our world. Instead, empiricists argued that what we know about the world comes to us through experience and observation, not through imagination or intuition. This view suggests that at birth, our minds are like a blank slate (*tabula rasa* in Latin) on which our experiences write a lifelong story. For well over a century now, empiricism has guided psychologists in seeking knowledge about behavior and mental processes through observations governed by the rules of science.

Wilhelm Wundt (1832–1920)

In an early experiment on the speed of mental processes, Wundt (seated) first measured how quickly people could respond to a light by releasing a button they had been holding down. He then measured how much longer the response took when they held down one button with each hand and had to decide, based on the color of the light, which one to release. Wundt reasoned that the additional response time reflected how long it took to perceive the color and decide which hand to move. As noted in the chapter on cognition and language, the logic behind this experiment remains a part of research on cognitive processes today.

INTERFOTO/Personalities/Alamy

Wundt and the Structuralism of Titchener

The "official" birth date of modern psychology is usually said to be 1879, the year that a physiologist named Wilhelm Wundt (pronounced "voont") established the first formal psychology research laboratory at the University of Leipzig in Germany (Benjamin, 2000). At around this time, German physiologists, including Hermann von Helmholtz and Gustav Fechner (pronounced "FECK-ner"), had been studying vision and other sensory and perceptual processes that empiricism identified as the channels through which human knowledge flows. Fechner's work was especially valuable because he realized that one could study these mental processes by observing people's reactions to changes in sensory stimuli. By exploring, for example, how much brighter a light must become before we see it as twice as bright, Fechner discovered complex but predictable ways that changes in the *physical* characteristics of stimuli produced changes in our *psychological experience* of them. Fechner's approach, which he called *psychophysics*, paved the way for much of the research described in the chapter on sensation and perception.

Wundt, too, used the methods of laboratory science to study sensory-perceptual systems, but the focus of his work was **consciousness**, the mental experiences created by these systems. Wundt wanted to identify the basic elements of consciousness and describe how they are organized and how they relate to one another (Schultz & Schultz, 2004). He developed ingenious laboratory methods to study the speed of decision making and other mental events, and in an attempt to observe conscious experience, Wundt used the technique of *introspection*, which means "looking inward." After training research participants in this method, he repeatedly showed a light or made a sound and asked participants to describe the sensations and feelings these stimuli created. Wundt concluded that "quality" (e.g., cold or blue) and "intensity" (e.g., brightness or loudness) are the two essential elements of sensation, and that feelings can be described in terms of pleasure or displeasure, tension or relaxation, and excitement or depression (Schultz & Schultz, 2004). In conducting this kind of research, Wundt began psychology's transformation from the *philosophy* of mental processes to the *science* of mental processes.

Edward Titchener, an Englishman who had been a student of Wundt's, used introspection in his own laboratory at Cornell University. He studied Wundt's basic elements of consciousness, as well as images and other aspects of conscious experience that are harder to quantify (see Figure 1.3). One result was that Titchener added "clearness" as an element of sensation (Schultz & Schultz, 2004). Titchener called his approach *structuralism* because he was trying to define the structure of consciousness.

Wundt was not alone in the scientific study of mental processes, nor was his work universally accepted. Some of his fellow German scientists, including Hermann Ebbinghaus, believed that analyzing consciousness through introspection was not as important as exploring the capacities and limitations of mental processes such as learning and memory. Ebbinghaus's own laboratory experiments—in which he served as the only participant—formed the basis for some of what we know about memory today.

consciousness The awareness of external stimuli and our own mental activity.

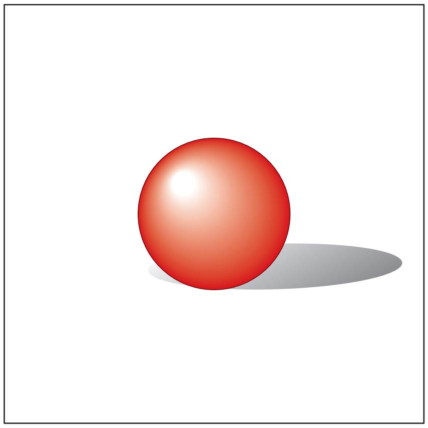


FIGURE 1.3
A Stimulus for Introspection

TRY THIS Look at this object, and try to ignore what it is. Instead, try to describe only your conscious experience, such as redness, brightness, and roundness, and how intense and clear the sensations and images are. If you can do this, you would have been an excellent research assistant in Titchener's laboratory.

Gestalt Psychologists

Around 1912, other German colleagues, including Max Wertheimer, Kurt Koffka, and Wolfgang Köhler, argued against Wundt's efforts to break down human experience or consciousness into its component parts. They were called *Gestalt psychologists* because they pointed out that the whole shape (*Gestalt* in German) of conscious experience is not the same as the sum of its parts. Wertheimer pointed out, for example, that if a pair of lights goes on and off in just the right sequence, we don't experience two separate flashing lights but a single light that appears to "jump" back and forth. You have probably seen this *phi phenomenon* in action on advertising signs that create the impression of a series of lights racing around a display. Movies provide another example. It would be incredibly boring to look one each of the thousands of still images contained one after another in a video recording. Yet when those same images appear on a screen at a particular rate, they combine to create a rich and seemingly seamless visual experience. To understand consciousness, then, said the Gestaltists, we have to study the whole "movie," not just its component parts.

Freud and Psychoanalysis

While Wundt and his colleagues in Leipzig were conducting scientific research on consciousness, Sigmund Freud was in Vienna, Austria, beginning to explore the unconscious. As a physician, Freud had presumed that all behavior and mental processes have *physical* causes somewhere in the nervous system. He began to question that assumption in the late 1800s, however, after encountering several patients who displayed a variety of physical ailments that had no apparent physical cause. After interviewing these patients using hypnosis and other methods, Freud concluded that the causes of these people's physical problems were not physical. The real causes, he said, were deep-seated problems that the patients had pushed out of consciousness (Friedman & Schustack, 2003). He eventually came to believe that all behavior—from everyday slips of the tongue to severe forms of mental disorder—is motivated by *psychological* processes, especially by mental conflicts that occur without our awareness, at an unconscious level. For nearly fifty years, Freud developed his ideas into a body of work known as *psychoanalysis*, which included a theory of personality and mental disorder, as well as a set of treatment methods. Freud's ideas have never been universally accepted, partly because they were based on a small number of medical cases, not on extensive laboratory experiments. Still, he was a groundbreaker whose theories have had a significant influence on psychology and many other fields.

William James and Functionalism

Scientific research in psychology began in North America not long after Wundt started his work in Germany. William James founded a psychology laboratory at Harvard University in the late 1870s, though it was used mainly to conduct demonstrations for his students (Schultz & Schultz, 2004). It was not until 1883 that G. Stanley Hall at Johns Hopkins University established the first psychology research laboratory in the United States. The first Canadian psychology research laboratory was established in 1889 at the University of Toronto by James Mark Baldwin, Canada's first modern psychologist and a pioneer in research on child development.

Like the Gestalt psychologists, William James rejected both Wundt's approach and Titchener's structuralism. He saw no point in breaking consciousness into component parts that never operate on their own. Instead, in accordance with Charles Darwin's theory of evolution, James wanted to understand how images, sensations, memories, and the other mental events that make up our flowing "stream of consciousness" *function* to help us adapt to our environment (James, 1890, 1892). This idea was consistent with an approach to psychology called *functionalism*, which focused on the role of consciousness in guiding people's ability to make decisions, solve problems, and the like.

James's emphasis on the functions of mental processes encouraged North American psychologists to look not only at how those processes work to our advantage but also at how they differ from one person to the next. Some of these psychologists began to measure individual differences in learning, memory, and other mental processes associated with intelligence, made recommendations for improving educational practices in the schools, and even worked with teachers on programs tailored to children in need of special help (Kramer, Bernstein, & Phares, 2014).

John B. Watson and Behaviorism

Besides fueling James's interest in the functions of consciousness, Darwin's theory of evolution led other psychologists—especially those in North America after 1900—to study animals as well as humans. These researchers reasoned that if all species evolved in similar ways, perhaps the behavior and mental processes of all species followed the same or similar laws, and if so, we can learn something about people by studying animals. They could not expect cats or rats or pigeons to introspect, so they watched what animals did when confronted with laboratory tasks such as finding the correct path through a maze. From these observations, psychologists made *inferences* about the animals' conscious experience and about the general laws of learning, memory, problem solving, and other mental processes that might apply to people as well.

John B. Watson, a psychology professor at Johns Hopkins University, agreed that the observable behavior of animals and humans is the most important source of scientific information for psychology. However, he thought it was utterly unscientific to use behavior as the basis for making inferences about consciousness, as structuralists and functionalists did—let alone about the unconscious, as Freudians did. In 1913, Watson published an article titled "Psychology as the Behaviorist Views It." In it, he argued that psychologists should ignore mental events and base psychology only on what they can actually see in overt behavior and in responses to known stimuli (Watson, 1913, 1919).

Watson's view, called *behaviorism*, recognized that consciousness exists, but it did not consider it worth studying because consciousness would always be private and therefore not observable by scientific methods. In fact, said Watson, preoccupation with consciousness would prevent psychology from ever being a true science. He believed that the most important determinant of behavior is *learning* and that it is through learning that animals and humans are able to adapt to their environments. Watson famously claimed that with enough control over the environment, he could create learning experiences that would make any infant into a doctor, a lawyer, or even a criminal.

The American psychologist B. F. Skinner was an early champion of behaviorism. From the 1930s until his death in 1990, Skinner worked on mapping out the details of how rewards and punishments shape, maintain, and change behavior through what he termed "operant conditioning." By conducting a *functional analysis of behavior*, he would explain, for example, how parents and teachers perhaps even unknowingly encourage children's tantrums by rewarding them with attention and how an addiction to gambling can result from the occasional and unpredictable rewards it brings.

Many psychologists were drawn to Watson's and Skinner's vision of psychology as the learning-based science of observable behavior. As such, behaviorism dominated psychological research from the 1920s through the 1960s, while the study of consciousness received less attention, especially in the United States. ("In Review: The Development of Psychology" summarizes behaviorism and the other schools of thought that have influenced psychologists in the past century.)

Psychology Today

Psychologists continue to study all kinds of overt behavior in humans and in animals. By the end of the 1960s, however, many had become dissatisfied with the limitations imposed by behaviorism (some, especially in Europe, had never accepted it in the first place). They grew uncomfortable about ignoring mental processes that might be important in more fully understanding behavior (e.g., Ericsson & Simon, 1994). The dawn of the computer age influenced these psychologists to think about mental activity in a new way—as information processing. Computers and rapid progress in computer-based biotechnology began to offer psychologists exciting new ways to study mental processes and the biological activity that underlies them. It is now possible to see what is happening in the brain when a person reads or thinks or makes decisions.

Armed with ever more sophisticated research tools, psychologists today are striving to do what Watson thought was impossible: to study mental processes with precision and scientific objectivity. In fact, there are probably now as many psychologists who study cognitive and biological processes as there are who study observable behaviors. So mainstream psychology has come full circle, once again accepting consciousness—in the form of cognitive processes—as a legitimate topic for scientific research and justifying the definition of psychology as the science of behavior and mental processes.

IN REVIEW

THE DEVELOPMENT OF PSYCHOLOGY

School of Thought	Early Advocates	Goals	Methods
Structuralism	Edward Titchener, trained by Wilhelm Wundt	To study conscious experience and its structure	Experiments; introspection
Gestalt psychology	Max Wertheimer	To describe the organization of mental processes: "The whole is different from the sum of its parts."	Observation of sensory-perceptual phenomena
Psychoanalysis	Sigmund Freud	To explain personality and behavior; to develop techniques for treating mental disorders	Study of individual cases
Functionalism	William James	To study how the mind works in allowing an organism to adapt to the environment	Naturalistic observation of animal and human behavior
Behaviorism	John B. Watson, B. F. Skinner	To study only observable behavior and explain behavior through learning principles	Observation of the relationship between environmental stimuli and behavioral responses

1. Darwin's theory of evolution had an especially strong influence on __________ ism and __________ ism .
2. Which school of psychological thought was founded by a European medical doctor? __________
3. In the history of psychology, __________was the first school of thought to appear.

APPROACHES TO THE SCIENCE OF PSYCHOLOGY

Why don't all psychologists explain behavior in the same way?

We have seen that the history of psychology is, in part, a history of differing ways in which psychologists thought about, or "approached," behavior and mental processes. Today, psychologists no longer refer to themselves as structuralists or functionalists but the psychodynamic and behavioral approaches remain, along with some newer ones known as the *biological, evolutionary, cognitive*, and *humanistic approaches*. Some psychologists adopt just one of these approaches, but most are eclectic—they blend aspects of two or more approaches in an effort to understand more fully the behavior and mental processes in their subfield (e.g., Cacioppo et al., 2000). Some approaches to psychology are more influential than others these days, but we will review the main features of all of them so you can more easily understand why different psychologists may explain the same behavior or mental process in different ways.

The Biological Approach

As its name implies, the **biological approach** to psychology assumes that behavior and mental processes are largely shaped by biological processes. Psychologists who take this approach study the psychological effects of hormones, genes, and the activity of the nervous system, especially the brain. So if they are studying memory, they might try to identify the changes taking place in the brain as information is stored there (Figure 6.14, in the chapter on memory, shows an example of these changes). If they are studying thinking, they might look for patterns of brain activity associated with, say, making quick decisions or reading a foreign language.

The Biology of Emotion

Robert Levenson, a psychologist at the University of California at Berkeley, takes a biological approach to the study of social interactions. He measures heart rate, muscle tension, and other physical reactions as couples discuss problems in their relationships. He then looks for patterns of physiological activity in each of the partners (such as overreactions to criticism) that might be related to success or failure in resolving their problems.

University of California Berkeley

We discuss research in nearly every chapter of this book to show the enormous influence of the biological approach on psychology today. To help you better understand the terms and concepts used in that research, we have provided an appendix on the principles of genetics and a chapter on biological aspects of psychology.

biological approach An approach to psychology in which behavior and behavior disorders are seen as the result of physical processes, especially those relating to the brain and to hormones and other chemicals.

natural selection The evolutionary mechanism through which Darwin said the fittest individuals survive to reproduce.

The Evolutionary Approach

Biological processes also figure prominently in an approach to psychology based on Charles Darwin's 1859 book *On the Origin of Species*. Darwin argued that the forms of life we see today are the result of *evolution*—of changes in life forms that occur over many generations. He said that evolution occurs through **natural selection**, which promotes the survival of the fittest individuals. Those whose behavior and appearance allow them to withstand the elements, avoid predators, and mate are able to survive and produce offspring, who may have similar characteristics. Those less able to adjust (or *adapt*) to changing conditions are less likely to survive and reproduce. Most evolutionists today see natural selection operating at the level of genes, but the process is the same. Genes that result in characteristics and behaviors that are adaptive and useful in a certain environment will enable the creatures that inherit them to survive and reproduce, thereby

FIGURE 1.4
What Do You See?

TRY THIS Take a moment to jot down what you see in these clouds.

According to the psychodynamic approach to psychology, what we see in cloud formations and other vague patterns reflects unconscious wishes, impulses, fears, and other mental processes. In the personality chapter, we discuss the value of personality tests based on this assumption.

Jack Hollingsworth/Getty Images

passing those genes on to the next generation. According to evolutionary theory, many (but not all) of the genes that animals and humans possess today are the result of natural selection.

The **evolutionary approach** to psychology assumes that the *behavior and mental processes* of animals and humans today are also affected by evolution through natural selection. For example, psychologists who take this approach see cooperation as an adaptive survival strategy, aggression as a form of territory protection, and gender differences in mate selection preferences as reflecting different ways through which genes survive in future generations (Griskevicius et al., 2009). The evolutionary approach has generated a growing body of research (e.g., Buss, 2009; Confer et al., 2010); in later chapters, you will see how it is applied in relation to topics such as helping and altruism, mental disorders, temperament, and interpersonal attraction.

The Psychodynamic Approach

The **psychodynamic approach** to psychology offers a different slant on the role of inherited instincts and other biological forces in human behavior. Rooted in Freud's psychoanalysis, this approach assumes that our behavior and mental processes reflect constant and mostly unconscious psychological struggles deep within us (see Figure 1.4). Usually, these struggles involve conflict between the impulse to satisfy instincts (such as for food, sex, or aggression) and the need to follow the rules of civilized society. So psychologists taking a psychodynamic approach might see aggression, for example, as a case of primitive urges overcoming a person's defenses against expressing those urges. They would see anxiety, depression, or other disorders as overt signs of inner turmoil.

Freud's original theories are not as influential today as they once were (Mischel, 2004a), but you will encounter modern versions of the psychodynamic approach when we discuss theories of personality, psychological disorders, and psychotherapy.

The Behavioral Approach

The assumptions of the **behavioral approach** to psychology contrast sharply with those of the psychodynamic, biological, and evolutionary approaches. The behavioral approach is rooted in the behaviorism of Watson and Skinner, which, as we have seen, focused entirely on observable behavior and on how that behavior is *learned*. Accordingly, psychologists who take a strict behavioral approach concentrate on understanding how past experiences with rewards and punishments act on the "raw materials" provided by genes and evolution

evolutionary approach An approach to psychology that emphasizes the inherited, adaptive aspects of behavior and mental processes.

psychodynamic approach A view developed by Freud that emphasizes the interplay of unconscious mental processes in determining human thought, feelings, and behavior.

behavioral approach An approach to psychology emphasizing that human behavior is determined mainly by what a person has learned, especially from rewards and punishments.

to shape observable behavior into what it is today. So whether they are trying to understand a person's aggressiveness, fear of spiders, parenting methods, or drug abuse, behaviorists look mainly at that person's learning history. And because they believe that behavior problems develop through learning, behaviorists seek to eliminate problems by helping people replace bad habits with new and more appropriate ones.

Recall, though, that the peak of behaviorism's popularity passed precisely because it ignored everything but observable behavior. That criticism has had an impact on the many behaviorists who now apply their learning-based approach in an effort to understand thoughts, or cognitions, as well as observable behavior. Those who take this *cognitive-behavioral*, or *social-cognitive*, approach explore how learning affects the development of thoughts, attitudes, and beliefs and, in turn, how these learned cognitive patterns affect overt behavior.

Why Is He So Aggressive?

Psychologists who take a cognitive-behavioral approach suggest that behavior is not shaped by rewards and punishments alone. They say that children's aggressiveness, for example, is learned partly by being rewarded (or at least not punished) for aggression but also partly by seeing family and friends acting aggressively. Further, attitudes and beliefs about the value and acceptability of aggressiveness can be learned as children hear others talk about aggression as the only way to deal with threats, disagreements, and other conflict situations (e.g., Cooper, Gomez, & Buck, 2008; Wilkowski & Robinson, 2008).

Mary Kate Denny/PhotoEdit

The Cognitive Approach

The growth of the cognitive-behavioral perspective reflects the influence of a broader cognitive view of psychology. This **cognitive approach** focuses on how we take in, mentally represent, and store information; how we perceive and process that information; and how all these cognitive processes affect our behavior. Psychologists who take the cognitive approach study the rapid series of mental events—including those outside of awareness—that accompany observable behavior. So in analyzing, say, an aggressive incident in a movie theater line, these psychologists would describe the following series of information processing events: First, the aggressive person (1) *perceived* that someone has cut into the ticket line, then (2) *recalled* information stored in memory about appropriate social behavior, (3) *decided* that the other person's action was inappropriate, (4) *labeled* the person as rude and inconsiderate, (5) *considered* possible responses and their likely consequences, (6) *decided* that shoving the person is the best response, and (7) *executed* that response.

Psychologists who take a cognitive approach focus on these and other mental processes to understand many kinds of individual and social behaviors, from decision making and problem solving to interpersonal attraction and intelligence, to name but a few. In the situation just described, for example, the person's aggression would be seen as the result of poor problem solving, because there were probably several better ways to deal with the problem of line-cutting. The cognitive approach is especially important in the field of *cognitive science*, in which researchers from psychology, computer science, biology, engineering, linguistics, and philosophy study intelligent systems in humans and computers. Together, they try to discover the building blocks of cognition and determine how these components produce complex behaviors such as remembering a fact, recognizing objects, writing words, or making a decision.

cognitive approach A way of looking at human behavior that emphasizes research on how the brain takes in information, creates perceptions, forms and retrieves memories, processes information, and generates integrated patterns of action.

humanistic approach A perspective to psychology that focuses on how each person has a unique capacity to choose how to think and act.

The Humanistic Approach

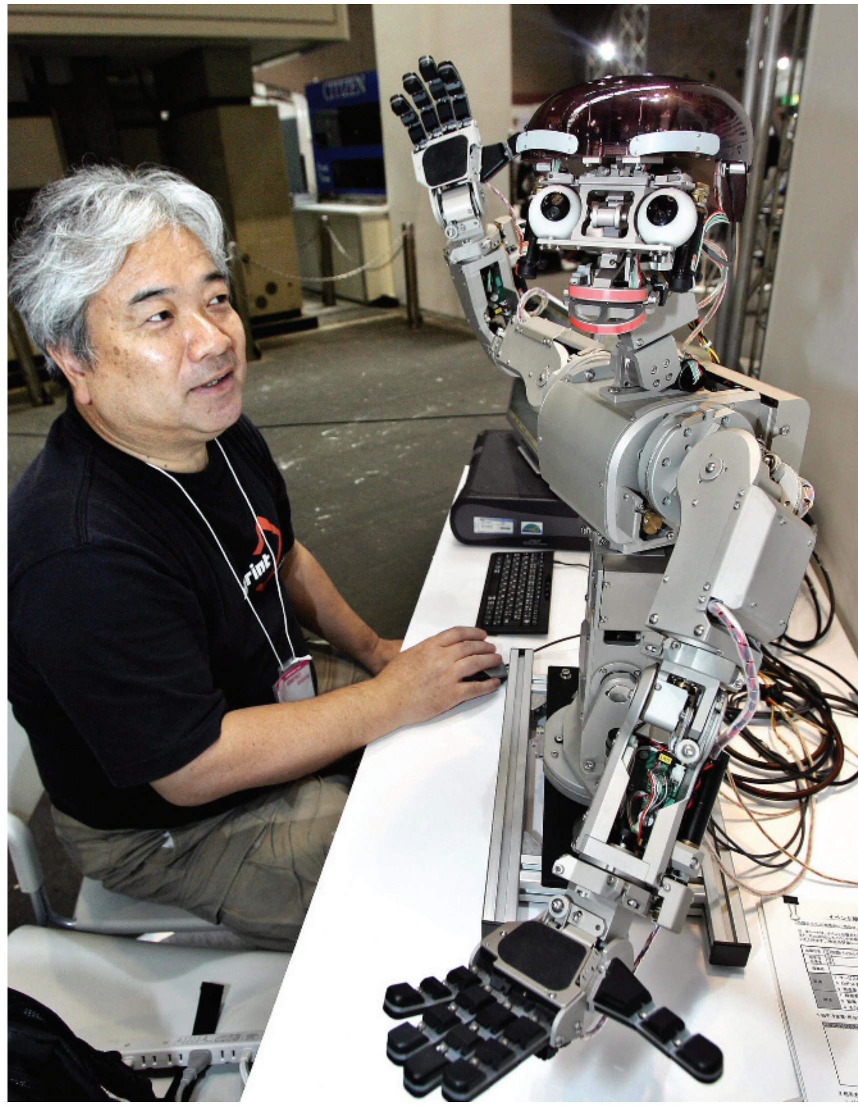
Mental events play a different role in the **humanistic approach** to psychology (also known as the *phenomenological approach*). Psychologists who favor the humanistic perspective see behavior as determined primarily by each person's unique capacity to choose how to think and act. They don't see these choices as driven by instincts, biological processes, or rewards and punishments but rather by each individual's own perceptions of the world. So if you see the world as a friendly place, you are likely to be optimistic and secure. If you perceive it as full of hostile, threatening people, you will probably be defensive and fearful.

Like their cognitively oriented colleagues, psychologists who use a humanistic approach would see aggression in a theater line as stemming from a perception that aggression is justified. But where the cognitive approach leads psychologists to search for laws governing *all* people's thoughts and actions, humanistic psychologists try to

Cognitive Science at Work

Psychologists and other cognitive scientists are working on a "computational theory of the mind" in which they create computer programs and robotic devices that simulate how humans process information. In the chapter on cognition and language, we discuss their progress in creating "artificial intelligence" in computers that can help make medical diagnoses and perform other complex cognitive tasks, including the Internet searches you do using Google and other sophisticated web search engines.

Yoshikazu Tsuno/AFP/Getty Images



understand how each individual's unique experiences guide *that* person's thoughts and actions. In fact, many who prefer the humanistic approach claim that because no two people are exactly alike, the only way to understand behavior and mental processes is to focus on how they operate in each individual. Humanistic psychologists see people as essentially good, in control of themselves, and with an innate tendency to grow toward their highest potential.

The humanistic approach attracted attention in North America in the 1940s through the writings of Carl Rogers, a psychologist who trained in, but later rejected, the psychodynamic approach. We describe his views on personality and his psychotherapy methods in the chapters on personality and the treatment of psychological disorders. Another influential figure of the same era was Abraham Maslow, a psychologist who shaped and promoted the humanistic approach through his famous hierarchy-of-needs theory of motivation, which we describe in the chapters on motivation and emotion and personality. Today, the impact of the humanistic approach to psychology is less noticeable, partly because many psychologists find humanistic concepts and predictions too vague to be tested scientifically. It has, however, helped inspire the theories and research in positive psychology that are now becoming so popular (Snyder & Lopez, 2009). (For a summary of all the approaches we have discussed, see "In Review: Approaches to the Science of Psychology.")

IN REVIEW

APPROACHES TO THE SCIENCE OF PSYCHOLOGY

Approach	Characteristics
Biological	Emphasizes activity of the nervous system, especially of the brain; the action of hormones and other chemicals; and genetics
Evolutionary	Emphasizes the ways in which behavior and mental processes are adaptive for survival
Psychodynamic	Emphasizes internal conflicts, mostly unconscious, which usually pit sexual or aggressive instincts against environmental obstacles to their expression
Behavioral	Emphasizes learning, especially each person's experience with rewards and punishments; the *cognitive-behavioral approach* adds emphasis on learning by observation and the learning of certain ways of thinking
Cognitive	Emphasizes mechanisms through which people receive, store, retrieve, and otherwise process information
Humanistic	Emphasizes individual potential for growth and the role of unique perceptions in guiding behavior and mental processes

1. Teaching people to be less afraid of heights reflects the __________approach.
2. Charles Darwin was not a psychologist, but his work influenced the __________ approach to psychology.
3. Assuming that people inherit mental disorders suggests a __________ approach.

Mary Whiton Calkins (1863–1930)

Mary Whiton Calkins studied psychology at Harvard University, where William James described her as "brilliant." Because she was a woman, though, Harvard refused to grant her a doctoral degree unless she received it through Radcliffe, which was then an affiliated school for women. She refused but went on to do research on memory and in 1905 became the first woman president of the American Psychological Association (APA). Margaret Washburn (1871–1939) encountered similar sex discrimination at Columbia University, so she transferred to Cornell and became the first woman to earn a doctorate in psychology. In 1921, she became the second woman president of the APA.

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HUMAN DIVERSITY AND PSYCHOLOGY

How does your cultural background influence your behavior?

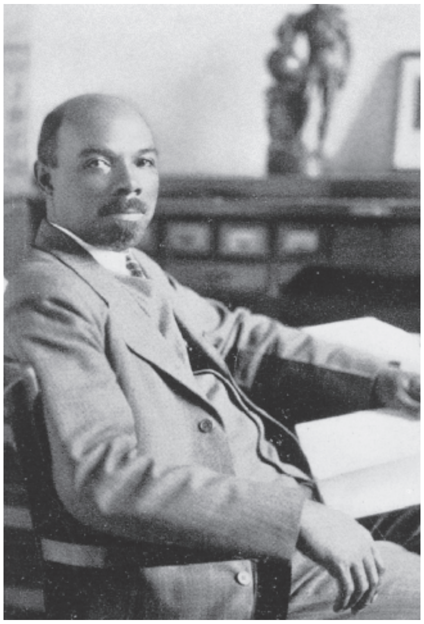
Today, the diversity seen in psychologists' approaches to their work is matched by the diversity in their own backgrounds. This was not always the case. As in other academic disciplines in the early twentieth century, most psychologists were white, middle-class men (Walker, 1991). Almost from the beginning, however, women and people of color were also part of the field (Schultz & Schultz, 2004). Throughout this book, you will find discussions of the work of their modern counterparts, whose contributions to research, service, and teaching have all increased, as has their representation in psychology. In the United States, women now constitute a majority of all working psychologists, and a majority of those earning doctoral degrees in psychology (Willyard, 2011). Moreover, about 25 percent of new doctoral degrees in psychology are being earned by members of ethnic minority groups (American Psychological Association, 2010; National Science Foundation, 2009). These numbers reflect continuing efforts by psychological organizations and governmental bodies, especially in the United States and Canada, to promote the recruitment, graduation, and employment of women and ethnic minorities in psychology.

The Impact of Sociocultural Diversity on Psychology

Another aspect of diversity in psychology lies in the wide range of people psychologists study and serve. This change is significant because most psychologists once assumed that all people are very much alike and that whatever principles emerged from research or treatment efforts with one group would apply to everyone, everywhere. They were partly right, because people around the world *are* alike in many ways. They tend to live in groups, have religious beliefs, and create rules, music, dances, and games. The principles of nerve cell activity or reactions to heat or a sour taste are likely the same in men and women everywhere, as is their recognition of a smile. But are all people's moral values, achievement motivation, or communication styles the same too? Would the results of research on white male college students in the midwestern United States apply to African American women or to people in Greece, Korea, Argentina, or Egypt? Not always. These and many other aspects of behavior and mental processes are affected by **sociocultural factors**, including people's gender, ethnicity, social class, and the culture in which they grow up. These variables create many significant differences in behavior and mental processes, especially from one culture to another (e.g., Shiraev & Levy, 2010).

Culture has been defined as the accumulation of values, rules of behavior, forms of expression, religious beliefs, occupational choices, and the like for a group of people who share a common language and environment (Fiske et al., 1998). Culture is an organizing and stabilizing influence. It encourages or discourages particular behaviors and thoughts; it also allows people to understand and know what to expect from others in that culture. It is a kind of group adaptation, passed along by tradition and example rather than by genes from one generation to the next (Castro & Toro, 2004). Culture determines, for example, whether children's education will focus on skill at hunting or reading, how close people stand during a conversation, and whether or not they form lines in public places.

Psychologists and anthropologists have found that cultures can differ in many ways (Cohen, 2009). They may have strict or loose rules governing social behavior. They might place great value on achievement or on self-awareness. Some seek dominance over nature; others seek harmony with it. Time is of great importance in some cultures but not in others. Psychologists have tended to focus on the differences between cultures that can best be described as individualist or collectivist (Triandis & Trafimow, 2001). As shown in Table 1.2, many people in *individualist* cultures, such as those typical of North America



Gilbert Haven Jones (1883–1966)

When Gilbert Haven Jones graduated from the University of Jena in Germany in 1909, he became one of the first African Americans to earn a doctorate in psychology. Many others were to follow, including J. Henry Alston, who was the first African American to publish research in a major U.S. psychology journal (Alston, 1920).

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TABLE 1.2 SOME CHARACTERISTICS OF BEHAVIOR AND MENTAL PROCESSES TYPICAL OF INDIVIDUALIST VERSUS COLLECTIVIST CULTURES

Psychologists and anthropologists have noticed that cultures can create certain general tendencies in behavior and mental processes among the people living in them (Bhagat et al., 2002). As shown here, individualist cultures tend to support the idea of placing one's personal goals before the goals of the extended family or work group, whereas collectivist cultures tend to encourage putting the goals of those groups ahead of personal goals. Remember, however, that these labels represent very rough categories. Cultures cannot be pigeonholed as being either entirely individualist or entirely collectivist, and not everyone raised in a particular culture always thinks or acts in exactly the same way (Na et al., 2010).

Variable	Individualist	Collectivist
Personal identity	Separate from others	Connected to others
Major goals	Self-defined; be unique; realize your personal potential; compete with others	Defined by others; belong; occupy your proper place; meet your obligations to others; be like others
Criteria for self-esteem	Ability to express unique aspects of the self; self-assurance	Ability to restrain the self and be part of a social unit; modesty
Sources of success and failure	Success comes from personal effort; failure is caused by external factors	Success is due to help from others; failure is due to personal faults
Major frame of reference	Personal attitudes, traits, and goals	Family, work group

sociocultural factors Social identity and other background factors, such as gender, ethnicity, social class, and culture.

culture The accumulation of values, rules of behavior, forms of expression, religious beliefs, occupational choices, and the like for a group of people who share a common language and environment.

and Western Europe, tend to value personal rather than group goals and achievement. Competitiveness to distinguish oneself from others is common in these cultures, as is a sense of isolation. By contrast, many people in *collectivist* cultures, such as Japan, tend to think of themselves mainly as part of their families or work groups. Cooperative effort aimed at advancing the welfare of these social units is highly valued, and although loneliness is seldom a problem, fear of rejection by the family or other group is common. Many aspects of U.S. culture—from self-reliant cowboy heroes and bonuses for "top" employees to the invitation to "help yourself" at a buffet table—reflect its tendency toward an individualist orientation (see Table 1.3).

A culture may be associated with a particular country, but most countries are actually *multicultural;* in other words, they host many *subcultures* within their borders. Often these subcultures are formed by people of various ethnic origins. The population of the United States, for instance, includes African Americans, Hispanic Americans, Asian Americans, and American Indians, as well as Americans whose families came from Italy, France, Germany, Britain, Poland, Brazil, India, Iraq, and many other places. In each of these groups, the individuals who identify with their cultural heritage tend to share behaviors, values, and beliefs based on their culture of origin, thus forming a *subculture*.

Like fish unaware of the water in which they swim, people often fail to notice how the culture or subculture in which they live shapes their thinking and behavior. Such influence may not be evident until people come in contact with other people whose culture or subculture has shaped different patterns. Consider hand gestures, for example. The "thumbs up" sign means that "everything is OK" to people in North America and Europe

TRY THIS

TABLE 1.3 CULTURAL VALUES IN ADVERTISING

The statements listed here appeared in advertisements in Korea and the United States. Those from Korea reflect collectivist values, whereas those from the United States emphasize a more individualist orientation (Han & Shavitt, 1994). See if you can tell which are which; then check at the bottom of page 24 for the answers. To follow up on this exercise, identify cultural values in ads you see in newspapers, magazines, billboards, television, and the Internet. By surfing the Internet or scanning international newspapers online, you can compare the values conveyed by ads in your culture with those in ads from other cultures.

1. "She's got a style all her own."
2. "You, only better."
3. "A more exhilarating way to provide for your family."
4. "We have a way of bringing people closer together."
5. "Celebrating a half-century of partnership."
6. "How to protect the most personal part of the environment: Your skin."
7. "Our family agrees with this selection of home furnishings."
8. "A leader among leaders."
9. "Make your way through the crowd."
10. "Your business success: Harmonizing with [company name]."

Source: Brehm, Kassin, & Fein (2005).

but is considered a rude gesture in Australia, Nigeria, and Bangladesh. And although in North America, making eye contact during social introductions is usually seen as a sign of interest or sincerity, it is likely to be considered rude in Japan. Even some of the misunderstandings that occur between men and women in the same culture can be traced to slight culturally influenced differences in their communication styles (Tannen, 2001, 2011). In the United States, for example, women's efforts to connect with others by talking are perceived by some men as "pointless" unless the discussion is aimed at solving a specific problem. As a result, women may feel frustrated and misunderstood by men who offer well-intentioned but unwanted advice instead of conversation.

For decades, the impact of culture on behavior and mental processes was of concern mainly to a relatively small group of researchers working in *cross-cultural psychology*. In the chapters ahead, however, you will see that psychologists in almost every subfield now look at how ethnicity, gender, age, and other sociocultural variables influence behavior and mental processes. In short, psychology strives to be the science of *all* behavior and mental processes, not just of those in the cultures where it began.

The Impact of Culture

Culture helps shape virtually every aspect of our behavior and mental processes, from how we dress to how we think to what we think is important. Because most people grow up immersed in a particular culture, they may not notice its influence on their thoughts and actions until—like these people who emigrated from Somalia to Lewiston, Maine—they encounter people whose culture has shaped them in different ways (Luna, Ringberg, & Peracchio, 2008; Markus, 2008; Masuda et al., 2008; Nisbett & Masuda, 2007; Varnum et al., 2008).

AP Images/Robert F. Bukaty

SUMMARY

Psychology is the science that seeks to understand behavior and mental processes and to apply that understanding in the service of human welfare.

The World of Psychology: An Overview

What is psychology and how did it grow?

The concept of "behavior and mental processes" is a broad one, encompassing virtually all aspects of what it means to be human. Some psychologists study and seek to alleviate problems that plague human life, while those working in *positive psychology* seek to understand happiness, optimism, human strengths, and the like.

Because the subject matter of psychology is so diverse, most psychologists work in different subfields within the discipline. For example, *biological psychologists*, also called physiological psychologists, study topics such as the role played by the brain in normal and disordered behavior. *Cognitive psychologists*, some of whom prefer to be called experimental psychologists, focus on basic psychological processes such as learning, memory, and perception; they also study judgment, decision making, and problem solving. *Engineering psychology*, the study of human factors in the use of equipment, helps designers create better versions of that equipment. *Developmental psychologists* specialize in trying to understand the development of behavior and mental processes over a lifetime. *Personality psychologists* focus on characteristics that set people apart from one another and by which they can be compared. *Clinical psychologists* and *counseling psychologists* provide direct service to troubled people and conduct research on abnormal behavior. *Community psychologists* work to prevent mental disorders and to extend mental health services to those who need them. *Health psychologists* study the relationship between behavior and health and help promote healthy lifestyles. *Educational psychologists* conduct and apply research on teaching and learning, whereas *school psychologists* specialize in assessing and alleviating children's academic problems. *Social psychologists* examine questions regarding how people influence one another. *Industrial and organizational psychologists* study ways to increase efficiency and productivity in the workplace. *Quantitative psychologists* develop ways to analyze research data from all subfields. *Sport psychologists*, *forensic psychologists*, and *environmental psychologists* exemplify some of psychology's many other subfields.

Psychologists often work in more than one subfield and usually share knowledge with colleagues in many subfields. Psychologists also draw on and contribute to knowledge in other disciplines, such as computer science, economics, and law.

Psychologists use the methods of science to conduct research. This means that they perform experiments and use other scientific procedures to systematically gather and analyze information about psychological phenomena.

The founding of modern psychology is usually marked as 1879, when Wilhelm Wundt established the first psychology research laboratory. Wundt studied consciousness in a manner that was expanded by Edward Titchener into an approach he called *structuralism*. It was in the late 1800s, too, that Sigmund Freud, in Vienna, began his study of the unconscious, while in the United States, William James took the functionalist approach, suggesting that psychologists should study how consciousness helps us adapt to our environments. In 1913, John B. Watson founded *behaviorism*, arguing that to be scientific, psychologists should study only the behavior they can see, not private mental events. Behaviorism dominated psychology for decades, but psychologists are once again studying consciousness in the form of cognitive processes.

Approaches to the Science of Psychology

Why don't all psychologists explain behavior in the same way?

Psychologists differ in their approaches to psychology—that is, in their assumptions, questions, and research methods. Some adopt just one approach; most combine features of two or more approaches. Those adopting a *biological approach* focus on how physiological processes shape behavior and mental processes. Psychologists who prefer the *evolutionary approach* emphasize the inherited, adaptive aspects of behavior and mental processes. In the *psychodynamic approach*, behavior and mental processes are seen as reflecting struggles to resolve conflicts between raw impulses and the social rules that limit the expression of those impulses. Psychologists who take the *behavioral approach* view behavior as determined primarily by learning based on experiences with rewards and punishments. The *cognitive approach* assumes that behavior can be understood through analysis of the basic mental processes that underlie it. To those adopting the *humanistic approach*, behavior is controlled by the decisions that people make about their lives based on their perceptions of the world.

Human Diversity and Psychology

How does your cultural background influence your behavior?

Psychologists are diverse in their backgrounds and in their activities. Most of the prominent figures in psychology's early history were white males, but women and people of color made important contributions from the start and continue to do so.

Psychologists are increasingly taking into account the influence of culture and other sociocultural variables such as gender and ethnicity in shaping human behavior and mental processes.

TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. The first research laboratory in psychology was established to study __________.
- **a.** consciousness
- **b.** the unconscious
- **c.** perceptual processes
- **d.** the collective unconscious

2. Dr. Gauzz believes that low-income families who live in crowded conditions are more likely to need mental health services. Therefore, she works to eliminate overcrowded high-rises for low-income families. Dr. Gauzz is most likely a(n) __________ psychologist.
- **a.** developmental
- **b.** industrial and organizational
- **c.** community
- **d.** engineering

3. Dr. Hemmings believes that human behavior is influenced by genetic inheritance, unconscious motivations, and environmental influences. Dr. Hemmings uses a(n) __________ approach.
- **a.** evolutionary
- **b.** eclectic
- **c.** humanistic
- **d.** behavioral

4. Solomon is a psychologist interested in conformity. He studies how the size of a group affects the amount of pressure that the group can exert on individuals. Solomon is most likely a __________ psychologist.
- **a.** personality
- **b.** clinical
- **c.** quantitative
- **d.** social

Answer key for Table 1.3: U.S. ads are numbers 1, 2, 6, 8, and 9.

5. You are marooned on a tropical island with a dangerous criminal. In your suitcase are four books on psychology. If you believe that the criminal's behavior is primarily due to unconscious conflicts, you should choose the book written by __________ to find more information.
   a. Sigmund Freud
   b. William James
   c. John Watson
   d. Wilhelm Wundt

6. Dr. Foreman studies what teachers actually do when they are teaching students to read. Dr. Foreman is most likely a(n) __________ psychologist.
   a. cognitive
   b. school
   c. educational
   d. community

7. Larry says that people act the way they have learned to act. He believes that if others stop rewarding a person's annoying behavior, that behavior will decrease. Larry most likely takes a(n) __________ approach to psychology.
   a. behavioral
   b. cognitive
   c. evolutionary
   d. humanistic

8. Marika just won a college scholarship because of her outstanding grades. If she is from a collectivist culture, she is most likely to say:
   a. "I've worked very hard for this honor and I appreciate the vote of confidence."
   b. "I had some tough times when I didn't think I would succeed, but this has made it all worthwhile."
   c. "I could not have won this award without the help of my teachers and family."
   d. "I am so happy that the committee recognized my hard work and perseverance and is rewarding it with this scholarship."

9. Dr. Rose, a cross-cultural psychologist, is most likely to find which behavior to be similar in all of the groups she studies?
   a. Striving for achievement
   b. Rules governing social behavior
   c. Styles of communication
   d. Recognition of a smile

10. Latisha is a forensic psychologist. You are most likely to find her working with a __________.
    a. physical therapist
    b. lawyer
    c. advertising company
    d. landscape architect

11. You have just graduated with a Ph.D. in human factors psychology and are now working at your first job. You are most likely to be __________.
    a. testing the personality traits of astronaut candidates
    b. helping to design a new video game console
    c. conducting group therapy with abused children
    d. designing research on racial prejudice

12. Psychology is best defined as the science of __________.
    a. behavior and mental processes
    b. psychological disorders and conditions
    c. personality development
    d. neurons and hormones

13. Research on the factors that lead people to be happy and satisfied with their lives is known as __________psychology.
    a. developmental
    b. humanistic
    c. positive
    d. existential

14. The concepts of behavior and mental processes include
    a. personality traits
    b. sensory abilities
    c. intelligence
    d. all of the above

15. A major difference between psychologists and psychiatrists is that psychiatrists __________.
    a. have more training in psychological testing
    b. are medical doctors
    c. are more active in research
    d. all of the above

16. Ali argues that, compared to men, women's greater selectivity in choosing a mate is an adaptive strategy that makes it more likely that fathers will be good providers. This view is rooted in the __________ approach to psychology.
    a. evolutionary
    b. behavioral
    c. cognitive-behavioral
    d. humanistic

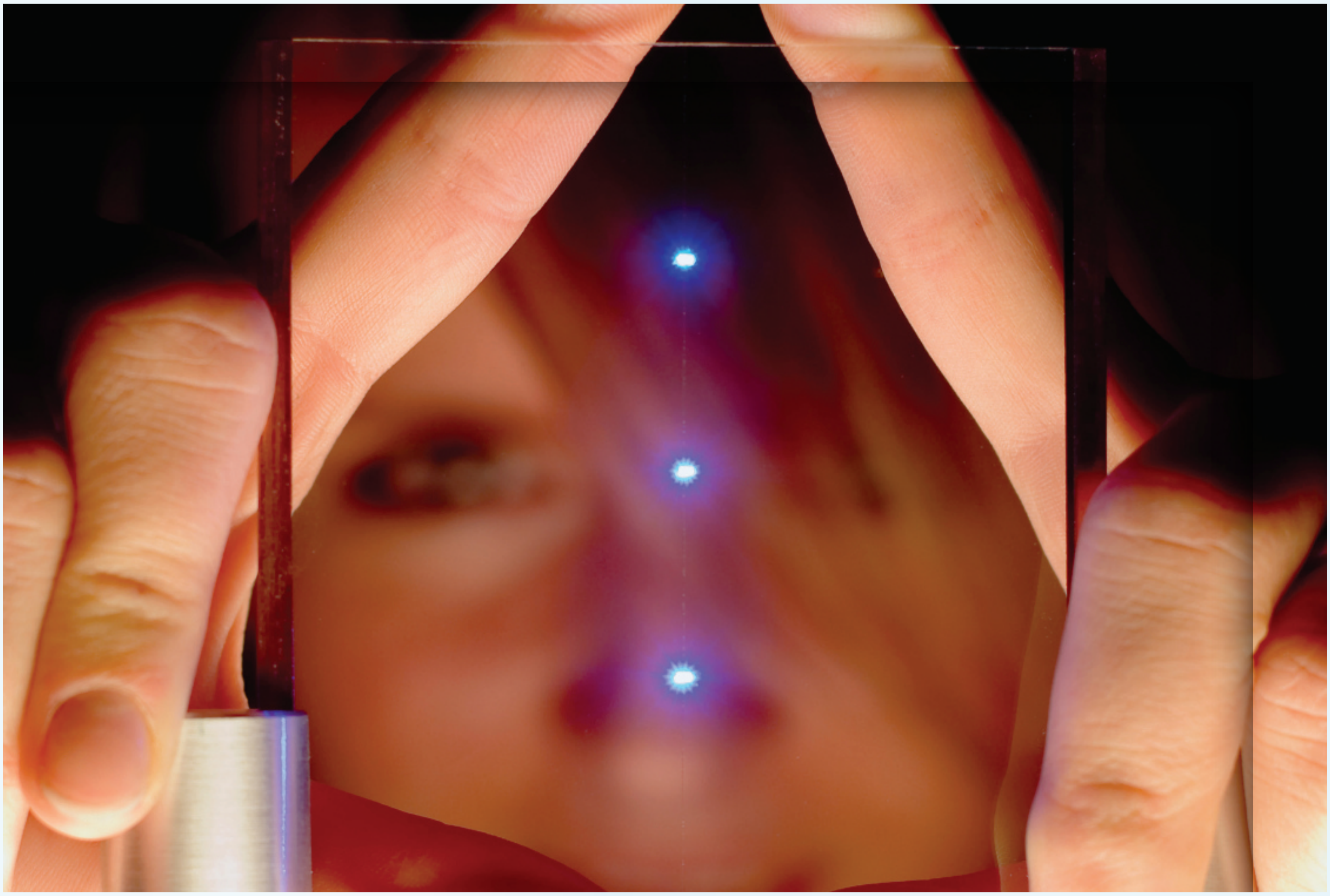
17. Today, the study of consciousness occurs mainly in the field of __________.
    a. psychoanalysis
    b. humanistic psychology
    c. functional analysis
    d. cognitive science

18. Paul tells his wife that she won't ever be able to understand him unless she can begin to understand his own unique view of the world. Without realizing it, Paul is expressing a basic principle of __________ psychology.
    a. psychodynamic
    b. cognitive-behavioral
    c. humanistic
    d. cognitive

19. Today, the majority psychologists in North America are __________.
    a. men
    b. women
    c. people of color
    d. psychoanalysts

20. People's gender, ethnicity, social class, religious beliefs, and the like are examples of the __________ variables that can affect behavior and mental processes.
    a. self-defined
    b. innate
    c. biological
    d. sociocultural

Research in Psychology



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Preview

Our goal in this chapter is to describe the research methods psychologists use to help answer their questions about behavior and mental processes. We will also describe the critical thinking processes that help psychologists form those questions and make sense of research results.

Francine Shapiro, a clinical psychologist in California, had an odd experience one day back in 1987. She was taking a walk and thinking about some distressing events when she noticed that her emotional reaction to them was fading away (Shapiro, 1989b). In trying to figure out why this should be, she realized that she had been moving her eyes from side to side. Could these eye movements have caused the change in her emotions? To test this possibility, she made more deliberate eye movements and found that the emotion-reducing effect was even stronger. Would the same thing happen to others? Curious, she first tested the effects of side-to-side eye movements with friends and colleagues and then with clients who had suffered traumatic experiences, such as sexual abuse, military combat, or rape. She asked these people to think about unpleasant experiences in their lives while keeping their eyes on her finger as she moved it rapidly back and forth in front of them. Like her, they found that during and after these eye movement sessions, their reactions to unpleasant thoughts faded away. They also reported that their emotional flashbacks, nightmares, fears, and other trauma-related problems decreased dramatically, often after only one session (Shapiro, 1989b).

Based on the success of these cases, Shapiro developed a treatment method she calls *eye movement desensitization and reprocessing*, or EMDR (Leeds, 2009; Shapiro, 1991, 2001; Shapiro & Forrest, 2004). She and her associates have trained more than 30,000 therapists in fifty-two countries to use EMDR in the treatment of an ever-widening range of anxiety-related problems in adults and children, from phobias and posttraumatic stress disorder to marital conflicts and skin rashes (e.g., Adúriz, Bluthgen, & Knopfler, 2009; Bloomgarden & Calogero, 2008; de Jongh et al., 2013; Gauvreau & Bouchard, 2008; Hase, Schallmayer, & Sack, 2008; Leer et al., 2013; Manfield & Shapiro, 2004; Marcus, 2008; Phillips et al., 2009; Rodenburg et al., 2009; Russell et al., 2007; Shapiro, 2005).

Suppose you had an anxiety-related problem. Would the popularity of EMDR be enough to convince you to try this treatment? If not, what would you want to know about EMDR before deciding? As a cautious person, you would probably ask some of the same questions that have also occurred to many scientists in psychology, such as these: Are the effects of EMDR caused by the treatment itself or by the faith that clients might have in any new treatment? And are EMDR's effects faster, stronger, and longer lasting than those of other treatments?

Raising tough questions about cause and effect, quality, and value is part of the process of *critical thinking*. Whether you are choosing a therapy method or an Internet provider, a college or a smartphone, critical thinking can guide you to ask the kinds of questions that lead to good decisions. But asking the right questions is not enough; you also have to try answering them. Critical thinking helps here, too, by prompting you to do some research on each of your options. For most people, this means asking the advice of friends or relatives, reading *Consumer Reports*, finding online reviews, studying a candidate's background, or the like. For psychologists, research means using scientific methods to gather information about behavior and mental processes.

In each chapter of this book, you will have the opportunity to think critically about many aspects of behavior and mental processes. In this chapter, we summarize five questions that will help you to do so in a systematic way, describe the scientific methods psychologists use in their research, and show how some of those methods have been applied in evaluating EMDR.

THINKING CRITICALLY ABOUT PSYCHOLOGY (OR ANYTHING ELSE)

How can critical thinking save you money?

Ask several friends and relatives if mental patients become more agitated when the moon is full, if psychics help the police solve crimes, and if people have suddenly burst into flames for no apparent reason. They will probably agree with at least one of these statements, even though not one of them is true. Perhaps you already knew that each of these statements is a myth, but don't feel too smug. At one time or another, we all accept things we are told simply because the information seems to come from a reliable source or because "everyone knows" it is true (Losh et al., 2003). If this were not the case, advertisers, politicians, salespeople, social activists, and others who seek our money, our votes, or our loyalty would not be as successful as they are. These people want you to believe their promises or claims without careful thought. In other words, they don't want you to think critically.

Uncritically accepting claims for the value of astrologers' predictions, get-rich-quick investment schemes, new therapies, or proposed government policies can be embarrassing, expensive, and dangerous. Critical thinkers carefully evaluate evidence for and against such claims before drawing a final conclusion.

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They often get their wish. Millions of people around the world waste untold amounts of money every year on worthless predictions by online and telephone "psychics"; on bogus cures for cancer, heart disease, and arthritis; on phony degrees offered by nonexistent Internet "universities"; and on "miracle" defrosting trays, eat-all-you-want weight-loss pills, "effortless" exercise devices, and other consumer products that simply don't work. Millions more lose money to investment scams and fraudulent charity appeals (Cassel & Bernstein, 2007).

Critical thinking is the process of assessing claims and making judgments on the basis of reasonable evidence (Wade, 1988). One way to apply critical thinking to EMDR—or to any other topic—is by asking these five questions:

1. ***What am I being asked to believe or accept?*** In this case, the assertion to be examined is that EMDR reduces or eliminates anxiety-related problems.
2. ***What evidence is available to support the assertion?*** Francine Shapiro experienced a reduction in her own emotional distress following certain kinds of eye movements. Later, she found the same effect in others.
3. ***Are there alternative ways of interpreting the evidence?*** The dramatic effects Shapiro reported might not have been due to EMDR but to people's desire to overcome their problems or perhaps their desire to prove her right. And who knows? They might eventually have improved without any treatment. Even apparently remarkable evidence can't automatically be accepted as proof of an assertion until other plausible alternatives have been ruled out. The ruling-out process leads to the next step in critical thinking: conducting scientific research.
4. ***What additional evidence would help evaluate the alternatives?*** An ideal method for collecting further evidence about the value of EMDR would be to identify three groups of people who not only suffered anxiety-related problems of the same kind and intensity but also were alike in every other way except for the anxiety treatment they received. One group would receive EMDR, a second group would get an equally impressive but useless treatment, and a third group would get no treatment at all. Now suppose that the people in the EMDR group improved much more than those who got no treatment or the impressive but useless treatment. Results such as these would make it harder to explain away the improvements following EMDR as due to client motivation or the mere passage of time.

critical thinking The process of assessing claims and making judgments on the basis of well-supported evidence.

Taking Your Life in Your Hands?

Can microwave radiation from cell phones cause brain tumors? This question generates strong opinions, but the answer will only come from research based on critical thinking. Though there is no conclusive evidence that cell phones cause tumors (Hauri et al., 2014; Hsu et al., 2013; Inskip, Hoover, & Devesa, 2010; Szmigielski, 2013), some scientists see danger in short- and long-term exposure (Kesari et al., 2013; Samet et al., 2014; Volkow et al., 2011) and in prenatal and early postnatal exposure (Clinical Digest, 2011). Research on this issue continues.

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5. ***What conclusions are most reasonable?*** The research evidence collected so far has not yet ruled out alternative explanations for the effects of EMDR (e.g., Goldstein et al., 2000; Hertlein & Ricci, 2004; Hughes, 2006; Lilienfeld, 2011; Lohr et al., 2003; Spates & Rubin, 2012). And although those effects are often greater than the effects of no treatment at all, they appear to be no stronger than those of several other kinds of treatment (e.g., Bériault & Larivée, 2005; Bradley et al., 2005; Cook-Vienot & Taylor, 2012; Cvetek, 2008; Field & Cotrell, 2011; Ho & Lee, 2012; Lilienfeld & Arkowitz, 2007; Wanders, Serra, & de Jongh, 2008). So the only reasonable conclusions to be drawn at this point are that EMDR remains a controversial treatment, it seems to benefit some clients, and further research is needed in order to understand it.

Do these conclusions sound inconclusive? Critical thinking sometimes does seem indecisive. Like the rest of us, scientists in psychology would love to find quick, clear, and final answers to their questions, but to have scientific value, conclusions must be based on what the available evidence has the capacity to determine. So if the evidence about EMDR is limited in some way, conclusions about whether and why the treatment works have to be limited too. In the long run, though, critical thinking opens the way to understanding. You will sharpen your own critical thinking skills in each chapter to come in a "Thinking Critically" section that examines a particularly interesting issue in psychology. Each time, we urge you to use the same five questions we illustrated here about EMDR.

Critical Thinking and Scientific Research

Scientific research often begins with questions born of curiosity, such as "Can eye movements reduce anxiety?" Like many seemingly simple questions, this one is more complex than it first appears. How rapid are the eye movements? How long do they continue in each session, and how many sessions should there be? What kind of anxiety is to be treated, and how will we measure improvement? In other words, scientists have to ask *specific* questions in order to get meaningful answers.

Psychologists and other scientists clarify their questions about behavior and mental processes by phrasing them in terms of a **hypothesis**—a specific, testable statement about something they want to study. Hypotheses are precise, clearly worded statements that describe what researchers think may be true and how they will know if it is not. A hypothesis about EMDR might be "EMDR treatment causes significant reduction in anxiety." To make it easier to understand and evaluate their hypotheses, scientists employ **operational definitions**, which are descriptions of the precise operations or methods they

hypothesis In scientific research, a specific, testable proposition about a phenomenon.

operational definition A statement that defines the exact operations or methods used in research.

I Love It!

When we want something—or someone—to be perfect, we may ignore all evidence to the contrary. This is one reason why people end up in faulty used cars—or in bad relationships. Psychologists and other scientists use special procedures, such as the double-blind methods described later in this chapter, to help keep *confirmation* bias from distorting the conclusions they draw from research evidence. We describe confirmation bias in more detail in the chapter on thought and language.

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will use in a research study. In other words, in an experiment, the researcher has to decide ahead of time exactly how each issue will be measured or manipulated. So, for our EMDR hypothesis, "EMDR treatment" might be operationally defined as a specific number of side-to-side eye movements per second over a particular period of time. And "significant reduction in anxiety" might be operationally defined as a decline of at least 10 points on a test that measures anxiety. The kind of treatment a client is given (say, EMDR versus no treatment) and the results of that treatment (the amount of anxiety reduction observed) are examples of research **variables**, the specific factors or characteristics that are manipulated and measured in research.

Scientists must also consider the value of the evidence they collect. They usually do this by evaluating its statistical reliability and validity. **Statistical reliability** (usually just called **reliability)** is the degree to which the data are stable and consistent. The **statistical validity** (usually just called **validity**) of data is the degree to which they accurately represent the topic being studied. For example, the first evidence for EMDR was based on Francine Shapiro's own experience with eye movements. If she had not been able to consistently repeat, or *replicate*, those effects in other people, one would have to question the reliability of such data. And if her clients' reports of reduced anxiety were not supported by, say, their overt behavior or the reports of their close relatives, one would have to doubt the validity of these data.

variable A factor or characteristic that is manipulated or measured in research.

statistical reliability (reliability) The degree to which test results or other research evidence occurs repeatedly.

statistical validity (validity) The degree to which evidence from a test or other research method measures what it is supposed to measure.

theory An integrated set of propositions that can be used to account for, predict, and even suggest ways of controlling certain phenomena.

The Role of Theories

After examining data from research, scientists may start to favor certain explanations as to why particular results occurred. Sometimes they organize their explanations into a **theory**, which is a set of statements designed to account for, predict, and even suggest ways of controlling certain phenomena. Shapiro's theory about the effects of EMDR suggests that eye movements may affect parts of the brain in which information about trauma or other unpleasant experiences is processed (Leeds, 2009; Shapiro & Forrest, 2004). Others (e.g., Lee, Taylor, & Drummond, 2006) suggest that EMDR may help troubled people think about stressful material in a more detached, less emotional way, perhaps as in a dream (Elofsson et al., 2008). In the chapter on introducing psychology, we review broader and more famous examples of explanatory theories, including Charles Darwin's theory of evolution and Sigmund Freud's theory of psychoanalysis.

Because theories are only tentative explanations, they must be examined scientifically using critical thinking. So although theories may be based on research results, they also generate new hypotheses that can be tested in research. The predictions of one

Theories of Prejudice

It is all too easy these days to spot evidence of prejudice against almost any identifiable group of people, especially minorities, but why does prejudice occur? The chapter on social psychology describes several theories, and the testing of these theories is an example of how theory and research go hand in hand. Without research results, there would be nothing to explain; without explanatory theories, the results might never be organized in a useful way. The knowledge generated by psychologists over the past century and a half has been based on this constant interaction of theory and research.

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psychologist's theory will be evaluated by other psychologists. If such research does not support a theory, the theory may need to be revised or abandoned.

The process of creating, evaluating, and revising psychological theories may not always lead to a single clear "winner." You will discover in the chapters ahead that there are several competing explanations for color vision, memory, sleep, aggression, eating disorders, and many other behaviors and mental processes. The conclusions we offer are based on what is known so far, and we always cite where there is need for new research. We do so because research often poses at least as many new questions as it answers. Data from one study might not apply to every situation or to all people. A treatment might be effective for mild depression in women, but it would have to be tested in more severe cases and with both sexes before drawing broader conclusions about the full extent of its value. Keep these points in mind the next time you hear a television personality confidently offering simple solutions to complex problems such as obesity or anxiety or presenting easy formulas for a happy marriage and perfect children. Such self-proclaimed experts—called "pop" (for *popular*) psychologists by the scientific community—may oversimplify issues, cite evidence for their views without concern for reliability or validity, and ignore evidence that contradicts their pet theories.

Psychological scientists must be more cautious, delaying judgments about behavior and mental processes until they have collected evidence. In evaluating theories and making conclusions, they are guided not only by the research methods described in the next section but also by the *law of parsimony* (also known as *simplicity*), summed up less scientifically as KISS ("Keep it simple, stupid"). The principle of parsimony is based on lessons from the long history of science. It suggests that when many alternative conclusions or several competing theories all offer convincing explanations of something, the simplest explanation is most often correct.

Throughout this book, you will see that research in psychology has created a large body of knowledge that is being put to good use in many ways. Let's now look at the scientific methods that psychologists use in their research and at some of the pitfalls that lie in their path.

RESEARCH METHODS IN PSYCHOLOGY

How do psychologists learn about people?

Like other scientists, psychologists try to achieve four main goals in their research: to *describe* a phenomenon, to *make predictions* about it, and to introduce enough *control* in their research to allow them to *explain* the phenomenon with some degree of confidence. Five research methods have proven especially useful for gathering the evidence needed to reach each of these goals. They include *observational methods, case studies, surveys, correlational studies,* and *experiments.*

Observational Methods: Watching Behavior

Sometimes, the best way to describe behavior is through **observational methods**, such as **naturalistic observation**, the process of watching without interfering as behavior occurs in the natural environment (Hoyle, Harris, & Judd, 2002). This method is especially valuable when more noticeable methods might alter the behavior you want to study. For example, if you ask people to keep track of how often they exercise, they might begin to exercise more than usual, so their reports might give a false impression of their typical behavior. Much of what we know about, say, gender differences in how children play and communicate with one another has come from psychologists' observations in classrooms and playgrounds. Observations of adults, too, have provided valuable insights into friendships, couple communication patterns, and even responses to terrorism (e.g., Mehl & Pennebaker, 2003a, 2003b).

observational methods Procedures for systematically watching behavior in order to summarize it for scientific analysis.

naturalistic observation The process of watching without interfering as a phenomenon occurs in the natural environment.

Little Reminders

If you asked this man what he needs to use various computer programs efficiently, he might not think to mention the notes on his monitor that list his usernames and passwords. Accordingly, researchers in human factors and in industrial and organizational psychology usually arrange to watch employees at work rather than just asking them what they do, how they do it, and how they interact with machines and fellow employees (Barriera-Viruet et al., 2006; Dempsey, McGorry, & Maynard, 2005).

Turbo/Corbis

Observational methods can provide good information, but they are not without problems. For one thing, people may act differently if they know they're being watched (and research ethics usually require that they do know). To combat this problem, researchers try to observe people long enough so that they get used to the situation and begin to behave more naturally. Still, observations can be incomplete or misleading if observers are not well trained or if they report what they expect to see rather than what actually occurs. Further, even the best observational methods don't allow researchers to make conclusions about what causes the behavior being observed.

Case Studies: Taking a Closer Look

Observations are often an important part of **case studies**, which are intensive examinations of behavior or mental processes in a particular individual, group, or situation. Case studies can also include tests, interviews, and the analysis of letters, school transcripts, medical charts, or other written records. Case studies are especially useful when studying something that is new, complex, or relatively rare (Sacks, 2002). Francine Shapiro's EMDR treatment, for example, first attracted psychologists' attention through case studies of its remarkable effects on her clients (Shapiro, 1989b).

Case studies have played a special role in **neuropsychology**, an area of psychology that focuses on the relationships among brain activity, thinking, and behavior. Consider the case of Dr. P., a patient described by neurologist Oliver Sacks (1985). Dr. P. was a distinguished musician who began to show odd symptoms. He could not recognize familiar people or other objects when he viewed them. For instance, while he and his wife were at the neurologist's office, Dr. P. looked at his foot and mistook it for his shoe. When he rose to leave, he tried to lift off his wife's head as if it were a hat and put it on his own head. He could not name common objects in front of him, but he could describe what he saw. When shown a glove, for example, he said, "A continuous surface, infolded on itself. It appears to have … five outpouchings, if this is the word … a container of some sort." Only later, when he put it on his hand, did he exclaim, "My God, it's a glove!" (Sacks, 1985, p. 13). Using case studies such as this one, neuropsychologists have been able to describe which symptoms people have after different kinds of brain damage (Heilman & Valenstein, 2011). Eventually, neuropsychologists have tied specific disorders to certain types of injuries, poisons, and other causes (Lezak et al., 2012). In Dr. P.'s case, a large brain tumor caused his symptoms.

Case studies have limitations. They may not represent people in general and may contain only the evidence a particular researcher considered important (Loftus & Guyer, 2002). Nonetheless, when conducted and used with care, case studies can give a unique glimpse into new phenomena, and these discoveries give valuable raw material for innovative research that can address novel ideas more systematically.

case study A research method involving the intensive examination of some phenomenon in a particular individual, group, or situation.

neuropsychology An area of psychology that studies the relationships among brain activity, thinking, and behavior.

survey A research method that involves giving people questionnaires or special interviews designed to obtain descriptions of their attitudes, beliefs, opinions, and intentions

Surveys: Looking at the Big Picture

In contrast to the individual close-ups provided by case studies, surveys offer wide-angle views of large groups. In **surveys**, researchers use interviews or questionnaires to ask people about their behavior, attitudes, beliefs, opinions, or intentions. Just as politicians and advertisers rely on opinion polls to test the popularity of policies or products, psychologists use surveys to gather descriptive data on just about any behavior or mental process, from parenting practices to sexual behavior. However, the validity of survey data can depend on how questions are asked (Bhopal et al., 2004; Wahl, Svensson, & Hydén, 2010). In one survey study at a health clinic, patients were asked how often they experienced headaches, stomachaches, and other symptoms (Schwarz & Scheuring, 1992). When the wording of questions suggested that most people frequently experience such symptoms, patients said that they frequently experienced them, too. But when the wording suggested that people rarely experience these symptoms, respondents said that they seldom had such symptoms.

Designing Survey Research

TRY THIS How do people feel about whether gay men and lesbians should have the right to legally marry? To appreciate the difficulties of survey research, try writing a question about this issue that you think is clear enough and neutral enough to generate valid data. Then ask some friends whether or not they agree it would be a good survey question and why.

Rob Melnychuk/Digital Vision/Getty Images

Learning from Rare Cases

We can learn a great deal from studying individual cases such as Dr. Temple Grandin, whose autism has not prevented her from becoming a professor of animal science, a noted advocate for the humane treatment of livestock, a best-selling author, and a champion of the rights of people with autistic disorder. Other case studies have focused, for example, on people who can correctly identify the day of the week for any date in the past or the future or tell at a glance that, say, exactly 125 paper clips are scattered on the floor. By carefully studying such rare cases, cognitive psychologists are learning more about human mental capacities and how they might be maximized in everyone (Biever, 2009; Geddes, 2008).

Nancy Kaszerman/ZUMA/Corbis

correlational studies Research methods that examine relationships between variables in order to analyze trends in data, test predictions, evaluate theories, and suggest new hypotheses.

correlation In research, the degree to which one variable is related to another.

A survey's validity also depends on who is surveyed. If the people surveyed don't represent the views of all of the population you're interested in, survey results can be misleading (Gosling et al., 2004; Kraut et al., 2004). For example, if you were interested in Americans' views on how common ethnic prejudice is, you could come to the wrong conclusion if you surveyed only African Americans or only European Americans. To get a complete picture, you would want to survey people from many ethnic groups so that all opinions could be fairly represented.

Some limitations of the survey method are harder to avoid. For example, a poll conducted for the American Society for Microbiology (ASM) found that 92 percent of U.S. adults surveyed said that they always wash their hands after using public toilet facilities. However, watching thousands of people in public restrooms across the United States revealed that the figure is closer to 77 percent (Harris Interactive, 2007). In other words, people may be unwilling to admit undesirable or embarrassing things about themselves or they may say what they believe they *should* say about an issue (Uziel, 2010). And those who respond to a survey may hold views that differ from those who choose not to respond (Visser, Krosnick, & Lavrakas, 2000). Such a problem creates a *response bias*, meaning that a survey's results are skewed to rely too much on the views of responders while not fairly capturing views of non-responders (Hoyle, Harris, & Judd, 2002). Still, surveys are an efficient way to gather large amounts of data about people's attitudes, beliefs, or other characteristics.

Correlational Studies: Looking for Relationships

Data collected from naturalistic observations, case studies, and surveys help describe behavior and mental processes, but they can do more than that. We can examine these data to see how research variables are related, or correlated, with each other. For example, fear surveys show that most people have fears, but correlational analysis of those surveys also shows that the number of fears is related to age. Specifically, adults have fewer fears than do children (e.g., Kleinknecht, 1991). **Correlational studies** examine relationships between variables in order to describe research data more fully, test predictions, evaluate theories, and suggest new hypotheses about why people think and act as they do.

Correlation refers to both the strength and the direction of the relationship between two variables. A *positive correlation* means that the two variables increase together or decrease together. A *negative correlation* means that the variables move in opposite

A Severely Flawed Survey

Using survey methods like this, you could probably get whatever results you want! Psychologists work hard to write questions and use methods that maximize the validity of their surveys' results.

DILBERT: © Scott Adams/Dist. by United Feature Syndicate, Inc.

directions. For example, James Schaefer observed 4,500 customers in sixty-five bars and found that the tempo of the music playing was negatively correlated with the rate at which the customers drank alcohol. The slower the tempo, the faster the drinking (Schaefer et al., 1988). Does this mean that Schaefer could have worn a blindfold and predicted exactly how fast people were drinking by timing the music? Could he have plugged his ears and determined the musical tempo just by watching people's sip rates? No and no, because the accuracy of predictions made about one variable from knowing the other depends not only on the direction but also on the *strength* of the correlation. Only a perfect correlation between two variables would allow you to predict the exact value of one based on the other. The weaker a correlation, the less one variable can tell you about the other.

Psychologists describe the strength and direction of correlations with a number called a *correlation coefficient,* which can range from a high of 1.00 to a low of .00 (see the "Statistics in Psychological Research" appendix). If the correlation between two variables is *positive*—if they both move in the same direction—the correlation coefficient will have a plus sign in front of it. If there is a minus sign, the correlation is *negative,* and the two variables will move in opposite directions. The larger the correlation coefficient, the stronger the relationship between the two variables. The strongest possible relationship is indicated by either $+1.00$ or -1.00. A correlation of .00 indicates that there is no relationship between variables.

Correlation coefficients describe the results of correlational research to help evaluate hypotheses, but psychological scientists must be extremely careful when interpreting what correlations mean. The mere fact that two variables are correlated does not guarantee that one causes an effect on the other. And even if one variable actually does cause an effect on the other, a correlation coefficient can't tell us which variable is influencing which, or why (see Table 2.1). As an example of this important point, consider the question of how aggression develops. Correlational studies of observational data indicate that children who are in day care for more than thirty hours a week are more aggressive than those who stay at home with a parent. Does separation from parents cause the greater aggressiveness with which it is associated? It might, but psychologists must be careful about jumping to such a conclusion. What may seem an obvious explanation for a correlational relationship may not always be correct. Perhaps the aggressiveness seen in some children in day care has something to do with the children themselves or with what happens to them in day care, not just with separation from their parents.

One way scientists evaluate such alternative hypotheses is to conduct further correlational studies to look for trends that support or conflict with those hypotheses (Rutter, 2007; West, 2009). Further analysis of day-care research, for example, shows that the aggressiveness seen in preschoolers who spend a lot of time in day care is the exception, not the rule. Most children don't show any behavior problems, no matter how much time they have spent in day care. This more general trend suggests that whatever effect separation has, it may be different for different children in different settings,

TABLE 2.1 CORRELATION AND CAUSATION

TRY THIS Look at the relationships described in the left-hand column, then ask yourself why the two variables in each case are correlated. Could one variable cause an effect on the other? If so, which is the cause, and how might it exert its effect? Could the relationship between the two variables be caused by a third one? If so, what might that third variable be? We suggest some possible explanations in the right-hand column. Can you think of others?

Correlation	Possible Explanations
The more sexual content U.S. teenagers reported watching on television, the more likely they were to begin having sex themselves in the following year (Collins et al., 2004).	Some teens' greater interest in sex may have led them to watch more sexually oriented shows and to become sexually active.
The number of drownings in the United States rises and falls during the year along with the amount of ice cream sold each month.	A third variable, the time of year, may explain the high consumption of ice cream and likelihood of water activities (Brenner et al., 2001).
In places where beer prices are increased, the number of new cases of sexually transmitted diseases falls among young people living in those places.	If price increases cause less beer consumption, people might stay sober enough to remember to use condoms during sex. The relationship could also be a coincidence, because prices don't always affect alcohol use. More research is required to understand this correlation.
A study found that the more antibiotics a woman has taken and the longer she has taken them, the greater is her risk of breast cancer (Velicer et al., 2004).	Long-term antibiotic use might have impaired the women's immune systems, but the cancer risk might also have been increased by the diseases for which the antibiotics were prescribed, not the drugs themselves. Obviously, much more research would be required before condemning the use of antibiotics.
The U.S. stock market rises during years when a team from the National Football Conference won the Super Bowl and falls when an American Conference team was the winner.	The so-called "Super Bowl Effect" has occurred in over 80 percent of Super Bowls through 2013; striking as this might seem, coincidence seems to be the most likely explanation.

causing some to express aggressiveness, others to show fear, and still others to be joyful. As described in the chapter on human development, psychologists are exploring this possibility by examining correlations between children's personality traits, qualities of different day-care programs, and reactions to day care (Belsky et al., 2007; Dupere, Leventhal, & Crosnoe, in press; NICHD Early Child Care Research Network, 2006a; Pluess & Belsky, 2010).

Throughout this book, you will see many more examples of how correlational studies help shed light on a wide range of topics in psychology (Rutter, 2007).

Experiments: Exploring Cause and Effect

The most direct way to test hypotheses and confirm cause-and-effect relationships between variables is to apply some control over those variables (Falk & Heckman, 2009). This kind of research usually takes the form of an experiment. An **experiment** is a type of study where a researcher controls one variable and then observes the effect of that manipulation on another variable, while holding all other variables constant.

experiment A study in which the researcher directly controls one variable and then observes the effect of that manipulation on another variable, while holding all other variables constant.

Consider the experiment Francine Shapiro conducted to study the effects of EMDR. As illustrated in Figure 2.1, she first identified twenty-two people who were suffering the ill effects of traumas such as rape or war. These were her research participants. She then assigned each of the participants to be in one of two groups. Members of the first group received a single fifty-minute session of EMDR treatment. Members of the second group

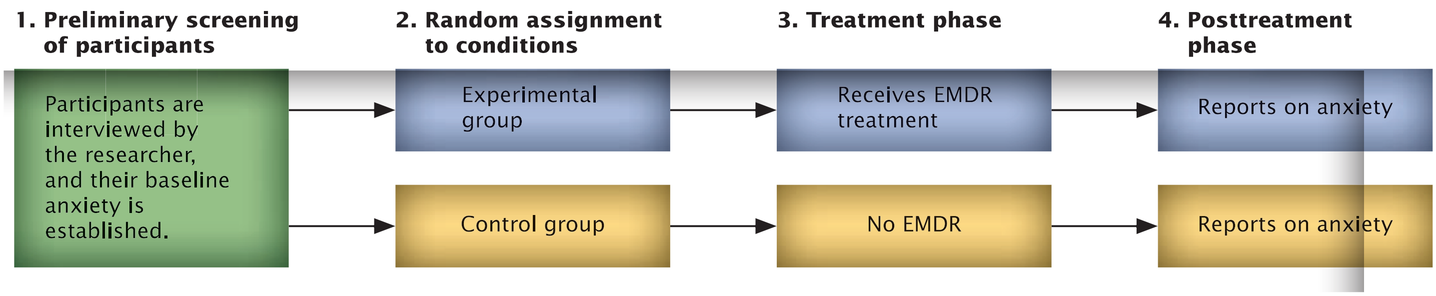


FIGURE 2.1
A Simple Two-Group Experiment

Ideally, the only difference between the experimental and control groups in experiments such as this one is whether the participants receive the treatment the experimenter wishes to evaluate. Under these ideal circumstances, at the end of the experiment, the best conclusion would be that any difference in the two groups' reported levels of anxiety would be due only to whether or not they received treatment.

received no EMDR treatment; instead, they focused on their unpleasant memories for eight minutes, without moving their eyes back and forth (Shapiro, 1989a).

The group assigned to receive an experimental treatment such as EMDR is called, naturally enough, the **experimental group**. The group not assigned to receive the treatment of interest is called the **control group**. Control groups provide baselines against which to compare the performance of other groups. In Shapiro's experiment, having a control group allowed her to measure how much change in anxiety could be expected from exposure to bad memories without EMDR treatment. Since people were assigned to the two groups by the experimenter, these groups should have been exactly the same before the experiment. Accordingly, any difference in anxiety between the groups afterward should have something to do with the EMDR treatment rather than with mere exposure to unpleasant memories.

Notice that Shapiro controlled one variable: whether or not her participants received EMDR. In an experiment, the name used for the variable controlled by the experimenter is the **independent variable**. It is called *independent* because the experimenter is free to adjust it at will, offering one, two, or three kinds of treatment, for example, or perhaps setting the length of treatment at one, five, or ten sessions. Notice, too, that Shapiro looked for the effects of treatment by measuring a different variable, her clients' anxiety level. This second variable is called the **dependent variable** because it is affected by, or depends on, the independent variable. So in Shapiro's experiment, the presence or absence of treatment was the independent variable, because she manipulated it. Her participants' anxiety level was the dependent variable, because she measured it to see how it was affected by treatment. (Table 2.2 describes the independent and dependent variables in other experiments.)

The results of Shapiro's experiment showed that participants who received EMDR treatment experienced a complete and nearly immediate reduction in anxiety related to their traumatic memories, whereas those in the control group showed no change (Shapiro, 1989a). You might conclude this difference suggests that EMDR caused the improvement. But look again at the structure, or design, of the experiment. The EMDR group's session lasted about fifty minutes, but members of the control group focused on their memories for only eight minutes. Would the people in the control group have improved, too, if they had spent fifty minutes focusing on their memories? We don't know, because the experiment did not compare methods of equal duration.

Anyone who conducts or relies on research must be on guard for such flaws in experimental design. So before drawing conclusions from research, experimenters must consider factors that might confound, or confuse, the interpretation of results. Any factor, such as differences in the length of treatment, that might have affected the dependent variable along with or instead of the independent variable can become a **confound**. When confounds are present, the experimenter cannot know whether the independent variable or the confound caused the results seen in the dependent variable.

experimental group In an experiment, the group that receives the experimental treatment.

control group In an experiment, the group that receives no treatment or provides some other baseline against which to compare the performance or response of the experimental group.

independent variable The variable directly controlled by the researcher in an experiment.

dependent variable In an experiment, the factor measured to see whether or not it has been affected by the independent variable.

confound In an experiment, any factor that affects the dependent variable, along with or instead of the independent variable.

TABLE 2.2 INDEPENDENT AND DEPENDENT VARIABLES

TRY THIS Fill in the names of the independent and dependent variables in each of these experiments (answers are at the bottom of page 38). Remember that the independent variable is set by the experimenter. The dependent variable is measured to learn how it was affected by the independent variable. How did you do on this task?

1. Children's reading skill is measured after taking either a special reading class or a standard reading class.	The independent variable is ___________. The dependent variable is ___________.
2. College students' memory for German vocabulary words is tested after a normal night's sleep or a night of no sleep.	The independent variable is ___________. The dependent variable is ___________.
3. Experiment title: "The effect of a daily walking program on elderly people's lung capacity."	The independent variable is ___________. The dependent variable is ___________.
4. People's ability to avoid "accidents" in a driving simulator is tested before, during, and after talking on a cell phone.	The independent variable is ___________. The dependent variable is ___________.

Let's examine three kinds of confounds: random variables, participants' expectations, and experimenter bias.

Random Variables

In an ideal research world, everything about the experimental and control groups would be the same except for what the experimenter did to the independent variable (such as whether or not they received treatment). In the real world, however, there may be other differences between the groups that reflect random variables (West, 2009). **Random variables** are uncontrolled, sometimes uncontrollable, factors such as the time of year when research takes place and differences in the participants' cultural backgrounds, personalities, life experiences, and sensitivity to stress, for example.

In fact, there are so many ways in which participants might vary from one another that it is usually impossible to form groups that are matched in all respects. Instead, experimenters simply flip a coin or use some other random process to assign each research participant to the experimental or control group. These procedures—called *random assignment* or **randomizing**—are presumed to distribute the impact of uncontrolled variables randomly (and probably about equally) across groups, thus minimizing the chance that these variables will distort the results of the experiment (Shadish, Cook, & Campbell, 2002).

random variable In an experiment, a confound in which uncontrolled or uncontrollable factors affect the dependent variable, along with or instead of the independent variable.

randomizing Assigning participants in an experiment to various groups through a random process to ensure that random variables are evenly distributed among the groups.

Participants' Expectations: The Placebo Effect

After eight minutes of focusing on unpleasant memories, participants in the control group in Shapiro's experiment were instructed to begin moving their eyes from side to side. At that point they, too, said they began to experience a reduction in anxiety. Was this improvement caused by the eye movements themselves, or could it be that the instructions made the participants feel more confident that they were now getting "real" treatment? This question illustrates a second kind of confound: differences in what people *think* about the experimental situation. If participants who receive an impressive treatment expect that it will help them, they may try to improve in a different way than those in a control group who receive no treatment or a less impressive treatment. When improvement occurs as a result of a participant's knowledge and expectations, it is called the *placebo effect*. A

Ever Since I Started Wearing This Titanium Necklace …

Placebo-controlled experiments establish cause-effect relationships between treatments and outcomes with human participants. For example, many people swear that titanium bracelets and necklaces relieve the pain of sports injuries and even arthritis (Atkinson, 2006; Galdeira, 2006; Marchman, 2008; Siber, 2005). Phiten, the leading manufacturer and marketer of titanium accessories, touts glowing testimonials and a scientific-sounding explanation of the technology behind titanium's alleged effects but offers no evidence from placebo-controlled experiments to support their claims (Boyles, 2008; Wagg, 2008). Such experiments have already failed to support the value of "power balance" bracelets that are supposed to improve strength, flexibility, and balance (Underdown, 2011).

Gene J. Puskar/AP Images

placebo (pronounced "pluh-SEE-boh") is a treatment that contains nothing known to be helpful but that still produces benefits because the person receiving the treatment believes it will be beneficial.

How can researchers measure the extent to which a result is caused by the independent variable or by the placebo effect? Usually, they include a special control group that receives *only* a placebo treatment. Then they compare results for the experimental group, the placebo group, and a no-treatment group. In one quit-smoking study, for example, participants in a placebo group took sugar pills described by the experimenter as "fast-acting tranquilizers" that would help them learn to endure the stress of giving up cigarettes (Bernstein, 1970). These people did far better at quitting than those who got no treatment; in fact, they did as well as participants in the experimental group, who received extensive treatment. These results suggested that the success of the experimental group may have been due largely to the participants' expectations, not to the treatment methods.

Some studies suggest the same conclusion about the effects of EMDR, because significant anxiety reduction occurred in people who got a version of the treatment that did not involve eye movements or even focusing on traumatic memories (e.g., Nieuwenhuis et al., 2013; Seidler & Wagner, 2006; Servan-Schreiber et al., 2006; van den Hout & Engelhard, 2012). Other experiments have shown that EMDR can outperform placebo treatments, but the fact that its effects are often no better overall than those of other therapies has led some to conclude that EMDR should not have special status in the treatment of anxiety-related disorders (Bisson, 2007; Lilienfeld, 2011; Lilienfeld & Arkowitz, 2007; Lohr et al., 2003; Taylor, 2004).

Experimenter Bias

Another potential confound is **experimenter bias**, the unintentional effect that researchers may exert on their results. Robert Rosenthal (1966) was among the first to demonstrate a kind of experimenter bias called *experimenter expectancies*. His research participants were laboratory assistants whose job was to place rats in a maze. Rosenthal told some of the assistants that their rats were "maze-bright"; he told the others that their rats were "maze-dull." In fact, both groups of rats were randomly drawn from the same population and should have had about equal maze-learning capabilities. But the maze-bright animals learned the maze significantly faster than the maze-dull rats. Why? Rosenthal concluded that the results had nothing to do with the rats and everything to do with the experimenters. The only difference imposed onto the two groups of rats were that the assistants had different expectations about the rats. The assistants' belief in supposedly superior or inferior capabilities must have caused them to alter their training and handling techniques somehow. These slight differences may have speeded or slowed the animals' learning. Similarly, when therapists are asked to give different kinds of treatment to different groups of people in a therapy evaluation experiment, the therapists may do a slightly better job using the treatments they expected to work best. Even a slight unintentional difference could improve the effects of that treatment compared to the others.

To prevent experimenter bias from influencing results, experimenters may use a **double-blind design**. In this arrangement, both the research participants and those giving the treatments are unaware of ("blind") who gets the placebo. Only researchers who have no direct contact with participants have this information, and they do not reveal it until the experiment is over. The fact that double-blind studies of EMDR have not yet been conducted is another reason for caution in drawing conclusions about this treatment.

placebo A physical or psychological treatment that contains no active ingredient but produces an effect because the person receiving it believes it will.

experimenter bias A confound that occurs when an experimenter unintentionally encourages participants to respond in a way that supports the experimenter's hypothesis.

double-blind design A research design in which neither the experimenter nor the participants know who is in the experimental group and who is in the control group.

Answers to Table 2.2

1. Independent variable: type of reading class; dependent variable: reading skill. 2. Independent variable: amount of sleep; dependent variable: score on a memory test. 3. Independent variable: amount of exercise; dependent variable: lung capacity. 4. Independent variable: using or not using a cell phone; dependent variable: performance on a simulated driving task.

Keeping Experimenters "Blind"

TRY THIS Suppose that you are a sport psychologist conducting an experiment to evaluate two methods for reducing performance anxiety: standard coaching and a new relaxation-based technique. How might you create a double-blind design for this experiment? If you cannot, how might you try to keep coaches in the dark about which method is expected to produce better results?

Christopher Bissell / Stone / Getty Images

To sum up, experiments are vital tools for examining cause-and-effect relationships between variables, but like the other methods we have described (see "In Review: Methods of Psychological Research"), they are vulnerable to error. To maximize the value of experiments, psychologists try to eliminate as many confounds as possible. Then they replicate their work to ensure consistent results and temper their interpretation of those results to take into account the limitations or problems that remain.

IN REVIEW

METHODS OF PSYCHOLOGICAL RESEARCH

Method	Features	Strengths	Pitfalls
Observational methods (e.g., naturalistic observation)	observation of human or animal behavior in the environment in which it typically occurs	Provides descriptive data about behavior presumably uncontaminated by outside influences	Observer bias and participant self-consciousness can distort results
Case studies	Intensive examination of the behavior and mental processes associated with a specific person or situation	Provide detailed descriptive analyses of new, complex, or rare phenomena	May not provide a representative picture of phenomena
Surveys	Standard sets of questions asked of a large number of participants	Gather large amounts of descriptive data relatively quickly and inexpensively	Sampling errors, poorly phrased questions, and response biases can distort results
Correlational studies	Examine relationships between research variable	Can test predictions, evaluate theories, and suggest new hypotheses	Cannot confirm causal relationships between variables
Experiments	Manipulation of an independent variable and measurement of its effect on a dependent variable	Can establish a cause-and-effect relationship between independent and dependent variables	Confounds may prevent valid conclusions

1. The ___________ method is most likely to use a double-blind design.
2. Research on a new treatment method is most likely to begin with ___________.
3. Studying language by listening to people in public places is an example of ___________ research.

Selecting Research Participants

TRY THIS Imagine that as a social psychologist, you want to study people's willingness to help each other. You have developed a method for testing helpfulness, but now you want a random sample of people to test. Take a minute to think about the steps necessary to select a truly random sample; then ask yourself how you might obtain a representative sample instead. Remember that although the names are similar, *random sampling* is not the same as *randomizing*. Random sampling is used in many kinds of research to ensure that the people studied are representative of some larger group. Randomizing is used in experiments to distribute participant characteristics as evenly as possible across various groups.

Jim West/The Image Works

Selecting Human Participants for Research

Visitors from another planet would be wildly mistaken if they tried to describe a typical earthling after meeting only Lady Gaga, Charlie Sheen, and a trained seal. Psychologists, too, can be led astray if the participants they encounter in their research are not typical of the people or animals about which they want to draw conclusions. Accordingly, a vital step in scientific research is selecting participants, a process called **sampling**.

If they want to make accurate statements about the behavior and mental processes of any large group, psychologists must conduct **representative sampling** of participants whose characteristics mirror the rest of that group in terms of age, gender, ethnicity, cultural background, socioeconomic status, sexual orientation, disability, and the like. In theory, a representative sample can be drawn at random from the entire population of interest. For example, psychologists could choose a representative sample of Canadians, Democrats, or any other group. Doing this would require putting hundreds of thousands—perhaps millions—of names into a computer, running a program to select participants randomly, and then tracking them down to invite them to take part in the research. This method would result in truly **random sampling**, because every single member of the population under study would have an equal chance of being chosen. (Any selection procedure that does not offer this equal chance is said to result in **biased sampling**.)

However, true random sampling is usually too expensive and time-consuming to be practical, so psychologists often find research participants in more conveniently available populations. The populations from which these *convenience samples* are drawn depend to some extent on the researcher's budget. They might include, for example, students enrolled in a course, students enrolled on a local campus, students who are willing to sign up for a study, or visitors to websites or Facebook groups. Ideally, this selection process will yield a sample that fairly represents the population from which it was drawn. However, scientists must realize that their conclusions might apply only to their samples (Kraut et al., 2004). Therefore, psychologists often conduct additional studies to determine whether their initial conclusions apply to other groups (APA Office of Ethnic Minority Affairs, 2000; Case & Smith, 2000).

sampling The process of selecting participants who are members of the population that the researcher wishes to study.

representative sampling A process for selecting research participants whose characteristics fairly reflect the characteristics of the population from which they were drawn.

random sampling The process of selecting a group of research participants from a population whose members all had an equal chance of being chosen.

biased sampling The process of selecting a group of research participants from a population whose members did not have an equal chance of being chosen.

LINKAGES How much of our behavior is due to genetics and how much to our environment? (A link to Biological Aspects of Psychology)

LINKAGES

PSYCHOLOGICAL RESEARCH METHODS AND BEHAVIORAL GENETICS

One of the most fascinating and difficult challenges in psychology is to find research methods that can help us understand the ways in which people's genetic inheritance (their biological *nature*) intertwines with environmental events and conditions before and after birth (often called *nurture*) to shape behavior and mental processes (Moffitt, Caspi, & Rutter, 2005). Consider Mark and John, identical twins who were both adopted at birth because their biological parents were too poor to care for them. John grew up with a married couple who made him feel secure and loved. Mark went from orphanage to foster home to hospital and, finally, back to his biological father's second wife. Thus, these genetically identical people lived in very different environments. Yet, when they met for the first time at the age of twenty-four, they discovered similarities that went far beyond physical appearance. They used the same aftershave lotion, smoked the same brand of cigarettes, used the same imported toothpaste, and liked the same sports. They had joined the military within eight days of each other, and their IQ scores were nearly identical. How had genetic influences operated in two different environments to shape such similarities?

Exploring questions such as these has taken psychologists into the field of **behavioral genetics**, the study of how genes shape behavior. They have discovered that most behavioral tendencies are likely to be influenced by interactions between the environment and many different genes. Accordingly, research in behavioral genetics is designed to explore how genetic and environmental factors act on each other to produce personality, mental ability, mental disorders, and patterns of behavior. Such research also seeks to identify which specific genes exert these influences.

Some behavioral genetics research takes the form of experiments, mainly on the selective breeding of animals (Suomi, 2004). For example, Stephen Suomi (1999) identified monkeys whose genes predisposed them to show strong or weak reactions to stress. He then mated strong reactors with other strong reactors and mated weak reactors with other weak reactors. Within a few generations, descendants of the strong-reactor pairs reacted much more strongly to stressors than did the descendants of the weak-reactor pairs. Selective-breeding experiments must be interpreted with caution, though, because animals do not inherit specific behaviors. Instead, they inherit differing sets of physical structures and capacities that make certain behaviors more likely or less likely.

Yet genes alone do not have a final say in these behavioral tendencies, since the behaviors can be altered by the environment (Grigorenko, 2002; Parker et al., 2006). For example, when Suomi (1999) placed young, highly stress-reactive monkeys with unrelated "foster mothers," he discovered that the foster mothers' own stress reactivity amplified or dampened the youngsters' genetically influenced behavioral tendencies. If stress-reactive monkeys were placed with stress-reactive foster mothers, they tended to be fearful of exploring their environments and had strong stress reactions. But if equally stress-reactive young monkeys had calm, supportive foster mothers, they appeared more eager to explore their environments and less upset by stressors than peers with stress-reactive foster mothers.

Research on behavioral genetics in humans must be interpreted with even greater care. Legal, moral, and ethical considerations obviously prohibit experiments on the selective breeding of people, so research in human behavioral genetics depends on correlational studies. Traditionally, these take the form of family studies, twin studies, and adoption studies (Plomin et al., 2008). Let's consider the logic of these behavioral genetics research methods. (The behavioral genetics appendix discusses basic principles of genetics and heredity that underlie these methods.)

In *family studies*, researchers look at whether close relatives are more likely than distant ones to show similar behavior and mental processes. If increasing similarity is associated with closer family ties, the similarities might be inherited. For example, family studies suggest a genetic basis for schizophrenia because this severe mental disorder appears much more often in the closest relatives of schizophrenics than in other people (see Figure 2.2). But remember that a correlation between variables does not establish that one is causing the other. Similar disorders might occur in close relatives due to environmental factors they

behavioral genetics The study of how genes and environment shape behavior.

have in common instead of or in addition to genetic ones. After all, close relatives tend to share both similar environments and similar genes. So family studies alone do not establish the role of genetic factors in mental disorders or other characteristics.

Twin studies explore the heredity-environment mix by comparing the similarities seen in identical twins with those of nonidentical pairs (Johnson et al., 2009). Twins usually share the same family environment as they grow up, and they may also be treated more similarly by parents and others. So if identical twins (whose genes are exactly the same) are more alike on some characteristic than nonidentical twins (whose genes are no more similar than those of other siblings), that characteristic may have a significant genetic component. As we learn in later chapters, this pattern of results holds for many characteristics, including some measures of intelligence and some mental disorders. As shown in Figure 2.2, for example, if one member of an identical twin pair develops schizophrenia, the chances are about 45 percent that the other twin will too. Those chances drop to about 17 percent if the twins are nonidentical.

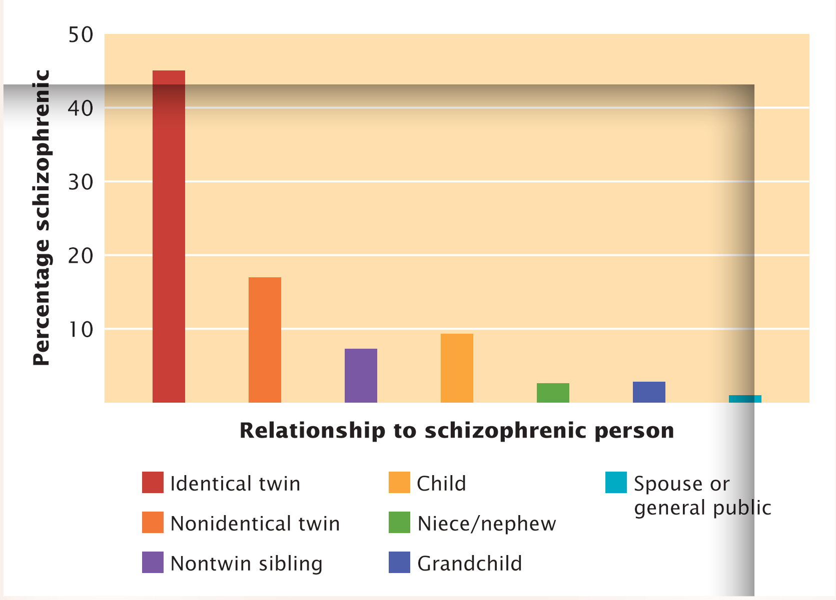


FIGURE 2.2
Family and Twin Studies of Schizophrenia

The risk of developing schizophrenia, a severe mental disorder, is highest for the siblings and children of schizophrenia patients and lowest for those who are not genetically related to anyone with schizophrenia. Does this mean that schizophrenia is inherited? These results are consistent with that interpretation, but the question cannot be answered through family studies alone. Studies comparing identical and nonidentical twins also suggest genetic influence, but even twin studies cannot eliminate the role of environmental influences. Environmental factors, such as stressors that close relatives share, could also play an important role and may even contribute to the heritable epigenetic effects discussed later in this section (Crespi, 2008; Ivleva, Thaker, & Tamminga, 2008; Singh & O'Reilly, 2009; Tandon, Keshavan, & Nasrallah, 2008).

Adoption studies take scientific advantage of cases in which babies are adopted very early in life. The logic of these studies is that if adopted children's characteristics are more like those of their biological parents than of their adoptive parents, genetics may play a role in those characteristics. In fact, as you will read in the chapter on personality, traits of young adults who had been adopted at birth tend to be more like those of their biological parents than those of their adoptive parents. Adoption studies can be quite valuable when they focus on identical twins who, like Mark and John, were separated at or near birth. If identical twins show similarities after years of living in different environments, the role of heredity in those similarities is highlighted. Adoption studies of intelligence tend to support the role of genetics in variations in mental ability, but they show the impact of environmental influences too.

Family, twin, and adoption studies have played an important role in behavioral genetics research, but when you read in other chapters about the role of genes in personality, intelligence, mental disorders, and other features of behavior, remember this important point: Research on human behavioral genetics can tell us about the relative roles of heredity and environment in creating differences *among* individuals, but cannot determine the degree to which a *particular* person's behavior is due to heredity or environment. The two factors are too closely entwined in an individual to be separated that way. For example, the influence exerted on an adopted baby by its biological parents reflects not only their genetic legacy but also the environment they provided before the baby was born and between birth and the adoption.

(*continued*)

Twins and Behavioral Genetics

Like other identical twins, each member of this pair has identical genes. Twin studies and adoption studies help reveal the interaction of genetic and environmental influences in human behavior and mental processes. Cases in which identical twins who had been separated at birth are found to have similar interests, personality traits, and mental abilities suggest that these characteristics are significantly influenced by genetic factors.

Comstock/Getty Images/Thinkstock

Today, research methods in behavioral genetics have been shaped by procedures made possible by the Human Genome Project, which established the genetic code contained in the DNA that makes each human being unique (International Human Genome Sequencing Consortium, 2001; see the behavioral genetics appendix). This achievement has allowed behavioral geneticists and other scientists to pinpoint some of the genes that contribute to individual differences in disorders such as autism, learning disabilities, hyperactivity, and Alzheimer's disease, as well as to the normal variations in personality and cognitive abilities that we see all around us (Plomin et al., 2008). Finding the DNA differences responsible for certain personal attributes and behaviors has made it possible to better understand how heredity interacts with the environment during a person's life. As described in the behavioral genetics appendix, analysis of DNA, which can be collected by rubbing a cotton swab inside an individual's cheek, is being used not only in behavioral genetics research but also in medical clinics, where it can more precisely diagnose some medical problems, specify the best treatment option, and determine the likelihood of passing on a genetic defect to future offspring (Euhus & Robinson, 2013; Solomon & Muenke, 2012).

DNA does not tell the whole story of behavioral genetics, however. As we have already discussed, biological and psychological scientists study how people's genetic inheritance (DNA) interacts with the environments in which their genes operate (Champagne, 2009; Champagne & Mashoodh, 2009). This field of study, called **epigenetics**, describes how events within cells can alter the *functions* of genes, even though the genetic code itself—the chemical sequence coded in the DNA—remains unchanged (Gräff & Mansuy, 2008; Keverne & Curley, 2008; Lickliter, 2008). Research in epigenetics suggests that the cellular environment can not only affect the expression of an individual's genetic characteristics but may also create structural changes in genes that can potentially be passed on to future generations (Keverne & Curley, 2008; Lamm & Jablonka, 2008; Lickliter, 2008). Epigenetic effects—which can be triggered by many environmental influences, including diseases and stress—have been linked to individual differences in learning, memory, and brain development (Gräff & Mansuy, 2008; Keverne & Curley, 2008; Lickliter, 2008), and they may also play a role in the appearance of cognitive disorders such as Alzheimer's disease, mental disorders such as schizophrenia and depression, illnesses such as cancer, and health problems such as obesity (Akbarian, Beeri, & Haroutunian, 2013).

STATISTICAL ANALYSIS OF RESEARCH RESULTS

What does it mean when scientists say that a research finding is statistically significant?

Observational methods, case studies, surveys, correlational studies, and experiments generate mountains of numbers—known as **data**—that represent research results and provide the basis for drawing conclusions about them (Keselman et al., 2004). These data might represent scores on intelligence tests, levels of stress hormones in blood samples, tiny differences in the time required to detect visual signals, ratings of people's personality traits, or whatever else a psychologist might be studying. Like other scientists, psychologists use descriptive and inferential *statistics* to summarize data and interpret what they mean.

As the name implies, **descriptive statistics** are used to describe a set of data. For example, the performance of a group of students on a math test could be described statistically by the *mean,* or average, score of the group. The mean is determined by adding up all the scores and dividing the total by the number of scores. Describing the difference between the performance of men and women could be done by calculating the difference

epigenetics The study of potentially inheritable changes in gene expression that do not alter a cell's DNA.

data Numbers that represent research findings and provide the basis for conclusions.

descriptive statistics Numbers that summarize a set of research data.

between the mean scores for each gender. And, as mentioned earlier, when psychologists want to describe the relationship between two variables, they use a descriptive statistic called the correlation coefficient.

Inferential statistics are mathematical procedures that help psychologists make inferences—that is, draw conclusions from their data and make assumptions about the meaning of results. Suppose, for example, that a group of trauma victims scored an average of ten points lower on an anxiety test after being treated with EMDR and that the scores of victims in a no-treatment control group dropped by an average of seven points. Does the three-point difference between these two groups reflect the impact of EMDR, or could it have been caused by random factors that made EMDR appear more powerful than it actually is? Inferential statistics allow researchers to estimate the likelihood that the difference between the average scores of the two groups was caused by chance factors rather than being due to the impact of the differing treatment they received. Other inferential statistics can help psychologists decide how likely it is that a correlation between two variables is large enough to suggest a real underlying relationship versus the possibility that it is just a fluke.

When inferential statistics argue that a correlation coefficient or the difference between groups is larger than expected by chance alone, the scientists say that the result has **statistical significance**. Statistical significance alone does not guarantee final "proof," but signifies that a finding merits more attention, especially when those results have been repeated, or *replicated,* in separate studies. When thinking critically about research, then, evaluating evidence about hypotheses includes asking whether a researcher's results are statistically significant and repeatable. (For more details on descriptive and inferential statistics and how to calculate them, see the "Statistics in Psychological Research" appendix.)

Statistics and Research Methods as Tools in Critical Thinking

As you think critically about evidence for or against any hypothesis, you should ask some tough questions. Does the evidence come from a study whose design is free of major confounds and other flaws? Have the results been subjected to careful statistical analysis? Have the findings been replicated? Using your critical thinking skills to evaluate research designs and statistical methods becomes most important when you think about results that are dramatic or unexpected.

This point was well illustrated when Douglas Biklen (1990) began promoting a procedure called "facilitated communication" to help people with severe versions of autistic spectrum disorder (ASD) use language for the first time (we describe ASD in the chapter on psychological disorders). Biklen claimed that these people have coherent thoughts but cannot express them using traditional language. He reported case studies in which people with ASD were apparently able to answer questions and speak intelligently using a special keyboard, but only when assisted by a "facilitator" who physically supported their unsteady hands. Controlled experiments have repeatedly shown this claim to be groundless, however (Jacobson, Mulick, & Schwartz, 1995; Mostert, 2001; Randi, 2009; Wegner, Fuller, & Sparrow, 2003). The alleged communication abilities of these people disappeared under conditions in which the facilitator (1) did not know the question being asked of the participant or (2) could not see the keyboard (Delmolino & Romanczyk, 1995). The discovery that facilitators were—perhaps inadvertently (Spitz, 1997)—guiding participants' hand movements has allowed those who work with people affected by ASD to see facilitated communication in a different light. So when a doctor in Belgium recently claimed that a man who had been in a coma for twenty-three years was suddenly able to communicate via a computer keyboard, skeptics were quick to point out that the person "supporting" his arm was clearly also guiding it (Black, 2009). The claim was soon withdrawn (BBC News, 2010).

The role of experiments and other scientific research methods in understanding behavior and mental processes is so important that in each chapter to come we include a special feature called "Focus on Research Methods." These features describe in detail

inferential statistics A set of mathematical procedures that help psychologists make inferences about what their research data mean.

statistical significance Referring to a correlation, or a difference between two groups, that is larger than would be expected by chance.

The Social Impact of Research

The impact of research in psychology depends partly on the quality of the results and partly on how people feel about those results. Despite negative results of controlled experiments on facilitated communication, the Facilitated Communication Institute's website continues to announce training for the many professionals and relatives of people with autistic disorder who still believe in its value. The fact that some people ignore or even attack research results that challenge cherished beliefs reminds us that scientific research has always affected and been affected by the social and political values of the society in which it takes place (Lynn et al., 2003; Tavris, 2002).

Robin Nelson/PhotoEdit

the specific procedures used in a particularly interesting research study. We hope that as you read these sections, you will see how the research methods discussed in this chapter are applied in every subfield of psychology.

ETHICAL GUIDELINES FOR PSYCHOLOGISTS

Do psychologists deceive people when they do research?

Some years ago, newspaper headlines claimed that hair dye causes cancer. Hairdressers were alarmed at first, then angry. The information given to the public was less than accurate. Rats—not humans—had been used in the research, and the animals developed cancer only after drinking the hair dye. Later research showed that using hair dye does not significantly increase human cancer risk (Takkouche, Etminan, & Montes-Martinez, 2005).

Splashy headlines sell newspapers and attract advertisers, but all scientists have an ethical obligation not to manipulate, distort, or sensationalize their research results. The obligation to analyze and report research fairly and accurately is just one of the ethical standards that guide psychologists. Preserving the welfare and dignity of research participants is another. So although researchers *could* measure anxiety by putting a loaded gun to people's heads or study marital conflicts by telling one partner that the other has been unfaithful, those methods could be harmful and are therefore unethical.

Whatever the research topic, psychologists' top priority is to investigate it with the highest ethical standards. They must first find ways to protect participants from harm, then determine how best to gather data of potential benefit for everyone. To measure anxiety, for example, a psychologist might ask people to enter a situation that is anxiety provoking but not traumatic (for example, approaching a feared animal or sitting in a dark room). And research on marital conflict usually involves observing couples as they discuss controversial issues in their relationship.

Psychologists take very seriously the obligation to minimize any immediate discomfort or risk for research participants as well as the need to protect those participants from long-term harm. A key element of this process is to inform prospective research subjects about every aspect of a study that might influence their decision to participate, and to ensure that each person's involvement is voluntary. But what if the purpose of the study is to measure people's emotional reactions to being insulted? Participants might not react normally if they know ahead of time that an "insult" will be part of the experiment. When deception is necessary to create certain experimental conditions, ethical standards require the

Caring for Animals in Research

Psychologists are careful to protect the welfare of animal participants in research. They do not wish to see animals suffer, and undue stress on animals can provoke reactions that can act as confounds. For example, in a study of how learning is affected by food rewards, the researcher could starve animals to make them hungry enough to want rewards. But this would introduce discomfort, making it impossible to separate the effects of the rewards from the effects of starvation.

Will & Deni McIntyre/Science Source

researcher to "debrief" participants as soon as the study is over by revealing all relevant information about the research and correcting any misconceptions it created.

Government regulations in the United States, Canada, and many other countries require that any research involving human participants must be approved by an Institutional Review Board (IRB) whose members have no connection with the research. If a proposed study is likely to create risks or discomfort for participants, IRB members weigh the potential benefits of the work in terms of knowledge and human welfare against any potential harm.

The obligation to protect participants' welfare also extends to animals, which are used in a small percentage of psychological research projects (American Psychological Association Committee on Animal Research and Ethics, 2012). Psychologists study animals partly because their behavior is interesting and partly because research with animals can provide information that would be impossible or unethical to collect from humans. For example, researchers can randomly assign animals to live alone and then look at how these conditions affect later social interactions. The same thing could not ethically be done with people, but animal studies offer clues about how social isolation might affect humans (see the chapter on motivation and emotion).

Contrary to some claims, animals used in psychological research are not routinely subjected to extreme pain, starvation, or other inhumane conditions. Even in the small proportion of studies that require the use of electric shock, the discomfort created is mild, brief, and not harmful. High standards for the care and treatment of animal participants are outlined in the Animal Welfare Act, the National Institutes of Health's *Guide for the Care and Use of Laboratory Animals,* the National Institute of Mental Health's *Methods and Welfare Considerations in Behavioral Research with Animals,* the American Psychological Association's *Principles on Animal Use,* and other laws and regulations (APA Committee on Animal Research and Ethics, 2012). In the rare studies that require animals to undergo short-lived pain or other forms of moderate stress, legal and ethical standards require that funding agencies—as well as local IRB and other committees charged with monitoring animal research—first determine that the discomfort is highly justified by the expected benefits to human welfare.

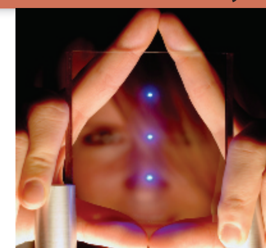
The responsibility for conducting research in the most humane fashion is one aspect of the *Ethical Principles of Psychologists and Code of Conduct* developed by the American Psychological Association (2010). The main purpose of these standards is to protect and promote the welfare of society and those with whom psychologists work. For example, as teachers, psychology instructors should give students complete, accurate, and up-to-date coverage of each topic, not a narrow and biased point of view. Further, psychologists should perform only those services and use only those techniques for which they are adequately trained. Psychologists should not reveal personal information obtained from clients or research participants except in the most unusual of circumstances (see the chapter on treatment of psychological disorders). Finally, they should avoid situations in which a conflict of interest might impair their judgment or harm others. They should not, for example, have sexual relations with their clients, students, or employees.

Despite these guidelines, doubt and controversy arise in some cases about whether a proposed experiment or a particular practice, such as deceiving participants, is ethical. The American Psychological Association has published a two-volume handbook (Knapp, 2011a, b) and a casebook (Campbell et al., 2009) to help psychologists resolve such issues. The ethical principles themselves must continually be updated to deal with complex new questions—such as how to protect the confidentiality of e-mail communications—that psychologists face in their ever-expanding range of work (American Psychological Association, 2010; Hays, 2006; Pipes, Holstein, & Aguirre, 2005; Warmerdam et al., 2010).

LINKAGES

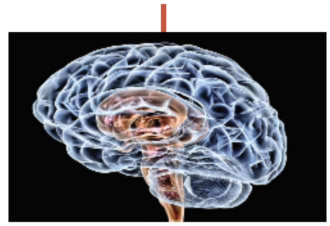
As noted in the chapter on introducing psychology, all of psychology's subfields are related to one another. Our discussion of behavioral genetics illustrates just one way in which the topic of this chapter, research in psychology, is linked to the subfield of biological psychology (see the chapter on biological aspects of psychology). The Linkages diagram shows ties to two other subfields as well, and there are many more ties throughout the book. Looking for linkages among subfields will help you see how they all fit together and help you better appreciate the big picture that is psychology.

CHAPTER 2 Research in Psychology



LINKAGES

How much of our behavior is due to genetics and how much to our environment?



CHAPTER 3
Biological Aspects of Psychology

Is it possible to do experiments on psychotherapy?

CHAPTER 15
Treatment of Psychological Disorders

Is it ethical to deceive people in order to learn about their social behavior?

CHAPTER 16
Social Psychology

SUMMARY

Thinking Critically About Psychology (or Anything Else)

How can critical thinking save you money?

Critical thinking is the process of assessing claims and making judgments on the basis of well-supported evidence.

Often questions about behavior and mental processes are phrased in terms of *hypotheses* about *variables* that have been specified by *operational definitions*. Tests of hypotheses are based on objective, quantifiable evidence, or data, representing the variables of interest. If data are to be useful, they must be evaluated for *reliability* and *validity*.

Explanations of phenomena often take the form of a *theory*, which is a set of statements that can be used to account for, predict, and even suggest ways of controlling certain phenomena. Theories must be subjected to careful evaluation.

Research Methods in Psychology

How do psychologists learn about people?

Research in psychology, as in other sciences, focuses on four main goals: description, prediction, control, and explanation.

Observational methods such as *naturalistic observation* entail watching without interfering as behavior occurs in the natural environment. These methods can be revealing, but care must be taken to ensure that observers are unbiased and do not alter the behavior being observed.

Case studies are intensive examinations of a particular individual, group, or situation. They are useful for studying new or rare phenomena and for evaluating new treatments or training programs.

Surveys ask questions, through interviews or questionnaires, about behavior, attitudes, beliefs, opinions, and intentions. They provide an efficient way to gather large amounts of data from many people at a relatively low cost, but their results can be distorted if questions are poorly phrased, if answers are not given honestly, or if respondents do not constitute a representative sample of the population whose views are of interest.

Correlational studies examine relationships between variables in order to describe research data, test predictions, evaluate theories, and suggest hypotheses. Correlational studies are an important part of psychological research. However, the reasons behind the relationships they reveal cannot be established by correlational studies alone.

In *experiments,* researchers directly control an *independent variable* and observe the effect of that manipulation on a *dependent variable*. Participants receiving experimental treatment are called the *experimental group*; those in comparison conditions are called *control groups.* Experiments can reveal cause-and-effect relationships between variables, but researchers should use *randomizing* procedures, *placebo* conditions, *double-blind designs,* and other strategies to avoid being misled by *random variables*, participants' expectations, *experimenter bias*, and other *confounds.*

Psychologists' research can be limited if their *sampling* procedures do not give them a fair cross section of the population they want to study and about which they want to draw conclusions. Anything other than *random sampling* is said to be *biased sampling* of participants. In most cases, psychologists try to conduct *representative sampling* of the populations that are available to them.

Statistical Analysis of Research Results

What does it mean when scientists say that a research finding is "significant"?

Psychologists use *descriptive statistics* and *inferential statistics* to summarize and analyze data. Psychologists employ descriptive statistics such as the mean, or average, scores of various groups to characterize the typical score in each group and to summarize differences between groups. Inferential statistics guide conclusions about data and help determine if correlations or differences between group averages have reached *statistical significance*—that is, are larger than would be expected by chance alone. Although valuable for describing relationships, *correlations* alone cannot establish that two variables are causally related, nor can they determine which variable might affect which or why.

Scientific evaluation of research requires critical thinking to carefully assess the design and statistical analysis of even seemingly dramatic or desirable results.

Ethical Guidelines for Psychologists

Do psychologists deceive people when they do research?

Ethical guidelines promote the protection of humans and animals in psychological research. They also set the highest standards for behavior in all other aspects of psychologists' scientific and professional lives.

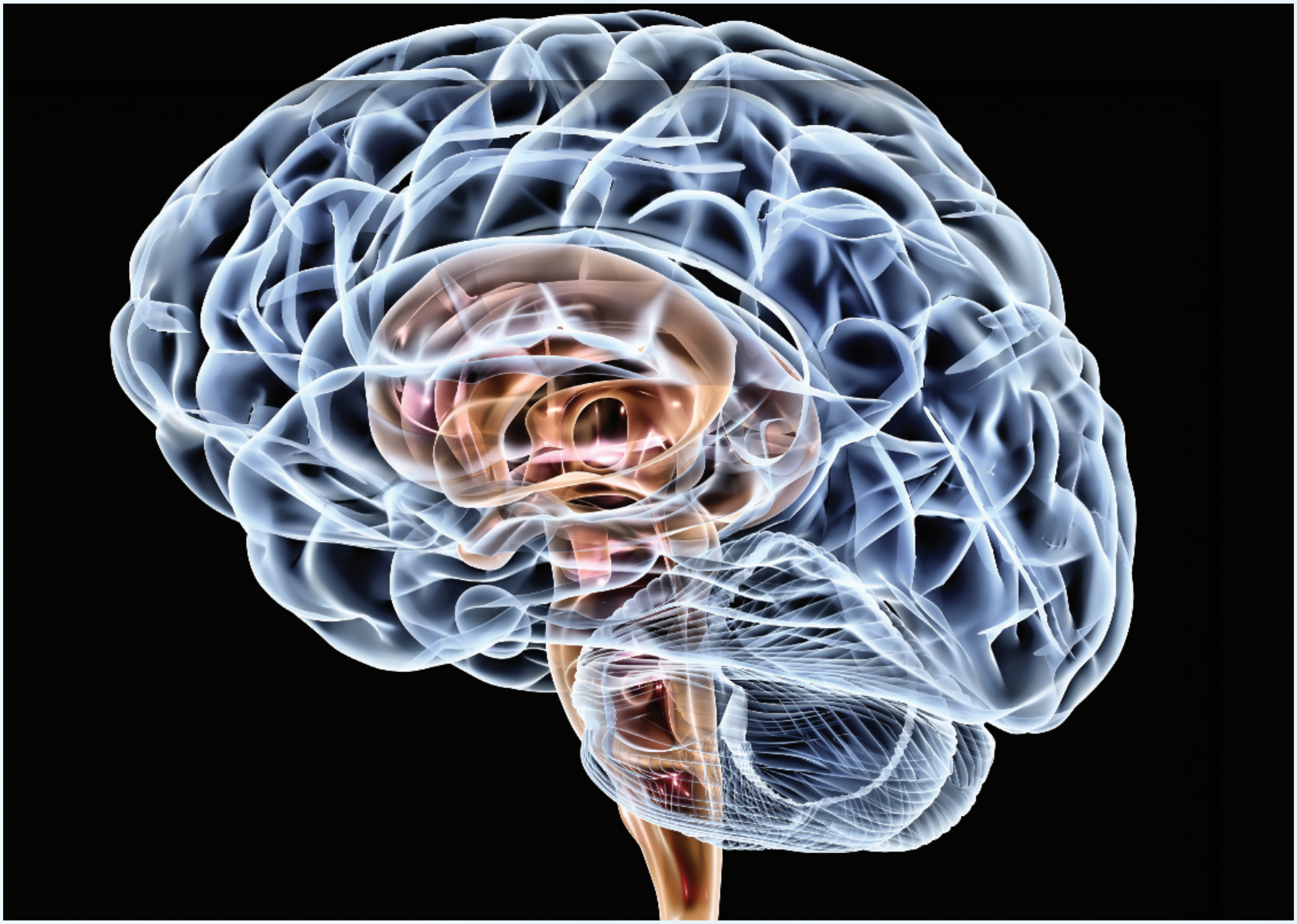
TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. You are watching an infomercial that claims that if you drink liquefied seaweed twice a day, you will lose ten pounds a month. As a wise consumer who knows the five critical thinking questions listed in this chapter, you would FIRST say to yourself:
   - **a.** "I don't know whether the person making the claim about the weight-loss effects of seaweed is a doctor or not."
   - **b.** "The only evidence they present in support of their claim is one woman's personal experience."
   - **c.** "I'll bet you also have to exercise to lose the ten pounds."
   - **d.** "They are asking me to believe that I can lose ten pounds a month by drinking seaweed."
2. Dr. Lucas is interested in the effect of seeing colors on people's moods. She has participants complete a mood survey in either a bright red room or a stark white one. A participant's score on the mood survey is the researcher's ___________ .
   - **a.** operational definition of mood
   - **b.** random variable
   - **c.** independent variable
   - **d.** descriptive statistic
3. Case studies are used to ___________.
   - **a.** avoid a placebo effect
   - **b.** determine the effects of an independent variable
   - **c.** collect descriptive data
   - **d.** provide control in an experiment
4. Before using survey results to support a hypothesis, we must be sure about which of the following?
   - **a.** The questions are properly worded.
   - **b.** The sample used is representative of the population of interest.
   - **c.** The responses are not strongly biased by efforts to appear socially acceptable.
   - **d.** All of the above.
5. When Dr. Beren compares the performance of his experimental group and his control group, he finds the difference in their scores to be statistically significant. This statement means that ___________.
   - **a.** the difference is larger than would be expected by chance
   - **b.** he used descriptive statistics
   - **c.** his results were confounded by random variables
   - **d.** he used a double-blind method
6. Dr. Daneli believes that memory is aided by an increase in a brain chemical called serotonin. To avoid the possibility that experimenter bias might confound the results of an experiment aimed at testing this hypothesis, she should use a(n) ___________design.
   - **a.** operational
   - **b.** naturalistic
   - **c.** random
   - **d.** double-blind

7. In Dr. Daneli's experiment, Group A receives serotonin before taking a memory test, whereas Group B takes the same test without receiving serotonin. In this experiment, performance on the memory test is the __________ variable.
   a. dependent
   b. independent
   c. control
   d. random
8. Angelica designed an experiment to test the effects of praise on the sharing behavior of children. Children in Group A will be praised after they share; children in Group B will only be observed. Group A is the __________ group.
   a. control
   b. experimental
   c. operational
   d. random
9. José wants to know whether growing up in an abusive family causes children to become physically violent. Which of the following research methods would create the greatest ethical problems in trying to study this question scientifically?
   a. case studies
   b. experiments
   c. observations
   d. surveys
10. A correlation coefficient can tell us all of the following except the __________ of a relationship between two variables.
   a. strength
   b. direction
   c. existence
   d. cause
11. Your psychology professor asks you to learn about the smoking habits of all students on your campus. The most practical yet scientific way to get participants for your study would be to find a __________.
   a. random sample of all students
   b. random sample of smokers
   c. representative sample of all students
   d. representative sample of all nonsmokers
12. Why do psychologists follow ethical guidelines?
   a. Psychologists would not want the cost of participating in an experiment to be too high in comparison with the information to be gained.
   b. The American Psychological Association has set standards for psychologists to follow when conducting research and treating clients.
   c. Stress and pain could act as confounding variables in an experiment.
   d. All of the above.
13. Maria wanted to assess reactions to a new school rule requiring students to wear uniforms. She put the names of all 400 students enrolled in the school into a bag, drew out 25 names, and sent them a questionnaire. In this study, Maria used __________.
   a. biased sampling
   b. double-blind assignment
   c. random sampling
   d. random assignment
14. Tariq wants to test whether wearing magnets can relieve the pain from sports injuries. He recruits college athletes with knee injuries and randomly assigns them to wear either a magnet or an identical, but nonmagnetic, piece of metal on their injured knee. Tariq's use of the nonmagnetic metal in this experiment was to control for __________.
   a. the placebo effect
   b. random variables
   c. experimenter bias
   d. generalizability
15. Dr. Feelgood is conducting an experiment to determine if exercise can alleviate depression. Half of her participants rode a stationary bicycle for thirty minutes a day, while the other half did not exercise. At the end of a month, she gave each participant a test for depression. Which of the following is the operational definition of the dependent variable in this study?
   a. Being in the control group
   b. Being in the experimental group
   c. Riding a stationary bike thirty minutes each day for a month
   d. Participants' scores on the depression test
16. Choose the strongest correlation coefficient.
   a. $+.75$
   b. $-.99$
   c. $+.01$
   d. $-.01$
17. Biff has discovered a correlation of $-.83$ between the amount of time his fraternity brothers spend working out in the gym and the number of dates they have during the semester. Based on this information, Biff can correctly conclude that __________.
   a. when the men work out more, they also have more dates
   b. when the men work out more, they also have fewer dates
   c. working out increases dating
   d. working out decreases dating
18. Psychologists' first obligation in conducting research is to __________.
   a. avoid deceiving participants
   b. follow strict ethical standards
   c. find private rather than government grant support
   d. identify a representative sample of human or animal participants
19. To assure that people participate voluntarily in psychological research, psychologists must __________.
   a. pay them a reasonable participation fee, even if they drop out of the study later
   b. give them the right to sue for damages in the event something goes wrong
   c. tell them the true purpose of the study beforehand and let them ask questions
   d. inform them about everything that might influence their decision to participate
20. Assuring that any potential risks of research is outweighed by and justified by the potential benefits of that research is ultimately the job of the __________.
   a. researcher
   b. agency that funds the research
   c. institutional review board
   d. journal that publishes the research results

Biological Aspects of Psychology



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Preview

TRY THIS Before you read the next sentence, close your eyes and touch your nose. This task is easy, but it is not simple. To get the job done, your brain used specific nerves to tell your eyelids to close. It used other nerves to tell your hand to extend a finger and then sent a series of messages that moved your arm in just the right direction until it received a message that your finger and your nose were in contact. This example illustrates that everything you do—including how you feel and think—is based on some kind of biological activity in your body, especially in your brain. This chapter tells the story of that activity, beginning with the neuron, one of the body's most basic biological units. We describe how neurons form systems capable of receiving and processing information and translate it into behavior, thoughts, and biochemical changes.

Biological factors are an intimate part of *all* behavior and mental processes. Brain cells, hormones, genes, and other body processes play a role in everything you think and feel and do, from the fleeting memory you had a minute ago to the anxiety or excitement or fatigue you felt last night to the eye movements you use to read these words. Biology does not reveal the whole story of psychology, but it tells an important part of it. Understanding the relationship between biology, behavior, and mental processes takes us into the realm of **biological psychology**—the study of cells, genes, and organs of the body and the physical and chemical changes involved in behavior and mental processes.

Studying the biology of behavior and mental processes also involves exploring the environment's role in influencing those processes. You will see later, for example, that the experiences we have in the environment can change the chemistry and even the structure of our brains. In this chapter we begin to consider in more detail the relationship between your body and your mind, between your brain and your behavior.

We will begin by considering the **nervous system**, the billions of cells that make up your brain, spinal cord, and nerves. The nervous system receives information, analyzes it, and sends messages from one part of the body to another. The combined activity of these cells helps you gather information, make decisions, and take action. Another system, the endocrine (pronounced "END-oh-krin") system, also helps direct body activities. It regulates internal activity of the body with glands that secrete chemicals, called *hormones*, into the bloodstream. Hormones affect energy consumption, reactions to stress, sexual functioning, and more. The nervous system and the endocrine system affect each other to coordinate activities of the body. Putting the pieces together about how all this happens is the next step in our understanding of the biology of our complex behavior.

CELLS OF THE NERVOUS SYSTEM

What are neurons, and what do they do?

The nervous system is a vast network of cells that tells you what is going on inside and outside your body and allows you to respond appropriately. For example, if you are jabbed with a pin, your nervous system gets the message and immediately causes you to flinch. But the nervous system can do far more than detect information and make responses. When information about the world reaches the brain, that information is *processed*—it is combined with information about past experiences and current wants and needs—to allow you to decide how to respond. Our exploration of the nervous system begins at the "bottom," with a description of its individual cells. Later we consider how these cells are organized to form the structures of the human nervous system.

biological psychology The psychological specialty focused on the physical and chemical changes that cause, and occur in response to, behavior and mental processes.

nervous system A complex combination of cells whose primary function is to allow an organism to gain information about what is going on inside and outside the body and to respond appropriately.

FIGURE 3.1
Three Functions of the Nervous System

The nervous system's three main functions are to receive information (input), integrate that information with past experiences (processing), and guide actions (output). When the alarm clock goes off, this person's nervous system, like yours, gets the message, recognizes what it means, decides what to do, and then takes action—by getting out of bed or perhaps hitting the snooze button.

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Neurons

The nervous system is an information-processing system with three functions: input, processing, and output (see Figure 3.1). These functions are possible partly because the nervous system is made up of cells that communicate with each other. Two major types of cells, *neurons* and *glial cells*, allow the nervous system to carry out its complex signaling tasks efficiently. The specialized cells that send and receive signals are called **neurons**, or **nerve cells**.

Most of our discussion of brain cells concerns neurons, but glial cells are important, too. *Glial* means "glue," and scientists had long believed that glial cells did no more than hold neurons together. We now know, however, that **glial cells** also help neurons communicate by directing their growth, regulating their chemical environment, providing energy, adjusting blood flow, pruning connections among neurons, and secreting chemicals to help repair damage (Paolicelli et al., 2011; Petzold & Murthy, 2011). In fact, glial cells can do many of the functions of neurons, including releasing chemicals that influence neurons, responding to chemicals from neurons, and changing in response to experience (Barres, 2008; Zonouzi et al., 2011). Without glial cells, neurons could not function, and malfunctions in glial cells may play a role in problems ranging from recurring pain to depression and other mental disorders (Miller, 2005a).

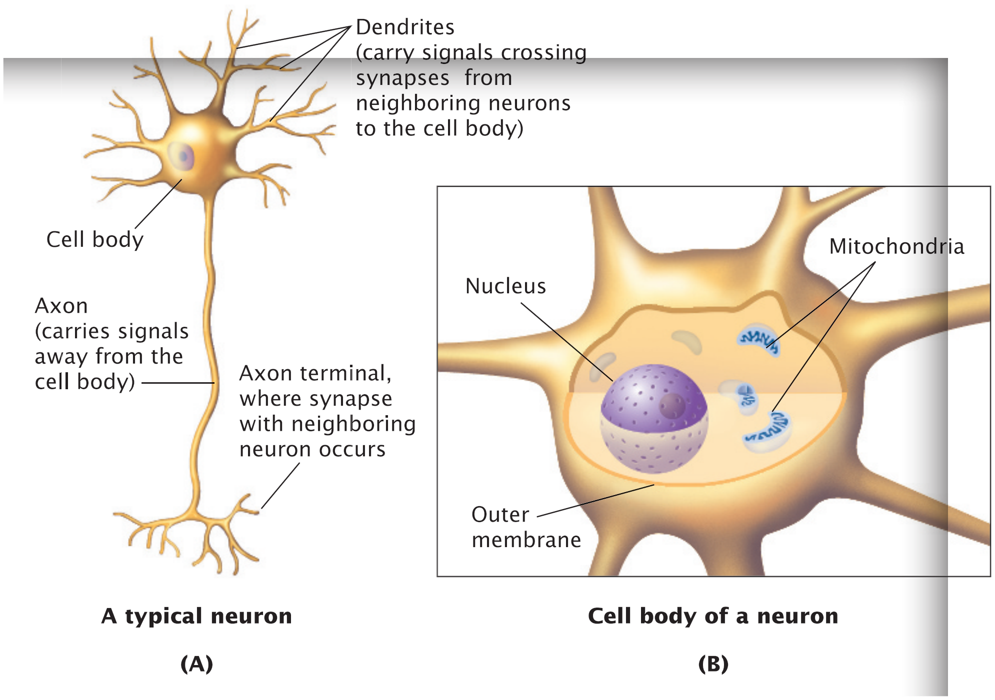
Every cell in the body has an *outer membrane*, which acts kind of like the skin of your body, and every cell has a body that (with the exception of red blood cells) contains a core called the *nucleus.* Also inside each cell body are tiny "engines," called *mitochondria* (pronounced "my-toh-CON-dree-uh"), structures that help the cell generate and use energy.

neurons (or nerve cells) Fundamental units of the nervous system.

glial cells Cells in the nervous system that hold neurons together and help them communicate with one another.

FIGURE 3.2
The Neuron

Part (A B) shows fibers extending outward from the cell body of a neuron, which is a nervous system cell. These fibers, called *axons* and *dendrites*, are among the features that make neurons unique. Part (B) shows an enlarged drawing of the neuron's cell body. The cell body of a neuron includes an outer membrane, a nucleus, and mitochondria.



Neurons are no different. A neuron's outer membrane acts like a screen, letting some substances pass in and out while blocking others. In the neuron's cell body, the nucleus carries genetic information that tells the cell what to do. And neurons' mitochondria turn oxygen and glucose into energy. This energy process is especially vital to brain cells, because although the human brain accounts for only 2 percent of body weight, it uses more than 20 percent of a body's oxygen. The human brain needs so much energy because its cells transmit signals among themselves to an even greater extent than do cells in the rest of the body.

Neurons use special structural and chemical features to communicate with each other. While neurons come in many shapes and sizes, they all have long, thin fibers that reach outward from the cell body like arms (see Part (A) in Figure 3.2). Communication between the cells can occur when these fibers are close to other neurons. The interweaving of these fibers with fibers from other neurons allows each neuron to be close to thousands or even hundreds of thousands of other neurons.

Fibers extending from the cell body are called *axons* and *dendrites*. As shown in Figure 3.2, each neuron generally has only one single **axon**, whose function is to carry signals away from the cell body. An axon may have many branches at its end, much like a tree has branches that reach to the sky. Axons can be short or long. In the brain, they may extend no more than a fraction of an inch, but the axon from your spine to your big toe is more than three feet long! **Dendrites** are the neuron fibers that receive signals from the axons of other neurons and carry those signals to the cell body. As you can see in Figure 3.2, whereas a neuron usually has just one axon, it can have many dendrites, each of which usually has many branches. Remember that *a*xons carry signals *away* from the cell body, and *d*endrites *detect* those signals.

axons Fibers that carry signals from the body of a neuron out to where communication occurs with other neurons.

dendrites Neuron fibers that receive signals from the axons of other neurons and carry those signals to the cell body.

action potential An abrupt wave of electrochemical changes traveling down an axon when a neuron becomes depolarized.

refractory period A short rest period between action potentials.

Action Potentials

The communication signal between neurons begins with an electrochemical pulse called an **action potential**, which shoots down the axon. This is an "all-or-nothing" affair: The cell either fires its action potential at full strength or it does not fire at all. Once a cell has fired, a very short recovery time called the **refractory period** follows, during which the cell cannot fire again. Even so, neurons are able to fire as often as 1,000 times per second. The speed of an action potential ranges from about 5 to 260 miles per hour and depends

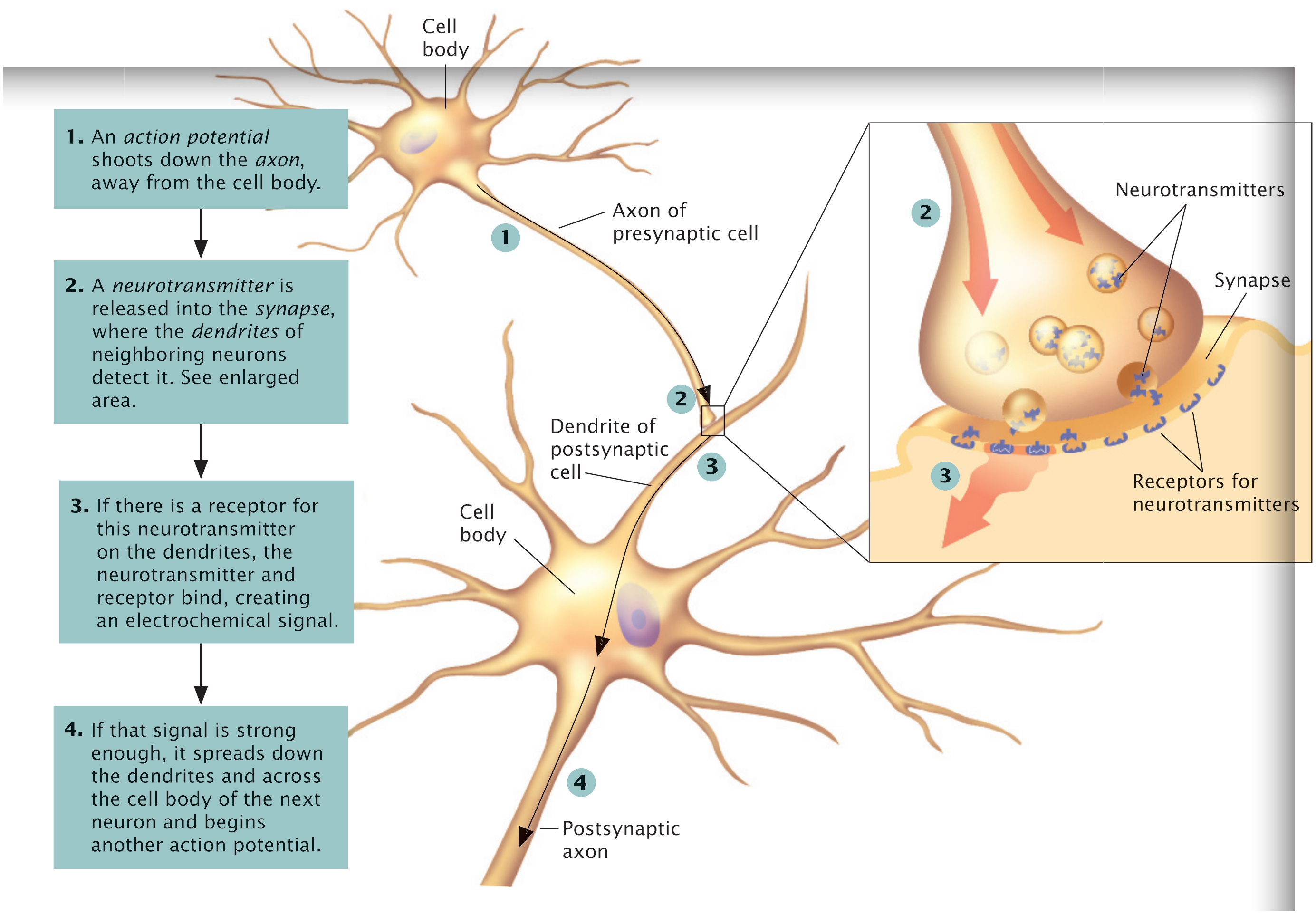


FIGURE 3.3
Communication between Neurons

When stimulation of a neuron reaches a certain level, the neuron fires, sending an action potential shooting to the end of its axon and triggering the release of a neurotransmitter into the synapse. This stimulates neighboring neurons and may cause them to fire their own action potentials. A cell's receptors can also receive signals that have the opposite effect, making the cell less likely to fire.

on the thickness or diameter of the axon—larger ones are faster—and on the presence of myelin (pronounced "MY-a-lin"). *Myelin* is a fatty substance that wraps around some axons like a stocking and speeds up action potentials. When a neuron fires, dendrites in the next cell detect the message and send the signal to their cell body.

Synapses and Communication Between Neurons

How do the dendrites detect a signal from another neuron? As shown in Figure 3.3, it works a little like the game of tag you may have played as a child. In this neural communication tag game, however, one neuron "sends" a tag without actually touching the next neuron. When an action potential reaches the ends of an axon's branches, it stimulates the release of a **neurotransmitter**. Neurotransmitters are chemicals that act as messengers between neurons. They're stored in little "bags" called *vesicles* (pronounced "VESS-ick-els"). Neurotransmitters flow across a tiny gap, less than a millionth of an inch wide, which separates the axon of one neuron and the dendrites of another. This is the *synaptic gap,* often referred to simply as the **synapse** (see Figure 3.4). Some nerve cells have direct electrical communication at specialized contact points called *gap junctions*, or *electrical synapses*. At these gap junctions, neurons can transfer either neurotransmitters or electrical signals. Electrical synapses allow clusters of neurons to fire together, and the strength of their activity can change in response to experience (Haas, Zavala, & Landiesman, 2011). As a result, electrical synapses may contribute to the process of learning. They may also be involved in epilepsy, a brain disorder in which large groups of neurons fire together and produce seizures (Dere & Zlomuzica, 2012).

When neurotransmitters cross a synapse and reach the dendrite of the next cell, they chemically fit, or bind, to proteins called **receptors**. Like a key fitting into the right lock, a neurotransmitter snugly binds to its own specific receptors but not to receptors for other

neurotransmitters Chemicals that assist in the transfer of signals from one neuron to another.

synapses The tiny gaps between neurons across which they communicate.

receptors Sites on the surface of a cell that allow only one type of neurotransmitter to fit into them, triggering a chemical response that may lead to an action potential.

neurotransmitters. Each receptor "recognizes" only one type of neurotransmitter. In the dendrite, this binding creates an electrochemical signal that is called a *postsynaptic potential* because it occurs *after* the neurotransmitter has crossed the synapse. The postsynaptic potential, in turn, passes the message to the cell body for the signaling process to continue.

Generally, more than one message must go to a cell to make it fire. Signals from groups of cells often arrive at the same postsynaptic cell at about the same time. The messages from these many cells may conflict with one another. Some messages tell the cell to fire, whereas others tell the cell not to fire. Whether it actually does fire depends on which kinds of signals are strongest and most numerous. In this way, axons, neurotransmitters, synapses, and dendrites allow nerve cells of the nervous system to communicate. If these components are damaged or disordered, however, problems occur. For example, spinal cord injuries may cut the neural communication lines that had once allowed people to feel and move their bodies. And when the myelin surrounding some axons is destroyed by a disorder known as *multiple sclerosis (MS)*, the result can disrupt vision, speech, balance, and other important functions.

Neurotransmitters are involved in every aspect of behavior and mental processes. You will see them involved, for example, in conveying pain messages, in creating the psychological effects of alcohol, and in providing the main targets for prescription drugs that treat schizophrenia and depression.

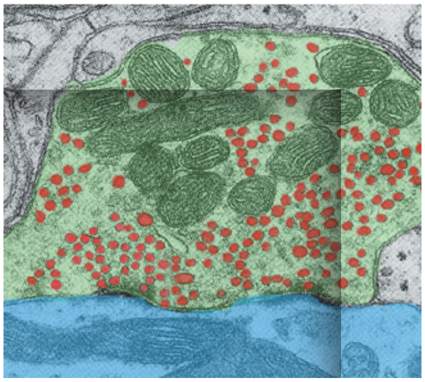


FIGURE 3.4
A Synapse

This photograph taken with an electron microscope shows part of a synaptic gap between two neurons, magnified 50,000 times. The ending of the first cell's axon is shaded green; the green ovals are mitochondria. The red spots are vesicles, which contain neurotransmitters. The synapse itself appears as the narrow gap between the first cell's green-shaded axon and the blue-shaded dendrite of the cell below.

Organization of the Nervous System

Impressive as individual neurons are (see "In Review: Neurons, Neurotransmitters, and Receptors"), we can best understand their functions by looking at how they operate in groups called **neural networks**. The billions of neurons that make up the nervous system are organized into two main parts—the *central nervous system* and the *peripheral nervous system* (see Figure 3.5). These systems work together closely to coordinate behavior and

A Damaged Nervous System

If axons, dendrites, or other components of the nervous system are damaged or disordered, serious problems can result. The spinal cord injury that this woman suffered in a car accident cut the neural communication lines that had allowed her to feel and move the lower part of her body.

Ariel Skelley/Corbis

neural networks Neurons that operate together to perform complex functions.

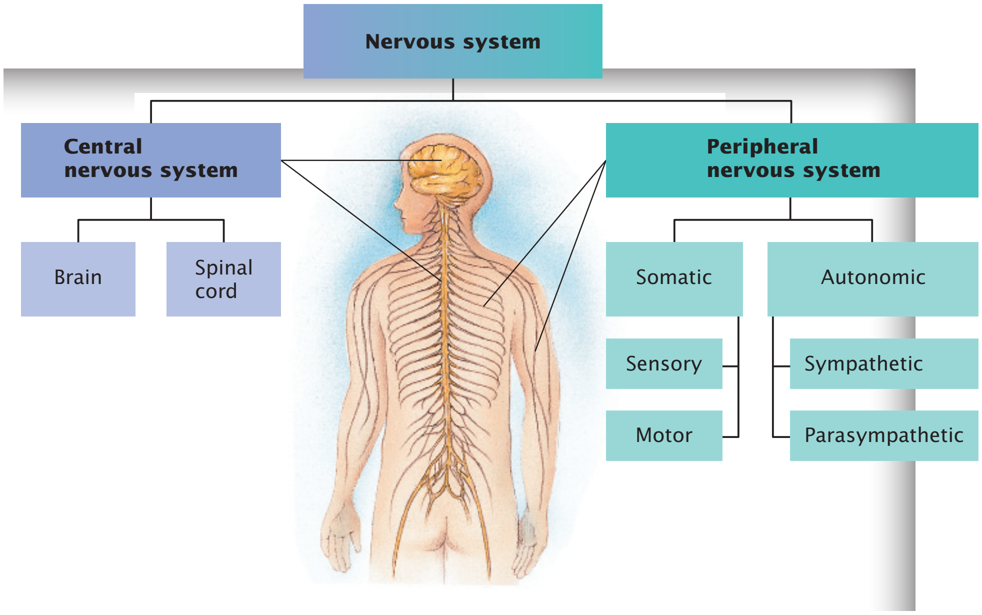


FIGURE 3.5
Organization of the Nervous System

The brain and spinal cord make up the bone-encased central nervous system (CNS), the body's central information processor, decision maker, and director of actions. The peripheral nervous system, which is not housed in bone, functions mainly to carry messages. The somatic subsystem of the peripheral nervous system transmits information to the CNS from the outside world and conveys instructions from the CNS to the muscles. The autonomic subsystem conveys messages from the CNS that alter the activity of organs and glands, and it sends information about that activity back to the brain.

mental processes, as we'll describe later on. The **central nervous system (CNS)** consists of the brain and spinal cord, which are encased in bone for protection. Like the chief executive officer in a company, the CNS receives information, processes it, and determines what actions should result (Banich, 2009). The **peripheral nervous system (PNS)** extends throughout the body and, like an e-mail or texting service, relays information to and from the brain.

IN REVIEW

NEURONS, NEUROTRANSMITTERS, AND RECEPTORS

Part	Function	Type of Signal Carried
Axon	Carries signals away from the cell body	The action potential, an all-or-nothing electrochemical signal that shoots down the axon to vesicles at the tip of the axon, releasing neurotransmitters
Dendrite	Detects and carries signals to the cell body	The postsynaptic potential, an electrochemical signal moving toward the cell body
Synapse	An area for the transfer of signals between neurons, usually between axon and dendrite	Chemicals that cross the synapse and reach receptors on another cell or electrical impulses transferred from one cell to another
Neurotransmitter	A chemical released by one cell that binds to the receptors on another cell	A chemical message telling the next cell to fire or not to fire its own action potential
Receptor	Proteins on the cell membrane that receive chemical signals	Recognizes certain neurotransmitters, allowing it to begin a postsynaptic potential in the dendrite

In Review Questions

1. In most cases, when one neuron communicates with another, a __________ crosses the __________ between them.
2. The nervous system's main functions are to __________, __________, and __________ information.
3. The two main types of cells in the nervous system are __________ and __________.

THE PERIPHERAL NERVOUS SYSTEM: KEEPING IN TOUCH WITH THE WORLD

How do sights and sounds reach my brain?

The peripheral nervous system sends sensory information from the eyes, ears, and other sense organs to the CNS. The PNS also carries messages from the brain and spinal cord to the muscles, glands, and other parts of the body. Unlike the CNS, it is not protected by bone. To accomplish its relay tasks, the peripheral nervous system has two subsystems—the somatic nervous system and the autonomic nervous system.

The Somatic Nervous System

Imagine that you're at the beach. It's hot, and the ocean smells salty. An attractive stranger approaches, catching your eye. The stranger smiles. You smile in return. The stranger continues walking away. In these few seconds, your nervous system has been busy. You feel the warmth of the sun and smell the ocean because your **somatic nervous system (SNS)** takes in this sensory information and sends it to the central nervous system for processing. The CNS evaluates the warmth and the smells, sending messages through the somatic

central nervous system (CNS) The parts of the nervous system encased in bone; specifically, the brain and the spinal cord.

peripheral nervous system (PNS) The parts of the nervous system not housed in bone.

somatic nervous system (SNS) The subsystem of the peripheral nervous system that transmits information from the senses to the CNS and carries signals from the central nervous system to the muscles.

Is That Your Final Answer?

Which is the geographically largest U.S. state?: (a) Montana, (b) Texas, (c) Alaska, or (d) Wyoming? Like contestants on shows such as *Who Wants to Be a Millionaire*, you must rely on your central nervous system, and especially on the information-processing power of your brain, to understand the question, recognize the correct option, and direct movements of your vocal muscles to speak your answer. (The correct choice in this case is (c).)

Rolf Vennenbernd/dpa/Corbis

nervous system to the muscles that allow you to turn over, sit up, or put on more sunscreen. **Sensory neurons** bring information into the brain. **Motor neurons** carry information from the part of the brain that directs motion.

The Autonomic Nervous System

The **autonomic nervous system** carries messages back and forth between the CNS and the heart, lungs, and other organs and glands. For example, the autonomic nervous system takes that passing stranger's "attractive" rating from the CNS and translates it into an increase in heart rate, pupil dilation, and perhaps a little blushing. This system is called "autonomic" (pronounced "aw-toh-NOM-ic") because its activities, including digestion and sweating, for example, are generally autonomous, or independent of your control. With training and practice, some people can use a technique called *biofeedback* to bring some of their involuntary responses, such as heart rate, under conscious (CNS) control.

As shown in Figure 3.5, the autonomic system has two subsystems of its own—the *sympathetic nervous system* and the *parasympathetic nervous system.* These two subsystems work like a seesaw on a playground. Generally, the **sympathetic nervous system** readies your body for action in the face of stress. The **parasympathetic nervous system** calms you down once the crisis has passed. So the *s*ympathetic nervous system *spends* energy, whereas the *p*arasympathetic nervous system *preserves* energy.

The functions of the autonomic nervous system may not get star billing, but you'd miss them if they were gone. Just as a racecar driver is nothing without a good pit crew, the somatic nervous system depends on the autonomic nervous system to get its job done. For example, when you want to move your muscles, you create a demand for energy. The autonomic nervous system fills the bill by increasing sugar fuels in the bloodstream. If you decide to stand up, you need increased blood pressure so that your blood does not flow out of your brain and settle in your legs. Again, the autonomic nervous system makes the adjustment. Disorders of the autonomic nervous system can make people sweat uncontrollably or faint whenever they stand up; they can also lead to other problems, such as an inability to have sex. We examine the autonomic nervous system in more detail in the chapter on motivation and emotion.

sensory neurons Cells in the nervous system that provide information to the brain about the environment.

motor neurons Cells in the nervous system that the brain uses to influence muscles and other organs to respond to the environment in some way.

autonomic nervous system A subsystem of the peripheral nervous system that carries messages between the central nervous system and the heart, lungs, and other organs and glands.

sympathetic nervous system The subsystem of the autonomic nervous system that readies the body for vigorous activity.

parasympathetic nervous system The subsystem of the autonomic nervous system that typically influences activity related to the protection, nourishment, and growth of the body.

THE CENTRAL NERVOUS SYSTEM: MAKING SENSE OF THE WORLD

How is my brain "wired"?

The amazing speed and efficiency of the central nervous system—the brain and spinal cord—have prompted many people to compare it to the central processor in a computer. But the CNS does not simply function as a high-powered computer. It certainly isn't laid out as neatly, either (Lichtman & Denk, 2011; Poldrack, 2010). The layout of the brain is more like the map of a college campus. There are clusters of offices for the administrators in one place, clusters of faculty offices in another place, and classrooms in yet another. Some of the sidewalks or hallways that connect these clusters are wide; others are narrow. There are many different but connected ways to get to the same place. Like a campus with its office clusters, one way that the CNS has organized some neuron cell bodies is into globelike clusters called *nuclei* (pronounced "NUKE-lee-eye"; *nuclei* is the plural of *nucleus*). The sidewalks and hallways of the CNS are axons that travel together in bundles called *fiber tracts*, or *pathways*. The axon (hallway) from any given cell (office) may merge with and leave many *fiber tracts* (sidewalks) and send branches out to other tracts.

Let's consider a practical example of nervous system functioning to begin learning our way around the "campus" of the brain. It is 6 A.M. and your alarm clock goes off, creating the simple case of information processing illustrated in Figure 3.1. Your ears receive sensory input in the form of sound from the alarm. The sound is converted into neural signals and sent to the brain. Your brain compares these signals with previous experiences stored in memory and correctly associates the sound with "alarm clock." Your muscle-guiding output is not yet at peak performance, though, because your brain activity has not yet reached the waking state. So, you fumble to turn off the alarm, shuffle to the kitchen, and accidentally touch the coffeemaker's heating element. Things get more lively now. Heat energy activates sensory neurons in your fingers, generating action potentials that speed along fiber tracts going into the spinal cord and up to your brain. Your motor neurons are guided by the rapid, automatic responses of very basic brain systems that cause muscles in your arm to contract and quickly withdraw your hand.

The Spinal Cord

The **spinal cord** receives signals such as pain and touch from the senses and passes those signals to the brain. Neuron fibers within the cord also carry signals downward from the brain to the muscles. Some cells of the spinal cord can make simple decisions or direct simple movements without needing instructions from the brain. One example is known as a **reflex**, because the response to an incoming signal is directly "reflected" back out, as shown in Figure 3.6. Spinal reflexes, such as when your leg jerks after your doctor taps just below your knee, are very fast because they include few time-consuming synaptic links. Reflexes are simple and unlearned reactions to external stimuli, and they are *involuntary*; they can occur without instructions from the brain. Note that such an organization is an example of a *feedback system*. Your muscles have receptors that send information to the spinal cord to let it know how extended they are so that adjustments can be made for a smooth, contracting motion. Information about the consequences of an action goes back to the source of the action for further adjustment.

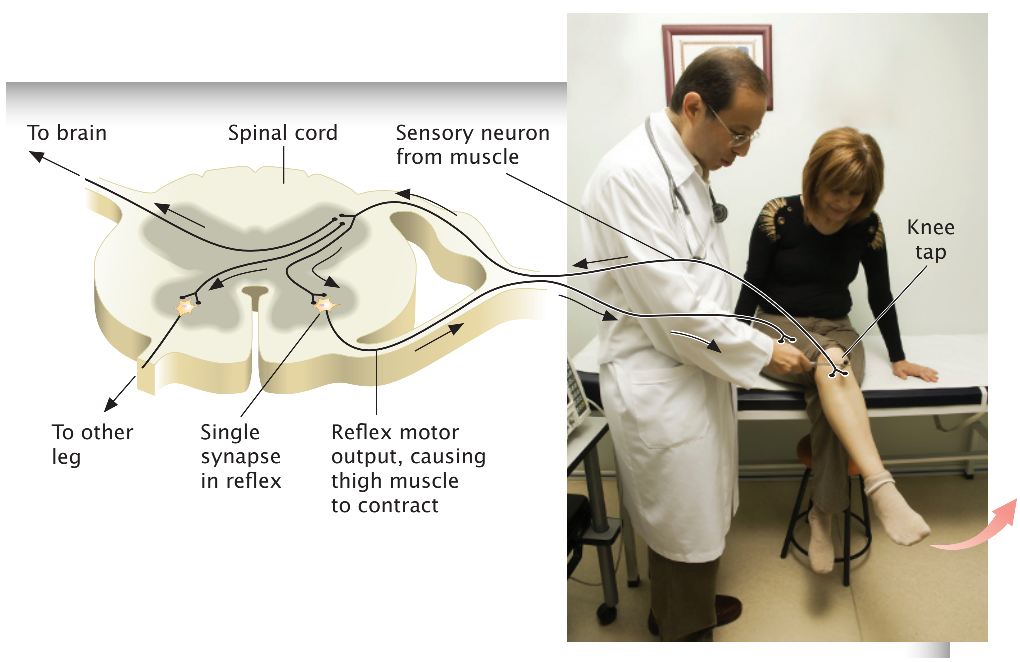


FIGURE 3.6
A Reflex Pathway

TRY THIS Sit on a chair, cross one leg over the other, and then use the handle of a butter knife or some other solid object to gently tap your top knee, just below the kneecap, until you get a "knee jerk" reaction. Tapping your knee at just the right spot sets off an almost instantaneous sequence of events that begins with stimulation of sensory neurons that respond to stretch. When those neurons fire, their axons, which end within the spinal cord, cause spinal neurons to fire. This firing stimulates the firing of motor neurons with axons ending in your thigh muscles. As a result those muscles contract, causing a kicking motion of the lower leg and foot. Information about the knee tap and about what the leg has done also goes to your cerebral cortex, but the reflex is completed without waiting for guidance from the brain.

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To make this system carry out the actions you want, though, you still need your brain. So, as reflexes occur, action potentials are also sent along fiber tracts to the brain. This way, your brain can choose to exert influence down the spinal cord. This influence explains why the strength of your knee-jerk reflex in a doctor's office can change depending on whether or not you watch the doctor tap your knee.

The Brain

When pain messages from a hot burner reach your brain, you may become aware of more than just being burned. You might also recall that you have burned yourself twice before in the past week and become annoyed at your carelessness. The brain is the most complex part

spinal cord The part of the central nervous system within the spinal column that relays signals from peripheral senses to the brain and conveys messages from the brain to the rest of the body.

reflexes Involuntary, unlearned feedback systems creating swift, automatic, and movements in response to external stimuli.

in the central nervous system, and it is your brain's astonishing capacity for information processing that allows you to have these thoughts and feelings (Cacioppo & Decety, 2009).

The Hindbrain

You can see the major structures of the brain in Figure 3.7. The **hindbrain** lies just inside the skull and is actually a continuation of the spinal cord. Signals coming from the spinal cord reach the hindbrain first. Many vital autonomic functions, such as heart rate, blood pressure, and breathing, are controlled by nuclei in the hindbrain, particularly in an area called the **medulla oblongata** (pronounced "meh-DUH-lah ah-blon-GAH-da"), sometimes just called the **medulla**.

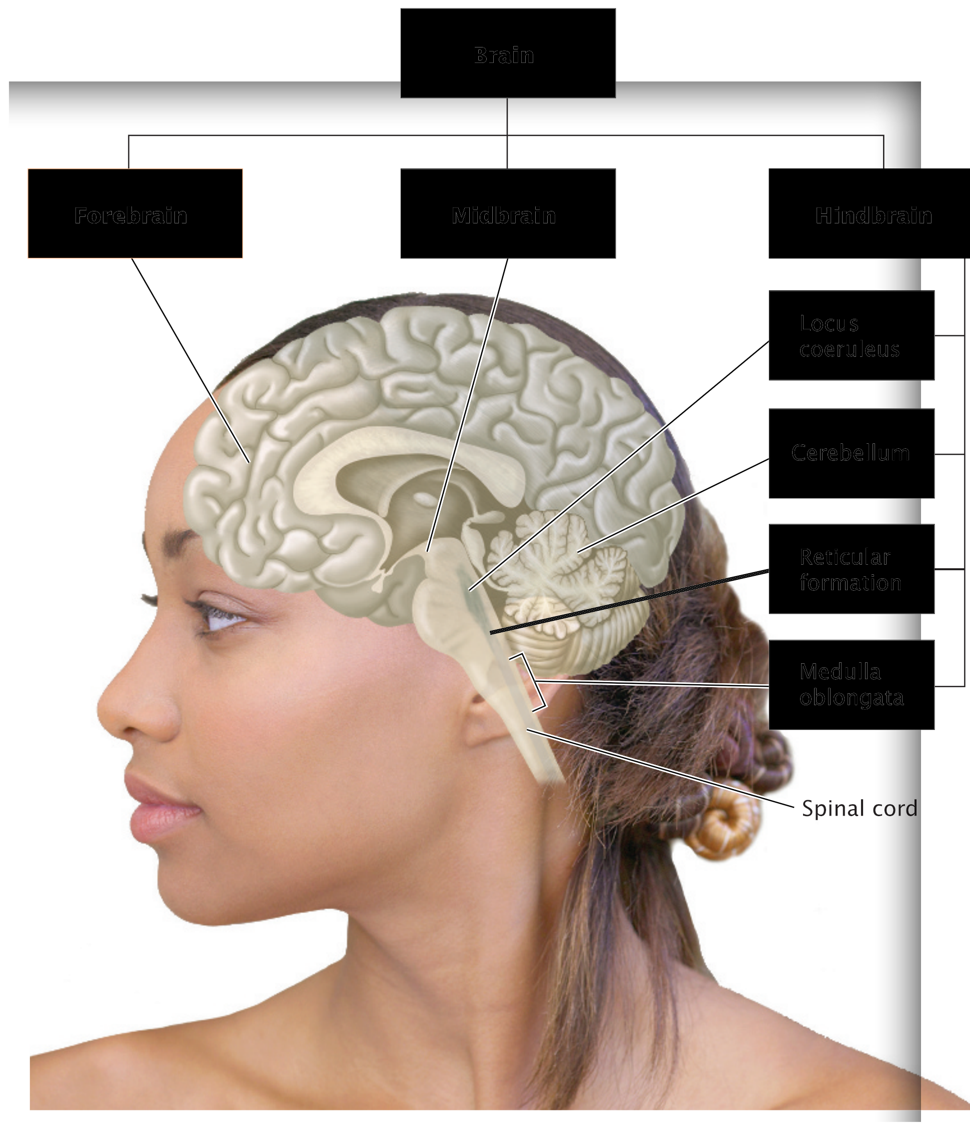

FIGURE 3.7
Major Structures of the Brain

This side view of a section cut down the middle of the human brain reveals the forebrain, midbrain, hindbrain, and spinal cord. Many of these subdivisions do not have clear-cut borders because they are all interconnected by fiber tracts. The anatomy of the mammalian brain reflects its evolution over millions of years. Newer structures (such as the cerebral cortex, which is the outer surface of the forebrain) that handle higher mental functions were built on older structures (such as the medulla oblongata) that coordinate heart rate, breathing, and other more basic functions.

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A meshlike collection of cells called the **reticular formation** (*reticular* means "netlike") weaves through the hindbrain and up through the midbrain. This network helps promote alertness and arousal. Destroying the reticular system would put a person into a coma. Some of the fibers that carry pain signals from the spinal cord connect in the reticular formation and immediately arouse the brain from sleep.

Axons from a small nucleus within the reticular formation, the **locus coeruleus** (pronounced "LOH-kus seh-ROO-lee-us"), branch extensively, making contact with as many

hindbrain An extension of the spinal cord contained inside the skull where nuclei control blood pressure, heart rate, breathing, and other vital functions.

medulla oblongata (medulla) An area in the hindbrain that controls blood pressure, heart rate, breathing, and other vital functions.

reticular formation A network of cells and fibers threaded throughout the hindbrain and midbrain that gives alertness and arousal to the rest of the brain.

locus coeruleus A small nucleus in the reticular formation that is involved in directing attention.

A Field Sobriety Test

The cerebellum is involved in the balance and coordination required for walking. When the cerebellum's activity is impaired by alcohol, these skills are disrupted, which is why the police ask suspected drunk drivers to walk a straight line. The cerebellum's importance is suggested by the fact that its size is second only to the cerebral cortex.

Zuma Press, Inc./Alamy

as 100,000 other cells. The locus coeruleus (which means "blue spot" in Latin) is involved in directing attention, particularly toward new or important stimuli in the environment (Eldar, Cohen, & Niv, 2013). Changes in the locus coeruleus have been linked to depression, attention deficit hyperactivity disorder, sleep disorders, and posttraumatic stress disorder (Aston-Jones & Cohen, 2005).

The **cerebellum** (pronounced "sair-a-BELL-um") is also part of the hindbrain. Its function to control finely coordinated movements, such as threading a needle, has been known for a long time (Aso et al., 2010). We now know that the cerebellum may be important for higher-level behavior, too. The cerebellum helps us move our eyes as we track a moving target accurately (Krauzlis & Lisberger, 1991) and it may be the storehouse for well-rehearsed movements, such as those associated with dancing, playing a musical instrument, and athletics (McCormick & Thompson, 1984). The cerebellum might also be involved in learning these skills (Hardwick et al., 2012) and may add to uniquely human tasks such as language and abstract thinking (Mariën et al., 2013). Neuroscientists believe that the cerebellum is involved in additional activities as well, including memory, emotion, language, impulse control, and other higher-order cognitive processes (e.g., Strick, Dum, & Fiez, 2009). For example, the cerebellum is important in timing (Manto, 2008), which plays a vital role in normal speech, integrating moment-to-moment feedback about vocal sounds with a sequence of precise movements of the lips and tongue (Leiner, Leiner, & Dow, 1993). Such a role for the cerebellum may explain why it appears to be among the brain structures that show abnormal activity in young people who stutter (Watkins et al., 2008). In short, the cerebellum seems to be involved in both physical and cognitive agility.

Reflexes, feedback systems, and other basic processes are important in the hindbrain. For example, if blood pressure drops, heart action reflexively increases to make up for that decrease. If you stand up quickly, your blood pressure can drop so suddenly that you feel lightheaded until the hindbrain reflexively "catches up." You'll faint if the hindbrain does not activate the autonomic nervous system to increase your blood pressure.

The Midbrain

A small region called the **midbrain** lies above the hindbrain. If you focus your eyes on another person and then move your head, midbrain circuits allow you to move your eyes smoothly in the direction opposite from your head movement so you never lose eye contact. When you swing a bat, swat a mosquito, or jump rope, part of the midbrain and its connections to the forebrain allow you to produce those movements smoothly. When a car backfires and you turn your head to look in the direction of the sound, it is again the midbrain at work. Together, the midbrain and parts of the hindbrain other than the cerebellum are called the *brainstem*.

The Forebrain

In humans, the **forebrain** controls the most complex aspects of behavior and mental life. The forebrain is also huge compared to the hindbrain and midbrain, which it completely covers. The outer surface of the forebrain is a sheet of neurons called the *cerebral cortex*. Some structures of the forebrain are shown in Figure 3.8.

Two structures deep within the forebrain, the *hypothalamus* and the *thalamus,* help operate basic drives, emotion, and sensation. The **thalamus** acts as a relay station for pain and sense-organ signals (except smell) from the body to the upper levels of the brain. It also processes and makes sense of these signals. The **hypothalamus** lies under the thalamus (*hypo* means "under") and helps regulate hunger, thirst, and sex drives. The hypothalamus is well connected to the autonomic nervous system and to other parts of the brain. Damage to parts of the hypothalamus upsets normal appetite, thirst, and sexual behavior.

Can you set an "internal alarm clock" to wake up in the morning at whatever time you want? If you can, it is with the help of a remarkable part of your hypothalamus called the *suprachiasmatic nuclei* that contains the brain's own clock. The suprachiasmatic (pronounced

cerebellum The part of the hindbrain whose main functions include controlling finely coordinated movements and storing memories about movement but which may also be involved in impulse control, emotion, and language.

midbrain A small structure between the hindbrain and forebrain that relays information from the eyes, ears, and skin and that controls certain types of automatic behaviors.

forebrain The most highly developed part of the brain; it is responsible for the most complex aspects of behavior and mental life.

thalamus A forebrain structure that relays signals from most sense organs to higher levels in the brain and plays an important role in processing and making sense out of this information.

hypothalamus A structure in the forebrain that regulates hunger, thirst, and sex drive.

FIGURE 3.8
Major Structures of the Forebrain

The structures of the forebrain are covered by an outer "bark" known as the *cerebral cortex*. This diagram shows some of the structures that lie within the forebrain. The amygdala, the hippocampus, the hypothalamus, the septum, and portions of the cerebral cortex are all part of the limbic system.

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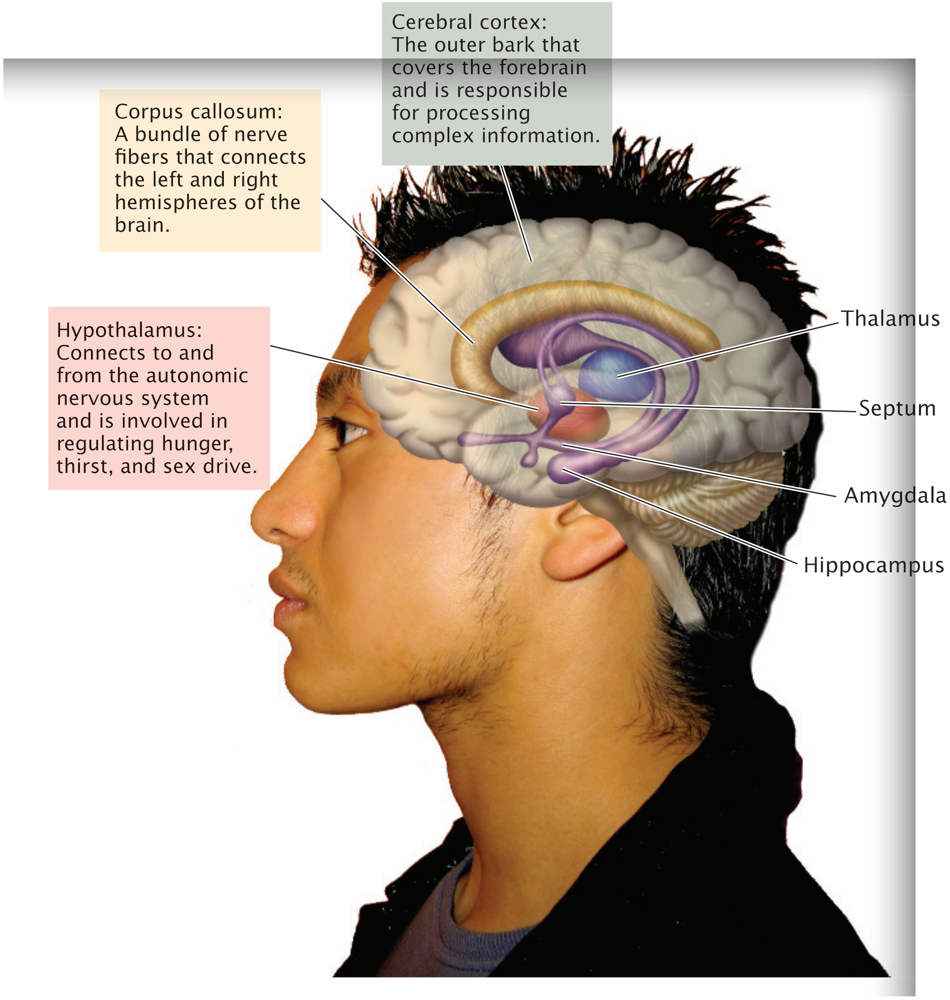

"soo-prak-eye-as-MAT-ik") neurons operate on approximately a twenty-four-hour cycle, controlling daily biological rhythms such as waking and sleeping as well as cycles of body temperature. We discuss this brain area more in the chapter on consciousness.

Other parts of the forebrain, especially the **amygdala** (pronounced "ah-MIG-duh-luh") and the **hippocampus**, help regulate memory and emotion. The amygdala links emotional and certain other kinds of sensory information in memory, such as when a song or scent triggers the intensely rich recall of a lover's embrace (Paz & Pare, 2013). The amygdala also plays a role in fear and other emotions (Cunningham & Brosch, 2012; LeDoux, 1995; Whalen, 1998), connecting emotion to sensation. People who suffer from posttraumatic stress disorder have unusual amygdala activity (Shin, Rauch, & Pitman, 2006). The amygdala may also influence our sensitivity to other people (Corden et al., 2006). Brain scans show that the amygdala responds strongly when people view angry faces rather than neutral faces (Furmark et al., 2009). Such findings may explain why the amygdala and other nearby structures appear to be dysfunctional in people with autistic spectrum disorders, clinical conditions causing disruptions in the ability to relate to other people (Laupin et al., 2012) (see the chapter on psychological disorders). The amygdala, hippocampus, and some portions of the cerebral cortex are part of a group of brain structures called the *limbic system*, which regulates aspects of memory and emotion.

The most vital role of the hippocampus is in helping you form new memories. For example, a patient known as R. B. suffered a stroke (an interruption of blood flow in the brain) that damaged only his hippocampus. Although his intelligence remained above average and he could recall old memories, he was almost totally unable to build

amygdala A structure in the forebrain that, among other things, associates features of stimuli involved in memory and emotion.

hippocampus A structure in the forebrain associated with the formation of new memories.

new ones (Squire, 1986). Damage to the hippocampus within a day of a mildly painful event seems to erase memories of the experience. However, if the damage occurs several days after the event, the memory remains. It seems that memories are not permanently stored in the hippocampus but instead are transferred from there to somewhere else in the brain.

It isn't surprising, then, that certain aspects of memory are related to the size and level of activity in the hippocampus (Zimmerman et al., 2008). For example, having a relatively small hippocampus predicts the development of severe memory problems in the elderly (Devanand et al., 2007). Other studies suggest that some people's physical responses to stress include a reduction in the number of neurons in the hippocampus (Caspi, Sugden, et al., 2003; Frodl et al., 2004). This effect was demonstrated in a study of people who had been close to the World Trade Center on 9/11. They showed less hippocampus volume, even three years after the event, than people who had been more distant (Ganzel et al., 2008). The loss of neurons in this region may help explain the memory problems that appear in some people who have suffered depression or posttraumatic stress disorder (Bremner et al., 2003, 2004). The hippocampus and memory also can be affected by disease (see Figure 3.9).

FIGURE 3.9
Alzheimer's Disease and the Brain

Compared to a normal brain (bottom), the brain of a person with Alzheimer's disease shows considerable degeneration in the cerebral cortex. The limbic system deteriorates, too (Callen et al., 2001). For example, the hippocampus of Alzheimer's patients is about 40 percent smaller on average than that of a person without the disease. Alzheimer's disease is a major cause of senile dementia, which involves the deterioration of cognitive capabilities.

Denis Balibouse/Reuters

The Cerebral Cortex

On the surface of the forebrain is the **cerebral cortex**. The total area of the cerebral cortex is between one and two square feet, but it fits into the skull because it is wrinkled and folded. (You can wad up a T-shirt and fit it into a small bowl in much the same way.) The cerebral cortex is much larger in humans than in most other animals (dolphins are an exception). It analyzes information from all the senses and controls voluntary movement, abstract thinking, and the other most complex aspects of our behavior and mental processes. The cerebral cortex looks somewhat round and has a long groove down the middle creating two halves, called *cerebral hemispheres*. The **corpus callosum**, a massive bundle of more than a million fibers, connects the two hemispheres.

The folds of the cerebral cortex give the surface of the human brain its wrinkled appearance, its ridges and valleys. The ridges are called *gyri* (pronounced "JI-rye"), and the valleys are known as *sulci* (pronounced "SUL-sigh") or *fissures.* As you can see in Figure 3.10, we take advantage of several deep sulci to divide the cortex into four areas, called *lobes*: the frontal (front), parietal (top), occipital (back), and temporal (side). We use gyri and sulci as landmarks for describing the structure of the cortex, but the *functions* of the cortex do not stick to these boundaries. When divided according to function, the cortex includes areas of the sensory cortex, motor cortex, and association cortex.

The Sensory and Motor Cortex

Areas of the **sensory cortex** lie in parts of the parietal, occipital, and temporal lobes. Different regions of the sensory cortex receive information from different senses. Occipital lobe nerve cells called the *visual cortex* receive visual information. Temporal lobe nerve cells called the *auditory cortex* receive information from the ears. And information from the skin, such as sensations of touch, pain, and temperature, is received by cells in the parietal lobe. The skin-related areas are called the *somatosensory cortex* (*soma* is Greek for "body"). Information about skin sensations from neighboring parts of the body comes to neighboring parts of the somatosensory cortex. The places on the cortex where information from each area of skin arrives can be represented by the figure of a tiny person stretched out along the cortex (see Figure 3.11). This figure is called the *homunculus* (Latin for "little man"). Experience can change how the sensory cortex responds to sensory stimulation (Schaefer, Heinze, & Rotte, 2008). For example, if a limb is lost, the part of the sensory cortex that had been stimulated by that limb will now be stimulated by other regions of skin. Similarly, practicing a musical instrument will increase the number of sensory neurons that respond to touch (Hyde et al., 2009); the same thing happens when blind people learn to read Braille with their fingertips (Amedi et al., 2005).

cerebral cortex The outer surface of the brain.

corpus callosum A massive bundle of axons that connects the right and left cerebral hemispheres and allows them to communicate with each other.

sensory cortex The parts of the cerebral cortex that receive stimulus information from the senses.

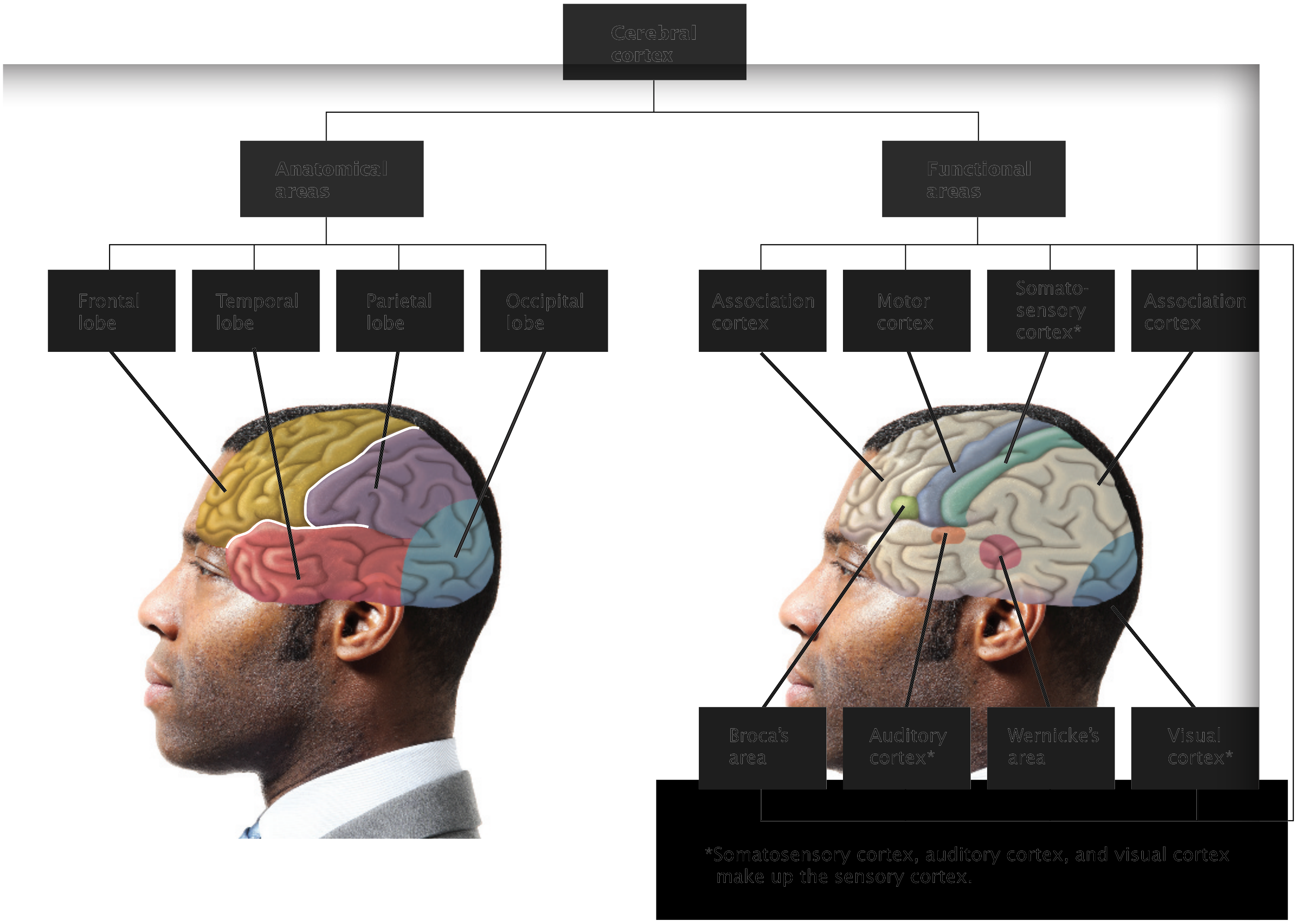

FIGURE 3.10

The Cerebral Cortex (viewed from the left side)

The brain's ridges (gyri) and valleys (sulci) divide the cortex into four lobes: the frontal, parietal, occipital, and temporal. These terms describe where the regions are (the lobes are named for the skull bones that cover them), but the cortex is also divided in terms of function. These functional areas include the motor cortex (which controls movement), sensory cortex (which receives information from various senses), and association cortex (which integrates information). Also labeled are Wernicke's area and Broca's area, two regions that are found only on the left side of the cortex and that are vital to the interpretation and production of speech.

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In the frontal lobes, different specific neurons of the **motor cortex** control voluntary movements in each specific part of the body (Indovina & Sanes, 2001). The arrangement of the motor cortex is like that of the somatosensory cortex; the parts of the motor cortex that control hand movement are near parts of the sensory cortex that receive sensory information from the hands.

Seems easy, doesn't it? You have a map of your body parts in your cerebral cortex, and you activate cells in the hand region of the cortex if you want to move your hand. But, in fact, the process is quite complex. To grasp the handle of a coffeepot, for example, your cortex must first translate the pot's location into a position relative to your body—to your left or right, for example. Next, the cortex must determine which muscles must be contracted to produce the desired movement toward that exact position. Groups of neurons work together to produce just the right combinations of direction and force in particular muscle groups. Making these determinations involves many interconnected areas of the cortex, and the specific neurons involved can change over time (Gallivan, Cavina-Pratesi,

motor cortex The part of the cerebral cortex whose neurons control voluntary movements in specific parts of the body.

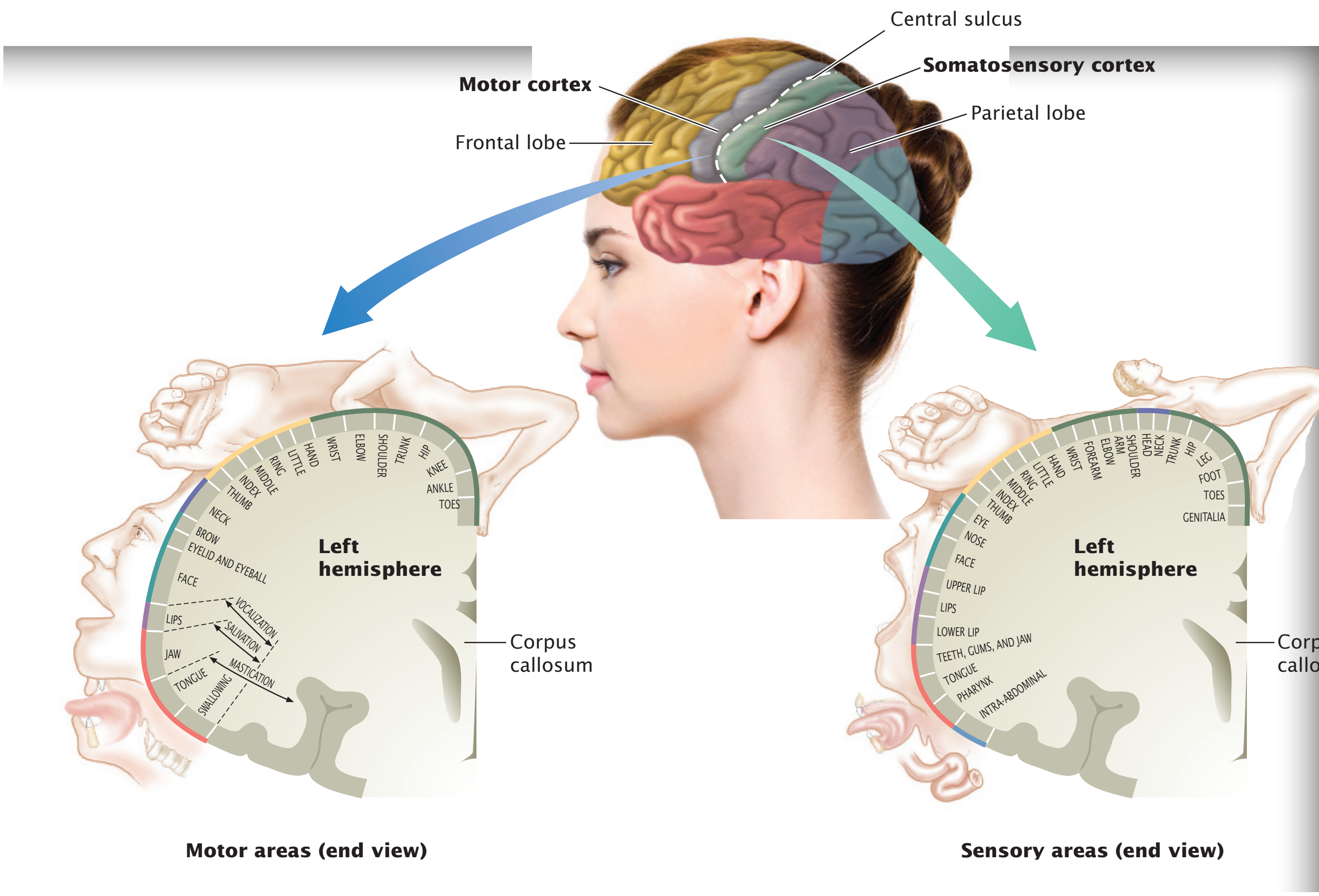

FIGURE 3.11
Motor and Somatosensory Cortex

The areas of the cortex that move parts of the body (motor cortex) and receive sensory input from body parts (somatosensory cortex) appear in both hemispheres of the brain. Here we show cross sections of only those on the left side, looking from the back of the brain toward the front. Areas receiving input from neighboring body parts, such as the lips and tongue, are near one another in the sensory cortex. Areas controlling movement of neighboring parts of the body, such as the foot and leg, occupy neighboring parts of the motor cortex. Notice that the size of these areas is uneven; the larger the area devoted to each body part, the larger that body part appears on the "homunculus."

Note: Did you notice the error in this classic drawing? The figure of the homunculus shows the right side of its body but its left hand and the left side of its face.

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& Culham, 2009; W. Wang et al., 2010). Computer models of neural networks show how these complex problem-solving processes might occur (Graziano, Taylor, & Moore, 2002; Krauzlis, 2002). ("In Review: Organization of the Brain" summarizes the major structures and functions of the brain.)

IN REVIEW

ORGANIZATION OF THE BRAIN

Major Division	Some Major Structures	Some Major Functions
Hindbrain	Medulla oblongata	Regulates breathing, heart rate, and blood pressure
	Reticular formation (also extends into midbrain)	Regulates alertness, arousal
	Cerebellum	Controls finely coordinated movements and certain cognitive processes
Midbrain	Various nuclei	Relays sensory signals to forebrain; creates automatic responses to certain stimuli, controls some aspects of eye movement

(continued)

IN REVIEW

ORGANIZATION OF THE BRAIN (CONT.)

Major Division	Some Major Structures	Some Major Functions
Forebrain	Thalamus	Interprets and relays sensory information
	Hypothalamus	Regulates hunger, thirst, and sex drives
	Amygdala	Connects certain sensations and emotions, especially with memory
	Hippocampus	Helps form new memories
	Cerebral cortex	Analyzes sensory information; controls voluntary movements, abstract thinking, and other complex cognitive activity
	Corpus callosum	Transfers information between the two cerebral hemispheres

In Review Questions

1. The oldest part of the brain is the __________.
2. Cells that operate as the body's twenty-four-hour "time clock" are found in the __________.
3. Memory problems seen in Alzheimer's disease are related to shrinkage of the __________.

Association Cortex

The parts of the cortex that do not directly receive specific sensory information or control specific movements are referred to as **association cortex.** The term *association* describes these areas well, because they receive input from more than one sense or input that combines sensory and motor information. For instance, these areas associate words with images. Association cortex appears in all lobes of the brain and forms a large percentage of the cerebral cortex in humans in particular. For this reason, damage to association areas can affect a wide range of mental abilities.

LINKAGES Where are the brain's language centers? (a link to Thought and Language)

Consider language. We rely on the auditory cortex to begin the process of understanding spoken language or the visual cortex for written language. Eventually, we need areas of the motor cortex to produce the speech or hand movements that express the language we want to get across. Putting all of this together in the complex activity known as language involves a network of neuron activity across many areas of association cortex. In the 1860s, a French surgeon named Paul Broca described the effects of damage to an area of association cortex in the left frontal lobe, near motor areas that control face muscles. This part of the cortex is now called *Broca's area* (see Figure 3.10). Damage to Broca's area causes *Broca's aphasia,* a language disorder where victims have difficulty getting words out, either by speaking or writing, and often making errors in grammar, though they can still understand fairly well the language that they hear or read.

Other language problems result from damage to a portion of association cortex described in the 1870s by a Polish neurologist named Carl Wernicke (pronounced "VER-nick-ee"). Figure 3.10 shows that, like Broca's area, *Wernicke's area* is on the left side of the brain, but it is in the temporal lobe, near the area of the sensory cortex that receives information from the ears. Wernicke's area also receives input from the visual cortex and is involved in the interpretation of both speech and written words. Damage to Wernicke's area produces complicated symptoms. Such patients have no hesitation to speak, but what they say often makes no sense, and they have a hard time understanding the meaning of words they hear or see.

association cortex The parts of the cerebral cortex that receive information from more than one sense or that combine sensory and motor information to perform complex cognitive tasks.

Language Areas of the Brain

TRY THIS Have you ever tried to write notes while you were talking to someone? You can probably write and talk at the same time because each of these language functions uses different association cortex areas. However, stop reading for a moment and try writing one word with your left hand and a different word with your right hand. If you had trouble, it is partly because you asked the same language area of your brain to do two things at once.

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Case studies illustrate the different effects of damage to each area (Lapointe, 1990). In response to the request "Tell me what you do with a cigarette," a person with Wernicke's aphasia replied, "This is a segment of a pegment. Soap a cigarette." This speech came out easily, quickly, without effort, but without meaning. In response to the same request, a person with Broca's aphasia replied, "Uh.. uh.. cigarette [pause] smoke it." This speech was meaningful but not fluent; it was halting and awkwardly phrased. Surprisingly, when a person with Broca's aphasia sings, words may come easily and correctly. Apparently, words set to music are handled by one part of the brain and spoken words by another (Jeffries, Fritz, & Braun, 2003). Some speech therapists take advantage of this fact through "melodic intonation" therapy, which helps Broca's aphasia patients improve fluency by speaking in a singsong manner (Norton et al., 2009). This therapy is enhanced by noninvasive electrical stimulation of the right hemisphere, perhaps helping to compensate for damage to Broca's area in the left hemisphere (Vines, Norton, & Schlaug, 2011).

Other mental functions depend on somewhat different areas of association cortex. Areas in the *prefrontal cortex* at the front of the brain are involved in the complex processes necessary for the conscious control of thoughts and actions and for understanding our world (Fincham & Anderson, 2006; Koechlin & Hyafil, 2007). For example, these areas of association cortex allow us to understand sarcasm or irony—that is, when someone says one thing but means the opposite. In one study, people with prefrontal cortex damage listened to sarcastic stories such as this: "Joe came to work, and instead of beginning to work, he sat down to rest. His boss noticed his behavior and said, 'Joe, don't work too hard.'" Most people immediately realized that the boss was being sarcastic, but people with prefrontal brain damage did not (Shamay-Tsoory & Tomer, 2005).

FOCUS ON RESEARCH METHODS

THE CASE OF THE DISEMBODIED WOMAN

Neurologist Oliver Sacks described the case of "Christina," a woman who had somehow lost the ability to feel the position of her own body (Sacks, 1985). The case study gives important insights about biological aspects of psychology that could not be studied through controlled experiments. It shows, for example, that the sense known as *kinesthesia* (pronounced "kin-es-THEE-see-uh") not only tells us where our body parts are but also plays an important role in our sense of self.

Christina was a healthy young woman who entered a hospital in preparation for minor surgery. Before the surgery could be performed, however, she began to have difficulty holding onto objects. Then she had trouble moving. She would rise from bed and flop onto the floor like a rag doll. Christina seemed to have "lost" her body. She felt disembodied, like a ghost. On one occasion, for example, she became annoyed at a visitor for tapping her fingers on a tabletop. But it was Christina's fingers, not the visitor's, that were tapping. Her body was acting on its own, doing things she did not know about.

What was the researcher's question?

Christina could not walk or use her hands and arms. Why was a seemingly normal, healthy young woman falling and dropping things?

How did the researcher answer the question?

A psychiatrist at the hospital thought that Christina was suffering from *conversion disorder,* a condition in which psychological problems cause physical disabilities (see the chapter on psychological disorders). Unconvinced, Sacks studied Christina further.

What did the researcher find?

Sacks's examinations and tests revealed that Christina had lost all sensory feedback about her joints and muscle tone and the position of her limbs. She'd suffered a breakdown, or degeneration, of the sensory neurons that normally bring kinesthetic information to her brain. There was a biological reason that Christina could not walk or control her hands and arms.

(*continued*)

What do the results mean?

Sacks argued that the sense we have of our bodies is based not only partly on what we see but also partly on *proprioception* (sensing the self). Christina herself put it this way: "Proprioception is like the eyes of the body, the way the body sees itself. And if it goes, it's like the body's blind." With effort and determination, Christina eventually regained some ability to move about. For example, if she looked intently at her arms and legs, she could coordinate their movement more. She was able to leave the hospital and resume many normal activities, but Christina never recovered her sense of self. She still feels like a stranger in her own body.

What do we still need to know?

Notice that Christina's case study did not test any hypotheses about kinesthesia in the way an experiment might. It did, however, focus attention on how it feels to have lost this sense. It also highlighted a rare condition that, seldom discussed before Sacks reported it, has been observed more often in recent years, especially among people taking an excess of vitamin B6, also known as *pyridoxine*. Too much of this vitamin can damage sensory neurons (Dordain & Deffond, 1994). How and why vitamin B6 does such damage is unknown. Are there other causes of such a kinesthetic disorder? What treatments might best help? These questions remain to be answered.

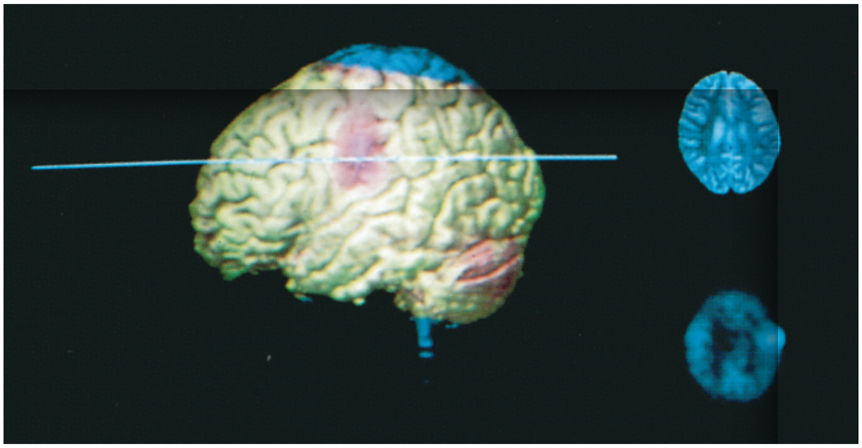


FIGURE 3.12
Combining a PET Scan and Magnetic Resonance Imaging

Researchers have superimposed images from PET scans and MRI to construct a three-dimensional view of the living brain. Here you can see the brain of a young girl with epilepsy. The picture of the outer surface of the brain is from the MRI. The pink area is from the PET scan and shows the source of epileptic activity. The images at the right are the MRI and PET images at one plane, or "slice," through the brain (indicated by the line on the brain at the left).

D. N. Levin, H. Xiaoping, K. K. Tan, S. Galhotra, C. A. Palizzare, G. T. Y. Chen, R. N. Beck, C. T. Chen, M. D. Cooper, J. F. Mullan, J. Hekmatpanah, & J. P. Spire (1989). The Brain: Integrated three-dimensional display of MR and PET images. Radiology, 172: 783-789.

Exporing the Brain

A variety of new techniques, combined with some older measures, give scientists ever better ways to study the brain and its activity (see Table 3.1). Each has different advantages and disadvantages. One of the earliest techniques, called the *electroencephalograph (EEG)*, measures general electrical activity of the brain. Electrodes are pasted on the scalp to detect the electrical fields resulting from the activity of billions of neurons (Figure 9.3 in the consciousness chapter shows how EEG can be used to record brain activity during sleep). Although this tool can associate rapidly changing electrical activity with changes in the activity of some brain surfaces, it cannot tell us exactly where the active cells are, and it can only reflect the activity of brain cells closest to the scalp.

A more recent technique, *PET* (for *positron emission tomography*), tries to locate brain cell activity by recording where radioactive blood sugar becomes concentrated after it is injected into the bloodstream. PET brain images show where the radioactive glucose goes in the brain as a person performs various tasks. Since the brain cells that fire action potentials should use the most glucose, PET brain scans essentially show which brain cells were most active during a task. For instance, PET studies have revealed that specific brain regions are activated when we look at fearful facial expressions or hear fearful voices (Pourtois et al., 2005) and that activity in these brain areas is modified in people with posttraumatic stress disorder (Murrough et al., 2011). PET scans can tell us a lot about where changes in brain activity occur, but they can't reveal details of the brain's physical structure.

Fortunately, we can get a detailed structural picture of what the brain physically looks like using *magnetic resonance imaging*, or *MRI*. MRI exposes the brain to a magnetic field and measures the resulting radiofrequency waves to make amazingly clear pictures of the brain's anatomical details (see Figure 3.12). *Functional MRI*, or *fMRI*, combines some advantages of PET and MRI, by detecting changes in blood flow and blood oxygen that suggest how active neurons are in each area of the brain, providing a sort of "moving picture" of brain functioning.

TABLE 3.1 TECHNIQUES FOR STUDYING HUMAN BRAIN FUNCTION AND STRUCTURE

Techniques	What It Shows	Advantages	Disadvantages
EEG (electroencephalograph) Electrodes are pasted to the outside of the head.	Lines that chart the summated electrical fields resulting from the activity of billions of neurons.	Detects very rapid changes in electrical activity, allowing analysis of stages of cognitive processing.	Poor spatial resolution of the source of electrical activity. Can only measure some brain activity.
PET (positron emission tomography) and SPECT (single-photon emission computed tomography) Radioactive substances, injected into the bloodstream, indicate activity in the brain.	An image of the amount and localization of any molecule that can be injected in radioactive form, such as neurotransmitters, drugs, or tracers for blood flow or glucose use (indicating specific changes in neuronal activity).	Allows functional and biochemical studies. Provides visual image corresponding to anatomy.	Requires exposure to low levels of radioactivity. Spatial resolution is better than EEG but poorer than MRI. Cannot follow rapid changes (faster than thirty seconds).
MRI (magnetic resonance imaging) A magnetic field measures radio frequency waves in the brain.	Traditional MRI provides high-resolution image of brain anatomy. Functional MRI (fMRI) provides images of changes in blood flow that indicate specific changes in neural activity. Another variant of MRI, diffusion tensor imaging (DTI), shows water flow in neural fibers, revealing the "wiring diagram" of neural connections in the brain.	Requires no exposure to radioactivity. Provides high spatial resolution of anatomical details (smaller than 1 mm). Provides high temporal resolution (less than one-tenth of a second).	Not safe for individuals with certain metals in their bodies, such as a pacemaker.
TMS (transcranial magnetic stimulation) Temporarily affects electrical activity of a small region of brain by exposing it to an intense magnetic field.	Studies normal function of a particular brain region by observing changes after TMS is applied to a specific location.	Shows which brain regions are necessary for given tasks.	Long-term safety not well established.
Optogenetics Genes are inserted into neurons to allow channels in the cell membranes to open or close in response to light, thus making action potentials more, or less, likely.	Allows scientists to manipulate brain activity by turning cells on or off by pointing a light on a brain area of interest	Shows how a person functions with or without the use of specific brain areas.	Long-term safety not well established. Invasive technique; requires placing genes into brain cells.

The newest techniques offer even deeper insight into brain activity, structure, and functioning. These techniques include a variant on fMRI called *diffusion tensor imaging (DTI),* which traces the activity of axon pathways, and a procedure called *transcranial magnetic stimulation (TMS),* which sets up magnetic fields outside the brain. These magnetic fields can either stimulate or disrupt neural activity (Glenberg, 2011; Lagopoulos & Malhi, 2008). Some researchers are studying brain functions by combining fMRI and TMS. For example, when one brain region is stimulated by TMS, and changes in activity are detected by fMRI in another region, this indicates that the two regions are functionally connected. Similarly, if the ability to perform a certain behavior is affected when TMS disrupts activity in a certain brain region, this suggests that the behavior is somehow controlled or influenced by that brain region (Muggleton, 2010). TMS may also have unexpected value in the treatment of depression and migraine headaches (O'Reardon et al., 2007).

A new technique, *optogenetics*, involves inserting genes of light-sensitive plants into brain cells of animals (Airan et al., 2009). The modified cells have channels in their cell membranes that open or close in response to light (Boyden et al., 2005; Wietek et al., 2014). The scientist then uses special lights that can actually penetrate through the skull and into the brain. When light strikes the genetically modified cells, their membrane channels allow electrically charged atoms to flow into or out of the cell. The result is that the cell becomes more or less likely to fire an action potential. In effect, the scientist can "turn on" or "turn off" brain cells just by shining a light on them! The results can be fascinating. For example, optogenetic work with mice has demonstrated that activating neurons within the hippocampus can create false memories; the mice remember things that never happened (Ramirez et al., 2013). Optogenetics has also begun to show how activity in certain brain areas may create or reduce psychological problems such as anxiety (Kim et al., 2013), and it holds promise for giving physicians new ways to treat diseases such as epilepsy (Bentley et al., 2013; Sukhotinsky et al., 2013).

THINKING CRITICALLY

WHAT CAN FMRI TELL US ABOUT BEHAVIOR AND MENTAL PROCESSES?

A picture may be worth a thousand words, but the pictures of brain activity offered by fMRI are generating millions of them. As of 2014, several thousand scientific articles have reported the results of fMRI scans taken while people engaged in various kinds of thinking or experienced various emotions. Neuroscientists who use brain-imaging techniques can now be found in psychology departments around the world, and, as described in other chapters, their work is changing the research landscape in cognitive, social, and abnormal psychology. Excitement over fMRI is not confined to scientists, however. Popular and scientific magazines routinely carry fMRI pictures that seem to "show" people's thoughts and feelings as they happen, and readers see claims made in these articles as more believable than those based on other kinds of data (Beck, 2010; McCabe & Castel, 2008). This may be one reason why some companies are able to make money by offering brain imaging services that can supposedly improve the quality of employee selection, lie detection, political campaign strategies, product design, and diagnosis of mental disorders (e.g., Ariely & Berns, 2010; Falk, Berkman, & Lieberman, 2012; Morin, 2011). Jurors, too, find evidence from fMRI scans extremely persuasive (McCabe, Castel, & Rhodes, 2011), even though research shows that it is not an effective method for detecting deception (Adelsheim, 2011; Ganis, et al., 2011). The editor of one scientific journal summed up this trend by saying that "a picture is worth a thousand dollars" (Farah, 2009).

What am I being asked to believe or accept?

In the early 1800s, similar excitement surrounded *phrenology,* a technique that involved measuring the bumps and depressions on the skull. It was claimed that these contours reflected the size of twenty-seven structures on the brain's surface that determine personality traits, mental abilities, talents, and other characteristics. Although wildly popular with the public (Benjamin & Baker, 2004), phrenology did not survive the critical thinking of nineteenth-century scientists, and the technique has long been discredited. Some scientists wonder whether fMRI is a twenty-first-century version of phrenology, at least in the sense that people might be accepting its value too readily. These scientists point out that although fMRI images can indicate where brain activity occurs as people think and experience emotion, there is no guarantee that this activity is *causing* the thoughts and feelings (Aldridge, 2005). Perhaps brain areas change their activity as a *reaction* to thoughts and feelings. Moreover, could it be that a brain area contributes to a mental task by changing how its nerve cells work, not whether they work more or less? Such questions challenge the assumption that increased energy use by a cell means that the cell is doing a more important job in support of some psychological function. These functions may not even "occur" in a particular brain structure or set of structures. It is easy to talk about "thinking" or "attention," but these psychological terms might not

(*continued*)

correspond to single biological processes that can be isolated and located by *any* technology (Miller, 2010). In short, critics claim that the results of fMRI scans can be misleading and that they don't necessarily tell us much about how the mind works (Uttal, 2003). Some believe that it would be better to focus on *how* the brain produces thoughts and feelings instead of searching for their locations (Poldrack, 2010).

What evidence is available to support the assertion?

When a participant in an fMRI experiment thinks or feels something, the colors in the scanned image of the brain change, much like the color changes you see on weather radar as a rainstorm intensifies or weakens. Looking at an fMRI scan, you see the brain areas that "light up" when a person experiences an emotion or performs a mental task are presumed to be the ones involved in that emotion or task.

These scans are not as precise as they seem, though, because fMRI doesn't measure brain cell activity directly. The colors shown in an fMRI scan reflect the flow of blood in the brain and the amount of oxygen the blood is carrying. Changes in blood flow and blood oxygen are *related* to changes in the firing rates of neurons (Kahn et al., 2013), but the relationship is complex; for example, the relationship differs from one brain region to another (Devonshire et al., 2011) and changes with age (Mohtasib et al., 2011). And changes in an fMRI signal can depend on how much neural firing was taking place before a stimulus appeared (Maandag et al., 2007; Perthen et al., 2008). Further, when brain cells process information, their firing rates may either increase or decrease (Gonsalves et al., 2005). If the increases and decreases in a particular brain region happen to cancel each other out, an fMRI scan will miss the neuronal activity taking place in that region (Glenberg, 2011). In fact, compared with the direct measurement of brain cell activity that can be done in research with animals, fMRI technology is still quite crude. It takes coordinated changes in millions of neurons to produce a detectible change in the fMRI signal.

Critics also argue that results of fMRI research can vary too much based on how experimenters interpret them. In a typical fMRI experiment, participants see some kind of display, such as pairs of photos, and then do various tasks. One task might be to press a button if the photos are exactly the same. A second task might be to press the button if objects in the photos are arranged in the same way. In this second task, a participant should press the button if one photo shows, say, a short man standing to the left of a tall woman and the other photo shows a small dog standing to the left of a giraffe. Both versions of the task require the participant to compare two images, but only the second of them requires considering whether things that look different are actually similar in some way. The fMRI scans taken during these tasks might show certain brain areas "lighting up" only during the second task. If so, the researcher would suggest that those areas are involved in recognizing *analogies*, or the similarities between apparently different things (Wharton et al., 2000). The researcher would base this conclusion on a computer program that compares fMRI scans taken during two tasks, subtracts all the "lighted" areas that are the same in both scans, and keeps only those that are different. But what the computer classifies as "different" depends on a rule that is set by the experimenter. If the experimenter programs the computer to display only big differences between the scans, not many "lit up" areas will remain after the comparison process. But if even tiny differences are allowed to count as "different," many more "lighted" areas will remain after the subtraction process. In our example, then, there could be large or small areas apparently associated with recognizing analogies, all depending on a rule set by the researcher.

These problems aside, critics wonder what it really means when fMRI research shows that certain brain areas appear activated during certain kinds of tasks or experiences. Their concern focuses on studies, such as one from the new field of *neuroeconomics*, which suggests that the neural basis of bad investment decisions is due to higher activity in a particular area of the brain (Kuhnen & Knutson, 2005). Other studies have used fMRI to identify the neural activity associated with trust, religious belief, political liberalism or conservatism, and even love (Amodio et al., 2007; Kapogiannis et al., 2009; Krueger et al., 2007). In this last study, on "the neural basis of romantic love" (Bartels & Zeki, 2000), investigators scanned people's brains as they looked at pictures of their romantic partners and compared these

(*continued*)

scans to those taken while the same people viewed nonromantic friends. According to the "difference" rule established by the experimenters, four brain areas were more active when viewing a romantic loved one than when viewing a friend. However, these same brain regions are active in many different emotions, so does the activity tell us anything specific about the neural basis of love? Critics of fMRI would say no.

Are there alternative ways of interpreting the evidence?

Supporters of fMRI disagree with those critics. They believe that the colorful areas seen on fMRI scans can provide information to answer important questions about behavior and mental processes. They point, for example, to fMRI research on brain mechanisms that help us appreciate what other people are feeling—that is, to experience empathy—and to learn by watching others.

These *mirror neuron mechanisms* were discovered accidentally by scientists who had been using surgical techniques to directly record the activity of monkeys' brain cells (Caggiano et al., 2009; Rizzolatti et al., 1996). They found that neurons in an area called F5 are activated not only when a monkey plans to reach for an object, such as a peanut, but also if the monkey sees an *experimenter* reach for a peanut (Glenberg, 2011)! After fMRI scanning became available, researchers could begin looking for mirror mechanisms in the human brain, and they did so with gusto: since 2003, more than 190 studies have used fMRI to study the mirror system in humans (Molenberghs et al., 2012). And in fact, some of the mirror systems they found in humans correspond to the F5 region in monkeys (Fizzolatti & Arbib, 1998) They are in other brain regions, too (Mukamel et al., 2010). One of them is *Broca's* area which, as described earlier, is an important component of our ability to speak. It makes sense that Broca's area contains a mirror mechanism, because language is a skill that we learn partly by imitation. The new fMRI findings suggest that Broca's area may also be important for many other skills that involve imitation. One study found that this area "lights up" when a guitar student learns chords by watching a professional guitarist (Buccino et al., 2004). Other fMRI research has found that mirror systems in other parts of the brain become active when a person sees someone experiencing emotion. For example, the brain area that is activated when you experience disgust (e.g., from the smell of rotten eggs) is also activated if you see a video in which someone else reacts to a smell with disgust (Wicker et al., 2003).

So fMRI can be uniquely useful, say its defenders. Without it, research on mirror neurons in humans could not have taken place. And because of it, we have evidence that the experience of empathy comes about because seeing the actions and emotions of others activates the same brain regions that would be active if we were doing or feeling the same things ourselves. Some fMRI studies have also found that malfunctioning mirror mechanisms are associated with the impairments in language development, imitative skills, and empathy seen in children diagnosed with autistic spectrum disorders (Dapretto et al., 2006; Perkins et al., 2010). Are all mirror functions affected in autistic spectrum disorders or just the emotional functions? This question is still being debated (Hamilton, 2013; see the chapter on psychological disorders).

What additional evidence would help evaluate the alternatives?

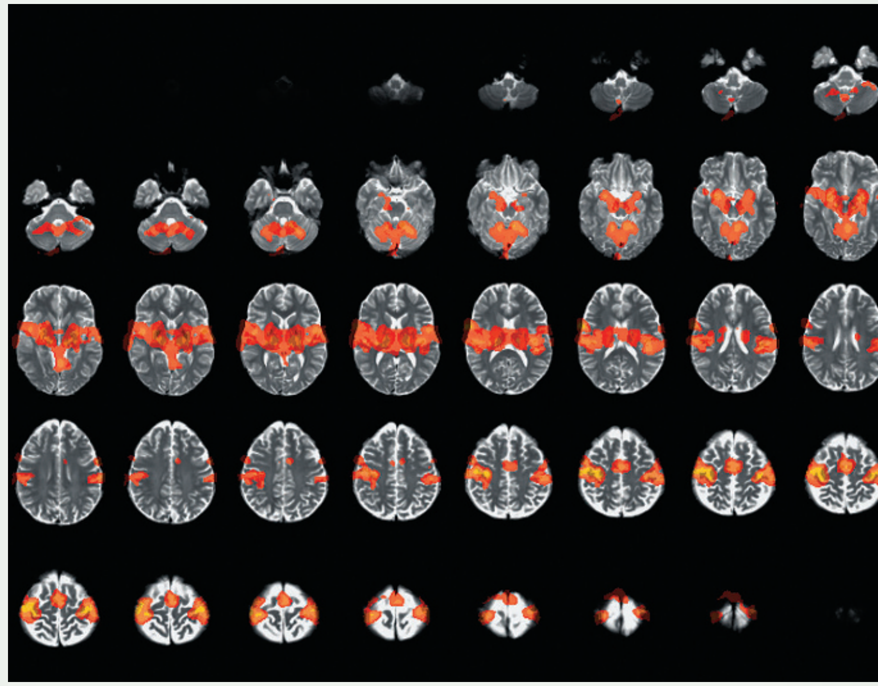
As technology continues to be refined, the quality of fMRI scans will improve, giving better images of where brain activity may occur. But the value of this scanning technology will depend on understanding of what it can and cannot tell us about how brain activity is related to behavior and mental processes. We also need more evidence about correlation and causation in fMRI research. For example, one study conducted fMRI scans on compulsive gamblers as they played a simple guessing game (Reuter et al., 2005). When they won the game, these people showed an unusually small amount of activity in a brain area that is normally activated by the experience of rewards, or pleasure. Noting the correlation between compulsive gambling and lower than normal activity in the reward area, the researchers suggested that an abnormality in the brain's reward mechanisms might be responsible for gambling addiction. But case studies also suggest that compulsive gambling appears in people taking a prescription drug that *increases* activity in reward areas—and that the gambling stops when the drug is discontinued (Abler et al., 2009; Cilia et al., 2008; Ferrara & Stacy, 2008).

(*continued*)

Exploring Brain Functions with fMRI

As a research participant performs a mental task, a functional magnetic resonance imaging scanner records blood flow and blood oxygen levels in her brain. The resulting computer analysis shows as "lit up" areas the parts of the brain that appear to be activated during the task, but critics doubt that fMRI scanning is as clear or accurate as its proponents suggest.

Image courtesy of Brad Sutton, Beckman Institute Biomedical Imaging Center, University of Illinois at Urbana-Champaign



As noted in the research in psychology chapter, correlation does not guarantee causation. Is the brain activity reflected in fMRI scans causing the thoughts and feelings that take place during the scanning process? Possibly, but those thoughts and feelings might themselves be *caused* by activity elsewhere in the brain that affects the areas being scanned. The transcranial magnetic stimulation (TMS) and optogenetic procedures mentioned earlier might help identify causal versus correlational relationships in the brain. These methods temporarily disrupt neural activity in brain regions identified by fMRI as related to a particular kind of thought or feeling, so perhaps scientists can determine if those thoughts or feelings are temporarily disrupted when TMS or optogenetic activity occurs.

What conclusions are most reasonable?

A full understanding of fMRI requires continuing dialogue between those who dismiss the technique and those who sing its praises. To make this dialogue easier, a group of government agencies and private foundations has funded an fMRI Data Center (http://www.nitrc.org/projects/fmridatacenter). This facility stores information from fMRI experiments and makes it available to both critics and supporters of fMRI, who can review the research data, conduct their own analyses, and offer their own interpretations.

Such a process has been seen before in biological psychology. For example, when the EEG was invented in the 1920s, scientists had their first glimpse of brain cell activity, as reflected in the "brain waves" traced on a long sheet of paper rolling from the EEG machine. To many of these scientists, EEG must have seemed like a golden gateway to an understanding of the brain and its relationship to behavior and mental processes. EEG has, in fact, helped advance knowledge of the brain, but it certainly didn't solve all of its mysteries. The same will probably be true of fMRI. It is an exciting tool, and it offers previously undreamed-of images of brain structure and functioning, but it is unlikely on its own to explain just how the brain creates our behavior and mental processes. It seems reasonable to conclude, then, that those who question the use of fMRI to study psychological processes are right in calling for a careful analysis of the value of this important high-tech tool.

Although the meaning of fMRI data will remain a subject for debate, there is no doubt that brain-scanning techniques in general have opened new frontiers for biological psychology, neuroscience, and medicine. Much of our growing understanding of how and why behavior and mental processes occur is coming from research with these techniques (Poldrack, Halchenko, & Hanson, 2009).

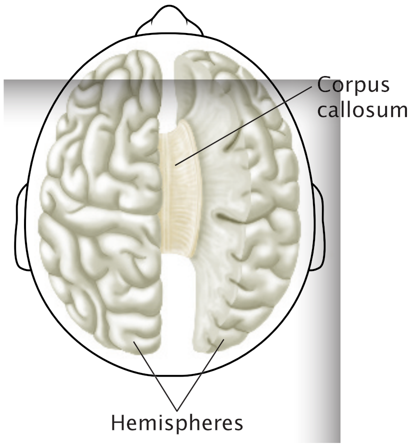


FIGURE 3.13
The Brain's Left and Right Hemispheres

The brain's two hemispheres are joined by a core bundle of nerve fibers known as the *corpus callosum*. In this figure, the hemispheres are separated to reveal the corpus callosum. The two cerebral hemispheres look nearly the same but perform somewhat different tasks. For one thing, the left hemisphere receives sensory input from and controls movement on the right side of the body. The right hemisphere senses and controls the left side of the body.

The Divided Brain: Lateralization

A striking idea emerged from observations of people with damage to the language areas of the brain. Researchers noticed that when damage was limited to areas of the left hemisphere, there were impairments in the ability to use or understand language. Damage to corresponding parts of the right hemisphere usually did not have these effects. Could it be that the right and left halves of the brain serve different functions?

This concept was not entirely new. It had long been understood, for example, that most skin sensation and motor pathways cross over as they enter or leave the brain. As a result, the left hemisphere receives information from and controls movements of the right side of the body, and the right hemisphere receives input from and controls the left side of the body. However, both sides of the brain perform these functions. The fact that language areas, such as Broca's area and Wernicke's area, are found almost exclusively on the left side of the brain suggested that each hemisphere might show **lateralization**, also known as *lateral dominance*. That is, each might be specialized to perform some functions more efficiently than, and almost independently of, the other hemisphere (Stephan et al., 2003).

Split-Brain Studies

As far back as the late 1800s, scientists had wanted to test the hypothesis that the cerebral hemispheres might be specialized, but they had no techniques for doing so. Then, during the 1960s, Roger Sperry, Michael Gazzaniga, and their colleagues began to study *split-brain* patients—people who had undergone a surgical procedure in an attempt to control severe epilepsy. Before the surgery, their seizures began in one hemisphere and then spread to engulf the whole brain. As a last resort, surgeons isolated the two hemispheres from each other by severing the corpus callosum, the massive bundle of axons that connects the two hemispheres (see Figure 3.13).

After the surgery, researchers used a special apparatus to present visual images to only one side of these patients' split brains (see Figure 3.14). They found that severing the tie between the hemispheres had dramatically affected the way these people thought about and dealt with the world. For example, when the image of a spoon was presented to the left, language-oriented side of one patient's split brain, she could say what the spoon was; but when the spoon was presented to the right side of her brain, she could not describe the spoon in words. She still knew what it was, however. Using her left hand (controlled by the right hemisphere), she could pick out the spoon from a group of other objects by its shape. But when asked what she had just grasped, she replied, "A pencil." The right hemisphere recognized the object, but the patient could not describe it because the left (language) half of her brain did not see or feel it (Sperry, 1968).

Although the right hemisphere has no control over spoken language in split-brain patients, it does have important capabilities, including some related to nonspoken language. For example, a split-brain patient's right hemisphere can guide the left hand in spelling out words with Scrabble tiles (Gazzaniga & LeDoux, 1978). Thanks to this ability, researchers discovered that the right hemisphere of split-brain patients has self-awareness and normal learning abilities. In addition, it is superior to the left hemisphere on tasks dealing with spatial relations (especially drawing three-dimensional shapes) and at recognizing human faces.

Lateralization of Normal Brains

Sperry (1974) concluded from his studies that each hemisphere in the split-brain patient has its own "private sensations, perceptions, thoughts, and ideas all of which are cut off from the corresponding experiences in the opposite hemisphere. . . . In many respects each disconnected hemisphere appears to have a separate 'mind of its own'" (p. 7). But what about people whose hemispheres are connected normally? Are certain of their functions, such as mathematical reasoning or language skills, lateralized?

lateralization (lateral dominance) The tendency for one cerebral hemisphere to excel at a particular function or skill compared with the other hemisphere.

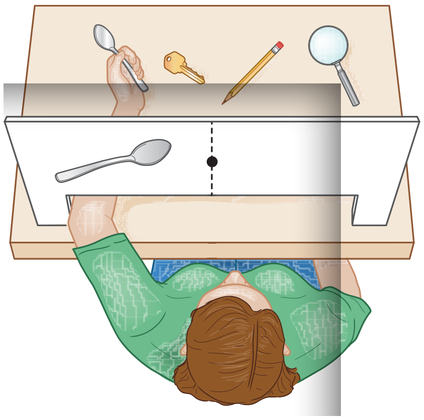


FIGURE 3.14
Apparatus for Studying Split-Brain Patients

When the person stares at a dot in the center of the screen, images briefly presented on one side of the screen go to only one side of the brain. For example, a picture of a spoon presented on the left side of the screen goes to the right side of the brain. The right side of the brain can find the spoon and direct the left hand to touch it. However, because the language areas on the left side of the brain did not see the spoon, the person is unable to say what it is.

To find out, researchers presented images to just one hemisphere of people with normal brains and then measured how fast they could analyze information. If information is presented to one side of the brain, and if that side is specialized to analyze that type of information, a person's responses will be faster than if the information must first be transferred to the other hemisphere for analysis. These studies have confirmed that the left hemisphere has better language abilities than the right, whereas the right hemisphere has better spatial, artistic, and musical abilities (Springer & Deutsch, 1989).

Having two somewhat specialized hemispheres allows the brain to be more efficient in performing some tasks, particularly difficult ones, but the differences between the hemispheres should not be exaggerated. The corpus callosum usually integrates the functions of the "two brains," a role that is particularly important in tasks that require sustained attention (Rueckert et al., 1999). As a result, the hemispheres work so closely together, and each makes up so well for whatever lack of ability the other may have, that people are normally unaware that their brains are made up of two partly independent, somewhat specialized halves (Banich, 2009; Staudt et al., 2001).

Plasticity in the Central Nervous System

The central nervous system has a remarkable property called **neural plasticity** (also known as *neuroplasticity* or simply *plasticity*), which is the ability to strengthen neural connections at synapses as well as to establish new connections (Choquet & Triller, 2013). Plasticity depends partly on neurons and partly on glial cells (Lee & Silva, 2009), and it occurs throughout the central nervous system. Plasticity appears in the spinal cord, where simple reflexes can be modified by life experiences (Wolpaw & Chen, 2006), and also in the brain, where the connections between neurons are not only highly changeable but can change in a fraction of a second (Bikbaev & Manahan-Vaughan, 2008; Stettler et al., 2006). Plasticity in the brain is the basis of our ability to form new memories and learn new things (Ho, Lee, & Martin, 2011; Roberts et al., 2010). For example, more cells in the brain's motor cortex become involved in controlling hand movements in people who have learned to play a musical instrument. The process can be seen in brain-imaging studies; as non-musicians get better at making rhythmic finger movements, the amount of motor cortex devoted to this task increases (Munte, Altenmuller, & Jancke, 2002). MRI studies of individuals who were learning to juggle found an increase in the density of cortical regions associated with processing visual information about moving objects (Draganski et al., 2004).

Even more amazing is that merely *imagining* practicing these movements causes changes in the motor cortex (Pascual-Leone, 2001). Athletes have long engaged in exercises in which they visualize skilled sports movements; brain-imaging research reveals that this "mental practice" can change the brain (Olsson et al., 2008). Among trained opera singers, similar changes have been observed in brain areas that control vocalization (Kleber et al., 2010). Given the impact of these specific experiences, it is no wonder that more general cultural experiences, such as growing up in a collectivist versus individualist culture, can also affect the development of a person's brain (Park & Huang, 2010).

Repairing Brain Damage

There are limits to plasticity, though, especially in repairing damage in the brain and spinal cord. Unlike the skin or the liver, the adult central nervous system does not automatically replace damaged cells. As a result, most victims of severe stroke, Parkinson's disease, Alzheimer's disease, or spinal cord injury are permanently disabled in some way. Scientists are searching for ways to help a damaged central nervous system heal some of its own wounds.

One approach has been to transplant, or graft, tissue from the still-developing brain of a fetus into the brain of an adult animal. If the receiving animal doesn't reject

neural plasticity The ability to create new synapses and to change the strength of synapses.

it, the graft may send axons out into the brain and make functional connections. This treatment has reversed some animals learning difficulties, movement disorders, and other results of brain damage (Noble, 2000). The technique has also been used to treat a small number of people with Parkinson's disease—a disorder characterized by tremors, rigidity of the arms and legs, and poor balance (Barker et al., 2013). Some patients showed improvement for several years, though improvement faded for others, and some patients had serious side effects (Freed et al., 2001). Brain tissue transplants in humans are controversial because they require using tissue from aborted fetuses. As an alternative, some scientists have tried transplanting neural tissue from another species, such as pigs, into humans (Drucker-Colin & Verdugo-Diaz, 2004). Russian physicians even transplanted neural tissue from fruit flies into the brains of Parkinson's patients. The results helped, and there were no immediate side effects (Saveliev et al., 1997), but the patients' bodies eventually rejected the fruit fly neurons (Korochkin, 2000).

The most promising source of new neurons may be an individual's own tissues because these cells would not be rejected. This is a revolutionary idea, because it was once believed that after humans reached adulthood, the cells of the central nervous system stopped dividing, leaving each of us with a fixed set of neurons (Rakic, 2002). Then came research showing that adult cell division *can* take place in certain limited circumstances in the adult central nervous systems (Braun & Jessberger, 2014). This capacity exists because the adult human brain has some *neural stem cells*, a special kind of glial cells that are capable of dividing to form new tissue, including new neurons (English et al., 2013; Gage & Temple, 2013; Hsu et al., 2013). The process of creating new neurons is called *neurogenesis*.

This discovery has created both excitement and controversy. There is excitement because stem cells raise hope that damaged tissue may someday be replaced by cells created from a person's own body. There is controversy because it was at first believed that these stem cells could come only from human embryos, which must be destroyed in the process of harvesting the cells. That ethical concern is abating, however, now that researchers have demonstrated that stem cells can be harvested from a person's own bone marrow, the lining of the nose, skin cells, and other places (Vierbuchen et al., 2010), and then made to grow into brain cells. It has even been claimed that a simple acid bath can make body cells in an adult mouse revert back to simpler stem cells (Obokata et al., 2014a, 2014b). This claim has been under severe scrutiny (Cyranoski, 2014), but if validated—and proven successful in humans—the technique could provide an easy way to create completely compatible stem cells for anyone. The benefits of using stem cells in treating brain disorders could be substantial, especially for patients with spinal cord injuries, Parkinson's disease, and Alzheimer's disease (Karimi-Abdolrezaee & Eftekharpour, 2013; Nishimura & Takahashi, 2013; Wojda & Kuznicki, 2013).

There is still a long way to go before any of these experimental strategies can be routinely used in the clinic (Lindvall & Kokaia, 2010), and in any case, successfully generating new neurons is only half the battle. New cells' axons and dendrites would have to reestablish all the synaptic connections that had been lost to damage or disease. They may be able to do this (Weick, Liu, & Zhang, 2011), but the process is hampered in the central nervous system by glial cells that actively suppress new connections between newly sprouted axons and other neurons (Olson, 1997). Several central nervous system proteins, including one aptly named *Nogo*, have the same suppressant effect.

Despite these challenges, research is progressing to promote healing in damaged brains and spinal cords. For example, blocking the action of Nogo in mice and rats with spinal cord injuries allows surviving neurons to make new axonal connections and repair the damage (Harvey et al., 2009; Kastin & Pan, 2005). Other research with animals has shown that both spontaneous recovery and the effectiveness of brain-tissue transplants can be greatly enhanced by naturally occurring proteins called *growth factors*, which promote the survival of neurons (Wu et al., 2009). Other scientists have begun to experiment with implantation of specially engineered neurons to encourage greater neuroplasticity (Boyden, 2011; Knöpfel et al., 2010; Li et al., 2011).

There are also things that patients themselves can do to promote the neural plasticity needed to restore lost central nervous system functions. Special mental and physical exercise programs appear useful in restructuring communication in the brains of stroke victims and spinal cord injury patients, thus reversing some forms of paralysis and improving some sensory and cognitive abilities (Bryck & Fisher, 2012; Kao et al., 2009).

He Was a Super Man

After suffering a spinal cord injury in 1995, *Superman* actor Christopher Reeve was told he would never again be able to move or feel his body. He refused to accept this gloomy prediction, and after years of devoted adherence to an exercise-oriented rehabilitation program, he regained some movement, and by the time of his death in 2004, he was able to feel sensations from most of his body (Blakeslee, 2002). Physicians and physical therapists hope to make such therapy programs even more effective in the future (Dunlop, 2008; Raineteau, 2008).

Neville Elder/Corbis

LINKAGES How do our brains change over a lifetime? (a link to Human Development)

LINKAGES

HUMAN DEVELOPMENT AND THE CHANGING BRAIN

Fortunately, most of the changes that take place in the brain are not the kind associated with damage and disease. How does the human brain change as we develop throughout our lives? Researchers are using PET and fMRI scans to begin to answer that question. For example, they have found that association areas of the cerebral cortex develop later than the sensory and motor cortexes do (Casey, Galvan, & Hare, 2005). There are also some interesting correlations between changes in neural activity and the behavior of newborns and infants. Among newborns, scans show that activity is relatively high in the thalamus but low in a portion of the forebrain related to smooth movement. This finding may be related to the way newborns move. They make random, sweeping movements of the arms and legs—much like patients with Huntington's disease, who have a hyperactive thalamus and a withering of the part of the forebrain that controls smooth movement (Chugani & Phelps, 1986). During the second and third months after birth, activity increases in many regions of the cortex. This change is correlated with the disappearance of certain reflexes, such as the grasping reflex. At eight or nine months of age, infants show increased frontal cortex activity, which correlates with the apparent beginnings of cognitive activity (Chugani & Phelps, 1986).

The brain continues to mature through adolescence, showing evidence of ever-more-efficient neural communication in its major fiber tracts (Gogtay et al., 2004; Lebel & Beaulieu, 2011; Thompson et al., 2000). However, research using diffusion tensor imaging reveals that the connections between the prefrontal cortex and other areas involved in judgment and decision making are not yet fully developed (Asato et al., 2010). Some researchers suggest that these underdeveloped connections may be related to the difficulties that many teenagers have in resisting dangerous peer influences and foreseeing the negative consequences of certain actions (Grosbras et al., 2007). These ideas are supported by fMRI studies of adolescents that correlate self-reports of poor impulse control with reduced activation of the lateral prefrontal cortex (Andrews-Hanna et al., 2011).

Most of the changes we have described reflect plasticity—changes in axons and synapses—not the appearance of new cells. After birth, the number of dendrites and synapses increases. Although different areas of the cortex sprout at different rates, the number of synapses can increase tenfold in the first year after birth (Huttenlocher, 1990). In fact, by the time children are six or seven years old, their brains have more dendrites than those of adults, and they use twice as much energy. In early adolescence, the number of dendrites and neural connections actually drops, so that the adult level is reached by about the age of fourteen. During childhood, the brain overproduces neural connections and then "prunes" the extra

(*continued*)

connections (Sowell et al., 2001). Figure 3.15 shows that as we grow, we develop more brainpower with less brain (Sowell et al., 2003).

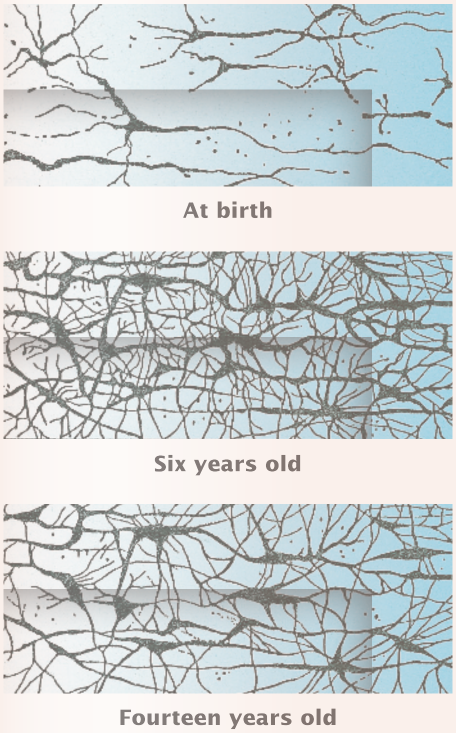


FIGURE 3.15
Developmental Changes in the Cerebral Cortex

During childhood, the brain overproduces neural connections, establishes the usefulness of certain connections, and then "prunes" the extra connections. Overproduction of synapses, especially in the frontal cortex, may be essential for infants to develop certain intellectual abilities. The changes that occur in the brain during adolescence are particularly important, as this is when many psychiatric disorders first appear (Paus, Keshavan, & Giedd, 2008). Adolescence is also a time of adjusting to and (sometimes) resisting negative peer influences. Research suggests that functional connectivity among brain regions in early adolescence is correlated with resisting such influences (Grosbras et al., 2007).

As already mentioned, the brain's plasticity allows it to restructure itself to form new connections throughout life (Hua & Smith, 2004; Kozorovitskiy et al., 2005). Genes apparently determine the basic pattern of growth and the major lines of connections. However, the details of the connections depend on experience, including how stimulating and interesting the environment is. For example, researchers have compared the brains of rats raised individually with only a boring view of their cages to the brains of rats raised with toys and playmates. The cerebral cortex of the rats from the enriched environment had more and longer dendrites as well as more synapses than did the cortex of animals raised alone in bare cages (Klintsova & Greenough, 1999). Furthermore, the number of synapses increased when old animals who had been living in boring cages were moved to an enriched environment. Such changes in the brain following increased environmental stimulation may help explain why the maze-learning ability of genetically "maze-dull" rats raised in stimulating cages can equal that of genetically "maze-bright" animals.

Researchers have not yet determined whether an enriched environment stimulates the development of new connections or slows down normal pruning. Also not known is whether animals that are moved from a stimulating environment to a boring one will lose synaptic connections. If existing findings apply to humans, however, they have implications for how we raise children and treat the elderly. It is surely the case that within the limits set by genetics, interactions with the world mold the brain itself (Chang & Merzenich, 2003; Dick et al., 2011; Holtmaat et al., 2006).

THE CHEMISTRY OF PSYCHOLOGY: NEUROTRANSMITTERS

How do biochemicals affect my mood?

We have already seen that neurons in the nervous system communicate with each other through chemical messengers called neurotransmitters. The neurotransmitters they use can differ from one set of nerve cells to another. A group of neurons that communicate using the same neurotransmitter is called a *neurotransmitter system*.

Promoting Research on Parkinson's Disease

Actor Michael J. Fox suffers from Parkinson's disease, a condition related to malfunctioning of dopamine systems in the brain. He founded the Michael J. Fox Foundation for Parkinson's Research to fund more research on treating, curing, and perhaps even preventing, Parkinson's disease.

Kevin Mazur/MJF/Getty Images

Certain neurotransmitter systems play a dominant role in particular functions, such as emotion or memory, and in particular problems, such as Alzheimer's disease.

Let's explore where some of these neurotransmitters operate in the brain and how they affect behavior and mental processes.

Three Classes of Neurotransmitters

Chemical neurotransmission was first demonstrated in 1921, and since then more than a hundred different neurotransmitters have been identified. The ones used in the nervous system fall into three main categories: *small molecules, peptides,* and *gases.*

Small Molecules

The most important of the small-molecule chemicals that act as neurotransmitters are acetylcholine, norepinephrine, serotonin, dopamine, GABA, and glutamate. *Acetylcholine* (pronounced "uh-see-tull-KOE-leen") was the first to be identified as a neurotransmitter. Among the many neurons that communicate using acetylcholine are those active in controlling movement of the body, in making memories, and in slowing the heartbeat and activating the digestive system. No wonder, then, that disruption of acetylcholine systems can result in a wide variety of problems, including the loss of memory and other mental powers seen in Alzheimer's disease.

Systems of neurons that use *norepinephrine* (pronounced "nor-eppa-NEF-rin") affect arousal, wakefulness, learning, and mood. This neurotransmitter is involved when your nervous system prepares you to fight or to run away from a threat. Changes in norepinephrine systems have also been implicated in depression.

The neurotransmitter *serotonin* (pronounced "sair-oh-TOE-nin") is similar to norepinephrine in that it is used in brain systems that affect both sleep and mood. Serotonin may also be involved in the appearance of aggressive and impulsive behaviors. Unlike norepinephrine, though, the amount of serotonin in your brain can be affected by what you eat. For example, eating carbohydrates can increase serotonin, and the increase in serotonin normally reduces the desire for carbohydrates. Some researchers suspect that malfunctions in serotonin systems can result in the mood and appetite problems seen in some types of obesity, premenstrual tension, and depression, including disorders in which depressed mood, suicidal tendencies, and impulsivity appear together (Bach-Mizrachi et al., 2006; McCloskey et al., 2009; Oquendo & Mann, 2000). Antidepressant medications such as Prozac, Zoloft, and Paxil appear to relieve some of the symptoms of depression by acting on serotonin systems to maintain proper functions of this neurotransmitter.

Dopamine (pronounced "DOPE-uh-meen") is a neurotransmitter that is important for movement. Malfunctions of dopamine systems contribute to movement disorders such as Parkinson's disease and the shakiness experienced by people who have it. Parkinson's has been treated with some success using drugs that enable neurons to use dopamine more efficiently and by implanting dopamine-using neurons (Chase, 1998; Connolly & Lang, 2014; Mendez et al., 2008). Permanently implanting an electrode that stimulates neurons in the brain's dopamine-influenced motor system not only offers an even more effective treatment but also carries a risk of surgical complications (Weaver et al., 2009). Other dopamine systems are involved in the experiencing of reward, or pleasure, which is vital in shaping and motivating behavior (Spanagel & Weiss, 1999). Animals will work very hard to receive a direct dose of dopamine to certain parts of the brain. These dopamine systems play a role in the rewarding properties of many drugs, including cocaine (Ciccocioppo, Sanna, & Weiss, 2001; Hyman, Malenka, & Nestler, 2006). Certain dopamine systems are also suspected to be partly responsible for the perceptual, emotional, and thought disturbances associated with schizophrenia, a severe mental disorder (Marenco & Weinberger, 2000).

GABA stands for gamma-amino butyric acid. Unlike most neurotransmitters, which excite neurons to fire action potentials, GABA *reduces* the likelihood that neurons will fire. In fact, it is the main neurotransmitter for slowing, or inhibiting, the brain's activity.

When you fall asleep, neurons that use GABA deserve part of the credit. Drugs that cause reduced neural activity often do so by amplifying the "braking" action of GABA. For example, alcohol's effect on GABA systems is partly responsible for the impairments in thinking, judgment, and motor skills that occur when people drink too much. Malfunctions of GABA systems contribute to severe anxiety and to *Huntington's disease*, an inherited disorder that causes its victims to suffer uncontrollable movement of the arms and legs along with a progressive loss of thinking abilities. Drugs that interfere with GABA's inhibitory effects produce intense repetitive electrical discharges, known as *seizures*. Researchers suspect that impaired GABA systems contribute to *epilepsy*, another brain disorder associated with seizures and convulsive movements. Repeated or sustained seizures can result in permanent brain damage. Drug treatments can reduce the frequency and severity of seizures but do not eliminate them and may cause undesirable side effects. An alternative treatment approach may someday come from the optogenetic techniques described earlier (Airan et al., 2009). There is evidence that this technique stops abnormal electrical activity in animal brain cells (Tonneson et al., 2009). It has already been used to prevent seizures in rats (Sukhotinsky et al., 2013), and is now being tested in primates (Bentley et al., 2013).

Glutamate (pronounced "GLOO-tuh-mate") is used by more neurons than any other neurotransmitter, and it also helps glial cells provide energy for neurons (Rouach et al., 2008). Glutamate is particularly important because it helps the brain strengthen its synaptic connections, allowing messages to more easily cross the gap between neurons. This strengthening process is necessary for normal development and may be at the root of learning and memory (Newpher & Ehlers, 2008). Yet overactivity of glutamate synapses can cause neurons to die, and is the main cause of the brain damage that occurs when oxygen is cut off from neurons during a stroke. Blocking glutamate receptors immediately after a brain trauma can prevent permanent brain damage (Colak et al., 2003). Glutamate may also contribute to the loss of brain cells that occurs in Alzheimer's disease (Cha et al., 2001).

Peptides

Hundreds of chemicals called *peptides* have been found to act as neurotransmitters. The first of these was discovered in the 1970s, when scientists were investigating *opiates,* such as heroin and morphine. Opiates can relieve pain, produce feelings of elation, and in high doses bring on sleep. After marking morphine with a radioactive substance, researchers traced where it became concentrated in the brain. They found that opiates bind to receptors that were not associated with any known neurotransmitter. Because it was unlikely that the brain had developed opiate receptors just in case a person might want to use morphine or heroin, researchers reasoned that the body must already contain a substance similar to opiates. This hypothesis led to the search for a naturally occurring, or endogenous, morphine, which was called *endorphin* (short for *endogenous morphine*). As it turned out, there are many natural opiate-like compounds. So the term *endorphins* refers to all neurotransmitters that can bind to the same receptors stimulated by opiates. Neurons in several parts of the brain use endorphins, including neuronal pathways that modify pain signals to the brain.

Gases

Our ideas of what neurotransmitters can be was radically altered following the discovery that *nitric oxide* and *carbon monoxide*—two toxic gases that contribute to air pollution—can act as neurotransmitters (Boehning & Snyder, 2003). When nitric oxide or carbon monoxide is released by a neuron, it spreads to nearby neurons, sending a signal that affects chemical reactions inside those neurons rather than binding to receptors on their surface. Nitric oxide is not stored in vesicles, as most other neurotransmitters are; it can be released from any part of the neuron. Nitric oxide appears to be one of the neurotransmitters responsible for such diverse functions as penile erection and the formation of memories—not at the same site, obviously.

In summary, neurotransmitters acting throughout the body link our biochemistry with every aspect of our behavior and mental processes. You will see other examples in the chapter on sensation and perception, where we describe some of the neurotransmitters that help convey pain messages. In the consciousness chapter, we consider how neurotransmitters are affected by alcohol and illegal drugs. In the chapter on psychological disorders, we discuss the role that neurotransmitters play in schizophrenia and depression, and in the chapter on the treatment of psychological disorders, we explore ways that prescription drugs act on neurotransmitters to alleviate the symptoms of those disorders. ("In Review: Classes of Neurotransmitters" lists the most important of these neurotransmitters and the consequences of malfunctioning neurotransmitter systems.)

IN REVIEW

CLASSES OF NEUROTRANSMITTERS

Neurotransmitter Class	Normal Function	Disorder Associated with Malfunction
Small Molecules		
Acetylcholine	Memory, movement	Alzheimer's disease
Norepinephrine	Mood, sleep, learning	Depression
Serotonin	Mood, appetite, impulsivity	Depression
Dopamine	Movement, reward	Parkinson's disease, schizophrenia
GABA	Sleep, movement	Anxiety, Huntington's disease, epilepsy
Glutamate	Memory	Damage after stroke
Peptides		
Endorphins	Pain control	No established disorder
Gases		
Nitric oxide	Memory	No established disorder

1. The main neurotransmitter for slowing, or inhibiting, brain activity is __________.
2. A group of neurons that use the same neurotransmitter is called a __________.
3. Which neurotransmitter's activity causes brain damage during a stroke?

THE ENDOCRINE SYSTEM: COORDINATING THE INTERNAL WORLD

How can my hormones help me in a crisis?

endocrine system Cells that form organs called glands and that communicate with one another by secreting chemicals called hormones.

As we mentioned earlier, neurons are not the only cells that can use chemicals to communicate with one another in ways that affect behavior and mental processes. Another class of cells with this ability resides in the **endocrine system** (pronounced "EN-doh-krin"), which regulates functions ranging from stress responses to physical growth. The cells of endocrine organs, or **glands,** communicate by secreting chemicals, much as neurons do. In the case of endocrine organs, the chemicals are called **hormones.** Figure 3.16 shows the location and functions of some of the major endocrine glands.

FIGURE 3.16
Some Major Glands of the Endocrine System

Each of the glands shown releases its hormones into the bloodstream. Even the hypothalamus, a part of the brain, regulates the nearby pituitary gland by secreting hormones.

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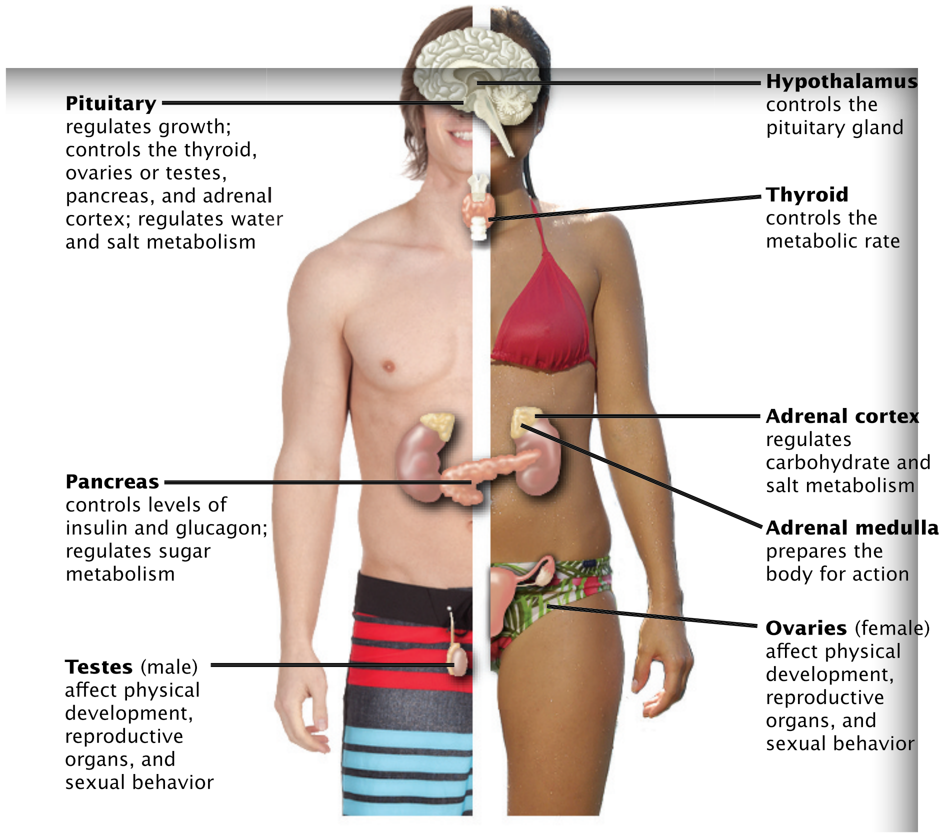

Hormones secreted from the endocrine organs are similar to neurotransmitters. In fact, many of these chemicals, including norepinephrine and the endorphins, act both as hormones and as neurotransmitters. However, whereas neurons release neurotransmitters into synapses, endocrine organs release their chemicals into the bloodstream, which carries them throughout the body. In this way, endocrine glands can stimulate cells with which they have no direct connection. But not all cells receive the hormonal message. Hormones, like neurotransmitters, can influence only cells with receptors capable of receiving them. Organs whose cells have receptors for a hormone are called *target organs.*

Each hormone acts on many target organs, producing coordinated effects throughout the body. For example, when the sex hormone *estrogen* is secreted by a woman's ovaries, it activates her reproductive system. It causes the uterus to grow in preparation for nurturing an embryo; it enlarges the breasts to prepare them for nursing; it stimulates the brain to enhance interest in sexual activity; and it stimulates the pituitary gland to release another hormone that causes a mature egg to be released by the ovary for fertilization. Male sex organs, called the *testes,* secrete *androgens,* which are sex hormones such as *testosterone.* Androgens stimulate the maturation of sperm, increase a male's motivation for sexual activity, and increase his aggressiveness (Romeo, Richardson, & Sisk, 2002).

The brain has ultimate control over the secretion of hormones. Through the hypothalamus, it controls the pituitary gland, which in turn controls endocrine organs in the body. The brain is also one of the target organs for most endocrine secretions. In fact, the brain creates some of the same hormones that are secreted in the endocrine system and uses them for neural communication (Melcangi et al., 2011). In summary, the endocrine system typically involves four elements:

glands Organs that secrete hormones into the bloodstream.

hormones Chemicals secreted by a gland into the bloodstream, which carries them throughout the body.

the brain, the pituitary gland, an endocrine organ, and the target organs, which include the brain. Each element in the system uses hormones to signal to the next element, and the secretion of each hormone is stimulated or suppressed by other hormones (Dubrovsky, 2005).

In stress hormone systems, for example, the brain controls the pituitary gland by signaling the hypothalamus to release hormones that stimulate receptors of the pituitary gland, which secretes another hormone, which stimulates another endocrine gland to secrete its hormones. More specifically, when the brain interprets a situation as threatening, the pituitary releases *adrenocorticotropic hormone (ACTH),* which causes the adrenal glands to release the hormone *cortisol* into the bloodstream. These hormones, in turn, act on cells throughout the body, including the brain. One effect of cortisol, for example, is to activate the emotion-related limbic system, making it more likely that you will remember stressful or traumatic events (Cahill & McGaugh, 1998). The combined effects of the adrenal hormones and the activation of the sympathetic system result in a set of responses called the **fight-flight reaction**, which, as mentioned earlier, prepares us for action in response to danger or other stress. With these hormones at high levels, the heart beats faster, the liver releases glucose into the bloodstream, fuels are mobilized from fat stores, and we usually enter a state of high arousal.

fight-flight reaction A physical reaction triggered by the sympathetic nervous system that prepares the body to fight or to run from a threatening situation.

The hormones provide feedback to the brain, as well as to the pituitary gland. Just as a thermostat and furnace regulate heat, this feedback system regulates hormone secretion so as to keep it within a certain range. Feedback systems are just one illustration of how the nervous system and the endocrine system—both systems of communication between and among cells—are integrated to form the biological basis for a smoothly functioning self. Together, they allow interaction of our thoughts and emotions and provide us with the ability to respond effectively to life's challenges and opportunities.

LINKAGES

As noted in the chapter on introducing psychology, all of psychology's subfields are related to one another. Our discussion of developmental changes illustrates just one way in which the topic of this chapter, the biological aspects of psychology, is linked to the subfield of developmental psychology, which is described in the chapter on human development. The Linkages diagram shows ties to two other subfields as well, and there are many more ties throughout the book. Looking for linkages among subfields will help you see how they all fit together and help you better appreciate the big picture that is psychology.

CHAPTER 3 Biological Aspects of Psychology

LINKAGES

Does the brain shut down when we sleep?

CHAPTER 9
Consciousness

How do our brains change over a lifetime?

CHAPTER 11
Human Development

How do drugs help people diagnosed with schizophrenia?

CHAPTER 15
Treatment of Psychological Disorders

SUMMARY

Biological psychology focuses on the biological aspects of our being, including the nervous system, which provide the physical basis for behavior and mental processes. The *nervous system* is a system of cells that allows an organism to gain information about what is going on inside and outside the body and to respond appropriately. Much of our understanding of the biological aspects of psychology has stemmed from research on animal and human nervous systems at levels ranging from single cells to complex organizations of cells.

Cells of the Nervous System

What are neurons, and what do they do?

The main units of the nervous system are cells called *neurons* (or *nerve cells*) and *glial cells*. Neurons are especially good at receiving signals from and transmitting signals to other neurons. Neurons have cell bodies and two types of fibers, called *axons* and *dendrites*. Axons usually carry signals away from the cell body, and dendrites usually carry signals to the cell body. Neurons can transmit signals because of the structure of these fibers, the excitable surface of some of the fibers, and the *synapses*, or gaps, between cells.

The membranes of neurons normally keep the distribution of electrically charged ions uneven between the inside of cells and the outside, creating an electrochemical force, or potential. The membrane surface of the axon can transmit a disturbance in this potential, called an *action potential*, from one end of the axon to the other. The speed of the action potential is fastest in neurons sheathed in *myelin*. Between firings there is a very brief rest, called a *refractory period*.

When an action potential reaches the end of an axon, the axon releases a chemical called a *neurotransmitter*. This chemical crosses the synapse and interacts with the postsynaptic cell at special sites called *receptors*. This interaction creates a *postsynaptic potential* that makes the postsynaptic cell more likely or less likely to fire an action potential of its own. So whereas communication within a neuron is electrochemical, communication between neurons is chemical. Because the fibers of neurons have many branches, each neuron can interact with thousands of other neurons. Each neuron constantly integrates signals received at its many synapses; the result of this integration determines how often the neuron fires an action potential.

Neurons are organized in *neural networks* of closely connected cells. Sensory systems receive information from the environment, and motor systems influence the actions of muscles and other organs. The two major divisions of the nervous system are the *central nervous system (CNS)*, which includes the brain and spinal cord, and the *peripheral nervous system (PNS).*

The Peripheral Nervous System: Keeping in Touch with the World

How do sights and sounds reach my brain?

The peripheral nervous system has two components: the somatic nervous system and the autonomic nervous system.

The first component of the peripheral nervous system is the *somatic nervous system*, which transmits information from the senses to the CNS via *sensory neurons* and carries signals from the CNS via *motor neurons* to the muscles that move the skeleton.

The second component of the peripheral nervous system is the *autonomic nervous system*, whose two subsystems, the *sympathetic nervous system* and the *parasympathetic nervous system*, carry messages back and forth between the CNS and the heart, lungs, and other organs and glands.

The Central Nervous System: Making Sense of the World

How is my brain "wired"?

The CNS is laid out in interconnected groups of neuronal cell bodies, called nuclei, whose collections of axons travel together in fiber tracts, or pathways.

The *spinal cord* receives information from the peripheral senses and sends it to the brain; it also relays messages from the brain to the periphery. In addition, cells of the spinal cord can direct simple movements, called *reflexes*, without instructions from the brain.

The brain's major subdivisions are the *hindbrain, midbrain*, and *forebrain*. The hindbrain includes the *medulla oblongata*, the *locus coeruleus*, and the *cerebellum*. The *reticular formation* is found in both the hindbrain and the midbrain. The forebrain is the largest and most highly developed part of the brain; it includes many structures, including the *hypothalamus* and *thalamus*. A part of the hypothalamus called the suprachiasmatic nuclei maintains a clock that determines biological rhythms. Other forebrain structures include the *hippocampus*, and *amygdala*. Several of these structures form the limbic system, which plays an important role in regulating emotion and memory. The outer surface of the cerebral hemispheres is called the *cerebral cortex*; it is responsible for many of the higher functions of the brain, including speech and reasoning. The functional areas of the cortex include the *sensory cortex*, *motor cortex*, and *association cortex*.

A variety of new techniques, combined with some older measures, give scientists ever better ways to study the brain and its activity. These methods include the *electroencephalograph (EEG), PET (for positron emission tomography), magnetic resonance imaging (MRI), functional MRI (fMRI), diffusion tensor imaging (DTI), transcranial magnetic stimulation (TMS), and optogenetics.*

The functions of the right and left hemispheres of the cerebral cortex show a certain degree of *lateralization*, or *lateral dominance*, which means they are somewhat specialized. In most people, the left hemisphere is more active in language and logical tasks and the right hemisphere is more active in spatial, musical, and artistic tasks. The hemispheres are connected through the *corpus callosum*, allowing them to operate in a coordinated fashion.

Neural plasticity in the central nervous system, the ability to strengthen neural connections at its synapses as well as to establish new synapses, forms the basis for learning and memory. Scientists are searching for ways to increase neural plasticity following brain damage, including through the use of neural stem cells.

The Chemistry of Psychology: Neurotransmitters

How do biochemicals affect my mood?

Neurons that use the same neurotransmitter form a neurotransmitter system.

There are three classes of neurotransmitters: small molecules, peptides, and gases. Acetylcholine systems in the brain influence memory processes and movement. Norepinephrine is released by neurons whose axons spread widely throughout the brain; it is involved in arousal, mood, and learning. Serotonin, another widespread neurotransmitter, is active in systems regulating mood and appetite. Dopamine systems are involved in movement, motivation, and higher cognitive activities. Both Parkinson's disease and schizophrenia involve a disturbance of dopamine systems. Gamma-amino butyric acid (GABA) is an inhibitory neurotransmitter involved in anxiety and epilepsy. Glutamate is the most common excitatory neurotransmitter. It is involved in learning and memory and, in excess, may cause neuronal death. Endorphins are peptide neurotransmitters that affect pain pathways. Nitric oxide and carbon monoxide are gases that function as neurotransmitters.

The Endocrine System: Coordinating the Internal World

How can my hormones help me in a crisis?

Like nervous system cells, those of the *endocrine system* communicate by releasing a chemical that signals to other cells. However, the chemicals released by endocrine organs, or *glands*, are called *hormones* and are carried by the bloodstream to remote target organs. The target organs often produce a coordinated response to hormonal stimulation. One of these responses is the *fight-flight reaction*, which is triggered by adrenal hormones that prepare for action in times of stress. Hormones also affect brain development, contributing to sex differences in the brain and behavior. Feedback systems are involved in the control of most endocrine functions.

TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. The nucleus of a cell __________, and the mitochondria __________.
  a. produces red blood cells; turn oxygen into glucose
  b. produces red blood cells; keep a stable chemical environment
  c. provides genetic information; turn oxygen into glucose
  d. provides genetic information; keep a stable chemical environment

2. A nurse has mixed up some test results on neurotransmitter function for several patients at the hospital where you work. To help her out, you tell her that the depressed patient's chart will probably show malfunctions in __________ systems and the Parkinson's patient's chart will probably show malfunctions in __________ systems.
  a. dopamine; norepinephrine
  b. dopamine; acetylcholine
  c. serotonin; dopamine
  d. acetylcholine; norepinephrine

3. Hannah had a stroke and oxygen was cut off from the neurons in her brain. This caused overactivity in __________ synapses, which led to brain damage.
  a. dopamine
  b. glutamate
  c. acetylcholine
  d. serotonin

4. Functional magnetic resonance imaging (fMRI) provides a way to __________.
  a. directly measure brain cell activity
  b. determine changes in blood flow and oxygen levels in various brain areas
  c. locate the causes of particular mental processes
  d. locate where certain emotions take place in the brain

5. As you switch on your favorite TV medical show, a doctor charges through the emergency room doors and tells a worried spouse that her husband has a neurological problem. "The nerves that carry signals to his muscles are not functioning," the doctor says, "which means the __________ nervous system has been damaged."
  a. central
  b. autonomic
  c. somatic
  d. sympathetic

6. Kalli finishes a difficult final exam, then hurries home and flops down on her bed to relax. As Kalli relaxes, her __________ nervous system becomes less active, whereas her __________ nervous system becomes more active.
  a. central; somatic
  b. somatic; central
  c. parasympathetic; sympathetic
  d. sympathetic; parasympathetic

7. Karena smells some cologne in a store, and suddenly remembers the emotions she had when her dad passed

away. He had worn that cologne. She was able to form this association partly because of the actions of the __________.
a. locus coeruleus
b. somatosensory cortex
c. amygdala
d. hypothalamus

8. A neuron's action potential shoots down its axon with greater speed when the __________.
a. axon is coated in myelin
b. refractory period is longer
c. neuron's diameter is smaller
d. neuron is in the brain

9. Jessica has severely damaged to her entire medulla. Most likely, Jessica __________.
a. is dead
b. will have memory problems
c. will have difficulty with fine motor movements
d. will not feel anything on the left side of her body

10. Damage in Lily's hindbrain caused her to lapse into a coma. The damage most likely occurred in the __________.
a. cerebellum
b. hippocampus
c. hypothalamus
d. reticular formation

11. Riley was an excellent pianist until he suffered brain damage. Now problems with fine motor skills make it impossible for him to play the piano. Riley most likely had damage to his __________.
a. cerebellum
b. hippocampus
c. hypothalamus
d. reticular formation

12. The hippocampus has been found to be significantly smaller in patients who are suffering from which of the following problems?
a. Parkinson's disease
b. Alzheimer's disease
c. Huntington's disease
d. an eating disorder

13. A woman was rushed to an emergency room with severely burned hands. She had picked up an iron because she couldn't tell it was hot, and she still doesn't feel pain from her burns. The neurologist who examined her concluded that the woman's __________ system is malfunctioning.
a. sensory
b. motor
c. autonomic
d. parasympathetic

14. Reginald has suffered damage to his occipital lobe. This means that Reginald will have difficulty __________.
a. feeling pain
b. moving his body
c. regulating body temperature
d. seeing

15. Elnora wants to hit a nail with a hammer so she can hang a picture on the wall. This involves voluntary movements that are controlled by neurons in the __________ cortex, which is located in the __________ lobe.
a. motor; frontal
b. motor; parietal
c. association; temporal
d. sensory; occipital

16. Roberto, an actor, is recovering following a freak accident on the set of his latest movie. When asked about the accident, Roberto, once a confident and fluent speaker, can now only say, "Noise … acting … hurts." The part of Roberto's brain most likely involved in this type of speech problem is __________ area.
a. Sperry's
b. Broca's
c. Wernicke's
d. Sylva's

17. Joe experienced such severe seizures that doctors had to sever his corpus callosum. Following surgery, a psychologist presented the left hemisphere of Joe's brain with a picture of a car and asked Joe what he saw. Most likely, Joe could __________.
a. correctly say "car"
b. not identify the car in words
c. only draw a car
d. not understand the question

18. Edie is 80 and has suffered a paralyzing stroke. Her doctors are likely to tell her that __________.
a. if she imagines moving her body, she can increase the number of neurons in her motor cortex
b. the Nogo protein will help regenerate nerve cells
c. neural stem cells will automatically repair the damage
d. mental and physical exercise programs can help reverse some of the effects of the stroke

19. Ted is creating a study sheet to help him learn the differences between neurotransmitters and hormones. Which of the following statements on his list is *not* correct?
a. Neurotransmitters travel through the bloodstream and hormones travel across synapses.
b. Both hormones and neurotransmitters stimulate only those cells and organs that have receptors for them.
c. Hormones and neurotransmitters regulate complex behaviors and mental processes.
d. Hormones operate mainly in the endocrine system; neurotransmitters operate mainly in the nervous system.

20. When Mitch saw a woman in danger of drowning, he jumped into the water to save her. Mitch's endocrine system readied him for this exertion by releasing __________ and other stress hormones into his bloodstream.
a. cortisol
b. GABA
c. glutamate
d. BABA

CHAPTER 4

Sensation and Perception

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Preview

You can understand what you read in this sentence because the lines and squiggles that make up its letters somehow become meaningful words. This "somehow" is what sensation and perception are all about. You translate incoming stimulation, such as the light bouncing off this page, into neural activity called *sensations*. Then you interpret these sensations as meaningful experiences called *perceptions*—in this case, as letters and words. These amazing processes are so quick and automatic that you probably take them for granted. In this chapter, we draw your attention to them. You will learn about how our sensory systems receive stimulation and how they encode that stimulation into patterns of nerve activity that the brain can decode. You will also discover how the brain interprets, or perceives, this information from your senses.

Years after Fred Aryee lost his right arm below the elbow in a boating accident, he could still "feel" sensations from his missing lower arm and hand. Once, his doctor asked Aryee to reach for a cup on the table in front of him with his right arm. When asked what he felt, Aryee said, "I feel my fingers clasping the cup" (Shreeve, 1993). People like Fred may also feel intense pain that seems to come from a lost limb (Glummarra et al., 2007; Ramachandran, 2008). Some people feel intense pain as a missing hand suddenly tightens into a fist, digging nonexistent fingernails into a phantom palm. Worse, they may not be able to "open" this hand to relieve the pain. To help such people, health workers can seat them in front of a mirror and angle the mirror to create the illusion that the amputated arm and hand have been restored. When these patients move their real hands while looking in the mirror, they not only "feel" movement in their phantom hands but can also "unclench" their phantom fists and stop their pain (Hsu & Cohen, 2013). This clever strategy arose from psychology research on how vision interacts with the sense of touch.

TRY THIS

To experience this kind of interaction yourself, sit across a table from someone and ask that person to stroke the tabletop while you stroke your own knee under the table in exactly the same way, in exactly the same direction. If you watch the person's hand as it strokes the table, you will soon experience the touch sensations coming from the table, not your knee! If the person's two hands do not move in sync, however, the illusion will not occur (Tsakiris & Haggard, 2005).

Where do "phantom limb" sensations and perceptions come from? Fred no longer has fingers to send messages to the brain, yet he experienced his "feeling" of the cup as real. Others who have lost, say, a left arm feel that they now have two right arms (Cipriani et al., 2011). These cases remind us that the "objective reality" we assume to be the same for everyone can actually differ from person to person (Bartoshuk, Fast, & Snyder, 2005). Just as someone can feel a hand that isn't actually "there," every individual's senses actively shape information about the outside world to create a personal reality.

SENSING AND PERCEIVING THE WORLD

What is the difference between sensation and perception?

Psychologists find it useful to distinguish between *sensation* (the stimulus message coming from the senses) and *perception* (the process of giving meaning to that message). You don't actually sense a cat lying on the sofa. You sense shapes and colors, the visual sensations. You then use your knowledge of the world to interpret, or perceive, these sensations as a cat. To be honest, it's impossible to draw a clear line between where sensation ends and perception begins, because interpreting sensations begins to some degree in the sense organs themselves. But psychologists make a distinction between sensation and perception nonetheless, in order to better organize our understanding of a very diverse set of processes.

To understand how sensory systems help us create reality, we need to consider some basic information about the senses. A **sense** is a system that translates outside information into activity in the nervous system. For example, your eyes convert light into neural activity that tells the brain something about the source of the light or about the objects reflecting it. Messages from the senses are called **sensations**. Sensations shape behaviors and mental processes by providing the vital link between the self and the world outside the brain.

sense A system that translates data from outside the nervous system into neural activity.

sensations Raw information from the senses.

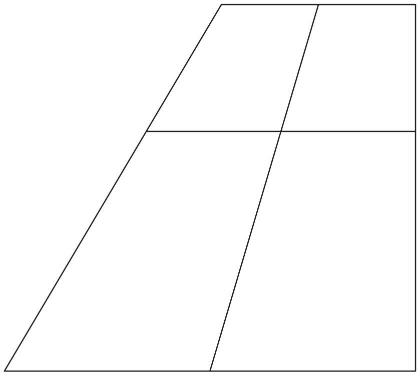

FIGURE 4.1
What do you see?

Perception is the process of using information and your understanding of the world to turn those sensations into meaningful experiences. Perception is more than a passive process of merely absorbing incoming data. For example, look at Figure 4.1. It contains only raw information about a series of intersecting lines, and so this is what your eyes help you "sense." But your perceptual system takes those data and automatically interprets them as an image of a rectangle, or perhaps a window frame, lying on its side. This act of perception is so quick and familiar that it may be difficult to appreciate the processes that allow you to turn sensory signals into your experience of reality. By shaping this experience, your perceptions influence your thoughts, feelings, and actions. But before you can perceive something, you must be able to sense it.

SENSORY SYSTEMS

How does information from my eyes and ears get to my brain?

Your senses gather information about the world by detecting various forms of energy, such as sound, light, heat, and physical pressure. Your eyes are specialized to be able to detect light energy, your ears detect the energy of sound, and your skin detects the energy of heat and pressure. Humans depend a lot on vision, hearing, and the skin senses to gain information about the world. Some animals depend more on smell and taste than we do. To your brain, "the world" also includes the rest of your body, so specific sensory systems provide information about the location and position of your body parts.

All senses detect information about stimuli, encode it into neural activity, and then send this encoded information to the brain. Figure 4.2 illustrates these basic steps in sensation. At each step, sensory information is "processed" in some way. So the information that arrives at one point in the system is not exactly the same information that goes to the next step.

The first step in most sensory systems involves **accessory structures**, which modify the incoming environmental stimuli (Step 1 in Figure 4.2). For example, the lens of the eye is an accessory structure that changes incoming light by focusing it. The flexible part of the ear that extends outside your head is an accessory structure that collects sound.

The second step in sensation is **transduction**, which is the process of converting incoming energy into neural activity (Step 2 in Figure 4.2). Your cell phone receives electromagnetic energy and transduces it into sounds. In much the same way, your ears receive sound energy and transduce it into neural activity that you recognize as voices and music. Transduction takes place in **neural receptors**, also called *sensory receptors*, which are specialized cells that can detect certain forms of energy. These receptors respond to incoming energy by changes in the firing of an action potential and release of neurotransmitters that send signals to neighboring cells. Sensory receptors respond best to *changes* in energy (Graziano et al., 2002). A constant level of stimulation usually produces **sensory adaptation**, or a decreasing responsiveness to the stimulus over time. This is the reason why the touch sensations you get from your glasses or wristwatch disappear shortly after you have put them on.

Sensory nerves carry information from receptors to the central nervous system—the spinal cord and the brain (Step 3 in Figure 4.2). For all the senses except smell, this information goes first to the brain's thalamus, which does initial processing before sending it on to the cerebral cortex (Step 4; Sherman, 2007). The most complex processing occurs in specialized areas of the sensory cortex (Step 5; Kanwisher, 2010).

Encoding Sensations: What Was That?

The neural activity created when neural receptors transduce incoming energy functions as a coded message about the stimulus that produced the energy. So our psychological experience of a stimulus, such as its brightness or color, is based on a corresponding feature of

perception The process through which people take raw sensations from the environment and give them meaning using knowledge, experience, and understanding of the world.

accessory structures Structures, such as the outer part of the ear, that modify a stimulus.

transduction The process of converting incoming physical energy into neural activity.

neural receptors Cells that are specialized to detect certain types of energy and convert it into neural activity.

sensory adaptation Decreasing responsiveness to an unchanging stimulus.

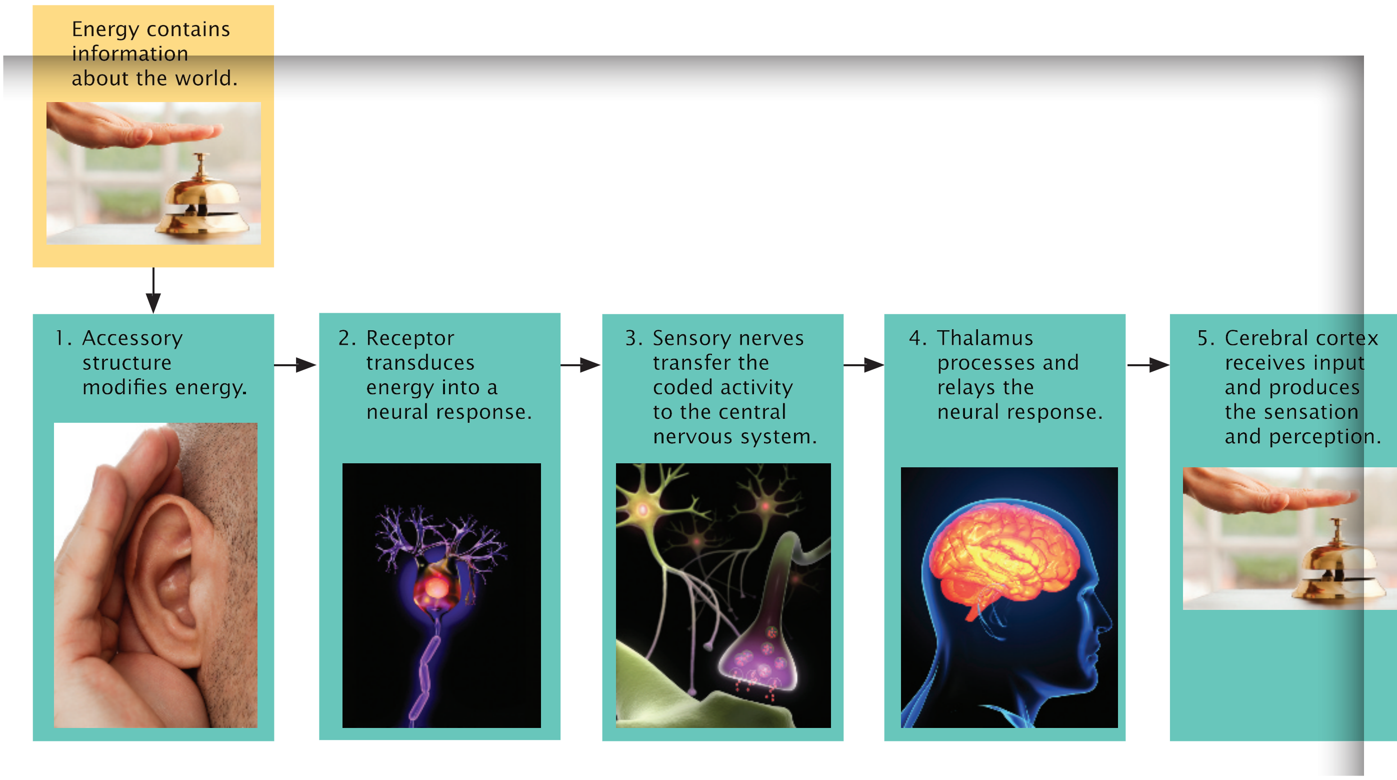

FIGURE 4.2
Elements of a Sensory System

Objects in the world generate energy that is focused by accessory structures and detected by sensory receptors, which convert the energy into neural signals. The signals are then relayed through parts of the brain, which processes them into perceptual experiences.

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its physical energy, as encoded by neural receptors. In other words, **encoding** translates the physical properties of a stimulus, such as its shape or intensity, into a pattern of neural activity that represents those physical properties. When the brain organizes these neural patterns, you can make sense of the stimulus and decide whether you are looking at a white cat, a black dog, or a tall person.

To better appreciate the problem of encoding physical stimuli into neural activity, imagine that for your birthday you receive a Pet Brain. You are told that your Pet Brain is alive, but it does not respond when you open the box and talk to it. You remove it from the box and show it a hot-fudge sundae; no response. You show it pictures of other attractive brains; still no response. You are about to toss your Pet Brain in the trash when you suddenly realize that the two of you are not speaking the same language. If you want to communicate with your Pet Brain, the only way to do so is by sending it messages that can stimulate whatever sensory receptors that it happens to have. Then, to read its responses, you will have to record how it sends signals out, such as from its motor nerve cells.

Eagerly, you set up an electric stimulator and a recording device, but how do you describe a hot-fudge sundae to sensory nerves so that they pass on the right information to a brain? If you want the brain to perceive seeing a sundae, you should stimulate its optic nerve (the nerve from the eye to the brain) rather than its auditory nerve (the nerve from the ear to the brain). This idea is based on the **specific energy doctrine** (Norrsell, Finger, & Lajonchere, 1999), which says that stimulation of a particular sensory nerve provides codes for that one sense, no matter how the stimulation takes place. **TRY THIS** To experience this phenomenon, apply some pressure (be gentle!) to your closed eye; doing so will produce activity in the optic nerve so you will sense little spots of light.

Having chosen the optic nerve to send visual information, you must now develop a code for all the specific features of the sundae: the soft, white curves of the vanilla ice cream, the dark richness of the chocolate, the shiny, bright red of the round cherry on

encoding Translation of the physical properties of a stimulus into a specific pattern of neural activity.

specific energy doctrine The discovery that stimulation of a particular sensory nerve provides codes for that sense, no matter how the stimulation takes place.

top. These dimensions must be coded in the language of nerve cell activity—that is, in the firing of action potentials.

In summary, the problem of encoding is solved by means of sensory systems, which allow the brain to receive detailed, accurate, and useful data about stimuli in its environment. If you succeed in creating the right coding system, your Pet Brain will finally know what a hot-fudge sundae looks like.

What Is It?

In the split second before you recognized this stimulus as a hot-fudge sundae, sensory neurons in your visual system detected the light reflected off this page and transduced it into a neural code that your brain could interpret. The encoding and decoding process occurs so quickly and efficiently in all our senses that we are seldom aware of it. Later in this chapter, we describe how this remarkable feat is accomplished.

Ed Bock/Corbis

Absolute Thresholds: Is Something Out There?

How much stimulus energy does it take to trigger a conscious perceptual experience? Not much! Normal human vision can detect the light equivalent to a candle flame burning in the dark 30 miles away. The minimum detectable amount of light, sound, pressure, or other physical energy has traditionally been called the *absolute threshold*. Table 4.1 lists absolute thresholds for human vision, hearing, taste, smell, and touch.

Psychologists discovered these thresholds by exploring *psychophysics*, the relationship between *physical* energy in the environment and your *psychological experience* of that energy (e.g., Purves et al., 2011). In a typical absolute threshold experiment, you would sit in a dark laboratory. After your eyes got used to the darkness, a researcher would show you brief light flashes. These flashes would differ in brightness, or stimulus intensity. Each time, you'd be asked if you saw the light. Averaged over a large number of trials, the pattern of your correct detections would probably form a curve like the one shown in Figure 4.3. As you can see, the absolute threshold is not an all-or-nothing affair. A stimulus at an intensity of three, which is below the absolute threshold in the figure, will still be detected 20 percent of the time it occurs. Because of such variability, psychophysicists redefined the **absolute threshold** as the smallest amount of energy that can be detected 50 percent of the time. Why does a supposedly "absolute" threshold vary? The two most important reasons have to do with "noise" and our response bias.

In psychophysics, the term internal **noise** describes the random firing of cells in the nervous system that continues in varying amounts whether or not you are stimulated by physical energy. If the amount of internal noise happens to be high at a particular moment, your sensory systems might mistakenly interpret the noise as an external stimulus.

TRY THIS

TABLE 4.1 SOME ABSOLUTE THRESHOLDS

Absolute thresholds can be amazingly low. Here are examples of the stimulus equivalents at the absolute threshold for the five primary senses. Set up the conditions for testing the absolute threshold for sound, and see if you can detect this minimal amount of auditory stimulation. If you can't hear it, the signal detection theory we discuss in this section may help explain why.

Human Sense	Absolute Threshold Is Equivalent to:
Vision	A candle flame seen at 30 miles on a clear night
Hearing	The tick of a watch under quiet conditions at 20 feet
Taste	One teaspoon of sugar in 2 gallons of water
Smell	One drop of perfume diffused into the entire volume of air in a six-room apartment
Touch	The wing of a fly falling on your cheek from a distance of 1 centimeter

Source: Galanter (1962).

absolute threshold The minimum amount of stimulus energy that can be detected 50 percent of the time.

noise The spontaneous random firing of nerve cells that occurs because the nervous system is always active.

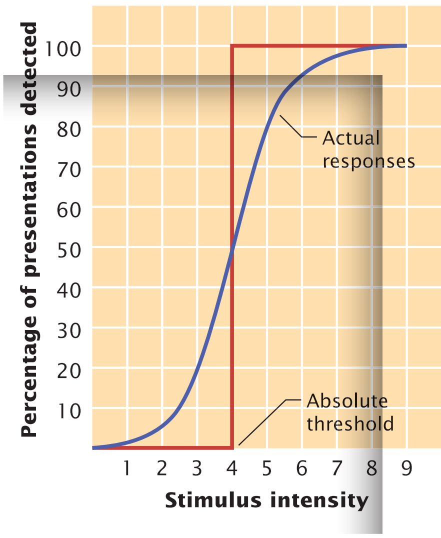


FIGURE 4.3
The Absolute Threshold

The curved line shows the relationship between the physical intensity of a signal and the chance that it will be detected. If the absolute threshold were truly absolute, or exact, all signals at or above a particular intensity would always be detected and no signals below that intensity would ever be detected (as shown by the red line). But this response pattern almost never occurs, so the "absolute" threshold is defined as the intensity at which the signal is detected 50 percent of the time.

The second source of variation in absolute threshold is **response bias**, also known as the **response criterion**, which reflects a person's willingness to respond to a stimulus. A person's *motivation*—wants and needs—as well as *expectations* affect response bias. For example, if you were punished for reporting that a faint light appeared when it did not, then you might be motivated to raise your response criterion. That is, you would report the light only when you were quite sure you saw it. Similarly, expecting a faint stimulus to occur lowers the response criterion. Suppose, for example, that you worked at an airport TSA checkpoint, examining security scans of people's handbags and luggage. The signal to be detected in this situation is a weapon. If there has been a recent terrorist attack or if the threat level has just been elevated, the airport will be on high alert. In that situation, you would lower your response criterion for deciding that a questionable object on the x-ray image might be a weapon. You will be more likely to detect a weapon if there is one, but you'll also be more likely to mistake, say, a hairdryer for a gun.

Signal Detection Theory

Once researchers understood that the detection of a stimulus depends on the combination of its physical energy, the effects of noise, and a person's response bias, they realized that measurement of absolute thresholds could never be more precise than the 50 percent rule mentioned earlier. So they abandoned the effort to pinpoint absolute thresholds and turned instead to signal detection theory.

Signal detection theory presents a mathematical model of how your personal sensitivity and response bias combine to determine your decision about whether or not a near-threshold stimulus occurred (Green & Swets, 1966). **Sensitivity** refers to your ability to detect a particular stimulus from a background of competing stimuli. It is influenced by internal noise, the intensity of the stimulus, and the capacity of your sensory systems. As already mentioned, response bias is the internal rule that you use in deciding whether to report a signal. How likely is it that an eyewitness can pick a criminal out of a lineup, or that an airport security guard will spot a weapon in a passenger's x-rayed luggage? Signal detection theory helps us understand and predict such responses more precisely (MacMillan & Creelman, 2004; Swets, 1996; Wixted & Mickes, 2014).

Judging Differences between Stimuli

Sometimes our task is not to detect a faint stimulus but to notice small changes in a stimulus or to decide whether two stimuli are the same or different. Musicians tuning up for a performance must discern whether a particular note played on one instrument matches the same note played by another instrument. When you repaint part of a wall, you have to judge whether the color of the new paint matches the old color. And when you are cooking, you have to decide whether your soup tastes any spicier after you've added some pepper.

Your ability to judge differences between stimuli depends on the strength of the stimuli you are dealing with. The weaker those stimuli are, the easier it is to detect small differences between them. For example, if you're comparing the weight of two oranges, you may be able to detect a difference of as little as a fraction of an ounce. But if you are comparing two boxes weighing around 50 pounds each, you might not notice a difference unless it is a pound or more.

An old law in psychology, named after German physiologist Ernst Weber (pronounced "VAY-ber"), describes how stimulus strength affects ability to detect differences. **Weber's law** states that the smallest detectable difference in stimulus energy is a constant fraction of the intensity of the stimulus. This smallest detectable difference is called the *difference*

response bias (response criterion) The internal rule a person uses to decide whether or not to report a stimulus.

signal detection theory A mathematical model of what determines a person's report of a near-threshold stimulus.

sensitivity The ability to detect a stimulus.

Weber's law A law stating that the smallest detectable difference in stimulus energy (just-noticeable difference) is a constant fraction of the intensity of the stimulus.

Detecting Vital Signals

According to signal detection theory, the likelihood that security screeners will detect the outline of a weapon appearing on x-ray images of luggage depends partly on the sensitivity of their visual systems and partly on their response criterion, their bias for responding to a questionable stimulus as a possible weapon. That bias, in turn, is affected by their expectations about how often weapons actually appear and by how motivated they are to look carefully for them. Airport security officials occasionally try to smuggle a simulated weapon through a checkpoint, not only to evaluate inspectors' performance but also to improve it by keeping their response criterion low enough to avoid missing real weapons (Fleck & Mitroff, 2007; McCarley et al., 2004; Wolfe et al., 2007; Wolfe & VanWert, 2010).

AP Images/Janet Hostetter

threshold, or **just-noticeable difference (JND)**. According to Weber's law, if an object weighs 25 pounds, the JND is only half a pound. So if you added a small container of yogurt to a grocery bag with three gallons of milk in it, you would not be able to tell the difference in weight. But candy snatchers beware: It takes a change of only two-thirds of an ounce to determine that someone has been into a 2-pound box of chocolates! The size of the just-noticeable difference differs for each sense. The human visual system, for example, is more sensitive than the taste system; that is why we will notice smaller differences in the brightness of a light than in, say, the saltiness of a salad.

The size of just-noticeable differences varies a bit among individuals, and as we age we tend to become less sensitive to stimulus differences. There are exceptions, however. If you like candy, you will be happy to know that Weber's fraction for sweetness stays fairly constant throughout life (Gilmore & Murphy, 1989). Weber's law does not hold when stimuli are very intense or very weak, but it does apply to complex, as well as simple, stimuli. We all tend to have our own personal JNDs that describe how much prices can increase before we notice or worry about the change. For example, if your JND for cost is .10, then you would surely notice, and perhaps protest, a 75-cent increase in a $2 bus fare. But the same 75-cent increase in your monthly rent would be less than a JND and thus unlikely to cause much notice or concern.

Sensory Energy

The sensory energies of light and sound vibrate as *waves* passing through space. These waves result from reflected light or from changes in air pressure caused when vocal cords and other objects move. The eye and ear detect the waves as light and sound, respectively. Waves of light and sound can be described in terms of wavelength, frequency, and amplitude, and these data determine what is sensed and perceived. **Wavelength** is the distance from one peak of the wave to the next. Wave **frequency** is the number of complete waves, or cycles, that pass a given point in a given amount of time. **Amplitude** is the height of the wave from baseline to peak (see Figure 4.4). Different wavelengths, frequencies, and amplitudes create different visual and sound experiences. Let's now consider how these physical properties of light and sound waves become sights and sounds.

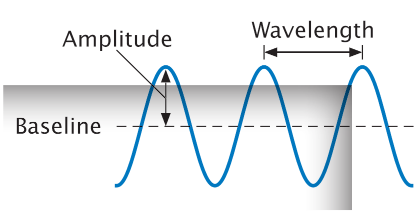


FIGURE 4.4
The Dimensions of a Wave

Wavelength is the distance from one peak of a wave to the next. *Frequency* is the number of complete waves, or cycles, that pass a given point in a given amount of time, such as one second. *Amplitude* is the height of a wave from baseline to peak.

just-noticeable difference (JND) The smallest detectable difference in stimulus energy. Also called difference threshold.

wavelength The distance between peaks in a wave of light or sound.

SEEING

Why do some people need eyeglasses?

Soaring eagles have the incredible ability to see a mouse move in the grass from a mile away. Cats have special "reflectors" at the back of their eyes that help them see even in very dim light. Nature has provided each species with a visual system well adapted to its way of life. The human visual system is also adapted to do many things well. It combines great sensitivity with great sharpness, enabling us to see objects near and far, in day and at night. Our night vision is not as good as that of some animals, but our color vision is excellent. Not a bad trade-off if being able to experience a sunset's splendor is worth an occasional stumble in the dark.

Light

Light is a kind of energy called *electromagnetic radiation*. Most electromagnetic radiation, including x-rays, radio waves, television signals, Wi-Fi, and radar, is invisible to the human eye. In fact, as shown in Figure 4.5, the range, or spectrum, of *visible light* is just the tiny slice of electromagnetic radiation that vibrates at wavelengths from just under 400 nanometers to about 750 nanometers. (A *nanometer*, abbreviated *nm*, is a billionth of a meter.) It is correct to refer to light as either *light* waves or *light* rays.

Sensations of light depend on the intensity and wavelength of light waves. **Light intensity**, which refers to how much energy the light contains, is what you sense as the brightness of light, while what color you sense depends mainly on **light wavelength**.

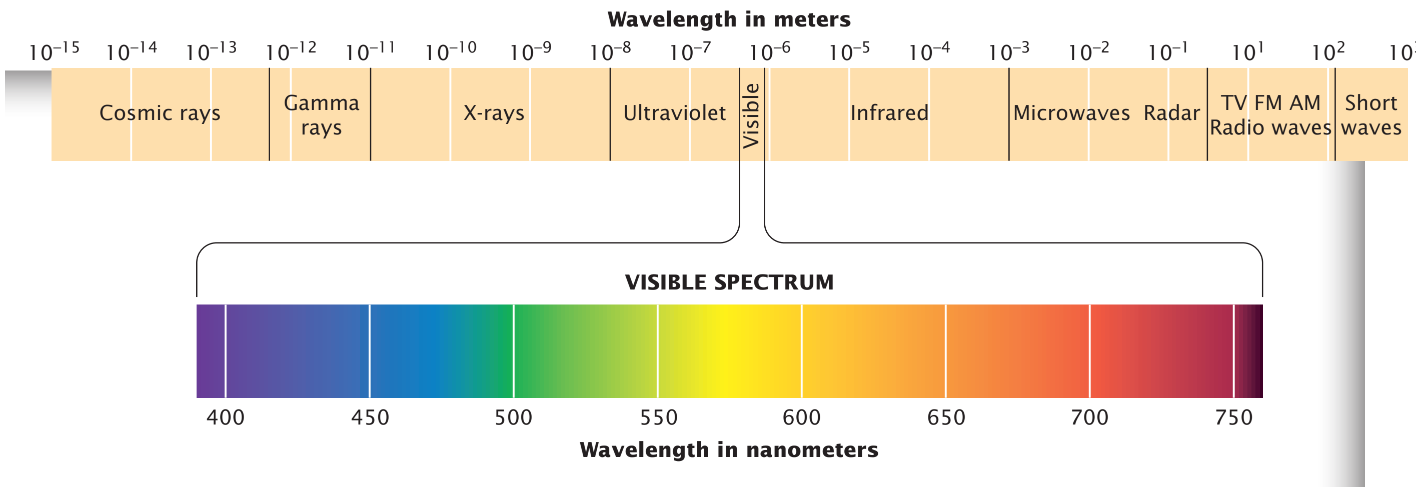


FIGURE 4.5
The Spectrum of Electromagnetic Energy

The human eye is sensitive to only a narrow range of electromagnetic wavelengths. To detect energy outside this range, we rely on radios, cell phones, TV sets, radar detectors, infrared night-vision scopes, and other electronic instruments that can "see" this energy, just as the eye sees visible light.

At a given intensity, different wavelengths produce sensations of different colors. For instance, 440-nm light appears violet blue, and 700-nm light appears orange-ish red.

Focusing Light

The eye transduces light energy into neural activity. First, accessory structures of the eye modify incoming light rays. The light rays enter the eye by passing through a curved, transparent, protective layer called the **cornea**. As shown in Figure 4.6, light passes on through the **pupil**, an opening behind the cornea. The **iris**, which gives the eye its color, adjusts the amount of light allowed into the eye by constricting (reducing) or dilating (enlarging) the pupil. Directly behind the pupil is the **lens**.

Both the cornea and lens of the eye are curved so that they bend light rays. (A camera lens works the same way.) This bending process focuses light rays coming from various

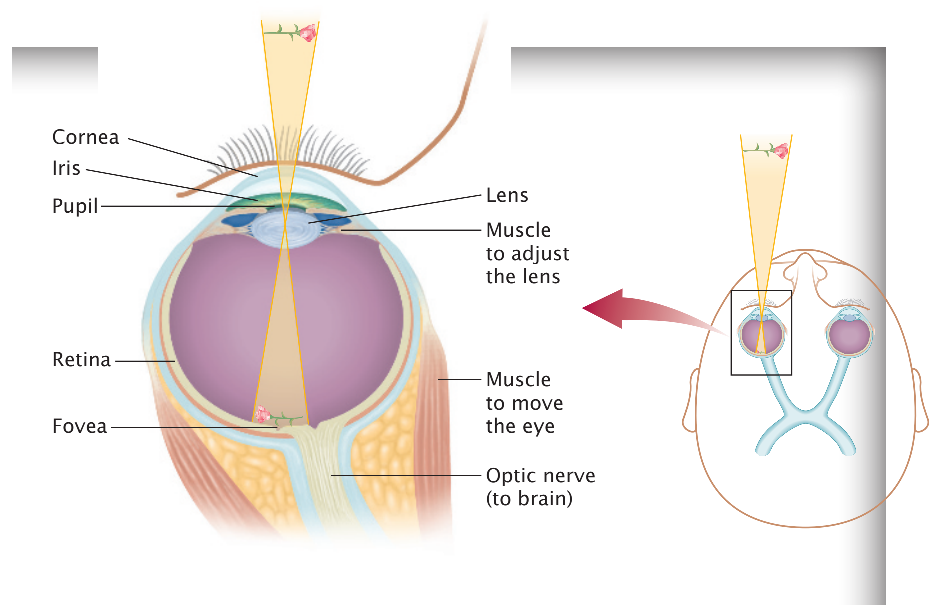


FIGURE 4.6
Major Structures of the Eye

As shown in this top view of the eye, light rays bent by the combined actions of the cornea and the lens are focused on the retina, where the light energy is converted into neural activity. Nerve fibers from the retina combine to form the optic nerve, which leaves the back of the eye and continues to the brain.

frequency The number of complete waves, or cycles, that pass a given point per unit of time.

amplitude The distance between the peak and the baseline of a wave.

light intensity A physical dimension of light waves that refers to how much energy the light contains and that determines our experience of its brightness.

light wavelength A physical dimension of light waves that refers to their length and that produces sensations of different colors.

cornea The curved, transparent, protective layer through which light rays enter the eye.

pupil An opening in the eye just behind the cornea through which light passes.

iris The part of the eye that gives it its color and adjusts the amount of light entering it.

lens The part of the eye directly behind the pupil.

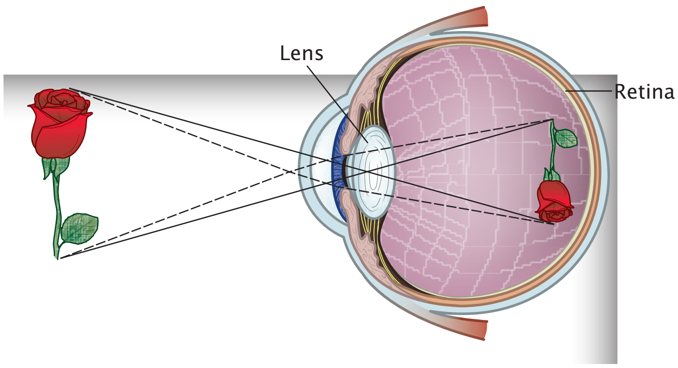


FIGURE 4.7
The Lens and the Retinal Image

To see objects as they are, your brain must rearrange the upside-down and reversed images that the lens focuses on the retina. If light rays are out of focus when they reach the retina, glasses usually correct the problem. In some older people, vision is impaired by cataracts, a condition in which a "cloudy" lens severely reduces incoming light. Cataracts can be cleared up with laser surgery or by replacing the natural lens with an artificial one (Snellingen et al., 2002).

angles into a sharp image onto the **retina**, which is the inner surface at the back of the eye. Light rays from the top of an object are focused at the bottom of the image on the retinal surface. Light rays from the right side of the object end up on the left side of the retinal image (see Figure 4.7). The brain rearranges this upside-down and reversed image so that we can see the object as it is. If the brain did not do so, as was claimed to be the case for one unfortunate lady (Haydon, 2013), you might have to read your newspaper upside down!

TRY THIS The muscles that hold the lens adjust its shape to focus light from near or far distances onto the retina. To illustrate this for yourself, try reading the next sentence while holding the book as close to your face as possible. To maintain a focused image at close range, your muscles have to tighten your lenses, making them more curved. This ability to change the shape of the lens to bend light rays is called **ocular accommodation**. As the lens loses flexibility with age, accommodation becomes more difficult. Converging light rays may come into focus either before or after they hit the retina, making images blurry. This is why older people may become "farsighted," seeing distant objects clearly but needing glasses for reading or close work. (For those who want to avoid glasses, a cell phone app has been developed with vision exercises that help train a stiffened lens to become more flexible again; Kaplan, 2014.)

A more common problem for people of all ages is "nearsightedness," in which close objects are clear but distant ones are blurry. This condition has a genetic component, but it may also be made more likely by environmental factors, such as when people spend more time looking at close-up images and less time gazing far away (French et al., 2013). These vision problems can usually be solved with glasses or contact lenses that add light-bending of their own. Other options include laser-assisted in-situ keratomileusis (LASIK) or photo-refractive keratectomy (PRK), eye surgeries that reshape or stretch the cornea (Shortt et al., 2013). These outpatient procedures change how the cornea bends light rays; thus the lens has to do less accommodation, eliminating the need for glasses or contacts.

Converting Light into Images

Converting light energy into neural activity occurs in the retina, using neurons that are actually an extension of the brain. The word *retina* is Latin for "net," and the retina is in fact an intricate network of cells (Masland, 2001).

Rods and Cones

Specialized cells in the retina called **photoreceptors** convert light energy into neural activity. There are two main types of photoreceptors: rods and cones. **Rods** and **cones** are retinal cells that are named for their shapes. These cells contain chemicals that respond to light. When light hits these chemicals, they break apart, creating a signal that can be transferred to the brain.

It takes time to rebuild these light-sensitive chemicals after they break down. This explains why you cannot see well when you come from bright sunshine into a dark room (Mahroo & Lamb, 2004). In the dark, as your rods build up their light-sensitive chemicals, your ability to see gradually increases. The increasing ability to see in the dark over time is called **dark adaptation** (Reuter, 2011). You become about 10,000 times more sensitive to light after about half an hour in a darkened room.

There are three kinds of light-sensitive chemicals in cones, and they provide the basis for color vision. Rods have only one kind of chemical, so they cannot discriminate colors. However, rods are more sensitive to light than cones, so they allow you to see in dim light, as on a moonlit night. It's only at higher light intensities that the cones, with their ability to detect colors, become most active. As a result, you might put on what looked like a matched pair of socks in a darkened bedroom only to go outside and discover that one is dark blue and the other is dark green.

retina The surface at the back of the eye onto which the lens focuses light rays.

ocular accommodation The ability of the lens to change its shape and bend light rays so objects are in focus.

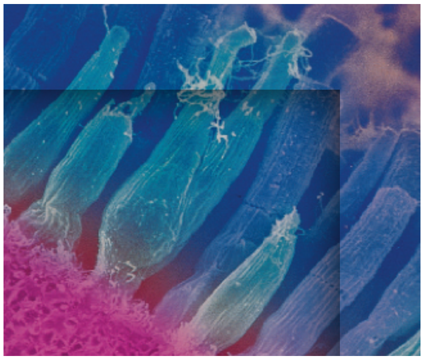
photoreceptors Specialized cells in the retina that convert light energy into neural activity.

rods Photoreceptors in the retina that allow sight even in dim light but that cannot distinguish colors.

cones Photoreceptors in the retina that are less light sensitive than rods but that can distinguish colors.

dark adaptation The increasing ability to see in the dark as time passes.

Cones are concentrated in the center of the retina in a circular region called the **fovea**, which is where the eye focuses incoming light. Differences in the density of cones in the fovea can lead to differences in visual *acuity,* or ability to see details (Beirne, Zlatkova, & Anderson, 2005). Decreases in cone density over time may also be partly to blame for some age-related losses in acuity (Song et al., 2011); in people with a condition known as *macular degeneration*, the cones die off altogether, causing blindness (Kent, 2014). New medical treatments may be able to treat such people by transplanting photoreceptors into the retina (Barber et al., 2013). There are no rods in the human fovea. With increasing distance from the fovea, though, the number of cones gradually decreases and the proportion of rods gradually increases. So if you are trying to detect a weak light, such as the light from a faint star, it is better to look slightly away from where you expect to see it. This focuses the weak light on the very light-sensitive rods outside the fovea. Because cones do not work well in low light, looking directly at the star will make it seem to disappear.



Rods and Cones

TRY THIS This electron microscope view of rods (blue) and cones (aqua) shows what your light receptors look like. Rods are more light-sensitive, but they do not detect color. Cones can detect color, but they require more light in order to be activated. To experience the difference in how these cells work, try looking at an unfamiliar color photograph in a room where there is barely enough light to see. This dim light will activate your rods and allow you to make out images in the picture. But because there is not enough light to activate your cones, you will not be able to see colors in the photo.

Science Source

From the Retina to the Brain

If the eye simply transferred to the brain the images it focused on the retina, we would experience something like a slightly blurry photograph. Instead, the eye first sharpens visual images. How? The key lies in the interactions among cells of the retina.

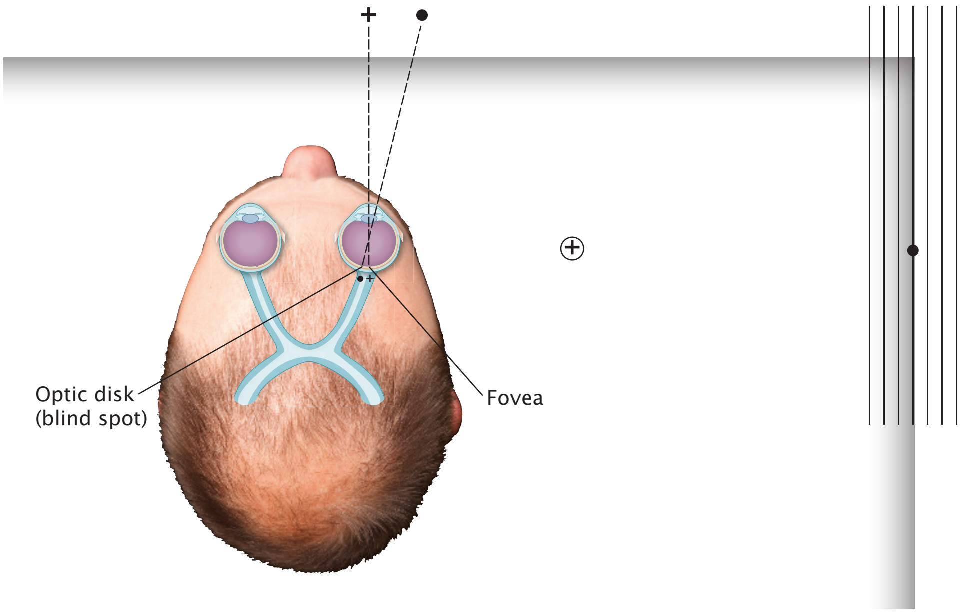
Light rays pass through several layers of retinal cells before striking the rods and cones. Signals generated by the rods and cones then go back toward the surface of the retina, making connections with *bipolar cells* and *ganglion cells,* which allow the eye to begin analyzing visual information even before that information leaves the retina (Freeman, Rizzo, & Fried, 2011). Actually, ganglion cells can act as photoreceptors and detect a bit of light all by themselves, but this information seems to be used mainly for keeping our internal body clocks synchronized with the light and dark cycles of the world around us, as discussed in the chapter on consciousness (Münch & Kawasaki, 2013). When it comes to using light for conscious visual sensations, we rely on the photoreceptor work of rods and cones, and the information that they send into bipolar cells and ganglion cells. The axons of the ganglion cells bundle together to form the **optic nerve**, which then connects to the brain. Because there are no receptors for visual stimuli at the point where the optic nerve exits the eyeball, a **blind spot** is created, as Figure 4.8 shows.

After leaving the retina, about half the axons in the optic nerve cross over to the opposite side of the brain, creating a structure called the *optic chiasm*. (*Chiasm* means "cross" and is pronounced "KYE-az-um.") The axons from the inside half of each eye

FIGURE 4.8

Find Your Blind Spot

TRY THIS There is a blind spot where the optic nerve exits the eye. To "see" your blind spot, cover your left eye and stare at the cross inside the circle. Move the page closer and farther away, and at some point the dot to the right should disappear from view. However, the vertical lines around the dot will probably look continuous, because the brain tends to fill in visual information at the blind spot (Spillmann et al., 2006). We are normally unaware of this "hole" in our vision because the blind spot of one eye is in the normal visual field of the other eye.



fovea A region in the center of the retina.

optic nerve A bundle of fibers that carries visual information to the brain.

blind spot The point at which the optic nerve exits the eyeball.

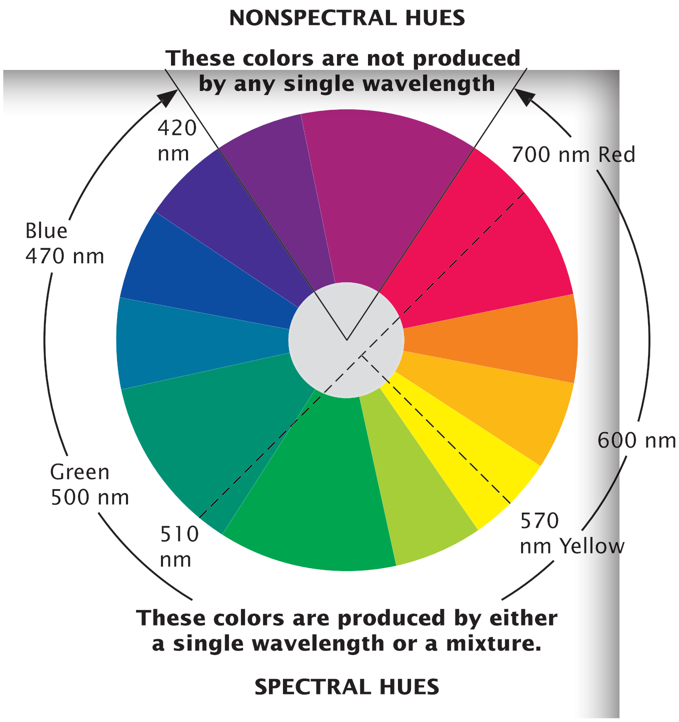


FIGURE 4.9
The Color Circle

Arranging colors according to their psychological similarities creates a color circle that predicts the result of additive mixing of two colored lights. For example, mixing equal amounts of pure green and pure red light will produce yellow, the color that lies at the midpoint of the line connecting red and green. (Note: nm stands for nanometers, the unit in which light wavelengths are measured.)

(nearest to the nose) cross over. The axons from the outside half of each eye do not. So no matter where you look, all the visual information about the right half of the visual world goes to the left hemisphere of your brain and all the visual information from the left half of the visual world goes to the right hemisphere (Roth, Lora, & Heilman, 2002).

Beyond the optic chiasm, the ganglion cell axons continue into the brain itself, finally forming synapses in the thalamus. Neurons there send axons to connect to the primary visual cortex in the occipital lobe at the back of the brain. The primary visual cortex does initial processing of visual information, then sends that refined information to many association areas of the brain for more specialized processing (Dhruv et al., 2011).

Certain cells in the brain's cerebral cortex are called **feature detectors** because they respond to specific characteristics of objects in the visual world (Hubel & Wiesel, 1979; Jia et al., 2010). For example, one type of feature detector responds most to straight lines of light. Others respond to corners, to angles, or to some other feature. The combined responses of several types of feature-detecting cells help us sense the shapes of objects such as rectangles or triangles. Most people can also detect color. Let's explore how color vision works.

Seeing Color

Like beauty, color is in the eye of the beholder. Many animals see only shades of gray, even when they look at a rainbow, but for humans, color is a key feature of vision.

Wavelengths and Color Sensations

Each wavelength of light is sensed as a certain color. However, the eye rarely (if ever) encounters a "pure" light of a single wavelength. Sunlight, for example, is a mixture of all wavelengths of light. When sunlight passes through a water droplet, each different wavelength of light bends to a different degree, separating into a colorful rainbow. The spectrum of color found in the rainbow illustrates an important concept: The sensation produced by a *mixture* of different wavelengths of light is not the same as the sensations produced by separate wavelengths. Color sensation results from features of the wavelength mixtures striking the eye. The three separate aspects of this sensation are hue, color saturation, and brightness. These labels refer to the *psychological* dimensions of what we experience when the light arrives, and they correspond roughly to the light's physical properties. **Hue**, the essential "color," is determined by the dominant wavelength in the mixture of the light. Black, white, and gray are not hues because they do not have a dominant wavelength. **Color saturation** is related to the purity of color. A color is said to be more *saturated* (more pure) if just one wavelength is more intense (contains more energy) than other wavelengths. The yellow of a school bus and the red of a stop sign are saturated colors. When many other wavelengths are added in, we say that the color is *desaturated.* Pastels are colors that have been desaturated by adding whiteness. **Brightness** refers to the overall intensity of the wavelengths making up light.

The *color circle* shown in Figure 4.9 arranges hues according to their perceived similarities. Mix two different light wavelengths of equal intensity and the color you sense is midway between the two original colors on the color circle. This process is called *additive color mixing,* because the effects of the wavelengths are added together. Keep adding different colored lights and you eventually get white, which is the combination of all wavelengths. You are probably more familiar with a different form of color mixing, called *subtractive color mixing,* which occurs when, for example, paints are combined. Paint, like other physical objects, reflects certain wavelengths and absorbs others. Green paint is green because it

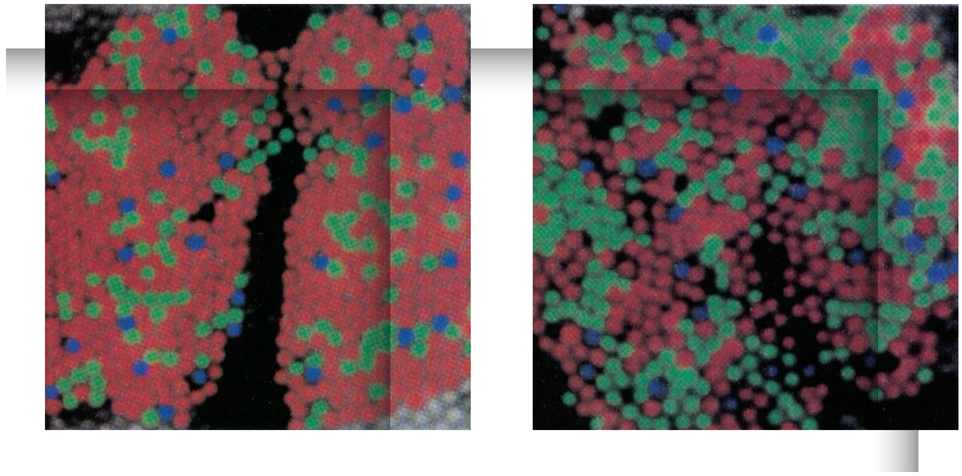
feature detectors Cells in the cerebral cortex that respond to a specific feature of an object.

hue The essential color determined by the dominant wavelength of light.

color saturation The purity of a color.

brightness The overall intensity of the wavelengths making up light.

FIGURE 4.10
Individual Differences in Cone Types



These photographs show that people can differ widely from one another in the distribution of blue, green, and red cones in their retinas (Roorda & Williams, 1999). J. W., whose retina is shown at left, has an especially high population of red cones, whereas green cones predominate in A. N., whose retina is shown on the right. Both have normal color vision, but J. W. will be somewhat more sensitive to long wavelengths of light, whereas A. N. will be somewhat more sensitive to light of medium wavelengths.

Reprinted by permission from Nature. Roorda, A. & Williams, D. R. (1999). The arrangement of the three cone classes in the living human eye. Nature, 397, 520–522. Copyright © 1999 Macmillan Magazines Ltd.

absorbs all wavelengths except wavelengths perceived as green. (White objects appear white because they reflect all wavelengths.) So if you keep combining different colored paints, all of the wavelengths will eventually be subtracted, resulting in black.

Theories of Color Vision

Psychologists have long tried to explain how color vision works, but only two theories have stood the test of time: trichromatic (or "three-color") theory and opponent-process theory.

The Trichromatic Theory of Color Vision

In the early 1800s, Thomas Young proved that mixing pure versions of blue, green, and red light in different ratios could produce any other color; Hermann von Helmholtz later confirmed these findings. The Young-Helmholtz theory of color vision is called the **trichromatic theory**.

Support for trichromatic theory comes from research on cones in the retina. There are three types of cones, each most sensitive to particular wavelengths. *Short-wavelength* cones respond most to light in the blue range. *Medium-wavelength* cones are most sensitive to light in the green range. *Long-wavelength* cones respond best to light in the reddish-yellow range, but by tradition they are known as "red" cones. No single cone by itself can signal the color of a light; it is the *ratio* of the activities of the three types of cones that determines the color you sense. As you can see in Figure 4.10, the exact mixture of these three cone types can differ from person to person. The trichromatic theory was applied in the creation of color television screens, which contain microscopic elements of red, green, and blue. A television broadcast excites these elements to varying degrees, mixing their colors to produce many other colors. You see color mixtures, not patterns of red, green, and blue dots, because the dots are too small and close together to be seen individually. However, with a magnifying glass you may be able to see similar pixels that make up the color photos in your local newspaper.

trichromatic theory A theory of color vision stating that information from three types of visual elements combines to produce the sensation of color.

opponent-process theory A theory of color vision stating that the visual elements that are sensitive to color are grouped into red-green, blue-yellow, and black-white pairs.

The Opponent-Process Theory of Color Vision

Although essentially correct, the trichromatic theory cannot explain some aspects of color vision, such as afterimages. To see an afterimage, stare at the black dot in the flag in Figure 4.11 for thirty seconds and then look at the black dot in the white space below it. What was yellow in the original image will be blue in the afterimage. What was green before will appear red, and what was black will now appear white.

This type of observation led Ewald Hering to offer another theory of color vision, called the **opponent-process theory**. Hering suggested that color-sensitive visual elements in the eye are arranged into three kinds of pairs and that the members of each pair oppose, or inhibit, each other. Each element signals one color or the other (red or green, blue or yellow, black or white), but never both. This theory explains color afterimages. When one member of an opponent pair is no longer stimulated, the other is activated. So in Figure 4.11, if the original image you look at is green, the afterimage will be red.

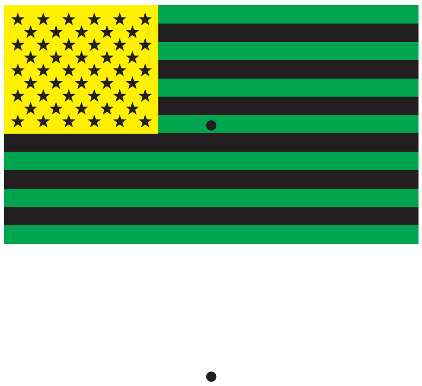


FIGURE 4.11
Afterimages Produced by the Opponent-Process Nature of Color Vision

TRY THIS Stare at the black dot in the flag for at least thirty seconds and then focus on the dot in the white space below it. The afterimage you will see can be explained by the opponent process theory of color vision. What colors appeared in the afterimage you saw?

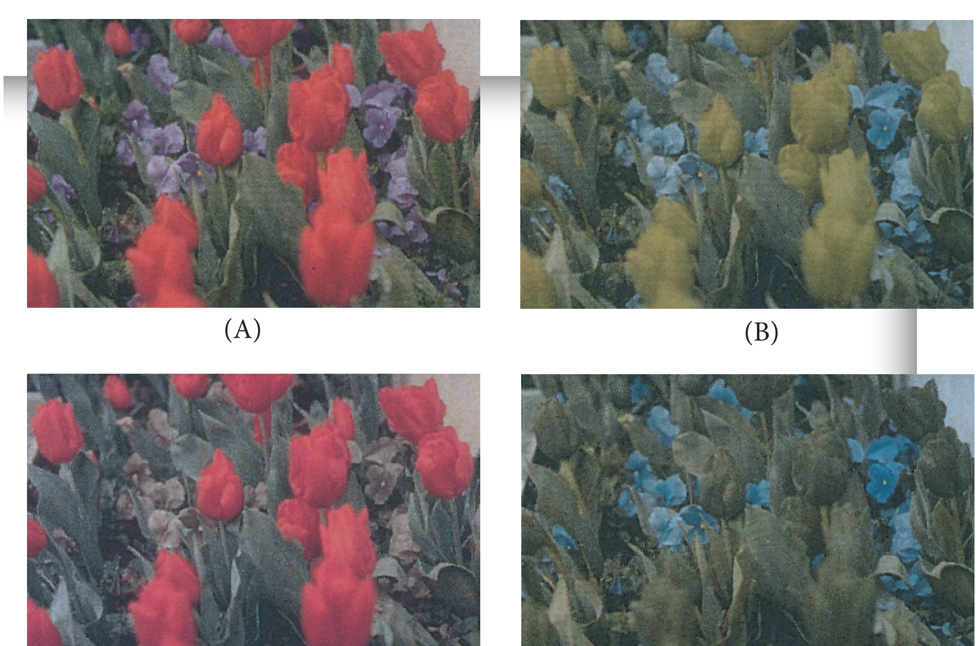
The Bottom Line on Color Vision

Together, the trichromatic and opponent-process theories encompass most of what we now know about the complex process of color vision. We see color because our three types of cones have different sensitivities to different wavelengths. We sense different colors when the three cone types are stimulated in different ratios. Because there are three types of cones, any color can be produced by mixing three pure wavelengths of light. But there is more to it than that. Cones connect to ganglion cells containing pairs of opposing elements that respond to different colors and inhibit each other. This arrangement provides the basis for afterimages. Therefore, the trichromatic theory explains color vision as it relates to rods and cones, whereas the opponent-process theory explains color vision as it relates to the ganglion cells. Both theories are needed to account for the complexity of color sensations (Jacobs, 2008).

Color vision also depends on what happens in the brain—especially in the cortex—where encoded color information from the retinas is assembled and processed (Conway, 2009; Gegenfurtner & Kiper, 2003; Heywood & Kentridge, 2003). As a result, certain kinds of brain damage can weaken or destroy color vision, even though all the cones in the retina are working normally (Bouvier & Engel, 2006).

Color Blindness

Cones normally contain three kinds of chemicals, each of which responds best to a particular wavelength of light. People who have cones containing only two of these three color-sensitive chemicals are described as *color blind* (Neitz & Neitz, 2011). They are not really blind to all color, but they discriminate fewer colors than do other people, as Figure 4.12 shows. Red-green color blindness, for example, means that reds and greens appear to be the same brownish-gray color. Color blindness is more common in men than in women. ("In Review: Seeing" summarizes our discussion of vision.)



(A) (B)

(C) (D)

FIGURE 4.12
Are You Color Blind?

TRY THIS Photograph A shows how this scene appears to people whose cones have all three types of color-sensitive chemicals. The other photos simulate how colors appear to people who are missing chemicals for long wavelengths (B), short wavelengths (C), or medium wavelengths (D). If any of these photos look to you just like the one at the upper left, you may have a form of color blindness.

Vienot, Brettel, Mollon–MNHN, CNRS

IN REVIEW

SEEING

Aspect of Sensory System	Elements	Key Characteristics
Energy	Visible light: electromagnetic radiation with a wavelength of about 400 nm to about 750 nm	The intensity, wavelength, and complexity of light waves determine the brightness, hue, and color saturation of visual sensations.
Accessory structures of the eye	Cornea, pupil, iris, lens	Light rays are bent to focus on the retina.
Conversion of visual stimuli to neural activity	Photoreceptors (rods and cones) in the retina	Rods are more sensitive to light than cones, but cones discriminate among colors. Sensations of color depend first on the cones, which respond differently to different light wavelengths, and then on processing by ganglion cells.
Pathway to the brain	Optic nerve to optic chiasm to thalamus to primary visual cortex	Neurons in the brain respond to particular aspects of the visual stimulus, such as shape.

In Review Questions

1. The ability to see in very dim light depends on photoreceptors called __________.
2. Color afterimages are best explained by the __________ theory of color vision.
3. Nearsightedness and farsightedness occur when images are not focused on the eye's __________.

HEARING

How would my voice sound on the moon?

In 1969, when Neil Armstrong became the first person ever to set foot on the moon, millions of people back on earth heard his radio transmission: "That's one small step for a man, one giant leap for mankind." But if Armstrong had been foolish enough to take off his space helmet and shout, "Whoo-ee! I can moonwalk!" not even an astronaut three feet away could have heard him. Why? Because he would have been speaking into airless, empty space. **Sound** is a repeating fluctuation—a rising and falling—in the pressure of a substance, such as air. Because the moon has almost no atmosphere and almost no air pressure, airborne sound cannot exist there.

Sound

Vibrations of an object produce the fluctuations in pressure that we experience as sound. When you speak, your vocal cords vibrate, causing fluctuations in air pressure that spread as sound waves. Figure 4.13 shows how these changes in air pressure can be described as sound waveforms. The waveforms are drawn in only two dimensions, but remember that sound waves actually move through the air in all directions. This is the reason that when people talk to each other during a movie or a lecture, others all around them are distracted by the conversation.

Just as the amplitude and wavelength of light waves affect our experience of light, characteristics of sound waves shape our experience of sound. The psychological experience we call **loudness** is determined by the amplitude, or height, of a sound wave. Greater amplitudes give louder sounds. Loudness is described in units called *decibels* (abbreviated *dB*). We define 0 dB as the minimum detectable sound for normal hearing. Every increase of 20 dB reflects a tenfold increase in the amplitude of sound waves. So the 40-dB sounds of an office are actually 10 times as intense as a 20-dB whisper; and traffic

sound A repetitive fluctuation in the pressure of a medium such as air.

loudness A psychological dimension of sound determined by the amplitude of a sound wave.

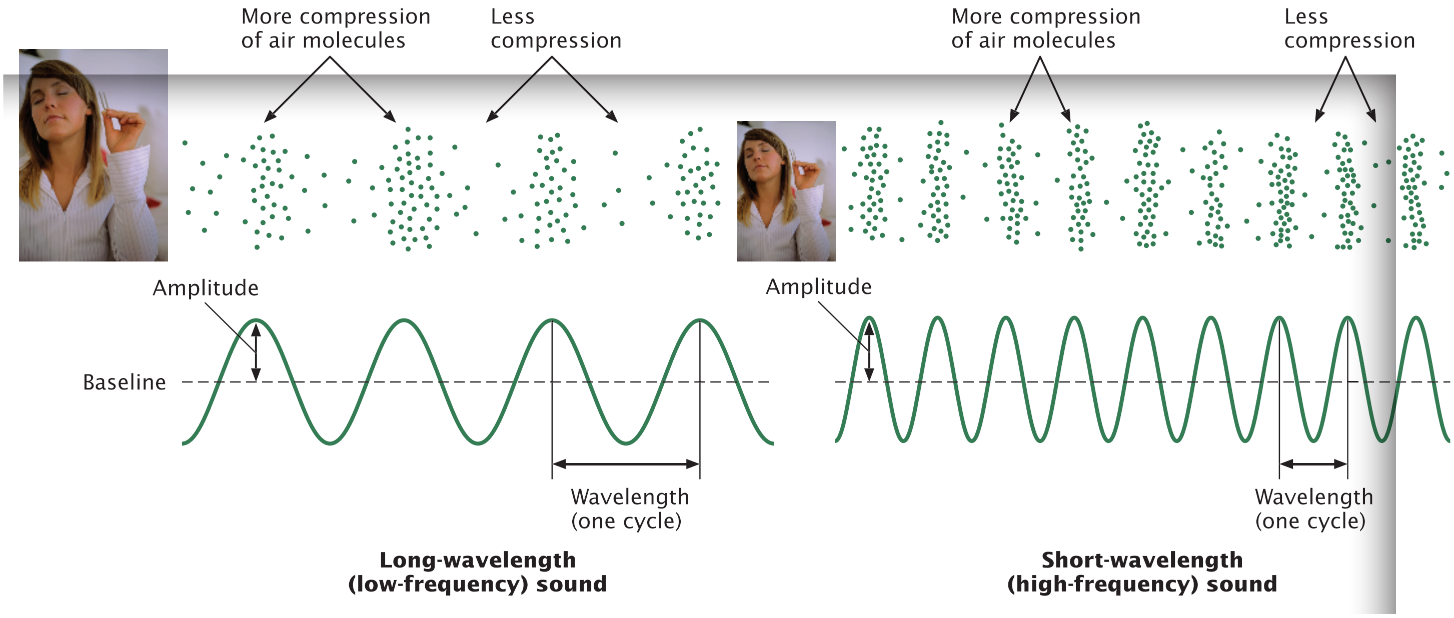


FIGURE 4.13
Sound Waves and Waveforms

Sound is created when objects, such as a tuning fork, vibrate. The vibration creates alternating regions of greater and lesser compression of air molecules, which can be represented as a waveform. The point of greatest compression is the peak of the wave. The lowest point of the wave is where compression is least. In each particular substance, or medium, such as air, a sound's wavelength (the distance between peaks) is related to its frequency (the number of waves per second). The longer the wavelength, the lower the sound frequency. The shorter the wavelength, the higher the frequency.

Daniel Krolls/Getty Images

noise of 100 dB is 10,000 times as intense as that whisper. The loudest musicians create sound intensity of 160 dB (Levine & Schefner, 1981).

The psychological dimension of **pitch**—how high or low a tone sounds—depends on the frequency of the sound wave. Frequency is the number of complete waves or cycles that pass a given point in one second. It is described in units called *hertz,* abbreviated *Hz* (for Heinrich Hertz, a nineteenth-century physicist). One cycle per second is 1 Hz. High-frequency waves are sensed as sounds of high pitch. The highest note on a piano has a frequency of about 4,000 Hz, and the lowest note has a frequency of about 50 Hz. Humans can hear sounds ranging from about 20 to 20,000 Hz.

Most sounds are a mixture of many frequencies and amplitudes, and this mixture creates a sound's **timbre** (pronounced "TAM-ber"), the psychological dimension of sound quality. Complex wave patterns added to the *fundamental,* or lowest, frequency of sound determine its timbre. The extra waves allow you to tell the difference between, say, a note played on a flute and the same note played on a clarinet.

The Ear

The human ear includes accessory structures that affect sound waves initially and transduction mechanisms that convert sound energy into neural activity. The visible part of the ear on the side of the head, called the **pinna**, collects sound waves in the outer ear. (People trying to hear a faint sound may cup a hand to their ear because this action tilts the pinna forward and enlarges the area that is collecting sound. Try this for a moment, and you will notice a clear difference in the sounds you hear.) The pinna funnels sound down through the ear canal. At the end of the ear canal, the sound waves reach the **middle ear** (see Figure 4.14). There they strike the **tympanic membrane**, a tightly stretched structure also known as the **eardrum**. The sound waves set up vibrations in the tympanic membrane. The *hammer*, the *anvil*, and the *stirrup*, three tiny bones named for their shapes, amplify these vibrations and direct them onto a smaller membrane called the *oval window*.

The Inner Ear

Sound vibrations passing through the oval window enter the inner ear, reaching the **cochlea** (pronounced "KOK-lee-ah"), where transduction occurs. The cochlea is rolled into a coiled spiral. (*Cochlea* comes from the Greek word for "snail.") A fluid-filled tube

TRY THIS

pitch How high or low a tone sounds; pitch depends on the frequency of a sound wave.

timbre The quality of a sound that identifies it.

pinna The crumpled part of the outer ear that collects sound waves.

middle ear The part of the ear that contains the hammer, anvil, and stirrup, which transmit sound from the tympanic membrane to the oval window.

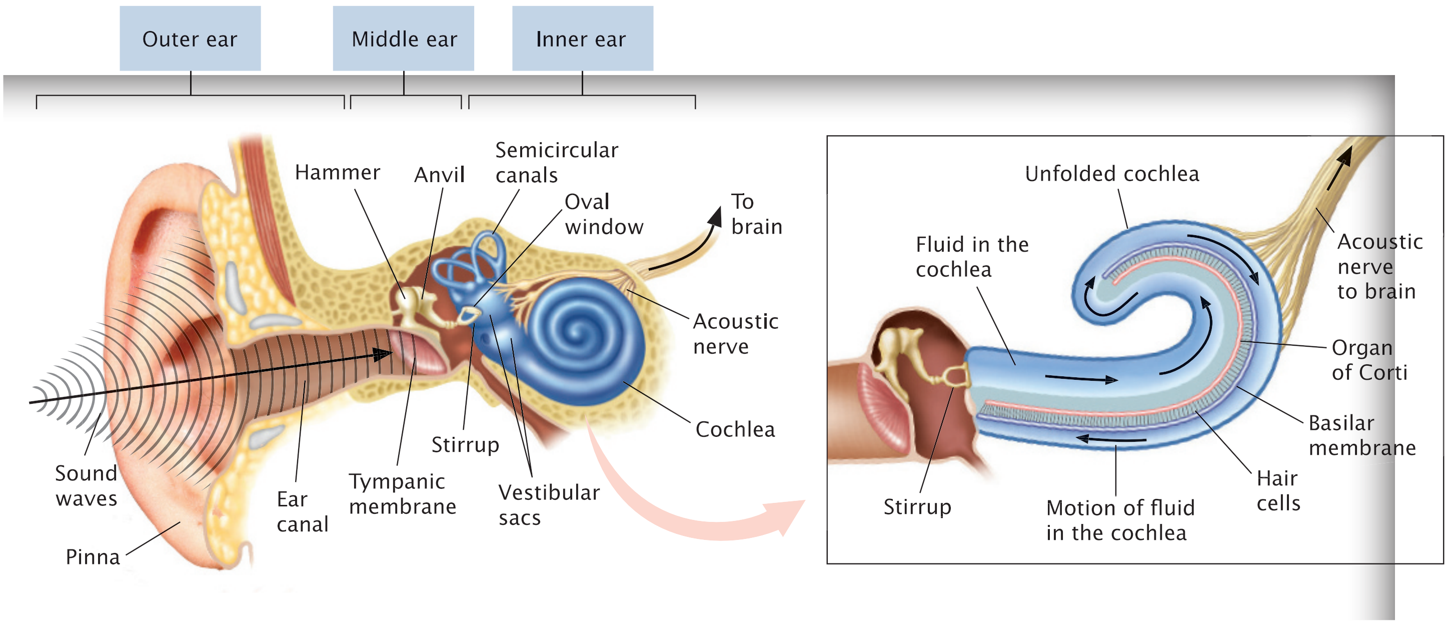


FIGURE 4.14
Structures of the Ear

The outer ear (pinna and ear canal) channels sound waves into the middle ear, where the vibrations of the tympanic membrane are amplified by the delicate bones that stimulate the cochlea. The close-up view of the cochlea shows how the vibrations of the stirrup set up vibrations in the fluid inside the cochlea. The coils of the cochlea are unrolled in this illustration to show the path of the fluid waves along the basilar membrane. Movements of the basilar membrane stimulate hair cells, which transduce the vibrations into changes in neural activity, which are sent along the acoustic nerve to the brain.

runs down its length. The **basilar membrane** forms the floor of this tube, as you can see in Figure 4.14. When a sound wave passes through the fluid in the tube, it makes the basilar membrane rise and fall like a bedsheet on a clothesline flapping in the wind (Ren, 2002). This movement, in turn, bends *hair cells* on the membrane. These hair cells make connections with fibers from the **acoustic nerve**, a bundle of axons that goes into the brain. Bending the hair cells stimulates the acoustic nerve, also known as the *auditory nerve,* which sends encoded signals to the brain about the amplitude and frequency of the sound waves (Griesinger, Richards, & Ashmore, 2005). These signals allow you to sense loudness, pitch, and timbre.

Deafness

The middle and inner ear are among the most delicate structures in the body, and damage to them can lead to impaired hearing or deafness. One form of deafness can be caused when the bones of the middle ear fuse together, preventing accurate conduction of vibrations (Stenfelt, 2011). This condition, called *conduction deafness,* can be treated by surgery to break the bones apart or to replace the natural bones with plastic ones (Manrique et al., 2014). Hearing aids that amplify incoming sounds can also help.

Nerve deafness results when the acoustic nerve or, more commonly, the hair cells that feed information to it, are damaged (Shepherd & McCreery, 2006). Hair-cell damage occurs gradually with age, but hair cells can be damaged earlier and more suddenly by very loud sounds, including amplified music (Sliwinska-Kowalska & Davis, 2012). High-intensity sounds actually rip the hair cells off the inner ear. Generally, any sound loud enough to produce ringing in the ears causes some damage. In humans, small amounts of damage gradually build up and can lead to significant hearing loss by middle age—as many older rock musicians (and their fans) later find out (Levine, 1999). Listening to music at high volume through headphones can also cause hearing loss (Petrescu, 2008; Vogel et al., 2009), which may explain the recent increase in hearing loss among adolescents (Shargorodsky et al., 2010).

Hair cells can be regenerated in chickens' ears (Cotanche, 1997), and a related kind of inner-ear hair cell has been regenerated in mammals (Malgrange et al., 1999). Scientists hope that human hair-cell regeneration might be possible by treating damaged areas with growth factors similar to those being used to repair damaged brain cells (Shepherd et al., 2005; see the chapter on biological aspects of psychology). Inserting genes that might stimulate the regrowth of damaged hair cells (Xia & Yin, 2013) and using stem cells to

tympanic membrane (eardrum) A tightly stretched membrane in the middle ear that generates vibrations that match the sound waves striking it.

cochlea A fluid-filled spiral structure in the inner ear in which auditory transduction occurs.

basilar membrane The floor of the fluid-filled duct that runs through the cochlea.

acoustic nerve The bundle of axons that carries messages from the hair cells of the cochlea to the brain.

Shaping the Brain

The brain region known as the primary auditory cortex is larger in trained musicians than in people whose jobs are less focused on fine gradations of sound. How much larger this area becomes is correlated with how long the musicians have studied their art. This finding reminds us that, as described in the chapter on biological aspects of psychology, the brain can literally be shaped by experience and other environmental factors.

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create new hair cells (Shi, Hu, & Edge, 2013) are two other promising approaches. Such efforts could revolutionize the treatment of nerve deafness, since hearing aids do not help. In the meantime, scientists have developed an artificial cochlea that can be implanted in the human ear to stimulate the acoustic nerve (Gaylor et al., 2013).

Auditory Pathways to the Brain

Before sounds can be heard, the information encoded in the firing of the many axons that make up the acoustic nerve must be sent to the brain for further analysis. This transmission process begins when the acoustic nerve conveys the information to the thalamus. From there, the information is relayed to the *primary auditory cortex,* an area in the temporal lobe of the brain. It is in the primary auditory cortex that information about sound is subjected to the most intense and complex analysis (Ciocca, 2008). Certain cells in the auditory cortex are differently specialized, much as different cells in the visual cortex show specialized responses to various aspects of light information. In the auditory cortex, different cells seem to fire most vigorously in response to sounds of particular frequencies; these are known as *preferred frequencies.* Each neuron in the acoustic nerve also has a "favorite," or characteristic, frequency, though each also responds to a range of frequencies, to some extent (Schnee et al., 2005). The auditory cortex examines the pattern of activity of many neurons to determine the frequency of a sound. This auditory analysis may be especially efficient in people who were deprived of visual experience because of blindness early in life (Stevens & Weaver, 2009).

Some parts of the auditory cortex are devoted to processing certain types of sounds. One part, for example, specializes in information from human speech (Belin, Zatorre, & Ahad, 2002); others are particularly responsive to sounds coming from animals, tools, or musical instruments (Lewis et al., 2005; Zatorre, 2003). Some specialization in the auditory cortex can be seen in brain scans. For example, fMRI scans of the auditory cortex look different in people who are listening to music and lyrics than to music alone (Brattico et al., 2011). Observing which brain areas become activated by which kind of sound has allowed researchers to detect whether a person is listening to words spoken by a familiar or unfamiliar voice and even to identify some details about what is being said (Formisano et al., 2008). The primary auditory cortex receives information from other senses as well. For example, it is activated when you watch someone say words (but not when the person makes other facial movements). This may reflect a biological basis for the lip-reading that helps you hear what people say (Campbell & Capek, 2008).

Encoding Sounds

Most people hear a wide range of sound intensities. The faintest sound that can be heard barely moves the ear's hair cells. Sounds more than a trillion times more intense can also be heard. Between these extremes, the auditory system encodes intensity in a simple way: The more intense the sound, the more rapid the firing of a given neuron. We're also very good at detecting differences between sound frequencies that allow us to hear differences in pitch (Shera, Guinan, & Oxenham, 2002). Information about frequency differences appears to be encoded in two ways: by their location on the basilar membrane and by the rate at which the auditory neurons fire.

As sound waves move down the basilar membrane, they reach a peak and then taper off, much like an ocean wave that crests and then dissolves. The waves produced by high-frequency sounds peak soon after they start down the basilar membrane. Waves produced by lower-frequency sounds peak farther down the basilar membrane. According to **place theory**, the greatest response by hair cells occurs at the peak of the wave. Because the location of the peak varies with the frequency of sound, it follows that hair cells at a particular place on the basilar membrane are most responsive to a particular frequency of sound. When cells with a particular characteristic frequency fire, we sense a sound of that frequency.

place theory A theory of hearing that states that hair cells at a particular place on the basilar membrane respond most to a particular frequency of sound.

But place theory cannot explain the encoding of very low frequencies (such as deep bass notes) because none of the acoustic nerve fibers have very low preferred frequencies. However, humans can hear frequencies as low as 20 hertz, so they must be encoded somehow. The answer appears to be *frequency matching,* a process in which certain neurons in the acoustic nerve fire each time a sound wave passes. So a sound wave whose frequency is 25 cycles per second would cause those neurons to fire 25 times per second. Frequency-matching theory is sometimes called the **volley theory** of frequency encoding because the outputs of many cells can combine to create a *volley* of firing.

The nervous system apparently uses more than one way to encode the range of audible frequencies. The lowest frequencies are encoded by frequency matching. Low to moderate frequencies are encoded by frequency matching as well as by the place on the basilar membrane where the wave peaks. And high frequencies are encoded solely by the place on the basilar membrane where the wave peaks. ("In Review: Hearing" summarizes the encoding process and other aspects of the auditory system.)

IN REVIEW

HEARING

Aspect of Sensory System	Elements	Key Characteristics
Energy	Sound: pressure fluctuations of air produced by vibrations	Amplitude, frequency, and complexity of sound waves determine the loudness, pitch, and timbre of sounds.
Accessory structures of the ear	Pinna, tympanic membrane, hammer, anvil, stirrup, oval window, basilar membrane	Changes in pressure produced by the original wave are amplified.
Conversion of sound frequencies into neural activity	Hair cells in the inner ear	Frequencies are encoded by the location of the hair cells receiving the greatest stimulation (place theory) and by the combined firing rate of neurons (volley theory).
Pathway to the brain	Acoustic nerve to thalamus to primary auditory cortex	Auditory cortex examines patterns of information from the auditory nerve, allowing us to sense loudness, pitch, and timbre.

In Review Questions

1. Sound energy is converted to neural activity in an inner ear structure called the __________.
2. Hearing loss due to damage to hair cells or the acoustic nerve is called __________.
3. How high or low a sound sounds is called __________ and is determined by the __________ of a sound wave.

Interaction of the Senses: Synesthesia

At the beginning of this chapter, we described the interaction of two senses, vision and touch, but there are many other kinds of interactions. For example, vision interacts with hearing. If a brief sound occurs just as lights are flashed, it can create the impression of more lights than there actually are (Shams, Kamitani, & Shimojo, 2000). Such interactions occur in everyone, but some people also report *synesthesia* (pronounced "sin-ess-THEE-zhuh"), a more unusual and stronger mixing of senses or of dimensions within senses (Ward, 2013). Some of these people say that they "feel" colors or sounds as touches or that they "taste" shapes or "smell" sounds; others say that they see certain colors, such as red, when they hear certain sounds, such as a trumpet or spoken words

volley theory A theory of hearing that states that the firing rate of an acoustic nerve matches a sound wave's frequency. Also called frequency-matching theory.

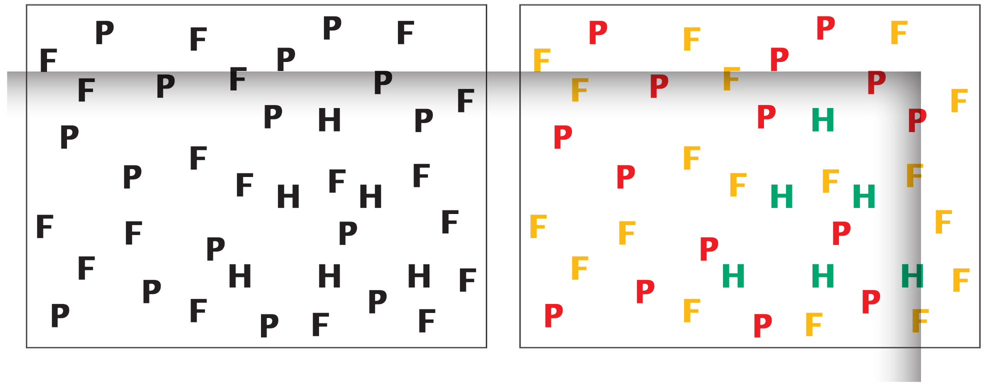


FIGURE 4.15
Synesthesia

In this experiment on synesthesia, a triangular pattern of Hs was embedded in a background of other letters, as shown at left. Most people find it difficult to detect the triangle, but J. C., a person with synesthesia, picked it out immediately because, as simulated at right, he saw the Hs as green, the Fs as yellow, and the Ps as red.

(Bargary et al., 2009). Though once dismissed as poetic delusions, many claims of synesthesia have been supported by scientific investigation (e.g., Hochel & Milán, 2008; see Figure 4.15).

Some researchers suggest that synesthesia occurs partly because brain areas that process one aspect of sensation (such as color) are near areas that process other aspects (such as the features of letters and numbers). Perhaps the synaptic connections between these neighboring areas are more extensive in people who experience synesthesia (Bargary & Mitchell, 2008; Wesson & Wilson, 2010). Synesthesia experiences are also associated with unusually wide-ranging activity in brain regions that process different kinds of sensory information (Hubbard & Ramachandran, 2005).

THE CHEMICAL SENSES: TASTE AND SMELL

Why can't I taste anything when I have a cold?

Some animals cannot see and some cannot hear, but all animals have some form of chemical sense. Chemical senses arise from the interaction of chemicals and receptors. **Olfactory perception**, also known as *olfaction*, or our **sense of smell**, detects chemicals that are airborne, or volatile. **Taste perception**, also known as *gustatory perception*, detects chemicals in solution that come into contact with receptors inside the mouth. These systems are connected.

Smell, Taste, and Flavor

If you have a stuffy nose, everything tastes like cardboard. Why? Because smell and taste act as two components of a single system known as *flavor* (Rozin, 1982). Most of the properties that make food taste good are actually odors detected by the olfactory system, not chemicals detected by the taste system. The scent and taste pathways converge in the *orbitofrontal cortex* of the brain (Rolls, 2006), perhaps explaining how smell and taste come to seem like one sensation.

Both tastes and odors prompt strong emotional responses. For tastes, the emotional reaction to bitterness or sweetness appears to be inborn (Mueller et al., 2005), but for most mammals, including humans, there are few other innate flavor preferences. Most of what we like to eat, and what we avoid, is based on the experiences we have had with various foods (Myers & Sclafani, 2006). Our emotional reactions to odors, too, are shaped by learning (Bartoshuk, 1991). In one study, people smelled a variety of odors while experiencing either pleasant or unpleasant tastes. Later, odors they had once rated as neutral were rated as pleasant if they had been paired with pleasant tastes (Barkat et al., 2008). Emotional reactions to smells can also be affected by expectations. Consider a study in which people sniffed an air sample that was described as coming from either cheddar cheese or body odor. Those who thought they were smelling body odor rated the air sample as more unpleasant than those who thought they were smelling cheese (de Araujo et al., 2005).

olfactory perception (sense of smell) The sense that detects chemicals that are airborne. Also called olfaction.

taste perception The sense that detects chemicals in solution that come into contact with receptors inside the mouth. Also called gustatory perception.

Variations in nutritional state also affect our experience of taste and flavor and our motivation to eat specific foods (Yeomans & Mobini, 2006). If we are deprived of food or don't get enough salt, then sweet or salty things taste better. Nutrition has a less direct influence on protein and fat intake. Protein and fat molecules have no particular taste or smell, so preferring or avoiding foods that contain these nutrients is based on associations between scent cues from other volatile substances in food and on the nutritional results of eating the foods (Bartoshuk, 1991; Schiffman et al., 1999).

We experience warm foods as sweeter, but temperature does not alter our experience of saltiness (Cruz & Green, 2000). Warming releases aromas that rise from the mouth into the nose and create more flavor sensations. This is why some people find hot pizza delicious and cold pizza disgusting. Spicy "hot" foods actually stimulate pain fibers in the mouth because they contain a substance called *capsaicin* (pronounced "kap-SAY-uh-sin") that stimulates pain-sensing neurons that are also stimulated by heat (Reyes-Escogido, Gonzalez-Mondragon, & Vazquez-Tzompantzi, 2011).

Our Sense of Smell

Pinching your nose makes it hard for you to smell odors, and putting a dilator strip on the bridge of your nose opens your nasal passages and intensifies odors (Raudenbush & Meyer, 2002). These effects occur because the nose (and the mouth, to some extent) acts as an accessory structure to collect airborne odor molecules and funnel them toward the olfactory sensory nerve cells (see Figure 4.16). As a result, odor molecules pass into the moist lining of the upper part of the nose—called the *mucous membrane*—and bind to receptors on the dendrites of olfactory neurons, causing a biochemical change. This change, in turn, leads to changes in the firing rates of these neurons, whose axons combine to form the *olfactory nerve* (Dionne & Dubin, 1994). It takes only a single molecule of an odorous substance to

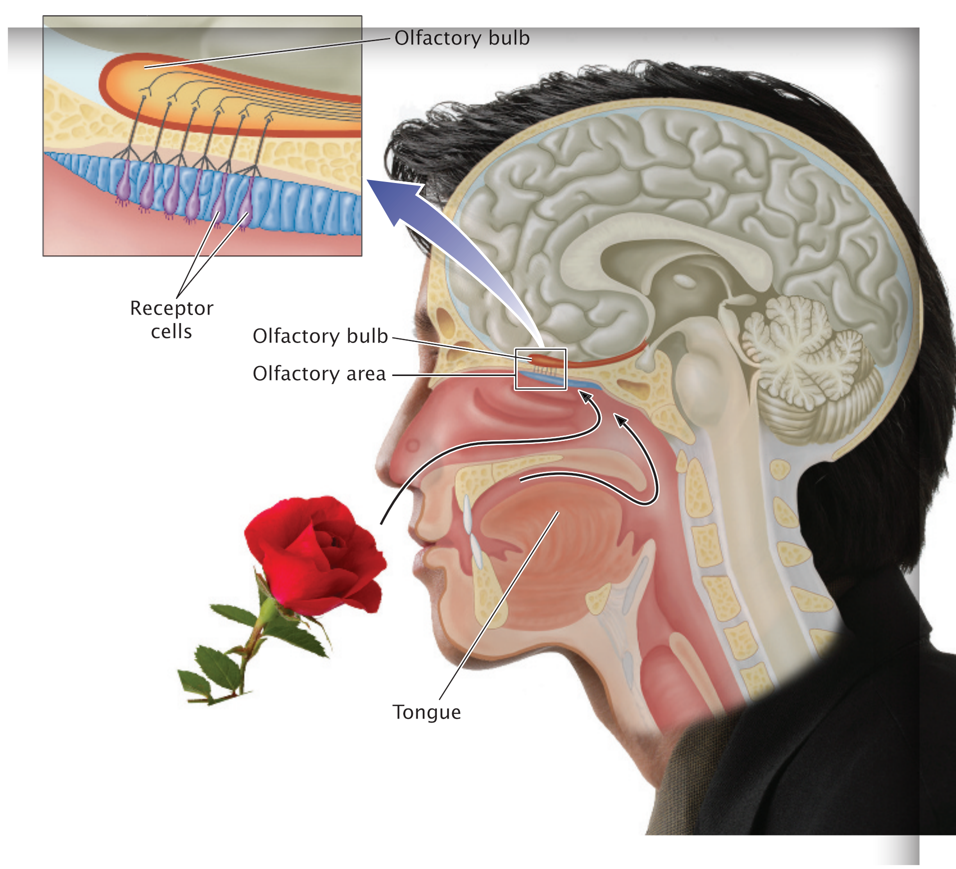


Figure 4.16
The Olfactory System: The Nose and the Rose

Airborne odor molecules reach the olfactory area either through the nose or through an opening in the palate at the back of the mouth. This opening allows us to sample odors from our food as we eat. Nerve fibers pass directly from the olfactory area to the olfactory bulb in the brain, and from there signals pass to areas that are involved in emotion. This arrangement helps explain why odors often trigger strong emotional memories.

Ron Krisel/The Image Bank/Getty Images; © iStockphoto.com/ra3rn cause a change in the activity of an olfactory neuron, but it takes about fifty such molecules before a human will detect the odor (Reed, 2004). The number of molecules needed to trigger an olfactory sensation can vary, however. For example, women are more sensitive to odors during certain phases of their menstrual cycles (Navarrete-Palacios et al., 2003).

Olfactory neurons are repeatedly replaced with new ones, as each lives only about two months (Ruitenberg & Vukovic, 2008). Scientists are especially interested in this process because, as noted in the chapter on biological aspects of psychology, most neurons cannot divide to create new ones. Understanding how new olfactory neurons are generated—and re-create appropriate connections in the brain—may someday help treat brain and spinal cord damage.

There are about a thousand different receptors for odors (Pinto, 2011) but there are even more possible odors in the world, and it seems that humans can discriminate over a trillion different ones (Bushdid et al., 2014). Any particular odor is sensed as a particular *pattern* of responses by these odorant receptors, and humans can discriminate among tens of thousands of different odors (Kajiya et al., 2001; Zou & Buck, 2006). So a rose, a pizza, and your favorite cologne each have a different smell because they stimulate their own unique patterns of activity in your odorant receptors. Scientists are just beginning to understand exactly how this odor encoding system works (Ma, 2007). This work has taken on special importance since the September 11, 2001, terrorist attacks in the United States. Researchers have intensified their efforts to develop an "electronic nose" capable of detecting odorants associated with guns and explosives (Thaler, Kennedy, & Hanson, 2001; Wilson & Baietto, 2011). Versions of these devices are in use at some airports. Elsewhere, electronic noses have been used to detect spoiled food (Abdullah et al., 2012) or assess air quality (Dentoni et al., 2012), and help doctors diagnose and treat patients. One electronic nose can "smell" the breath of asthma patients to predict who will respond to a medication (van der Schee et al., 2013). Other electronic noses detect cancers (Leunis et al., 2013), lung disease (Dragonieri et al., 2012), or liver failure (Wlodzimirow et al., 2013).

Unlike other senses, our sense of smell does not send its messages through the thalamus. Instead, axons from olfactory neurons in the upper nose extend straight up through a bony plate of the skull, directly into the brain, reaching a structure called the **olfactory bulb**, where odor processing continues (Kay & Sherman, 2007). Connections from the olfactory bulb spread throughout the brain (Zou, Li, & Buck, 2005), but they are especially plentiful in the amygdala, a part of the brain involved in emotional experience and learning (Su, Menuz, & Carlson, 2009). In humans, the amygdala is especially active in response to disgusting odors (Zald & Pardo, 1997).

The unique anatomy of the olfactory system may help account for the intense relationship between smells and emotion (Stevenson & Boakes, 2003). Smells tend to evoke emotional states, for example. Associations between particular odors and experiences—especially emotional experiences—are not weakened much by time or later experiences (Lawless & Engen, 1977). So catching a whiff of the cologne once worn by a lost loved one can reactivate intense feelings of love or sadness associated with that person. Odors can also bring back accurate memories of experiences linked with them, especially emotionally positive experiences (Engen, Gilmore, & Mair, 1991; Mohr et al., 2001). These special features of the olfactory system may account for the fact that losing the sense of smell can sometimes be an early sign of brain diseases that disrupt memory and emotion (Ruan et al., 2012). This is why doctors have developed special tests to identify even small changes in the sense of smell (Haxel et al., 2011).

Species ranging from humans to worms have remarkably similar neural mechanisms for sensing smell. And all mammals, including humans, have brain systems for detecting the source of smells by comparing the strength of sensory inputs reaching the left and right nostrils (Porter et al., 2005). Different species vary considerably, however, in their sensitivity to odor and in the degree to which they depend on it for survival. Humans have about 9 million olfactory neurons, compared with about 225 million in dogs, a

olfactory bulb A brain structure that receives messages regarding smell.

species far more dependent on smell to identify food, territory, and receptive mates. Dogs and many other species also have an accessory olfactory system that detects pheromones. **Pheromones** (pronounced "FAIR-oh-mohns") are chemicals that are released by one creature and when detected by another can shape the second animal's behavior or physiology (Swaney & Keverne, 2009). For example, when a male snake detects a chemical on the skin of a female snake, it is stimulated to court her. Other pheromones may be released during emotional states, such as fear, thereby alerting nearby animals of possible danger (Hauser et al., 2011).

The discovery of a possible human gene for pheromone receptors (Rodriguez et al., 2000) suggests that people may have a physiological basis for this type of social communication, but to date there are only limited examples of known pheromone influence on human behavior (Gelstein et al., 2011; Mildner & Buchbauer, 2013; Wyatt, 2009). For example, men have been shown to behave in more sexually oriented ways when around women who are ovulating (Haselton & Gildersleeve, 2011; Miller & Maner, 2010). Other research shows that women make more risky decisions while playing a computer game if they are first exposed to sweat samples taken from men who had been under stress (Haegler et al., 2010). Pheromones have also been shown to cause reproduction-related physiological changes in humans (Grammer, Fink, & Neave, 2005). Specifically, pheromonal signals secreted in women's perspiration can influence nearby women's menstrual cycles. As a result, women living together eventually tend to menstruate at about the same time (Stern & McClintock, 1998). Furthermore, odorants that cannot be consciously detected can nevertheless influence mood and stimulate activity in non-olfactory areas of the brain (e.g., Jacob et al., 2001).

Despite steamy ads for cologne and perfume, however, there is little or no evidence that humans give off or can detect pheromones that promote sexual behavior (Mast & Samuelsen, 2009). In one study, for example, exotic dancers reported that their income from customer tips increased during the ovulation phase of their menstrual cycles (Miller, Tyber, & Jordan, 2007), but the difference was probably not due to pheromones. During ovulation, females tend to speak in a more sexually alluring way (Pipitone & Gallup, 2008), to be more interested in erotic stimuli (Mass et al., 2008), and to be more receptive to courtship (Gueguen, 2008; Rosen & López, 2009). So it could well be that differences in their behavior, and not pheromones, were responsible for their higher tip income during ovulation (Miller, Tyber, & Jordan, 2007).

If a certain scent does enhance a person's readiness for sex, it is probably because the person has learned to associate that scent with previous sexual experiences. There are many other examples of people using olfactory information in social situations. For instance, after just a few hours of contact with their newborn babies, mothers can usually identify their infant by smell (Porter, Cernich, & McLaughlin, 1983). And if infants are breastfed, they can discriminate their own mother's odor from that of other breastfeeding women and appear to be comforted by it (Porter, 1991). Recognizing this odor may help establish the mother-infant bond discussed in the chapter on human development.

Our Sense of Taste

Our receptors for taste are in the taste buds, which are grouped together in structures called **papillae** (pronounced "puh-PILL-ee"). Normally, there are about 10,000 taste buds in a person's mouth, mostly on the tongue but also on the roof of the mouth and on the back of the throat. Unlike the many complexities of flavor, which combines the experiences of smell and taste, when it comes to human taste alone, we detect only a few basic sensations: sweet, sour, bitter, and salty. Each taste bud responds best to one or two of these categories (Zhang et al., 2003), but it responds weakly to others, too. Research has also revealed two additional taste sensations (Rolls, 1997). One, called *umami* (which means "delicious" in Japanese), enhances other tastes and is produced by certain proteins as well as by monosodium glutamate (MSG; Beauchamp, 2009). The other, called *astringent,* is the taste produced by tannins, which are found in tea and wine, for example. Activation

pheromones Chemicals that are released by one creature and detected by another, shaping the second creature's behavior or physiology.

papillae Structures in the mouth on which taste buds are grouped.

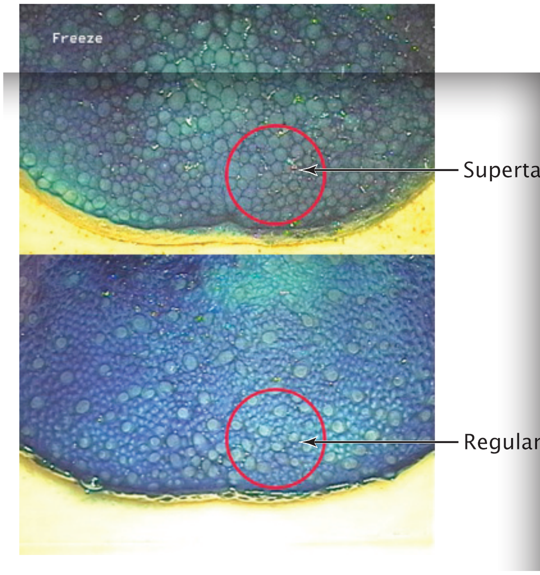


FIGURE 4.17
Are You a Supertaster?

TRY THIS The top photo shows papillae on the tongue of a "supertaster." If you don't mind a temporary stain on your mouth and teeth, you can look at your own papillae by painting the front of your tongue with a cotton swab soaked in blue food coloring. Distribute the dye by moving your tongue around and swallowing; then look into a magnifying mirror as you shine a flashlight on your tongue. The pink circles you see against the blue background are papillae, each of which has about six taste buds buried in its surface. Get several friends to do this test, and you will see that genes create wide individual differences in taste-bud density.

Linda Bartoshuk, Ph.D., Director of Human Research, Center for Smell and Taste, University of Florida

of each specific basic taste activates a correspondingly different set of brain areas (Chen et al., 2011; Rolls, 2009) and causes different patterns of blood flow to the face (Kashima & Hayashi, 2011).

About 25 percent of us are *supertasters*—individuals whose genes have given them an especially large number of papillae on their tongues (Bartoshuk, 2000; Hayes & Keast, 2011; see Figure 4.17). Supertasters are more sensitive than other people to bitterness, as revealed in their reactions to foods such as broccoli, soy products, and grapefruit.

Scientists are learning more and more about how foods interact with taste receptors to signal various tastes (e.g., Chandrashekar et al., 2006), and they are putting the information to good use. Understanding how we detect sweetness, for example, has led to new chemicals that fit into sweetness receptors and taste thousands of times sweeter than sugar. When used as artificial sweeteners, they offer new ways to enjoy good-tasting but low-calorie sweets. Interestingly, it turns out that the sensation of sweetness can bypass the traditional taste system altogether. Scientists have learned that food chemicals evaporate in our mouths as we eat, and some of the "volatile" compounds that result stimulate the smell system. This process can create a sweet taste sensation without involving the taste buds (Tieman et al., 2012). So, in part, you "taste" sweetness with your nose! Researchers are also looking into how taste is affected by other senses such as hearing. It appears, for example, that people may experience the taste of wine differently depending on the type of music they hear while drinking it (North, 2011). ("In Review: Smell and Taste" summarizes our discussion of these senses.)

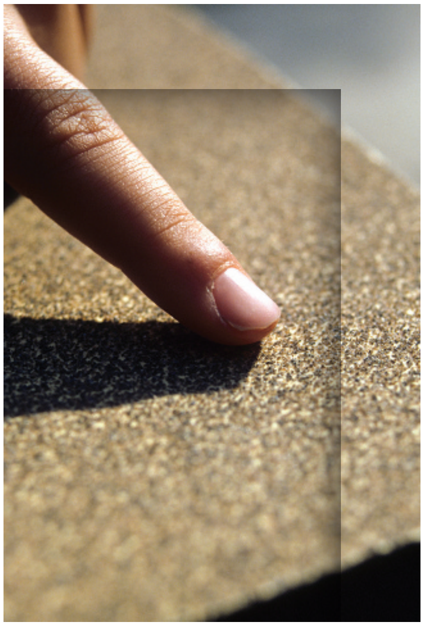
IN REVIEW

SMELL AND TASTE

Aspect of Sensory System	Elements	Key Characteristics
Energy	Smell: volatile chemicals Taste: chemicals in solution	The amount, intensity, and location of the chemicals determine taste and smell sensations.
Structures of taste and smell	Smell: chemical receptors in the mucous membrane of the nose Taste: taste buds grouped in papillae in the mouth	Odor and taste molecules stimulate chemical receptors.
Pathway to the brain	Olfactory bulb and taste buds	Axons from the nose and mouth bypass the thalamus and extend directly to the olfactory bulb.

In Review Questions

1. The flavor of food arises from a combination of __________ and __________.
2. Emotion and memory are linked especially closely to our sense of __________.
3. Perfume ads suggest that humans are affected by __________ that increase sexual attraction.



Timing Is Everything

TRY THIS Some touch sensations depend on the timing of skin stimulation. You can experience this for yourself if you first try to feel the roughness of sandpaper by just placing your fingers on it. A much clearer sensation of roughness will appear if you slide your fingers over the surface (Hollins & Bensamaia, 2007). As you do so, the ridges that form your fingerprints vibrate in succession, activating special receptors in each ridge. Encoded messages about the timing of this sequence of activation tells the brain about the characteristics of the surface you are touching (Hartmann, 2009; Scheibert et al., 2009).

Ted Foxx/Alamy

SENSING YOUR BODY

Which is the largest organ in my body?

Some senses are not located in one place, such as in the eye or the ear. These are the *somatic senses,* also called *somatosensory systems,* and they are spread throughout the body. The **cutaneous senses** include the skin senses of touch, temperature, and pain. Another body sense, called *kinesthesia,* or *kinesthetic perception,* tells the brain where the parts of the body are. Kinesthetic perception is closely related to our sense of balance. Although balance is not strictly a somatosensory system, we describe it here.

Touch and Temperature

People can function and prosper without vision, hearing, or smell. But a person with no sense of touch might not survive. Without this sense, you could not even swallow food, because you could not tell where it was in your mouth and throat. You receive touch sensations through your skin, which is the body's largest organ. The skin covers nearly two square yards of surface area, weighs more than twenty pounds, and has hair virtually everywhere on it. The hairs on your skin do not sense anything, but they bend when contacted, creating pressure at their bases which stimulates touch receptors on and in the skin beneath them. Neural receptors in and just below the skin send the information from "touch" to the brain (Delmas, Hao, & Rodat-Despoix, 2011).

Encoding Touch Information

The sense of touch encodes information about two aspects of an object contacting the skin: its weight and its location. The *intensity* of the stimulus—how heavy it is—is encoded both by the firing rate of individual neurons and by the number of neurons stimulated. A heavy object triggers a higher rate of firing and stimulates more neurons than a light object. The brain "knows" where the touch occurs based on the *location* of the nerves that sense the touch information.

Touch information is organized so that signals from neighboring points on the skin stay next to one another as they travel from the skin through the spinal cord to the thalamus and on to the somatosensory cortex. So just as there is a map of the visual field in the brain, the area of cortex that receives touch information resembles a map of the surface of the body. As with the other senses, input from the left side of the body goes to the right side of the brain, and vice versa.

Adapting to Touch Stimuli

Continuous, unchanging input from all your touch neurons would provide a lot of unnecessary information. Once you get dressed, you don't need to be constantly reminded that you are wearing clothes. Thanks in part to the process of sensory adaptation described earlier, you don't continue to feel your clothes against your skin.

Changes in touch (as when your belt or shoe suddenly feels loose) provide the most important sensory information. The touch sense emphasizes these changes and acts to filter out the excess information. How? Typically, a touch neuron responds with a burst of firing when a stimulus is applied then quickly returns to its baseline firing rate, even though the stimulus may still be in contact with the skin. If the touch pressure increases, the neuron again responds by increasing its firing rate and then slowing down. A few neurons adapt more slowly, however, continuing to fire as long as pressure is applied. By attending to this input, you can sense a constant stimulus **TRY THIS** (try doing this by focusing on touch sensations from your clothes or shoes, or the surface you are sitting on).

Sensing Temperature

Some of the skin's sensory neurons respond to a change in temperature but not to simple contact. "Warm fibers" and "cold fibers" respond to specific temperature changes only.

cutaneous senses Senses including touch, temperature, pain, and kinesthetic perception that are spread throughout the body. Also called somatosensory systems.

A Girl Who Can't Feel Pain

Ashlyn Blocker, shown here being tested at age eleven, was born with a rare genetic disorder that prevented the development of pain receptors. As a result, she feels no pain if she is cut or bruised, if she bites her tongue while eating, or even if she is burned by hot soup or a hot stove. She only knows she has been injured if she sees herself bruised or bleeding, so she must find ways to protect herself from danger without the vital information provided by the pain system.

Erica Brough/The Gainesville Sun

However, many of these neural receptors respond not just to temperature but also to touch, so these sensations sometimes interact. For example, if you touch an object made up of alternating warm and cool sections, you'll have the sensation of intense heat (Thunberg, 1896, cited in Craig & Bushnell, 1994).

Pain

Touch can feel pleasurable, but if the intensity of touch stimulation increases too much, it can turn into a pain sensation. Pain tells you about the impact of the world on your body. It also has a distinctly negative emotional component that interrupts whatever you are doing (Eccleston & Crombez, 1999).

Pain as an Information Sense

The receptors for pain are free nerve endings that come from the spinal cord, enter the skin, and then simply end. Painful stimuli cause the release of chemicals that fit into these specialized receptors in pain neurons, causing them to fire. The axons of pain-sensing neurons release neurotransmitters not only near the spinal cord (thus sending pain information to the brain) but also near the skin (causing inflammation).

Two types of nerve fibers carry pain signals from the skin to the spinal cord. *A-delta fibers* carry signals that feel like sharp, pricking pain sensations; *C-fibers* carry signals that create a sensation of dull, continuous aches and burning sensations. When you stub your toe, for example, that immediate wave of sharp, intense pain is signaled by A-delta fibers, whereas that slightly delayed wave of gnawing, dull pain is signaled by C-fibers. When pain impulses reach the spinal cord, they form synapses with neurons that relay the pain signals to the thalamus and other parts of the brain. Different pain neurons are activated by different types and degrees of painful stimulation (Ploner et al., 2002).

Emotional Aspects of Pain

Specific pathways carry the emotional component of a painful stimulus to areas of the hindbrain, the reticular formation, and the cortex via the thalamus (Shackman et al., 2011). However, our overall emotional response depends greatly on our mood and how we think about the pain (e.g., Kirschneck et al., 2013; Miró, Huguet, & Jensen, 2014). In one study, some participants were told about the kind of painful stimulus they were to receive and when to expect it. Others were not informed. Those who knew what to expect objected less to the pain, even though the sensation was reported to be equally noticeable in both groups (Mayer & Price, 1982). People can lessen their emotional responses to pain by using pain-reducing strategies such as listening to music or focusing on pictures or distracting thoughts (e.g., Buhle et al., 2012; Simavli et al., 2013), especially if they expect these strategies to succeed (Bantick et al., 2002). Another emerging technology is "real-time functional MRI," a system that allows people to watch their own brain activity, live as it occurs, on a video display (Weiskopf, 2012). When people in pain view these images, they can learn movements, behaviors, or relaxation techniques that lessen activity in brain regions that process pain signals, and as they do so, they experience pain relief (Chapin, Bagarinao, & Mackey, 2013).

The Gate Control Theory of Pain

gate control theory of pain A theory suggesting the presence of a "gate" in the spinal cord that either permits or blocks the passage of pain impulses to the brain.

Pain is useful because it can protect you from harm. There are times, though, when enough is enough. Fortunately, the nervous system has several ways to control the experience of pain. One theory about how these mechanisms work is called the **gate control theory of pain** (Melzack & Wall, 1965). The theory suggests that a "gate" in the spinal cord either allows pain signals to reach the brain or stops them. Some details of the original theory were incorrect, but it continues to guide medical efforts at pain management (Mendell, 2014). That's because there is evidence that natural mechanisms can indeed block pain sensations at the level of the spinal cord (DeLeo, 2006; Dickenson, 2002).

For example, input from other skin senses can come into the spinal cord at the same time the pain gets there and take over the pathways that the pain impulses would have used. This may be why we can temporarily relieve pain by rubbing the skin around a wound or using electrical stimulation or creams that produce temperature sensations (Henderson, 2008; Slavin, 2008). It also helps explain why scratching relieves itching; itchy sensations involve activity in fibers located close to pain fibers (Andrew & Craig, 2001; bin Saif et al., 2012).

Unfortunately, pain gates can sometimes be "left open." Chronic pain conditions can be caused by damage or inflammation in the peripheral nervous system that sensitizes incoming pain pathways, making them more likely to send pain signals to the brain (D'Mello & Dickenson, 2008). Gate control theory suggests a way to help individuals with these problems. One study focused on people with pain throughout their bodies caused by *neuropathy*, a condition that damages tiny nerves (Kessler & Hong, 2013). These patients reported reductions in their pain after receiving "whole body vibration therapy," a technique in which they stand on a rapidly vibrating platform for three-minute sessions three times a week for a month (Galea, 2012). Such findings suggest that the spinal pain gate was overwhelmed by the harmless non-painful vibration sensations, making it impossible for pain signals to enter.

The brain itself can close the gate to pain impulses by sending signals down the spinal cord. These messages from the brain block incoming pain signals at spinal cord synapses. The result is **analgesia**, a reduction in pain sensation in the presence of a normally painful stimulus. Aspirin and other *analgesic* drugs can dull pain sensations, but it may also be possible to help the brain close the pain gate without them. For example, research participants who received fifteen minutes of transcranial magnetic stimulation (see Table 3.1 in the chapter on biological aspects of psychology) found it easier to withstand a painful heat stimulus (Borckardt et al., 2007), and patients suffering from pain caused by brain damage are being helped by other brain-stimulation techniques (Arle & Shils, 2008).

Itchy and Scratchy

The gate control theory of pain may partly explain why scratching relieves itching, because itch sensations involve activity in fibers located close to pain fibers (Andrew & Craig, 2001). Scratching itchy skin also activates brain regions related to reward (Vierow et al., 2009) and creates the temporary pleasure you get from doing so. Itch was once thought to result from low-level activity in pain neurons, but we now know that there are sensory pathways from the skin to the brain specifically dedicated to itch (Sun et al., 2009). Scientists are working on ways to block the spinal cord's response to itch signals from the skin. If they succeed, their methods may someday be applied in reducing the suffering of thousands of people afflicted with chronic itchiness (Gawande, 2008).

AJPhoto/Science Source

Natural Analgesics

As described in the chapter on biology and behavior, natural opiates called *endorphins* play a role in the brain's ability to block pain signals. Endorphins are natural painkillers that act as neurotransmitters at many levels of the pain pathway. In the spinal cord, for example, they block the synapses of the fibers that carry pain signals. Endorphins may also relieve pain when the adrenal and pituitary glands secrete them into the bloodstream as hormones. The more endorphin receptors a person has inherited, the more pain tolerance that person has (Benjamin, Wilson, & Mogil, 1999).

Several conditions can cause the body to ease its own pain. For example, endorphins are released where inflammation occurs (Cabot, 2001). A spinal cord endorphin system is activated during the late stages of pregnancy, and the more endorphins a woman spontaneously generates, the less additional analgesia she needs during childbirth (Dabo et al., 2010). An endorphin system is also activated when people believe they are receiving a painkiller, even when they are not (Wager et al., 2011; Zubieta & Stohler, 2009); this may help explain some of the placebo effects described in the chapter on research in psychology (Stewart-Williams, 2004). The resulting pain inhibition is experienced in the part of the body where the person expected it to occur, but not elsewhere (Benedetti, Arduino, & Amanzio, 1999). Physical or psychological stress can also activate natural analgesic systems. Stress-induced release of natural analgesics may account for the fact that injured soldiers and athletes sometimes continue to perform in the heat of battle or competition with no apparent pain (Colloca & Benedetti, 2005).

analgesia Reduction in the sensation of pain in the presence of a normally painful stimulus.

THINKING CRITICALLY

DOES ACUPUNCTURE RELIEVE PAIN?

Acupuncture, a widely used 3,000-year-old Asian medical treatment, is said to relieve pain (Chon & Lee, 2013). The treatment is based on the idea that body energy, called *Qi*, flows along lines called *channels* that link the internal organs to places on the surface of the skin (Vincent & Richardson, 1986). According to this theory, there are fourteen main channels, and a person's health depends on the balance of energy flowing in them. Stimulating the channels by inserting fine needles into the skin and twirling them is said to restore a balanced flow of energy. The needles produce an aching and tingling sensation called *Teh-ch'i* at the site of stimulation and they relieve pain in distant, seemingly unrelated parts of the body (Liu & Akira, 1994; Yan et al., 1992).

What am I being asked to believe or accept?

Acupuncturists claim that twirling needles in the skin can relieve pain caused by everything from tooth extraction to cancer.

What evidence is available to support the assertion?

There is no scientific evidence for the existence of the energy channels proposed by acupuncturists (Wang, Kain, & White, 2008). However, there *is* evidence from functional magnetic resonance imaging (MRI) studies that stimulating acupuncture sites changes activity in brain regions related to pain sensory regulation (Zhang et al., 2009 Jiang et al., 2013). Numerous studies have also shown positive results in 50 to 80 percent of patients treated by acupuncture for various kinds of pain (e.g., Brinkhaus et al., 2006). One study found, for example, that acupuncture was more effective than an acupuncture-like placebo treatment in reducing the frequency of chronic migraine headaches (Li et al., 2012). A summary of eleven other headache studies found greater overall reductions in pain among patients who had been randomly assigned to receive acupuncture as compared to those randomly assigned to receive standard drug therapies (Linde et al., 2009). In another study, after acupuncture was added to a program of drugs and exercise, fibromyalgia patients had less pain, and the benefit remained at a three-month follow-up (Targino et al., 2008). Yet another study found that after receiving acupuncture, hospitalized infants needed less analgesic or sedative medications and showed improved eating and respiration (Gentry et al., 2011). Several studies have found that acupuncture reduces pain and nausea after surgeries, decreasing the need for pain-relieving drugs and reducing patients' distress (Cheong et al., 2013).

Are there alternative ways of interpreting the evidence?

Yes. Evidence about acupuncture might be interpreted as simply confirming that the body's pain-killing system can be stimulated by external means. Acupuncture may merely provide one activating method (Pariente et al., 2005); other methods might work just as well. For example, low-intensity laser beams applied to acupuncture sites can reduce arthritic knee pain even though no needles and no "true" acupuncture is used (Al Rashoud et al., 2013). There may even be other methods that are even more efficient than acupuncture (Petrovic et al., 2005; Ulett, 2003). We already know, for example, that successful placebo treatments for human pain appear to operate by activating the endorphin system.

What additional evidence would help evaluate the alternatives?

Placebo-controlled studies of acupuncture are needed, but it has been difficult to control for the placebo effect in acupuncture treatment, especially in double-blind fashion (e.g., Derry et al., 2006; Kaptchuk et al., 2006). How could a study be set up so that therapists would not know whether the treatment they are giving is acupuncture or not? What placebo treatment could look and feel like having a needle inserted and twirled in the skin? Some researchers have created single-blind placebo acupuncture using "sham" techniques in which the needles do not actually break the skin or are inserted but not twirled or are inserted in locations that should not, according to acupuncturists, have any effect on

(*continued*)

pain. In one study of "sham" techniques, research participants were indeed unable to tell whether they were getting genuine acupuncture (Enblom et al., 2008). So far, only a few studies have used sophisticated "sham" methods (e.g., Al Rashoud et al., 2013; Li et al., 2012), and some have found acupuncture to be no more effective than placebo methods (e.g., Cherkin et al., 2009; Haake et al., 2007; Linde et al., 2009). More controlled experiments could eventually reveal the degree to which placebo effects play a role in the results of acupuncture treatment.

Researchers must also learn more about what factors govern whether acupuncture will activate the endorphin system. Other important unknowns include the types of pain for which acupuncture is most effective, the types of patients who respond best, and the precise procedures that are most effective. Knowing more about the general relationship between internal pain-killing systems and external methods for stimulating them would also be valuable.

What conclusions are most reasonable?

Although acupuncture is no cure-all, in some circumstances it may help to relieve pain and reduce other unpleasant sensations like nausea. What we still don't know is exactly why this may be and through what mechanism any genuine effects might operate. Acupuncture remains a fascinating phenomenon, a treatment used on millions of people around the world. Some critics argue that further expenditures for acupuncture research are not warranted, but it seems likely that studies will continue. The quality of these studies' methodology and the nature of their results will determine whether acupuncture finds a more prominent place in Western medicine.

Sensing Body Position

Most sensory systems receive information from the outside world, such as the light reflected from a flower or the feeling of cool water. But as far as the brain is concerned, the rest of the body is "outside" too. You know about the position of your body and what each of its parts is doing only because sensory systems provide this information to your brain. Your sense of body movement and position is called **proprioception** (meaning "received from the self" and pronounced "pro-pree-oh-SEP-shun").

Kinesthetic Perception

In the biological aspects of psychology chapter, we describe the case of Christina, a woman who did not recognize her own body. She had lost her **kinesthetic perception** (pronounced "kin-es-THEH-tic"), which tells us where the parts of the body are in relation to one another. To better appreciate kinesthetic perception, try this: Close your eyes; then hold your arms out in front of you and touch your two index fingers together. You probably did this easily because your kinesthetic sense told you where each finger was with respect to your body. You depend on kinesthetic information to guide all your movements, from walking to complex athletic actions. These movement patterns become simple and fluid because with practice the brain uses kinesthetic information automatically. Normally, kinesthetic information comes primarily from **proprioceptors**, which are special receptors in the joints and muscles (Proske, 2006). These receptors send information to the brain about the stretching of muscles. When the position of the bones changes, receptors in the joints set off neural activity. This encoded information goes to the spinal cord and then to the thalamus, along with sensory information from the skin. Finally, it goes to the cerebellum and to the somatosensory cortex, both of which help coordinate movements (Longo & Haggard, 2010).

TRY THIS

proprioception The sensory processes that tell us about the location of our body parts and what each is doing.

kinesthetic perception The proprioceptive sense that tells us where the parts of the body are with respect to one another.

proprioceptors Neural receptors that provide information about movement and body position.

sense of equilibrium (vestibular sense) The proprioceptive sense that provides information about the position of the head and its movements.

Balance

Have you ever been on a roller coaster? How did you feel when the ride ended? Your **sense of equilibrium**, sometimes called the **vestibular sense** (pronounced "ves-TIB-u-ler"), tells your brain about the position of your head (and, to some degree, the rest of your body) and about its general movements. You have probably heard it referred to as the *sense of balance.* People usually become aware of the sense of equilibrium only when they overstimulate it and become dizzy or experience motion sickness.

The organs for the vestibular sense are in the inner ear. As shown in Figure 4.14, each inner ear has two fluid-filled *vestibular sacs* that contain tiny, delicate crystals called *otoliths* ("ear stones") that rest on hair endings. There are also three arc-shaped tubes, called *semicircular canals,* and they, too, are filled with fluid. Tiny hairs extend into the fluid in the canals. When your head moves, the otoliths shift in the vestibular sacs and the fluid moves in the semicircular canals, stimulating hair endings. These responses to head movement activate neurons that travel along the acoustic nerve, signaling the brain about the amount and direction of head movement (Angelaki & Cullen, 2008). If the otoliths become displaced within the vestibular sacs, as they do in a condition called *benign paroxysmal positional vertigo,* or BPPV, the result can be intense spinning sensations (Fife, 2009). BPPV can sometimes be treated by having the patient lie down and make specific head movements that shift allow the otoliths to go back into their correct position (Bruintjes et al., 2014).

TRY THIS

Neural connections from the vestibular system to the cerebellum help coordinate bodily movements. Connections to the part of the autonomic nervous system that affects the digestive system help create the nausea that may follow overstimulation of the vestibular system—by a roller-coaster ride, for instance. Finally, connections to the eye muscles produce *vestibular-ocular reflexes,* which cause your eyes to move opposite to your head movements. These reflexes allow you to focus on one spot even when your head is moving. You can experience these reflexes by having a friend spin you around on a stool for a while. When you stop, try to fix your gaze on one point in the room. You'll be unable to do so, because the excitation of the vestibular system will cause your eyes to move repeatedly in the direction opposite from the way you were spinning. Our vestibular reflexes adjust to the lack of gravity in outer space (Thornton, 2011), which is why astronauts returning to Earth have postural and movement difficulties until their vestibular systems readjust to gravity (Paloski, 1998). (See "In Review: Body Senses" for a summary of our discussion of touch, temperature, pain, and kinesthesia.)

IN REVIEW

BODY SENSES

Sense	Energy	Conversion of Physical Energy to Nerve Activity	Pathways and Characteristics
Touch	Mechanical deformation of skin	Neural receptors in the skin (may be stimulated by hair on the skin)	Nerve endings respond to changes in weight (intensity) and location of touch.
Temperature	Heat	Sensory neurons in the skin	Changes in temperature are detected by warm-sensing and cool-sensing fibers. Temperature interacts with touch.
Pain	Increases with intensity of touch or temperature	Free nerve endings in or near the skin surface	Changes in intensity cause the release of chemicals detected by receptors in pain neurons. Some fibers convey sharp pain; others convey dull aches and burning sensations.

(*continued*)

IN REVIEW

BODY SENSES (CONT.)

Sense	Energy	Conversion of Physical Energy to Nerve Activity	Pathways and Characteristics
Kinesthetic perception	Mechanical energy of joint and muscle movement	Neural receptors in muscle fibers	Information from muscle fibers is sent to the spinal cord, thalamus, cerebellum, and cortex.
Sense of equilibrium	Mechanical energy of head movement	Neural receptors in the inner ear	Information about fluid moving in the semicircular canals is sent to the brain along the acoustic nerve.

In Review Questions

1. Gate control theory offers an explanation of why we sometimes do not feel ___________.
2. Professional dancers look at the same spot as long as possible during repeated spins. They are trying to avoid the dizziness caused when the sense of ___________ is overstimulated.
3. Without your sense of ___________ you would not be able to swallow food without choking.

FOCUS ON RESEARCH METHODS

THE CASE OF THE MYSTERIOUS SPELLS

Early in this chapter, we discussed the specific energy doctrine, which says that each sensory system can send information to the brain only about its own sense, regardless of how the stimulation occurs. So gently pressing on your closed eye will send touch sensations from the skin on your eyelid and visual sensations from your eye. This doctrine applies even when stimulation of sensory systems arises from within the brain itself. The following case study illustrates an example in which spontaneous brain activity resulted in erotic sensations.

What was the researcher's question?

A thirty-one-year-old woman we'll call "Linda" reported that for many years, she had been experiencing recurring "spells" that began with what seemed like sexual sensations (Janszky et al., 2002). These "orgasm-like euphoric erotic sensations" were followed by a staring, unresponsive state in which she lost consciousness. The spells, which occurred without warning and in response to no obvious trigger, interfered severely with her ability to function normally in everyday life. Linda was examined by József Janszky, a neurologist, who suspected that she might be suffering from epilepsy, a seizure disorder in which nerve cells in the brain suddenly start firing uncontrollably. Seizures that activate the motor area of the cerebral cortex will cause uncontrollable movements, seizures that activate visual cortex will create the sensation of images, and so on. Could there be a specific brain region that, when activated by a seizure, cause the sensations of orgasm that are normally brought on by external stimulation?

How did the researcher answer the question?

It is not easy to study the neurological basis of sexual sensations because most people are understandably reluctant to allow researchers to monitor their sexual activity. In the process of diagnosing Linda's problem, Janszky had a unique opportunity to learn something about the origin of orgasmic sensations without intruding on his patient's privacy. His approach exemplifies the *case study* method of research. As described in the chapter on research in psychology, case studies

(*continued*)

focus intensively on a particular individual, group, or situation. Sometimes they lead to important insights about clinical problems or other phenomena that occur so rarely that they cannot be studied through surveys or controlled experiments. In this case, Janszky decided to study Linda's brain activity while she was actually having a spell. He reasoned that if the spells were caused by seizures in a specific brain region, it might be possible to eliminate the problem through surgery.

What did the researcher find?

Linda's brain activity was recorded during five of her spells, using electroen-cephalography (EEG), a method described in the chapter on biological aspects of psychology. During each spell, the EEG showed that she was having seizures in the right temporal lobe of her brain. A subsequent MRI of her brain revealed a small area of abnormal tissue in the same area of the right temporal lobe. The organization of nerve cells in abnormal brain tissue can make it easier for seizures to occur, so Linda was advised to have some tissue surgically removed from the problem area. After the surgery, her seizures stopped.

What do the results mean?

Janszky concluded that Linda had been having "localization-related epilepsy," meaning that her spells were seizures coming from a specific brain location. This conclusion was supported by the fact that she had right temporal lobe seizures on the EEG each time she had a spell. Her MRI showed an abnormality in the same region that commonly gives rise to seizures, and her spells disappeared after the abnormality was removed. Linda's case also led Janszky to suggest that the right temporal lobe may play a special role in creating the sensory experience of orgasm.

What do we still need to know?

Janszky's suggestion might be correct, meaning that activation of the right temporal cortex may be sufficient for the sensory experience of orgasm. But at least one important question remains: How specific is the linkage between activity in this brain region and the sensory experiences of orgasm? Could seizures in other brain regions cause similar experiences? Is right temporal cortex activity one of many ways to generate orgasm-like experiences, or is it necessary for these experiences? Answering this question would be easier if we knew whether Linda continued to experience orgasms during sexual activity. If she did, the implication would be that the area of right temporal lobe tissue that was removed was not necessary for the experience of orgasm. Unfortunately, Janszky's report is silent on this point, but future cases and further research will no doubt shed additional light on this fascinating sensory puzzle.

PERCEPTION

How do sensations become perceptions?

So far, we have explored how sensory information reaches the brain. Let's now consider the processes of perception that allow the brain to make sense of that information. These perceptual processes can sometimes make the difference between life and death. For example, at a traffic circle in Scotland, fourteen fatal accidents occurred in one year, partly because drivers did not slow down as they approached the circle. After warning signs failed to solve the problem, Gordon Denton, a British psychologist, found a clever solution. He recommended that white lines be painted across the road leading to the circle, in a pattern something like this:

/ / / / / / / / / ///

Crossing these lines, which were spaced progressively more closely, gave drivers the impression that they were speeding up, so their automatic response was to slow down (Denton, 1980). During the fourteen months after Denton's idea was implemented, there were only two fatalities at the traffic circle! Similar kinds of striping patterns are now widely used throughout Britain and on approaches to some towns and intersections in the United States. Denton's solution depended partly on his knowledge of sensation but mostly on the principles of human perception.

Some perceptual tasks take attention and effort, as when a child struggles to recognize printed letters. But as experienced readers know, a lot of the perceptual work that transforms sensory information into meaningful experiences happens automatically without conscious awareness. To illustrate the workings of these complex processes, psychologists draw attention to *perceptual failures*—cases in which we perceive stimuli incorrectly (e.g., Ito, 2012; Witt, Linkenauger, & Proffitt, 2012). Just as drivers at the traffic circle incorrectly perceived themselves as speeding up, you will probably perceive the two lines in Figure 4.18 as differing in length, even though they are the same.

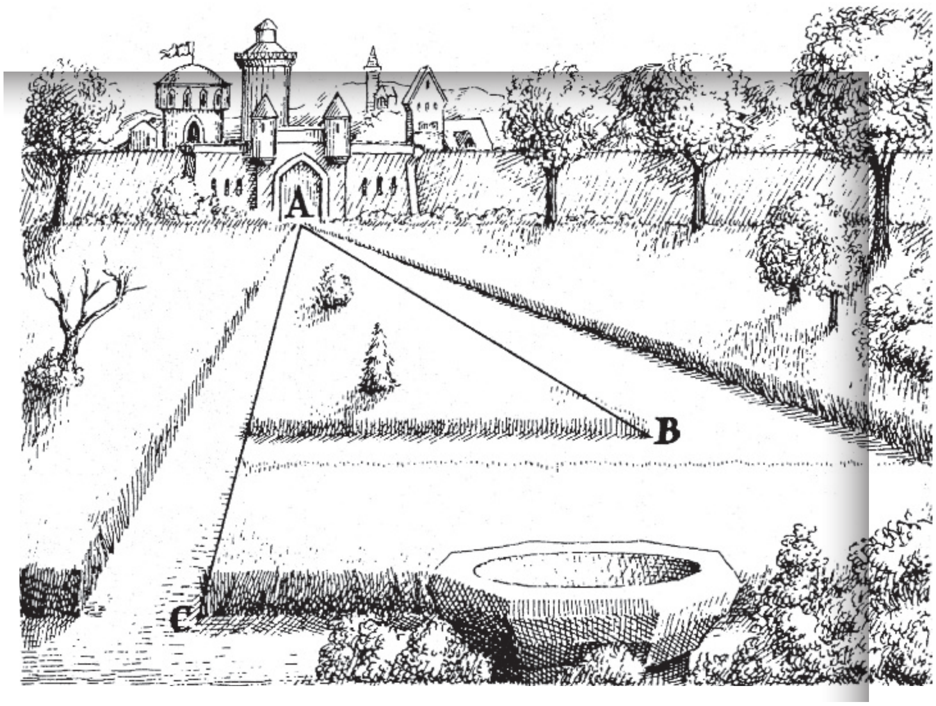


FIGURE 4.18
Misperceiving Reality

TRY THIS Measure lines A–C and A–B. They are exactly the same length, but you probably perceived A–C as longer. Why? Partly because your visual system tries to interpret all stimuli as three-dimensional, even when they are not. A three-dimensional interpretation of this drawing would lead you to see the two lines as the edges of two parallel paths, one of which ends closer to you than the other. Your eyes tell you that the two paths start at about the same point (the castle entrance), so you assume that the closer line must be the longer of the two.

Source: Gardner (1988).

ORGANIZING THE PERCEPTUAL WORLD

What determines how I perceive my world?

To further appreciate the wonder of the complicated perceptual work you do every day, imagine yourself driving on a busy road searching for Barney's Diner, an unfamiliar restaurant where you are to meet a friend. The roadside is crammed with signs of all shapes and colors, some flashing, some rotating. If you are ever to recognize the sign that says "Barney's Diner," you will have to impose some sort of organization on this overwhelming mixture of visual information. How do you do this? How do you know where one sign ends and another begins? And how do you know that an apparently tiny sign is not really tiny but just far away?

Principles of Perceptual Organization

Before you can recognize the Barney's Diner sign, your perceptual system must separate that sign from its background of lights, colors, letters, and other competing stimuli. Two basic principles—*figure ground perception* and *grouping*—guide this initial organization.

Figure and Ground

When you look at a complex scene or listen to a noisy environment, your perceptual apparatus automatically emphasizes certain features, objects, or sounds. These emphasized features become the **figure**. This part of the visual field has meaning, stands in front of the rest, and always seems to include contours or edges. These contours and edges separate

figure The part of the visual field that has meaning.

the figure from the less relevant background, called the **ground** (Rubin, 1915; Zhang & von der Heydt, 2010). As you drive toward an intersection, a stop sign will become a figure that stands out clearly against the background of trees or buildings.

To experience your own **figure ground discrimination** ability, look at Figure 4.19. Notice that you can decide how to organize the stimuli in the drawings. You can repeatedly reverse figure and ground to see faces, then a vase, then faces again (4.19B) or to see the word *figure* or the word *ground* (4.19A). The fact that you can mentally manipulate these "reversible" images means that your perceptual systems are not just recording devices that passively absorb incoming sensations; you play an active part in organizing what you perceive. We also usually organize sensory stimulation into only one perceptual category at a time. This is why it is difficult to see both a vase and two faces—or the words *figure* and *ground*—at the same time.

FIGURE 4.19
Reversible Images

TRY THIS These *reversible images* can be organized by your perceptual system in two ways. If you perceive Part A as the word "figure," the space around the letters becomes meaningless background. Now emphasize the word "ground," and what had stood out a moment ago now becomes background. In Part B, when you emphasize the white vase, the black profiles become background; if you organize the faces as the figure, what had been a vase now becomes background. We normally tend to see smaller, lower elements in a scene as figure and larger, higher elements as ground (Vecera, Vogel, & Woodman, 2002), but images like these don't allow us to use that rule of thumb.

Grouping

Why do certain parts of the world become figure and others become ground, even when nothing in particular stands out in the pattern of light that falls on the retina? The answer is that certain properties of stimuli lead you to group them together more or less automatically.

In the early 1900s, several German psychologists described the principles behind this grouping of stimuli. They argued that people perceive sights and sounds as organized wholes. These wholes, they said, are different from the sum of the individual sensations, just as a house is something other than a pile of bricks and wood and glass. Because the German word for figure or shape is *Gestalt* (pronounced "ge-SHTALT"), these researchers became known as *Gestalt psychologists*. Max Wertheimer, one of the founders of Gestalt psychology, proposed a number of principles that describe how the perceptual system "glues" raw sensations together in particular ways (Wagemans et al., 2012; Wertheimer, 1923):

1. *Proximity*. The closer objects or events are to one another, the more likely they are to be perceived as belonging together, as Figure 4.20(A) illustrates.
2. *Similarity*. Elements that are similar in size, color, orientation, and texture are perceived to be part of a group, as in Figure 4.20(B). This is why students wearing the same school colors at a stadium will be perceived as belonging together even if they are not seated close together.
3. *Continuity*. Sensations that appear to create a continuous form are perceived as belonging together, as in Figure 4.20(C).
4. *Closure*. We tend to mentally fill in missing parts of incomplete objects, as in Figure 4.20(D). The gaps are easy to see, but the tendency to link disconnected parts can be so strong that you may perceive faint connections that aren't actually there (Lleras & Moore, 2006).
5. *Simplicity*. We tend to group features of a stimulus in a way that provides the simplest interpretation of the world. You can see the simplicity principle in action in Figure 4.20(D), where it is simpler to see a single cube than an assortment of separate and unrelated arrows and Ys.
6. *Common fate*. Sets of objects that move in the same direction at the same speed are perceived together. So even though the individual birds in a flock are separated from each other as they fly, they will be perceived as a group. Choreographers and marching-band directors use this principle of common fate when they arrange for groups or subgroups of dancers or musicians to move in unison, causing the audience to perceive waves of motion or a single large moving object.

Stephen Palmer (1999) has identified three additional grouping principles:

1. *Synchrony*. Stimuli that occur at the same time are likely to be perceived as coming from the same source. For example, if you see a car up ahead stop violently at the same instant that you hear a crash, you will probably perceive these visual and auditory stimuli as part of the same event.

ground The contourless part of the visual field; the background.

figure ground discrimination The ability to organize a visual scene so that it contains meaningful figures set against a less relevant ground.

2. *Common region.* Stimuli located within some boundary tend to be grouped together. The boundary can be created by an enclosing perimeter, as in Figure 4.20(E), a region of color, or other factors.

3. *Connectedness.* Stimuli that are connected by other elements tend to be grouped together. In Figure 4.20(F), the circles connected by dotted lines seem to go together even though they are farther apart than some pairs of unconnected circles. Here, the principle of connectedness appears more important than the principle of proximity.

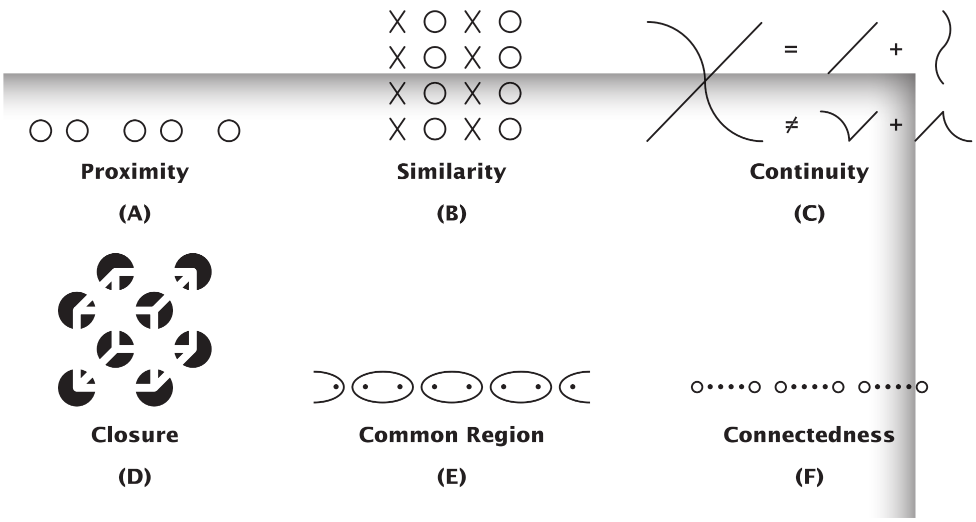


FIGURE 4.20
Gestalt Principles of Perceptual Grouping

We tend to perceive Part A as two groups of two circles plus one single circle rather than as, say, five circles. In Part B, we see two columns of Xs and two columns of Os, not four rows of XOXO. We see the X in Part C as being made out of two continuous lines, not a combination of the odd forms shown. In Part D, we fill gaps so as to perceive a hollow cube. In Part E, we tend to pair up dots in the same oval even though they are far apart. Part F shows that connected objects are grouped together.

Why do we organize the world according to these grouping principles? One answer may be that they reflect the way stimuli are often organized in the natural world. Nearby elements are in fact more likely than separated elements to be part of the same object. Stimulus elements moving in the same direction at the same rate are also likely to be part of the same object. Your initial impression of the cube in Figure 4.20(D) reflects this *likelihood principle* in action. At first glance, you probably saw the cube as being below you rather than above you. This tendency makes adaptive sense, because boxes and other cube-shaped objects are more likely to be on the ground than hanging in midair.

Perception of Location and Distance

One of the most important perceptual tasks we face is to determine where objects and sound sources are located. This task involves knowing both their two-dimensional position (left or right, up or down) and their distance from us.

Two-Dimensional Location

Determining whether an object is to your right or your left appears to be simple. All the perceptual system has to do, it seems, is determine where the object's image falls on the retina. If the image falls on the center of the retina, then the object must be straight ahead. But when an object is, say, far to your right, and you focus its image on the center of your retina by turning your head and eyes toward it, you do not assume it is straight ahead. Instead, your brain calculates an estimate of the object's location by combining information about where an image strikes the retina with information about the movement of your eyes and head.

When it comes to locating the source of sounds, your brain depends on cues about differences in the information received by each of your ears. Sound waves coming toward the right side of your head will reach the right ear before reaching the left ear. Similarly, a sound coming toward the right side of your head will seem a little bit louder to the right ear than to the left ear, because your head blocks some of the sound to the left ear. The brain uses these slight differences in the timing and the intensity of a sound as cues to locate its source. Visual cues are often integrated with auditory cues to determine the exact identity and location of the sound source. However, there are times when the two senses produce conflicting impressions; in such cases, we tend to believe our eyes rather than our ears. This bias toward using visual information is known as *visual dominance.*

Depth Perception

We are able to experience the world in three-dimensional depth even though the visual information we receive from it is projected onto two-dimensional retinas. This is possible because of **depth perception**, our ability to perceive distance. Depth perception, in turn, is made possible by *stimulus cues* provided by the environment and also by the properties of our visual system (Anderson, 2003; Hildreth & Royden, 2011). To some extent, people perceive depth through the same cues that artists use to create the impression of depth and distance on a two-dimensional canvas. Figure 4.21 demonstrates several of these cues:

FIGURE 4.21
Stimulus Cues for Depth Perception

TRY THIS See if you can identify the cues of relative size, interposition, linear perspective, height in the visual field, textural gradient, and shadows that combine to create a sense of three-dimensional depth in this photograph. Notice, too, that sidewalk artist Kurt Wenner has used some of these same cues to create a dramatic illusion of depth in his drawing. (You can see more of Wenner's amazing work at http://www.kurtwenner.com/index.htm.)

Dies Irae. Copyright © Kurt Wenner, 1988

- One of the most important depth cues is *interposition*: Closer objects block the view of things farther away. This cue is illustrated in Figure 4.21 by the couple walking away from the camera. Because their bodies block out part of the buildings, we perceive them as being closer to us than the buildings are.
- You can see the principle of *relative size* operating in Figure 4.21 by measuring the images of that same couple and comparing it to the size of the man in the foreground. If two objects are assumed to be about the same size, the object producing a larger image on the retina is perceived as closer than the one producing a smaller image.
- Another cue comes from *height in the visual field*: On the ground, objects that are more distant are usually higher in the visual field than those that are nearby. Because the building in the center of Figure 4.21 is higher than the people in the restaurant, the building appears to be farther away from you. This is one reason why objects higher in the visual field are more likely to be interpreted as the background for objects that are lower in a scene (Vecera, Vogel, & Woodman, 2002).

depth perception Perception of distance, allowing us to experience the world in three dimensions.

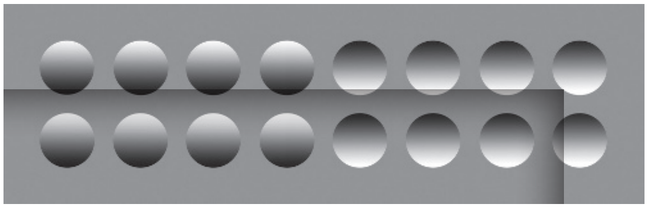
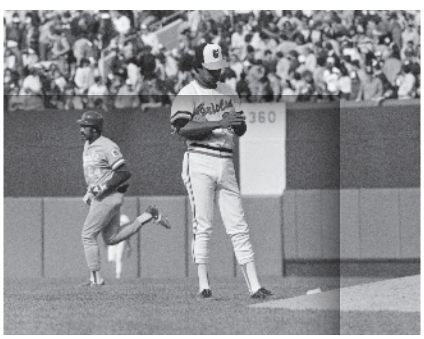


FIGURE 4.22

Light, Shadow, and Depth Perception

TRY THIS Shadows create three-dimensional impressions of bumps on the left side of this drawing and of dents on the right side. But if you turn the book upside down, the bumps will look like dents, and the dents will look like bumps. This reversal in depth perception occurs partly because people normally assume that illumination comes from above and interpret the pattern of light and shadow accordingly (Adams, Graf, & Ernst, 2004; Cook et al., 2008).



A Case of Depth Misperception

The runner in this photo is actually farther away than the man on the pitcher's mound. But because he is lower, not higher, in the visual field the runner appears smaller than normal rather than farther away (Vecera, Vogel, & Woodman, 2002).

AP images

TRY THIS

- The tiny figures near the center of Figure 4.21 are seen as very far away because they are near a point where the buildings on each edge of the plaza, like all parallel lines that recede into the distance, appear to converge toward a single point. This apparent *convergence* provides a cue called *linear perspective*. The closer together two converging lines are, the greater the perceived distance.
- Notice that the street in Figure 4.21 fades into a hazy background. Increased distance usually produces less clarity, and this *reduced clarity* is interpreted as a cue for greater distance. Hazy, distant objects also tend to take on a bluish tone, which is why art students are taught to add a little blue when mixing paint for deep background features.
- *Light and shadow* also contribute to the perception of three dimensions (Kingdom, 2003; Ramachandran, 1988). The buildings in Figure 4.21 are seen as three-dimensional, not flat, because of the shadows on some of their surfaces. Figure 4.22 shows a more dramatic example.
- An additional stimulus-based depth cue comes from continuous changes across the visual field, called *gradients*. For example, a textural gradient is a graduated change in the texture, or "grain," of the visual field, as you can see in the plaza and the street in Figure 4.21. Texture appears more compact and less detailed as distance increases. As the texture of a surface changes across the retinal image, you perceive a change in distance.

An important visual depth cue that cannot be demonstrated in Figure 4.21, or in any other still image, comes from motion. You may have noticed, for example, that when you look out the side window of a moving car, objects nearer to you seem to speed across your visual field, whereas objects in the distance seem to move slowly, if at all. This difference in the apparent rate of movement is called **motion parallax**, and it provides cues to differences in the distance of various objects.

Some depth cues result from the way human eyes are built and positioned. Recall that to bring an image into focus on the retina, the lens of the eye changes shape, or *accommodates*. Information about the muscle activity involved is used by brain so that this *accommodation cue* helps create the perception of distance.

The depth cues described so far are called *monocular* cues because we can detect them with just one eye. There are also two *binocular* depth cues which are produced by the relative location of our two eyes. The first is **eye convergence**. Because each eye is located at a different place on the skull, the eyes must converge, or rotate inward, to project the same image on each retina. The closer the object, the more the eyes must converge. Eye muscles send information about this convergence to the brain, which processes it as a distance cue. You can experience this feedback from your eye muscles by holding up a finger at arm's length and then trying to keep it in focus as you move it toward your nose.

The second binocular cue occurs because each of our two eyes sees the world from a slightly different angle. The difference between these different retinal images is called **retinal disparity**, also known as *binocular disparity*. The difference, or disparity, between images decreases for objects that are far away and increases for objects that are nearby. The brain not only combines the two images of an object but also takes into account how much they differ. This information helps generate the impression of a single object that has a rich sense of depth as well as height and width and is located at a particular distance. Three-dimensional movies and some virtual reality systems use these *binocular cues* to create the appearance of depth in a two-dimensional stimulus. They show each eye an image of a scene as viewed from a slightly different angle.

In short, many cues—some present in the environment and in retinal images, others arising from the structure of the visual system—combine to give us a powerful and accurate sense of depth and distance.

motion parallax A depth cue whereby a difference in the apparent rate of movement of different objects provides information about the relative distance of those objects.

eye convergence A depth cue that results when the eyes rotate to project the image of an object on each retina.

retinal disparity A depth cue based on the difference between the retinal images received by each eye.

Retinal Disparity and Distance

TRY THIS There is a smaller difference, or disparity, between each eye's view of an object when the object is far away than when it is close by. The amount of this retinal disparity helps us estimate the object's distance from us. To see for yourself how retinal disparity changes with distance, hold a pen vertically about six inches in front of your nose; then close one eye and notice where the pen is in relation to the background. Now open that eye, close the other one, and notice how much the pen "shifts." These are the two different views your eyes have of the pen. Repeat this procedure while holding the pen at arm's length. Notice that there is now less disparity or "shift," because there is less difference in the angles from which your two eyes see the pen.

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Perception of Motion

Sometimes the most important property of an object is its motion—how fast it is going and where it is heading. Many cues about motion come from *optical flow,* or the changes that take place in retinal images across the visual field. As in the case of depth perception, you automatically translate this two-dimensional information into a three-dimensional experience. One particularly meaningful pattern of optical flow is known as **looming**, the rapid expansion in the size of an image so that it fills the retina. When an image looms, there is an automatic tendency to perceive it as an approaching object. If the expansion is as fast to the right as to the left and as fast above as below, this information signals that the object is approaching the eyes directly. In other words, duck! One reason that young children are at high risk when crossing streets alone is that they may not yet perceive the danger posed by cars and other rapidly looming objects (Wann, Poulter, & Purcell, 2011).

We are lucky that movement of the retinal image isn't the only factor contributing to motion perception. If it were, everything in sight would appear to move every time you moved your eyes and head (Ölveczky, Baccus, & Meister, 2003). This doesn't happen, because as noted earlier, the brain receives and processes information about the motion of the eyes and head (Wexler, 2005). TRY THIS If you look around you right now, tables, chairs, and other stationary objects will not appear to move because your brain determines that all the movement of images on your retinas is due to the movement of your eyes and head (Goltz et al., 2003). But now close one eye and wiggle your open eyeball by gently pushing your lower eyelid. Because your brain receives no signals that your eye is being moved by its own muscles, everything in the room will appear to move.

When your body is moving, as in a car, the flow of visual information across the retina combines with information from the vestibular and touch senses to give you the experience of being in motion. If the car accelerates, you feel pressure from the back of the seat and feel your head tilting backward. Motion sickness may result if you perceive visual flow without appropriate sensations from other parts of the body, particularly the vestibular senses. This explains why you might feel nauseous while in a motion simulator or playing certain video games, especially those with virtual reality technology. The images suggest that you are moving through space when there is no real motion.

Other illusions of motion are more enjoyable. The most important of these occurs when still images appear, one at a time, in rapid succession, as they do on videos. Because each image differs slightly from the preceding one, the brain sees the objects in each image at one location for only a fraction of a second before they disappear and immediately reappear in a slightly different location. The entertaining result is the **stroboscopic illusion** of motion; when objects disappear and then quickly reappear nearby, the brain assumes that they have moved smoothly from one location to another. The same illusion is at work when it appears that flashing lights on a theater or casino sign are moving around the sign.

Perceptual Constancy

Suppose that one sunny day you are watching someone walking toward you along a tree-lined path. The visual sensations produced by this person are actually very strange. For one thing, the size of the image on your retinas keeps getting larger as the person gets closer. TRY THIS To see this for yourself, hold out a hand at arm's length and look at someone far away. The retinal image of that person will be so small that you can cover it with your hand. If you do the same thing when the person is three feet away, the retinal image will be too large to be covered by your hand, yet you will perceive the person as being closer now, not bigger. Similarly, as you watch the person pass from bright sunshine through the shadows of trees, your retinas receive images that shift back and forth from light to dark, but you perceive the person's coloring as staying the same.

looming A motion cue whereby rapid expansion in the size of an image fills the available space on the retina.

stroboscopic illusion An illusion of motion that is created when we see slightly different images or slightly displaced lights flashed in rapid succession.

These examples illustrate **perceptual constancy**, the perception that objects keep their size, shape, color, and other properties despite changes in their retinal image. Without this aspect of perception, you would experience the world as a place where solid objects continuously changed their properties.

Size Constancy

Why does an object's perceived size stay more or less constant, regardless of changes in the size of its retinal image? One reason is that the brain perceives a change in the distance of an object and automatically adjusts the perception of size (Combe & Wexler, 2010). Specifically, the *perceived size* of an object is equal to the size of the retinal image multiplied by the perceived distance (Holway & Boring, 1941). As an object moves closer, or as we move closer to it, the size of its retinal image increases yet the perceived distance decreases at the same rate. As a result the perceived size of the object remains constant. If a balloon is inflated in front of your eyes, perceived distance remains constant and the perceived size (correctly) increases as the size of the retinal image increases.

Shape Constancy

TRY THIS

The principles behind shape constancy are closely related to those of size constancy. To see shape constancy at work, close this book (remember what page you're on) and tilt it toward and away from you several times. The book will continue to look rectangular, even though the shape of its retinal image changes dramatically as you move it. Your brain automatically combines information about retinal images and distance as movement occurs. In this case, the distance information has to do with the difference in distance between the near and far edges of the book.

Brightness Constancy

TRY THIS

Even with dramatic changes in the amount of light striking an object, our perception of the object's brightness remains relatively constant (MacEvoy & Paradiso, 2001). To see this for yourself, place a piece of charcoal in sunlight and a piece of white paper in nearby shade. The charcoal will look very dark and the paper very bright, yet a light meter would tell you that much more light energy is reflected from the sun-bathed coal than from the shaded paper. The reason is partly that the charcoal is the darkest object relative to its sunlit background and the paper is the brightest object relative to its background of shade. As shown in Figure 4.23, the brightness of an object is perceived in relation to its background.

FIGURE 4.23
Brightness Contrast

TRY THIS At first glance, the inner rectangle on the left probably looks lighter than the inner rectangle on the right. But carefully examine the inner rectangles alone by covering their surroundings and you will see that both are of equal intensity. The brighter surround in the right-hand figure leads you to perceive its inner rectangle as relatively darker.

perceptual constancy The perception that objects retain the same size, shape, color, and other properties despite changes in their retinal image.

Size Illusions

Usually the visual perceptual system works automatically and perfectly to create correct impressions of depth, distance, and size. Sometimes, though, it can fail, resulting in *size illusions* such as the ones shown in Figure 4.24. Why does the monster that is placed higher in Figure 4.24(A) look larger than the lower one even though they are exactly the same size? The converging lines in the tunnel provide depth cues telling you that the higher monster is farther away. Because the retinal image of the "distant" monster is the

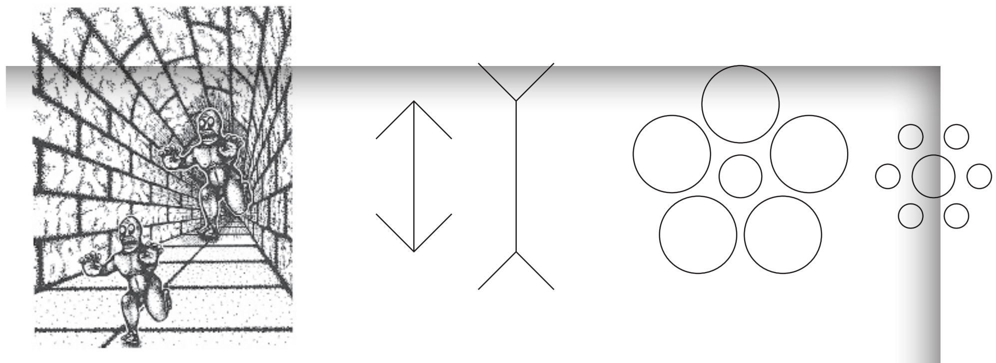

FIGURE 4.24
Three Size Illusions

These illusions are named for the scientists who described them. In Part A, a version of the Ponzo illusion, the upper monster looks bigger but is actually the same size as the lower one. In the Müller-Lyer illusion (Part B), both vertical lines are actually of equal length; in the Ebbinghaus illusion shown in Part C, both center circles are exactly the same size. To prove that you can't always believe your eyes, measure these drawings for yourself.

same size as the "closer" one, your perceptual system calculates that the more distant monster must be bigger. This shows the principle of size constancy at work: When two objects have retinal images of the same size, you perceive the one that seems farther away as larger. Now look at Figure 4.24(B). The two vertical lines are the same length, but the one on the right looks longer. Why? One possible reason is that the perceived length of an object is based on what frames it. When the frame is perceived as larger, as on the right side of Figure 4.24(B), the line segment within it is perceived as larger too (Rock, 1978). In Figure 4.24(C), the inner circle at the left looks smaller than the one at the right because, like the brightness of the center rectangles in Figure 4.23, the inner circles are judged in relation to what surrounds them. Because perception is based on many principles, and can be affected by many factors, illusions like these probably reflect the violation of more than one of them. (See "In Review: Principles of Perceptual Organization and Constancy.")

IN REVIEW

PRINCIPLES OF PERCEPTUAL ORGANIZATION AND CONSTANCY

Principle	Description	Example
Figure ground discrimination	Certain objects or sounds automatically become identified as figure, whereas others become meaningless background.	You see a person standing against a building, not a building with a person-shaped hole in it.
Grouping	Properties of stimuli lead us to automatically group them together. These include proximity, similarity, continuity, closure, simplicity, common fate, synchrony, common region, and connectedness.	People who are sitting together, or who are dressed similarly, are perceived as a group.
Depth perception	The world is perceived as three-dimensional, with help from stimulus cues such as relative size, height in the visual field, interposition, linear perspective, reduced clarity, light and shadow, and gradients, and from visual system cues such as accommodation, eye convergence, and retinal disparity.	A person who looks tiny and appears high in the visual field will be perceived as being of normal size, but at a great distance.
Perceptual constancy	Objects are perceived as constant in size, shape, color, and other properties despite changes in their retinal images.	A train coming toward you is perceived as getting closer, not larger; an advertising sign is perceived as rotating, not changing shape.

(continued)

IN REVIEW

PRINCIPLES OF PERCEPTUAL ORGANIZATION AND CONSTANCY (CONT.)

In Review Questions

1. The movement we see in videos is due to a perceptual illusion called __________.
2. People who have lost an eye also lose the ability to use __________ depth cues, two of which are called __________ and __________.
3. The grouping principle of __________ allows you to identify objects seen through a picket fence.

RECOGNIZING THE PERCEPTUAL WORLD

How do I recognize familiar people?

In discussing how people organize the perceptual world, we have set the stage for addressing one of the most vital questions that perception researchers must answer: How do we recognize what objects are? If you are driving in search of Barney's Diner, exactly what happens when your eyes finally locate the pattern of light that spells out its name?

To know that you have finally found what you've been looking for, your brain must analyze incoming patterns of information and compare them with information about the target that you have stored in memory. If the brain finds a match, recognition takes place. Once you recognize a stimulus as belonging to a particular category, your perception of that stimulus may never be the same again. Look at Figure 4.25. Do you see anything familiar? If not, turn to Figure 4.26; then look at Figure 4.25 again. You should now see it in an entirely new light. The difference between your "before" and "after" experiences is the difference between the sensory world before and after a perceptual match occurs and recognition takes place.

FIGURE 4.25
Categorizing Perceptions
TRY THIS What do you see here? For the identity of this figure, turn to Figure 4.26.

FIGURE 4.26
Another Version of Figure 4.25
Now that you can identify a dog in this figure, it should be much easier to recognize when you look back at the original version.

How does this matching process occur? Some aspects of recognition begin at the "top." That is, they are based on applying knowledge, expectations, and other psychological factors. This phenomenon is called **top-down processing**, because it involves high-level, knowledge-based information. Other aspects of recognition begin at the "bottom," relying on specific detailed information from the sensory receptors and assembling them into a whole. This phenomenon is called **bottom-up processing**, because it begins with basic information units that serve as a foundation for recognition.

Bottom-Up Processing

All along the path from the eye to the brain, certain cells respond to selected features of a stimulus. The stimulus is first analyzed into these *basic features,* which are then recombined to create the perceptual experience.

What are these features? As mentioned earlier, certain cells specialize in responding to lines, edges, corners, and stimuli that have specific orientations in space (Hubel & Wiesel, 1979). For example, some cells in the cerebral cortex fire only in response to a diagonal line of light, so they act as *feature detectors* for diagonal lines. The analysis by such feature detectors early in the sensation-perception sequence may contribute to recognition of letters or judgments of shape. Other features seem to be detected and assembled farther down the visual pathway (Kubilius, Wagemans, & de Beeck, 2011). Color and motion are sensory features that appear to be analyzed separately in different parts of the brain before full perceptual recognition takes place (e.g., Levinthal & Franconeri, 2011). The brain also apparently analyzes patterns of light and darkness in the visual scene. Analyzing these patterns may help us perceive textural gradients, which in turn help us to judge depth and recognize the general shape of blurry images.

Psychologists know that feature analysis is involved in pattern recognition because they have been able to determine what type of object a person is looking at (e.g., a face versus a house) based on the pattern of activity occurring in visual processing areas of the person's brain (Haxby et al., 2001; Taylor & Downing, 2011).

Top-Down Processing

Bottom-up feature analysis can explain why you recognize the letters in a sign for Barney's Diner. But why is it that you can recognize the sign more easily if it appears where you were told to expect it rather than a block earlier? And why can you recognize it even if a few letters are missing from the sign? Top-down processing seems to be at work in those cases. In

top-down processing Aspects of recognition guided by higher-level cognitive processes and by psychological factors such as expectations.

bottom-up processing Aspects of recognition that depend first on information about stimuli that come up to the brain from the sensory systems.

top-down processing, people use their knowledge to make inferences, or "educated guesses," that help them recognize objects, words, or melodies, especially when sensory information is vague or ambiguous (DeWitt & Samuel, 1990; Rock, 1983). For example, once you knew that there was a dog in Figure 4.25, it became much easier for you to perceive one. Similarly, police officers find it easy to recognize familiar people on blurry security-camera videos, but it is much more difficult for them to identify strangers (Burton et al., 1999).

Top-down processing illustrates that our experiences create **schemas**, mental representations of what we know and expect about the world. Schemas can bias our perception to be more likely to recognize one specific pattern over another by creating a *perceptual set*—that is, a readiness to perceive a stimulus in a certain way. These expectations operate automatically, whether we are aware of them or not. For example, look again at Figure 4.20D. We see a hollow cube floating above the circles because once the closure principle has filled in the gaps, our experience tells us that the most likely interpretation of the resulting pattern of lines is a cube—even though it is not really there. Other perceptual sets are more conscious. For example, with deadly shooting incidents so much in the news, many people have become "set" to perceive ambiguous objects as weapons, especially in public places. A recent example occurred in Olympia, Washington, when police received a report of a man wearing a ski mask, carrying what appeared to be an assault rifle. A citywide manhunt ensued, and schools went into lockdown. The man had no idea about all the fuss until he noticed a helicopter tracking him. Police found that his "assault rifle" was actually an umbrella, and the "ski mask" just a black turtleneck and cap. Another misperceived umbrella caused a three-hour lockdown at a Carolina college after someone reported seeing a "gunman" near campus.

Expectancy can be shaped by the *context* in which a stimulus occurs. For example, we expect to see people, not gorillas, on a city street, so when a large gorilla escaped from Boston's Franklin Park zoo in 2003, a woman who saw him at a bus stop later said, "I thought it was a guy with a big black jacket and a snorkel on" (MacQuarrie & Belkin, 2003). Context has biasing effects for sounds as well as sights. When shots are heard on a downtown street, they are often perceived as a car backfiring. The same sounds heard at a shooting range would immediately be interpreted as gunfire.

Motivation is another aspect of top-down processing that can affect perception. For example, people tend to perceive desirable objects as being closer to them than less desirable ones (Balcetis & Dunning, 2010). They're also more likely to see objects as weapons if they feel angry or threatened (Baumann & DeSteno, 2010), and a very hungry person might at first misperceive a sign for "Burger's Body Shop" as indicating a place to eat (Radel & Clément-Guillotin, 2012). Similarly, perhaps you remember a time when an obviously incompetent referee incorrectly called a penalty on your favorite sports team. You knew the call was wrong because you clearly saw the other team's player at fault. But if you had been cheering for that other team, chances are good you would have agreed with the referee's call.

schemas Mental representations of what we know and expect about the world.

Top-Down and Bottom-Up Processing Together

Top-down and bottom-up processing usually work together to help us recognize the perceptual world (Förster, 2012). This interaction is beautifully illustrated by the process of reading. When the quality of the raw stimulus on the page is poor, as in Figure 4.27, top-down processes compensate to make continued reading possible. They allow you to fill in the gaps where words or letters are missing, or if they're shown backwards in a mirror, thus giving you a general idea of the meaning of the text (Duñabeitia, Molinaro, & Carreiras, 2011).

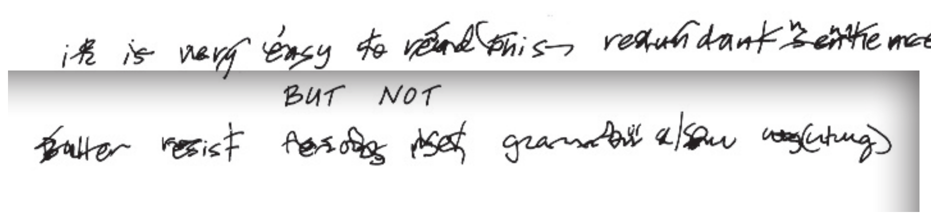

FIGURE 4.27
Interaction of Top-Down and Bottom-Up Processing

TRY THIS Which obscured line do you find easier to read: the first or the second? Top-down processing should help you read the obscured text on the first line. However, in the second line, the words are not related, so top-down processing cannot operate.

You can fill in the gaps because the world is *redundant;* it provides multiple clues about what is going on. So even if you lose or miss one stimulus in a pattern, other clues can help you recognize the pattern. There is so much redundancy in written language, for instance, that many of the words and letters you see are not needed. Fo- ex-mp-e, y-u c-n r-ad -hi- se-te-ce -it- ev-ry -hi-d l-tt-r m-ss-ng. Similarly, vision in three dimensions normally provides multiple cues to depth, making recognition of distance easy and clear. It is when many of these cues are eliminated that ambiguous stimuli create the sorts of depth illusions discussed earlier.

In hearing, too, top-down processing can compensate for ambiguous stimuli. In one experiment, participants heard strings of five words in meaningless order, such as "wet brought who socks some." There was so much background noise, however, that participants who heard this sequence could recognize only about 75 percent of the words (Miller, Heise, & Lichten, 1951). The words were then read to a second group of participants in a meaningful order (e.g., "who brought some wet socks"). The second group was able to recognize almost all of the words, even under the same noisy conditions. In fact, it took twice as much noise to reduce their performance to the level of the first group. Why? When the words were in meaningless order, only bottom-up processing was available. Recognizing one word was no help in identifying the next. Meaningful sentences, however, provided a more familiar context and allowed for some top-down processing. Hearing one word helped the listener make a reasonable guess (based on knowledge and experience) about the others. (See "In Review: Mechanisms of Pattern Recognition" for a summary of bottom-up and top-down processing.)

IN REVIEW

MECHANISMS OF PATTERN RECOGNITION

Mechanism	Description	Example
Bottom-up processing	Raw sensations from the eye or the ear are analyzed into basic features, such as edges, color, or movement; these features are then recombined at higher brain centers, where they are compared with stored information about objects or sounds.	You recognize a dog as a dog because its features—four legs, barking, panting—match your perceptual category for "dog."
Top-down processing	Knowledge of the world and experience in perceiving allow people to make inferences about the identity of stimuli, even when the quality of raw sensory information is low.	On a dark night, a small, vaguely seen blob pulling on the end of a leash is recognized as a dog because the stimulus occurs at a location where we would expect a dog to be.

In Review Questions

1. Your ability to read a battered old sign that has some letters missing is a result of ___________ processing.
2. When stimulus features match the stimuli we are looking for, ___________ takes place.
3. Schemas can create a ___________ that makes us more likely to perceive stimuli in a particular way.

Culture, Experience, and Perception

We have been talking as if all aspects of perception work or fail in the same way for everyone everywhere. The truth is, though, that virtually all perceptual abilities are shaped to some extent by the sensory experiences we have or have not had. For example, people are better at judging the size and distance of familiar objects than of unfamiliar ones. Size and shape constancy, too, depend partly on the knowledge and experience that tell us that most solid objects do not suddenly change their size or shape. The experience-based nature of perception can also be seen in brightness constancy: You perceive charcoal to be darker than a sheet of writing paper partly because no matter how much light the charcoal reflects, you *know* charcoal is black. Experience even teaches us when to ignore certain stimulus cues (Yang & Kubovy, 1999). To fully experience the depth portrayed in a painting, for example, you have to ignore ridges, scratches, dust, or other texture cues from the canvas that would remind you of its flatness. And the next time you're watching TV, notice the indistinct reflections of objects in the room that appear on the screen. You've learned to ignore these reflections, so it will take a little effort to perceive them and a lot of effort to focus on them for long.

TRY THIS

What if you hadn't had a chance to learn or practice these perceptual skills? One way to explore this question is through case studies of people who have been blind for decades and then have had surgery that restored their sight. It turns out that these people can immediately recognize simple objects and perceive movement, but they usually have problems with other aspects of perception. For example, M. M. had been blind from early childhood. When his vision was restored in his forties, he adjusted well overall, but he still has difficulty with depth perception and object recognition (Fine et al., 2003). Often, as people move toward or away from him, they appear to shrink or inflate. Identifying common objects can be difficult for him, and faces pose a particular challenge. To recognize individuals, he depends on features such as hair length or eyebrow shape. M. M. also has trouble distinguishing male faces from female ones and has great difficulty recognizing the meaning of facial expressions. He is unable to experience many of the perceptual illusions shown in this chapter, such as the closure illusion in Figure 4.20(D) or the size illusions in Figure 4.24. M. M.'s early blindness appears to have prevented his brain from fully developing the neural connections necessary for drawing accurate inferences about the visual world.

For the rest of us, too, the ability to experience perceptual illusions depends on our sensory history. People who grow up in significantly different sensory environments are likely to have noticeably different perceptual experiences (Caparos et al., 2012). For example, the size illusion shown in Figure 4.24(A) is strongest in the "carpentered world," where seeing straight lines is an everyday experience (Leibowitz et al., 1969). Responses to illusions such as this one are not as strong for people from rural areas of the Third World in which the visual environment contains more irregular and curved lines than straight ones (Coren & Girgus, 1978). Similarly, responses to depth cues in pictures and paintings differ in cultures that do and do not use such images to represent reality. People in the Me'n or the Nupa cultures of Africa, who have little experience with pictorial representation, have a more difficult time judging distances shown in pictures than do people in picture-oriented cultures (see Figure 4.28). These individuals also tend to have a harder time sorting pictures of three-dimensional objects into categories, even though they can easily sort the objects themselves (Derogowski, 1989). And residents of dense tropical rain forests, where most objects are seen over relatively short distances, may have some difficulty when asked to judge the distance of remote objects on an open plain (Turnbull, 1961). In other words, although the structure and principles of human perceptual systems tend to create generally similar views of the world for all of us, our perception of reality is also shaped by experience, including the experience of living in a particular culture (Chua, Boland, & Nisbett, 2005; Hedden et al., 2008).

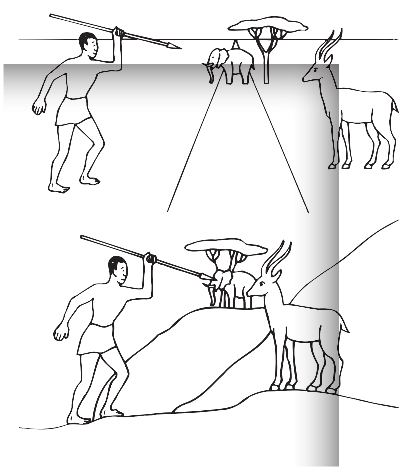

FIGURE 4.28
Culture and Depth Cues

People in various cultures were shown drawings like these and asked to judge which animal is closer to the hunter. Those in cultures that provide lots of experience with pictured depth cues choose the antelope, which is at the same distance from the viewer as the hunter. Those in cultures less familiar with such cues may choose the elephant, which, though closer on the page, is more distant when depth cues are considered.

LINKAGES How do infants perceive the world? (*a link to Human Development*)

LINKAGES

PERCEPTION AND HUMAN DEVELOPMENT

We have seen that perception is influenced by the knowledge and experience we gain over time, but what perceptual abilities do we start with? To learn about infants' perception, psychologists have studied two inborn patterns called habituation and dishabituation. Infants spend significantly less time looking at stimuli that are perceived to be unchanging. This is habituation. If they see a stimulus that is perceived to be new and different, they greatly increase their looking. This is dishabituation. Using the habituation/dishabituation technique, researchers have found that newborns can perceive differences in stimuli showing various amounts of black-and-white contrast but that they distinguish color differences very poorly, if at all (e.g., Bornstein, 2006). Other studies using the same methods have shown that newborns can perceive differences in the angles of lines (Slater et al., 1991). Taken together, these studies suggest that we are born with the basic components of feature detection.

Are we also born with the ability to combine features into perceptions of whole objects? This is still a matter of debate. We know that at one month, infants concentrate their gaze on one part of an object, such as the corner of a triangle (Goldstein, 2002). By two months, though, their eyes systematically scan around the edges of the object. This change suggests that they are now perceiving the pattern, or shape, of the object, not just its component features. However, other researchers have found that newborns show dishabituation (that is, they pay attention) when a familiar set of features are combined in a new way. So even newborns appear to notice and keep track of the ways some stimulus features are put together (Slater et al., 1991).

Infants may also be innately tuned to perceive at least one important complex pattern of features: the human face. In one study of newborns, patterns such as those in Figure 4.29 were moved slowly past the infants' faces (Johnson et al., 1991). The infants moved their heads and eyes to follow these patterns. But they tracked the facelike pattern shown on the left side of Figure 4.29 significantly farther than any of the nonfaces. The differences in tracking in this study and others indicate that infants can tell faces from nonfaces and are more interested in faces, or at least in facelike patterns (Cassia et al., 2008; Simion et al., 2003). Why should this be? Investigators who take an evolutionary approach suggest that interest in human faces is adaptive because it helps newborns focus on their only source of food and care. Further support for the evolutionary perspective comes from the finding that infants are also excellent at detecting potentially threatening stimuli, such as snakes (LoBue & DeLoache, 2010).

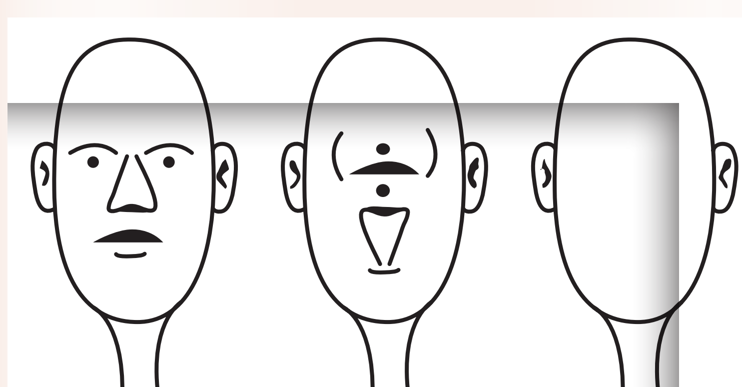

FIGURE 4.29
Infants' Perceptions of Human Faces

Newborns show significantly greater interest in the facelike pattern on the left than in either of the other patterns. Evidently some aspects of face perception are innate.

Other research on perceptual development suggests that our ability to accurately perceive depth and distance develops more slowly than our ability to recognize shapes (see Figure 4.30).

(*continued*)

For example, infants' ability to use binocular disparity and motion cues to judge depth appears to develop sometime after about three months of age (Yonas, Arterberry, & Granrud, 1987). They do not use textural gradients and linear perspective as cues to depth until they are five to seven months old (Arterberry, Craton, & Yonas, 1993; Bhatt & Bertin, 2001).

FIGURE 4.30
The Visual Cliff

The *visual cliff* is a glass-topped table that creates the impression of a sudden drop-off. A ten-month-old placed at what looks like the edge will calmly crawl across the shallow side to reach a parent but will hesitate and cry rather than crawl over the "cliff" (Gibson & Walk, 1960). Changes in heart rate show that infants too young to crawl also perceive the depth but are not frightened by it. Here is another example of the adaptive interaction of nature and nurture: Depth perception appears shortly after birth, but fear and avoidance of dangerous depth do not develop until an infant is old enough to crawl into trouble.

Mark Richards/PhotoEdit

In summary, there is little doubt that many of the basic building blocks of perception are present within the first few days after birth. The basics include such depth cues as accommodation, eye convergence, and information about movement (Arterberry & Yonas, 2000; Valenza & Bulf, 2007). Maturation of the visual system adds to these basics as time goes by. Over the first few months after birth, the eye's fovea gradually develops the number of cone cells necessary for high visual acuity and perception of fine details (Goldstein, 2002). Visual experience is also necessary. Experience teaches the infant to recognize unified patterns and objects and to interpret depth and distance cues and use them to move safely through the world (Bhatt & Quinn, 2011; Quinn & Bhatt, 2005). Like so many aspects of human psychology, perception is the result of a blending of heredity and environment. From infancy onward, the perceptual system creates a personal reality.

ATTENTION

Can you run out of attention?

Believe it or not, you still haven't found Barney's Diner! By now, you understand *how* you will recognize the right sign when you perceive it. But how can you be sure you *will* perceive it? The diner's sign will appear as one small piece of a sensory puzzle that also includes road signs, traffic lights, sirens, talk radio, and dozens of other stimuli. You can't perceive all of them at once. To find Barney's, you're going to have to be sure that the information you process includes the stimuli that will help you reach your goal. In short, you are going to have to pay attention.

Attention is the process of directing and focusing certain psychological resources to enhance perception, performance, and mental experience. We use attention to *direct* our sensory and perceptual systems toward certain stimuli, to *select* specific information for further processing, to *allocate* the mental energy required to do that processing, and to *regulate* the flow of resources necessary for performing a task or coordinating several tasks at once (Wickens & Carswell, 2012).

attention The process of directing and focusing certain psychological resources to enhance perception, performance, and mental experience.

Psychologists have discovered three important characteristics of attention.

1. *Attention improves mental processing.* You often need to concentrate attention on a task to do your best at it.

2. *Attention takes effort.* Prolonged concentration of attention can leave you drained (McNay, McCarty, & Gold, 2001). When you're already tired, focusing attention on anything becomes more difficult.
3. *Attention is limited.* When your attention is focused on reading this book, for instance, you will have less attention left over to listen to a conversation in the next room.

Directing Attention

TRY THIS

To experience the process of attention, try "moving it around" a bit. When you finish reading this sentence, look at something behind you, then face forward and notice the next sound you hear, then visualize your best friend, then focus on how your tongue feels. You just used attention to direct your perceptual systems toward different aspects of your external and internal environments. When you looked behind you, shifting attention involved *overt orienting*—pointing sensory systems at a particular stimulus. But you shifted attention to an image of your friend's face without having to move a muscle. This is called *covert orienting.* (We have heard a rumor that students sometimes use covert orienting to shift their attention from their lecturer to thoughts that have nothing to do with the lecture.)

How do you control, or allocate, your attention? Research shows that control over attention can be voluntary or involuntary (Yantis, 1993). *Voluntary,* or goal-directed, control over attention occurs when you purposely focus so that you can perform a task. Voluntary control reflects top-down processing because attention is guided by knowledge-based factors such as intention, beliefs, expectations, and motivation (e.g., Colzato et al., 2010; Liuzza et al., 2011; Pacheco-Unguetti et al., 2010). As people learn certain skills, they voluntarily direct their attention to information they once ignored (Zhang, Jiang, & He, 2012). For example, experienced drivers are better than new drivers are at noticing all that is going on around their vehicles, including events taking place far down the road (Koustanaï, Van Elslande, & Bastien, 2012).

When some aspect of the environment—such as a loud noise—diverts your attention, control is said to be *involuntary*, or stimulus driven. Stimulus characteristics that tend to capture attention include abrupt changes in lighting or color (such as flashing signs), movement, and the appearance of unusual shapes (Folk, Remington, & Wright, 1994). Engineering psychologists' findings about which stimuli are most likely to attract—and distract—attention have been used in the design of everything from websites to operator warning devices for airliners, nuclear power plants, and other complex systems (Clay, 2000; Hervet et al., 2011; Laughery, 1999). Other psychologists use the results of attention research to help design advertisements, logos, and product packaging that grab potential customers' attention.

As already mentioned, when we attend to some stimuli, we are less able to attend to others. In other words, attention is *selective*. It's like a spotlight that can illuminate only a part of the world at any particular moment. So if you focus intently on your reading or on a computer game, you may fail to perceive even dramatic changes in other parts of your environment (Hallett, Labert, & Regan, 2012). This phenomenon is called *inattentional blindness* (Mack, 2003; Mack & Rock, 1998). In one study, a researcher asked college students for directions to a campus building (Simons & Ambinder, 2005). During each conversation, two "workmen" carrying a large door passed between the researcher and the student. As the door hid the researcher from the student's view, one of the "workmen" took his place. This new person then resumed the conversation with the student as though nothing had happened. Amazingly, only half of the students noticed that they were suddenly talking to a new person! The rest had apparently been paying so much attention to the researcher's question or to the map he was showing that they did not notice what he looked like. Other studies have shown that most research participants can become so focused on their cell phone conversations or on their assigned task of counting the passes made during a basketball video that they fail to notice a clown riding by on a unicycle or a woman in a gorilla suit walking across the court (Hyman et al., 2010; Simons & Chabris, 1999).

FIGURE 4.31
Change Blindness

TRY THIS If you didn't immediately notice the difference between these photos, it was probably because you focused your attention on the similarity of their main features rather than on their specific elements. This common tendency results in blindness to a small, but obvious difference (Wilford & Wells, 2010; see page 136 for the answer). Just as we are usually unaware of our visual blind spot, we tend to be blind to inattentional blindness. We think we can see everything around us, but accidents are caused everyday because people sometimes fail to see what is right in front of their eyes (Galpin, Underwood, & Crundall, 2009). Fortunately, it may be possible to improve attentional skills through training and practice (Martens, 2011; Pollatsek, Romoser, & Fisher, 2011).

Dr. Ronald Rensink

Anyone can be affected by inattentional blindness. In one study, highly skilled doctors looking at computerized tomography scans of patients' chests were searching so intently for the presence of lung tumors that most of them failed to notice the image of a gorilla that researchers had superimposed onto the scans (Drew, Võ, & Wolfe, 2013)! Magicians take advantage of inattentional blindness when they use sudden movements or other attention-grabbing stimuli to draw our attention away from the actions that lie behind their tricks. To experience a type of inattentional blindness known as "change blindness," take a look at the photos in Figure 4.31.

Your search for Barney's Diner will be helped by your ability to overtly allocate attention to a certain part of the environment. It would be made even easier if Barney's had the only flashing sign on the road. As the most intense stimulus around you, it would attract your attention automatically. Psychologists describe this ability to search for targets rapidly and automatically as *parallel processing.* It is as if you can examine all nearby locations at once (in parallel) and rapidly detect the target no matter where it appears.

The Dangers of Distracted Driving

Talking on any kind of phone—including hands-free models—can create inattentional blindness and distractions that impair driving and may contribute to accidents (e.g., Briggs, Hole, & Land, 2011; Hyman et al., 2010; Strayer & Drews, 2007). Twelve of the United States, the District of Columbia, Puerto Rico, Guam, the U.S. Virgin Islands, and many countries around the world have outlawed drivers' use of handheld cell phones. Forty–one states, the District of Columbia, Guam, and the U.S. Virgin Islands ban text messaging for all drivers (for the latest developments on this topic, visit http://distraction.gov).

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Dividing Attention

Often you can divide your attention efficiently enough to allow you to perform more than one activity at a time (Damos, 1992). You can drive a car, listen to the radio, sing along, and keep a beat by drumming on the steering wheel. However, your attention cannot be divided beyond a certain point without a loss in performance and mental-processing ability. For example, automobile drivers are much more likely to miss important signals, make errors in following directions, and react slowly to potentially dangerous situations when talking on a cell phone, even if it is a hands-free model (Reimer et al., 2010; Strayer & Drews, 2007). This is especially true if the conversation is an emotional one (Briggs, Hole, & Land, 2011). Distracted walking can be dangerous, too. The number of pedestrians killed or injured while listening to music on headphones more than tripled between 2004 and 2011 (Lichenstein et al., 2012). In other words, attention is a limited resource. If you try to spread it over too many targets, you "run out" of attention.

Still, it can sometimes be hard to keep your attention focused rather than divided. Look at the list of words in Figure 4.32 and as rapidly as possible call out *the color of the ink* in which each word is printed. *This Stroop task* (Stroop, 1935) is not easy, because your

BLUE	GREEN
GREEN	ORANGE
PURPLE	ORANGE
GREEN	BLUE
RED	RED
GRAY	GRAY
RED	BLUE
BLUE	PURPLE

FIGURE 4.32
The Stroop Task

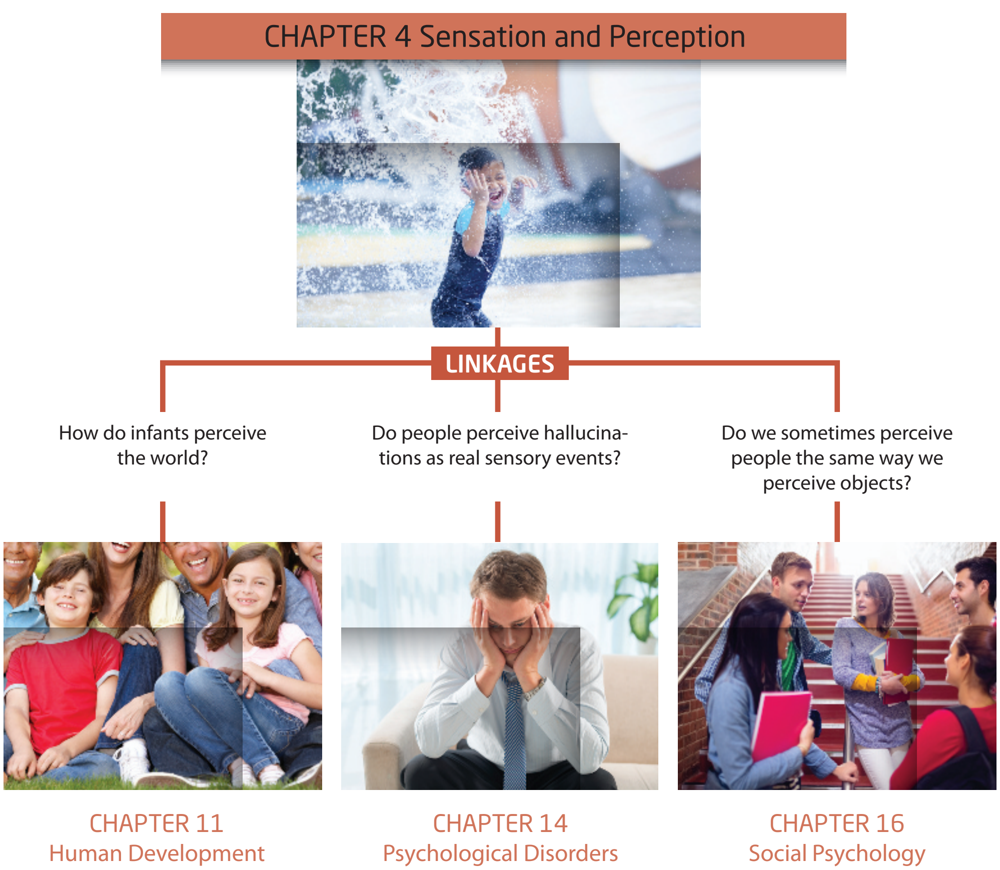
TRY THIS Look at this list of words and as rapidly as possible call out the color of the *ink* in which each word is printed. How did you do?

brain automatically reads and processes the meanings of the familiar words in the list. These meanings then compete for attention with the responses you are supposed to give. To do well, you must focus on the ink color and not allow your attention to be divided between color and meaning. Children just learning to read have far less trouble with this task because they don't yet process the meanings of words as automatically as experienced readers do.

Although you can walk while talking or drive while listening to music, you would find it virtually impossible to read and talk at the same time. Why is it sometimes so easy and at other times so difficult to do two things at once (Connell & Lynott, 2010)? When one task is so automatic as to require little or no attention, it is usually easy to do something else at the same time (Schneider, 1985). Even when two tasks require attention, it may still be possible to perform them simultaneously if each taps into different kinds of attention (Wickens, 2002; Wickens et al., 1992). Some types of attention are devoted to perceiving incoming stimuli. Others handle making responses. This specialization allows a skilled pianist to use one kind of attention to read a new piece of music while using another kind of attention at the same time to press the correct keys. Apparently, the human brain can manage more than one type of attention and more than one spotlight of attention (Wickens, 1989). This notion of different types of attention also helps explain why an experienced driver can listen to the radio while steering safely. If two tasks require the same kind of attention, however, performance on both tasks will suffer (Just et al., 2001; Newman et al., 2007).

LINKAGES

As noted in the introductory chapter, all of psychology's subfields are related to one another. Our discussion of the development of perception illustrates just one way that the topic of this chapter, sensation and perception, is linked to the subfield of developmental psychology, which is described in the chapter on human development. The Linkages diagram shows ties to two other subfields, and there are many more ties throughout the book. Looking for linkages among subfields will help you see how they all fit together and help you better appreciate the big picture that is psychology.



The difference between the photos in Figure 4.31 is that the top picture includes a clump of trees just to the left of the statue.

SUMMARY

Sensing and Perceiving the World

What is the difference between sensation and perception?

A ***sense*** is a system that translates information from outside the nervous system into neural activity. Messages from the senses are called ***sensations***. ***Perception*** is the process through which people actively use knowledge and understanding of the world to interpret sensations as meaningful experiences.

Sensory Systems

How does information from my eyes and ears get to my brain?

Accessory structures collect and modify incoming energy from sensory stimuli. Then comes ***transduction***, the process of converting that energy into neural activity. It is accomplished by sensory ***neural receptors***, which are neural cells specialized to detect energy of some type. ***Sensory adaptation*** takes place when receptors continue to receive stimulation that does not change. Except in the case of smell, sensory neural activity is transferred through the thalamus, which relays it to the cerebral cortex. ***Encoding*** is the translation of the physical properties of a stimulus into patterns of neural activity that specifically identify those physical properties. It's the language the brain uses to describe sensations. Encoding is characterized by the *specific energy doctrine:* Stimulation of a particular sensory nerve provides codes for that one sense, no matter how the stimulation takes place.

The minimum amount of light, sound, pressure, or other physical energy that can be detected 50 percent of the time is called the ***absolute threshold***. ***Internal noise*** is the spontaneous random firing of cells in the nervous system that occurs whether or not you are stimulated by physical energy. Your ***response bias***, or ***response criterion,*** reflects your willingness to respond to a stimulus or ignore it. ***Signal detection theory*** addresses whether you will perceive a stimulus. ***Sensitivity*** refers to your ability to discriminate a stimulus from its background. ***Weber's law*** states that the smallest detectable difference in stimulus energy is a constant fraction of the intensity of the stimulus. This smallest detectable difference in a stimulus is called the difference threshold or ***just-noticeable difference (JND)***. The distance from one peak of a sound wave or light wave to the next is its ***wavelength***. Wave ***frequency*** is the number of complete waves, or cycles, that pass a given point per unit of time. ***Amplitude*** is the height of the wave from baseline to peak.

Seeing

Why do some people need eyeglasses?

Visible light is electromagnetic radiation with a wavelength of about 400 to about 750 nanometers. ***Light intensity***, or the amount of energy in light, determines its brightness. Differing ***light wavelengths*** are sensed as different colors. Accessory structures of the eye include the ***cornea***, the ***pupil***, the ***iris***, and the ***lens***. Through ***ocular accommodation*** and other means, these structures focus light rays on the ***retina***, the netlike structure of cells at the back of the eye.

Photoreceptors in the retina—***rods*** and ***cones***—convert light into neural activity. Rods and cones differ in shape, sensitivity to light, ability to discriminate colors, and distribution across the retina. Photoreceptors, especially rods, contribute to ***dark adaptation***. The ***fovea***, the area of highest acuity, has only cones, which are color sensitive. Rods are more sensitive to light but don't discriminate colors; they're distributed in areas around the fovea. From the photoreceptors, neural activity is transferred to bipolar cells and then to ganglion cells. A ***blind spot*** is created at the point where axons of ganglion cells leave the eye as a bundle of fibers called the ***optic nerve***. Half of these fibers cross over at the optic chiasm. ***Feature detectors*** are cells in the cerebral cortex that respond to specific characteristics of objects in the visual field.

The color of an object depends on which of the wavelengths striking it are absorbed and which are reflected. The sensation of color has three psychological dimensions: ***hue***, ***color saturation***, and ***brightness***.

According to the ***trichromatic*** (or Young-Helmholtz) ***theory,*** color vision results from the fact that the eye includes three types of cones, each of which is most sensitive to short, medium, or long wavelengths. Information from the three types combines to produce the sensation of color. According to the ***opponent-process*** (or Hering) ***theory***, there are red-green, blue-yellow, and black-white visual elements and the members of each pair inhibit each other so that only one member of a pair may produce a signal at a time. Opponent-process theory explains color afterimages.

People who have cones containing only two of these three color-sensitive chemicals are described as *color blind.*

Hearing

How would my voice sound on the moon?

Sound is a repetitive fluctuation in the pressure of a medium such as air; it travels in waves. The frequency (which is related to wavelength) and amplitude of sound waves produce the psychological experiences of ***pitch*** and ***loudness***, respectively. ***Timbre***, the quality of sound, depends on complex wave patterns added to the basic frequency of sound. The energy from sound waves is collected and transmitted to the ***cochlea*** through a series of accessory structures, including the ***pinna***, and components of the ***middle ear***, including the ***tympanic membrane***, the hammer, the anvil, the stirrup, and the oval window. Transduction occurs when sound energy stimulates hair cells on the ***basilar membrane*** of the cochlea, which in turn stimulate the ***acoustic nerve***. Auditory information is relayed through the thalamus to the primary auditory cortex.

The intensity of a sound stimulus is encoded by the firing of auditory neurons. ***Place theory*** describes the encoding of high frequencies based on the place on the basilar membrane at which the sound wave peaks. Each neuron in the acoustic nerve is most sensitive to a specific frequency (its preferred frequency). According to ***volley theory***, some frequencies may be matched by the firing rate of a group of neurons.

The Chemical Senses: Taste and Smell

Why can't I taste anything when I have a cold?

The chemical senses include smell (olfaction) and taste (gustatory perception). ***Olfactory perception*** (**sense of smell**) detects volatile chemicals that come into contact with olfactory receptors in the nose. **Taste perception**, also known as *gustatory perception,* detects chemicals in solution that come into contact with receptors inside the mouth. Smell and taste act as two components of a single system known as *flavor.* The scent and taste pathways converge in the *orbitofrontal cortex* of the brain. Olfactory signals are sent through the olfactory nerve to the ***olfactory bulb*** in the brain without passing through the thalamus. ***Pheromones*** are odors from one creature that change the physiology or behavior of another.

Taste perception detects chemicals that come into contact with taste receptors in ***papillae*** in the mouth, especially on the tongue. The basic taste sensations are sweet, sour, bitter, salty, umami, and astringent. The senses of smell and taste interact to produce flavor.

Sensing Your Body

Which is the largest organ in my body?

The ***cutaneous senses***, also called somatosensory systems, include the skin senses and are related to proprioception. The skin senses detect touch, temperature, and pain. When they are mechanically stimulated, nerve endings in the skin generate touch sensations. Some nerve endings are sensitive to temperature and some respond to both temperature and touch.

Pain provides information about intense stimuli. Sharp pain is carried by A-delta fibers; dull, chronic pain is carried by C-fibers. The emotional response to pain depends on how the painful stimulus is interpreted. According to the ***gate control theory of pain***, pain signals can be blocked on their way to the brain, sometimes by messages sent from the brain down the spinal cord, resulting in ***analgesia***. Endorphins act at several levels in pain systems to reduce sensations of pain.

Proprioception includes ***kinesthetic perception***, which provides information about the position of body parts with respect to one another, and the ***sense of equilibrium***, or ***vestibular sense*** (balance), which provides information about the position of the head in space. This information is provided by ***proprioceptors***, which are sensory receptors for movement and body position.

Perception

How do sensations become perceptions?

Perception is the knowledge-based interpretation of sensations. Much of this interpretation takes place automatically, but sometimes conscious effort is required to translate sensations into meaningful experience.

Organizing the Perceptual World

What determines how I perceive my world?

Our perceptual systems automatically engage in ***figure ground discrimination*** to sense the difference between ***figure*** and ***ground***. They also automatically group stimuli into patterns on the basis of the Gestalt principles of proximity, similarity, continuity, closure, texture, simplicity, common fate, and three others known as synchrony, common region, and connectedness.

Depth perception depends partly on stimulus cues and partly on the physical structure of the visual system. Stimulus cues include relative size, height in the visual field, interposition, linear perspective, ***motion parallax*** reduced clarity, light and shadow, and textural gradients. Cues based on the structure of the visual system include ***eye convergence*** (movement of the eyes to focus on the same object), ***retinal disparity*** (due to each eye seeing the world from a slightly different angle), and accommodation (changes in the shapes of the lenses as objects are brought into focus).

The perception of motion results, in part, from the movement of stimuli across the retina. Expanding or ***looming*** stimulation is perceived as an approaching object. Movement of the retinal image is interpreted along with information about movement of the head, eyes, and other body parts to discriminate one's own movement from the movement of external objects. The ***stroboscopic illusion*** is a movement illusion arising when a series of slightly different still images is seen in rapid succession.

Because of ***perceptual constancy***, the brightness, size, and shape of objects are seen as unchanging despite changes in the sensations received from those objects. Size constancy and shape constancy depend on the relationship between the retinal image of the object and one's knowledge-based perception of how far away the object is. Brightness constancy depends on the perceived relationship between the brightness of an object and its background.

Size illusions are distortions of reality that result when principles of perception are applied inappropriately. Many of these illusions occur when we misread depth cues or when we are overly influenced by the contexts (surroundings) in which visual stimuli appear.

Recognizing the Perceptual World

How do I recognize familiar people?

Both ***bottom-up processing*** and ***top-down processing*** contribute to our recognition of the world. Our ability to recognize objects is based on our capacity to match the pattern of sensations organized by the perceptual system with a pattern stored in our memory. Bottom-up processing occurs as the brain analyzes features, or combinations of features, such as form, color, motion, and depth. Top-down processing is influenced by our knowledge, expectations, and motivation. ***Schemas*** based on our past experiences can create a perceptual set; that is, a readiness or predisposition to perceive stimuli in certain ways. The context in which a stimulus appears can also create expectancies. Top-down and bottom-up processing commonly work together to create recognition. Top-down processing can fill in gaps in physical stimuli, in part because the environment provides redundant stimuli.

To the extent that the visual environments of people in different cultures differ, their perceptual experiences—and their responses to perceptual illusions—may differ as well. The ability to perceive color, basic shape features, and possibly the human face is present at or near birth. Other abilities, such the ability to recognize forms, develop later. Depth is also perceived early, but its meaning is learned later. Perceptual abilities are modified by both experience and maturation.

Attention

Can you run out of attention?

Attention is the process of focusing psychological resources to enhance perception, performance, and mental experience. We can shift attention overtly (by moving the eyes, for example) or covertly (without any movement of sensory systems). Attention is selective; it is like a spotlight that illuminates different parts of the external environment or specific mental processes. Control over attention can be voluntary and knowledge-based or involuntary and driven by environmental stimuli. People can sometimes attend to two tasks at once, but there are limits to how much they can divide their attention.

TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. Sandra reads English but not Chinese. So when she looks at a Chinese newspaper, there is more __________ than __________.
   a. sensation; perception
   b. perception; sensation
   c. perception; transduction
   d. sensation; transduction

2. As Jeremy listens to music on his iPod, sound waves are converted by his auditory system into neural signals. This process is called __________.
   a. attention
   b. transduction
   c. adaptation
   d. accommodation

3. In an experiment, Dante raises his hand each time he hears a tone through a set of headphones. The tone gets quieter and quieter until he fails to hear it half the time. After repeating the same procedure many times, the researcher ends the experiment because she has found Dante's __________.
   a. absolute threshold
   b. difference threshold
   c. internal noise
   d. response criterion

4. Jane is told that she will be paid $100 for each needle she can find in a haystack. According to signal detection theory, this information should __________ Jane's __________.
   a. raise; specificity
   b. lower; specificity
   c. raise; response criterion
   d. lower; response criterion

5. Matt finishes his can of soda as he walks across campus with Brad and Andy, and now he wants to slip the empty can into one of their open backpacks. Brad's pack has several heavy textbooks in it; Andy's contains only a notebook. Weber's law suggests that to avoid detection, Matt should put the can in __________ pack because the change in weight will be __________ than a just-noticeable difference.
   a. Andy's; less
   b. Brad's; less
   c. Andy's; more
   d. Brad's; more

6. Bianca wants Bruce to see the distant star she wishes on every night. Because the star is so faint, to have him see it she should have him look __________.
   a. directly at the star
   b. slightly away from where the star is expected to be
   c. at the star's reflection in a mirror
   d. at the star when there is a full moon

7. A projection-screen TV aims green, red, and blue lights at a screen. Because the TV can show a full range of colors by combining the green, red, and blue lights in differing amounts, it best illustrates the __________ theory of color vision.
   a. convergence
   b. frequency-matching
   c. opponent-process
   d. trichromatic

8. When Sarah stubbed her toe, she immediately began to rub it. According to the gate control theory of pain, the rubbing __________.
   a. shut down the brain's pain-sensing mechanisms
   b. released serotonin
   c. created an increase in pain tolerance
   d. created sensations that "took over" the pain pathways

9. Mick has been a rock musician for fifty years. The constant loud noise from his band has caused hair-cell damage, literally ripping off hair cells from his inner ear. We would expect that Mick now has __________.
   a. extremely acute hearing
   b. conduction deafness
   c. nerve deafness
   d. normal hearing loss for someone his age

10. Jeremy developed a disease that destroyed his thalamus. The only sense that was unaffected was __________.
    a. vision
    b. hearing
    c. touch
    d. smell

11. Your blind spot is located __________.
    a. where the optic nerve leaves the eye
    b. where visual fibers cross at the optic chiasm
    c. in the center of the fovea
    d. where accommodation takes place

12. In cooking school, Natalie studied flavor. She learned that the flavor of food can be altered by __________.
    a. changing its texture
    b. changing its temperature
    c. changing its color
    d. both a and b

13. Andrea cannot yet read but Lorraine can. They are each shown a list of color names (e.g., blue, red, yellow), but each word is printed in a color that doesn't match the word. They are asked to say the color of the ink each word is printed in, not the word itself. __________ will do better at this Stroop task because __________.
    a. Andrea; she can use top-down processing
    b. Lorraine; she is older
    c. Andrea; she will not be distracted by word meanings
    d. Lorraine; word meaning will help focus on the ink color

14. Ally has lost her sense of kinesthetic perception. She will most likely be unable to __________.
    a. know that her hand is raised without looking at it
    b. identify the flavor of her ice cream cone
    c. feel the warmth of the sun on her face
    d. feel pain

15. Shanelle likes the lights that appear to race around her Christmas tree as they flash on and off in sequence. This illusion is known as __________.
    a. motion parallax
    b. dishabituation
    c. the stroboscopic illusion
    d. texture gradient

16. Four swimmers practicing their synchronized swimming routine are perceived as a group because they are performing the same movements at the same speed. This is an example of __________.
    a. synchrony
    b. common fate
    c. orientation
    d. interposition

17. When you perceive an object as being closer to you because it blocks out part of the background, you are using the depth cue called __________.
    a. linear perspective
    b. reduced clarity
    c. interposition
    d. movement gradient

18. As Cliff walks out his front door, he sees a snowball coming straight at him. The retinal image of the snowball is increasing and he realizes that the snowball is approaching, not getting larger. This example illustrates __________.
    a. induced motion
    b. stroboscopic motion
    c. the movement gradient
    d. looming

19. Jeff and Larry were making chili. Jeff tasted the chili and thought it was perfectly seasoned. Then, while Jeff's back was turned, Larry added some more salt. When they sat down to eat Jeff immediately said the chili was too salty. Because he didn't know about the added salt, Jeff's perception must have been based on __________.
    a. top-down processing
    b. bottom-up processing
    c. pattern recognition
    d. selective attention

20. Although José appears to be listening as Rich talks about his new clothes, vacation plans, and exercise routine, José is thinking about the list of errands he has to run. José is __________.
    a. covertly orienting
    b. overtly orienting
    c. using parallel distributed processing
    d. using serial processing

Learning

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Preview

Live and learn. This simple phrase captures the idea that learning is a lifelong process that affects our behavior every day. Understanding how learning takes place is an important part of understanding ourselves. Sometimes learning involves one event signaling another, as when we learn to associate wailing sirens with ambulances. Other times learning depends on what happens after we do something—whether we receive praise or punishment, for example. But learning is more than these kinds of associations. What we think and how we feel about life's signals and consequences also have an impact on what we learn to do and not to do. Blend in practice and feedback about our behavior, mix well, and you have all the ingredients of the learning process.

Like most newborn babies, Jeffrey cried until he was fed. He awakened at 3 A.M. nearly every morning, hungry and crying for food. And as she had done every day since he was born, his mother would put on her slippers and walk down the tiled hallway to his bedroom. After a quick change of his diaper came the feeding. By the time he was four months old, Jeffrey would cry for about a minute and then quietly wait a few more minutes for his mother to arrive for his feeding. One particular morning, as his mother was halfway down the hall, she stopped in her tracks as she felt a sneeze coming. She pinched her nostrils together and the urge to sneeze passed. However, she noticed that Jeffrey had begun to cry again. This was unusual. She began to walk again and he quieted. Her scientific curiosity aroused, she walked a few steps, then stopped, then started, then stopped. She discovered that Jeffrey stopped crying when he heard her footsteps but resumed crying when the sound of footsteps stopped.

Jeffrey had learned a lot in the four months since his birth. He could anticipate events and predict outcomes based on the meaning of certain sounds. Like the rest of us, he showed an ability to learn about relationships in the environment and adjust to them. This adjustment to changes in the environment is called *adaptation*. Along with adaptation come expectations and predictions about what is and what is not likely to occur in our world.

The entire process of development, from birth to death, involves adapting to increasingly complex, ever-changing environments using continuously updated knowledge and skills gained through experience. This ability to adapt is especially impressive in humans, but it appears to varying degrees in every species. Charles Darwin highlighted the importance of adaptation in his theory of evolution, noting that individuals who do not adapt may not survive to reproduce. Many forms of adaptation follow the principles of learning.

Learning is a relatively permanent change in behavior or knowledge due to experience. We are born with some behaviors and knowledge, we acquire others automatically as we grow (through maturation), and we learn still others. In fact, learning plays a central role in most aspects of human behavior. If you want to know who you are and how you became the person you are today, examining what and how you have learned is a good place to start.

In this chapter, we first consider the simplest forms of learning—learning about sights, sounds, and other *stimuli* (the plural of *stimulus*). Then we examine the two major kinds of learning that involve associations between events—classical conditioning and operant conditioning. You will see that cognitive processes underlie some of the most complex forms of learning, such as the ability to learn from watching others. Some learning takes place consciously, as when you study for an exam, but you also learn many things without being aware that you are doing so. We conclude by discussing how research on learning might help people learn better.

LEARNING ABOUT STIMULI

Why do constant sounds seem to disappear?

In a changing world, our senses are constantly bombarded by massive amounts of information. If we tried to pay attention to every sight and sound, our information-processing systems would be overloaded, and we would be unable to focus on anything. People appear to be genetically tuned to attend to certain kinds of events, such as loud sounds, special tastes, or pain. *Novel* stimuli—things we have not experienced before—also tend to attract our attention.

learning The modification of preexisting behavior and understanding.

Learning to Live with It

People who move from a small town to a big city may at first be distracted by the din of traffic, low-flying aircraft, and other urban sounds, but after a while, the process of habituation makes all this noise far less noticeable.

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By contrast, our response to *unchanging* stimuli decreases over time. This aspect of adaptation is a simple form of learning called **habituation**, and it can occur in relation to sights, sounds, smells, tastes, or touches. As described in the chapter on sensation and perception, it is through habituation that you eventually lose awareness of your glasses or your watch and that after being in a room for a while, you no longer smell its odor or hear its ticking clock. Habituation is especially important for adapting to initially startling but harmless events such as the repeated popping of balloons, but it occurs in some degree to all kinds of stimuli and in all kinds of animals, from simple sea snails to humans (Rankin et al., 2009; Thompson, 2009). After our response to a stimulus has habituated, it may quickly return if the stimulus changes or the situation changes. So you may become aware again of the ticking of a grandfather clock after the hourly chime has sounded because now, something in your environment has changed. The reappearance of your original response when a stimulus changes is called *dishabituation.* In the sensation and perception chapter, we described how habituation and dishabituation processes helped psychologists determine what babies notice, and fail to notice, as perceptual skills develop.

A second simple form of learning, called *sensitization*, appears as an increase in responsiveness to a stimulus. Sensitization occurs, for example, when people and animals show exaggerated responses to unexpected, potentially threatening sights or sounds, especially during periods of emotional arousal. So while breathlessly exploring a dark, spooky house, you might scream, run, or violently throw something in response to the unexpected creaking of a door.

Habituation and sensitization provide organisms with a useful way to adapt to their environments, but notice that these kinds of learning result from exposure to a single stimulus. Neither kind involves associating one stimulus with another, as when we learn that, say, dark clouds signal rain. For this reason, habituation and sensitization are referred to as *nonassociative learning* (Chance, 2009). These nonassociative processes cannot, by themselves, explain many of the behaviors and mental processes that are the focus of psychology. To better understand how learning affects our thoughts and behaviors, we have to consider forms of learning that involve noticing the associations between various stimuli, as well as between stimuli and responses. One major type of associative learning is called *classical conditioning.*

habituation Reduced responsiveness to a repeated stimulus.

CLASSICAL CONDITIONING: LEARNING SIGNALS AND ASSOCIATIONS

How did Russian dogs teach psychologists about learning?

At the first notes of the national anthem, an athlete's heart may start to pound because those sounds signal that the game is about to begin. A flashing red light on the instrument panel might raise your heart rate, too, because it means that something is wrong with your car. People are not born with these reactions. They have learned them by observing relationships, or *associations,* between events in the world. The experimental study of this kind of learning was begun, almost by accident, by Ivan Petrovich Pavlov.

Pavlov's Discovery

Pavlov is one of the best-known figures in psychology, but he was not a psychologist. He was a Russian physiologist who won the Nobel Prize in 1904 for his research on the digestive system of dogs. In the course of this research, Pavlov noticed a strange phenomenon. His dogs sometimes salivated, or drooled, when no food was present. For instance, they salivated when they saw the assistant who normally brought their food, even if he was empty-handed.

Pavlov devised a simple experiment to determine why salivation occurred without an obvious physical cause, such as food. First he performed an operation to divert a dog's saliva into a container so that the amount of salivation could be measured. Next he placed the dog in an apparatus similar to the one shown in Figure 5.1. The experiment had three phases.

In the first phase, Pavlov and his associates confirmed that when meat powder was placed in the dog's mouth, the dog automatically salivated (Anrep, 1920). They also confirmed that the dog did not automatically salivate in response to a musical tone. The researchers had now established the two basic components of Pavlov's experiment: (1) a quick automatic response and (2) a neutral stimulus that does not trigger that response.

In the second phase of Pavlov's experiment, the tone was sounded and then meat powder was placed in the dog's mouth. The dog salivated. This pairing of the tone and the meat powder was repeated several times. The tone always preceded the arrival of the meat powder, but had the dog learned that relationship? It had.

FIGURE 5.1
Apparatus for Measuring Conditioned Responses

Pavlov used this laboratory apparatus to precisely measure the amount of saliva flowing from a dog's mouth.

Bettmann/Corbis

FIGURE 5.2
Classical Conditioning

Before classical conditioning, putting meat powder on a dog's tongue produces salivation, but the sound of a tone—a neutral stimulus—brings only orienting responses such as turning toward the sound. During the process of conditioning, the tone is repeatedly paired with the meat powder. After classical conditioning, the tone alone is a conditioned stimulus, producing salivation.

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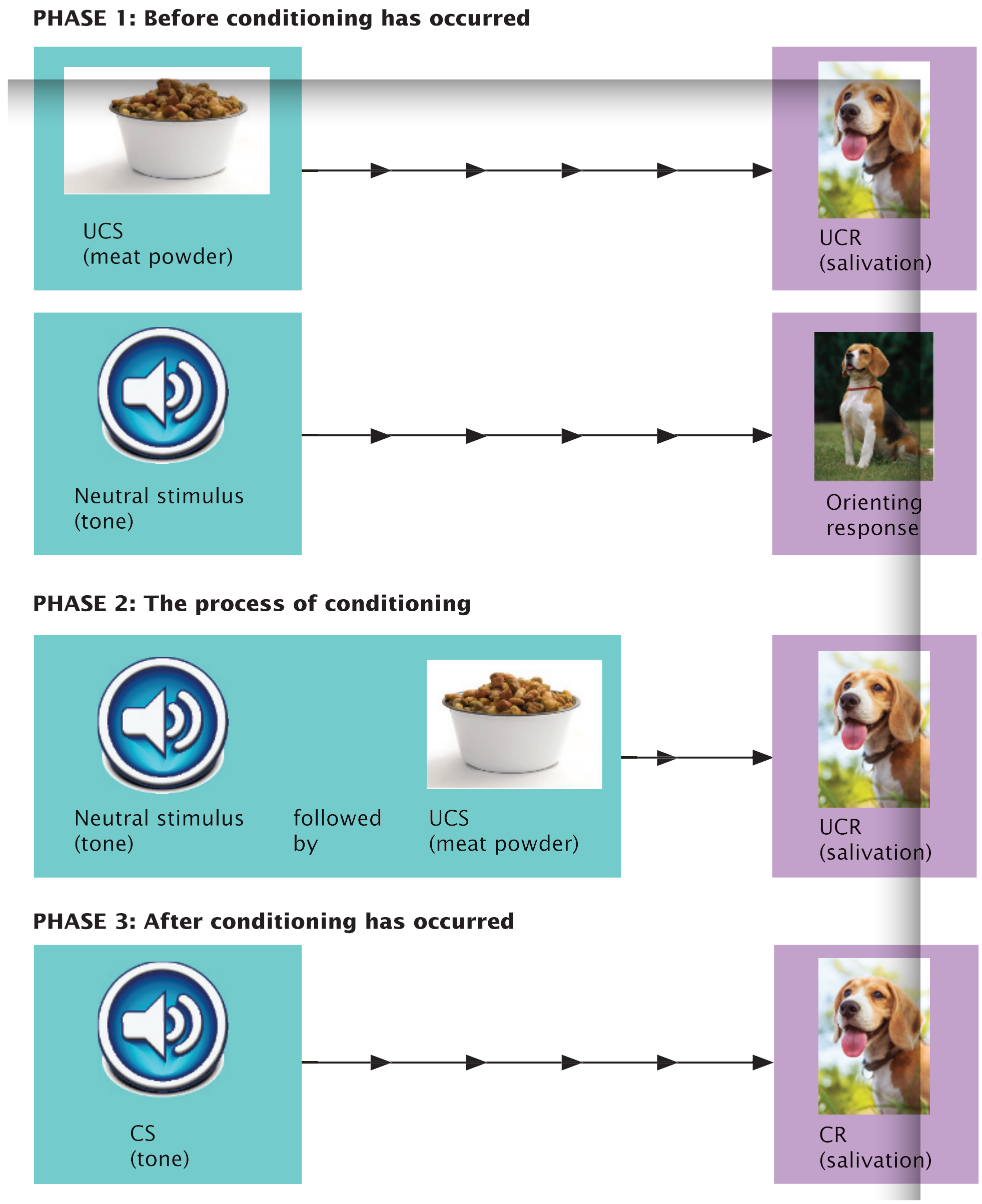


classical conditioning A procedure in which a neutral stimulus is paired with a stimulus that triggers an automatic response until the neutral stimulus alone comes to trigger a similar response.

unconditioned stimulus (UCS) A stimulus that triggers a response without conditioning.

unconditioned response (UCR) The automatic, unlearned, reaction to a stimulus.

conditioned stimulus (CS) An originally neutral stimulus that now triggers a conditioned response.

conditioned response (CR) The response triggered by the conditioned stimulus.

In the third phase of the experiment, the tone was sounded but no meat powder was presented. The dog still salivated. The tone alone was now enough to trigger salivation. You may have seen a similar process if you regularly open pet food with an electric can opener. The sound of the opener probably brings your pet running (and salivating) because that sound means that food is on its way.

Pavlov's experiment demonstrated what we now call **classical conditioning**. In this procedure, a neutral stimulus is repeatedly paired with a stimulus that already triggers an automatic response. As a result of this pairing, the previously neutral stimulus itself comes to trigger a response that is similar to the automatic one. Figure 5.2 shows the basic elements of classical conditioning. The stimulus that naturally elicits a response without conditioning, such as the meat powder in Pavlov's experiment, is called the **unconditioned stimulus (UCS)**. The automatic, unlearned, response to this stimulus is called the **unconditioned response (UCR)**, in this case, salivation. After being paired with the unconditioned stimulus (meat powder), the previously neutral stimulus becomes the **conditioned stimulus (CS)** and the response it comes to trigger is a learned or **conditioned response (CR)**.

Conditioned Responses over Time: Extinction and Spontaneous Recovery

If you have ever been bitten by a barking dog, you might have learned to feel distress whenever you hear a dog's bark. The more bad experiences you have had with dogs, the stronger will be your learned distress in response to barking sounds. In the language of classical conditioning, continued pairings of a conditioned stimulus (CS/bark) with an unconditioned stimulus (UCS/bite) strengthen the conditioned response (CR/distress). The curve on the left side of Figure 5.3 shows an example: Repeated associations of a tone (CS) with meat powder (UCS) caused Pavlov's dogs to increase their salivation (CR) to the tone alone.

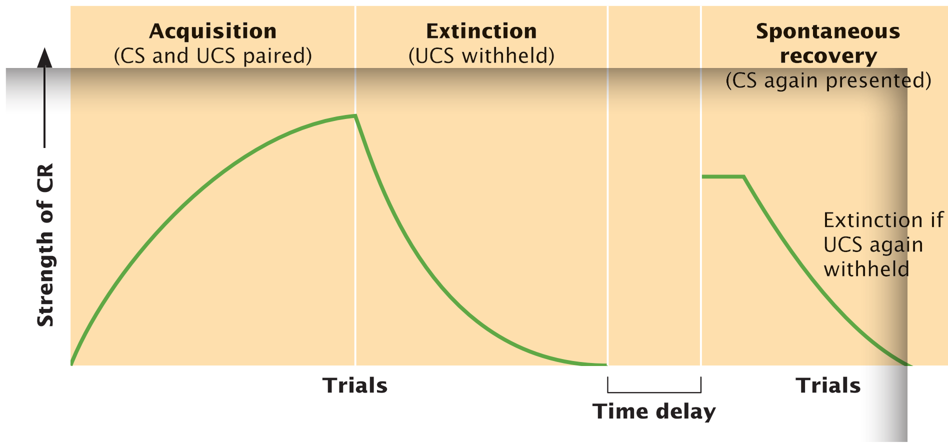


FIGURE 5.3
Changes over Time in the Strength of a Conditioned Response

As the conditioned stimulus (CS) and the unconditioned stimulus (UCS) are repeatedly paired during initial conditioning, the strength of the conditioned response (CR) increases. If the CS is then repeatedly presented without the UCS, the CR weakens—and eventually disappears—through a process called extinction. If the CS is presented again later on, a weaker version of the CR will reappear (Rescorla, 2004). This phenomenon, called spontaneous recovery, is only temporary, though. Unless the UCS is again paired with the CS, the recovered CR soon disappears.

What if the tone (CS) is repeatedly sounded but the meat powder (UCS) is no longer given? As you might expect, if the unconditioned stimulus is not paired with the conditioned stimulus at least now and then, the conditioned response will gradually disappear. This loss of the conditioned response is known as **extinction** (see the center section of Figure 5.3). The term is not entirely accurate, though. *Extinction* suggests that like the dinosaurs, the conditioned response has been wiped out, never to return. However, in this context we know that extinction merely suppresses a conditioned response but does not completely destroy it (Vurbic & Boutton, 2014). For instance, if the CS (tone) and the UCS (meat powder) are again paired after the conditioned response has been extinguished, that conditioned response will return to its original strength after as few as one or two trials. This quick relearning of a conditioned response after extinction is called **reconditioning**. Reconditioning takes much less time than the original conditioning, so it appears that extinction does not entirely erase the association between the conditioned stimulus and the conditioned response (Bouton, 1993, 2002; Myers & Davis, 2007).

The right side of Figure 5.3 provides more evidence for this conclusion. After a conditioned response has been extinguished it will temporarily reappear if the conditioned stimulus occurs again, even in a different situation (Neumann & Kitlertsirivatana, 2010). This is called **spontaneous recovery**, the temporary reappearance of a conditioned response after extinction (and without further CS-UCS pairings). In general, the longer the time between extinction and the reappearance of the CS, the stronger the recovered conditioned response (Devenport, 1998; Rescorla, 2005). Unless the UCS is again paired with the CS, extinction will reoccur and will further suppress the conditioned response (Leung & Westbrook, 2008). Still, even after many years, spontaneous recovery can create a ripple of emotion—a conditioned response—when we hear a song or catch a scent associated with a long-lost lover or a departed relative.

extinction The gradual disappearance of a conditioned response.

reconditioning The relearning of a conditioned response following extinction.

spontaneous recovery The temporary reappearance of a conditioned response after extinction.

stimulus generalization A process in which a conditioned response is triggered by stimuli similar to the original conditioned stimulus.

Stimulus Generalization and Discrimination

Once a conditioned stimulus is able to trigger a conditioned response, stimuli similar to the conditioned stimulus will also trigger some version of that response. This phenomenon, called **stimulus generalization**, is illustrated by the fact that a person who was

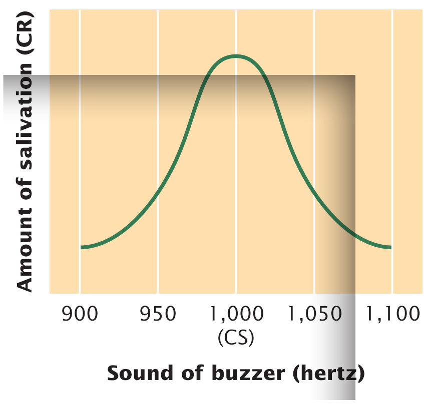


FIGURE 5.4
Stimulus Generalization

The strength of a conditioned response (CR) is greatest when the original conditioned stimulus (CS) occurs. However, some version of the CR is also triggered by stimuli that closely resemble the CS. Here, the CS is the sound of a buzzer at a frequency of 1,000 hertz (Hz), and the CR is salivation. Notice that the CR generalizes well to stimuli at 990 or 1,010 Hz, but that it gets weaker and weaker as the buzzer sounds less and less similar to the CS.

bitten by one particular dog may now show some fear of all dogs. Usually, the greater the similarity between a new stimulus and the original conditioned stimulus, the stronger the conditioned response will be. If the person was bitten by a small, curly-haired dog, fear responses would be strongest to other small dogs with similar types of hair. Figure 5.4 shows an example involving sounds.

Stimulus generalization has some obvious advantages. For example, it is important for survival that if you get sick after drinking sour-smelling milk, you now avoid dairy products that have a similar odor. Generalization would be a problem if it had no limits, however. You would probably be justifiably frightened if you found a lion in your living room, but imagine how disruptive it would be if your fear response generalized so widely that you were panicked by the sight of lions on TV or even by the word "lion" in a book.

Stimulus generalization does not run wild because it is usually balanced by a process called stimulus discrimination. Through **stimulus discrimination**, we learn to make distinctions among similar stimuli. Many parents find that the sound of their own baby whimpering soon becomes a conditioned stimulus, triggering a conditioned response that wakes them up. That conditioned response may not occur if a visiting friend's baby whimpers.

stimulus discrimination A process through which people learn to differentiate among similar stimuli and respond appropriately to each one.

The Signaling of Significant Events

Early research suggested that classical conditioning involves nothing more than automatic associations that allow one stimulus (the conditioned stimulus, or CS) to substitute for another (the unconditioned stimulus, or UCS) in triggering a response. However, classical conditioning is not that simple. For example, a rat's unconditioned, automatic response to a mild shock (UCS) will be flinching and jumping. But the animal's conditioned response to the sound of a tone (CS) that always precedes shock will not be to flinch and jump but to freeze—much as it would if threatened by a predator (Domjan, 2005). In other words, classical conditioning allows the rat to prepare for an upcoming shock. Many psychologists now believe that classical conditioning provides a way for organisms to build *mental representations* of the relationships between events in their environment and expectancies about when such events will occur (Rescorla, 1988; Shanks, 1995; Sternberg & McClelland, 2012). These representations help us adapt and survive. When two events repeatedly take place together, we can predict that one will occur based on what we know about the other. Baby Jeffrey predicted his feeding from hearing his mother's footsteps. You have learned that a clear blue sky means dry weather, that too little sleep makes you irritable, that you can reach someone on the telephone by pressing certain buttons, and that yelling orders motivates some people and angers others.

What determines whether conditioned responses are learned? In general, these responses develop when one event *signals* the appearance of another. Other important factors are the timing, predictability, and intensity of the CS and UCS; the amount of attention that is devoted to them; and how easily the signals can be associated with other stimuli.

Timing

If your instructor always dismisses class at 9:59 and a bell rings at 10:00, the bell cannot prepare you for the dismissal. It comes too late to be a useful signal. For the same reason, classical conditioning works best when the conditioned stimulus comes before the unconditioned stimulus (called *forward conditioning*), rather than when the conditioned stimulus comes after the unconditioned stimulus (called *backward conditioning*). This timing makes sense for adaptation and survival, since it is more helpful to know when something important is going to occur before it happens. Indeed, the presence of food, predators, or other significant stimuli is most reliably signaled by smells, sounds, or other events that come just before their appearance (Einhorn & Hogarth, 1982).

It is logical that the brain should be "wired" to form associations most easily between things that occur at about the same time. How close together do they have to be? There is no one "best" interval for every situation. Classical conditioning can occur in some cases when the interval between the CS and the UCS is less than a second and in other cases when that interval is longer than a minute. It all depends on the particular CS, UCS, and UCR that are involved (Longo, Klempay, & Bitterman, 1964; Ross & Ross, 1971). However, classical conditioning will always be weaker if the interval between the CS and the UCS is longer than what is ideal for the stimuli and responses in a given situation.

Predictability

It is not enough for the CS merely to come before the UCS. Suppose your dogs, Moxie and Fang, have very different personalities. When Moxie growls, she sometimes bites, but sometimes she doesn't. Fang growls only before biting. Your conditioned fear response to Moxie's growl will probably occur slowly, because her growl does not reliably signal the danger of a bite. However, you are likely to quickly develop a classically conditioned fear response to Fang's growl. It always means that you are in danger of being bitten. Classical conditioning proceeds most rapidly when the CS *always* signals the UCS and only the UCS. Even if both dogs provide the same number of pairings of the CS (growl) and the UCS (bite), it is only with Fang that the CS *reliably* predicts the UCS (Rescorla, 1968).

Intensity

A conditioned response will be learned more rapidly if the UCS is strong. For example, a CS that acts as a predictive signal will be more rapidly associated with a strong shock (UCS) than with a weak one. As with the importance of timing and predictability, the effect of UCS strength on classical conditioning makes adaptive sense. It's more important to be prepared for major events than for minor ones.

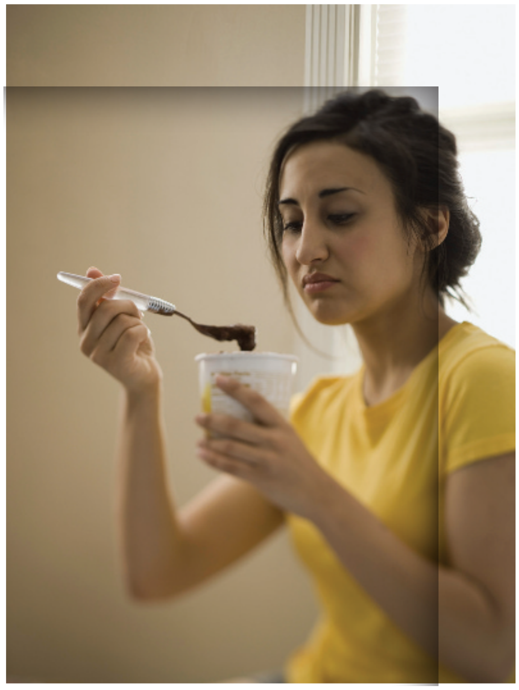
Attention

An association between a pair of stimuli is most predictably learned when there are no other potentially distracting stimuli present (Jones & Haselgrove, 2011). In Pavlov's laboratory, just one conditioned stimulus, a tone, was linked to just one unconditioned stimulus, meat powder. In the natural environment, a wide variety of stimuli might be present just before a UCS occurs. Suppose you are at the beach. You're eating a hot dog, reading a magazine, listening to Katy Perry, digging your toes in the warm sand, and enjoying the smell of suntan lotion when you are surprised by the sting of a buzzing wasp. Which of these stimuli is most likely to become a conditioned stimulus that might later trigger discomfort? It depends partly on where you were focusing your attention at the moment you were stung. Because your attention was focused on the music or your reading, you might not have noticed the buzzing sound that preceded the sting (UCS). The stimulus you most closely attended to—the one you most fully perceived—is most likely to become a CS. In general, loud tones, bright lights, and other intense stimuli tend to get extra attention, so they are the ones most rapidly associated with an unconditioned stimulus. As long as it remains a reliable predictive signal, however, even a low-intensity CS will produce a reliable CR if repeatedly paired with a UCS (Jakubowska & Zielinski, 1978).

Biopreparedness

Certain kinds of signals or events are especially likely to become associated with other signals or events (Logue, 1985). Which stimulus becomes a conditioned stimulus for fear will depend not only on attention but also on whether the stimulus is a sight, a sound, or a taste and what kind of unconditioned stimulus follows it. The apparently natural tendency for certain events to become linked suggests that organisms are "biologically prepared" to develop certain conditioned associations (Öhman & Soares, 1993, 1998). This *biopreparedness* is seen in infants as young as fourteen months of age (LoBue & DeLoache, 2010).

The most dramatic example of the biopreparedness phenomenon is seen in conditioned taste aversions. In one study, rats were either shocked or made nauseous in the presence of a light, a buzzer, and flavored water. The rats formed only certain conditioned associations.



Taste Aversions

Humans can develop classically conditioned taste aversions, even to preferred foods. For example, Ilene Bernstein (1978) gave one group of cancer patients Mapletoff ice cream an hour before they received nausea-provoking chemotherapy. A second group ate this same kind of ice cream on a day they did not receive chemotherapy. A third group got no ice cream. Five months later, the patients were asked to taste several ice cream flavors. Those who had never tasted Mapletoff and those who had not eaten it in association with chemotherapy chose it as their favorite. Those who had eaten Mapletoff before receiving chemotherapy found it distasteful.

RubberBall/SuperStock

Animals that had been shocked developed a conditioned fear response to the light and the buzzer but not to the flavored water. Those that had been made nauseous developed a conditioned avoidance of the flavored water, but they showed no particular response to the light or buzzer (Garcia & Koelling, 1966). These results reflect an adaptive process. Nausea is more likely to be caused by something we eat or drink than by a noise or a light. So nausea is more likely to become a conditioned response to an internal stimulus, such as a flavor, than to an external stimulus. In contrast, the sudden pain of a shock is more likely to have been caused by an external stimulus, so it makes evolutionary sense that the organism should be "tuned" to associate shock or sudden pain with a sight or sound. In our beach example, it is more likely that you would have associated the pain of that wasp sting with the sight of the insect than with the taste of your hot dog.

Conditioned taste aversion shows that for certain kinds of stimuli, classical conditioning can occur even when there is a long delay between the CS (taste) and the UCS (sickness). The nausea caused by eating spoiled food may be delayed for minutes or hours, but people who have experienced food poisoning may never again eat the food that made them ill. Organisms that are biologically prepared to link taste signals with illness, even a delayed illness, are more likely to survive than organisms not so prepared.

Evidence from several sources suggests other ways in which animals and people are innately prepared to learn aversions to certain stimuli. For example, experiments with animals suggest that they are prone to learn the types of associations that are most common in or most relevant to their environments (Wilcoxon, Dragoin, & Kral, 1971). Birds are strongly dependent on their vision in searching for food and may develop taste aversions on the basis of visual stimuli. Coyotes and rats, more dependent on their sense of smell, tend to develop aversions related to odor. In humans, preparedness results in far more cases of conditioned fear of harmless dogs or snakes than of potentially more dangerous objects, such as electrical outlets or knives (Öhman & Mineka, 2001, 2003). We are also particularly likely to learn fear responses to people who are "different," such as members of other ethnic groups (Olsson et al., 2005).

Higher Order Conditioning

Once we learn that a conditioned stimulus (CS) signals the arrival of an unconditioned stimulus (UCS), the CS may operate as if it actually were that UCS. For instance, suppose that a child endures a painful medical procedure (UCS) at the doctor's office and the pain becomes associated with the doctor's white coat. The white coat might then become a conditioned stimulus (CS) that can trigger a conditioned fear response. Once the white coat is able to set off a conditioned fear response, the coat may take on some properties of an unconditioned stimulus. So, if the child later sees a white-coated pharmacist at the drugstore, that once-neutral store can become a conditioned stimulus for fear because it signals the appearance of a white coat, which in turn signals pain. When a conditioned stimulus (the white coat) acts like an unconditioned stimulus, creating conditioned stimuli (the drugstore) out of events associated with it, the process is called **higher order conditioning**. This process serves as an adaptive "early warning system." It prepares us for threatening events (UCS) that are signaled not only by a CS but also by associated events that precede—and thus predict—that CS.

higher order conditioning A process through which a conditioned stimulus comes to signal another conditioned stimulus that is already associated with an unconditioned stimulus.

Some Applications of Classical Conditioning

The principles of classical conditioning are summarized in "In Review: Basic Processes of Classical Conditioning." These principles have proven useful in many areas, including in recent efforts to use insects to help detect explosive material. In one study, for example, after the taste of sugar water was associated with the smell of a chemical used in certain explosives, wasps quickly developed a conditioned response to the smell alone. When several of these trained insects were placed in a plastic tube and brought near the target chemical, they displayed an

The Power of Higher Order Conditioning

Cancer patients may feel queasy when they enter a chemotherapy room because they have associated the room with nausea-producing treatment. Through higher order conditioning, almost anything associated with the room can also become a conditioned stimulus for nausea. One cancer patient who was flying out of town on a business trip became nauseated just by seeing her hospital from the air.

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immediate attraction to it (Rains, Utley, & Lewis, 2006). Researchers hope that it may someday be possible to use these so-called Wasp Hounds and other similar devices to detect explosives or drugs concealed in airline passengers' luggage (Tomberlin, Rains, & Sanford, 2008). Classical conditioning principles have also been applied in overcoming fears and understanding certain aspects of drug addiction (Xue et al., 2012).

Phobias

Phobias are intense, irrational fears of objects or situations—such as public speaking—that are not dangerous or that are less dangerous than the fear response would suggest. Classical conditioning often plays a role in the development of phobias (Bouton, Mineka, & Barlow, 2001; Waters, Henry, & Neumann, 2009). As mentioned earlier, a person frightened by a dog may learn a fear that is so intense and generalized that it leads the person to avoid all dogs and all situations in which dogs might be encountered. Classically conditioned fears can be very long lasting, especially when based on experiences with strong unconditioned stimuli. Combat veterans and victims of violent crime, terrorism, or other traumatic events may show intense fear responses to trauma-related stimuli for many years afterward.

Classical conditioning has also been used to treat phobias (see the chapter on treatment of psychological disorders). Joseph Wolpe (1958) was a pioneer in this effort. He showed that irrational fears could be relieved through *systematic desensitization,* a procedure that associates a new response, such as relaxation, with a feared stimulus. To treat a thunderstorm phobia, for instance, a therapist might first teach the client to relax

IN REVIEW

BASIC PROCESSES OF CLASSICAL CONDITIONING

Process	Description	Example
Acquisition	A neutral stimulus and an unconditioned stimulus (UCS) are paired. The neutral stimulus becomes a conditioned stimulus (CS), eliciting a conditioned response (CR).	A child learns to fear (conditioned response) the doctor's office (conditioned stimulus) by associating it with the automatic emotional reaction (unconditioned response) to a painful injection (unconditioned stimulus).
Stimulus generalization	A conditioned response is elicited not only by the conditioned stimulus but also by stimuli similar to the conditioned stimulus.	A child fears most doctors' offices and places that smell like them.
Stimulus discrimination	Generalization is limited so that some stimuli similar to the conditioned stimulus do not elicit the conditioned response.	A child learns that his mother's doctor's office is not associated with the unconditioned stimulus.
Extinction	The conditioned stimulus is presented alone, without the unconditioned stimulus. Eventually the conditioned stimulus no longer elicits the conditioned response.	A child visits the doctor's office several times for a checkup but does not receive a shot. Fear may eventually cease.

Review Questions

1. If a person with a conditioned fear of spiders is also frightened by the sight of creatures that look somewhat like spiders, the person is demonstrating stimulus ___________.
2. Because of ___________ , we are more likely to learn a fear of snakes than a fear of cars.
3. Feeling sad upon hearing a song associated with a long-lost relationship illustrates ___________.

Predator Control through Conditioning

In the western United States, some ranchers lace a sheep carcass with enough lithium chloride to make wolves and coyotes nauseous (Pfister et al., 2003). The predators associate nausea with the smell and taste of sheep and afterward stay away from the ranchers' flocks. A similar program in India has greatly reduced the human death toll from tiger attacks. Stuffed dummies are connected to a shock generator and placed in areas where tigers have killed people. When the animals approach the dummies, they receive a shock (UCS). After learning to associate shock with the human form (CS), the tigers tend to avoid people (CR).

NHPA/Photoshot

deeply and then associate that relaxation with increasingly intense sights and sounds of thunderstorms presented on video (Öst, 1978). Because, as Wolpe (1958) noted, a person cannot be relaxed and afraid at the same time, the new conditioned response (relaxation) to thunderstorms replaces the old one (fear).

Drug Addiction

When people repeatedly use addictive drugs, their responses to the drugs become weaker. As already mentioned, this reduction in responsiveness to a repeated stimulus is called habituation. According to Richard Solomon's (1980) *opponent-process theory*, habituation is the result of two processes that balance each other, like a seesaw. The first process is a quick, automatic, involuntary response—essentially an unconditioned response (UCR) to the drug. The second—or opponent—process is a response that follows and counteracts the first. When a person is taking addictive drugs, this opponent response can be learned, or conditioned (McDonald & Siegel, 2004). So if the unconditioned response to a drug injection includes an increase in body temperature, the conditioned response will include an opponent process that reduces body temperature somewhat, creating the sensation of "chills." As the addict continues drug injections day after day, the learned opponent process ("chills") gets stronger and occurs sooner. As this CR strengthens, the rise in temperature caused by the drug gets smaller, resulting in habituation. In the same fashion, the intense pleasure first experienced as an unconditioned response to the drug begins to be weakened over time by an unpleasant opponent process (CR) that becomes faster and stronger. The addict begins to take larger drug doses in an effort to achieve the "high" once created by smaller doses. As described in the chapter on consciousness, people who display this pattern are said to have developed a *tolerance* for the drug.

The location where a drug is usually taken and the rituals that precede an injection (such as preparing the syringe) can become conditioned stimuli that trigger conditioned opponent-process responses even before the drug enters the bloodstream. These stimuli signal that the drug is coming, and the body begins to brace itself. But what if a person takes the drug in a new location or doesn't follow the usual ritual? According to opponent-process theory, in the absence of these conditioned environmental stimuli, the conditioned responses that normally dampen the user's unconditioned responses to the drug will not be as strong. As a result, the drug dose the addict took in the usual way yesterday might cause a potentially fatal overdose today (e.g., Siegel, 2005).

INSTRUMENTAL AND OPERANT CONDITIONING: LEARNING THE CONSEQUENCES OF BEHAVIOR

How do reward and punishment work?

Classical conditioning is an important form of learning, but you also learn many associations between responses and the stimuli that *follow* them, between behavior and its consequences. A child learns to say "please" and gets a piece of candy. A headache sufferer takes a pill and escapes pain. A dog "shakes hands" and earns a treat. Such actions are called *goal-directed* if the response is made with the outcome in mind, while they are called *habits* if the response occurs simply because the action has previously been rewarded in a similar situation (Balleine & Dickinson, 1998). The capacity for goal-directed action appears in children around the age of three (Klossek, Russell, & Dickinson, 2008) and develops early in the lives of other species, too (Hall et al., 2000).

From the Puzzle Box to the Skinner Box

While Pavlov was exploring classical conditioning in Russia, Edward L. Thorndike, an American psychologist, was studying the consequences of behavior and animal intelligence,

law of effect A law stating that if a response made in the presence of a particular stimulus is rewarded, the same response is more likely to occur when that stimulus is encountered again.

operant conditioning A process in which responses are learned on the basis of their rewarding or punishing consequences.

operant A response that has some effect on the world.

reinforcer A stimulus event that increases the probability that the response immediately preceding it will occur again.

positive reinforcers Stimuli that strengthen a response if they follow that response.

negative reinforcers The removal of unpleasant stimuli.

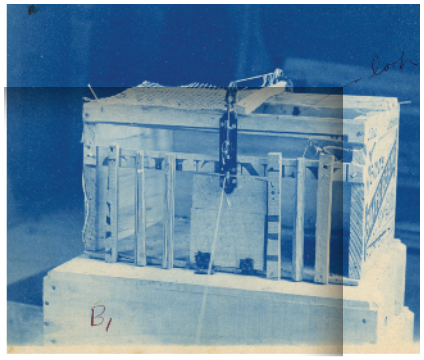


FIGURE 5.5
Thorndike's Puzzle Box

This photograph shows the kind of puzzle box used in Thorndike's research. His cats learned to open the door and reach food by stepping on a pedal, but the learning occurred gradually. Some cats actually took longer to get out of the box on one trial than on a previous trial.

Yale University Library

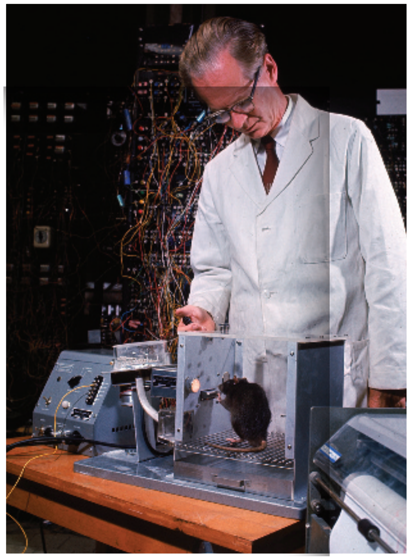


FIGURE 5.6
B. F. Skinner (1904–1990)

In the operant conditioning chamber shown here, the rat can press a bar to obtain food pellets from a tube. Operant and instrumental conditioning are similar in most respects, but they do differ in one way. Instrumental conditioning is measured by how long it takes for a response (such as a bar press) to occur. Operant conditioning is measured by the rate at which responses occur. In this chapter, the term operant conditioning refers to both.

Nina Leen/Time Life Pictures/Getty Images

including the ability to solve problems. For example, he placed a hungry cat in a *puzzle box* like the one in Figure 5.5. The cat had to learn some response—such as stepping on a pedal—to unlock the door and get food. During the first few trials in the puzzle box, the cat explored and prodded until it finally hit the pedal. The animal eventually solved the puzzle, but very slowly. It did not appear to understand, or suddenly gain insight into, the problem (Thorndike, 1898). After many trials, though, the cat solved the puzzle quickly each time it was placed in the box. What was it learning? Thorndike argued that any response (such as pacing or meowing) that did not produce a satisfying effect (opening the door) gradually became weaker, whereas any response (pressing the pedal) that did have a satisfying effect gradually became stronger. The cat's learning, said Thorndike, is governed by the **law of effect**. According to this law, if a response made to a particular stimulus is followed by a satisfying effect (such as food or some other reward), that response is more likely to occur the next time the stimulus occurs. In contrast, responses that produce discomfort are less likely to be performed again. Thorndike described this kind of learning as *instrumental conditioning* because responses are strengthened when they are instrumental in producing rewards (Thorndike, 1905).

About thirty years after Thorndike published his work, B. F. Skinner extended and formalized many of Thorndike's ideas. Skinner (1938) noted that during instrumental conditioning, an organism learns a response by *operating on* the environment. So he used the term **operant conditioning** to refer to the learning process in which behavior is changed by its consequences, specifically by rewards and punishments. The terms operant and instrumental conditioning are now used to refer to the same thing. To study operant conditioning, Skinner devised new tools. One of these was a small chamber that, over Skinner's objections, came to be known as the *Skinner box* (see Figure 5.6).

Basic Components of Operant Conditioning

The chamber Skinner designed allowed researchers to arrange relationships between a particular response and its consequences. If an animal pressed a lever in the chamber, for example, it might receive a food pellet. The researchers could then analyze how consequences affect behavior. It turned out that stimulus generalization, stimulus discrimination, extinction, spontaneous recovery, and other phenomena seen in classical conditioning also appear in operant conditioning. However, research in operant conditioning also focused on concepts known as operants, reinforcers, and discriminative conditioned stimuli.

Operants and Reinforcers

Skinner coined the term *operant,* or *operant response,* to distinguish the responses in operant conditioning from those in classical conditioning. In classical conditioning, the conditioned response does not affect whether or when the stimulus occurs. Pavlov's dogs salivated when a tone sounded. The salivation had no effect on the tone or on whether food was presented. In contrast, an **operant** has some effect on the world. It is a response that operates on the environment. When a dog stands whimpering by the front door and is then taken for a walk, it has made an operant response that influences when it will get to go outside.

A **reinforcer** is a stimulus that increases the probability that the operant behavior will occur again. There are two main types of reinforcers: positive and negative. **Positive reinforcers** strengthen a response if they are presented after that response occurs. The food that hungry pigeons received after pecking a response key in Skinner's training chamber was a positive reinforcer. Receiving the food increased the birds' key pecking. For people, positive reinforcers can include food, smiles, money, and other desirable outcomes. Presentation of a positive reinforcer after a response is called *positive reinforcement.* **Negative reinforcers** also strengthen responses because they are followed by the *removal* of unpleasant stimuli, such as pain or noise. For example, the disappearance of a headache

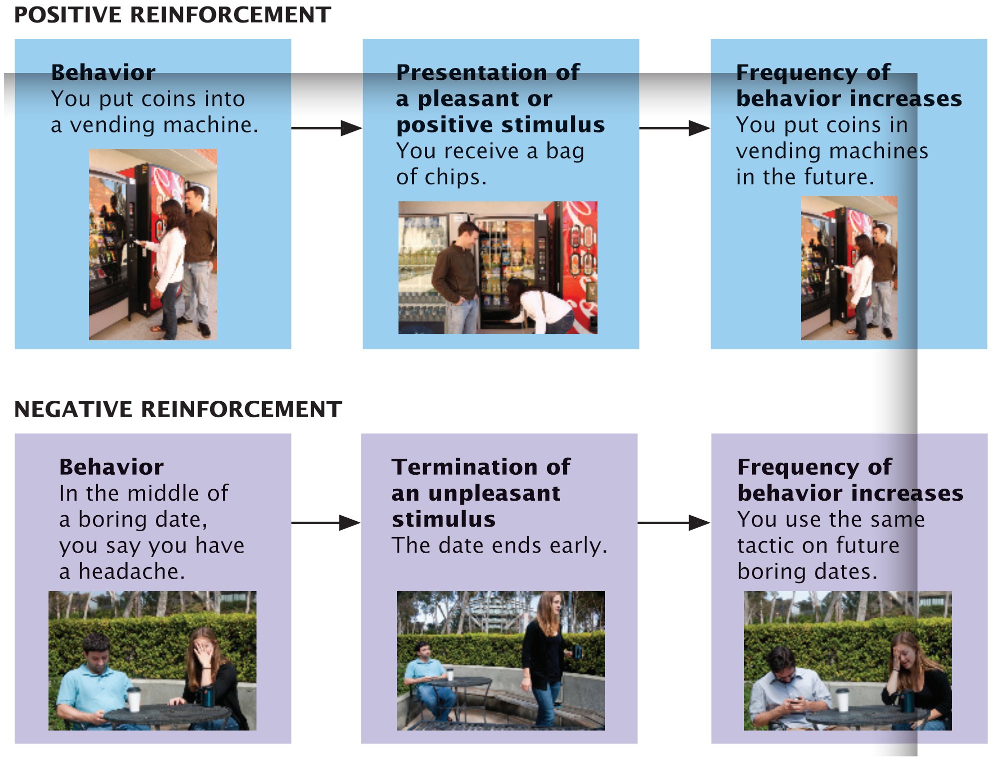


FIGURE 5.7
Positive and Negative Reinforcement

TRY THIS Remember that behavior is strengthened through positive reinforcement when something pleasant or desirable occurs following the behavior. Behavior is strengthened through negative reinforcement when the behavior results in the removal or termination of something unpleasant. To see how these principles apply in your own life, list two examples of situations in which your behavior was affected by positive reinforcement and two in which you were affected by negative reinforcement.

Maria Deseo/PhotoEdit; Maria Deseo/PhotoEdit; © Jonathan Sammartino

after you take a pain reliever acts as a negative reinforcer that makes you more likely to take that pain reliever in the future. When a response is strengthened by the removal of an unpleasant stimulus, the process is called *negative reinforcement.*

Notice that **reinforcement** always increases the likelihood of the behavior that came before it, whether the reinforcer is adding something pleasant or removing something unpleasant. Figure 5.7 shows this relationship.

Escape and Avoidance Conditioning

The effects of negative reinforcement can be seen in both escape conditioning and avoidance conditioning. **Escape conditioning** occurs when we learn responses that stop an unpleasant stimulus. The left-hand panel of Figure 5.8 shows an example from an animal laboratory, but escape conditioning operates in humans, too. Not only do we learn to take pills to stop pain, but some parents learn to stop their child's annoying demands for a toy by agreeing to buy it. And television viewers learn escape annoying commercials by muting the sound.

When an animal or a person responds to a signal in a way that *avoids* an aversive stimulus before it arrives, **avoidance conditioning** has occurred (see the right-hand sections of Figure 5.8). Avoidance conditioning is an important influence on everyday behavior. We go to work even when we would rather stay in bed, we stop at red lights even when we are in a hurry, we apologize for our mistakes even before they are discovered, and we stay away from feared or dangerous places. Each of these behaviors helps us avoid a negative consequence, such as lost pay, a traffic ticket, a scolding, or anxiety or injury.

Avoidance conditioning represents a marriage of classical and operant conditioning. If, as shown in Figure 5.8, a buzzer predicts shock (an unconditioned stimulus), the buzzer becomes a conditioned stimulus (CS). Through classical conditioning, the buzzer (now a CS) triggers a conditioned fear response (CR). Like the shock itself, conditioned fear is an unpleasant internal sensation. The animal then learns the instrumental response of jumping the barrier. The instrumental response (jumping) is reinforced because it reduces fear.

reinforcement The process through which a particular response is made more likely to recur.

escape conditioning The process of learning responses that stop an aversive stimulus.

avoidance conditioning The process of learning particular responses that avoid an aversive stimulus.

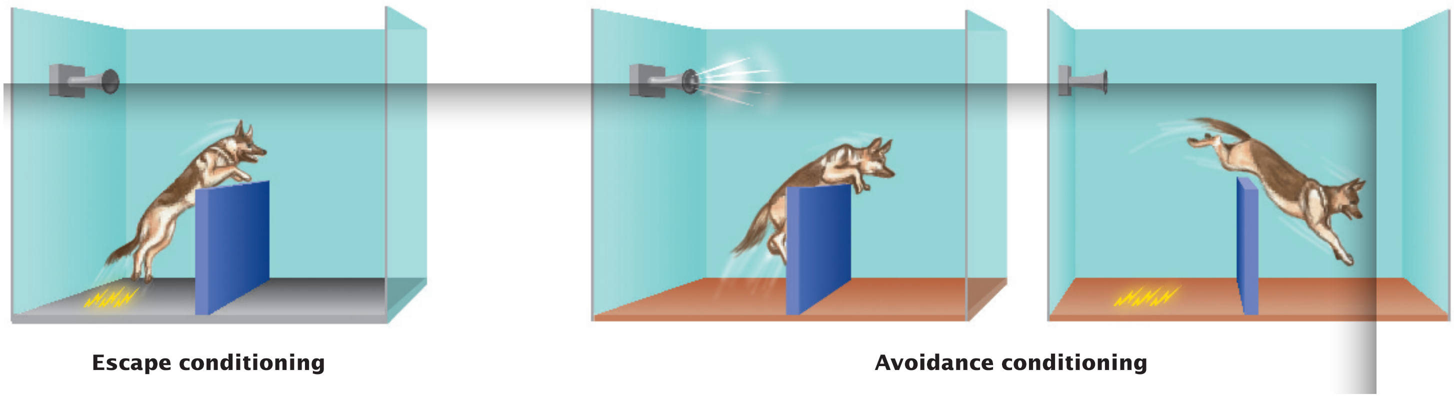


FIGURE 5.8
A Shuttle Box

A shuttle box has two sections that are usually separated by a barrier; its floor is an electric grid. Shock can be administered through the grid to either section. The left-hand panel shows escape conditioning, in which an animal learns to get away from a mild shock by jumping over the barrier when the electricity is turned on. The next two panels show avoidance conditioning. Here, the animal has learned to avoid shock altogether by jumping over the barrier when it hears a warning buzzer just before shock occurs.

Once learned, avoidance is a difficult habit to break, because avoidance responses continue to be reinforced by fear reduction (Solomon, Kamin, & Wynne, 1953). So even without the shock, animals may keep jumping over the barrier when the buzzer sounds because they never discover that avoidance is no longer necessary. The same is often true of people. Those who avoid escalators out of fear never get a chance to find out that they are safe. Others avoid potentially embarrassing social situations, but doing so also prevents them from learning how to be successful in those situations.

The study of avoidance conditioning has not only expanded our understanding of negative reinforcement but also has led some psychologists to consider more complex cognitive processes in operant learning. These psychologists suggest, for example, that in order for people to learn to avoid an unpleasant event (such as getting fired or paying a fine), they must have established an expectancy or other mental representation of that event. The role of such mental representations is emphasized in the cognitive theories of learning described later in this chapter.

Discriminative Conditioned Stimuli and Stimulus Control

The consequences of our behavior often depend on the situation we are in. Most people know that a flirtatious comment about someone's appearance may be welcomed on a date but not at the office. And even if you have been rewarded for telling jokes, you are not likely to do so during a funeral. In the language of operant conditioning, situations serve as **discriminative conditioned stimuli**, which are stimuli that signal whether reinforcement is available if a certain response is made. *Stimulus discrimination* occurs when an organism learns to make a particular response in the presence of one stimulus but not another. The response is then said to be under *stimulus control*. Stimulus discrimination allows people or animals to learn what is appropriate (reinforced) and inappropriate (not reinforced) in particular situations. For example, bears searching for food in Yosemite National Park campgrounds tend to break into minivans; it appears that they've learned that minivans are more likely than other vehicles to contain the goodies they are after (Breck, Lance, & Seher, 2009).

Stimulus generalization also occurs in operant conditioning. That is, an animal or person will perform a response in the presence of a stimulus that is similar to (but not exactly like) a stimulus that has signaled reinforcement in the past. The more similar the new stimulus is to the old one, the more likely it is that the response will be performed. Suppose you ate a wonderful meal at a restaurant called "Captain Jack's," which was decorated to look like the inside of a sailing ship. You might later be attracted to other restaurants with nautical names or with interiors that look something like the one where you had that great meal.

Stimulus generalization and stimulus discrimination complement each other. In one study, for example, pigeons received food for pecking at a response key, but only when they saw certain kinds of artwork (Watanabe, Sakamoto, & Wakita, 1995; see Figure 5.9). As a

discriminative conditioned stimuli Stimuli that signal whether reinforcement is available if a certain response is made.

FIGURE 5.9
Stimulus Discrimination

Pigeons reinforced for responding to the work of a particular painter learned to tell the difference between his paintings and those of other artists (Watanabe, Sakamoto, & Wakita, 1995).

Photo courtesy of Bruce E. Hesse, Ph.D., Department of Psychology and Child Development, California State University, Stanislaus

result, these birds learned to *discriminate* the works of the impressionist painter Claude Monet from those of the cubist painter Pablo Picasso. Later, when the birds were shown new paintings by other impressionist and cubist artists, they were able to *generalize* from the original artists to other artists who painted in the same style, as if they had learned the conceptual categories of "impressionism" and "cubism." We humans learn to place people and objects into even more finely detailed categories, such as "honest," "dangerous," or "tax deductible." We discriminate one stimulus from another and then through generalization respond similarly to all those we perceive to be in a particular category. This ability to respond in a similar way to all members of a category can save us considerable time and effort, but it can also lead to the development of unwarranted prejudice against certain groups of people (see the chapter on social psychology).

Forming and Strengthening Operant Behavior

Your daily life is full of examples of operant conditioning. You go to movies, parties, classes, and jobs primarily because doing so brings reinforcement. What is the effect of the type or timing of your reinforcers? How do you learn new behaviors? How can you get rid of old ones?

Shaping

Let's say you want to train your dog, Sugar, to sit and "shake hands." You figure that positive reinforcement should work, so you decide to give Sugar a treat every time she sits and shakes hands. But there's a problem with this plan. As smart as Sugar is, she may never make the desired response on her own, so you might never be able to give the reinforcer. The way around this problem is to shape Sugar's behavior. **Shaping** is the process of reinforcing *successive approximations*—that is, responses that come successively closer to the desired behavior. For example, you might first give Sugar a treat whenever she sits down. Next, you might reinforce her only when she sits and partially lifts a paw. Finally, you might reinforce only complete paw lifting. Eventually, you would require Sugar to perform the entire sit-lift-shake sequence before giving the treat. Shaping is a powerful tool. Animal trainers have used it to teach chimpanzees to roller-skate, dolphins to jump through hoops, and pigeons to play Ping-Pong (Coren, 1999).

Secondary Reinforcement

Operant conditioning often begins with the use of **primary reinforcers**, which are events or stimuli—such as food or water—that satisfy needs that are basic to survival. The effects of primary reinforcers are powerful and automatic. But constantly giving Sugar food as a reward can disrupt training, because she will stop to eat after every response. Also, once she gets full, food will no longer act as an effective reinforcer. To avoid these problems, animal trainers, parents, and teachers rely on the principle of secondary reinforcement.

Secondary reinforcers are previously neutral stimuli that take on reinforcing properties after being paired with stimuli that are already reinforcing. In other words, they are rewards that people or animals learn to like (Seo & Lee, 2009). If you say "Good girl!" just before feeding Sugar, those words will become reinforcing after a few pairings. "Good girl!" can then be used alone, without food, to reinforce Sugar's behavior. It helps if the words are again paired with food every now and then. Does this remind you of classical conditioning? It should, because the primary reinforcer (food) is an unconditioned stimulus. If the words "Good girl!" become a reliable signal for food, they will act as a conditioned stimulus (CS). For this reason, secondary reinforcers are sometimes called *conditioned reinforcers.*

shaping The reinforcement of responses that come successively closer to some desired response.

primary reinforcers Events or stimuli that satisfy physiological needs basic to survival.

secondary reinforcers Rewards that people or animals learn to like.

Getting the Hang of It

Learning to eat with a spoon is, as you can see, a hit-and-miss process at first. However, this child will learn to hit the target more and more often as the food reward gradually shapes a more efficient (and far less messy) pattern of behavior.

PureStock RF/Jupiter Images

The power of operant conditioning can be greatly increased by using secondary reinforcers. Consider the secondary reinforcer we call money. Some people will do almost anything for it despite the fact that it tastes terrible and won't quench your thirst. Its reinforcing power lies in its association with the many rewards it can buy. Smiles and other forms of social approval (such as the words "Good job!") are also important secondary reinforcers for human beings. However, secondary reinforcers can vary widely from person to person and culture to culture. Tickets to a rock concert may be an effective secondary reinforcer for some people but not for others. A ceremony honoring outstanding job performance might be strongly reinforcing in an individualist culture, but the same experience might be embarrassing for a person in a collectivist culture, where group cooperation is given greater value than personal distinction (Miller, 2001). When carefully chosen, however, secondary reinforcers can build or maintain behavior, even when primary reinforcement is absent for long periods.

Delay and Size of Reinforcement

Much of our behavior is learned and maintained because it is regularly reinforced. But many of us overeat, smoke, drink too much, or procrastinate, even though we know these behaviors are bad for us. We may want to eliminate them, but they are hard to change. We seem to lack self-control. If behavior is controlled by its consequences, why do we do things that are ultimately self-defeating?

Part of the answer lies in the timing of reinforcers. For example, the good feelings (positive reinforcers) that follow excessive drinking are immediate. But because hangovers and other negative consequences are usually delayed, their effects on future drinking are weakened. In other words, operant conditioning is stronger when reinforcers appear soon after a response occurs (Rachlin, 2000). Under some conditions, delaying a positive reinforcer for even a few seconds can decrease the effectiveness of positive reinforcement. The size of the reinforcer is also important. In general, conditioning is faster when the reinforcer is large than when it is small.

Reinforcement Schedules

When a *continuous reinforcement schedule* is in effect, a reinforcer is delivered every time a particular response occurs. This schedule can be helpful when teaching someone a new skill, but it can be impractical in the long run. Imagine how inefficient it would be, for example, if an employer had to deliver praise or pay following every little task employees performed all day long. In most cases, reinforcement is given only some of the time, on a *partial,* or *intermittent, reinforcement schedule.* Intermittent schedules are described in terms of when and how reinforcers are given. "When" refers to the number of responses that have to occur, or the amount of time that must pass, before a reinforcer will occur. "How" refers to whether the reinforcer will be delivered in a predictable or unpredictable way.

1. *Fixed-ratio (FR) schedules* provide reinforcement following a fixed number of responses. Rats might receive food after every tenth time they press the lever in a Skinner box (FR 10) or after every twentieth time (FR 20). Technicians working at computer help centers might be allowed to take a break after every fifth call they handle, or every tenth.
2. *Variable-ratio (VR) schedules* also call for reinforcement after a certain number of responses, but that number varies. As a result, it is impossible to predict which particular response will bring reinforcement. On a VR 30 schedule, for example, a rat will be reinforced after an *average* of thirty lever presses. This means that the reward sometimes comes after ten presses, sometimes after fifteen, and other times after fifty or more. Gambling offers humans a similar variable-ratio schedule. Casino slot machines pay off only after a frustratingly unpredictable number of button-pushes, averaging perhaps one in twenty.
3. *Fixed-interval (FI) schedules* provide reinforcement for the first response that occurs after some fixed time has passed since the last reward. On an FI 60 schedule,

Reinforcement Schedules on the Job

TRY THIS Make a list of all the jobs you have ever held, along with the reinforcement schedule on which you received your pay for each. Which of the four types of schedules (fixed ratio, fixed interval, variable ratio, or variable interval) was most common, and which was most satisfying to you?

Jim West/The Image Works

for instance, the first response after sixty seconds has passed will be rewarded, regardless of how many responses have been made during that interval. Some radio stations make use of fixed-interval schedules. Listeners who have won a call-in contest might have to wait at least ten days before they are eligible to win again.

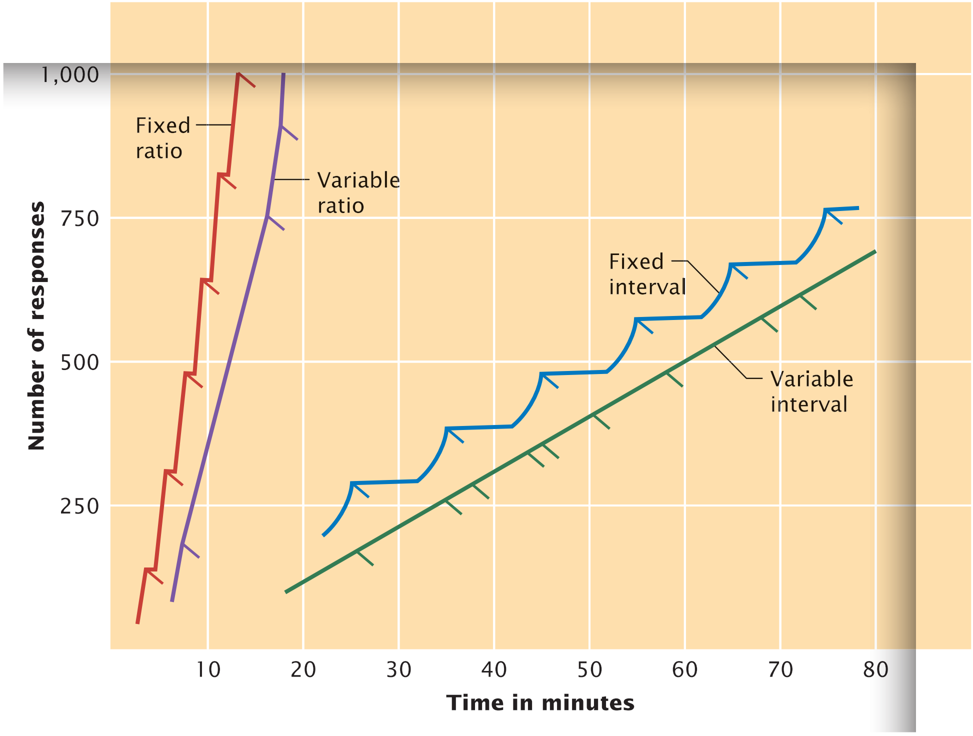
4. *Variable-interval (VI) schedules* reinforce the first response after some period of time, but the amount of time varies unpredictably. So on a VI 60 schedule, the first response that occurs after an *average* of 60 seconds is reinforced, but the actual time between reinforcements might vary anywhere from 1 to 120 seconds or more. Police in Illinois and California have used a VI schedule to encourage seat belt use and careful driving. They stopped drivers at random times and awarded prizes to those who were buckled up and driving safely (Associated Press, 2007; Mortimer et al., 1988). Kindergarten teachers use VI schedules when they give rewards to children who are in their seats when a chime sounds at random intervals.

As shown in Figure 5.10, different **reinforcement schedules** produce different patterns of responding (Skinner, 1961). Both fixed-ratio and variable-ratio schedules produce especially high response rates overall. The reason, in both cases, is that the frequency of reward depends directly on the rate of responding.

Fixed-interval and variable-interval schedules generally produce lower response rates than ratio schedules. This makes perfect sense. Under a fixed-interval schedule, for example, it does not matter how many responses you make between one reward and the next. You will only be reinforced for the first response you make after a specified amount of time has passed. Because the timing of the reinforcement is so predictable, the rate of responding typically drops immediately after reinforcement and then increases as the time for another reward approaches. When teachers schedule quizzes on the same day each week, most students will study just before each quiz and then cease studying almost immediately afterward. Variable-interval schedules produce a slower, but steadier, response rate. Because one can never be sure how long it will be before the next response will be reinforced,

FIGURE 5.10
Results of Four Partial Reinforcement Schedules

These curves illustrate the patterns of behavior typically seen under different reinforcement schedules. The steeper the curve, the faster the response rate was. The thin, diagonal lines crossing the curves show when reinforcement was given. In general, the rate of responding is higher under ratio schedules than under interval schedules.



reinforcement schedules In operant conditioning, rules that determine how and when certain responses will be reinforced.

Superstition and Partial Reinforcement

Partial reinforcement helps sustain superstitious athletic rituals—such as a fixed sequence of actions prior to hitting a golf ball or shooting a free throw in basketball. If the ritual has preceded success often enough, failure to execute it may upset the player and disrupt performance.Former Oakland Athletics infielder Nomar Garciaparra tugged, loosened, and retightened each batting glove after every pitch. Those who watch sports have their superstitious rituals, too. One Pittsburgh Steelers football fan we know insists on wearing the same outfit while watching every game and eats a particular brand of lime-flavored corn chips because he believes this will ensure victory.

AP Images/Ben Margot

rewards will be maximized by responding at a regular, but not frantic, pace. This is why students whose teachers give unannounced "pop" quizzes on an unpredictable schedule are likely to study on a steady, regular basis just in case a quiz might occur at the next class (Kouyoumdjian, 2004). Variable-interval schedules also encourage the transformation of a goal-directed action (e.g., steady studying to do well on one professor's "pop" quizzes) into a habit that gains momentum from reinforcement and becomes, for example, a more general studying style (Nevin et al., 2001).

Schedules and Extinction

Ending the relationship between an operant response and its consequences weakens that response. In fact, failure to reinforce a response eventually extinguishes it. The response occurs less and less often and eventually may disappear. If you keep sending text messages to someone who never replies, you eventually stop trying. But extinction in operant conditioning does not erase learned relationships (Delamater, 2004). If a discriminative stimulus for reinforcement reappears some time after an operant response has been extinguished, that response may recur (spontaneously recover). And if it is reinforced again, the response will quickly return to its former level, as though extinction had never happened.

In general, behaviors learned under a partial reinforcement schedule are far more difficult to extinguish than those learned on a continuous reinforcement schedule. This phenomenon is called the **partial reinforcement effect**. Imagine, for example, that you are in a gambling casino, standing near a broken candy machine and a broken slot machine. You might deposit money in the broken candy machine once, but this behavior will probably stop (extinguish) very quickly. The candy machine should deliver its goodies on a continuous reinforcement schedule, so you can easily tell that it is not going to provide a reinforcer. But you know that slot machines give rewards on an unpredictable, intermittent schedule. So, you might put in coin after coin, unsure of whether the machine is broken or is simply not paying off at the moment.

Partial reinforcement helps explain why superstitious behavior is so resistant to extinction (Vyse, 2000). Suppose you had been out for a run just before hearing that you passed an important exam. The run did nothing to cause this outcome. The reward followed it through sheer coincidence. Still, for some people, this kind of *accidental reinforcement* can strengthen the behavior that appeared to "cause" good news (Mellon, 2009; Pronin et al., 2006). These people might decide that it is "lucky" to go running after taking an exam. Similarly, someone who wins the lottery or a sports bet while wearing a particular shirt may begin wearing the "lucky shirt" more often (Hendrick, 2003). Of course, if the person wears the shirt often enough, something good is bound to follow every now and then, thus further strengthening the superstitious behavior on a sparse partial schedule.

Why Reinforcers Work

What makes a reinforcer reinforcing? Research by biological psychologists suggests that reinforcers may exert particular effects on the brain. In a classic study on this point, James Olds and Peter Milner (1954) discovered that mild electrical stimulation of certain areas of the brain's hypothalamus can be a powerful reinforcer. Hungry rats will ignore food if they can press a lever that stimulates these "pleasure centers" (Olds, 1973). It has since been discovered that activation of certain brain systems that use the neurotransmitter dopamine is associated with the pleasure of many stimuli, including food, music, sex, and highly addictive drugs such as cocaine (e.g., Baik, 2013; Beierholm et al., 2013). Actions that produce unexpected rewards, such as gambling, also involve increased brain dopamine activity (Potenza, 2013). In fact, the same brain reward areas are activated whether we are receiving money or food rewards (Kim, Shimojo, &

partial reinforcement effect A phenomenon in which behaviors learned under a partial reinforcement schedule are more difficult to extinguish than those learned on a continuous reinforcement schedule.

O'Doherty, 2011). In short, complex and widespread patterns of brain activity are involved in our response to reinforcers, allowing us to enjoy them, to learn to want them, and to learn how to get them (e.g., Dreher et al., 2010; Pessiglione et al., 2006).

Punishment

Positive and negative reinforcement increase the frequency of a response, either by presenting something pleasurable (i.e., positive reinforcement) or by removing something that is unpleasant (i.e., negative reinforcement). In contrast, positive and negative **punishment** *reduce* the frequency of an operant behavior by presenting an unpleasant stimulus or removing a pleasant one (in other words, by increasing discomfort or reducing pleasure). Shouting "No!" and swatting your cat when it scratches your furniture is an example of positive punishment, because it *presents* an aversive stimulus following a response. Taking away a child's TV privileges because of rude behavior is called negative punishment because it *removes* a pleasurable stimulus (see Figure 5.11).

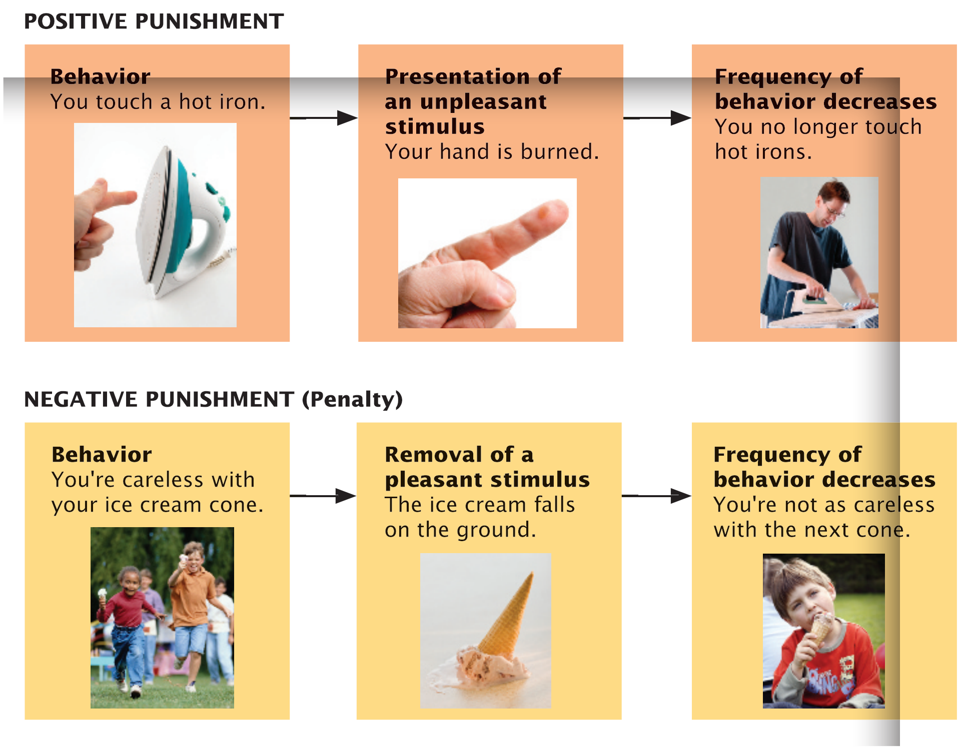


FIGURE 5.11
Two Kinds of Punishment

In positive punishment, an aversive, or unpleasant, stimulus follows a behavior. In negative punishment, sometimes called penalty, a pleasant stimulus is removed following a behavior. In either case, punishment decreases the chances that the behavior will occur in the future. Now you decide: When a toddler reaches toward an electric outlet and her father says "NO!" and gently taps her hand, is that punishment or negative reinforcement? If you said punishment, you're right, because it will reduce the likelihood of her touching outlets in the future.

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Punishment is often confused with negative reinforcement, but the two are quite different. Just remember that reinforcement of any type always *strengthens* behavior, whereas punishment always *weakens* behavior. If shock is *turned off* when a rat presses a lever, negative reinforcement occurs. It increases the probability that the rat will press the lever when shock occurs again. But if shock is *turned on* when the rat presses the lever, punishment occurs. The rat will be less likely to press the lever again.

Although punishment can change behavior, it has some drawbacks (Gershoff & Bitensky, 2007). First, it does not "erase" an undesirable behavior. It merely suppresses the behavior temporarily. In fact, people often repeat punished acts when they think they can do so without getting caught. Second, punishment can produce unwanted side effects. If you punish a child for swearing, the child may associate the punisher with the punishment and end up fearing you. Third, punishment is often ineffective unless it is given

punishment The presentation of an aversive stimulus or the removal of a pleasant one following some behavior.

immediately after the undesirable behavior and each time that behavior occurs. If a child gets into the cookie jar and enjoys a few cookies before being discovered and punished, the effect of the punishment will be greatly reduced. Fourth, physical punishment can become aggression, even abuse, if given in anger or with an object other than a hand (Zolotor et al., 2008). Fifth, because children tend to imitate what they see, frequent punishment may lead them to behave aggressively themselves (e.g., Taylor et al., 2010). Finally, punishment lets people know they have done something wrong, but it doesn't specify what they should do instead. An "F" on a term paper means that the assignment was poorly done, but the grade alone tells the student nothing about how to improve.

In the 1970s and 1980s, concerns over these drawbacks led many professionals to discourage parents from using spanking and some other forms of punishment with their children (Rosellini, 1998). More recent studies suggest, though, that occasional mild spanking can be an effective way to discipline children who are between three and thirteen years of age (e.g., Larzelere, 2000). Debate on this issue continues (e.g., Berlin et al., 2009; Kazdin & Benjet, 2003; Straus, 2005). Opponents point out that some youngsters who are spanked go on to show behavioral control problems, but proponents note that those same problems sometimes appear after children are given nonphysical punishments such as grounding, removing privileges, or being sent to their rooms (Larzelere, Cox, & Smith, 2010).

While some remain against spanking children under any circumstances (Gershoff, 2013), the results of an extensive review of the relevant research literature suggests that the long-term negative effects of spanking are minimal (Ferguson, 2013a). Indeed, the effects of spanking should be viewed in relation to when, where, and how it is used. For example, spanking is more common in some cultures and subcultures than in others (Runyan et al., 2010), and its negative effects, such as anxiety or aggressiveness, appear less likely to occur where it is a socially accepted form of discipline (Gershoff et al., 2010; Lansford et al., 2005). Further, occasional spanking may be least likely to harm children's development when it is used in combination with other disciplinary practices, such as requiring children to pay a penalty for their misdeeds, having them provide restitution to the victims of their actions, and making them aware of what they did wrong (Gunnoe & Mariner, 1997; Larzelere, 1996).

Punishment can even be therapeutic (Baumrind, Larzelere, & Cowan, 2002). As shown in Figure 5.12, for example, it can help children who suffer from certain developmental disorders or who purposely injure themselves (Flavell et al., 1982). So when properly used, punishment can be valuable, especially when a few guidelines are followed:

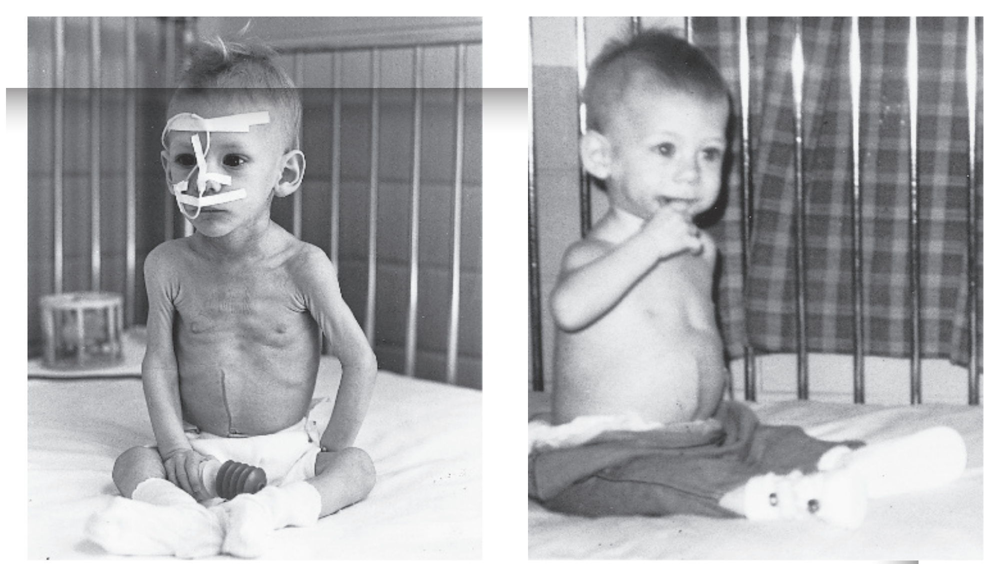


FIGURE 5.12
Life-Saving Punishment

This child suffered from chronic ruminative disorder, a condition in which he vomited everything he ate. At left, the boy was approximately one year old and had been vomiting for four months. At right is the same child thirteen days after punishment with electric shock had eliminated the vomiting response; his weight had increased 26 percent. He was physically and psychologically healthy when tested six months, one year, and two years later (Lang & Melamed, 1969).

University of Florida; University of Florida

- Specify why punishment is being given, in order to prevent the development of a general fear of the punisher.
- Emphasize that the behavior, not the person, is being punished.
- Make the punishment immediate and noticeable enough to eliminate the undesirable response, without being abusive. A half-hearted "Quit it" may actually reinforce a child's misbehavior, because almost any attention is rewarding to some children. And once a child gets used to mild punishment, the parent may resort to punishment that is far more severe than would have been necessary if stern, but moderate, punishment had been used in the first place. (You may have witnessed this *escalation effect* in grocery stores or restaurants where children ignore their parents' initially weak efforts to stop their misbehavior.)
- Identify and positively reinforce more appropriate responses.

When these guidelines are not followed, the beneficial effects of punishment may be wiped out or may be only temporary. As prison systems demonstrate, punishment alone does not usually lead to rehabilitation because the punishment of confinement is not usually supplemented by efforts to teach and reinforce noncriminal lifestyles. Following their release, about two-thirds of U.S. prison inmates are rearrested for felonies or serious misdemeanors within three years, and about 50 percent will go back to prison (Cassel & Bernstein, 2007; U.S. Department of Justice, 2002).

Some Applications of Operant Conditioning

Although the principles of operant conditioning were originally worked out with animals in the laboratory, they are valuable for understanding human behavior in an endless variety of everyday situations. ("In Review: Reinforcement and Punishment" summarizes some key concepts of operant conditioning.) Effective use of reinforcements and punishments by parents, teachers, and peers is vital to helping children learn what is and is not appropriate behavior at the dinner table, in the classroom, or at a birthday party. People learn how to be "civilized" in their culture partly through experiencing positive and negative responses from others. And differing patterns of rewards and punishments for boys and girls underlie the development of behavior that fits culturally approved *gender roles*, a topic explored in more detail in the chapter on human development.

Speak Up!

Students are often reluctant to make comments or to ask or answer questions, especially in large classrooms. Some professors have used operant conditioning principles to help overcome this problem. In one introductory psychology course, classroom participation was reinforced with coinlike tokens that students could exchange for extra credit (Boniecki & Moore, 2003). The students responded faster to the professor's questions and offered many more comments and questions when this "token economy" was introduced. The frequency of student questions and comments dropped again when tokens were no longer given, but students continued their quick responses to the professor's questions. By that time, apparently, the professor's social reinforcement was enough to encourage this aspect of classroom participation.

Thomas Imo/Alamy

The scientific study of operant conditioning has been applied in many practical ways. For example, operant reinforcement of carpooling has been successful in reducing the number of cars on the road during big city rush hours (Ben-Elia & Ettema, 2011), and rewarding children for trying foods they once disliked has helped them learn to enjoy those foods (Cooke et al., 2011). Programs that combine the use of rewards and extinction (or carefully administered punishment) have helped improve the behavior of countless people with mental disorders, intellectual disability, and brain injuries, as well as preschoolers with behavioral and emotional disorders (e.g., Alberto, Troutman, & Feagin, 2002; Dickerson, Tenhula, & Green-Paden, 2005; Martin & Pear, 2010). These programs include establishing goal behaviors, choosing reinforcers and punishers, and developing a systematic plan for applying them to achieve desired changes. Many self-help books also incorporate the principles of positive reinforcement, recommending self-reward following each small victory in people's efforts to lose weight, stop smoking, avoid procrastination, or reach other goals (e.g., Grant & Kim, 2002; Rachlin, 2000).

When people cannot alter the consequences of a behavior, discriminative conditioned stimuli may help change their behavior. For example, many smokers find it easier to quit if they temporarily avoid bars and other places where there are powerful discriminative conditioned stimuli for smoking. Stimulus control can also help alleviate insomnia. Many insomniacs tend to use their beds for activities such as watching television, writing letters, reading magazines, worrying, and so on. Soon the bedroom becomes a discriminative stimulus for so many activities that relaxation and sleep become less and less likely. *Stimulus control therapy* encourages these people to use their beds only for sleeping, and perhaps sex, making it more likely that they will sleep better when in bed (Perlis et al., 2011).

IN REVIEW

REINFORCEMENT AND PUNISHMENT

Concept	Description	Example or Comment
Positive reinforcement	Increasing the frequency of a behavior by following it with the presentation of a positive reinforcer—a pleasant, positive stimulus or experience	You say "Good job!" after someone works hard to perform a task.
Negative reinforcement	Increasing the frequency of a behavior by following it with the removal of an unpleasant stimulus or experience	You learn to use the mute button on the TV remote control to remove the sound of an obnoxious commercial.
Escape conditioning	Learning to make a response that removes an unpleasant stimulus	A little boy learns that crying will cut short the time that he must stay in his room.
Avoidance conditioning	Learning to make a response that avoids an unpleasant stimulus	You slow your car to the speed limit when you spot a police car, thus avoiding being stopped and reducing the fear of a fine; very resistant to extinction.
Punishment	Decreasing the frequency of a behavior by either presenting an unpleasant stimulus (positive punishment) or removing a pleasant one (negative punishment)	You swat the dog after it steals food from the table or you take a favorite toy away from a child who misbehaves. A number of cautions should be kept in mind before using punishment.

In Review Questions

1. Taking a pill can relieve headache pain, so people learn to do so through the process of __________ reinforcement.
2. The "walk" sign that tells people it is safe to cross the street is an example of a __________ stimulus.
3. Response rates tend to be higher under __________ schedules of reinforcement than under __________ schedules.

LINKAGES How are learned associations stored in memory? (a link to memory)

LINKAGES

NETWORKS OF LEARNING

Associations between conditioned stimuli and automatic responses or between responses and their consequences play an important role in learning, but how are they actually stored in the brain? No one yet knows for sure, but associative network models provide a good way of thinking about the process. As suggested in the chapter on memory, the associations we form among stimuli and events are represented in complex networks of connections among neurons in the brain. Consider the word "dog." As shown in Figure 5.13, each person's experience builds many associations to this word, and the strength of each association will reflect the frequency with which "dog" has been mentally linked to the other objects, events, and ideas in that person's life.

Using what they know about the laws of learning and the way neurons communicate and alter their connections, psychologists have developed computer models of how these associations are established (Messinger et al., 2001). These "neural network" models build on the observation that the brain uses many regions that work together across a widely dispersed system in order to accomplish mental tasks. Accordingly, many neural network models use the idea of distributed memory or distributed knowledge. These models suggest, for example, that your knowledge of "dog" does not lie in a single spot, or node, in your brain. Instead, that knowledge is distributed throughout the network of associations that connect the letters D, O, and G, along with other dog-related experiences. In addition, as shown in Figure 5.13, each of the interconnected nodes that make up your knowledge of "dog" is connected to many other nodes as well. So the letter D will be connected to "daisy," "danger," and many other concepts.

Neural network models of learning focus on how these connections develop through experience (Carasatorre & Ramírez-Amaya, 2013; Klingberg, 2010). For example, suppose you are learning a new word in a foreign language. Each time you read the word and associate it with its English equivalent, you strengthen the neural connections between the sight of the letters forming that word and all of the nodes activated when its English equivalent is brought to mind. Neural network models are sometimes called *connectionist* because they focus on how different parts of the network form connections with other parts. These models of learning predict how much the strength of each connection grows (in terms of the likelihood of neural communication between the two connected nodes) each time the two words are experienced together.

The details of various theories about how these connections grow are very complex, but a theme common to many of them is that the weaker the connection between two items, the greater the increase in connection strength when they are experienced together. So in a classical conditioning experiment, the connections between the nodes that characterize the

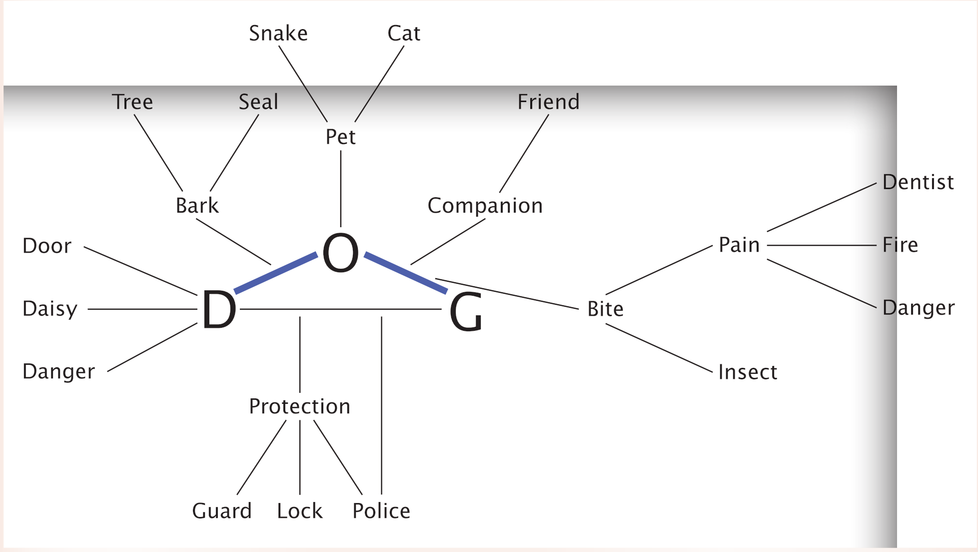


FIGURE 5.13
An Associative Network

Here is an example of a network of associations to the word "dog." Network theorists suggest that the connections shown here represent patterns of connections among nerve cells in the brain.

(*continued*)

conditioned stimulus and those that characterize the unconditioned stimulus will show the greatest increase in strength during the first few learning trials. Notice that this prediction nicely matches the typical learning curve shown in Figure 5.3 (Rescorla & Wagner, 1972). Further research using neural network models is likely to help us understand more about how we learn to recognize associations between the stimuli, responses, and events of our lives (e.g., Boden, 2006; Coutanche & Thompson-Schill, 2012).

COGNITIVE PROCESSES IN LEARNING

Can people learn to be helpless?

In the first half of the twentieth century, psychologists in North America tended to look at learning through the lens of behaviorism. Though they knew that mental representations, expectancies, and other cognitive processes can be involved in learning, they wanted to focus on studying the formation or modification of associations between observable stimuli and observable responses. Their research resulted in a rich set of learning principles based on classical and operant conditioning experiments.

In the decades since, however, psychologists have increasingly focused on exploring other, more complex forms of learning and the cognitive processes associated with them. These forms of learning include the development of concepts; of skill at communication, navigation, and tool use; and of abilities and behavior patterns formed by watching what others do (Blaisdell, Sawa, & Leising, 2006; Wasserman, 1993). Researchers in an area known as *comparative cognition,* for example, explore how cognitive processes in these more complex forms of learning may be seen in nonhumans as well as humans. How, they wonder, can food-storing birds hide, and then later retrieve, thousands of individual food items they need to survive over the winter? Their search might look random, but there is evidence that these birds form memories not only of where they have hidden something, but what they hid and when they hid it (Clayton & Dickinson, 1998; Suddendorf & Corballis, 2007). And although tool use was once thought to be a uniquely human form of adaptation, research by animal behaviorists has shown that chimpanzees, crows, sea otters, and other nonhuman animals have learned to use tools, too (e.g., Cheke et al., 2011; Goodall, 1964). It appears that nonhumans form mental representations, have expectations, and make generalizations that go beyond simply associating a particular response with a reward in an instrumental conditioning experiment (Asen & Cook, 2012; Blaisdell, Sawa, & Leising, 2006).

Examples of cognitive processes that affect learning include several phenomena, including learned helplessness, latent learning, cognitive maps, insight, and observational learning.

Learned Helplessness

Babies learn that crying attracts attention. Children learn how to make the TV louder. Adults learn what actions lead to success or failure in the workplace. People learn to expect that certain actions have certain consequences. But sometimes events are beyond our control. What happens when our actions have no effect on events, and especially when our escape or avoidance behaviors fail? If these circumstances last long enough, one result may be **learned helplessness**, a tendency to give up on efforts to control the environment (Overmier, 2002; Seligman, 1975).

Learned helplessness was first demonstrated in animals. As described earlier, dogs in a shuttle box will learn to jump over a partition to escape a shock (see Figure 5.8). But if the dogs first receive shocks that they cannot escape, they later do not even try to escape when the shock is turned on in the shuttle box (Overmier & Seligman, 1967). It is as if the animals had learned that "shock happens, and there is nothing I can do about it." Do people learn the same lesson?

learned helplessness A process in which a person or animal stops trying to exert control after experience suggests that no control is possible.

FOCUS ON RESEARCH METHODS

AN EXPERIMENT ON HUMAN HELPLESSNESS

What lessons do abused and neglected children learn about their ability to get what they need from the environment? Do they learn that even their best efforts result in failure? Do they give up even trying? Why would a student with above average ability tell a counselor, "I can't do math"? How do people develop an "I can't do it" attitude?

What was the researcher's question?

Can lack of control over the environment lead to helplessness in humans? Donald Hiroto (1974) conducted an experiment to test the hypothesis that people develop learned helplessness either after experiencing lack of control or after simply being told that their control is limited.

How did the researcher answer the question?

Hiroto (1974) randomly assigned research participants to one of three groups. One group heard a series of thirty bursts of loud, obnoxious noise and, like dogs receiving inescapable shock, had no way to stop it. A second group could control the noise by pressing a button to turn it off. The third group heard no noise at all. After this preliminary phase, all three groups heard eighteen additional bursts of noise, each preceded by a red warning light. During this second phase, all participants could prevent the noise if they pushed a lever quickly enough. However, they didn't know whether to push the lever left or right on any given trial. Before these new trials began, the experimenter told half the participants in each group that avoiding or escaping the noise depended on their skill. The other half were told that their success would be a matter of chance.

What did the researcher find?

The people who had previously experienced lack of control now failed to control noise on about four times as many trials as did those who had earlier been in control (50 percent versus 13 percent). This finding was similar to that of the research with dogs and inescapable shock. When the dogs were later placed in a situation in which they could escape or avoid shock, they did not even try. Humans, too, seem to use prior experiences to guide later efforts to try, or not to try, to control their environment.

Expectation of control, whether accurate or not, also had an effect on behavior. In Hiroto's study, those participants who expected that skill could control the noise exerted control on significantly more trials than did those who expected chance to govern the result. This outcome occurred regardless of whether the participants had experienced control before.

What do the results mean?

These results support Hiroto's hypothesis that people, like animals, tend to make less effort to control their environment when prior experience suggests that those efforts will be of no use. But unlike animals, humans need only be *told* that they have no control or are powerless in order for this same effect to occur.

Hiroto's (1974) results appear to show a general phenomenon. When prior experience leads people to *believe* that there is nothing they can do to change their lives or control their destiny, they may stop trying to improve their lot (Faulkner, 2001; Peterson, Maier, & Seligman, 1993). Instead, they may passively endure painful situations. Has this ever happened to you?

What do we still need to know?

Further research is needed on when and how learned helplessness affects people's thoughts, feelings, and actions. For example, could learned helplessness explain why some battered women remain with abusive partners? Could a soldier's sense of a lack of control during combat be at the root of a subsequent post-traumatic stress disorder (LoLordo & Overmier, 2011)? We do know that learned helplessness experiences are associated with the development of depression and other psychological disorders (Hammack, Cooper, & Lezak, 2012). Learned

(*continued*)

helplessness may increase a *pessimistic explanatory style*, such as occurs in people with depression (Peterson & Seligman, 1984). In this style of thinking, individuals explain away any good things that happen to them as temporary and due to chance, but they see the bad things as permanent and due to internal factors (e.g., lack of ability). This explanatory style has been linked with poor grades, inadequate sales performance, health problems, and other negative outcomes (Bennett & Elliott, 2002; Seligman & Schulman, 1986; Taylor, 2002).

By contrast, repeated success at controlling events may create a sense of "learned mastery" or "learned resourcefulness." Experiments suggest that animals are more resistant to learned helplessness tasks if they have first performed tasks in which their responses actually did determine what happened to them (Volpicelli et al., 1983). Such findings suggest that a learned sense of control may be enough to reduce learned helplessness effects. Some research suggests that, in rats at least, an expectation of control may depend on activity in the brain's medial prefrontal cortex. Chemicals that reduce nerve cell activity in this area tend to make learned helplessness more likely, whereas chemicals that stimulate medial prefrontal functioning tend to prevent learned helplessness (Amat et al., 2005). We do not yet know whether this brain area is equally important for human helplessness.

Whatever its biological basis, it is clear that a sense of control is important for humans. People with a history of successful control appear more likely than others to develop the *optimistic cognitive style*, hopefulness, and resilience that lead to even more success and healthier lives (Gillham, 2000; Zimmerman, 1990; see the chapter on health, stress, and coping). Accordingly, psychologists have been working on how best to help people minimize learned helplessness and maximize learned optimism in areas such as education, parenting, and psychotherapy (e.g., Jackson, Sellers, & Peterson, 2002). One option is "resiliency training" for children and adults at risk for depression or other problems (Bradshaw et al., 2007; Cardemil, Reivich, & Seligman, 2002; Waite & Richardson, 2004). Time will tell if such training leads to beneficial outcomes.

Latent Learning and Cognitive Maps

Decades ago, Edward Tolman conducted pioneering studies of cognitive processes in learning by watching rats trying to find their way through a complex maze to get food that was waiting for them at the end. At first, the rats took many wrong turns. But, over time, they made fewer and fewer mistakes. Behaviorists interpreted this result by saying that the rats learned a long chain of turning responses, because these responses were reinforced by getting food. But Tolman disagreed and offered evidence for a cognitive interpretation.

In one of his studies, three groups of rats were placed in the same maze once a day for several days (Tolman & Honzik, 1930). For Group A, food was placed at the end of the maze on each trial. As shown in Figure 5.14, these rats gradually improved their performance. Group B also ran the maze once a day, but there was never any food waiting for them. The animals in Group B continued to make many errors. Neither of these results is surprising.

The third group of rats, Group C, was the critical one. For the first ten days, they received no reinforcement for running the maze and continued to make many mistakes. Then, on the eleventh day, food was placed at the end of the maze for the first time. What do you think happened? On the day after receiving reinforcement, these rats made almost no mistakes (again, see Figure 5.14). In fact, their performance was as good as that of the group that had been reinforced every day. The single reinforcement trial on day 11 produced a dramatic change in their performance the next day.

Tolman argued that these results support two conclusions. First, because the rats in Group C improved their performance the first time they ran the maze after being reinforced, the reinforcement on day 11 could not have significantly affected their *learning* of the maze. Rather, the reinforcement simply changed their subsequent *performance*. They must have already learned the maze earlier as they wandered around making mistakes on their way to the end of the maze. These rats demonstrated **latent learning**—learning that had obviously occurred in the animal even though it was not evident when it first took place. (Latent learning occurs in humans, too; for example, after years of experience in

latent learning Learning that is not demonstrated at the time it occurs.

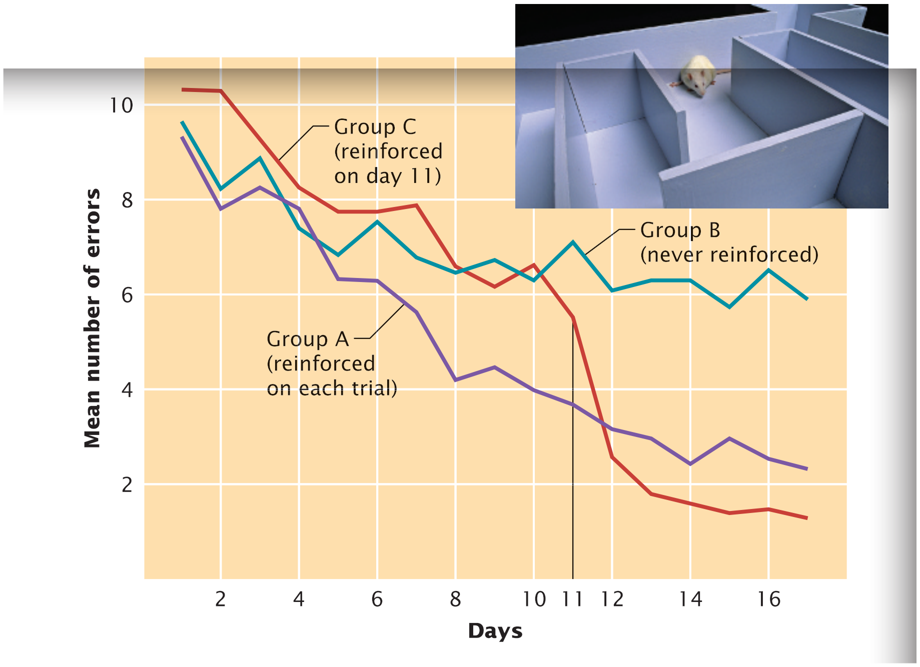


FIGURE 5.14
Latent Learning

This graph shows the average number of wrong turns that Tolman's rats made on their way to the end of a maze (Tolman & Honzik, 1930). Notice that when rats in Group C did not receive food reinforcement, they continued to make many errors. The day after first finding food at the end of the maze, however, they took almost no wrong turns! The reinforcement, argued Tolman, affected only the rats' performance; they must have learned the maze earlier, without reinforcement.

Matt Meadows/Photolibrary/Getty Images

your neighborhood, you could probably tell a visitor that the corner drugstore is closed on Sundays, even if you had never tried to go there on a Sunday yourself.)

The second conclusion that Tolman drew from his data was that the rats' sudden improvement in performance after the first reinforcement trial could have occurred only if the rats had earlier developed a cognitive map of the maze. A **cognitive map** is a mental representation of some physical arrangement—in this case, a maze. How are such maps created? The hippocampus, a brain area associated with the formation of new memories, appears to play a special role. Scientists have discovered *place cells* in the rat hippocampus that fire only when particular locations in a maze are visited. When rats sleep after a maze-learning session, cells in the hippocampus "replay" the firing sequences and patterns that had occurred during the session, thus apparently strengthening, or *consolidating*, the maze's features in memory (Prerau et al., 2014; Suzuki, 2008).

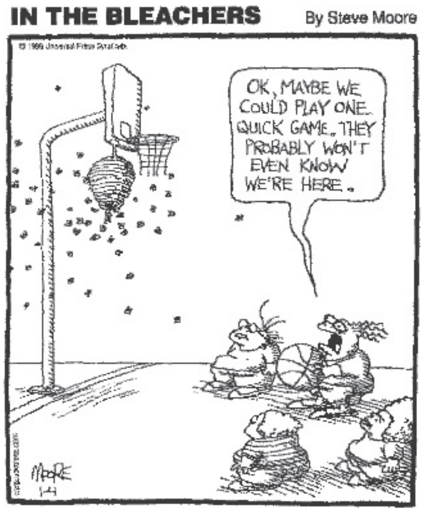
Tolman could not have known about these specific processes, but he nevertheless concluded that cognitive maps develop naturally through experience, even in the absence of any overt response or reinforcement. Research on learning in the natural environment has supported this view. We develop mental maps of shopping malls and city streets even when we receive no direct reward for doing so (Tversky & Kahneman, 1991). Having such a map allows you to tell that neighborhood visitor exactly how to get to the corner drugstore from where you are standing.

Insight and Learning

Wolfgang Köhler was a psychologist whose work on the cognitive aspects of learning happened almost by accident. He was visiting Tenerife, one of the Canary Islands in the Atlantic Ocean, when World War I broke out in 1914. As a German citizen in territory controlled by Germany's enemy, Britain, Köhler was stuck on the island until the war ended in 1918. He put this time to good use by studying problem solving in a colony of local chimpanzees (Köhler, 1924).

For example, Köhler would put a chimpanzee in a cage and place a piece of fruit where the chimp could see it but not reach it. He sometimes hung the fruit too high to be reached or placed it on the ground too far outside the animal's cage to be retrieved. Many of the chimps overcame these obstacles easily. If the fruit was out of reach beyond the cage, some chimps looked around, found a long stick, and used it to rake in the fruit. Surprised that

cognitive map A mental representation of the environment.



Despite the power of observational learning, some people just have to learn things the hard way.

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the chimpanzees could solve these problems, Köhler tried more difficult tasks. Again, the chimps quickly got to the fruit. Like Tolman, Köhler became convinced that learning was likely to involve cognitive processes.

Three aspects of Köhler's observations convinced him that animals' problem solving does not have to depend exclusively on trial and error and the gradual associative learning from matching a response with a consequence. First, once a chimpanzee solved one type of problem, it would immediately do the same thing in a similar situation. In other words, it acted as if it understood the problem. Second, Köhler's chimpanzees rarely tried a solution that did not work. Apparently, the solution was not discovered randomly but "thought out" ahead of time and then acted out successfully. Third, the chimps often reached a solution quite suddenly. When confronted with a piece of fruit hanging from a string, for instance, a chimp would jump for it several times, then it would stop jumping, look up, and pace back and forth. Finally, it would run over to a wooden crate, place it directly under the fruit, and climb on top of it to reach the fruit. Once, when there were no other objects in the cage, a chimp went over to Köhler, dragged him by the arm until he stood beneath the fruit, and then started climbing up his back!

Köhler argued that the only explanation for these results was that the chimpanzees had experienced **insight**, a sudden understanding of a problem as a whole. Was he right? Possibly, but what Köhler saw as sudden insight might not have been so sudden. Other psychologists found that previous trial-and-error experience with objects, such as boxes and sticks, is necessary for "insight" in chimps (Birch, 1945). In fact, some psychologists argue that all known cases of "insight" by humans and nonhumans alike include a long history of experience with the objects that are used to solve the problem (Epstein et al., 1984; Kounios et al., 2006; Wynne, 2004). Others have suggested true insight seems to result from a "mental trial-and-error process" in which people (and perhaps certain other animals) envision a course of action, mentally simulate its results, compare it with the imagined outcome of other alternatives, and settle on the course of action most likely to aid complex problem solving and decision making (Klein, 1993). So although Köhler's work helped highlight the importance of cognitive processes in learning, questions remain about whether it demonstrated true insight in chimps.

Observational Learning: Learning by Imitation

People and animals learn a lot from personal experience, but they can also learn by observing what others do and what happens to them when they do it (e.g., Akins & Zentall, 1998; Mattar & Gribble, 2005). Learning by watching others—a kind of **observational learning**—is efficient and adaptive. In observational learning, we learn by what we see happen around us without having to experience it ourselves. Such "social learning" means that we don't have to find out for ourselves that a door is locked or an iron is hot if we have just seen someone else try the door or suffer a burn.

The biological basis for observational learning may lie partly in the activity of brain systems that help us predict what will happen when other people do something like walk on the thin ice of a recently frozen pond (Burke et al., 2010). It is also based partly on the operation of the brain's *mirror neurons* (Kilner & Lemon, 2013), which fire not only when we do something or experience something but also when we see someone else do or experience the same thing. This mirrored pattern of activity in our own brains makes it almost as though we are actually performing the observed action or having the observed experience. Mirror neurons are activated, for example, when we feel disgust upon seeing someone react to the taste of sour milk. They also probably fire when we imitate the correct pronunciation of foreign words or follow someone's example in using an unfamiliar tool.

Children are particularly influenced by the adults and peers who act as *models* for appropriate behavior. In a classic experiment, Albert Bandura showed nursery school children a film starring an adult and a large, inflatable, bottom-heavy Bobo doll (Bandura, 1965). The adult in the film punched the doll in the nose, kicked it, threw things at it, and hit its head with a hammer while saying things like "Sockeroo!" There were different endings to the film. Some children saw an ending in which the aggressive adult was called

insight A sudden understanding of what is required to solve a problem.

observational learning Learning how to perform new behaviors by watching others.

Learning by Imitation

TRY THIS Much of our behavior is learned by imitating others, especially those who serve as role models. To appreciate the impact of social learning in your life, list five examples of how your own actions, speech, appearance, or mannerisms have come to match those of a parent, a sibling, a friend, a teacher, or even a celebrity.

Rommel/Masterfile

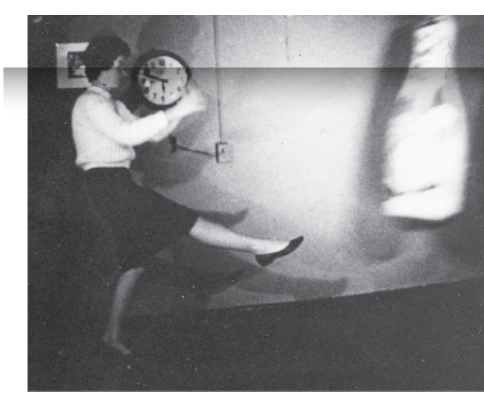
a "champion" by a second adult and rewarded with candy and soft drinks. Some saw the aggressor scolded and called a "bad person." Some saw a neutral ending in which there was neither reward nor punishment. After the film, each child was allowed to play alone with a Bobo doll. The way they played in this and similar studies led to some important conclusions about learning and the role of cognitive factors in it.

Bandura found that children who saw the adult rewarded for aggression showed the most aggressive acts in play (see Figure 5.15). They had received *vicarious conditioning,*

FIGURE 5.15
Observational Learning

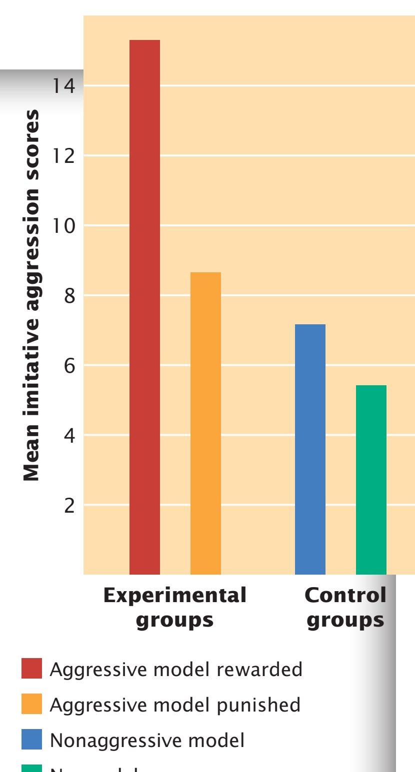
Bandura found that after observing an aggressive model, many children imitate the model's acts precisely, especially if the model's aggression was rewarded.

Source: Ross, L. A. et al. (1963). Imitation of film-mediated aggressive models. Journal of Abnormal and Social Psychology, 66, 3–11.



Albert Bandura/Stanford University

Albert Bandura/Stanford University



Albert Bandura/Stanford University

a kind of social observational learning through which a person is influenced by watching or hearing about the consequences of others' behavior. The children who had seen the adult punished for aggressive acts showed less aggression, but they still learned something. When later offered rewards for imitating all the aggressive acts they had seen in the film, these children displayed just as many of these acts as the children who had watched the adult being rewarded. Observational learning can occur even when there are no vicarious consequences; many children in the neutral condition also imitated the model's aggression.

Like direct reward and punishment, observational learning is a powerful force in the *socialization* process through which children learn about which behaviors are—and are not—appropriate in their culture (Bandura, 1999; Caldwell & Millen, 2009). For example, children show long-term increases in their willingness to help and share after seeing a demonstration of helping by a friendly, impressive model (Schroeder et al., 1995). Fears, too, can be learned partly by the sight of fearfulness in others (e.g., Broeren et al., 2011; Burstein & Ginsburg, 2010) and seeing other people behave dishonestly may lead observers to do the same (Gino, Ayal, & Ariely, 2009).

THINKING CRITICALLY

DOES WATCHING VIDEO VIOLENCE MAKE CHILDREN MORE VIOLENT?

If observational learning is important, then surely movies, video games, handheld and web-based videos, and television—and the violence they so often portray—must teach children a great deal. Psychologists have spent a great deal of time studying these media, and especially the possible effects of watching video images of violence. According to one recent estimate, the average child in the United States in 2013 spent about thirty-five hours a week watching television (Rothman, 2013). If true, that would be an increase of almost two hours a day compared to 2009 (Christakis & Garrison, 2009; Tandon et al., 2011). Much of what kids see on television is violent. In addition to the real-life violence in the news (Van der Molen, 2004), prime-time entertainment programs in the United States present an average of five acts of simulated violence per hour, and cartoons can be especially violent (American Psychological Association, 1993; Klein & Schiffman, 2011). As a result, the average child will see at least 8,000 murders and more than 100,000 other acts of violence before finishing elementary school and twice that number by age 18 (Annenberg Public Policy Center, 1999; Parents Television Council, 2006).

Psychologists have long worried that watching so much violence might be emotionally arousing, making viewers more likely to react violently to frustration (Huston & Wright, 1989). Some evidence suggests that exposure to media violence can trigger or amplify viewers' aggressive thoughts and feelings, thus increasing the likelihood that they will act aggressively (Anderson & Dill, 2000; Bushman, 1998). Televised violence might also provide models that viewers imitate, particularly if the violence is carried out by the "good guys" (Huesmann et al., 2003). Finally, prolonged viewing of violent TV programs might desensitize viewers, making them less distressed when they see others suffer, less likely to help them, and less disturbed about inflicting pain on others (Bushman & Anderson, 2009; Smith & Donnerstein, 1998).

What am I being asked to believe or accept?

For some time now, many have argued that watching video images of violence causes kids to behave violently (e.g., Anderson et al., 2003; Bushman & Gibson, 2011; Bushman & Huesmann, 2014). A National Academy of Sciences report concluded that "overall, the vast majority of studies, whatever their methodology, showed that exposure to television violence resulted in increased aggressive behavior, both contemporaneously and over time" (Reiss & Roth, 1993, p. 371). The American Psychological Association has repeatedly reached the same conclusion (American Psychological Association, 1993; Huesmann et al., 2003).

What evidence is available to support the assertion?

Three types of evidence back up the claim that watching violent video increases violent behavior. First, there are anecdotes and case studies. Children have poked one another in

(*continued*)

the eye after watching the Three Stooges appear to do so on television, and adults have claimed that watching TV shows prompted them to commit murders or other violent acts like those seen on the shows (Werner, 2003). The teenager who shot and killed twenty schoolchildren and six adults in Newton, Connecticut on December 14, 2012, had been "obsessed" with violent video games and had developed a "score sheet" to tabulate "points" for killing victims (Lupica, 2013).

Second, correlational studies have found a strong link between watching violent programs and later acts of aggression and violence (Christakas & Zimmerman, 2007; Gentile et al., 2014; Johnson et al., 2002). A Canadian study found that children who watch more violent videos were more likely to bully and cyber-bully classmates (Beran et al., 2013). Another study tracked people from the time they were six or seven until they reached their early twenties. Those who watched more violent television as children were significantly more aggressive as adults (Huesmann et al., 1997, 2003) and more likely to engage in criminal activity (Huesmann, 1995). They were also more likely to use physical punishment on their own children, who themselves tended to behave more aggressive than average. Such results were found not only in the United States but also in Israel, Australia, Poland, the Netherlands, and even Finland, even though they have fewer violent TV shows (Centerwall, 1990; Huesmann & Eron, 1986).

Finally, experiments show that watching violent video sequences can cause an increase in aggressive behavior (e.g., Boxer et al., 2009; Huesmann & Taylor, 2006; Polman, de Castro & van Aken, 2008). In one study, groups of boys were assigned to watch either violent or nonviolent programs in a controlled setting, and then they played floor hockey (Josephson, 1987). The boys who had been assigned to watch the violent shows were more likely to behave aggressively on the hockey floor than the boys who had been told to watch nonviolent programs. This effect was greatest for boys who had the most aggressive tendencies to begin with. More extensive experiments in which children are exposed to carefully controlled types of television programs over long periods of time also found that being assigned to view more violent activity on television resulted in more aggressive behavior (Eron et al., 1972).

Are there alternative ways of interpreting the evidence?

To some, the evidence argues that media violence causes increases in aggressive and violent behavior, especially in children (Anderson et al., 2003). Others, however, suggest that the evidence is not conclusive and is open to qualifications and alternative interpretations (e.g., Ferguson et al., 2013; Thakkar, Garrison, & Christakis, 2006), or that increases in youth violence are due to other factors (Ferguson, San Miguel, & Hartley, 2009).

Anecdotal reports and case studies are certainly open to different interpretations. If people face imprisonment or execution for their violent acts, how believable are their claims that their actions were triggered by television programs? How many other people might say that the same programs made them less likely to be violent? Anecdotes alone do not provide a good basis for drawing final scientific conclusions.

What about the correlational evidence? As noted in the chapter on research in psychology, a correlation between two variables does not necessarily mean that one is causing the other. Both might be caused by a third factor. At least one possible "third factor" might account for the observed relationship between watching TV violence and acting aggressively: Certain people may enjoy violent themes and therefore both prefer to watch more violent TV programs and also choose to behave aggressively toward others. So personality could at least partly account for the observed correlations between watching violence and behaving aggressively (e.g., Aluja-Fabregat & Torrubia-Beltri, 1998; Steinberg & Monahan, 2011).

Further, video violence is just one of many influences that contribute to the learning of aggressive behavior (Kirsh, 2011). One study found, for example, that children who are more prone to violent behavior had been exposed not only to more video violence but also to more real violence in their neighborhoods and in their homes (Grabell et al., 2012).

As for the results of controlled experiments on the effects of televised violence, some researchers suggest that those effects may be short-lived and may not apply beyond the

(*continued*)

"I have **HAD** it with you two and your violent video games!"

The violence that may affect children's aggressive behavior is not always limited to what they see on television and video games.

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experimental situation (Anderson, Lindsay, & Bushman, 1999; Browne & Hamilton-Giachritsis, 2005; Freedman, 2002). Who is to say, for example, whether an increase in aggressive acts during a hockey game has any later bearing on a child's tendency to commit an act of violence?

What additional evidence would help evaluate the alternatives?

By their nature, correlational studies of the role of TV violence in violent behavior can never be conclusive. As we've pointed out, a third, unidentified causal variable could always be responsible for the results. More important would be further evidence from controlled experiments in which equivalent groups of people were given different long-term "doses" of TV violence and its effects on their subsequent behavior were observed for many years. Such experiments could also explore the circumstances under which different people (for example, children versus adults) are affected by various forms of violence. However, conducting studies such as these would create an ethical dilemma. If watching violent television programs really does cause violent behavior, are psychologists justified in creating conditions that might lead some people to be more violent? If such violence occurred, would the researchers be responsible to the victims and to society? If some participants commit violent acts, should the researchers continue the experiment to establish a pattern or should they terminate the participation of those individuals? Difficulty in answering questions such as these is partly responsible for the use of short-term experiments and correlational designs in this research area, as well as for some of the remaining uncertainty about the effects of television violence.

One approach to this problem might be to conduct experiments in which children watch television shows that portray cooperative rather than violent behavior. If exposure to such *prosocial* programming were followed by significant increases in viewers' own prosocial behavior, it would strengthen—though still not prove—the argument that what children see on television can have a causal impact on their actions. Recent experiments have already shown that people who played prosocial video games were later more helpful than those who had played neutral games (Greitemeyer & Osswald, 2010), and showed greater empathy and less pleasure at others' misfortunes (Greitemeyer, Osswald, & Brauer, 2010; Um et al., 2011).

What conclusions are most reasonable?

The evidence collected so far reasonably argues that watching TV violence may be a cause of violent behavior, especially in some children and especially in boys (e.g., Anderson & Bushman, 2002a; Browne & Hamilton-Giachritsis, 2005; Bushman & Anderson, 2001). Playing violent video games may be another (e.g., Anderson et al., 2008, 2010). Some research suggests that violent video games may lead players to dehumanize other people, making them mere "targets" and releasing acts of real violence (e.g., Greitemeyer & McLatchie, 2011).

But a cause-and-effect relationship between watching TV violence or playing violent games and acting violently is not inevitable and may not always be long lasting (e.g., Ferguson & Kilburn, 2009, 2010; Ferguson et al., 2010; Savage & Yancey, 2008). Further, there are many circumstances in which the effect does not occur (Ferguson, 2009; Freedman, 1992, 2002). Parents, peers, and other environmental influences as well as personality factors may dampen or amplify the effect of watching televised violence or playing violent video games (Markey & Markey, 2010). So may the nature of the games themselves; aggressive behavior may be more strongly associated with games that feature competitiveness, difficulty, and a fast pace (Adachi & Willoughby, 2011). In addition, not every viewer interprets violence in the same way, and not everyone is equally vulnerable to its possible effects (e.g., Ferguson, 2009; Kirsh, 2011). The most vulnerable may be young boys, especially those who are the most aggressive or violence-prone in the first place, a trait that could well have been acquired by observing the behavior of parents or peers (Ferguson et al., 2010; Kirsh, 2011).

Still, the fact that violence on television and in video games *can* have a causal impact on violent behavior is reason for serious concern. Nevertheless, in June 2011, the U.S. Supreme Court ruled that free speech laws apply to video games, making it unconstitutional to regulate their sale to minors (Ferguson, 2013b). Public debate about the effects of violent television and video games will no doubt continue, as will controversy over what should and should not be aired on television and offered by video game manufacturers.

USING RESEARCH ON LEARNING TO HELP PEOPLE LEARN

What should teachers learn about learning?

The study of how people learn obviously has important implications for improved teaching in our schools and for helping people develop skills (Bjork & Linn, 2006; Halpern & Hakel, 2003; Li, 2005; Newcombe et al., 2009).

Active Learning

The importance of cognitive processes in learning is apparent in instructional methods that emphasize *active learning* (Bonwell & Eison, 1991). These methods take many forms, including, for example, small-group problem-solving tasks, discussion of "one-minute essays" written in class, use of student response devices ("clickers") or just "thumbs up" or "thumbs down" gestures to indicate agreement or disagreement with the instructor's lecture, and multiple-choice questions that give students feedback about their understanding of the previous fifteen minutes of a lecture (Goss Lucas & Bernstein, 2015). Students typically find classes that include active learning experiences to be interesting and enjoyable (Bruff, 2009; Moran, 2000; Murray, 2000). In addition, active learning methods help students go beyond memorizing isolated facts. These methods encourage students to think more deeply, to consider how new material relates to what they already know, and to apply it in new situations. This kind of thinking also makes the material easier to remember, which is why we have included so many opportunities for you to actively learn, rather than just passively read, the material in this book.

Virtual Surgery

Using a virtual reality system, this medical student can actively learn and practice eye surgery skills before working with real patients. Computer-based human body simulators are also giving new doctors active learning experience in emergency room diagnosis and treatment; heart, lung, and abdominal surgery; and other medical skills (e.g., Aggarwal, Cheshire, & Darzi, 2008; Heinrichs et al., 2008; Kanno et al., 2008; Kato, 2010; Tsang et al., 2008).

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Studies of students in elementary schools, high schools, community colleges, and universities have found that compared with instructional techniques that are more passive, active learning approaches result in better test performance and greater class participation (e.g., Altman, 2007; Deslauriers, Schelew, & Wieman, 2011; Freeman et al., 2014; Karpicke & Blunt, 2011; Saville et al., 2006). In one study, a fifth-grade teacher spent some days calling only on students whose hands were raised. On other days, all students were required to answer every question by holding up a card with their response written on it. Scores on next-day quizzes and biweekly tests showed that students remembered more of the material covered on the active learning days than on the "passive" days (Gardner, Heward, & Grossi, 1994). In another study of two consecutive medical school classes taught by the same instructor, scores on the final exam were significantly higher when students learned mainly through small-group discussions and case studies than when they were taught mainly through lectures (Chu, 1994). Similarly, among adults being taught to use a new computer program, active learning with hands-on practice was more effective than passively watching a demonstration video (Kerr & Payne, 1994). Finally, high school and college students who passively listened to a physics lecture received significantly lower scores on a test of lecture content than did those who participated in a virtual reality lab that allowed them to interact with the physical forces covered in the lecture (Brelsford, 1993). Results like these have fueled the development of other science education programs that place students in virtual laboratory environments in which they actively manipulate materials and test hypotheses (e.g., Horwitz & Christie, 2000).

Despite the enthusiasm generated by active learning methods, rigorous experimental research is still needed to compare their short- and long-term effects with those of more traditional methods in teaching various kinds of course content (Alexander, Eaton, & Egan, 2010; Fiorella & Mayer, 2012; Moran, 2006). At least one study has shown that college students who learned about pathogens or electromechanical devices through the use of interactive computerized "adventure games" did not perform as well on exams as students who learned the same material using more conventional methods (Adams et al., 2011). Other studies have found standard textbooks superior to e-books and podcasts for delivering primary text material in college courses (Daniel & Woody, 2010; Woody, Daniel, & Baker, 2010). It may turn out that traditional teaching methods (including interesting lectures and engaging textbooks) are effective tools for presenting basic course material, but that active learning methods—including repeated testing and self-testing—may be superior to passive ones for helping students to retain, recall, and apply new information.

Skill Learning

The complex action sequences, or *skills,* that people learn to perform in everyday life develop through learning processes that include feedback and lots of practice (Ackerman, 2007). In fact, *practice*—the repeated performance of a skill—is critical to mastery (Howe, Davidson, & Sloboda, 1998). For perceptual-motor skills such as playing pool or piano, both physical and mental practice are beneficial (Druckman & Bjork, 1994). To be most effective, practice should continue past the point of correct performance until the skill can be performed automatically, with little or no attention. Feedback about the correctness of the response is also necessary. As with any learning process, the feedback should come soon enough to be effective but not so quickly that it interferes with the learner's efforts to learn independently.

Large amounts of guidance may produce very good performance during practice, but too much guidance may hurt later performance (Kluger & DeNisi, 1998; Wickens, 1992). For instance, coaching students about correct responses in math may impair their ability later to retrieve the correct response from memory on their own. Independent practice at retrieving previously learned responses or information requires more effort, but it is critical for skill development (Ericsson & Charness, 1994). There is little or no evidence to support "sleep learning" or similar schemes designed to make learning effortless (Druckman & Bjork, 1994). In short, "no pain, no gain."

Reciprocal Teaching

Ann Brown and her colleagues (1992) demonstrated the success of reciprocal teaching, in which children take turns teaching each other. This technique, which is similar to the cooperative arrangements seen in Japanese education, has become increasingly popular in North American schools (Palincsar, 2003; Spörer, Brunstein, & Kieschke, 2009).

Payless Images/ Alamy

Classrooms across Cultures

Many people have expressed concern that schools in the United States are not doing a very good job. A recent report by the Center on Education Policy found, for example, that nearly half of U.S. public schools failed to meet federal standards for adequate yearly progress (Usher, 2011). Further, the average performance of U.S. students on tests of reading, math, and other basic academic skills has tended to fall short of that of youngsters in other countries, especially Asian countries (Mullis et al., 2007; National Center for Education Statistics, 2002; Program for International Student Assessment, 2005). In one early comparison study, Harold Stevenson (1992) followed a sample of pupils in Taiwan, Japan, and the United States from the first grade, in 1980, to the eleventh grade, in 1991. In the first grade, the Asian students scored no higher than their U.S. peers on tests of mathematical aptitude and skills and they did not enjoy math more. However, by the fifth grade, the U.S. students had fallen far behind. Corresponding differences were seen in reading skills. More recent studies have found similar results (Mullis et al., 2004, 2007).

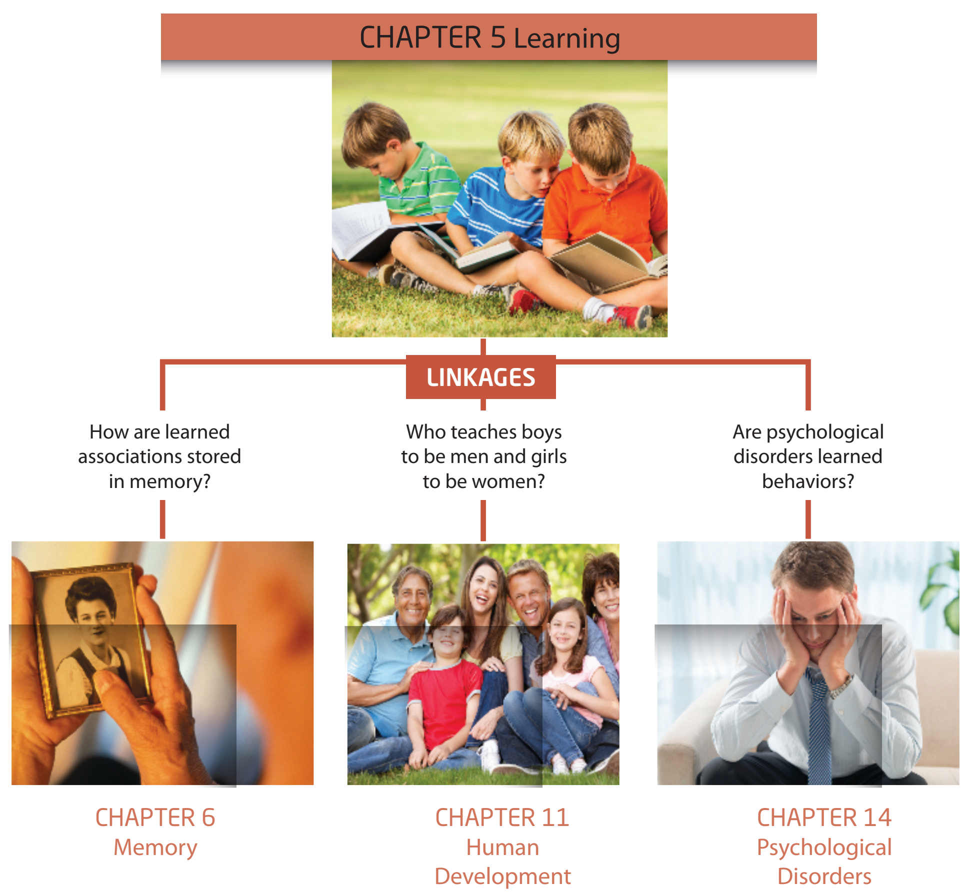
Some possible causes of these differences were found in the classroom itself (Rindermann & Ceci, 2009). In a typical U.S. classroom, teachers talked to students as a group, then students worked at their desks independently. Reinforcement or other feedback about performance on their work was usually delayed until the next day or not provided at all. In contrast, the typical Japanese classroom placed greater emphasis on cooperative work among students (Kristof, 1997). Teachers provided more immediate feedback on a one-to-one basis. And there was an emphasis on creating teams of students with varying abilities, an arrangement in which faster learners help teach slower ones. However, before concluding that the differences in performance are the result of social factors alone, we must consider another important distinction: The Japanese children practiced more. They spent more days in school during the year and, on average, spent more hours doing homework.

Psychologists and educators are considering how various principles of learning can be applied to improve education. For example, anecdotal and experimental evidence suggests that some of the most successful educational techniques are those that apply basic principles of operant conditioning, offering frequent testing, positive reinforcement for correct performance, and immediate corrective feedback following mistakes (Oppel, 2000; Roediger, McDaniel, & McDermott, 2006).

Further, research in cognitive psychology suggests that students will retain more of what they learn if they study in several sessions distributed over time rather than in a single "cramming" session on the night before a test (e.g., Cepeda et al., 2009; Kramár et al., 2012; Rawson & Dunlosky, 2011). To encourage this kind of *distributed practice*, researchers say, teachers should give enough exams and quizzes (some unannounced, perhaps) that students will be reading and studying more or less continuously. And because learning is aided by repeated opportunities to use new information, these exams and quizzes should cover material from throughout the term, not just the material from recent classes (Karpicke, 2012). These recommendations are not necessarily popular with students, but there is good evidence that they promote long-term retention of course material (e.g., Bjork, 2001; Bjork & Linn, 2006).

LINKAGES

As noted in the introductory chapter, all of psychology's subfields are related to one another. Our discussion of associative network models illustrates just one way that the topic of this chapter, learning, is linked to the subfield of memory, which is described in the chapter by that name. The Linkages diagram shows ties to two other subfields, and there are many more ties throughout the book. Looking for linkages among subfields will help you see how they all fit together and help you better appreciate the big picture that is psychology.



SUMMARY

Individuals adapt to changes in the environment through the process of ***learning***, which is the modification, through experience, of preexisting behavior and understanding.

Learning about Stimuli

Why do constant sounds seem to disappear?

One of the simplest kinds of learning is ***habituation***, which is reduced responsiveness to a repeated stimulus. A second kind of simple, nonassociative learning, called *sensitization,* appears as an increase in responsiveness to a stimulus.

Classical Conditioning: Learning Signals and Associations

How did Russian dogs teach psychologists about learning?

One form of learning is ***classical conditioning***. It occurs when a previously neutral ***conditioned stimulus***, or ***CS*** (such as a tone), is repeatedly paired with an ***unconditioned stimulus***, or ***UCS*** (such as meat powder on a dog's tongue), which naturally brings about an ***unconditioned response***, or ***UCR*** (such as salivation). Eventually the conditioned stimulus will elicit a response, known as the ***conditioned response***, or ***CR***, even when the unconditioned stimulus is not presented.

The strength of a conditioned response grows as CS-UCS pairings continue. If the UCS is no longer paired with the CS, the conditioned response eventually disappears; this is ***extinction***. After extinction, the conditioned response may reappear if the CS is presented after some time; this is ***spontaneous recovery***. In addition, if the conditioned and unconditioned stimuli are paired once or twice after extinction, ***reconditioning*** occurs; that is, the conditioned response regains much of its original strength.

Because of ***stimulus generalization***, conditioned responses occur to stimuli that are similar, but not identical, to conditioned stimuli. Generalization is limited by ***stimulus discrimination***, which prompts conditioned responses to some stimuli but not to others.

Classical conditioning involves learning that the CS is an event that predicts the occurrence of another event, the UCS. Many psychologists see the conditioned response as a means through which animals and people develop mental representations of the relationships between events. Classical conditioning works best when the conditioned stimulus precedes the unconditioned stimulus by intervals ranging from less than a second to a minute or more, depending on the stimuli involved. Conditioning is also more likely when the CS reliably signals the UCS. In general, the speed of conditioning increases as the intensity of the UCS increases. Which particular stimulus is likely to become a CS linked to a subsequent UCS depends partly on which stimulus was being attended to when the UCS occurred; more intense stimuli are more likely to attract attention. ***Higher order conditioning*** occurs when one conditioned stimulus signals a conditioned stimulus that is already associated with an unconditioned stimulus. Some stimuli become associated more easily than others; taste aversions provide illustrations that organisms seem to be biologically prepared to learn certain associations.

Classical conditioning plays a role in the development and treatment of phobias as well as in the development of drug tolerance and some cases of drug overdoses.

Instrumental and Operant Conditioning: Learning the Consequences of Behavior

How do reward and punishment work?

Learning occurs not only through associating stimuli but also through associating behavior with its consequences. Thorndike's ***law of effect*** holds that any response that produces satisfaction becomes more likely to occur again and that any response that produces discomfort becomes less likely to recur. Thorndike referred to this type of learning as instrumental conditioning. Skinner called the process ***operant conditioning***.

An ***operant*** is a response that has some effect on the world. A ***reinforcer*** increases the probability that the operant preceding it will occur again. There are two types of reinforcers: ***positive reinforcers***, desirable stimuli that strengthen a response if they are presented after that response occurs, and ***negative reinforcers***, which are the removal of an unpleasant stimulus following some response. Both kinds of reinforcers strengthen the behaviors that precede them. When behavior is strengthened by a positive reinforcer, the process is called positive reinforcement. When behavior is strengthened by a negative reinforcer, the process is called negative reinforcement. ***Escape conditioning*** results when a behavior stops an unpleasant stimulus. ***Avoidance conditioning*** results when behavior prevents an unpleasant stimulus from occurring; it reflects both classical and operant conditioning. Behaviors learned through avoidance conditioning are hard to extinguish. ***Discriminative conditioned stimuli*** signal whether reinforcement is available for a particular behavior.

Complex responses can be learned through ***shaping***, which involves reinforcing successive approximations of the desired response. ***Primary reinforcers*** are innately rewarding; ***secondary reinforcers*** are rewards that people or animals learn to like because of their association with primary reinforcers. In general, operant conditioning proceeds more quickly when the delay in receiving reinforcement is short rather than long and when the reinforcer is large rather than small. Reinforcement may be delivered on a continuous reinforcement schedule or on one of four types of partial, or intermittent, ***reinforcement schedules***: fixed-ratio (FR), variable-ratio (VR), fixed-interval (FI), and variable-interval (VI) schedules. Ratio schedules lead to a rapid rate of responding. Behavior learned through partial reinforcement is very resistant to extinction; this phenomenon is called the ***partial reinforcement effect***. Partial reinforcement is involved in superstitious behavior, which results when some action is followed by, but does not actually cause, a reinforcer.

Research in neuroscience suggests that reinforcers act as rewards largely because of their ability to create activity in "pleasure centers" in the hypothalamus as well as in other brain areas that use the chemical dopamine.

Punishment decreases the frequency of a behavior by following it either with an unpleasant stimulus (*positive punishment*) or with the removal of a pleasant one (*negative punishment*). Punishment can be useful when performed properly, but it can have drawbacks. It only suppresses behavior; fear of punishment may generalize to the person doing the punishing; it is ineffective when delayed; it can be physically harmful and may teach aggressiveness; and it teaches only what not to do, not what should be done to obtain reinforcement.

The principles of operant conditioning have been applied in many areas, from teaching social skills to treating sleep disorders.

Cognitive Processes in Learning

Can people learn to be helpless?

Cognitive processes—how people represent, store, and use information—play an important role in learning. ***Learned helplessness*** appears to result when people believe that their behavior has no effect on the world. Both animals and humans display ***latent learning***. They also form ***cognitive maps*** of their environments, even in the absence of any reinforcement for doing so. Experiments on ***insight*** also suggest that cognitive processes play an important role in learning. The process of learning by watching others is a kind of ***observational learning***, sometimes called "social learning." Some observational learning occurs through vicarious conditioning, in which a person is influenced by seeing or hearing about the consequences of others' behavior. Observational learning is more likely to occur when the observed model's behavior is seen to be rewarded. It is a powerful source of socialization.

Using Research on Learning to Help People Learn

What should teachers learn about learning?

Research on how people learn has implications for improved teaching and for the development of a wide range of skills. The degree to which learning principles such as immediate reinforcement are used in teaching varies considerably from culture to culture. The importance of cognitive processes in learning is seen in active learning methods designed to encourage people to think deeply about and apply new information instead of just memorizing isolated facts. Observational learning, practice, and corrective feedback play important roles in the learning of skills.

TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. Which saying best reflects learning?
   a. "A watched pot never boils."
   b. "A stitch in time saves nine."
   c. "Once burned, twice shy."
   d. "If you will it, it is no dream."

2. In a classical conditioning experiment, a puff of air was blown into Ralph's eye and he automatically blinked. The experimenter then began flashing a green light just before presenting the puff of air. After many pairings of the green light and the puff of air, Ralph began to blink as soon as the green light appeared, whether or not the air puff followed. In this experiment, the green light is the
   a. unconditioned stimulus.
   b. conditioned stimulus.
   c. conditioned response.
   d. unconditioned response.

3. Suppose that the experimenter in the previous question continues presenting the green light but never again follows it with the puff of air. Ralph will soon __________ through the process of __________.
   a. blink faster; reconditioning
   b. stop blinking; extinction
   c. blink slower; stimulus control
   d. stop blinking; spontaneous recovery

4. Kim has gone out with both Alan and Brad this week. Even though she said she hates loud concerts, Alan took her to one, and she came home with a headache. Brad took her to a movie she had been wanting to see. According to __________, Kim would be more likely to date Brad in the future.
   a. the law of effect
   b. Premack's principle
   c. classical conditioning theory
   d. all of the above

5. After being bitten by a dog at a young age, Najla became fearful of all dogs. Now, when Najla sees a dog, her heart races and she feels like running away. Najla has developed __________ through __________ conditioning.
   a. habituation; operant
   b. habituation; classical
   c. a phobia; operant
   d. a phobia; classical

6. The idea that knowledge is located in many areas throughout the brain rather than in one particular place is a basic assumption of __________.
   a. neural network theories
   b. classical conditioning
   c. observational learning
   d. stimulus generalization

7. Because of birth defects, Justin, a four-year-old, has had to have a number of surgeries. As a result, just seeing a doctor or nurse in a surgical mask makes Justin fearful and tearful. At Halloween this year, Justin had the same reaction to children wearing masks. This is an example of __________.
   a. stimulus generalization
   b. stimulus discrimination
   c. vicarious learning
   d. observational learning

8. Laverne lost control and ate an entire coconut cream pie. Later that day she got the flu, complete with nausea and vomiting. After this experience, Laverne associated coconut cream pie with being sick, and now she can't even stand the smell of it. This is an example of __________, which supports the concept of __________.
   a. escape conditioning; spontaneous recovery
   b. discriminative conditioning; biopreparedness
   c. taste aversion; biopreparedness
   d. latent learning; spontaneous recovery

9. When baby Sally cries after being put to bed, her parents check to see that she is all right but otherwise they ignore her. After several evenings of this treatment, Sally's bedtime crying stopped. This is an example of __________.
   a. extinction
   b. habituation
   c. higher order conditioning
   d. shaping

10. Manuel has learned that every time he cleans his room, his mother makes his favorite dessert. This is an example of __________.
   a. classical conditioning
   b. operant conditioning
   c. negative reinforcement
   d. extinction

11. Loretta gets a backache every day, but if she sits in a hot bath, the pain goes away. So she decides to take a hot bath every day. She has learned to do this through __________.
   a. positive reinforcement
   b. negative reinforcement
   c. stimulus discrimination
   d. shaping

12. Doug hates to hear children misbehaving in the grocery store, so he always shops late at night when children are not present. Doug's choice of shopping time is an example of __________.
   a. escape conditioning
   b. avoidance conditioning
   c. shaping
   d. secondary reinforcement

13. Ten minutes before a movie starts, the theater is filled with people who are talking and laughing. As soon as the lights go out, everyone becomes quiet. Sudden darkness serves as a __________ in this example of operant conditioning.
   a. positive reinforcer
   b. negative reinforcer
   c. punishment
   d. discriminative conditioned stimulus

14. Craig wanted to teach his dog, JoJo, to sit up and beg using operant conditioning principles. He started by giving JoJo a treat when she was sitting. Next, he gave her a treat only if she was sitting and had raised one paw, and so on. This is an example of __________.
   a. stimulus discrimination
   b. stimulus generalization
   c. negative reinforcement
   d. shaping

15. When Jamey has washed the dinner dishes after five evening meals, his parents take him to the movies. Susan's dad occasionally gives her a dollar after she washes the dinner dishes. Jamey is on a __________ reinforcement schedule, and Susan is on a __________ schedule.
   a. fixed interval; variable interval
   b. fixed ratio; variable ratio
   c. variable ratio; fixed interval
   d. variable interval; fixed ratio

16. Which of the following is a potential problem with using punishment to change behavior?
   a. It can produce unwanted side effects.
   b. Frequent punishment can teach children to behave aggressively.
   c. It signals that inappropriate behavior occurred but doesn't indicate what should be done instead.
   d. These are all potential problems with using punishment.

17. Whenever Javier asked his next-door neighbor to turn down her loud music, she ignored him. Later, when a new neighbor moved in next door and began playing loud music, Javier did not even bother to complain. His case demonstrates __________.
   a. latent learning
   b. learned helplessness
   c. observational learning
   d. trial and error

18. When Kenzi got a flat tire not far from campus, he walked down the street to a service station he drove by every day but had never visited. The fact that he immediately knew where it was illustrates __________.
   a. insight learning
   b. observational learning
   c. latent learning
   d. vicarious learning

19. After watching a number of people petting and playing with a dog, Najla decides that dogs aren't as scary as she'd thought. The next day, at her neighbors' house, she pets their dog. Najla's fear has been reduced through __________.
   a. classical conditioning
   b. operant conditioning
   c. spontaneous recovery
   d. observational learning

20. Whether the skill you want to learn involves a foreign language, the words of a speech, or a golf swing, the most important thing you can do is __________.
   a. delay feedback until you have almost reached perfection
   b. read all you can about the task you want to learn
   c. engage in all the practice you can
   d. work in a group

Memory

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Preview

Have you ever forgotten where you parked your car? Have you ever had a name on the tip of your tongue but couldn't quite recall it? Researchers in the field of memory explore these common experiences. They have found that memory is a complex system. You use different kinds of memory for storing different types of information, such as personal experiences, specific skills, and abstract concepts. They have also found that once information is stored in memory, recalling it can sometimes be difficult. In this chapter, you'll learn about some techniques that can help you to retrieve memories. Psychologists have used what they've learned about memory to create study techniques that really work!

Several years ago, an air traffic controller at Los Angeles International Airport cleared a US Airways flight to land on runway 24L. A couple of minutes later, the US Airways pilot radioed the control tower that he was on approach for runway 24L, but the controller did not reply because she was conversing with another pilot. After finishing that conversation, the controller told a Sky West commuter pilot to taxi onto runway 24L for takeoff, completely forgetting about the US Airways plane that was about to land on the same runway. The US Airways jet hit the commuter plane, killing thirty-four people. The controller's forgetting was so complete that she assumed the fireball from the crash was an exploding bomb. How could her memory have failed her at such a crucial time? This chapter will help you understand the nature of memory—how you form memories, how memory errors happen, and how you forget.

THE NATURE OF MEMORY

How does information turn into memories?

Memory is a funny thing. You might be able to remember the name of your first-grade teacher but not the name of someone you met five minutes ago. Mathematician John Griffith estimated that in an average lifetime, a person stores roughly five hundred times as much information as can be found in all the volumes of the *Encyclopaedia Britannica* (Hunt, 1982). Keep in mind, however, that although we retain a great deal of information, we also lose a great deal (Wixted, 2004). Consider Joshua Foer. In his book, *Moonwalking with Einstein: The Art and Science of Remembering Everything,* Foer (2011) describes his journey from forgetful science writer to U.S. Memory Champion but says that he still sometimes can't recall where he left his car keys. Memory is made up of many different abilities, some of which may be better than others from person to person and from time to time.

Memory plays a critical role in your life. Without it, you wouldn't know how to shut off your alarm, take a shower, get dressed, recognize objects, or communicate. You would be unaware of your own likes and dislikes. You would have no idea of who you are. The impressive capacity of human memory depends on the operation of a complex mental system.

Basic Memory Processes

In February 2002, prison warden James Smith lost his set of master keys to the Westville Correctional Facility. As a result, 2,559 inmates were kept under partial lockdown for eight days while the Indiana Department of Correction spent $53,000 to change locks in the affected areas. As it turned out, the warden had put the keys in his pocket when he went home, forgot he had done so, and reported the keys "missing" when they were not in their usual place in his office the next day (Associated Press, 2002). What went wrong? There are several possibilities. Memory depends on three basic processes: *encoding, storage,* and *retrieval* (see Figure 6.1). Our absent-minded warden might have had problems with any one of these processes.

First, information must be put into memory, a step that requires encoding. **Encoding** is a process that takes the information to be remembered and describes it in a form that our memory system can accept and use. We use *memory codes* to translate information from the senses into mental representations of that information. Codes for **auditory memory** (also known as **acoustic memory**) represent information as sequences of sounds, such as a tune or a rhyme. Codes for **visual memory** represent information as pictures, such as the image of your best friend's face. Codes for **semantic memory** represent the general meaning of an experience. So if you see a billboard that reads "Huey's Going-Out-of-Business Sale,"

encoding The process of putting information into a form that the memory system can accept and use.

auditory memory (acoustic memory) Mental representations of stimuli as sounds.

visual memory Mental representations of stimuli as pictures.

semantic memory Memory for generalized knowledge about the world.

FIGURE 6.1
Basic Memory Processes

Remembering something requires, first, that the information be encoded—put in a form that can be placed in memory. It must then be stored and, finally, retrieved, or recovered. If any of these processes fails, forgetting will occur.

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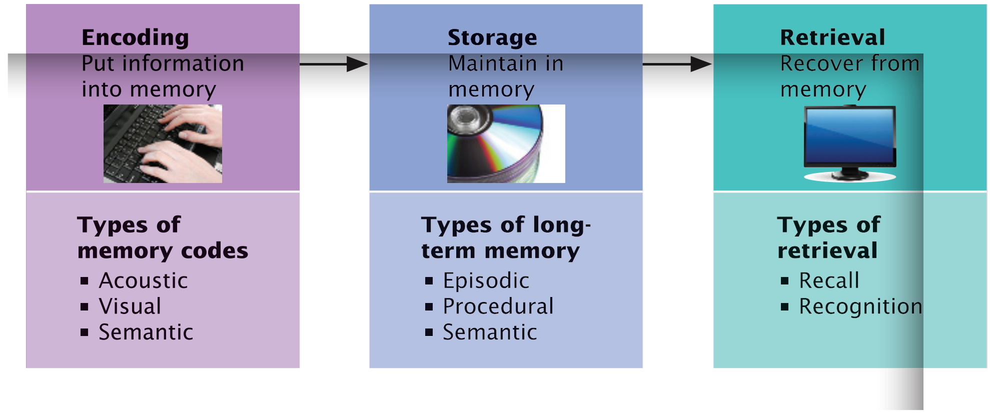

you might encode the sound of the words as if they had been spoken (acoustic encoding), the image of the letters as they were arranged on the sign (visual encoding), or the fact that you recently saw an ad for Huey's (semantic encoding). The type of encoding we use influences what we remember. Semantic encoding might allow you to remember the fact that an unfamiliar car was parked in your neighbors' driveway just before their house was robbed. If little or no other encoding took place, however, you might not be able to remember the make, model, or color of the car.

The second basic memory process is storage. **Storage** refers to the holding of information in your memory over time. When you recall a vacation you took in childhood or find that you can use a pogo stick many years after you last played with one, you are depending on the storage capacity of your memory.

The third memory process—**retrieval**—occurs when you find information stored in memory and bring it into conscious awareness. Retrieving stored information such as your address or telephone number is usually so fast and effortless that it feels automatic. The search-and-retrieval process becomes more noticeable, however, when you read a quiz question but cannot quite recall the information you need to answer it. Retrieval can take the form of either *recall* or *recognition*. To **recall** information, you have to retrieve it from memory on your own, without much help, such as when you answer an essay test question. In **recognition**, retrieval is aided by clues, such as when you have to select from among the correct response alternatives given on multiple-choice tests. Since recognition gives you more help, it tends to be easier than recall.

Types of Memory

When was the last time you made a phone call? Who was the first president of the United States? How do you keep your balance on roller skates? Answering each of these questions involves different aspects of memory. To answer the first question, you must remember a particular event in your life. To answer the second one, you have to recall general knowledge that is unlikely to be tied to a specific event. And the answer to the third question is easier to demonstrate than to describe. So how many types of memory are there? No one is sure, but most research suggests that there are at least three. Each type of memory is named for the kind of information it handles: *episodic*, *semantic*, and *procedural* (Rajaram & Barber, 2008).

Any memory of your experience of a specific event that happened while you were present is an **episodic memory** (Ezzyat & Davcachi, 2010; Tulving, 2005). It is a memory of an episode in your life. What you had for dinner yesterday, what you did last summer, or whether you've already told someone a story may be episodic memories (Gopie & MacLeod, 2009). Semantic memory refers to your generalized knowledge of the world—such as the fact that twelve items make a dozen—separate from a memory of experiencing a specific event. So if you were asked "Are wrenches pets or tools?" you could answer

storage The process of maintaining information in the memory system over time.

retrieval The process of finding information stored in memory.

recall Retrieving information stored in memory without much help from retrieval clues.

recognition Retrieving information stored in memory with the help of retrieval clues.

episodic memory Memory for events in one's own past.

How Does She Do That?

TRY THIS As she practices, this youngster is developing procedural memories of how to ride a bike that may be difficult to put into words. To appreciate the special nature of procedural memory, try writing a step-by-step description of exactly how to tie a shoe.

Masterfile

using your semantic memory; you don't have to remember a specific episode in which you learned that wrenches are tools. As a general rule, people report episodic memories by saying, "I remember when . . ." whereas they report semantic memories by saying, "I know that . . ." (Tulving, 2000). Memory of how to do things, such as riding a bike, folding a map, or playing golf, is called **procedural memory**, or **procedural knowledge** (Cohen & Squire, 1980). Procedural memory often consists of a sequence of movements that are difficult or impossible to put into words. As a result, teachers of music, dance, cooking, woodworking, and other skills usually prefer to first show their students what to do rather than describe how to do it.

Many activities require all three types of memory. Consider the game of tennis. Knowing the official rules or the number of sets needed to win a match involves semantic memory. Remembering who served last requires episodic memory. And your skill in hitting the ball involves procedural memory.

Recalling these three kinds of memories can be either intentional or unintentional. When you deliberately choose to try to remember something, such as where you went on your last vacation, you are showing **explicit memory** when you access that information (Masson & McLeod, 1992). In contrast, **implicit memory** occurs when you unintentionally recall or otherwise show an influence of prior experiences (e.g., McDermott, 2002; Mulligan, 2012). For example, if you were to read this chapter twice, implicit memories from your first reading would help you to read it more quickly the second time. For the same reason, you can solve a puzzle faster if you have solved it in the past. This improvement of performance—often called *priming*—is automatic, and it occurs without conscious effort. In fact, people are often unaware that their actions have been influenced by previous events (see the chapter on consciousness). Have you ever found yourself disliking someone you just met but you didn't know why? The person might have triggered an implicit memory of a similar-looking person who once treated you badly. In such cases, we are usually unaware of any connection between the two individuals (Lewicki, 1992). Because some influential events cannot be recalled even when people try to do so, implicit memory has been said to involve "retention without remembering" (Roediger, Guynn, & Jones, 1995).

Models of Memory

We remember some information far better than other information. Suppose your friends throw a surprise party for you. When you enter the room, you might barely notice the flash of a camera. Later, you cannot recall it at all. And you might forget in a few seconds the name of a person you met at the party. But if you live to be a hundred, you might never forget where the party took place or how surprised and pleased you were. Why do some things stay in memory forever, whereas others barely make an impression? Five *models* of memory each provide a way to understand how memory works. Let's see what the levels-of-processing, transfer-appropriate processing, neural network processing, multiple memory systems, and information-processing models have to say about memory.

Levels of Processing

The **levels-of-processing model of memory** suggests that memory depends on the extent to which you encode and process information when you first encounter it (Craik & Lockhart, 1972). Consider, for example, the task of remembering a phone number you just heard on the radio. If you were unable to write it down, you would probably repeat the number over and over to yourself until you could find a pen or get to your phone. This repetition process is called **maintenance rehearsal**. It can be effective for encoding information temporarily, but what if you need to remember something for hours, months, or years? In that case, you would be better off using **elaborative rehearsal**, a process in which you relate new material to information you already have stored in memory. For example, instead of trying to remember a new person's name by simply repeating it to yourself, you could try thinking about how the name is related to something you know well. So if you are introduced to a man named Jim Crews, you might think, "He is as tall as my Uncle Jim, who always has a crew cut."

procedural memory (procedural knowledge) A type of memory containing information about how to do things.

explicit memory Information retrieved through a conscious effort to remember something.

implicit memory The unintentional recollection and influence of prior experiences.

levels-of-processing model of memory A model that suggests that memory depends on the degree or depth to which we mentally process information.

maintenance rehearsal A memorization method that involves repeating information over and over to keep it in memory.

elaborative rehearsal A memorization method that relates new information to information already stored in memory.

Study after study has shown that using elaborative rehearsal rather than maintenance rehearsal improves memory (Jahnke & Nowaczyk, 1998). Why? According to the levels-of-processing model of memory, when you use elaborative rehearsal you process material more "deeply" (Roediger, Gallo, & Geraci, 2002). The more you think about new information, organize it, and relate it to something you already know, the "deeper" the processing and the better your memory of the information becomes. Teachers use this idea when they ask students not only to define a new word but also to use it in a sentence. Figuring out how to use the new word takes deeper processing than merely defining it does. (The next time you come across an unfamiliar word in this book, don't just read its definition. Try to use the word in a sentence by coming up with an example of the concept that is related to your knowledge and experience.)

TRY THIS

Transfer-Appropriate Processing

Level of processing is not the only factor that affects memory (Baddeley, 1992). The **transfer-appropriate processing model of memory** suggests that another critical factor is the match between how we try to retrieve information and how we originally encoded it. For example, what do you think would happen to your performance on an exam if your instructor told you it would be in a multiple-choice format but then surprised you with an essay test? In a study about just such a situation, half the students in a class were told that their next exam would contain multiple-choice questions. The rest were told to expect essay questions. Only half the students actually got the type of exam they expected. These students did much better on the exam than those who took an unexpected type of exam. Apparently, in studying for the exam, each group used encoding strategies that were most appropriate to the type of exam they expected. Students who tried to retrieve the information in a way that didn't match their encoding method had a harder time (d'Ydewalle & Rosselle, 1978). Results such as these indicate that how well the encoding method aligns with the retrieval task is just as important as the depth of processing (Bauch & Otten, 2012; Mulligan & Picklesimer, 2012).

Neural Network Processing

A third way of thinking about memory is based on **neural network models of memory** (Avery, Dutt, & Krichmar, 2013; Lv et al., 2014). These models suggest that new experiences do more than provide specific facts that are stored and later retrieved one at a time. Those facts are also understood as they relate to each of the vast array of other facts that you already know. As a result, each new experience changes your overall understanding of the world and how it operates. For example, when you first arrived on campus, you learned lots of specific facts, such as where classes are held, how to get Wi-Fi access, and where to get the best pizza. Over time, these and many other facts about student life form a network of information that creates a more general understanding of how the whole system works. The development of this network makes experienced students not only more knowledgeable than new students but also more sophisticated. It allows them to, say, allocate their study time in order to do well in their most important courses and to plan a schedule that doesn't conflict with work commitments and maybe even avoids early morning classes—and certain professors.

Parallel distributed processing (*PDP*; Rumelhart & McClelland, 1986) is an example of such a neural network approach. PDP is a computational approach to brain function that seeks to model many aspects of the mind, including memory. A PDP model for memory sees each unit of knowledge as connected to every other unit. The connections between units become stronger as they are experienced together more frequently. In other words, your knowledge about the world is distributed across a network of associations that all operate at the same time, in parallel. The computations of such a PDP network allow you to be quick and efficient in drawing inferences and generalizations about the world, including how you get information that is not already in your knowledge base. For example, because of your network of associations, just seeing the word "chair" allows you to connect immediately to what a chair looks like, what it's used for, where it tends to be located, who might buy one, and how—such as through an Internet search—you can find one for sale (Sparrow, Liu, & Wegner, 2011). PDP models of memory explain this process very effectively.

transfer-appropriate processing model of memory A model that suggests that memory depends on how the encoding process matches up with what is later retrieved.

neural network models of memory Memory models in which new experiences are seen as changing one's overall knowledge base.

multiple memory systems model A model that suggests the existence of specialized and separated memory systems in the brain.

information-processing model of memory A model that suggests that information must pass through sensory memory, short-term memory, and long-term memory in order to become firmly embedded in memory.

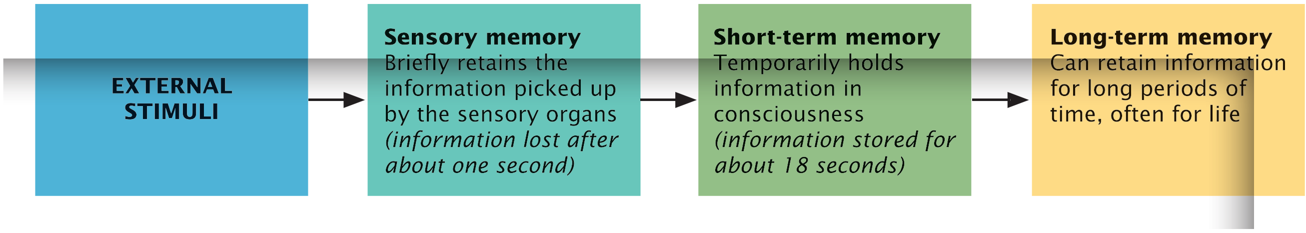

FIGURE 6.2
Three Stages of Memory

This traditional information-processing model describes the three stages in the memory system.

Multiple Memory Systems

The **multiple memory systems model** suggests that the brain contains several relatively separate memory systems, each of which resides in a different area and each of which serves somewhat different purposes (Mizumori et al., 2004; Schacter, Wagner, & Buckner, 2000). Some evidence for the multiple memory systems approach comes from studies of people with brain damage (White, Packard, & McDonald, 2013). As described later, for example, damage to the hippocampus can leave people without explicit memory of doing a task, but their implicit memory allows their performance on that task to improve with practice (e.g., Warrington & Weiskrantz, 1970). Other research shows that inactivating the hippocampus with drugs causes massive disruption of explicit but not implicit memory processes (Frank, O'Reilly, & Curran, 2006).

Information Processing

The **information-processing model of memory** is the oldest and still probably the most influential and comprehensive memory model (Roediger, 1990). It suggests that for information to be firmly implanted in memory, it must pass through three stages of mental processing: sensory memory, short-term memory, and long-term memory (Atkinson & Shiffrin, 1968; see Figure 6.2).

In *sensory memory,* information from the senses—sights or sounds, for example—is held very briefly before being lost. But if information in sensory memory is attended to, analyzed, and encoded as a meaningful pattern, we say that it has been *perceived* (see the chapter on sensation and perception). Perceived information in sensory memory can now enter *short-term memory.* That information will disappear in less than twenty seconds, if nothing further is done with it. With additional processing, however, the information may be encoded into *long-term memory,* where it may remain indefinitely.

The act of reading illustrates all three stages of memory processing. As you read any sentence in this book, light energy reflected from the page reaches your eyes, where it is converted to neural activity and registered in your sensory memory. If you pay attention to these visual stimuli, your perception of the patterns of light can be held in short-term memory. This stage of memory links one moment in time with the next, holding the early parts of the sentence so that they can be integrated and understood as you read the rest of the sentence. As you read, you constantly recognize words by matching your perceptions of them with the patterns and meanings you have stored in long-term memory. In other words, all three stages of memory are necessary for you to understand a sentence.

Contemporary views of the information-processing model emphasize these constant interactions among sensory, short-term, and long-term memory. For example, sensory memory can be

Sensory Memory at Work

TRY THIS In a darkened room, ask a friend to hold a small flashlight and move it very slowly in a circle. You will see a moving point of light. If it appears to have a "tail," like a comet, that is your sensory memory of the light before it fades. Now ask your friend to move the light faster. You should now see a complete circle of light, because as the light moves, its impression on your sensory memory does not have time to fade before the circle is completed. A similar process allows us to see "sparkler circles."

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FIGURE 6.3
The Role of Long-Term Memory in Understanding New Information

TRY THIS Read the paragraph shown here, then turn away and try to recall as much of it as you can. It probably didn't make much sense, and it was probably difficult to remember. But if you read it again after checking the footnote on page 188, the meaning will not only be clearer but it will now be much easier to remember (try it again!). Why? Because knowing the title of the paragraph allows you to retrieve from long-term memory what you already know about the topic (Bransford & Johnson, 1972).

The procedure is actually quite simple. First, you arrange items into different groups. Of course, one pile may be sufficient, depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step; otherwise, you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run, this may not seem important, but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then, one never can tell. After the procedure is completed, one arranges the materials into different groups again. Then they can be put into their appropriate places. Eventually they will be used once more, and the whole cycle will then have to be repeated. However, that is part of life.

thought of as that part of your knowledge base (or long-term memory) that is momentarily activated by information sent to the brain via the sensory nerves. And short-term memory can be thought of as that part of your knowledge base that is the focus of attention at any given moment (Cowan, 2011; Wagner, 1999). Like perception, memory is an active process, so what is already in long-term memory influences how new information is encoded (Cowan, 1988; Schacter, 2012). To understand this interaction better, try the exercise in Figure 6.3.

Which model offers the best explanation? There may not be a single "right" one. Each model makes important observations. The best conclusion is that more than one model may be required to understand memory. Psychologists find it useful to think of memory as both a sequential process, as suggested by the information-processing model, and as a parallel process, as suggested by neural network models such as parallel distributed processing. "In Review: Models of Memory" summarizes each of the five memory models we have described.

IN REVIEW

MODELS OF MEMORY

Model	Assumptions
Levels of processing	The more deeply material is processed, the better our memory of it.
Transfer-appropriate processing	Retrieval is improved when we try to recall material in a way that matches how the material was encoded.
Neural network	New experiences add to and alter our overall knowledge base; they are not separate, unconnected facts. Networks of associations allow us to draw inferences and make generalizations about the world.

(*continued*)

IN REVIEW

MODELS OF MEMORY (CONT.)

Model	Assumptions
Multiple memory systems	The brain contains relatively separate memory systems that serve somewhat different purposes.
Information processing	Information is processed in three stages: sensory memory, short-term memory, and long-term memory.

In Review Questions

1. The value of elaborative rehearsal over maintenance rehearsal has been cited as evidence for the __________ model of memory.
2. Deliberately trying to remember something means using your __________ memory.
3. Playing the piano uses __________ memory.

STORING NEW MEMORIES

What am I most likely to remember?

Storing information is critical to memory because we can retrieve only information that has been stored. According to the information-processing model, sensory memory, short-term memory, and long-term memory each provide a different type of storage. Let's take a closer look at these three memory systems in order to better understand how they work—and sometimes fail.

Sensory Memory

To recognize incoming information, the brain must analyze and compare it with what is already stored in long-term memory. This process is very quick, but it still takes time. The major function of **sensory memory** is to hold information long enough for it to be processed further (Nairne, 2003). This "holding" function is the job of the **sensory registers**, which act as temporary storage bins. There is a separate register for each of the senses. Each register can store a nearly complete representation of a sensory stimulus, but it can do so only briefly, often for less than one second (Eysenck & Keane, 2005).

Sensory memory helps us experience a smooth flow of information, even if that flow is interrupted. To see this for yourself, move your head and eyes slowly from left to right. It may seem as though your eyes are moving smoothly, like a movie camera scanning a scene, but that's not what is happening. Your eyes fixate at one point for about one-fourth of a second and then rapidly jump to a new position. You perceive smooth motion because you hold the scene in your visual sensory register (also known as your **iconic memory**) until your eyes fixate again. Similarly, when you listen to someone speak, your auditory sensory register allows you to experience a smooth flow of information, even though there are actually short silences between or within words.

The fact that sensory memories fade quickly if they are not processed further is actually an adaptive characteristic of the memory system (Baddeley, 1998). You simply cannot deal with all of the sights, sounds, odors, tastes, and touch sensations that come to your sense organs at any given moment. Using **selective attention**, you focus your mental resources on only some of the stimuli around you, thus controlling what information is processed further in short-term memory.

TRY THIS

sensory memory A type of memory that is very brief but lasts long enough to connect one impression to the next.

sensory registers Memory systems that briefly hold incoming information.

iconic memory The sensory register for visual information.

selective attention The process of focusing mental resources on only part of the stimulus field.

Short-Term Memory and Working Memory

The sensory registers allow your memory system to develop a representation of a stimulus. However, they can't perform the more thorough analysis needed if the information is going to be used in some way. That function is accomplished by short-term memory and working memory.

Short-term memory (STM) is the part of your memory system that stores limited amounts of information for up to about twenty seconds. When you check the building directory to see which floor your new dentist's office is on, and then keep that number in mind as you press the correct elevator button, you are using short-term memory. **Working memory** is the part of the memory system that allows us to mentally work with, or manipulate, the information being held in short-term memory. When you mentally calculate what time you have to leave home in order to have lunch on campus, return a library book, and still get to class on time, you are using working memory.

Short-term memory is actually a component of working memory, and together these memory systems allow us to do many kinds of mental work (Baddeley, 2003). Suppose you're buying something for eighty-three cents. You go through your change and pick out two quarters, two dimes, two nickels, and three pennies. To do this you use both short-term memory and working memory to remember the price, retrieve the rules of addition from long-term memory, and keep a running count of how much change you have so far.

TRY THIS

Now try to recall how many windows there are on the front of the house or apartment where you grew up. In answering this question, you probably formed a mental image of the building. You used one kind of working-memory process to form that image and then you maintained the image in short-term memory while you "worked" on it by counting the windows. So working memory has at least two components: *maintenance* (holding information in short-term memory) and *manipulation* (working on that information).

Encoding in Short-Term Memory

Encoding information in short-term memory is much more elaborate and varied than encoding in the sensory registers (Brandimonte, Hitch, & Bishop, 1992; Logie, 2011). Acoustic encoding (by sound) seems to dominate. This conclusion comes from research on the mistakes people make when encoding information in short-term memory, which tend to involve the substitution of similar sounds. For instance, Robert Conrad (1964) showed people strings of letters and asked them to repeat the letters immediately. Among their most common mistakes was the replacement of the correct letter with another that sounded like it. So if the correct letter was *C*, it was often replaced with a *D*, *P*, or *T*. The participants made these mistakes even though the letters were presented visually, without any sound. Studies in several cultures have also shown that items are more difficult to remember if they sound similar. For example, native English speakers do less well when they try to remember a string of letters like *ECVTGB* (which all have similar sounds) than when trying to remember one like *KRLDQS* (in which there are different sounds).

Encoding in short-term memory is not always acoustic, however. Information in short-term memory also can be encoded visually, semantically, and even kinesthetically (in terms of physical movements; Best, 1999). In one study, deaf people were shown a list of words and then asked to immediately write down as many as they could remember (Shand, 1982). When these participants made errors, they wrote words expressed through similar *hand movements* in American Sign Language rather than words that *sounded* similar to the correct words. Apparently, these individuals had encoded the words on the basis of the movements they would use when making the signs for them.

Storage Capacity of Short-Term Memory

How much information can you hold in short-term memory? The simple, classic test presented in Figure 6.4 will help you determine your **immediate memory span**, which is the largest number of items you can recall perfectly after one presentation. If your memory span is like most people's, you can repeat six or seven items from the test in this figure. Further, you should

short-term memory (STM) A stage of memory in which information normally lasts less than twenty seconds; a component of working memory.

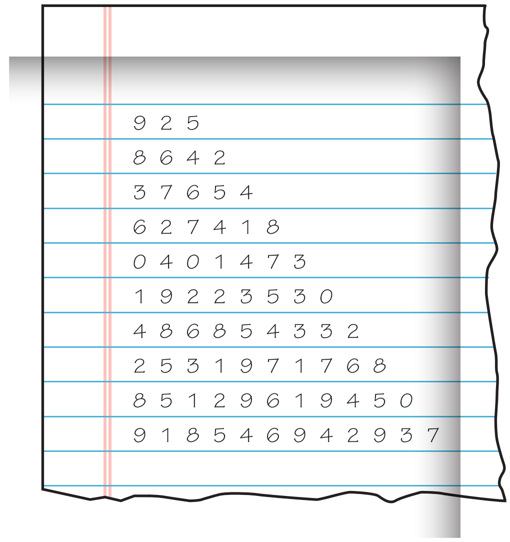
working memory Memory that allows us to mentally work with, or manipulate, information being held in short-term memory.

immediate memory span The maximum number of items a person can recall perfectly after one presentation of the items.

The title of the paragraph in Figure 6.3 is "Washing Clothes."

FIGURE 6.4
The Capacity of Short-Term Memory

TRY THIS Here is a test of your immediate memory span (Howard, 1983). Ask someone to read to you the numbers in the top row at the rate of about one per second, then try to repeat them back in the same order. Then try the next row and the one after that, until you make a mistake. Your immediate memory span is the maximum number of items you can repeat back perfectly.



come up with about the same result whether you use digits, letters, words, or virtually anything else (Pollack, 1953). George Miller (1956) noticed that studies using many different tasks always seemed to show the same limit on the ability to process information. This "magic number," which is seven plus or minus two, appears to be the immediate memory span or capacity of short-term memory, at least for most adults in laboratory settings. In addition, the "magic number" refers not only to discrete elements, such as words or digits, but also to *chunks,* meaningful groupings of information that are produced by a process called **chunking** (Gilchrist & Cowan, 2012; Mathy & Feldman, 2012).

TRY THIS

To see the difference between discrete elements and chunks, read the following letters to a friend, pausing at each dash: *FB-ILO-LM-TVN-BCB-MW*. The chances are very good that your friend will not be able to repeat this string of letters perfectly. Why? There are fifteen letters, which exceeds most people's immediate memory span. Now, give your friend the test again, but group the letters like this: *FBI-LOL-MTV-NBC-BMW.* Your friend will probably repeat the string easily. Although the same fifteen letters are involved, they will be processed as only five meaningful chunks of information.

The Power of Chunking

Chunks of information can be quite complex. If you heard someone say, "The boy in the red shirt kicked his mother in the shin," you could probably repeat the sentence perfectly. Yet it contains twelve words and forty-three letters. How can you repeat the sentence so effortlessly? The answer is that you are able to build bigger and bigger chunks of information (Ericsson & Staszewski, 1989). In this case, you might represent "the boy in the red shirt" as one chunk of information rather than as six words or nineteen letters. Similarly, "kicked his mother" and "in the shin" represent separate chunks of information.

Learning to use bigger and bigger chunks of information can improve short-term memory. In fact, children's short-term memories improve partly because they gradually become able to hold more chunks in memory and also because they get better at grouping information into chunks (Cowan, 2010; Servan-Schreiber & Anderson, 1990). Adults also can greatly increase the capacity of their short-term memory by using more efficient chunking (Zhang & Luck, 2011). For example, after extensive training, one college student increased his immediate memory span from seven to eighty digits (Neisser, 2000a), and experienced waiters often use chunking techniques to remember the details of numerous dinner orders without taking notes (Bekinschtein, Cardozo, & Manes, 2008). So although the capacity of short-term memory is more or less constant (from five to nine chunks of meaningful information), the size of those chunks can vary tremendously.

Duration of Short-Term Memory

Why don't you remember every phone number you ever called or every conversation you ever had? The answer is that unless you do something to retain it, information in short-term memory is soon forgotten. This feature of short-term memory is adaptive because it gets rid of a lot of useless information; indeed, there are rare cases of people whose inability to forget interferes with their ability to concentrate (Parker, Cahill, & McGaugh, 2006; Storm, 2011). But losing information from short-term memory can also be inconvenient. You may have discovered this if you ever spotted an interesting web address on TV, got distracted before you visited it, and then forgot it.

chunking Organizing individual stimuli so that they will be perceived as larger units of meaningful information.

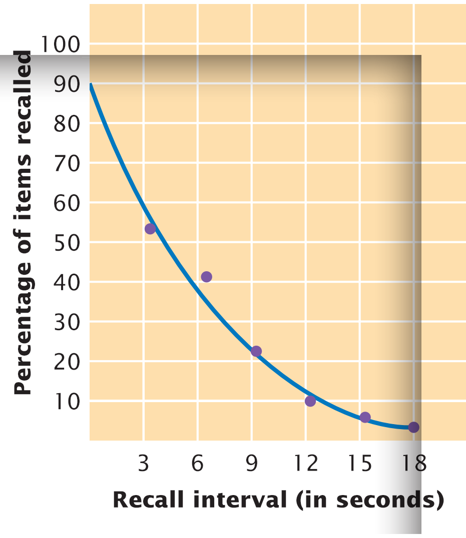


FIGURE 6.5
Forgetting in Short-Term Memory

This graph shows the percentage of items recalled after various intervals during which rehearsal was prevented. Notice that forgetting was virtually complete after a delay of eighteen seconds.

Source: Data from Peterson & Peterson (1959).

How long does information remain in short-term memory if you don't keep rehearsing it? John Brown (1958) and Lloyd and Margaret Peterson (1959) devised the **Brown-Peterson distractor technique** to measure the duration of short-term memory when no rehearsal is allowed. In this procedure, participants are presented with a group of three letters, such as *GRB.* They then count backward by threes from some number until they get a signal. Counting serves as a distraction that prevents the participants from rehearsing the letters. At the signal, they stop counting and try to recall the letters. By varying the number of seconds spent counting backward, the experimenter can determine how much forgetting takes place over time. As you can see in Figure 6.5, information in short-term memory is forgotten rapidly: After only twenty seconds or so, participants can remember almost nothing. Evidence from other such experiments also suggests that unrehearsed information can be held in short-term memory for no more than about twenty seconds. However, if the information is rehearsed or processed further in some other way, it may be encoded into long-term memory.

Long-Term Memory

When most of us talk about memory, we're usually referring to long-term memory. **Long-term memory (LTM)** is the part of the memory system where encoding and storage capabilities can produce memories that last a lifetime.

Encoding in Long-Term Memory

Sometimes information is encoded into long-term memory even if we don't try to memorize it (Ellis, 1991; Hoffman, Bein, & Maril, 2011). However, putting information into long-term memory is often the result of more elaborate and effortful processing that usually involves *semantic encoding.* As we mentioned earlier, semantic encoding often leaves out details in favor of the more general underlying meaning of the information.

In a classic study, Jacqueline Sachs (1967) demonstrated the dominance of semantic encoding in long-term memory. Her participants first listened to tape recordings of people speaking. She then showed them sets of similar sentences and asked them to say which contained the exact wording heard on the tape. Participants did well at this task when tested immediately, using mainly short-term memory. However, after twenty-seven seconds, they couldn't be sure which of two sentences they had heard. For example, they could not remember whether they had heard "He sent a letter about it to Galileo, the great Italian scientist" or "A letter about it was sent to Galileo, the great Italian scientist." They didn't do as well after the delay because they had to recall information from long-term memory, where they had encoded the general meaning of what they had heard, but not the exact wording.

Perhaps you are thinking, "So what?" After all, the two sentences mean the same thing. Unfortunately, when people encode the general meaning of information they hear or read, they can make mistakes about the details (Brewer, 1977). For example, after listening to a list of words such as *cold, white, ice, winter, frosty, blizzard, frozen, drift, flurries, parka, shovel, skis, sled,* and *flakes,* people often remember having heard the related word "snow" even though it was not presented (Gallo, 2006; Roediger & McDermott, 1995). This kind of false memory can be a problem when recalling exact words is important—such as in the courtroom, during business negotiations, and in agreements between students and teachers about course requirements. Later in this chapter, we show that such mistakes occur partly because people encode into long-term memory not only the general meaning of information but also what they think and assume about that information (McDermott & Chan, 2006).

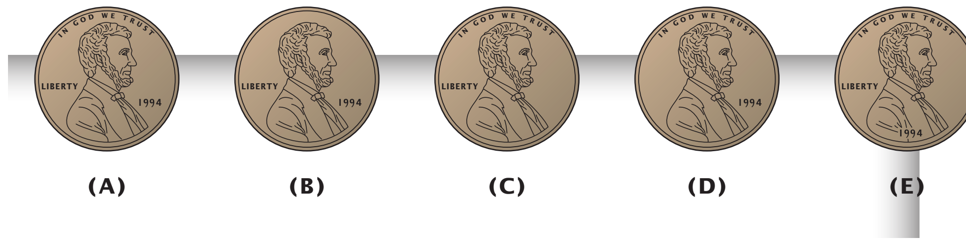
Counterfeiters depend on the fact that people encode the general meaning of visual stimuli rather than specific details. For example, look at Figure 6.6 and find the correct drawing of a U.S. penny (Nickerson & Adams, 1979). Research shows that most people from the United States are unsuccessful at this task. People from other countries do poorly at recognizing their country's coins, too (Jones, 1990). This research has prompted the U.S. Department of the Treasury to begin using more distinctive drawings on the paper currency it distributes.

Brown-Peterson distractor technique A method for determining how long unrehearsed information remains in short-term memory.

long-term memory (LTM) The stage of memory that researchers believe has an unlimited capacity to store new information.

FIGURE 6.6
Encoding into Long-Term Memory

TRY THIS Which is the correct image of a U.S. penny? (See page 192 for answers.)



Storage Capacity of Long-Term Memory

The capacity of long-term memory is extremely large. In fact, it may be unlimited (Matlin, 1998). There is no way to prove this, but we do know that people store vast quantities of information in long-term memory that can be remembered remarkably well after long periods of time (Seamon, Punjabi, & Busch, 2010). For example, people are amazingly accurate at recognizing the faces of their high school classmates after having not seen them for over twenty-five years (Bruck, Cavanagh, & Ceci, 1991). They also do surprisingly well on tests of a foreign language or algebra fifty years after having formally studied these subjects (Bahrick et al., 1994; Bowers, Mattys, & Gage, 2009).

But long-term memories can become distorted. Are you old enough to remember where were you were and what you were doing when you heard about the 9/11 terrorist attacks on the United States? If so, you may be quite sure you can answer correctly, but if you are like the students tested in one study, your memories of 9/11 may not be entirely correct (Hirst et al., 2009; Talarico & Rubin, 2003). Most of the students whose memories had been substantially distorted over time were unaware that this distortion had occurred. In fact, they were very confident that their reports were accurate. Later, we will see that such overconfidence can also appear in courtroom testimony by eyewitnesses to crime.

Distinguishing between Short-Term and Long-Term Memory

Some psychologists argue that short-term memory and long-term memory have different features and obey different laws (Cowan, 1988; Talmi et al., 2005). ("In Review: Storing New Memories" summarizes the characteristics of these systems.) Evidence that information is transferred from short-term memory to a distinct storage system comes primarily from experiments on recall.

A Remarkable Memory

TRY THIS Using only his long-term memory, Franco Magnani created amazingly accurate paintings of his hometown in Italy even though he had not seen it for more than 30 years (Sacks, 1992). People like Magnani display *eidetic imagery*, commonly called *photographic memory*. About 5 percent of school-age children have eidetic imagery, but it is extremely rare in adults (Haber, 1979). You can test yourself for eidetic imagery by drawing a detailed picture or map of a place that you know well but have not seen recently, then comparing your version with a photo or map of the same place. How did you do?

Franco Magnani, www.francomagnani.com; Exploratorium, www.exploratorium.edu, photo by Susan Schwartzenberg

Magnani's painting

Photo of the same scene

TRY THIS

You can conduct your own recall experiment by reading aloud a list of words at a slow pace (about one word every two seconds). After reading the list just once, look away and write down as many of the words as you can, in any order. Here is a list you can use: *desk, frame, carburetor, flag, grill, book, urn, candle, briefcase, screen, tree, soup, ocean, castle, monster, bridge*. Did you notice anything about which words you remembered and which ones you forgot? If you are like most people, your recall depended partly on where each word appeared on the list—its serial position. As shown in the serial-position curve in Figure 6.7, memory researchers have found that recall tends to be very good for the first two or three words in a list. This result is called the **primacy effect**. The probability of recall decreases for words in the middle of the list and then rises dramatically for the last few words. The ease of recalling words near the end of the list is called the **recency effect**. The primacy effect may reflect the rehearsal that puts early words into long-term memory. The recency effect may occur because the last few words are still in short-term memory when you try to recall the list (Glanzer & Cunitz, 1966; Koppenaal & Glanzer, 1990).

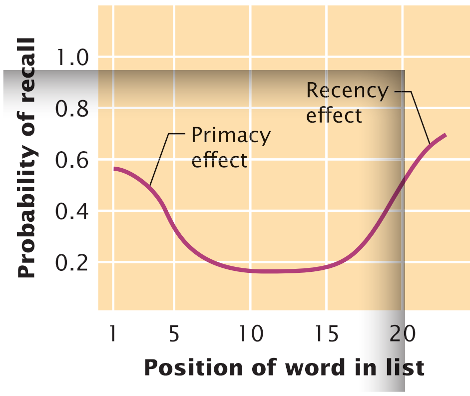


FIGURE 6.7
A Serial-Position Curve

This curve shows the probability of recalling items that appear at various serial positions in a list. Generally, the first several items and the last several items are most likely to be recalled (Silverman, 2012).

IN REVIEW

STORING NEW MEMORIES

Storage System	Function	Capacity	Duration
Sensory memory	Briefly holds representations of stimuli from each sense for further processing	Large: absorbs all sensory input from a particular stimulus	Less than one second
Short-term and working memory	Hold information in awareness and manipulate it to accomplish mental work	Five to nine distinct items or chunks of information	About eighteen seconds
Long-term memory	Stores new information indefinitely	Unlimited	Unlimited

In Review Questions

1. If you looked up a phone number but forgot it before you could call it, the information was probably lost from __________ memory.
2. The capacity of short-term memory is about __________ to __________ items.
3. Encoding is usually __________ in short-term memory and __________ in long-term memory.

RETRIEVING MEMORIES

How do I retrieve stored memories?

Most people have trouble remembering things at one time or another. Have you ever been unable to recall the name of a song or movie star, only to think of it the next day? Remembering requires not only the encoding and storing of information but also the ability to bring it into consciousness. In other words, you have to be able to *retrieve* it.

Retrieval Cues and Encoding Specificity

Retrieval cues are stimuli that help you retrieve information from long-term memory. As mentioned earlier, these cues make recognition tasks (such as multiple-choice tests) easier than recall tasks (such as essay exams).

primacy effect A characteristic of memory in which recall is particularly good for the first two or three items in a list.

recency effect A characteristic of memory in which recall is particularly good for the last few items in a list.

retrieval cues Stimuli that allow or help people to recall information.

Answer for Figure 6.6: Drawing A shows the correct penny image.

Context-Dependent Memories

TRY THIS Many people attending a reunion at their old high school find that being in the building again provides context cues that help bring back memories of their school days. Visit your elementary school or high school and see if it helps you to remember things you'd forgotten. Be sure to look into specific rooms where you had classes or assemblies, and check out the restroom and your old locker, too.

Steve Skjold/Alamy

The key to retrieval cues is that they are more effective when they tap into information that was encoded at the time of learning (Tulving, 1983). This rule is known as the **encoding specificity principle**. Because long-term memories are often encoded in terms of their general meaning, cues that trigger the meaning of the stored information tend to work best. For example, imagine that you have learned a long list of sentences. One of them was either (1) "The man lifted the piano" or (2) "The man tuned the piano." Now suppose that on a later recall test, you were given the retrieval cue "something heavy." This cue would probably help you to remember the first sentence (because you probably encoded something about the weight of a piano as you read it) but not the second sentence (because it has nothing to do with weight). Similarly, the cue "makes nice sounds" would probably help you recall the second sentence but not the first (Barclay et al., 1974; Goh & Lu, 2012).

Context and State Dependence

Have you ever taken a test in a classroom other than the one where you learned the material for that test? If so, was your performance affected? Research has shown that people tend to recall more of what they have learned when they're in the place where they learned it (Smith & Vela, 2001). Why? Because if they have encoded features of the environment where the learning occurred, these features can later act as retrieval cues (Richardson-Klavehn & Bjork, 1988). Smells are especially effective retrieval cues (Toffolo, Smeets, & van den Hout, 2012). In one experiment, people studied a series of photos while in the presence of a particular odor. Later, they reviewed a larger set of photos and tried to recognize the ones they had seen earlier. Half of the people were exposed to the original odor while taking the recognition test. The rest were tested in the presence of another odor. Those who smelled the same odor during learning and testing did significantly better on the recognition task than those who were tested in the presence of a different odor. The matching odor served as a powerful retrieval cue (Cann & Ross, 1989).

Context-specific memory, also known as **context-specific learning**, refers to memories that are helped or hindered by similarities or differences in environmental context. Police and prosecutors sometimes ask eyewitnesses to revisit the scene of a crime because they hope that being there will provide retrieval cues that can improve the accuracy of eyewitness testimony (e.g., Campos & Alonso-Quecuty, 2006). This context-specificity effect is not always strong (Smith, Vela, & Williamson, 1988), but some students do find it helpful to study for a test in the classroom where the test will be given.

encoding specificity principle A principle stating that the ability of a cue to aid retrieval depends on how well it taps into information that was originally encoded.

context-specific memory (context-specific learning) Memories that are helped or hindered by similarities or differences between the contexts in which they are learned and recalled.

Sometimes we also encode information about how we felt during a learning experience, and this information, too, can act as a retrieval cue. When our internal state influences retrieval, we have a **state-dependent memory**, also known as **state-dependent learning**. For example, if people learn new material while under the influence of marijuana, they tend to recall it better if they are tested on the material while under the influence of marijuana (Eich et al., 1975). Similar effects have been found with alcohol and other psychoactive drugs (Eich, 1989; Overton, 1984), although memory is best when people aren't using any drugs during encoding or retrieval. Mood states, too, can affect memory (Eich & Macaulay, 2000). College students are more likely to remember pleasant events when they're feeling good at the time of recall (Bower, 1981; Eich & Macaulay, 2006). Negative events are more likely to be recalled when people are feeling sad or angry (Lewinsohn & Rosenbaum, 1987). These *mood congruency* effects are strongest when people try to recall personally meaningful episodes (Eich & Metcalfe, 1989). The more meaningful the experience, the more likely it is that the memory has been colored by their mood. (See "In Review: Factors Affecting Retrieval from Long-Term Memory.")

IN REVIEW

FACTORS AFFECTING RETRIEVAL FROM LONG-TERM MEMORY

Process	Effect on Memory
Encoding specificity	Retrieval cues are effective only to the extent that they tap into information that was originally encoded.
Context-specific memory	Retrieval is most successful when it occurs in the same environment where the information was originally learned.
State-dependent memory	Retrieval is most successful when people are in the same physiological or psychological state as when they originally learned the information.

In Review Questions

1. Stimuli called ___________ help you recall information stored in long-term memory.
2. If it is easier to remember something in the place where you learned it, you have ___________ learning.
3. The tendency to remember the last few items in a list is called the ___________ effect.

Retrieval from Semantic Memory

The retrieval situations we have discussed so far are relevant to episodic memory—our memory for events. But how do we retrieve information from semantic memory, where we store our general knowledge about the world? Researchers studying this question typically ask participants general knowledge questions, such as (1) Are fish minerals? (2) Is a beagle a dog? (3) Do birds fly? and (4) Does a car have legs? As you might imagine, most people answer such questions correctly. But by measuring how long it takes to answer them, psychologists gain important clues about how semantic memory is organized and how we retrieve information from it.

state-dependent memory (state-dependent learning) Memory that is helped or hindered by similarities or differences in a person's internal state during learning versus recall.

Semantic Networks

One view of semantic memory suggests that virtually everything we know about, including concepts such as "bird" or "animal," is represented in a dense network of associations (Churchland, 1989). Figure 6.8 presents just a tiny part of what our *semantic memory*

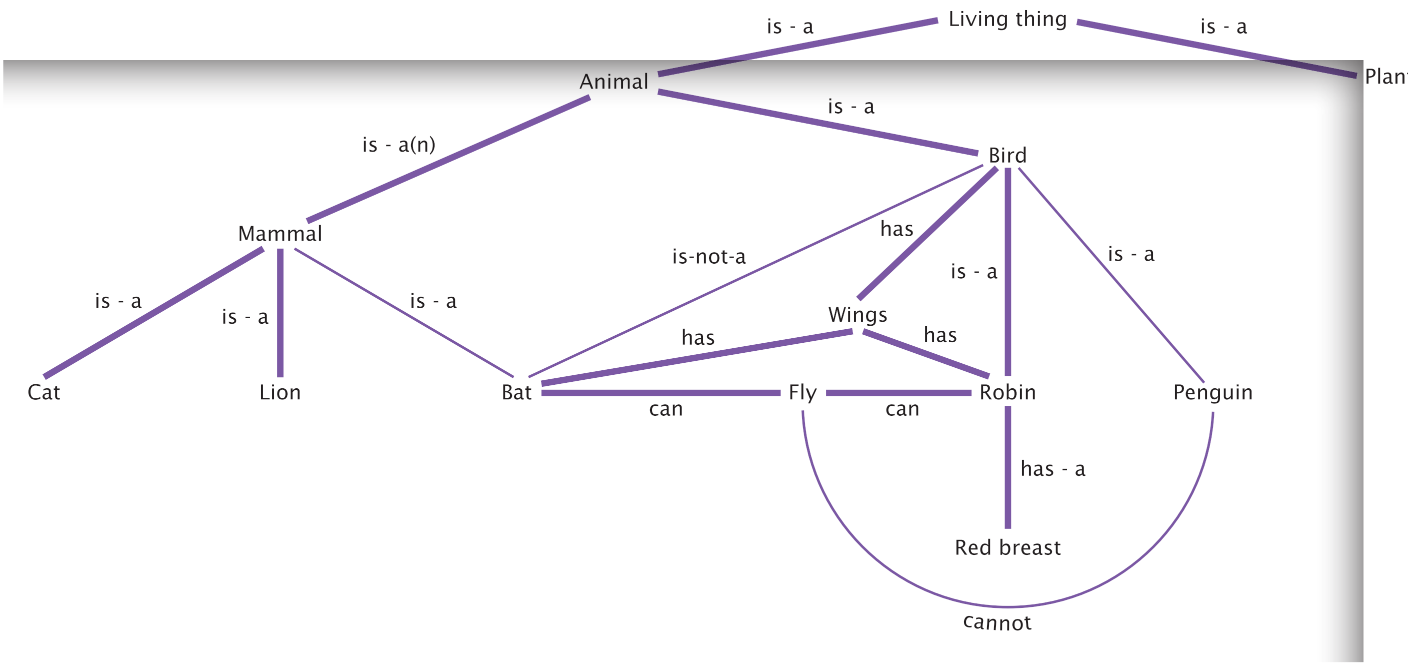


FIGURE 6.8
Semantic Memory Networks

This drawing represents just a small part of a network of semantic associations. Semantic network theories of memory suggest that networks like these allow us to retrieve specific pieces of previously learned information, draw conclusions about how concepts are related, and make new inferences about the world.

network might look like. In general, semantic network theories suggest that information is retrieved from memory through the principle of **spreading activation** (Medin, Ross, & Markman, 2001). In other words, when you think about some concept, it becomes activated in the network and this activation begins to "spread" down all the paths that are related to it. So if you are asked if a robin is a bird, the concepts of both "robin" and "bird" will become activated and the spreading activation from each will intersect somewhere in these paths. When they do, you know what answer to give.

Some associations in the network are stronger than others, as illustrated by the thicker lines between some concepts in Figure 6.8. For instance, you probably have a stronger association between "bat" and "wings" than between "bat" and "mammal." Spreading activation travels faster along stronger paths than along weaker ones. As a result, you'd probably respond more quickly to "Can a bat fly?" than to "Is a bat a mammal?"

Because of the tight organization of semantic networks and the speed at which activation spreads through them, we can gain access to an enormous body of knowledge about the world quickly and effortlessly. We can retrieve not only facts we have learned from others but also knowledge that allows us to draw our own conclusions and inferences (Matlin, 1998). For example, imagine answering these two questions: (1) Is a robin a bird? and (2) Is a robin a living thing? You can probably answer the first question "directly," because you probably learned this fact at some point in your life. However, you may never have consciously thought about the second question, so answering it requires some inference. Figure 6.8 illustrates the path to that inference. Because you know that a robin is a bird, a bird is an animal, and animals are living things, you infer that a robin must be a living thing. As you might expect, however, it takes slightly longer to answer the second question than the first.

spreading activation In semantic network theories of memory, a principle that explains how information is retrieved.

Retrieving Incomplete Knowledge

Figure 6.8 shows that concepts such as "bird" or "living thing" are represented in semantic memory as unique sets of features or attributes. As a result, there may be times when you can retrieve some features of a concept from your semantic network but not enough of them to identify the concept. For example, you might know that there is an animal that has wings, can fly, and is not a bird and yet you might not be able to retrieve its name (Connor, Balota, & Neely, 1992). When this happens, you are retrieving *incomplete knowledge.* (The animal in question is a bat.)

You've probably experienced a particular example of incomplete knowledge called the *tip-of-the-tongue phenomenon* (Schwartz & Metcalfe, 2011). In a typical experiment on this phenomenon, participants listen to dictionary definitions and then are asked to name the word being defined (Brown & McNeill, 1966). If they can't recall the correct word, they are asked if they can recall any feature of it, such as its first letter or how many syllables it has. People are surprisingly good at this task, indicating that they are able to retrieve at least some knowledge of the word (Brennen et al., 1990). Most people experience the tip-of-the-tongue phenomenon about once a week; older people tend to experience it more often than younger people (Brown, 1991; Brown & Nix, 1996).

Another example of retrieving incomplete knowledge is the *feeling-of-knowing experience,* which some researchers study by asking trivia questions (Reder & Ritter, 1992). When research participants cannot answer a question, they are asked to say how likely it is that they could recognize the correct answer among several options. Again, people are remarkably good at this task. Even though they cannot recall the answer, they can retrieve enough knowledge to determine whether the answer is actually stored in their memory (Costermans, Lories, & Ansay, 1992).

CONSTRUCTING MEMORIES

How accurate are my memories?

Our memories are affected by what we experience but also by what we already know about the world in general and about the particular culture and family in which we live (Ross & Wang, 2010; Simpson, Rholes, & Winterheld, 2010). We use that existing knowledge to organize the new information we encounter, and we fill in gaps in that information as we encode and retrieve it (Schwabe, Nader, & Pruessner, 2014). These processes are called *constructive memory.*

Constructive Memory

TRY THIS Here is a photo of the office used in the Brewer & Treyens (1981) study. Ask a friend to examine it for a minute or so (cover this caption). Then close the book and ask whether each of the following items appeared in the office: chair, wastebasket, bottle, typewriter, coffeepot, and book. If your friend reports having seen a wastebasket or a book, you will have demonstrated constructive memory.

Courtesy Professor William F. Brewer. From Brewer, W. F., & Treyens, J. C. (1981). Role of schemata in memory for places. Cognitive Psychology, 13, 207-230.

In one study of constructive memory, undergraduates were asked to wait for several minutes in a graduate student's office (Brewer & Treyens, 1981). Later, they were asked to recall everything that was in the office. Most of the students mistakenly "remembered" seeing books, even though there were none. Apparently, the general knowledge that graduate students read many books influenced the participants' memory of what was in the room (Roediger, Meade, & Bergman, 2001). In another study, participants read one of two versions of a story about a man and woman at a ski lodge. One version ended with the man proposing marriage to the woman. The second version was identical until the end, when instead of proposing, the man sexually assaulted the woman. A few days after reading the story, all the participants were asked what they remembered from it. Those who had read the "proposal" version recalled nice things about the man, such as that he wanted the woman to meet his parents. Those who read the "assault" version recalled negative things, such as that the man liked to drink a lot. However, neither kind of information had actually been part of the original story. The participants had "recalled" memories of the man that they had constructed in accordance with their overall impression of him (Carli, 1999).

FOCUS ON RESEARCH METHODS

I COULD SWEAR I HEARD IT!

By constructing our own versions of what we have seen and heard, we may remember an event differently from the way it actually happened. These errors, called *false memories,* can occur in relation to anything from the objects present in a room to the identity of an armed robber (Clancy et al., 2000).

What was the researchers' question?

How easy is it for people to form false memories? Henry Roediger and Kathleen McDermott (1995) addressed this question in an experiment to test for false memories as people recalled lists of words that had been read to them.

How did the researchers answer the question?

On each of sixteen trials, college students heard a different list of words. Each list related to a particular theme. For example, the "cold" list contained fifteen words such as *sleet, slush, frost, white, snow,* and so on. Yet the list's theme word—in this case, *cold*—was not included. In half of these trials, the students were simply asked to recall as many words as possible from the list they had just heard. But in the other half, the students did math problems instead of trying to recall the words. Once all sixteen lists had been presented, the students were given a new list of words and asked to say which of them they recognized as having been on the lists they had heard earlier. Some of the words on this new list were theme words, such as *cold,* that had not been presented earlier. Would the students "remember" hearing these theme words on the list even though they hadn't? And if so, how confident would they be about their "memory" of these words?

What did the researchers find?

The students falsely, but confidently, recognized the theme words from twelve of the sixteen lists. In fact, theme words were falsely recognized as often as listed words were correctly recognized. As you might expect, the chance of accurately recognizing the listed words was greater when the students had been allowed to recall them shortly after hearing them. However, false memory of never-presented theme words occurred in both conditions.

What do the results mean?

The results of this study suggest that the participants could not always distinguish words they had heard from those they had not heard. Why? The never-presented theme words "belonged" with the lists of presented words and apparently were "remembered" because they fit logically into the gaps in the students' memories. In short, the students' knowledge of words that *should* have been included on the lists created a "memory" that they *were* presented.

(*continued*)

What do we still need to know?

Studies such as this one make it clear that memory is constructive and that memory distortion and inaccuracy are very common (e.g., Arndt, 2012; Otgaar et al., 2012; Zhu et al., 2012). In fact, even people with highly superior memory for the events of their lives still have many false memories and do not realize it (Patihis et al., 2013). With appropriate feedback, people may be able to recognize and correct false memories (Clark et al., 2012; Leding, 2012), but exactly how the distortion process works and why false memories seem so real is still unclear. Perhaps the more frequently we recall an event, as when students were allowed to rehearse some lists, the stronger our belief is that we have recalled it accurately. There is also evidence that merely thinking about certain objects or events or hearing sounds or seeing photos associated with them appears to make false memories of them more likely (Garry & Gerrie, 2005; Henkel, Franklin, & Johnson, 2000). And there are times when, after watching someone else do something, we form the false memory that we have done that same thing ourselves (Lindner et al., 2010). This phenomenon may involve the activity of mirror neurons, which are discussed in the chapter on biological aspects of psychology. Questions about how false memories are created lead to even deeper questions about the degree to which our imperfect memory processes might distort our experiences of reality. Is there an objective reality, or do we each experience our own version of reality?

Neural Network Models and Constructive Memory

If you hear that "our basketball team won last night," your schema about basketball might prompt you to encode, and later retrieve, the fact that the players were men. Such spontaneous, though often incorrect, generalizations associated with neural network models of memory help explain the appearance of constructive memories.

AP Images/Phil Klein

Constructive Memory and Neural Network Models

Neural network models of memory offer one way of explaining how semantic and episodic information become integrated in constructive memories. As mentioned earlier, these models suggest that newly learned facts alter our general knowledge of the world. These network models focus on how memory creates associations between different specific facts. Let's say, for example, that your own network "knows" that your friend Joe is a male European American business major. It also "knows" that Claudia is a female African American student, but it has never learned her major. Now suppose that every other student you know is a business major. In this case, the connection between "students you know" and "business majors" would be so strong that you would conclude that Claudia is a business major, too. You would be so confident in this belief that it would take overwhelming evidence for you to change your mind (Rumelhart & McClelland, 1986). In other words, you would have constructed a memory about Claudia.

Neural networks of memory also create *spontaneous generalizations.* So if your friend tells you that Claudia just bought a new car, you would know without asking that like all other cars you have experienced, it has four wheels. This is a spontaneous generalization from your knowledge base. Spontaneous generalizations are obviously helpful, but they can also create significant errors if the network is based on limited or biased experience with a class of objects or people.

If it occurs to you that prejudice based on ethnicity or other personal characteristics can result from spontaneous generalization errors, you're right (Greenwald & Banaji, 1995). Researchers are actually encouraged by this aspect of neural network models, though, because it accurately reflects human thought and memory. Virtually all of us make spontaneous generalizations about males, females, European Americans, African Americans, the young, the old, and many other categories (Rudman et al., 1999). Is prejudice, then, a process that we have no choice in or control over? Not necessarily. Relatively unprejudiced people tend to recognize that they are making generalizations and consciously try to ignore or suppress them (Amodio et al., 2004).

Schemas

schemas Mental representations of categories of objects, places, events, and people.

Neural network models also help us understand constructive memory, because these models explain how *schemas* guide memory. As described in the chapters on social psychology and thought and language, **schemas** are mental representations of categories of objects, places, events, and people. For example, most North Americans have a schema for *baseball game,* so simply hearing these words is likely to activate entire clusters of information in long-term memory, including the rules of the game and images of players, bats, balls, a green field, summer days, and perhaps hot dogs and stadiums. The generalized knowledge contained in schemas provides a basis for making inferences about new information during the encoding stage. So, if you hear that a baseball player was injured, your schema about baseball might prompt you to encode the incident as game related, even though the cause was not mentioned. Later, you are likely to recall the injury as having occurred during a game (see Figure 6.9 for another example).

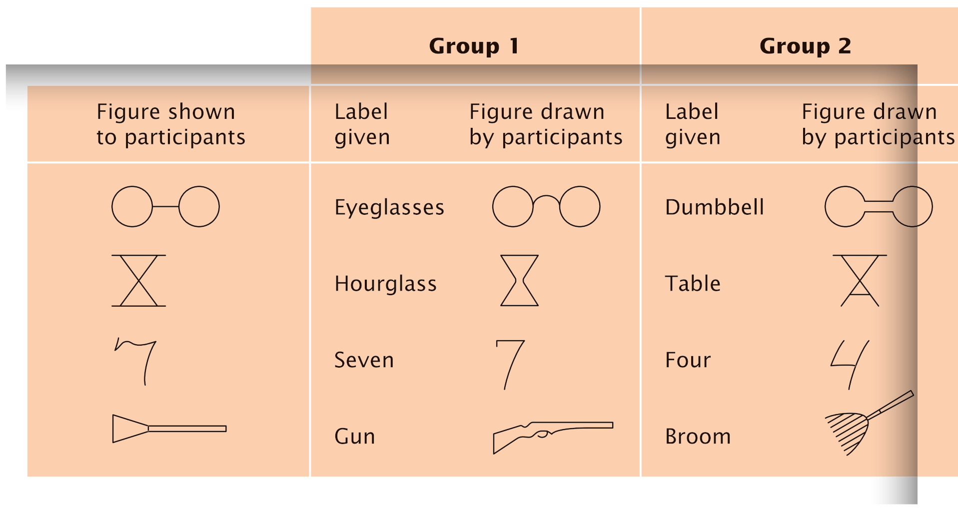


FIGURE 6.9
The Effect of Schemas on Recall

In a classic experiment, people were shown figures like these, along with labels designed to activate certain schemas (Carmichael, Hogan, & Walter, 1932). For example, when showing the top figure, the experimenter said either "This resembles eyeglasses" or "This resembles a dumbbell." When the participants were later asked to draw these figures from memory, their drawings tended to resemble the items mentioned by the experimenter. In other words, their memory had been altered by the schema-activating labels.

LINKAGES How accurate is eyewitness testimony? (a link to Sensation and Perception)

LINKAGES

MEMORY, PERCEPTION, AND EYEWITNESS TESTIMONY

There are few situations in which accurate retrieval of memories is more important—and constructive memory is more dangerous—than when an eyewitness testifies in court about a crime. Let's consider the accuracy of eyewitness memory and how it can be distorted.

The presence of an eyewitness can be a key factor in deciding to prosecute an alleged criminal (Flowe, Mehta, & Ebbesen, 2011), and in the courtroom it is the most compelling evidence a lawyer can provide. Nevertheless, eyewitnesses often make mistakes (Brewer & Wells, 2011; Police Executive Research Forum, 2013; Roediger, Wixted, & DeSoto, 2012). In 1984, for example, North Carolina college student Jennifer Thompson confidently identified Ronald Cotton as the man who had raped her at knifepoint. Mainly on the basis of Thompson's testimony, Cotton was convicted of rape and sentenced to life in prison. He was released eleven years later, when DNA evidence revealed that he was innocent (and identified another man as the rapist). The eyewitness/victim's certainty had convinced a jury, but her memory had been faulty (O'Neill, 2000).

Like the rest of us, eyewitnesses can remember only what they perceive, and they can perceive only what they attend to (Backman & Nilsson, 1991). We have already seen in the chapter on sensation and perception that perception is an active process in which we interpret what our senses tell us. Eyewitness perceptions can also be affected by physiological arousal and many other factors (Gallo, 2013; Hope et al., 2012). All these influences affect the memory that an eyewitness may form. So when witnesses are asked to report as accurately as possible what they saw or heard, no matter how hard they try to be accurate, there are limits to how valid their reports can be (e.g., Fahsing, Ask, & Granhag, 2004).

(*continued*)

For example, hearing new information about a crime (including in the form of a lawyer's question) can alter a witness's memory (Belli & Loftus, 1996; Wells & Quinlivan, 2009). Experiments show that when witnesses are asked "How fast were the cars going when they *smashed into* each other?" they are likely to recall a higher speed than when asked "How fast were the cars going when they hit each other?" (Loftus & Palmer, 1974; see Figure 6.10). There is also evidence that an object mentioned during questioning about an incident is often mistakenly remembered as having been there during the incident (e.g., Broaders & Goldin-Meadow, 2010). So if a lawyer says that a screwdriver was lying on the ground when it was not, witnesses may recall with great certainty having seen it (Ryan & Geiselman, 1991). This *misinformation effect* can occur in several ways (Loftus & Hoffman, 1989; Steblay et al., 2014). In some cases, hearing new information can make it harder to retrieve the original memory (Tversky & Tuchin, 1989). In others, the new information may be integrated into the old memory, making it impossible to distinguish from what was originally seen (Loftus, 1992). In still others, an eyewitness report might be influenced by the person's assumption that if a lawyer or police officer says an object was there or that something happened, it must be true (Chan, Thomas, & Bulevich, 2009). Even the hand gestures used when asking eyewitnesses to report a memory can change what the witnesses say they recall (Gurney, Pine, & Wiseman, 2013).

Jurors' belief in a witness's testimony often depends at least as much on how the witness gives evidence as it does on the evidence itself (Leippe, Manion, & Romanczyk, 1992). For example, jurors are particularly impressed by witnesses who give lots of details about what they saw. So extremely detailed testimony from prosecution witnesses are more likely to lead to guilty verdicts, even if the details reported are irrelevant (Bell & Loftus, 1989). When a witness reports details, such as the color of the criminal's shoes, jurors may assume that the witness had paid very close attention or has a really good memory. This assumption seems reasonable, but there are limits on how much people can pay attention to, particularly when they are emotionally aroused and the crime happens quickly. Witnesses whose attention was drawn to details such as shoe color might not have accurately perceived the criminal's facial features (Backman & Nilsson, 1991; Perfect, Andrade, & Syrett, 2012). So the fact that an eyewitness reports many details doesn't guarantee that all of them were remembered correctly.

Even when judges and juries know about the many factors that can affect eyewitness recall (Houston et al., 2013), they may be guided by other factors instead. For example, jurors tend to believe witnesses who respond quickly to questions (Oeberst, 2012) or otherwise appear confident about their testimony (Leippe, Manion, & Romanczyk, 1992). Unfortunately, research shows that witnesses' confidence is frequently much higher than their accuracy (Devilly et al., 2007; Dobolyi & Dodson, 2013; Luna & Martín-Luengo, 2012). In some cases, repeated exposure to misinformation and the repeated recall of that misinformation can lead witnesses to feel certain

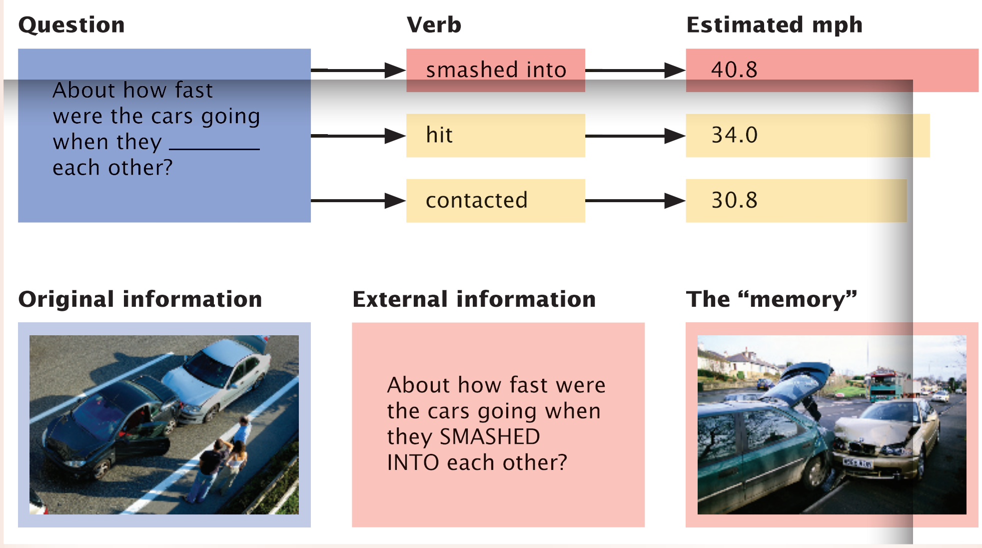


FIGURE 6.10
The Impact of Questions on Eyewitness Memory

After seeing a filmed traffic accident, people were asked, "About how fast were the cars going when they (smashed into, hit, or contacted) each other?" As shown here, the witnesses' responses were influenced by the verb used in the question. "Smashed" was associated with the highest average speed estimates. A week later, people who heard the "smashed" question remembered the accident as being more violent than did people in the other two groups (Loftus & Palmer, 1974).

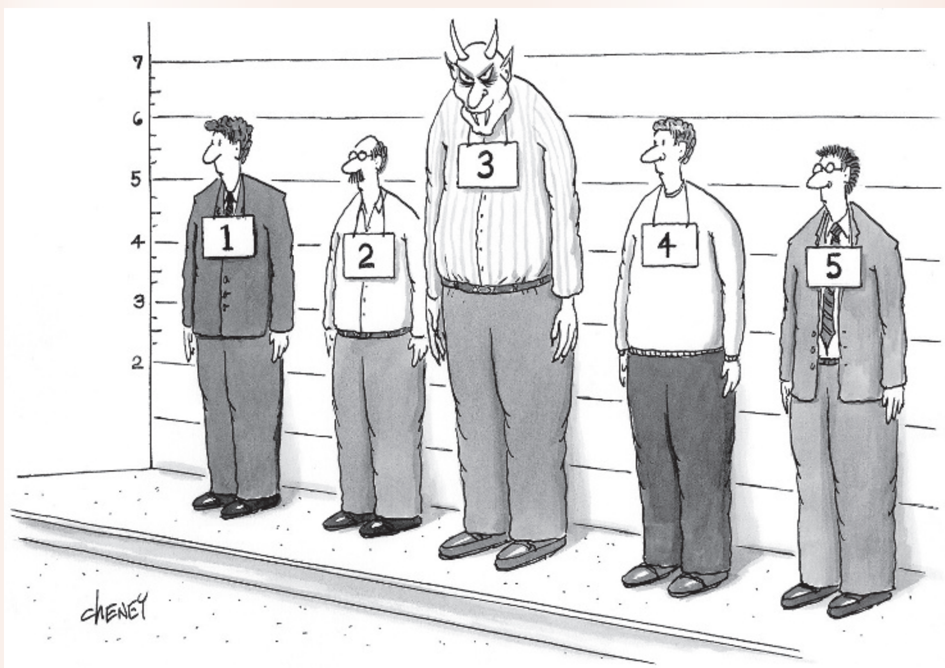
Aspix/Alamy ; Ashley Cooper/Corbis

(*continued*)

about their testimony even when—as in the Jennifer Thompson case—it may not be correct (Foster et al., 2012; Frenda, Nichols, & Loftus, 2011; Roediger, Jacoby, & McDermott, 1996).

The accuracy of eyewitness memory can also be affected by how police lineups or certain other criminal identification procedures are set up (e.g., Brewer & Wells, 2011; Laudan, 2012; Wells, Memon, & Penrod, 2006; Wells, Steblay, & Dysart, 2012). For example, in one study, eyewitnesses were more accurate in identifying a criminal when viewing suspects standing together in a lineup, as opposed to viewing them one at a time. However, the witnesses were (wrongly) more confident in their identifications when they had seen the suspects one at a time (Dobolyi & Dodson, 2013). In another study, participants watched a videotaped crime and then tried to identify the criminal from a set of photographs (Wells & Bradfield, 1999). None of the photos showed the person who had committed the crime, but some participants nevertheless identified one of them as the criminal they saw on tape. When these mistaken participants were led to believe that they had correctly identified the criminal, they became even more confident in the accuracy of their false identification (Semmler, Brewer, & Wells, 2004; Wells, Olson, & Charman, 2003). These incorrect but confident witnesses became more likely than other participants to claim that it had been easy for them to identify the criminal from the photos because they had had a good view of him and had paid careful attention to him.

According to the Death Penalty Information Center (2014), 143 people, including Ronald Cotton, have been released from U.S. prisons since 1973 after DNA tests or other evidence revealed that they had been falsely convicted—mostly on the basis of faulty eyewitness testimony. Research on memory and perception helps explain how such miscarriages of justice can occur, and it has also been guiding efforts to prevent such errors in the future. In 1999, the U.S. Department of Justice officially acknowledged the potential for errors in eyewitness evidence as well as the dangers of asking witnesses to identify suspects from lineups and photo arrays. The result was *Eyewitness Evidence: A Guide for Law Enforcement* (U.S. Department of Justice, 1999), the first-ever guide for police and prosecutors involved in obtaining eyewitness evidence. The guide warned that asking witnesses leading questions about what they saw could distort their memories. It also suggested ways to avoid witness mistakes. For example, it pointed out that false identifications are less likely if witnesses viewing a lineup are told that the criminal they saw might not be included (Humphries, Holliday, & Flowe, 2012; Quinlivan et al., 2012; Wells & Olson, 2003). Research on other methods for improving the accuracy of eyewitness testimony continues on several fronts (e.g., Ahola, 2012; Clark, 2012a, 2012b; Gronlund, Wixted, & Mickes, 2013; Newman & Loftus, 2012).



"Thank you, gentlemen—you may all leave except for No. 3."

This is exactly the sort of biased police lineup that *Eyewitness Evidence: A Guide for Law Enforcement* (U.S. Department of Justice, 1999) is designed to avoid. Based on research in memory and perception, this guide recommends that no suspect should stand out from all the others in a lineup, that witnesses should not assume that the real criminal is in the lineup, and that they should not be encouraged to "guess" when making an identification.

Tom Cheney The New Yorker Collection/The Cartoon Bank

FORGETTING

What causes me to forget things?

The frustrations of forgetting—where you left your cell phone, the answer to a test question, an anniversary—are apparent to most people nearly every day (Neisser, 2000b). Let's look more closely at the nature of forgetting and what causes it.

It's All Coming Back to Me

This grandfather hasn't fed an infant for decades, but his memory of how to do it is not entirely gone. He showed some "savings"; it took him less time to relearn the skill than it took him to learn it initially. In fact, sometimes previously forgotten information is later recalled in exquisite, accurate detail, a phenomenon called *hypermnesia* (Erdelyi, 2010).

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How Do We Forget?

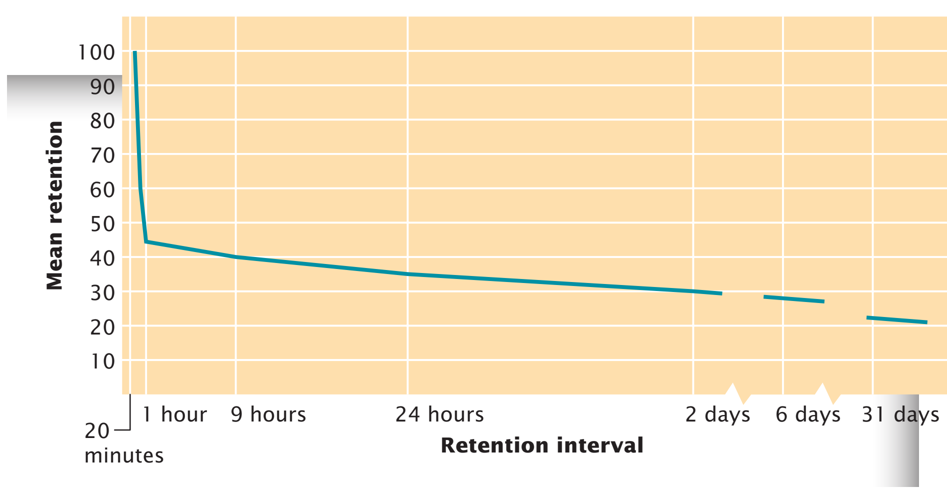
Hermann Ebbinghaus, a German psychologist, began the systematic study of memory and forgetting in the late 1800s, using only his own memory as his laboratory. He read aloud a list of nonsense syllables (such as *POF, XEM*, and *QAL*) at a constant pace and then tried to recall them.

Ebbinghaus devised a special **relearning method** to measure how much he forgot over time. He compared the number of repetitions (or trials) it took him to learn a list of items and the number of trials needed to relearn that same list later. Any reduction in the number of relearning trials represents the *savings* from one learning to the next. If it took Ebbinghaus ten trials to learn a list and another ten trials to relearn it, there would be no savings. Forgetting would have been complete. If it took him ten trials to learn the list and only five trials to relearn it, there would be a savings of 50 percent.

Ebbinghaus's research produced two lasting discoveries. One is the shape of the forgetting curve shown in Figure 6.11. Even when psychologists substitute words, sentences, and stories for nonsense syllables, the forgetting curve shows the same large initial drop in memory, followed by a more moderate decrease over time (Slamecka & McElree, 1983; Wixted, 2004). Of course, we remember sensible stories better than nonsense syllables, but the shape of the curve is the same no matter what type of material is involved (Davis & Moore, 1935). Even the forgetting of events from daily life tends to follow Ebbinghaus's forgetting curve (Thomson, 1982).

FIGURE 6.11
Ebbinghaus's Curve of Forgetting

TRY THIS List 30 words, selected at random from a dictionary, and spend a few minutes memorizing them. After an hour has passed, write down as many words as you can remember, but don't look at the original list again. Test yourself again eight hours later, a day later, and two days later. Now look at the original list and see how well you did on each recall test. Ebbinghaus found that most forgetting occurs during the first nine hours after learning, especially during the first hour. If this was not the case for you, why do you think your results were different?



Ebbinghaus also discovered just how long-lasting "savings" in long-term memory can be. Psychologists now know from the method of savings that information about everything from algebra to bike riding is often retained for decades (Matlin, 1998). So although you may forget something you have learned if you do not use the information, it is very easy to relearn the material if the need arises, indicating that the forgetting was not complete (Hall & Bahrick, 1998).

Why Do We Forget?

We have seen how forgetting occurs, but *why* does it happen? In principle, one of two processes can be the cause (Best, 1999). One process is described by **decay theory**, which

relearning method A method for measuring forgetting.

decay theory A description of forgetting as the gradual disappearance of information from memory.

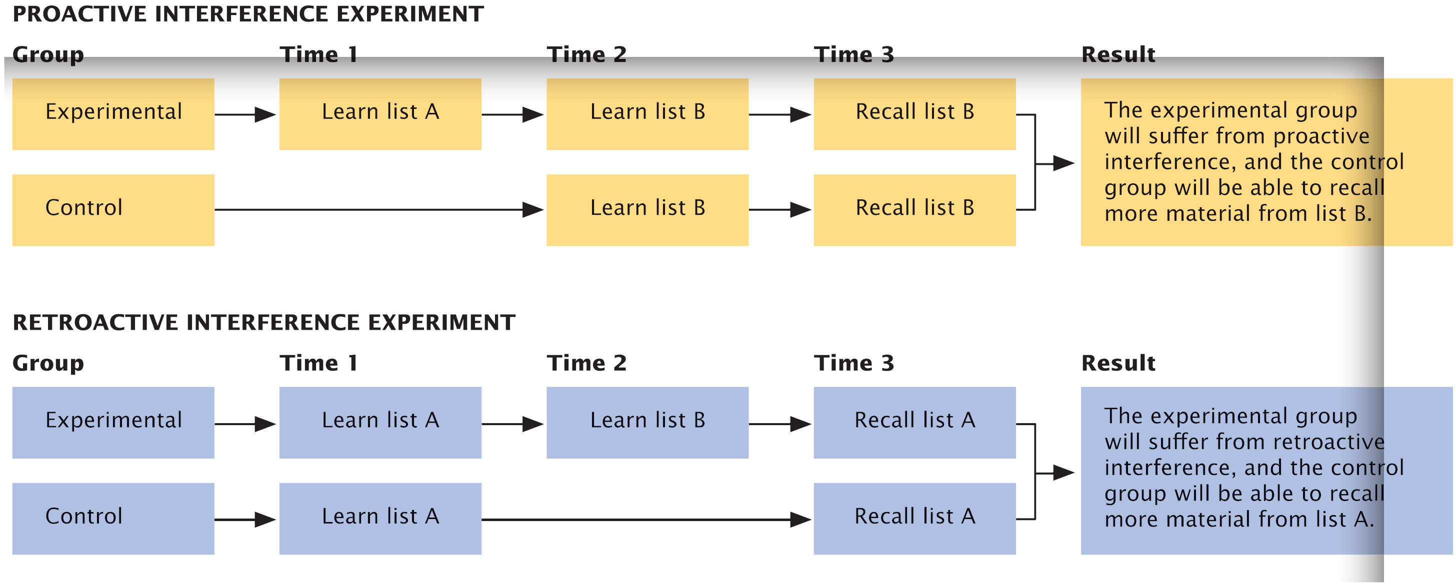


FIGURE 6.12
Procedures for Studying Interference

To remember the difference between the two types of interference, note that prefixes *pro* and *retro* indicate directions in time. Pro means "forward," and retro means "backward." In proactive inhibition, previously learned material "comes forward" to interfere with new learning; retroactive inhibition occurs when new information goes back to interfere with the recall of past learning.

suggests that information gradually disappears from memory. Decay occurs in memory in much the same way that the inscription on a ring or bracelet wears away and fades over time. Forgetting might also occur because of **interference**, a process in which other information impairs either the storage or the retrieval of the information that was to be remembered (Healy et al., 2010; Robertson, 2012). Interference might occur because one piece of information actually displaces other information, pushing it out of memory. It might also occur because one piece of information makes storing or recalling other information more difficult.

Memory for an item in short-term memory decreases consistently over the course of about twenty seconds if it isn't rehearsed or thought about. So decay appears to play the main role in forgetting in short-term memory. But interference through displacement also matters. Like the top of a desk, short-term memory can hold only so much. Once it is full, adding additional items tends to make others "fall off" and become unavailable (Haberlandt, 1999). Displacement is one reason why the web address you just saw is likely to drop out of short-term memory if you see another one immediately afterward. Rehearsal prevents displacement by continually reentering the same information into short-term memory.

Unlike the situation in short-term memory, the forgetting that occurs from long-term memory appears to be more directly tied to interference (Raaijmakers & Jakab, 2013). Sometimes the interference is due to **retroactive inhibition**, in which learning new information interferes with our ability to recall older information (Miller & Laborda, 2011; Wixted, 2005). Interference can also occur because of **proactive inhibition**, a process by which old information interferes with our ability to learn or remember newer information (Wright, Katz, & Ma, 2012). Retroactive inhibition would help explain why studying French vocabulary this term might make it more difficult to remember the Spanish words you learned last term. And because of proactive inhibition, the French words you are learning now might make it harder to learn German vocabulary next term. Figure 6.12 outlines the types of experiments used to study the influence of each form of interference in long-term memory.

Does interference push information out of memory or does it merely make it harder to retrieve the information? To find out, Endel Tulving and Joseph Psotka (1971) presented people with lists of words that represented a particular category. For example, there was a "buildings" list (e.g., *hut, cottage, cabin, hotel*) and a geographical features list (e.g., *cliff, river, hill, volcano*). Some people learned a list and then recalled as many of its words as possible. Other groups learned one list and then learned up to five additional lists before trying to recall the first one.

interference The process through which storage or retrieval of information is impaired by the presence of other information.

retroactive inhibition A cause of forgetting whereby new information placed in memory interferes with the ability to recall information already in memory.

proactive inhibition A cause of forgetting whereby previously learned information interferes with the ability to remember new information.

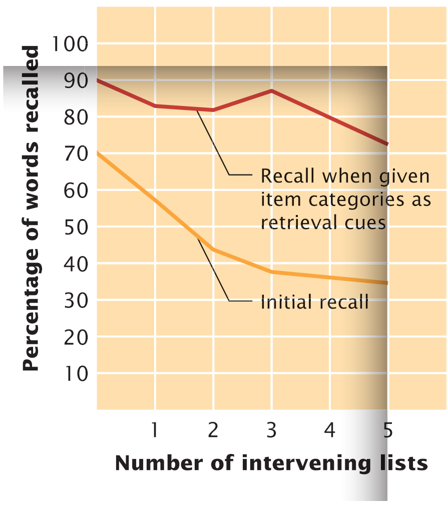


FIGURE 6.13
Retrieval Failures and Forgetting

Tulving and Psotka (1971) found that people's ability to recall a list of items was strongly affected by the number of other lists they learned before being tested on the first one.

The results were dramatic. As the number of additional lists increased, the number of words that people could recall from the original list decreased. This finding reflected strong retroactive inhibition; the new lists were interfering with recall of the first one. Then the researchers gave a second test, but this time they provided a retrieval cue by telling the category of the words (such as "types of buildings") to be recalled. Now the number of additional lists had almost no effect on the number of words recalled from the original list, as Figure 6.13 shows. These results indicate that the words from the first list were still in long-term memory: They had not been pushed out, but the participants couldn't remember them without appropriate retrieval cues. In short, faulty retrieval caused the original forgetting. Putting more and more information in long-term memory may be like putting more and more items in a suitcase or a refrigerator. Although none of the items disappear, it becomes increasingly difficult to find the one you are looking for (Malmberg et al., 2012).

Some theorists have suggested that all forgetting from long-term memory is due to retrieval failure (Ratcliff & McKoon, 1989). Does this mean that everything in long-term memory remains there for life, even if you cannot always (or ever) recall it? No one knows for sure yet, but as described in the next section, this question lies at the heart of some highly controversial court cases.

THINKING CRITICALLY

CAN TRAUMATIC MEMORIES BE REPRESSED, THEN RECOVERED?

In 1989, Eileen Franklin told California police that when she looked into her young daughter's eyes one day, she suddenly remembered seeing her father kill her childhood friend more than 20 years earlier. On the basis of her testimony about this memory, her father, George Franklin, Sr., was sent to prison for murder (Loftus & Ketcham, 1994).

What am I being asked to believe or accept?

Other cases have also resulted in imprisonment as adults claim to have recovered childhood memories of physical or sexual abuse. The juries in these trials accepted the claim that memory of shocking events can be *repressed,* or pushed into an inaccessible corner of the mind where subconscious processes keep it out of awareness for decades, yet potentially subject to accurate recall (Hyman, 2000). Jurors are not the only ones who have accepted claims of a **repressed memory** phenomenon. Some years ago a large American news organization reported that the United States had illegally used nerve gas during the war in Vietnam. This story was based, in part, on a Vietnam veteran's account of recovered memories of having been subjected to a nerve gas attack.

What evidence is available to support the assertion?

First, as discussed in the chapter on consciousness, a lot of mental activity occurs outside of awareness (Kihlstrom, 1999). Second, research on implicit memory shows that our behavior can be influenced by information of which we are not aware (Betch et al., 2003; Kouider & Dupoux, 2005). Third, research on *motivated forgetting* suggests that people may sometimes be able to suppress information willfully, so that it is no longer accessible on a later memory test (Anderson & Levy, 2009; Bailey & Chapman, 2012). Even suppressing one's emotional reactions to events can interfere with memories of those events (Richards & Gross, 2000). And people appear more likely to forget unpleasant rather than pleasant events (Erdelyi, 1985; Lynn et al., 2014). One psychologist kept a detailed record of his daily life over a six-year period. When he later tried to recall these experiences, he remembered more than half of the positive events but only a third of the negative ones (Waagenaar, 1986). In another study, 38 percent of women who had been brought to a hospital when they were children because of sexual abuse did not report the incident when they were interviewed as adults (Williams, 1994). Fourth, retrieval cues can help people recall memories that had previously

(*continued*)

repressed memory A painful memory that is said to be kept out of consciousness by psychological processes.

been inaccessible to conscious awareness (Andrews et al., 2000; Landsdale & Laming, 1995). For example, these cues have helped soldiers remember for the first time the circumstances under which they had been wounded many years before (Karon & Widener, 1997). Finally, there is the confidence with which people report recovered memories; they say they are just too vivid to be anything but real.

Are there alternative ways of interpreting the evidence?

Skeptical psychologists agree that subconscious memory and retrieval processes exist (Kihlstrom, 1999), and that, sadly, child abuse and other traumas are too common. Nevertheless, some of these psychologists conclude that the available evidence is not strong enough to support the conclusion that traumatic memories are likely to be repressed and then accurately recalled years later. For one thing, several studies have confirmed that memories of childhood events are no more accurate overall when people are adults than when they were still children (Brainerd, 2013). Any memory purportedly "recovered" in adulthood, then, could easily be a distorted or constructed memory (Clancy et al., 2000; Hyman, 2000; Loftus, 1998). Our recall of past events is affected by what happened at the time, what we knew beforehand, and everything we have experienced since. The people in the study mentioned earlier who "remembered" nonexistent books in an office inadvertently used their prior knowledge of what is usually in graduate students' offices to construct a false memory of seeing books. Similarly, that Vietnam veteran's "recovered memory" of a nerve gas attack appears to have had no basis in fact; the news organization that published the story later retracted it.

As we saw in the Focus on Research Methods section, false memories—distortions of actual events and the recall of events that didn't actually happen—can be just as vivid as real, accurate memories, and people can be just as confident about them (Brainerd & Reyna, 2005; Loftus, 2004; Roediger & McDermott, 2000). Most of us have experienced everyday versions of false memories. It is not unusual to "remember" turning off the coffeemaker or mailing the rent check, only to discover later that we didn't. Researchers have demonstrated that false memories can occur in relation to more emotional events, too. For example, a teenager named Chris was given descriptions of four incidents from his childhood and asked to write about each of them every day for five days (Loftus, 1997a). One of these incidents—being lost in a shopping mall at age five—never really happened. Yet Chris eventually "remembered" this event, and even added many details about the mall and the stranger whose hand he was supposedly found holding. He also rated this (false) memory as being more vivid than two of the other three (real) incidents he wrote about. Similar results occurred with about half of 77 child participants in other case studies (Porter, Yuille, & Lehman, 1999).

The same pattern of results has appeared in formal experiments about planting emotion-laden false memories (Hyman & Pentland, 1996; Loftus & Pickrell, 1995). Researchers have been able to create vivid and striking (but completely false) memories of events that people thought they experienced when they were one day old (DuBreuil, Garry, & Loftus, 1998). And some people will begin to avoid a certain food after researchers create in them a false memory of having been ill after eating that food as a child (Bernstein & Loftus, 2009a; Geraerts et al., 2008a). In other experiments, children who were repeatedly asked about a nonexistent trauma (getting a hand caught in a mousetrap) eventually developed a clear and unshakable false memory of experiencing it (Ceci et al., 1994). Results like these have led to concern that inaccurate reports and false memories might be made more likely by the use of repeated questioning and anatomically correct dolls during interviews with children about whether they have been touched inappropriately by an adult (Poole, Bruck, & Pipe, 2011).

Studies have found that people who are prone to fantasy, who easily confuse real and imagined stimuli, and who tend to have lapses in attention and memory are more likely than others to develop false memories and possibly more likely to report the recovery of repressed memories (e.g., Fuentemilla et al., 2009; McNally, 2003; McNally et al., 2005; Wilson & French, 2006). Two other studies have found that women who have suffered physical or sexual abuse are more likely to falsely remember words on a laboratory recall test (Bremner, Shobe, & Kihlstrom, 2000; Zoellner et al., 2000). This tendency appears strongest among abused women who show signs of posttraumatic stress disorder (Bremner, Shobe, & Kihlstrom, 2000). Another study found that the tendency to have false memories during a word recall task was greater in

(*continued*)

women who reported recovered memories of sexual abuse than in nonabused women or in those who had always remembered the abuse they suffered (Clancy et al., 2000).

Why would anyone "remember" a trauma that did not actually occur? Elizabeth Loftus (1997b) suggests that popular books about repressed memory may lead people to believe that anyone who experiences guilt, depression, low self-esteem, over-emotionality, or virtually any other psychological problem is harboring repressed memories of abuse. This message may be reinforced and elaborated by certain therapists, particularly those who specialize in using guided imagination, hypnosis, and other methods to "help" clients recover repressed memories (Lindsay et al., 2004; McHugh, 2009). In so doing, these therapists may influence their clients to construct false memories by encouraging them to imagine experiencing events that might never have actually occurred or that occurred only in a dream (Mazzoni & Loftus, 1996; Olio, 1994). As one client described her therapy, "I was rapidly losing the ability to differentiate between my imagination and my real memory" (Loftus & Ketcham, 1994, p. 25). To such therapists, a client's failure to recover memories of abuse or refusal to accept that they exist is evidence of denial of the truth (Loftus, 1997a; Tavris, 2003).

Exploring Memory Processes

Elizabeth Loftus (at center) is shown here with her students. Loftus and other cognitive psychologists have demonstrated mechanisms through which false memories can be created. They have shown, for example, that false memories appear even in research participants who are told about them and asked to avoid them (McDermott & Roediger, 1998). Their work has helped focus scientific scrutiny on reports of recovered memories, especially those arising from contact with therapists who assume that most people have repressed memories of abuse.

Courtesy of Elizabeth Loftus

The possibility that recovered memories might actually be false memories has led to dismissed charges or not-guilty verdicts for defendants in some repressed memory cases. In other cases, previously convicted defendants have been released. (George Franklin's conviction was overturned, but only after he spent five years in prison.) Many families (including George Franklin's) filed lawsuits against hospitals and therapists. In 1994, California winery executive Gary Ramona received $500,000 in damages from two therapists who had "helped" his daughter recall his alleged sexual abuse of her. Similar cases in Wisconsin and Illinois have more recently resulted in multimillion dollar judgments against therapists who had "found" their patients' lost memories (Heller, 2011; Loftus, 1998).

What additional evidence would help evaluate the alternatives?

Evaluating reports of recovered memories would be easier if we had more information about whether it is possible for people to repress memories of traumatic events. If it is possible, we also need to know how common it is and how accurate recovered memories might be. So far, we know that some people apparently forget intense emotional experiences but that most people's memories of them are vivid and long lasting (Alexander et al., 2005; Henckens et al., 2009; Porter & Peace, 2007). Some of these memories are called *flashbulb memories* because they preserve particular experiences in great detail (Brown & Kulik, 1977; McGaugh, 2003). In other words, evidence suggests that negative emotional information is retained as long, and as accurately, as any other information (Nørby, Lange, & Larsen, 2010).

(*continued*)

In fact, many people who live through trauma are *unable* to forget it, though they wish they could (Henig, 2004). In the sexual abuse study mentioned earlier, for example (Williams, 1994), 62 percent of the victims recalled as adults the trauma that had been documented in their childhoods. A similar study of a different group of adults found that about 92 percent of them recalled the abuse that had been documented in their childhoods (Alexander et al., 2005; Goodman et al., 2003). The true recall figures might actually be even higher in such studies, because some people who remember abuse may not wish to talk about it. In any case, additional studies like these—studies that track the fate of memories in known abuse cases—would not only help estimate the prevalence of this kind of forgetting but also might offer clues as to the kinds of people and events most likely to be associated with it.

It would also be valuable to know more about the processes through which repression might occur. Is there a mechanism that specifically pushes traumatic memories out of awareness and then keeps them at a subconscious level for long periods? Despite some suggestive results (e.g., Anderson & Levy, 2009; DePrince & Freyd, 2004), cognitive psychologists have so far not found reliable evidence for such a mechanism (Bulevich et al., 2006; Geraerts et al., 2006; Loftus, 1997a; McNally, 2003).

What conclusions are most reasonable?

LINKAGES Do forgotten memories remain in the subconscious? (a link to Consciousness)

An objective reading of the research evidence suggests that the recovery of traumatic memories is at least possible but that the implantation of false memories is also possible—and has been demonstrated repeatedly in controlled experiments. With this in mind, it is not easy to decide whether any particular case is an instance of recovered memory or false memory, especially when there is no objective corroborating evidence to guide the decision (Belli, 2012).

The intense conflict between those who uncritically accept claims of recovered memories and those who are more wary about the accuracy of such claims reflects a fundamental disagreement about evidence (Tavris, 2003). To many therapists who deal daily with victims of sexual abuse and other traumas, clients' reports constitute stronger proof of recovered memories than do the results of laboratory experiments. Client reports are viewed with considerably more skepticism by psychologists who engage in, or rely on, empirical research on the processes of memory and forgetting (Loftus, 2003, 2004; Pope, 1998). They would like to have additional sources of evidence, including from research on brain activity "signatures" that might someday distinguish true memories from false ones (e.g., Bernstein & Loftus, 2009b; Rissman, Greely, & Wagner, 2010; Slotnick & Schacter, 2004).

So people's responses to claims of recovered memory may be determined by the relative weight that they assign to reports of personal experiences versus evidence from controlled experiments. Still, the apparent ease with which false memories can be created should lead judges, juries, and the general public to exercise great caution before accepting unverified memories of traumatic events as the truth. At the same time, we should not automatically reject the claims of people who appear to have recovered memories (Geraerts et al., 2007; McNally & Geraerts, 2009). Perhaps the wisest course is to use all the scientific and circumstantial evidence available to carefully and critically examine claims of recovered memories while keeping in mind the possibility that constructive memory processes might have influenced those memories (Alison, Kebbell, & Lewis, 2006; Geraerts et al., 2007). This careful scientific approach is vital if we are to protect the rights of those who report recovered memories as well as those who face accusations arising from them (Geraerts et al., 2008b).

BIOLOGICAL BASES OF MEMORY

How does my brain change when I store a memory?

Many psychologists who study memory focus on explicit and implicit mental processes (e.g., Rubin et al., 2011; Schott et al., 2005). Others explore the physical, electrical, and chemical changes that take place in nerve cells when people encode, store, and retrieve information (e.g., Goldinger & Papesh, 2012; Kuhl, Bainbridge, & Chun, 2012; Linden et al., 2012; Prepau et al., 2014).

The Biochemistry of Memory

As described in the chapter on biological aspects of psychology, brain cells communicate at synapses, which are places where an axon from one cell meets with the dendrites of another. This communication uses chemicals called *neurotransmitters* that axons release into the synapses. The formation and storage of new memories are associated with at least two kinds of changes in synapses.

The first kind of change occurs when stimulation from the environment promotes the formation of *new* synapses. Scientists can actually see this process occur. As shown in Figure 6.14, repeatedly sending signals across a particular synapse increases the number of special little branches, called *spines,* that appear on the receiving cell's dendrites (Enriquez-Barreto et al., 2014; Roberts et al., 2010; Stepanyants & Escobar, 2011). The second kind of change occurs as new experiences change how *existing* synapses operate. For example, when two neurons fire at the same time and together stimulate a third neuron, that other neuron will later be more responsive than before to stimulation by either neuron alone (Sejnowski, Chattarji, & Stanton, 1990). This process of "sensitizing" synapses is called *long-term potentiation* (Fidzinski et al., 2012; Lisman, Yasuda, & Raghavachari, 2012). Other patterns of electrical stimulation can weaken synaptic connections, a process called *long-term depression* (Malenka, 1995). Changes in the sensitivity of synapses might account for the development of conditioned responses and other types of learning and for the operation of working memory.

In the brain's hippocampus (see Figure 6.15), such changes may be particularly likely at synapses using the neurotransmitter *glutamate* (Malenka & Nicoll, 1999). Other neurotransmitters, such as *acetylcholine,* also play important roles in memory formation (e.g., Furey, Pietrini, & Haxby, 2000; Li et al., 2003). The memory problems seen in conditions such as Alzheimer's disease appear related to disruptions in the activity of these neurons in the hippocampus (e.g., Ferrarini et al., 2014; Leal & Yassa, 2013). It is not surprising, then, that drugs designed to treat Alzheimer's disease seem to work by affecting synapses that use glutamate or acetylcholine (Schneider, 2013).

In summary, research has shown that the formation of memories is associated with changes in many individual synapses that, together, strengthen and improve the communication in networks of neurons.

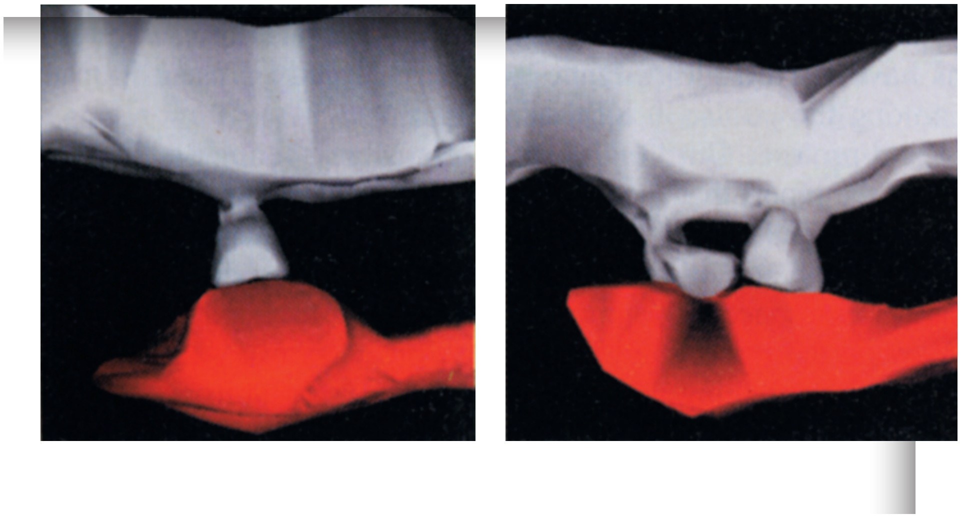


FIGURE 6.14
Building Memories

These models are based on electron microscope images of synapses in the brain. The model on the left shows that before signals were repeatedly sent across the synapse, just one spine (shown in white) appears on this part of the dendrite. Afterward, as shown in the other model, there are two spines, which help improve communication across the synapse. The creation and changing of many individual synapses in the brain appear to underlie the formation and storage of new memories.

Courtesy of Professor Dominique Muller

FIGURE 6.15
Brain Structures Involved in Memory

Combined neural activity in many parts of the brain allows us to encode, store, and retrieve memories. The complexity of the biological bases of these processes is underscored by research showing that different aspects of a memory—such as the sights and sounds of some event—are stored in different parts of the cerebral cortex.

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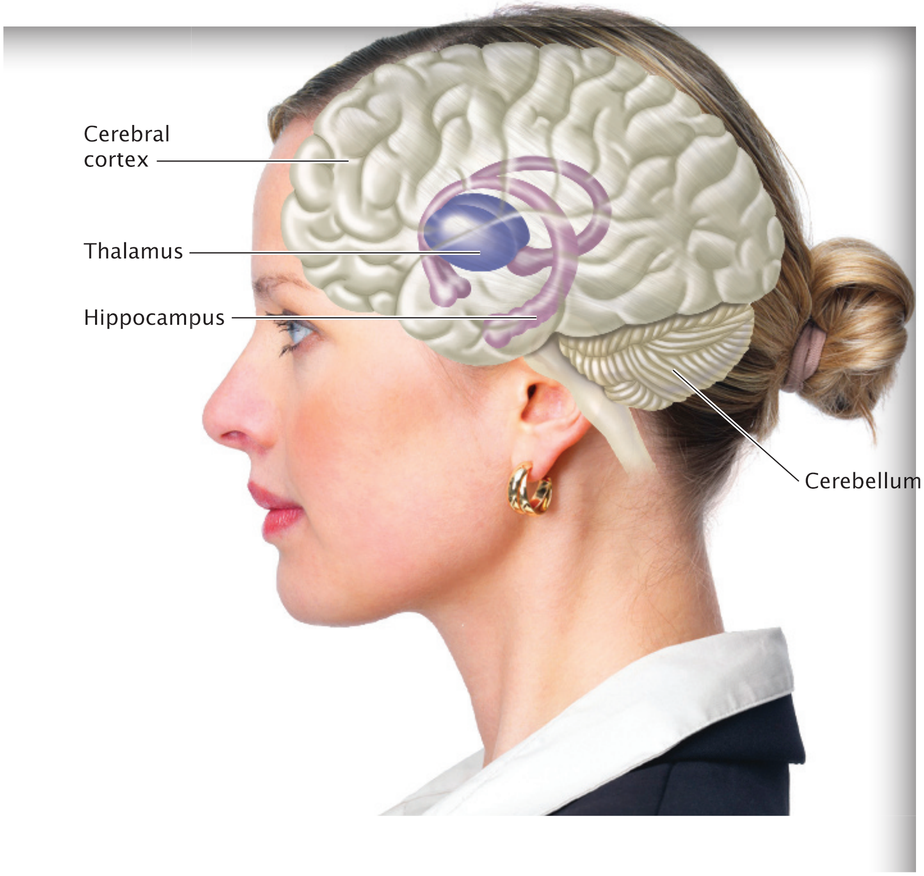

Brain Structures and Memory

LINKAGES Where are memories stored? (a link to Biological Aspects of Psychology)

Are the biochemical processes involved in memory concentrated in certain brain regions, or are they distributed throughout the brain? Research suggests that memory involves both specialized regions where various types of memories are formed and widespread areas for storage (Takashima et al., 2006).

The Impact of Brain Damage

Studies of how brain injuries affect memory give hints about which parts of the brain are involved in various kinds of memory. For example, damage to the hippocampus, nearby parts of the cerebral cortex, and the thalamus often cause **anterograde amnesia**, a loss of ability to form new memories for events after the injury (Zhuang et al., 2011).

The case of Henry Molaison (once known only as H. M.; Eichenbaum, 2013) provides a striking example of anterograde amnesia (Milner, 1966). When H. M. was twenty-seven years old, part of his hippocampus was surgically removed to help stop his frequent epileptic seizures. After the operation, his long-term and short-term memory appeared normal, but something was wrong. Two years later, he still believed that he was twenty-seven. When his family moved into a new house, he couldn't remember the new address or how to get there. When his uncle died, he grieved in a normal way, but later asked why his uncle had not visited him. He had to be repeatedly reminded of the death, and each time, H. M. began to mourn all over again. The surgery had apparently destroyed the mechanism that

anterograde amnesia A loss of memory for events that occur after a brain injury.

transfers new information from short-term to long-term memory (Annese, et al., 2014). Until his death in 2008, H. M. lived in a nursing home, where his only long-term memories were from fifty years earlier, before the operation. He was still unable to recall events and facts he had experienced since then—not even the names of people he saw every day (Hathaway, 2002; Squire, 2009).

Although patients with damage to the hippocampus may not form new episodic memories, they may still form implicit memories. For example, H. M.'s performance on a complicated puzzle improved steadily over several days of practice, just as it does with normal people, and eventually he became almost perfect. But each time he tried the puzzle, he said he had never seen it before (Cohen & Corkin, 1981). Even people without a hippocampus can form certain kinds of memories. For example, Clive Wearing, a pianist whose hippocampus was destroyed by a viral infection, has only a few seconds of short-term memory, but he can still play pieces he'd learned before the infection. He can also learn new ones, though he has no memory of doing so (Sacks, 2007). The same is true of P. M., a cellist with a similar condition (Finke, Esfahani, & Ploner, 2013). So although the hippocampus is needed to form new episodic memories, it appears that implicit memory, procedural memory, and working memory can all form using other brain regions (Budson, 2009; Touzani, Puthanveettil, & Kandel, 2007).

Retrograde amnesia involves loss of memory formed prior to a brain injury (Kapur, 1999). A person with this type of amnesia would have trouble remembering anything that took place in the months or years before the injury. In 1994, head injuries from a car crash left thirty-six-year-old Perlene Griffith-Barwell with retrograde amnesia so severe that she forgot virtually everything she had learned about everything and everyone she had known over the previous twenty years. She thought she was still sixteen and did not recognize her husband, Malcolm, or her four children. She said, "The children were sweet, but they didn't seem like mine," and she "didn't feel anything" for Malcolm. Her memories of the previous twenty years never fully returned. She is divorced, but at last report she was living with her children, working in a bank, and planning to remarry (Echo News, 2000).

Unlike Perlene, most people with retrograde amnesia after brain trauma gradually recover their memories (Riccio, Millin, & Gisquet-Verrier, 2003). The most distant events are recalled first, then the person gradually regains memory for events leading up to the injury. Recovery is seldom complete, however, and the person may never remember the last few seconds before the injury. One man received a severe blow to

A Famous Case of Retrograde Amnesia

After Ralf Schumacher slammed his race car into a wall during the U.S. Grand Prix in June of 2004, he sustained a severe concussion that left him with no memory of the crash. Retrograde amnesia is relatively common following concussions, so if you ride a bike or a motorcycle, wear that helmet!

Paul Gilham/Getty Images

retrograde amnesia A loss of memory for events that occurred prior to a brain injury.

the head after being thrown from his motorcycle. Upon regaining consciousness, he thought he was eleven years old. Over the next three months, he slowly recalled more of his life. He remembered when he was twelve, thirteen, and so on—right up until the day of the accident. But he was never able to remember what happened just before the accident (Baddeley, 1982). Those final events were probably never transferred into long-term memory (Dudai, 2004).

The appearance of retrograde amnesia following a blow to the head has led researchers to suggest that as memories are transferred into long-term memory, they are initially unstable and therefore vulnerable to disruption (Dudai, 2004). It may take minutes, hours, days, or even longer before these memories are fully solidified, or *consolidated* (Donegan & Thompson, 1991). Such consolidation processes may depend on movement of electrochemical impulses within clusters of neurons in the brain (Taubenfeld et al., 2001). Accordingly, conditions that suppress nerve cell activity in the brain may also disrupt the transfer of information into long-term memory. These conditions include anesthetic drugs, poisoning by carbon monoxide or other toxins, and strong electrical impulses such as those in the electroconvulsive therapy that is sometimes used to treat cases of severe depression (see the chapter on treatment of psychological disorders).

Multiple Storage Areas

Obviously, the hippocampus does not permanently store long-term memories (Bayley, Hopkins, & Squire, 2003; Rosenbaum et al., 2000). If it did, H. M. would not have retained memories from the years before part of his hippocampus was removed. The hippocampus and thalamus send nerve impulses to the cerebral cortex, and it is in and around the cortex that long-term semantic and episodic memories are probably stored—but not just in one place (Levy, Bayley, & Squire, 2004; Ranganath, 2010). As described in the chapter on biological aspects of psychology, different regions of the cortex receive messages from different senses. Specific aspects of an experience are probably stored in or near these regions. For example, damage to the auditory association cortex disrupts memory for sounds (Colombo et al., 1990). A memory, however, involves more than one sensory system. Even in the simple case of a rat remembering a maze, the experience of the maze involves vision, smell, movements, and emotions, each of which may be stored in different regions of the brain (Gallagher & Chiba, 1996). So memories are both localized and distributed. Certain brain areas store specific aspects of each remembered event, but many brain systems are involved in experiencing a whole event (Brewer et al., 1998; Kensinger & Corkin, 2004). For example, the cerebellum (see Figure 6.15) is involved in the storage of procedural knowledge, such as dance steps and other movements.

What happens in the brain as we retrieve memories? Brain imaging studies show that the hippocampus and various regions of the cerebral cortex are active during memory retrieval (e.g., Andrews-Hanna, Saxe, & Yarkoni, 2014; McDermott, Szpunar, & Christ, 2009; Wing, Marsh, & Cabeza, 2013). There is also evidence to suggest that retrieving memories of certain experiences, such as a conversation or a tennis game, reactivates the sensory and motor regions of the brain that had been involved during the event itself (Danker & Anderson, 2010; Nyberg et al., 2001). Research shows, too, that when people or animals recall a stored emotional (fear-related) memory, that memory may have to be stored again. During this biological restorage process known as *reconsolidation*, it may be either strengthened or distorted (e.g., Dudai, 2004; Inda, Muravieva, & Alberini, 2011; Schiller et al., 2010).

Cognitive neuroscientists are trying to determine whether different patterns of brain activity occur with the storage and retrieval of accurate versus inaccurate memories (Bäuml & Samenieh, 2012; Bernstein & Loftus, 2009b; Urbach et al., 2005). Another line of investigation concerns the ability to think about the future (Atance & O'Neill, 2001; Szpunar, 2010). Scientists have found, for example, that patients with amnesia due to damage to the medial temporal lobe are not only unable to recollect the past, but they also cannot vividly envision future events, such as their next birthday party (Hassabis et al., 2007; Maguire & Hassabis, 2011). It appears from neuroimaging studies that the same brain regions involved in remembering are important for envisioning, too (Szpunar, Watson, & McDermott, 2007; Szpunar, Chan, & McDermott, 2009).

IMPROVING YOUR MEMORY

How can I remember more information?

Some questions remain about what memory is and how it works, but the results of memory research offer many valuable guidelines to help people improve their memories. For example, the physiological arousal that accompanies walking and other exercise appears to promote the storage and retrieval of memories (Lin et al., 2012; Salas, Minakata, & Kelemen, 2011), and as noted in the consciousness chapter, a good night's sleep can help consolidate the memories you formed during the day (Payne et al., 2012; Simmons, 2012). More specific memory enhancement strategies are based on the elaboration of incoming information and especially on linking new information to what you already know.

Mnemonic Strategies

One way to improve your memory is to use mnemonic strategies (pronounced "nee-MON-ik"). **Mnemonic strategies** are ways to put information into an organized framework in order to remember it more easily. To remember the names of the Great Lakes, for example, you could use the acronym HOMES (for Huron, Ontario, Michigan, Erie, and Superior). Verbal organization is the basis for many mnemonic strategies. You can link items by weaving them into a story, a sentence, or a rhyme. To help customers remember where they left their cars, some large parking lots have replaced traditional section

"YOU SIMPLY ASSOCIATE EACH NUMBER WITH A WORD, SUCH AS 'TABLE' AND 3,476,029."

Mnemonic Strategies

You can improve your memory by using mnemonic strategies, but make sure they are easy to remember!

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mnemonic strategies Methods for organizing information in order to remember it.

designations such as “A1” or “G8” with the names of colors, months, or animals. Customers can then tie the location of their cars to information already in long-term memory—for example, “I parked in the month of my mother’s birthday.” And which do you think would be easier to remember: 1-800-438-4357 or 1-800-GET-HELP? Obviously, the more meaningful “get help” number is more memorable (Topolinski, 2011), and there are Web sites that can help you translate any phone number into words or a phrase.

TRY THIS

A simple but powerful mnemonic strategy is called the *method of loci* (pronounced “LOW-sigh”), or the “method of places.” To use this method, first think about a set of familiar locations. Use your home, for example. You might imagine walking through the front door, around all four corners of the living room, and through each of the other rooms. Next, imagine that each item you want to remember is in one of these locations. Creating vivid or unusual images of how the items appear in each location seems to be particularly effective (Kline & Groninger, 1991). For example, tomatoes smashed against the front door or bananas hanging from the bedroom ceiling might be helpful in recalling these items on a grocery list. Whenever you want to remember a new list, you can create new images using the same locations in the same order.

Guidelines for More Effective Studying

The success of mnemonic strategies demonstrates again the importance of relating new information to knowledge already stored in memory. All mnemonic systems require that you have a well-learned body of knowledge (such as locations) that can be used to provide a framework, or context, for organizing incoming information.

When you want to remember complex material, such as a textbook chapter, the same principle applies. You can improve your memory for text material by first creating an outline or other overall context for learning, rather than by just reading and rereading (Glover et al., 1990). Repetition may *seem* effective because it keeps material in short-term memory, but for retaining information over long periods, repetition alone tends to be ineffective, no matter how much time you spend on it (Bjork, 1999). In short, “work smarter, not harder.”

In addition, spend your time wisely. **Distributed practice** is much more effective than **massed practice** for learning and retaining new information. If you are going to spend 10 hours studying for a test, you will be much better off studying for ten 1-hour blocks, separated by periods of sleep and other activity. “Cramming” for one 10-hour block will not be as successful (Rohrer & Pashler, 2007). By scheduling more study sessions, you will stay fresh and be able to think about the material from a new perspective during each session. This method will remind you of the previously studied material and help you elaborate on the material, as in elaborative rehearsal, and thus remember it better (Benjamin & Tullis, 2010; Cepeda et al., 2009).

Elaborative rehearsal may also explain why, as mentioned in the learning chapter, students develop better long-term memory for course material if they are tested in a series of exams, each of which includes material presented during the entire course so far, as compared to a program of non-cumulative exams that cover only a specific part of the course (Lawrence, 2013). Apparently, the opportunity to encode, store, and retrieve the same material several times—and relate it to an ever-growing knowledge base in the process—creates more enduring memories.

You should also practice retrieving what you have learned by testing yourself repeatedly. For example, instead of simply rereading a section of a chapter, close the book and try to jot down the section’s main points from memory. Both laboratory and classroom studies have found that students’ exam performance is clearly better after self-testing than after merely reading and rereading the material they are trying to learn (e.g., Bugg & McDaniel, 2012; Hartwig & Dunlosky, 2012; Karpicke & Smith, 2012; Nunes & Weinstein, 2012; Roediger et al., 2011). Taking practice tests has been shown to have many benefits. It can

distributed practice Learning new information in many study sessions that are spaced across time.

massed practice Trying to learn complex new information in a single long study period.

help you study, store, and retrieve information in ways that match the task you will face when taking real tests. Practice tests also tell you what you know and what you don't know, so you can decide if you are ready for the real test or whether you need to study certain topics more thoroughly (Roediger, Putnam, & Smith, 2011). It is for reasons like these that we have included self-tests following each "In Review" table and at the end of every chapter of this book.

Reading a Textbook

More specific advice for remembering textbook material comes from a study that examined how successful and unsuccessful college students approached their reading (Whimbey, 1976). Unsuccessful students tended to read the material straight through. They did not slow down when they reached a difficult section. They kept going even when they did not understand what they were reading. In contrast, successful college students monitored their understanding, reread difficult sections, and periodically stopped or reviewed what they had learned. (This book's "In Review" features are designed to help you do that.) In short, effective learners engage in a deep level of processing. They are active learners. They think of each new fact in relation to other material, and they develop a context in which many new facts can be organized effectively.

Research on memory suggests two specific guidelines for reading a textbook. First, make sure that you understand what you are reading before moving on (Herrmann & Searleman, 1992). Second, try the *PQ4R method* (Thomas & Robinson, 1972). PQ4R stands for six activities to engage in when you read a chapter: *preview, question, read, reflect, recite,* and *review.* These activities are designed to increase the depth to which you process the information you read and should be done as follows:

1. ***Preview.*** Begin by skimming the chapter. Look at the section headings and any boldfaced or italicized terms. Get a general idea of what material will be discussed, the way it is organized, and how its topics relate to one another and to what you already know. Some people find it useful to survey the entire chapter once and then survey each major section a little more carefully before reading it in detail.
2. ***Question.*** Before reading each section, ask yourself what content will be covered and what information you should be getting from it.
3. ***Read.*** Read the text, but think about the material as you read. Are the questions you raised earlier being answered? Do you see the connections between and among the topics?
4. ***Reflect.*** As you read, think of your own examples—and create visual images—of the concepts and phenomena you encounter. Ask yourself what the material means and consider how each section relates to other sections in the chapter and other chapters in the book (this book's Linkages features are designed to promote this kind of reflection).
5. ***Recite.*** At the end of each section, recite the major points. Resist the temptation to be passive and say, "Oh, I'll remember that." Be active. Put the ideas into your own words by reciting them aloud to yourself (MacLeod et al., 2010) or by summarizing the material in a mini-lecture to a friend or study partner.
6. ***Review.*** When you reach the end of the chapter, review all of its material. You should now see connections not only within each section but also among sections. The objective is to see how the material is organized. Once you grasp that organization, the individual facts will be far easier to remember.

By following these procedures, you will learn and remember the material better. You will also save yourself considerable time.

Understand and Remember

Research on memory suggests that students who simply read their textbooks won't remember as much as those who read for understanding using strategies such as the PQ4R method. Further, memory for the material is likely to be better if you read and study it over a number of weeks rather than in one marathon session on the night before a test.

David Fischer/Photodisc/Getty Images

Lecture Notes

Students and employees often have to learn and remember material from lectures or other presentations. Taking notes will help, but effective note taking is a learned skill that improves with practice (Pauk & Owens, 2010). Research on memory suggests some simple strategies for taking and using notes effectively.

Recognize first that in note taking, more is not necessarily better. Taking detailed notes on everything requires that you pay close attention to unimportant as well as important content, leaving little time for thinking about the material. Note takers who concentrate on expressing the major ideas in relatively few words remember more than those who try to catch every detail (Pauk & Owens, 2010). In short, the best way to take notes is to think about what is being said. Draw connections with other material in the presentation. Then summarize the major points clearly and concisely (Kiewra, 1989).

Once you have a set of lecture notes, review them as soon as possible after the lecture so that you can fill in missing details. (Remember: Most forgetting from long-term memory occurs during the first hour after learning.) When the time comes for serious study, use your notes as if they were a chapter in a textbook. Write a detailed outline. Think about how various points are related. Once you have organized the material, the details will make more sense and will be much easier to remember. ("In Review: Improving Your Memory" summarizes tips for studying.)

IN REVIEW

IMPROVING YOUR MEMORY

Goal	Helpful Techniques
Remembering lists of items	■ Use mnemonic strategies. ■ Look for meaningful acronyms. ■ Try the method of loci.
Remembering textbook material	■ Follow the PQ4R system. ■ Allocate your time to allow for distributed practice. ■ Read actively, not passively. ■ Test yourself repeatedly as you read.
Taking lecture notes	■ Take notes, but record only the main points. ■ Think about the overall organization of the material. ■ Review your notes as soon after the lecture as possible in order to fill in missing points.
Studying for exams	■ Write a detailed outline of your lecture notes rather than passively reading them.

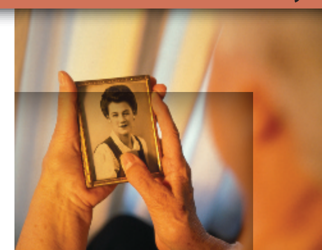
In Review Questions

1. Using mnemonic strategies and the PQ4R system to better remember course material are examples of the value of __________ rehearsal.
2. "Cramming" illustrates __________ practice that usually leads to __________ long-term retention than __________ practice.
3. To minimize forgetting, you should review lecture notes __________ after a lecture ends.

LINKAGES

As noted in the introductory chapter, all of psychology's subfields are related to one another. Our discussion of eyewitness testimony illustrates just one way that the topic of this chapter, memory, is linked to the subfield of sensation and perception, as discussed in the chapter by that name. The Linkages diagram shows ties to two other subfields, and there are many more ties throughout the book. Looking for linkages among subfields will help you see how they all fit together and help you better appreciate the big picture that is psychology.

CHAPTER 6 Memory

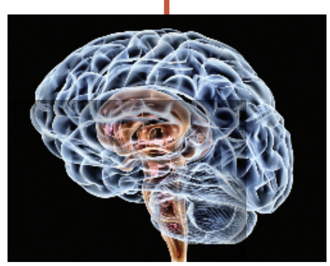


LINKAGES

Where are memories stored?

How accurate is eyewitness testimony?

Why does memory improve during childhood?



CHAPTER 3
Biological Aspects of Psychology

CHAPTER 4
Sensation and Perception

CHAPTER 11
Human Development

SUMMARY

The Nature of Memory

How does information turn into memories?

Human memory depends on a complex mental system. There are three basic memory processes. ***Encoding*** transforms stimulus information into some type of mental representation. Codes for ***auditory*** (or ***acoustic) memory*** represent information as sounds, codes for ***visual memory*** represent information as images, and codes for semantic memory represent information as general meanings. ***Storage*** maintains information in the memory system over time. ***Retrieval*** is the process of gaining access to previously stored information.

Most psychologists agree that there are at least three types of memory. ***Episodic memory*** refers to memory for specific events in a person's life. ***Semantic memory*** refers to generalized knowledge about the world. ***Procedural memory***, or ***procedural knowledge***, refers to information about how to do things. Research on memory focuses on ***explicit memory***, the information we retrieve through a conscious effort to remember something, and ***implicit memory***, the unintentional recollection and influence of prior experiences.

Five models of memory have guided most research. The ***levels-of-processing model of memory*** suggests that the most important determinant of memory is how extensively information is encoded or processed when it is first received. In general, ***elaborative rehearsal*** is more effective than ***maintenance rehearsal*** in learning new information, because it represents a deeper level of processing. According to the ***transfer-appropriate processing model of memory***, the critical determinant of memory is not how deeply information is encoded but whether the processes used during retrieval match those used during encoding. ***Neural network models of memory***, such as parallel distributed processing (PDP) models, suggest that new experiences not only provide specific information but also become part of (and alter) a whole network of associations. The **multiple memory systems model** suggests that the brain contains several relatively separate memory systems. The ***information-processing model of memory*** suggests that for information to become firmly embedded in memory, it must pass through three stages of processing: sensory memory, short-term memory, and long-term memory.

Storing New Memories

What am I most likely to remember?

Sensory memory maintains information about incoming stimuli in the ***sensory registers***, such as in ***iconic memory***, for a very brief time. ***Selective attention***, which focuses mental resources on only part of the stimulus field, controls what information in the sensory registers is actually perceived and transferred to short-term memory.

Working memory is a system that allows us to store, organize, and manipulate information in order to think, solve problems, and make decisions. The storage, or maintenance, component of working memory is referred to as ***short-term memory (STM)***. Various memory codes can be used in short-term memory, but acoustic codes seem to be used in most verbal tasks. Studies of the ***immediate memory span*** indicate that the capacity of short-term memory is approximately seven meaningful groupings of information, created by ***chunking***. Studies using the ***Brown-Peterson distractor technique*** show that information in short-term memory is usually forgotten in about twenty seconds or so if it is not rehearsed.

Long-term memory (LTM) normally results from semantic encoding, which means that people tend to encode the general meaning of information, not the surface details, into long-term memory. The capacity of long-term memory to store new information is extremely large and perhaps unlimited. The appearance of a ***primacy effect*** and a ***recency effect*** suggests that short-term and long-term memory may be distinct systems.

Retrieving Memories

How do I retrieve stored memories?

Retrieval cues help people remember things that they would otherwise not be able to recall. The effectiveness of retrieval cues follows the ***encoding specificity principle***: Cues help retrieval only if they match some feature of the information that was originally encoded. All else being equal, memory may be better when we attempt to retrieve information in the same environment in which it was learned; this is called ***context-specific memory***, or ***context-specific learning.*** When our internal state can affect retrieval, we have a ***state-dependent memory***, or ***state-dependent learning***. Researchers usually study retrieval from semantic memory by examining how long it takes people to answer general knowledge questions. It appears that ideas are represented as associations in a dense semantic memory network and that the retrieval of information occurs by a process of ***spreading activation***. Each concept in the network is represented as a unique collection of features or attributes. The tip-of-the-tongue phenomenon illustrates the retrieval of incomplete knowledge.

Constructing Memories

How accurate are my memories?

In the process of constructive memory, people use generalized knowledge, or ***schemas***, to fill in gaps in the information they encode and retrieve. PDP models provide one explanation of how people make spontaneous generalizations about the world.

Eyewitnesses can remember only what they perceive, and they can perceive only what they attend to. As a result, eyewitness testimony is often much less accurate than witnesses—and jurors—think it is.

Forgetting

What causes me to forget things?

In his research on long-term memory and forgetting, Ebbinghaus devised a ***relearning method*** to measure the amount of time that is saved when previously learned material is learned again after a delay. He found that most forgetting from long-term memory occurs during the first hour after learning and that savings can be extremely long lasting. ***Decay theory*** and ***interference*** describe two mechanisms of forgetting. There is evidence of both decay and interference in short-term memory; it appears that most forgetting from long-term memory is due to interference caused by either ***retroactive inhibition*** or ***proactive inhibition***. There is considerable controversy over the possibility of ***repressed memory*** of traumatic events, especially about whether recovered memories of such events are more likely to be true recollections or false, constructed ones.

Biological Bases of Memory

How does my brain change when I store a memory?

Research has shown that memories can result from new synapses forming in the brain and improved communication at existing synapses. Studies of ***anterograde amnesia***, ***retrograde amnesia***, and other consequences of brain damage provide information about the brain structures involved in memory. For example, the hippocampus and thalamus are known to play a role in the formation of memories. These structures send nerve impulses to the cerebral cortex, and it is there that memories are probably stored. Memories appear to be both localized and distributed throughout the brain.

Improving Your Memory

How can I remember more information?

Mnemonic strategies are methods that can be used to remember things better. One of the simplest but most powerful mnemonic strategies is the method of loci. It is useful because it provides a context for organizing material effectively. Another key memory strategy is to space out your study sessions over time. This ***distributed practice*** is much more effective than ***massed practice*** ("cramming"), in which you try to learn a lot of information all at once. The key to remembering textbook material is to read actively rather than passively. One way to do this is to follow the PQ4R method: preview, question, read, reflect, recite, and review. Similarly, to take lecture notes or to study them effectively, organize the points in a meaningful outline and think about how each main point relates to the others.

TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. Ludwig had an extraordinary memory for sound. Even when he lost his hearing in his later years, he was still able to create beautiful music. This demonstrates his well-developed __________ codes.
   a. acoustic
   b. visual
   c. semantic
   d. auditory

2. Henry is talking about his high school graduation ceremony. He remembers that his parents and grandparents were there and that afterward they gave him a laptop computer. Henry's memory of this event is both __________ and __________.
   a. semantic; explicit
   b. episodic; explicit
   c. semantic; implicit
   d. episodic; implicit

3. Riesa was uncomfortable when she was introduced to her roommate's cousin. She was not aware of it, but the cousin reminded her of a hated classmate in elementary school. This incident provides an example of the operation of __________ memory.
   a. procedural
   b. semantic
   c. implicit
   d. anterograde

4. Raquel was still studying ten minutes before her test. As she entered the classroom, she kept repeating the last sentence she had read: "Henry VIII had six wives." She was using __________ to keep this information in mind.
   a. elaborative rehearsal
   b. maintenance rehearsal
   c. the method of loci
   d. spreading activation

5. In a memory study, half the students in a class were told to expect multiple-choice questions on their upcoming exam and the other half was told to expect essay questions. Students did better if they got the type of exam they expected, which is consistent with the __________model of memory.
   a. levels-of-processing
   b. transfer-appropriate processing
   c. parallel distributed processing
   d. information-processing

6. Reepal listens as her father describes a party the family is planning. She also smells popcorn from the kitchen, hears the radio playing, notices flashes of lightning outside, and feels too warm in her sweater. Yet Reepal is able to transfer the information about the party to her short-term memory, primarily because of __________ .
   a. elaborative rehearsal
   b. implicit memory cues
   c. selective attention
   d. transfer-appropriate processing

7. Larry was thrilled when he met the girl of his dreams at the mall. She told him her phone number before she left, but if Larry doesn't use any rehearsal methods, he will remember the number for only about __________.
   a. one second
   b. twenty seconds
   c. one minute
   d. five minutes

8. Remembering your bank account number (2171988) as your birthday (February 17, 1988) is an example of __________.
   a. chunking
   b. the Brown-Peterson distractor technique
   c. the PQ4R method
   d. the method of loci

9. Lisbeth's mother once told her to remember that "the nail that stands out will get pounded down." But when Lisbeth tried to tell a friend about this saying, she remembered it as "if you stand out too much you'll get in trouble." Her problem in recalling the exact words is probably due to the fact that encoding in long-term memory is usually __________.
   a. acoustic
   b. visual
   c. semantic
   d. state dependent

10. Nesta had made a list of twenty CDs that she wanted to check out of the library, but she forgot to bring it with her. Nesta is most likely to remember the CDs that were at the __________ of the list.
    a. beginning
    b. middle
    c. end
    d. beginning and end

11. Janetta has been studying for tomorrow's test while drinking strong caffeinated coffee. A friend tells Janetta that her test score can be improved if she takes advantage of state-dependent memory by __________.
   a. drinking strong, caffeinated coffee just before the test
   b. doing the rest of her studying where the test will be given
   c. avoiding any kind of coffee just before the test
   d. using mnemonic strategies to remember key terms

12. Molly, a high school student, knows that she knows the name of her kindergarten teacher, but she can't quite remember it when asked. This experience is called __________.
   a. constructive memory block
   b. sensory memory impairment
   c. the tip-of-the-tongue phenomenon
   d. anterograde amnesia

13. When asked if there was a fever thermometer in her doctor's office, Careen says she remembers seeing one, even though it wasn't actually there. This is an example of __________, which is influenced by __________.
   a. the tip-of-the-tongue phenomenon; schemas
   b. the tip-of-the-tongue phenomenon; selective attention
   c. constructive memory; schemas
   d. constructive memory; selective attention

14. The use of DNA evidence has had what effect on the U.S. legal system's view of eyewitness testimony?
   a. It has had generally convinced witnesses to change their minds.
   b. It has demonstrated that eyewitness testimony, though not always accurate, is much better than anyone thought it was.
   c. It has revealed that eyewitness testimony has put many people in prison for crimes they did not commit.
   d. It has had little effect.

15. Robin memorized the names of all of the U.S. presidents when she was ten. Two years later, she had forgotten most of them, so she was pleasantly surprised that she could learn them a second time much more quickly than the first. This faster relearning time is an example of what Ebbinghaus called __________.
   a. mnemonic strategies
   b. state dependence
   c. context dependence
   d. savings

16. Berean studied French during his first year at college and then started learning Spanish in his second year. Now he is having difficulty remembering his Spanish vocabulary because the French words keep popping into his mind. This is an example of __________.
   a. retrograde amnesia
   b. anterograde amnesia
   c. retroactive inhibition
   d. proactive inhibition

17. When her brother said he had gotten a job in a bookstore, Danielle immediately assumed it would be a large room with books along the walls, a magazine section, a children's section, and cash registers near the door. But he had been hired by an online store, so Danielle was wrong. Her mistaken assumptions occurred because of __________, which is/are predicted by the model of memory.
   a. spontaneous generalizations; a neural network
   b. spontaneous generalizations; information-processing
   c. constructive memory; depth of processing
   d. semantic memory; transfer-appropriate

18. Jerry, a factory worker, suffered a brain injury when a steel beam fell on his head. Jerry cannot remember anything that has happened since the accident. Jerry is experiencing __________ amnesia.
   a. retrograde
   b. anterograde
   c. proactive
   d. retroactive

19. The brain area Jerry (above) most likely damaged was the __________.
   a. visual cortex
   b. corpus callosum
   c. cerebellum
   d. hippocampus

20. Loretta wanted to remember a list of important memory researchers, so she pictured them all visiting her apartment. She imagined Elizabeth Loftus playing video games in the living room, Hermann Ebbinghaus napping in the bathtub, Henry Roediger and Kathleen McDermott dancing in the kitchen, and so on. Loretta is using the memory strategy called __________.
   a. the method of loci
   b. procedural memorization
   c. encoding cues
   d. context dependence

Thought and Language

Chris Rout/Alamy

Preview

"Say what you mean, and mean what you say." This is good advice, but following it isn't always easy, partly because our thoughts don't always come to us in clear, complete sentences. We have to construct those sentences—using the language we've learned—from the words, images, ideas, and other mental material in our minds. Often, the material's complexity makes it difficult to accurately express what we're thinking. We all manage to do it, but with varying degrees of success. In this chapter, we explore what thoughts are, what language is, and how people translate one into the other. We also consider how thinking guides decision making and problem solving.

Dr. Joyce Wallace, a New York City physician, was having trouble figuring out what was the matter with a forty-three-year-old patient, "Laura McBride." Laura reported pain in her abdomen, aching muscles, irritability, occasional dizzy spells, and fatigue (Rouéché, 1986). The doctor's first hypothesis was iron-deficiency anemia, a condition in which there is not enough oxygen-carrying hemoglobin in the blood. There was some evidence to support this idea. A physical examination revealed that Laura's spleen was a bit enlarged, and blood tests showed low hemoglobin and high production of red blood cells, suggesting that her body was attempting to compensate for lost hemoglobin. However, other tests revealed normal iron levels. Perhaps she was losing blood through internal bleeding, but other tests ruled that out. Had Laura been vomiting blood? She said no. Blood in the urine? No. Abnormally heavy menstrual flow? No.

As Dr. Wallace puzzled over the problem, Laura's condition worsened. She reported more intense pain, cramps, shortness of breath, and loss of energy. Her blood was becoming less and less capable of sustaining her, but if it was not being lost, what was happening to it? Finally, the doctor looked at a smear of Laura's blood on a microscope slide. What she saw indicated that a poison was destroying Laura's red blood cells. What could it be? Laura spent most of her time at home, and her teenage daughters, who lived with her, were perfectly healthy. Dr. Wallace asked herself, "What does Laura do that the girls do not?" She repairs and restores paintings. Paint. Lead! She might be suffering from lead poisoning! When the next blood test showed a lead level seven times higher than normal, Dr. Wallace had found the answer at last.

To unravel this medical mystery, Dr. Wallace relied on her ability to think, solve problems, and make judgments and decisions. She put these vital cognitive abilities to use in weighing the pros and cons of various hypotheses and in reaching decisions about what tests to order and how to interpret them. In consulting with the patient and other physicians, she relied on another remarkable human cognitive ability: *language*. Let's take a look at what psychologists have discovered about these complex mental processes and how to measure them. We begin by examining a general framework for understanding human thinking and then go on to look at some specific cognitive processes.

BASIC FUNCTIONS OF THOUGHT

What good is thinking, anyway?

Thinking involves five main operations or functions: describing, elaborating, deciding, planning, and guiding action. Figure 7.1 shows how these functions can be organized into a *circle of thought*.

The Circle of Thought

Consider how the circle of thought operated in Dr. Wallace's case. It began when she received information about Laura's symptoms that allowed her to *describe* the problem. Next,

FIGURE 7.1
The Circle of Thought

The circle of thought begins as our sensory systems receive information from the world. Our perceptual system describes and elaborates this information, which is represented in the brain in ways that allow us to make decisions, formulate plans, and guide our actions. As those actions change our world, we receive new information, which begins another journey around the circle of thought.

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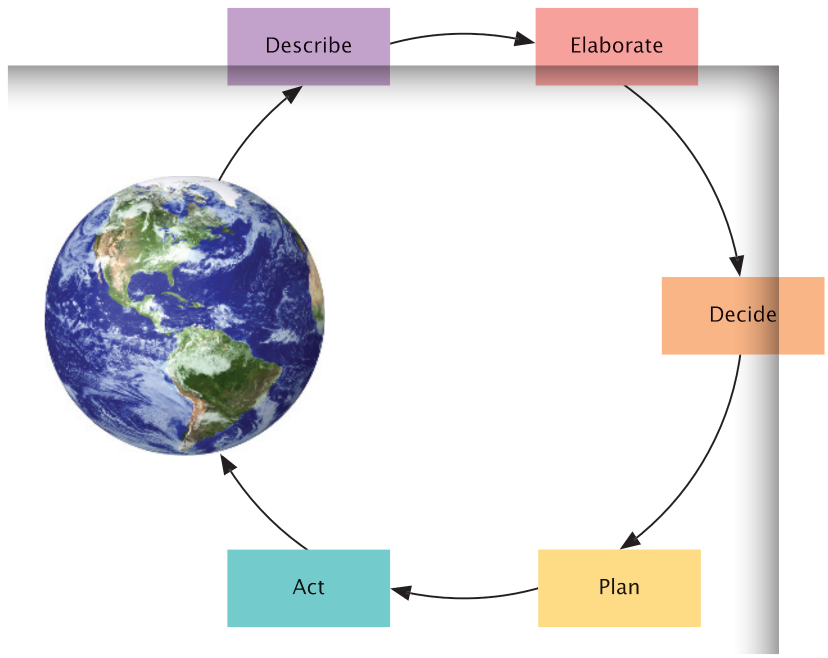
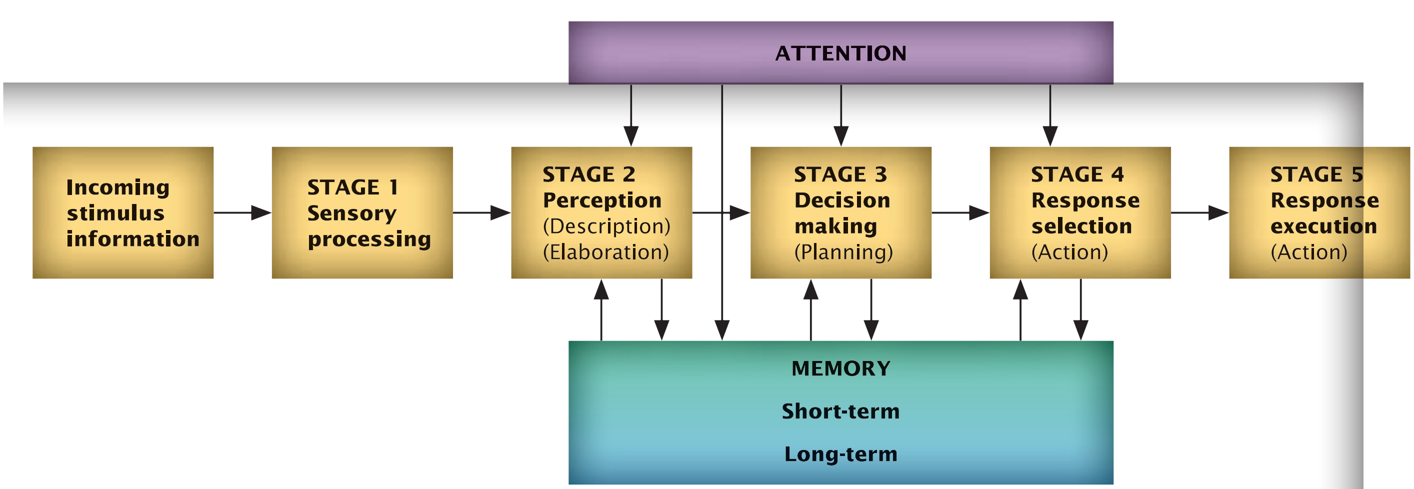


Dr. Wallace *elaborated* on this information by using her knowledge, experience, and powers of reasoning to consider what disorders might cause such symptoms. Then she made a *decision* to investigate a possible cause, such as anemia. To pursue this decision, she came up with a *plan*—and then *acted* on that plan. But the circle of thought did not stop there. Information from the blood test gave new descriptive information, from which Dr. Wallace elaborated further to reach another decision, create a new plan, and guide her next action. Each stage in the circle of thought was also influenced by her overall intention—in this case, to find and treat her patient's problem.

The processes making up the circle of thought usually occur so quickly and are so complex that slowing them down for careful analysis might seem impossible. Some psychologists approach this difficult task by studying thought processes as if they were part of a computer-like information-processing system. An **information-processing system** receives information, represents the information with symbols, and then manipulates those symbols (e.g., Anderson, Bothell et al., 2004). In an information-processing model, **thinking** is defined as the manipulation of mental representations. Figure 7.2 shows how an information-processing model might describe the sequence of mental events that make up one trip around the circle of thought.

FIGURE 7.2
An Information-Processing Model

Some stages in the information-processing model depend heavily on both short-term and long-term memory and require some attention—that limited supply of mental resources required for information processing to be carried out efficiently (Oberauer & Hein, 2012).



"Automatic" Thinking

The sensory, perceptual, decision-making, response-planning, and action components of the circle of thought can occur so rapidly that—as when playing a fast-paced video game—we may only be aware of the incoming information and our quick response to it. In such cases, our thinking processes become so well practiced that they are virtually automatic (Charlton & Starkey, 2011).

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In the first stage, information about the world reaches your brain through the senses we discussed in the chapter on sensation and perception. This stage does not require attention. In the second stage, you must perceive and recognize the information—processes that do require attention. Also in this stage, you consciously elaborate information using the short-term and working-memory processes described in the memory chapter. These processes allow you to think about new information in relation to knowledge stored in your long-term memory. Once the information has been elaborated in this way, you must decide what to do with it. This third stage—decision making—demands attention, too. Your decision might be to store the information or to take some action. If the decision is to act, it is at this stage that you plan what to do. In the fourth and fifth stages, the action is carried out. Your action usually affects the environment, providing new information that is "fed back" to the system for processing in the ongoing circle of thought.

Measuring Information Processing

"Elliot," an intelligent and successful young businessman, had a cancerous tumor removed from the front of his brain. After surgery, his normally sharp reasoning and decision-making abilities failed. He made a series of reckless, impulsive business moves that put him into bankruptcy (Damasio, 1994). The brain damage that Elliot suffered appeared to have mainly affected the decision-making and response selection stages of information processing. Analyzing the effects of brain damage is just one method scientists use to study the details of how the entire information-processing sequence normally works and what can interfere with it.

Mental Chronometry

Drivers and video game players know that there is always a slight delay between seeing a red light or a "bad guy" and hitting the brakes or firing the laser gun. The delay occurs because each of the processes described in Figure 7.2 takes some time. Psychologists began the laboratory study of thinking by exploring *mental chronometry,* the timing of mental events (Posner, 1978). Specifically, they examined **reaction time**, the time elapsing between the presentation of a stimulus and the appearance of an overt response to it. Reaction time, they reasoned, should give us an idea of how long it takes for all the processes shown in Figure 7.2 to occur. In a typical reaction time experiment, a person is asked to say a word or to push a button as rapidly as possible after a stimulus appears. Even in such simple situations, several factors influence reaction times (Wickens, Gordon-Becker, & Liu, 2004).

One such factor is the *complexity* of the decision. The more options we have in responding to a set of stimuli, the longer the reaction time. The tennis player who knows that her opponent usually serves to a particular spot on the court will have a simple decision to make when the serve is completed and will react rapidly. But if she faces an opponent whose serve is less predictable, her reaction will be slower, because a more complex decision about which way to move is now required.

Expectancy, too, affects reaction time. People respond faster to stimuli that they expect and more slowly to stimuli that surprise them. So your reaction time will be shorter when braking for a traffic light that you knew might turn red than when dodging a ball thrown at you unexpectedly. Reaction time is also influenced by *stimulus-response compatibility.* If the relationship between a set of stimuli and possible responses is a natural or compatible one, reaction time will be fast. If not, reaction time will be slower (see Figure 7.3). Finally, in any reaction time task, there is a *speed-accuracy trade-off.* If you attempt to respond quickly, errors increase. If you try for an error-free performance, reaction time increases (Wickens & Carswell, 2006). At a track meet, for example, contestants who try too hard to anticipate the starting gun may have especially quick starts but may also have especially frequent false starts that disqualify them.

information-processing system Mechanisms for receiving information, representing it with symbols, and manipulating it.

thinking The manipulation of mental representations.

reaction time The time between the presentation of a stimulus and an overt response to it.

FIGURE 7.3
Stimulus-Response Compatibility

TRY THIS Imagine standing in front of an unfamiliar stove when a pot starts to boil over. Your reaction time in turning down the heat will be quicker on the stove shown in the left photo, because each knob is positioned to indicate the burner it controls. There is compatibility between the source of the stimulus and the location of the response. The stove in the right photo shows far less compatibility. Here, which knob you should turn is not as obvious, so your reaction time will be slower. Are there devices in your own house or apartment that lack stimulus-response compatibility? If so, how would you redesign them?

Courtesy of BadDesigns.com

Research on reaction time helped establish the time required for information processing to occur, but reaction times alone cannot provide a detailed picture of what goes on between the presentation of a stimulus and the execution of a response. They do not tell us, for example, whether we respond more quickly to an expected stimulus because we perceive it faster or because we make a decision about it faster. To analyze mental events more directly, psychologists have turned to other methods, such as neuroimaging.

Neuroimaging

Using positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and other neuroimaging techniques described in the chapter on biological aspects of psychology, cognitive neuroscientists can watch the activity occurring in the brain during information processing (e.g., Karuza, Emberson, & Aslin, 2014; Price, 2012). In one study, for example, participants performed a task that required complex problem-solving skills. The brain's frontal lobe was especially active when this task was still relatively new and difficult, as shown by the red-shaded areas in Figure 7.4. As the participants learned the skills, however, frontal lobe activity decreased. When the task was well learned, the hippocampus became especially active (see the green-shaded areas in Figure 7.4). Activation in the hippocampus suggests that the participants were no longer struggling with a problem-solving task but instead were drawing upon memory systems.

Other studies of brain activity during the performance of cognitive tasks have also found that the frontal lobes are especially important for making decisions and solving problems (Wallis, Anderson, & Miller, 2001; Yarkoni et al., 2005), so it is no wonder that damage to Elliot's frontal area disrupted his decision-making and impulse-control abilities.

FIGURE 7.4
Watching People Think

Cognitive psychologists and other cognitive neuroscientists have found ways to watch brain activity as information processing takes place. These fMRI pictures show activity in two "slices" of the brain of a research participant who was practicing a complex problem-solving task. The areas shown in red were activated early in the learning process. As skill developed, the areas shown in green became activated.

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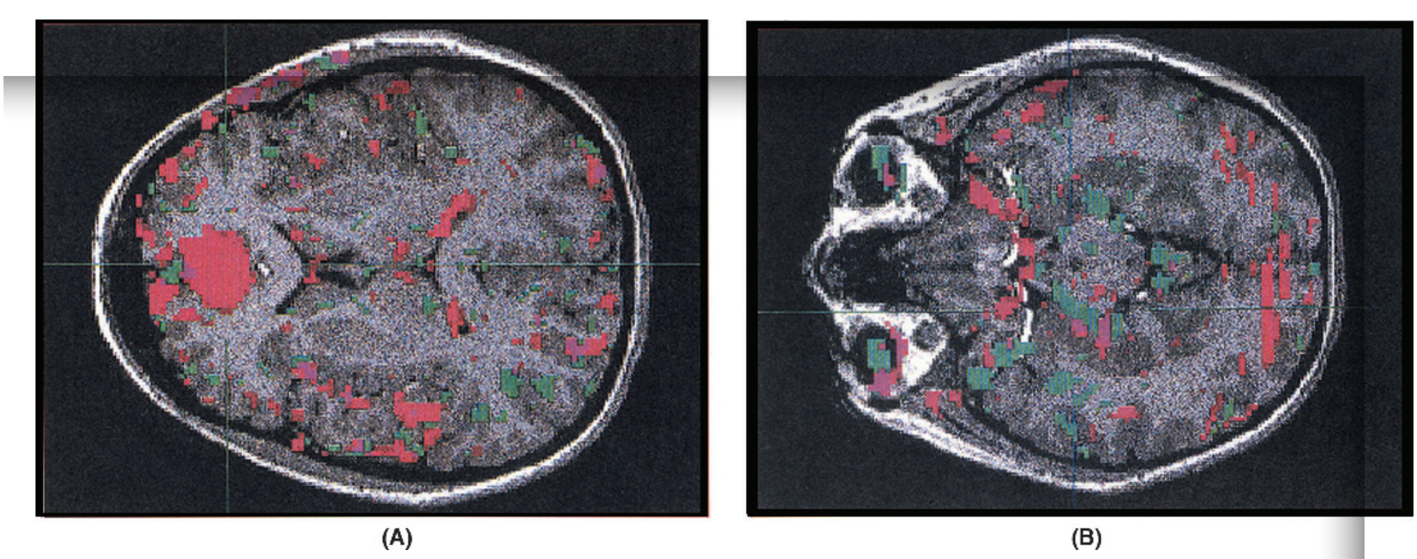

(A) (B)

MENTAL REPRESENTATIONS: THE INGREDIENTS OF THOUGHT

What are thoughts made of?

Just as measuring, stirring, and baking are only part of the story of cookie making, describing the processes of thinking tells only part of the story behind the circle of thought. Psychologists usually describe the ingredients of thought as information. But that is like saying that you make cookies with "stuff." What specific forms can information take in our minds? Cognitive psychologists have found that information can be mentally represented in many ways, including as concepts, propositions, schemas, scripts, mental models, images, and cognitive maps. Let's explore these ingredients of thought and how people manipulate them as they think.

Concepts

When you think about anything—dogs, happiness, sex, movies, pizza—you are manipulating a basic ingredient of thought called concepts. **Concepts** are categories of objects, events, or ideas with common properties. Some concepts, such as "round" and "red," are visual and concrete. Concepts such as "truth" and "justice" are more abstract and harder to define. To have a concept is to recognize the properties, or features, that tend to be shared by members of a category. For example, the concept of "bird" includes such properties as having feathers, laying eggs, and being able to fly. The concept of "scissors" includes such properties as having two blades, a connecting hinge, and a pair of finger holes. Concepts allow you to relate each object or event you encounter to a category that you already know. Using concepts, you can say, "No, that is not a dog," or "Yes, that is a car." Concepts also make it possible for you to think logically. If you have the concepts "whale" and "bird," you can decide whether a whale is a bird without having either creature in the room with you.

Types of Concepts

Some concepts—called *formal concepts*—clearly define objects or events by a set of rules and properties, so that every member of the concept has all of the concept's defining properties and nonmembers do not. For instance, the concept "square" can be defined as "a shape with four equal sides and four right-angle corners." Any object that does not have all of these features is simply not a square. Formal concepts are often used to study concept learning in the laboratory because the members of these concepts can be neatly defined (Trabasso & Bower, 1968).

TRY THIS

Now stop reading for a moment and make a list of the features that define the concepts "home" or "game." You might have said that "home" is the place where you live and that a "game" is a competition between players. However, some people define "home" as the place where they were born, and almost everyone thinks of solitaire as a card game even though it involves only one player. These are just two examples of *natural concepts.* Unlike formal concepts, natural concepts don't have a fixed set of defining features. Instead, natural concepts have a set of typical or *characteristic* features, and members don't need to have all of them. For example, the ability to fly is a characteristic feature of the natural concept "bird," but an ostrich is still a bird even though it can't fly. It is a bird because it has enough other characteristic features of "bird" (such as feathers and wings). Having just one bird property is not enough, though. A snake lays eggs and a bat can fly, but neither animal is a bird. It is usually a combination of properties that defines a concept. In most situations outside the laboratory, people are thinking about natural rather than formal concepts. These natural concepts include object categories, such as "bird" or "house." They also include abstract idea categories, such as "honesty" or "justice," and goal-related categories, such as "things to pack for my vacation" (Barsalou, 1993).

concepts Categories of objects, events, or ideas that have common properties.

The boundaries of a natural concept are fuzzy, so some members are better examples of it than others. A robin, a chicken, an ostrich, and a penguin are all birds. But a robin is a better example of the bird concept than the others, because it is closer to what most people

A Natural Concept

A space shuttle and a hot-air balloon are two examples of the natural concept "aircraft," but most people think of the space shuttle, with its wings, as the better example. A prototype of the concept is probably an airplane. Members of natural concepts share a kind of "family resemblance" that helps us recognize items that belong in the same category, even if they are not identical.

NASA; © BenC/Shutterstock.com

have learned to think of as a typical bird. A member of a natural concept that possesses all or most of its characteristic features is called a **prototype**. The robin is a *prototypical* bird. The more prototypical of a concept something is, the more quickly you can decide whether it is an example of the concept. This is the reason people can answer just a little more quickly when asked "Is a robin a bird?" than when asked "Is a penguin a bird?" With practice, most of us get very good at using natural concepts to organize our thinking about the world (Wahlheim, Finn, & Jacoby, 2012). And, because prototypes are fundamental to the way we perceive and understand the world, understanding the nature of people's prototypes can have great practical value. For example, smokers—particularly young male smokers—are at greater risk for long-term cigarette use if their prototype for "smoker" includes traits such as "smart and independent" (Piko, Bak, & Gibbons, 2007). This is why health psychologists' anti-smoking programs often include efforts to create in smokers' minds a more negative prototype of the "typical smoker."

Propositions

We often combine concepts in units known as propositions. A **proposition** is a mental representation that expresses a relationship between concepts. Propositions can be true or false. Suppose you hear someone say that your friend Heather broke up with her boyfriend Jason. Your mental representation of this event will include a proposition that links your concepts of "Heather" and "Jason" in a particular way. This proposition could be diagrammed (in an unscientific way) as follows: Heather → dumped → Jason.

The arrows indicate that this statement is a proposition rather than a sentence. Propositions can be expressed as sentences, but they are actually general ideas that can be conveyed in any number of specific ways. In this case, the words "Jason was dumped by Heather" and "Heather is not willing to date Jason anymore" would all express the same proposition. If you later discovered that it was Jason who caused the breakup, the diagram of your proposition about the event would change to reflect this new information, shown here as reversed arrows: Heather ← dumped ← Jason.

prototype A member of a natural concept that possesses all or most of its characteristic features.

proposition A mental representation that expresses a relationship between concepts.

Schemas, Scripts, and Mental Models

We organize the basic units of our thought in increasingly complex ways, and doing so allows us to see how these units are linked. For example, sets of propositions are often so closely associated that they form more complex mental representations called *schemas*.

You Can't Judge a Book by Its Cover

Does this person look like a millionaire to you? Our schemas tell us what to expect about objects, places, events, and people, but those expectations can sometimes be wrong. This was dramatically illustrated in October 1999 when Gordon Elwood died. The Medford, Oregon, man, who dressed in rags and collected cans, left over $9 million to charity (McMahon, 2000).

© iStock.com/Anna Bryukhanova

As mentioned in the chapters on sensation and perception, memory, and human development, **schemas** are generalizations that we develop about categories of objects, places, events, and people. Our schemas help us understand the world. If you borrow a friend's car, your "car" schema will give you a good idea of where the accelerator and brake are, and how to raise and lower the windows. Schemas also generate expectations about objects, places, events, and people—telling us that stereo systems have speakers, that picnics occur in the summer, that rock concerts are loud, and so on.

Scripts

Schemas about familiar activities, such as going to a restaurant, are known as **scripts** (Anderson, 2000). Your "restaurant" script represents the sequence of events you can expect when you go out to eat (see Figure 7.5). That script tells you what to do when you are in a restaurant and helps you understand stories involving restaurants (Whitney, 2001). Scripts also shape your interpretation of events. For example, on your first day of high school, you no doubt assumed that the person standing at the front of the class was a teacher, not a security guard or a janitor.

If our scripts are violated, however, it is easy to misinterpret events. In one case, a heart attack victim in London lay for nine hours in the hallway of an apartment building after an ambulance crew smelled alcohol on his breath and assumed he was "sleeping it off." The crew's script for what happens in the poorer sections of big cities told them that someone slumped in a hallway is drunk, not sick. Because script-violating events are unexpected, our reactions to them tend to be slower and less effective than our reactions to expected events. Your "grocery shopping" script, for example, probably includes pushing a cart, putting items in it, going to the checkout stand, paying, and leaving. But suppose you are at the back of the store when a robber near the entrance fires a gun and shouts at the manager to open the safe. People sometimes ignore these script-violating events, interpreting gunshots as a car backfiring and shouted orders as "someone fooling around" (Raisig et al., 2010). Others simply freeze, unsure of what to do or not realizing that they could call the police on their cell phones.

Mental Models

The relationships among concepts can be organized not only as schemas and scripts but also as **mental models** (Johnson-Laird, 1983). For example, suppose someone

schemas Generalizations about categories of objects, places, events, and people.

scripts Mental representations of familiar sequences of activity.

mental models Sets of propositions that represent people's understanding of how things look and work.

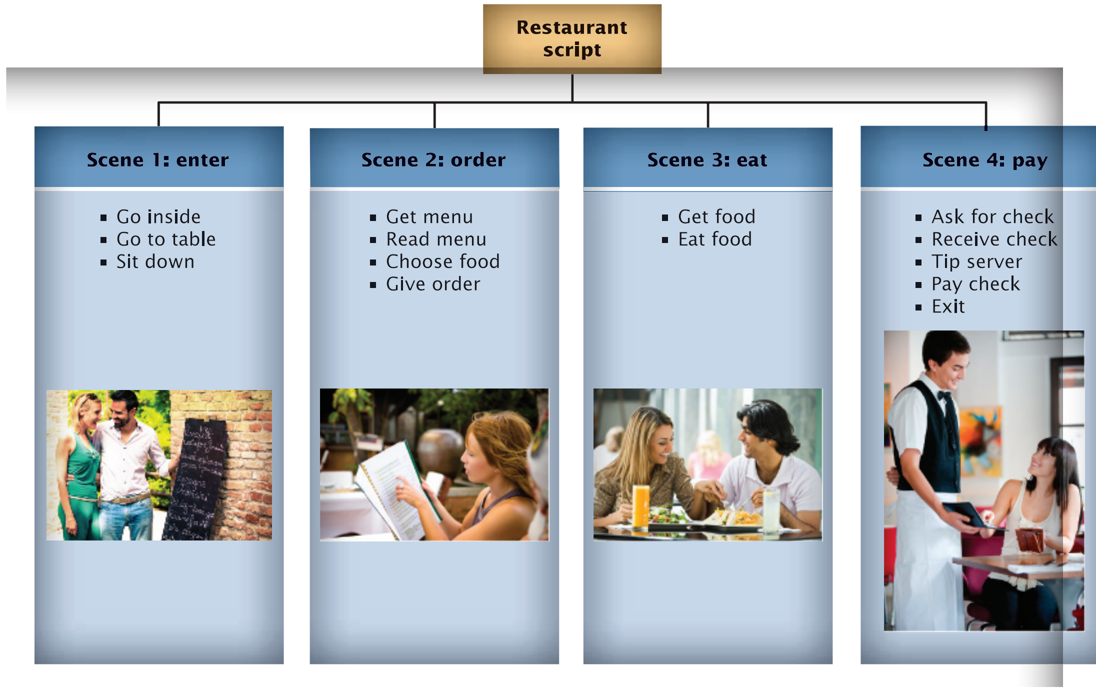

FIGURE 7.5
Following a Script: Eating at a Restaurant

Schemas about what happens in restaurants and how to behave in them take the form of scripts, represented here in four "scenes." Scripts guide our actions in all sorts of familiar situations and also help us understand descriptions of events occurring in those situations (e.g., "Our service was really slow").

Source: Whitney (2001).

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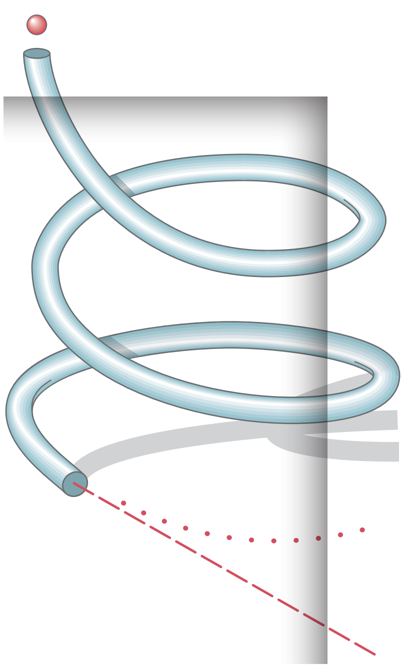

FIGURE 7.6
Applying a Mental Model

TRY THIS Try to imagine the path that the ball will follow when it leaves the curved tube. In one study, most people drew the incorrect (curved) path indicated by the dotted line, rather than the correct (straight) path indicated by the dashed line (McCloskey, 1983). Their error was based on the construction of a faulty mental model of the behavior of physical objects.

tells you, "My living room has blue walls, a white ceiling, and an oval window across from the door." You will mentally represent this information as propositions about how the concepts "wall," "blue," "ceiling," "white," "door," "oval," and "window" are related. However, you will also combine these propositions to create in your mind a three-dimensional model of the room. As more information about the world becomes available, either from existing memories or from new information we receive, our mental models become more complete.

Accurate mental models are excellent guides for thinking about, and interacting with, many of the things we encounter every day (Johnson-Laird, 2010). If our mental models are incorrect, however, we are likely to make mistakes (e.g., Michael, Garry, & Kirsch, 2012; see Figure 7.6). For example, college students conduct more effective online searches while shopping or consulting academic databases if their mental models of search engines recognize that those search engines require precise search terms. Students who think that human operators read and interpret the meaning of the search terms they enter are less likely to use precise terms and thus less likely to get useful results (Holman, 2011). Similarly, people who hold an incorrect mental model of how physical illness is cured might stop taking their antibiotic medication when their symptoms begin to disappear, well before the bacteria causing those symptoms have been eliminated (Medin, Ross, & Markman, 2001). Others overdose on medication because according to their faulty mental model, "if taking three pills a day is good, taking six would be even better."

Images and Cognitive Maps

Think about how your best friend would look in a clown suit. The mental picture you just got illustrates that thinking often involves the manipulation of **images**—mental representations of visual information. We can manipulate these images in a way that is similar to manipulating the objects themselves (Reed, 2000; Trickett, Trafton, & Schunn, 2009; see Figure 7.7). Our ability to think using images extends beyond the manipulation of stimuli such as those in Figure 7.7. We also create mental images that serve as mental models of descriptions we hear or read (Mazoyer et al., 2002). For example, you probably created an image a minute ago when you read about that blue-walled room.

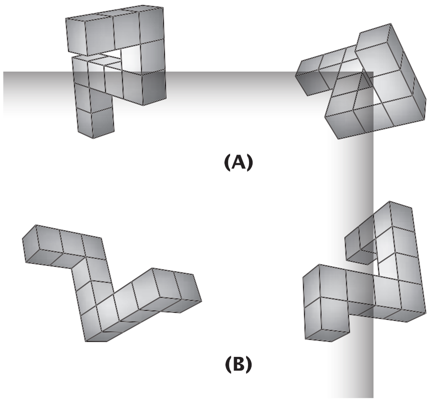

FIGURE 7.7
Manipulating Images

TRY THIS Are these pairs of objects the same or different? To decide, you will have to rotate one member of each pair. Manipulating mental images, like manipulating actual objects, takes time, so the speed of your decision will depend on how far you have to mentally rotate one object to line it up with the other for comparison. (The top pair matches; the bottom pair does not.)

The same thing happens when someone gives you directions to a new pizza place in town. In this case, you scan your **cognitive map**—a mental model of familiar parts of your world—to find the location. In doing so, you use a mental process similar to the visual process of scanning a Google map (Anderson, 2000; Hölscher, Tenbrink, & Wiener, 2011; Taylor & Tversky, 1992). Manipulating images on a different cognitive map would help you if a power failure left your home pitch dark. Even though you couldn't see a thing, you could still find a flashlight or a candle because your cognitive map would show the floor plan, furniture placement, door locations, and other physical features of your home. You would not have this mental map in a hotel room or an unfamiliar house; there, you would have to walk slowly, arms outstretched, to avoid wrong turns and painful collisions. In the chapter on learning, we describe how experience shapes cognitive maps that help animals navigate mazes and people navigate shopping malls. ("In Review: Ingredients of Thought" summarizes the ways we mentally represent information.)

IN REVIEW

INGREDIENTS OF THOUGHT

Ingredient	Description	Examples
Concepts	Categories of objects, events, or ideas with common properties; basic building blocks of thought	"Square" (a formal concept); "game" (a natural concept)
Propositions	Mental representations that express relationships between concepts; can be true or false	Assertions such as "The cow jumped over the moon."
Schemas	Sets of propositions that create generalizations and expectations about categories of objects, places, events, and people	A schema might suggest that all grandmothers are elderly, have gray hair, and bake a lot of cookies.
Scripts	Schemas about familiar activities and situations that guide behavior in those situations	You pay before eating in fast-food restaurants and after eating in fancier restaurants.
Mental models	Representations of how concepts relate to each other in the real world; can be correct or incorrect	Mistakenly assuming that airflow around an open car will send thrown objects upward, a driver tosses a lighted cigarette butt overhead, causing it to land in the back seat.
Images	Mental representations of visual information	Hearing a description of your blind date creates a mental picture of him or her.
Cognitive maps	Mental representations of familiar parts of the world	You can get to class by an alternate route even if your usual route is blocked by construction.

In Review Questions

1. Thinking is the manipulation of __________.

2. Arguments over what is "fair" occur because "fairness" is a __________ concept.

3. Your __________ of "hotel room" would lead you to expect yours to include a bathroom.

images Mental representations of visual information.

cognitive map A mental model that represents familiar parts of the environment.

THINKING STRATEGIES

Do people always think logically?

We have seen that our thinking capacity is based largely on our ability to manipulate mental representations—the ingredients of thought—much as a baker manipulates the ingredients of cookies. The baker's food-processing system combines and transforms these ingredients into a delicious treat. Our information-processing system combines, transforms, and elaborates mental representations in ways that allow us to engage in reasoning, problem solving, and decision making. Let's begin our discussion of these thinking strategies by considering **reasoning**: the process through which we generate and evaluate arguments, as well as reach conclusions about them.

Formal Reasoning

Astronomers tell us that the temperature at the core of the sun is about 27 million degrees Fahrenheit. How do they know this? They can't put a temperature probe inside the sun, so their estimate is based on *inferences* from other things that they know about the sun and about physical objects in general. For example, telescopic observations allowed astronomers to calculate the energy coming from one small part of the sun. They then used what geometry told them about the surface area of spheres to estimate the sun's total energy output. Further calculations told them how hot a body would have to be to generate that much energy.

In other words, astronomers' estimates of the sun's core temperature are based on **formal reasoning** (also called *logical reasoning*)—the process of following a set of rigorous steps intended to reach valid, or correct, conclusions. Some of these steps included applying specific mathematical formulas to existing data in order to generate new data. Such formulas are examples of **algorithms**—systematic methods that always reach a correct solution to a problem if a correct solution exists.

The astronomers also followed the rules of **logic**, a set of statements that provide a formula for drawing valid conclusions about the world. For example, each step in the astronomers' thinking took the form of if-then propositions: if we know how much energy comes from one part of the sun's surface and if we know how big the whole surface is, then we can calculate the total energy output. You use the same logical reasoning processes when you conclude, for example, that if your friend José is two years older than you are, then his twin brother, Juan, will be two years older, too. This kind of reasoning is called *deductive reasoning,* because it takes a general rule (e.g., twins are the same age) and applies it to deduce conclusions about specific cases (e.g., José and Juan).

Most of us try to use logical or deductive reasoning to reach valid conclusions and avoid invalid ones. However, even when our logic is perfect, we can make mistakes if we base our reasoning on false assumptions. Likewise, correct assumptions combined with faulty logic can lead to errors. Do you think the following example leads to a valid conclusion?

Assumption 1: *All women want to be mothers.*
Assumption 2: *Jill is a woman.*
Conclusion: *Jill wants to be a mother.*

If you said that the first assumption is not necessarily correct, you're right. Now consider this example:

Assumption 1: *All gun owners are people.*
Assumption 2: *All criminals are people.*
Conclusion: *All gun owners are criminals.*

Here, the assumptions are correct but the logic is faulty. According to the rules of logic, if "all As are B" and "all Cs are B," it does not follow that "all As are C." So it is true that all gun owners are people and that all criminals are people, but it does not follow that all gun owners are criminals.

reasoning The process by which people generate and evaluate arguments and reach conclusions about them.

formal reasoning A set of rigorous procedures for reaching valid conclusions.

algorithms Systematic procedures that cannot fail to produce a correct solution to a problem.

logic A system of formulas for drawing valid conclusions.

informal reasoning The process of evaluating a conclusion based on the evidence available to support it.

heuristics Mental shortcuts or rules of thumb.

Pitfalls in Logical Reasoning

"Elderly people cannot be Antarctic explorers; this is an elderly man; therefore, he cannot be an Antarctic explorer." The logic is correct, but because the first statement is wrong, so is the conclusion. In 1929, Norman Vaughan reached the South Pole as part of Richard Byrd's team of Antarctic explorers. Here he is in 1994, at the age of 88, after climbing Antarctica's Mount Vaughan, a mountain named for him.

Gordon Wiltsie/National Geographic Creative

So logical reasoning can fail because assumptions are wrong or because the logic applied to those assumptions is wrong. Psychologists have discovered that both kinds of pitfalls can lead people to make errors in logical reasoning. This finding is one reason that misleading advertisements or speeches can still attract sales and votes (Cialdini, 2007).

Informal Reasoning

Using the rules of formal logic to deduce answers about specific cases is an important kind of reasoning, but it is not the only kind. A second kind, **informal reasoning**, comes into play when we are trying to assess the *believability* of a conclusion based on the evidence available to support it. Informal reasoning is also known as *inductive reasoning*, because its goal is to induce a general conclusion to appear on the basis of specific facts or examples. Psychologists use informal reasoning when they design experiments and other research methods whose results will provide evidence for (or against) their hypotheses. Judges and jurors use informal reasoning when weighing evidence for the guilt or innocence of a defendant. Doctors use this type of thinking when they try to decide why a patient has a headache. And air crash investigators use it in their efforts to discover and eliminate the causes of aviation accidents.

Formal reasoning is guided by algorithms, or formulas, but there are no foolproof methods for informal reasoning. For instance, how many white swans would you have to see before concluding that all swans are white? Fifty? A hundred? A million? Formal logic would require that you observe every swan in existence. A more practical approach is to base your conclusion on the number of observations that some mental rule of thumb leads you to believe is enough. In other words, you would take a mental shortcut to reach a conclusion that is probably, but not necessarily, correct (there are, in fact, black swans). Such mental shortcuts are called **heuristics** (pronounced "hyoor-IST-ix").

Suppose that you are about to leave home but can't find your watch. Applying an algorithm would mean searching in every possible location, room by room, until you find the watch. But you can reach the same outcome more quickly by using a heuristic—that is, by searching only where your experience suggests you might have left the watch. In short, heuristics are often valuable in guiding judgments about which events are probable or which hypotheses are likely to be true. These "rules of thumb" are easy to use and frequently work well.

However, heuristics can also bias our thinking and result in errors. Suppose that your rule of thumb is to vote for all the candidates in a particular political party instead of researching the views of each candidate. You might help elect someone with whom you strongly disagree on some issues. The extent to which heuristics are responsible for important errors in judgment and decision making is a matter of continuing research and debate by cognitive psychologists (e.g., Deng & Sloutsky, 2012; Hilbert, 2012; Keysar, Hayakawa, & An, 2012; Weaver, Vandello, & Bosson, 2012), and awareness of their potentially biasing influences has caused reexamination of decision-making processes in many fields, including medicine and economics (e.g., Handgraaf & Van Raaij, 2005; Kahneman & Shane, 2005; Slovic et al., 2005).

Formal reasoning follows the rules of logic, but there are no foolproof rules for informal reasoning, as this fool demonstrates.

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Anchoring to a Price

The anchoring heuristic operates in many bargaining situations. The asking price of this house, for example, has probably anchored the sellers' perception of its value. As a result, they may be reluctant to accept a lower price, even if their sales agent suggests that they should. The buyers' judgment of the house's value will also be anchored to some extent by the seller's asking price. Even if the buyers discover that the house needs some repairs, they are more likely to offer 90 percent of the price rather than 50 percent.

Jason Homa/The Image Bank/Getty Images

Amos Tversky and Daniel Kahneman (1974; 1993) have described three potentially problematic heuristics that often affect people's judgments. These are the *anchoring heuristic* (also known as *anchoring bias*), the *representativeness heuristic,* and the *availability heuristic.*

The Anchoring Bias

People use the **anchoring bias** (or **anchoring heuristic**) when they estimate the probability of some event by adjusting their existing estimate rather than starting from scratch, on the basis of new information (Furnham & Boo, 2011; Rottenstreich & Tversky, 1997). This strategy sounds reasonable, but their existing estimate biases their final judgment. So even if new information suggests that their first estimate is way off, people may not adjust that estimate enough. It is as if they have dropped a "mental anchor" that keeps them from drifting too far from their original judgment. For example, suppose you think that the chance of being mugged in Los Angeles is 90 percent, but then you see evidence to suggest that the figure is closer to 1 percent. Since you started your estimate at 90 percent, though, you might reduce your original estimate only to, say, 80 percent, so your new estimate would still be quite inaccurate. The anchoring heuristic presents a challenge for defense attorneys in U.S. criminal courts because the prosecution presents its evidence first. Once this evidence has created the impression that a defendant is guilty, some jurors mentally anchor to that impression and may not be swayed much by defense evidence to the contrary (Greene & Loftus, 1998; Hogarth & Einhorn, 1992). In a similar way, first impressions of people are not easily shifted by later evidence (see the chapter on social psychology).

The Representativeness Heuristic

People use the **representativeness heuristic** when they conclude that something belongs in a certain class based on how similar it is to other items in that class. For example, consider this personality sketch:

> *Tom W. is of high intelligence although lacking in true creativity. He has a need for order and clarity and for neat and tidy systems in which every detail finds its appropriate place. His writing is rather dull and mechanical, occasionally enlivened by somewhat corny puns and by flashes of imagination of the sci-fi type. He has a strong drive for competence. He seems to have little feeling and little sympathy for other people and does not enjoy interacting with others. Self-centered, he nonetheless has a deep moral sense.*

Do you think Tom is majoring in computer science or psychology? Research by Kahneman and Tversky (1973; Tversky & Kahneman, 1974) showed that most people would choose *computer science.* But this answer would probably be wrong. True, the description given is more similar to the prototypical computer science major than to the prototypical psychology major. However, there are many more psychology majors than computer science majors in the world. So there are probably more psychology majors than computer science majors who match this description. In fact, almost any personality sketch is more likely to describe a psychology major than a computer science major.

The representativeness heuristic affects many real-life judgments and decisions. For example, when jurors hear an expert witness presenting technical or scientific evidence, they are supposed to consider only the validity of the evidence itself, not the characteristics of the person presenting it. However, they're more likely to be persuaded by the evidence if the witness looks and acts in ways that are representative of the "expert" category (Bornstein & Greene, 2011; McAuliff, Kovera, & Nuñez, 2008). (See the chapter on social psychology for more on the role of communicator characteristics in persuasion.)

The Availability Heuristic

People use the **availability heuristic** when they judge the likelihood of an event or the correctness of a hypothesis by how easy it is to think of that event or hypothesis (Tversky & Kahneman, 1974). In other words, they tend to choose the hypothesis or predict the event

anchoring bias (anchoring heuristic) A shortcut in the thought process that involves adding new information to existing information to reach a judgment.

representativeness heuristic A mental shortcut that involves judging whether something belongs in a given class on the basis of its similarity to other members of that class.

availability heuristic A mental shortcut through which judgments are based on information that is most easily brought to mind.

that is most mentally "available," much as they might select the box of cereal that happens to be at the front of a supermarket shelf. Although the availability heuristic tends to work well, it too can lead to biased judgments—especially when the mental availability of events doesn't match their actual frequency (Morewedge, Gilbert, & Wilson, 2005). For example, news reports about shark attacks and urban shootings lead many people to overestimate how often these memorable but relatively rare events actually occur (Courtenay, Smith, & Gladstone, 2012; Ungemach, Chater, & Stewart, 2009). As a result, people may suffer undue anxiety over swimming in the ocean or being in certain cities (Bellaby, 2003). Similarly, many students stick with their first responses to multiple-choice test questions because it is especially easy to recall those galling occasions on which they changed a right answer to a wrong one. Research shows, though, that an answer that is changed in light of further reflection is more likely to be correct than incorrect (Kruger, Wirtz, & Miller, 2005; Skinner, 2009).

The three heuristics we have presented represent only a few of the many mental shortcuts that people use more or less automatically in making judgments in daily life (Todd & Gigerenzer, 2007), and they describe only some of the biases and limitations that operate in human reasoning. Other biases and limitations are described in the following sections, as we consider two important goals of thinking: problem solving and decision making.

PROBLEM SOLVING

What's the best way to solve a problem?

Suppose that you're lost, you don't have a cell phone or a GPS, and there's nobody around to ask for directions. You have a *problem*. The circle of thought suggests that the most efficient approach to solving it would be to first diagnose the problem in the elaboration stage, then formulate a plan for solving it, then execute the plan, and finally evaluate the results to determine whether the problem remains (Bransford & Stein, 1993). But people's problem-solving efforts are not always so systematic. This is one reason why medical tests are sometimes given unnecessarily, diseases are sometimes misdiagnosed, and auto parts are sometimes replaced when there is nothing wrong with them (Mamede et al., 2010).

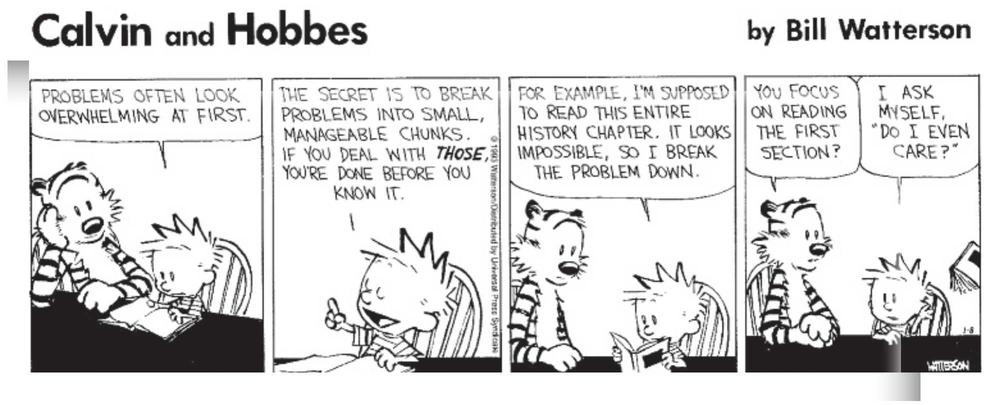
Strategies for Problem Solving

When you're trying to get from one place to another, the best path may not necessarily be a straight line. In fact, obstacles may require going in the opposite direction to get around them. So it is with problem solving. Sometimes the best strategy doesn't involve mental steps aimed straight at your goal. Psychologists have identified a variety of strategies that people use when solving a problem (Marewski & Schooler, 2011). For example, when a problem is especially difficult, it can sometimes be helpful to allow it to "incubate" by setting it aside for a while. A solution that once seemed out of reach may suddenly appear after you have been thinking about other things. The benefits of *incubation* probably arise from forgetting incorrect ideas that may have been blocking the path to a correct and possibly creative solution (Koppel & Storm, 2014). Other effective problem-solving strategies are more direct.

One of these strategies is called *means-end analysis.* It involves continuously asking where you are in relation to your final goal and then deciding on the means by which you can get one step closer to that goal (Newell & Simon, 1972). In other words, rather than trying to solve the problem all at once, you identify a subgoal that will take you toward a solution (this process is also referred to as *decomposition*). After reaching that subgoal, you identify another one that will get you even closer to the solution, and you continue this step-by-step process until the problem is solved. Some students apply this approach to the problem of writing a major term paper. The task might seem overwhelming at first, but their first subgoal is simply to write an outline of what they think the paper should cover. When the outline is complete, they decide whether a paper based on it will satisfy the assignment. If it will, the next subgoal might be to search the library and the Internet for information about each section. If they decide that this information is adequate, the next subgoal would be to write a rough draft of the introduction, and so on.

Simply knowing about problem-solving strategies, such as decomposition, is not enough. As described in the chapter on motivation and emotion, people must believe that the effort required is worth the rewards it can bring.

CALVIN AND HOBBES © Watterson Reprinted with permission of UNIVERSAL PRESS SYNDICATE. All rights reserved.



A second strategy in problem solving is to *work backward.* Many problems are like a tree. The trunk is the information you are given; the solution is a twig on one of the branches. If you work forward by taking the "givens" of the problem and trying to find the solution, it's easy to branch off in the wrong direction. Sometimes the more efficient approach is to start at the twig end and work backward (Galotti, 1999b). Consider the problem of planning a climb to the summit of Mount Everest. The best strategy is to figure out, first, what equipment and supplies are needed at the highest camp on the night before the attempt to reach the summit, then how many people are needed to stock that camp the day before, then how many people are needed to supply those who must stock the camp, and so on until a plan for the entire expedition is established. People often overlook the working-backward strategy because it runs counter to the way they have learned to think. It is hard to imagine that the first step in solving a problem could be to assume that you have already solved it. It is partly because of failure to apply this strategy that climbers sometimes die on Everest (Krakauer, 1997).

A third problem-solving strategy is trying to find *analogies,* or similarities, between today's problem and others you have encountered before. A supervisor may discover that a seemingly hopeless problem between co-workers can be resolved by the same compromise that worked during a recent family squabble. Of course, to take advantage of analogies, you must first recognize the similarities between current and previous problems. Then you will be in a position to recall the solution that worked before. Unfortunately, most people are surprisingly poor at seeing the similarities between new and old problems (Anderson, 2000). They tend to concentrate on the surface features that make problems appear different. But, research shows that if you practice focusing on the ways in which different problems may have similarities, you can get better at this skill over time, leading to better problem-solving success in new situations (Nokes-Malach et al., 2013).

Working Backward to Forge Ahead

Whether you are organizing a family vacation or preparing to sail alone around the world, as sixteen-year-old Laura Dekker did, working backward from the final goal through all the steps necessary to reach that goal is a helpful approach to solving complex problems.

Jerry Lampen/epa/Corbis

FOCUS ON RESEARCH METHODS

PROBLEM-SOLVING STRATEGIES IN THE REAL WORLD

How do people use the problem-solving strategies we have described to solve real-world problems? To explore this question, researchers have reconstructed problem-solving strategies associated with major inventions and scientific discoveries (Klahr & Simon, 1999; Weber, 1992).

What was the researcher's question?

On December 17, 1903, Wilbur and Orville Wright successfully flew the first heavier-than-air flying machine. Gary Bradshaw (1993a, 1993b) was interested in identifying the problem-solving strategies that led to this momentous event. He found that 49 individuals or teams

(*continued*)

had worked on the problem of heavier-than-air flight, but only the Wright brothers were successful. In fact, it took them only four years to develop the airplane, whereas others worked for decades without success. Bradshaw asked himself how the Wright brothers solved the problem of creating a heavier-than-air flying machine when so many others had failed?

How did the researcher answer the question?

Bradshaw compared the written records left by all the individuals and teams who had worked on an airplane design. Using this *comparative case study* method, he was able to see patterns in the ways they approached the flying machine problem.

What did the researcher find?

Bradshaw found several factors that might have contributed to the Wright brothers' success. First, as bachelors, they had a lot of spare time to work on their designs. Second, they owned a bicycle shop, so they were familiar with lightweight but sturdy structures. Third, they were brothers who had a good working relationship. And finally, as mechanics, they were good with their hands. Were any of these features directly responsible for their successful invention of the airplane?

Perhaps, but Bradshaw's use of the comparative case study method revealed that everyone else working on the problem of flight shared at least one of these features with the Wright brothers. For instance, an engineer named Octave Chanute was good with his hands and familiar with lightweight, sturdy structures. And two other pairs of brothers had worked together to try to invent a flying machine.

However, Bradshaw found one feature that was unique to the Wright brothers' approach. Of all the inventors working on the problem, only the Wrights spent considerable time and energy testing aircraft components before field-testing complete machines. This feature was important because even the best designs of the day flew for only a few seconds—far too briefly to reveal what was working and what was not. As a result, inventors had to guess about what to fix and often ended up with an "improved" model that was worse than the previous one.

What do the results mean?

Bradshaw's comparative case study method suggested that the problem-solving strategy of decomposition was the basis for the Wright brothers' success. By testing components, they were able to collect the information they needed to develop an efficient propeller, improve the shape of the wings for maximum lift, and refine other vital components of their aircraft.

What do we still need to know?

Decomposition is a strategy often seen in the laboratory, and as demonstrated by the case of the Wright brothers, it is a potentially important aspect of major inventions and discoveries beyond the laboratory. But is decomposition, or means-end analysis, used in other real-world settings as well? To find out, researchers will need to conduct additional studies of the mental strategies people use as they attempt to solve problems ranging from how to install a new computer to how to efficiently search the Internet.

Obstacles to Problem Solving

The failure of the Wright brothers' competitors to use decomposition is just one example of the obstacles that problem solvers encounter every day. Difficulties frequently occur at the start, during the diagnosis stage, when a person forms and then tests hypotheses about a problem.

As a case in point, consider this true story: John Gatiss was in the kitchen of his rented house in Cheltenham, England, when he heard a faint "meowing" sound. Worried that a kitten had become trapped somewhere, he called for the fire brigade to rescue the animal. The sound seemed to be coming from the electric stove, so the rescuers dismantled it, disconnecting the power cord in the process. The sound stopped, but everyone assumed that wherever the kitten was, it was now too frightened to meow. The search was reluctantly abandoned and the stove was reconnected. Four days later, however, the meowing began anew. This time, Gatiss and his landlord called the Royal Society for the Prevention of Cruelty to Animals (RSPCA), whose inspectors heard the kitten in distress and asked the fire brigade to come back. They spent the next three days searching for the cat. First, they dismantled parts of the kitchen walls and ripped up the floorboards. Next, they called in plumbing and drainage specialists, who used cables tipped with fiber-optic cameras to search remote cavities where a kitten might hide. Rescuers then brought in a disaster search team, which tried to find the kitten with acoustic and ultrasonic equipment normally used to locate victims trapped under earthquake debris. Not a sound was heard. Increasingly concerned about how much longer the kitten could survive, the fire brigade tried to coax it from hiding with the finest-quality fish, but to no avail. Suddenly, there was a burst of "purring" that, to everyone's surprise (and the landlord's dismay), was traced by the ultrasonic equipment to the clock in the electric stove! Later, the landlord commented that everyone assumed Gatiss's original hypothesis was correct—that the "meowing" came from a cat trapped in the kitchen. "I just let them carry on. If there is an animal in there, you have to do what it takes. The funniest thing was that it seemed to reply when we called out to it" (*London Daily Telegraph,* 1998).

How could fifteen fire-rescue workers, three RSPCA inspectors, four drainage workers, and two acoustics experts waste eight days and cause thousands of dollars in damage to a house in pursuit of a nonexistent kitten? The answer lies in the fact that they, like the rest of us, were prone to the four main obstacles to efficient problem solving described in the following sections.

Quantity	Jar A	Jar B	Jar C
1. 21 quarts	8	35	3
2. 10 quarts	6	18	1
3. 19 quarts	5	32	4
4. 21 quarts	20	57	8
5. 18 quarts	8	40	7
6. 6 quarts	7	17	2
7. 15 quarts	12	33	3

FIGURE 7.8
The Jar Problem

TRY THIS The task here is to come up with the number of quarts of water shown in the first column by using jars with the capacities shown in the next three columns. Each line represents a different problem and you have an unlimited supply of water for each one. Try to solve all seven problems without looking at the answers in the text.

Melvyn Longhurst/Alamy

Multiple Hypotheses

Often we begin to solve a problem with only a hazy notion of which hypotheses to test. Suppose you heard a strange sound in your kitchen. It could be caused by several different things, but which hypotheses should you test, and in what order?

People have a difficult time working with more than two or three hypotheses at a time (Mehle, 1982). The limited capacity of short-term memory may be part of the reason (Halford et al., 2005). As discussed in the memory chapter, a person can hold only about seven chunks of information in short-term memory. Because a single hypothesis, let alone two or three, might include more than seven chunks, it may be difficult or impossible to keep them all in mind at once. Further, the availability and representativeness heuristics may lead people to choose the hypothesis that comes most easily to mind and seems most likely to fit the circumstances (Tversky & Kahneman, 1974). That hypothesis may be wrong, though, meaning that the correct hypothesis is never considered (Bilalić, McLeod, & Gobet, 2010). Mr. Gatiss diagnosed what he heard as distressed meowing because it sounded more like a kitten than a clock and because it was easier to imagine an animal trapped behind the stove than a suddenly faulty clock inside it.

Mental Sets

Sometimes people are so blinded by one hypothesis or strategy that they stick with it even when better alternatives should be obvious. This is a clear case of the anchoring heuristic at work. Once Gatiss reported hearing a "trapped kitten," his description created an assumption that everyone else accepted and no one challenged. Figure 7.8 shows a problem-solving situation in which such errors often appear. The first problem in the figure is to come up with 21 quarts of liquid by using 3 jars that have capacities of 8, 35, and 3 quarts, respectively. Before you read any further, try to solve this problem and all the others listed in Figure 7.8.

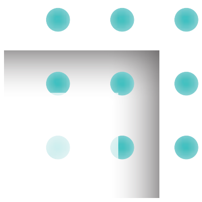


FIGURE 7.9
The Nine-Dot Problem

TRY THIS Draw four straight lines that run through all nine dots on the page without lifting your pen or pencil from the paper. Figure 7.11 shows how to go beyond mental sets to solve this problem.

How did you do? You probably figured out that the solution to the first problem is to fill Jar B to its capacity of 35 quarts, and then use its contents to fill Jar A to its capacity of 8 quarts, leaving 27 quarts in Jar B. Finally, you pour from Jar B to fill Jar C twice, leaving 21 quarts in Jar B [$27 - (2 \times 3) = 21$]. You probably found that a similar solution worked for each problem. In fact, by the time you reached Problem 7, you might have developed a **mental set**, a tendency for old patterns of problem solving to persist (Luchins, 1942; Sweller & Gee, 1978). If so, your mental set probably caused you to use the same old formula ($B - A - 2C$) even though a simpler one ($A + C$) would have worked just as well. Figures 7.9 and 7.11 show another way in which mental sets can restrict our perception of the possible solutions to a problem.

Another restriction on problem solving may come from experience with objects. Once people become familiar with using an object for one purpose, they may be blinded to other ways of using it. Long experience may produce **functional fixedness**, a tendency to use familiar objects in familiar rather than creative ways (German & Barrett, 2005). Figure 7.10 provides an example. An incubation strategy often helps to break mental sets.

FIGURE 7.10
An Example of Functional Fixedness

TRY THIS Before reading further, look at this image and ask yourself how you would fasten together two strings that are hanging from the ceiling but are too far apart for you to grasp at the same time. Several tools are available, yet most people don't think of attaching, say, a hammer to one string and swinging it like a pendulum until it can be reached while holding the other string. This solution is not obvious because we tend to fixate on the hammer's function as a tool rather than as a weight. People are more likely to solve this problem if the tools are scattered around the room. If the hammer is in a toolbox, its function as a tool is emphasized, and functional fixedness becomes nearly impossible to break.

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Ignoring Negative Evidence

On September 26, 1983, Lt. Col. Stanislav Petrov was in command of a secret facility that analyzed information from Russian early-warning satellites. Suddenly alarms went off as computers found evidence that five U.S. missiles were being launched toward Russia. Tension between the two countries was high at the time, so based on the availability heuristic, Petrov hypothesized that a nuclear attack was under way. He was about to alert his superiors to launch a counterattack on the United States when it occurred to him that if this were a real nuclear attack, it would involve many more than five missiles. Fortunately for everyone, he realized that the "attack" was a false alarm (Hoffman, 1999). As this near-disaster shows, the *absence* of symptoms or events can sometimes provide important evidence for or against a hypothesis. Compared with evidence that is present, however, symptoms or events that do not occur are less likely to be noticed (Hunt & Rouse, 1981). People have a difficult time using the absence of evidence to help eliminate hypotheses from consideration (Hyman, 2002). In the "trapped kitten" case, when the "meowing" stopped for several days after the stove was unplugged and reconnected, rescuers assumed that the animal was frightened into silence. They ignored the possibility that their hypothesis was incorrect in the first place.

mental set The tendency for old patterns of problem solving to persist.

functional fixedness The tendency to think about familiar objects in familiar ways.

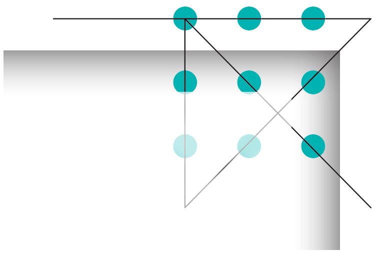


FIGURE 7.11
A Creative Solution to the Nine-Dot Problem

TRY THIS Many people find problems like this difficult because mental sets create artificial limits on the range of solutions. In this case, the mental set involves the tendency to draw within the frame of the dots. As shown here, however, there are other possibilities.

Confirmation Bias

Anyone who has had a series of medical tests knows that diagnosis is not a one-shot affair. Instead, physicians choose their first hypothesis on the basis of observed symptoms—perhaps the most dramatic or obvious ones—and then order tests or evaluate additional symptoms to support or eliminate that hypothesis (Kwan et al., 2012; Trillin, 2001). This process can be distorted by a **confirmation bias**: Humans have a strong bias to confirm rather than reject a hypothesis they have chosen, even in the face of strong evidence against the hypothesis (Aronson, Wilson, & Akert, 2005; Groopman, 2007; Mendel et al., 2011). In other words, people are quite willing to perceive and accept data that support their hypothesis, but they tend to ignore information that is inconsistent with it (Groopman, 2000). Confirmation bias may be seen as a form of the anchoring heuristic. Once you've "anchored" to your first hypothesis, you may be reluctant to abandon it. The would-be rescuers of John Gatiss's "trapped kitten" were so intent on their efforts to pinpoint its location that they never stopped to question its existence. Similarly, as described in the chapter on social psychology, we tend to look for and pay extra attention to information that is consistent with our first impressions of other people. This tendency can create positive or negative bias in, say, a teacher's views of children's cognitive abilities or an interviewer's judgments of a job candidate's skills (Jussim & Eccles, 1992; Reich, 2004).

Confirmation bias can also serve to perpetuate and intensify differences of opinion. People often get their news from media outlets that support their own political views, and they pay more attention to areas of discord than to areas of agreement when talking to individuals who hold differing views (Jern, Chang, & Kemp, 2014; Wojcieszak & Price, 2010). With this phenomenon in mind, some psychologists have developed programs designed to reduce the confirmation bias that can impair communication on "hot button" issues (Lilienfeld, Ammirati, & Landfield, 2009). Confirmation bias is also a concern in criminal cases because it can lead people to see evidence as "proving" a suspect's guilt even though that suspect might actually be innocent (Kassin, Dror, & Kukucka, 2013). The National Academy of Science's *Committee on Identifying the Needs of the Forensic Sciences Community* (2009) has pointed out that such cognitive biases have led to wrongful arrests and convictions in the United States criminal justice system, and has made recommendations for procedures aimed at avoiding such outcomes.

Building Problem-Solving Skills

How do experts in any field avoid some of the obstacles that normally limit problem solving? What do they bring to a situation that a beginner does not? Knowledge based on experience is particularly important (Mayer, 1992). One way that they develop this knowledge is through deliberate practice, solving progressively more difficult problems and forming ever more accurate mental models over a long period of time (Campitelli & Gobet, 2008, 2011; Plant & Stanton, 2012). Using that knowledge, experts frequently proceed by looking for similarities or analogies between current and past problems. Their experience makes experts better than beginners at identifying the common principles that underlie seemingly different problems. Experts' superior ability to link information about a new problem to what they already know (Anderson, 1995) also allows them to organize information about a problem into manageable and memorable *chunks,* a process described in the chapter on memory (Jaušovec & Jaušovec, 2012). By chunking many elements of a problem into a smaller number of units, experts are better than beginners at visualizing problems clearly and efficiently (Reingold et al., 2001). Their experience also helps experts to stay calm while working on a problem, thus reducing the emotion-related disruptions in cognitive skills often seen in nonexperts under stress (Decety, Yang, & Cheng, 2010; Worthy et al., 2011).

It is no wonder, then, that experts are often better problem solvers than beginners, but their expertise also carries a danger: Extensive experience may create mental sets. Top-down, knowledge-driven processes can bias experts toward seeing what they expect or want to see and prevent them from seeing a problem in new ways (Dror, 2011). As in the

confirmation bias The tendency to pay more attention to evidence in support of one's hypothesis about a problem than to evidence that refutes that hypothesis.

case of the "trapped kitten," confirmation bias sometimes prevents experts from appreciating that a proposed solution is incorrect. Several studies have shown that although experts may be more confident in their solutions (Payne, Bettman, & Johnson, 1992), they are not always more accurate than others in such areas as medical diagnosis, accounting, pilot judgment, and predicting political events (Sibbald, Panisko, & Cavalcanti, 2011; Stiegler et al., 2012; Tetlock, 2006). In other words, there is a fine line between using past experience and being trapped by it. Experience alone does not ensure excellence at problem solving, and practice may not make perfect. (For a summary of problem solving and its pitfalls, see "In Review: Solving Problems.")

IN REVIEW

SOLVING PROBLEMS

Steps	Pitfalls	Remedies
Define the problem.	Inexperience: the tendency to see each problem as unique.	Gain experience and practice in seeing the similarity between present problems and previous problems.
Form hypotheses about solutions.	Availability heuristic: the tendency to recall the hypothesis or solution that is most available to memory.	Force yourself to write down and carefully consider many different hypotheses.
	Anchoring bias, or mental set: the tendency to anchor on the first solution or hypothesis and not adjust your beliefs in light of new evidence or failures of the current approach.	Break the mental set, stop, and try a fresh approach.
Test hypotheses.	The tendency to ignore negative evidence.	In evaluating a hypothesis, consider the things you should see (but don't) if the hypothesis is true.
	Confirmation bias: the tendency to seek only evidence that confirms your hypothesis.	Look for disconfirming evidence that, if found, would show your hypothesis to be false.

In Review Questions

1. People stranded without water could use their shoes to collect rain, but they may not do so because of an obstacle to problem solving called __________.
2. Because of the __________ heuristic, once sellers set a value on their house, they may refuse to take much less for it.
3. If you tackle a massive problem one small step at a time, you are using an approach called __________.

Problem Solving by Computer

artificial intelligence (AI) The field that studies how to program computers to imitate the products of human perception, understanding, and thought.

Researchers have created artificial limbs, retinas, cochleas, and even hearts to help people with disabilities move, see, hear, and live more normally. They are also developing artificial brains in the form of computer systems that not only see, hear, and manipulate objects but also reason and solve problems. These systems are the product of research in **artificial intelligence (AI)**, a field that seeks to develop computers that imitate the processes of human perception and thought.

Symbolic Reasoning and Computer Logic

Chess-playing artificial intelligence systems have won games against the world's best chess masters. This result is not surprising, because chess is a clearly defined, logical game at which computers can perform effectively. However, it is precisely their reliance on logic and formulas that accounts for the shortcomings of all the artificial intelligence systems developed so far (Dowe & Hernández-Orallo, 2012). For example, these systems are successful only in narrowly defined fields, not in general problem solving. This limitation stems from the fact that AI systems are based on logical symbolic manipulations that depend on if-then rules. Unfortunately, it is difficult to tell a computer how to recognize the "if" condition in the real world (Dreyfus & Dreyfus, 1988). Consider this simple if-then rule: "If it is a clock, then set it." Humans recognize all kinds of clocks because we are good at using the natural concept of "clock," but computers are still not very good at forming natural concepts. Doing so requires putting into the same category many examples that have very different physical features, from your bedside digital alarm clock to London's Big Ben. The fact that computers cannot yet do this allows online businesses to protect themselves from potentially dangerous computer programs that pose as human customers. So when ordering something online, you may be shown a set of distorted, odd-looking letters and numbers and then be asked to type them. By doing so, you are proving that you are a human being, not a computer.

Neural Network Models

Recognizing the problems posed by the need to teach computers to form natural concepts, many researchers in AI have moved toward a connectionist, or neural network, approach. This approach uses computers to simulate the information processing taking place at many different but interconnected locations in the brain. Neural network models have helped researchers develop computers that are able to recognize voices, understand speech, read print, guide missiles, and perform many other complex tasks (Ashcraft, 2006). Some of the newest of these computer systems are even capable of recognizing and expressing certain basic emotions (e.g., D'Mello & Graesser, 2010; Velik, 2010; Yang & Wang, 2011).

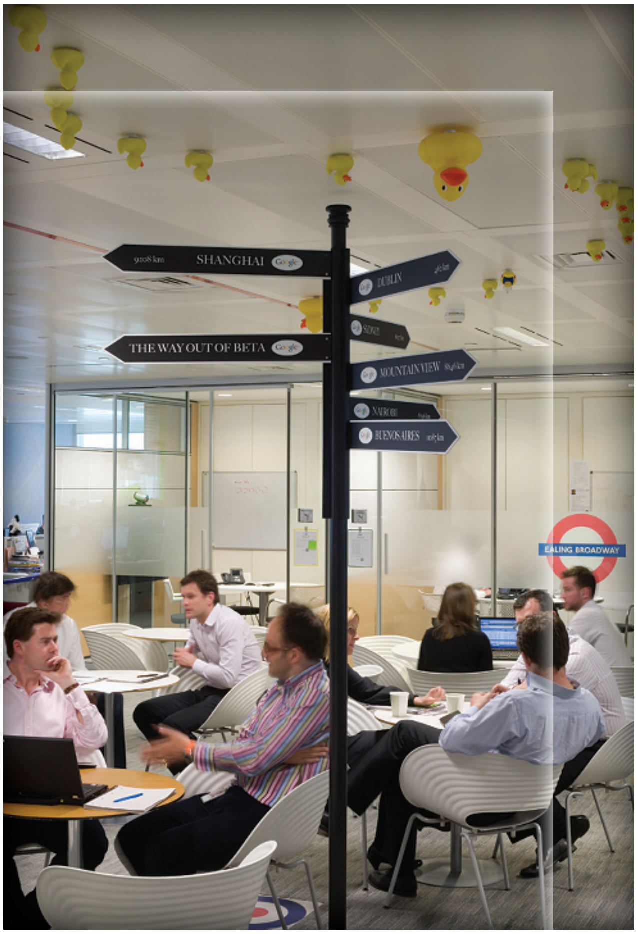
Artificial Intelligence

Artificial intelligence systems such as IBM's Deep Blue have been able to win chess games against the world's best competitors, and AI researchers hope to have the same success someday against champion players of the ancient Chinese board game called Go (Harré et al., 2011). Still, even the most sophisticated computers cannot perceive and think about the world in general anywhere near as well as humans can. Some observers believe that this situation will eventually change as progress in computer technology—and a deepening understanding of human cognitive processes—leads to dramatic breakthroughs in artificial intelligence.

STR New/Reuters

Applications of connectionist research in AI are all around us. It is being used to improve the speech recognition software that allows us to interact with our smartphones and GPS navigation systems through voice commands (Nasoz, Lisetti, & Vasilakos, 2010). Apple has even attempted to create a sense of humor for Siri, the assistance service in its iPhone (Fowler, Sherr, & Troianovski, 2011). Other AI systems help people with disabilities and medical conditions to remain more independent (e.g., Boger & Mihailidis, 2011; Chittaro et al., 2011). Still others have been used to improve on human decision making; AI systems have been found superior to humans in making decisions in areas ranging from judging meat quality and running credit checks to detecting credit card fraud, and diagnosing and prescribing treatment for various medical conditions (e.g., Başçiftçi & Hatay, 2011; Chen et al., 2012; Faisal, Taib, & Ibrahim, 2012; Keleş, Keleş, & Yavuz, 2011; Wong et al., 2012).

"Intelligent" Internet search engines such as Google are also based on neural network models, as are the systems that guide you to the news items, films, books, and other material that your previous online activity suggests will be of greatest interest to you. Artificial intelligence systems are also at the heart of interactive learning programs that not only present course material but adjust the content and pace of instruction to match each student's abilities and understanding (e.g., Bakardjieva & Gercheva, 2011; Corbett et al., 2010; Gaudioso, Montero, & Hernandez-del-Olmo, 2012; Hsu, & Ho, 2012). Some researchers are even hoping to develop computers that can grade papers and evaluate other complex student work (Nehm Ha, & Mayfield, 2012; Nehm & Haertig, 2012).



Thinking Outside the Box

Psychological scientists are finding that people tend to think less creatively while in confined spaces or when their movements are restricted (Ambrosini, Sinigaglia, & Costantini, 2012; Goldin-Meadow & Beilock, 2010; Leung et al., 2012). Perhaps the boundaries that limit physical movement create psychological boundaries that—like the mental sets and functional fixedness discussed earlier—limit the options we consider when solving problems and developing new ideas. With this possibility in mind, many businesses today work with environmental psychologists to design workplaces that avoid the physical confinements of traditional office cubicles.

James Brittain/Corbis

Unfortunately, however, most computer models of neural networks still fall well short of the capacities of the human perceptual system. For example, computers are slow to learn how to classify visual patterns, which has led to disappointment in efforts to develop computerized face recognition systems capable of identifying terrorists and other criminals in public places (Feder, 2004; Fleuret et al., 2011). But even though neural networks are far from perfect "thinking machines," they are sure to play an important role in psychologists' efforts to build ever more intelligent systems and to better understand the principles of human problem solving (Gamez, 2008; Schapiro & McClelland, 2009).

One approach to overcoming the limitations of both computers and humans is to have them work together in ways that create a better outcome than either could achieve alone. In medical diagnosis, for example, the human's role is to establish the presence and nature of a patient's symptoms. The computer then combines this information in a completely unbiased way to identify the most likely diagnosis (Roy et al., 2009; Swets, Dawes, & Monahan, 2000). This kind of human-machine teamwork can also help in the assessment of psychological problems (Kramer, Bernstein, & Phares, 2014).

Creative Thinking

One of the greatest challenges in the development of artificial intelligence will be to program devices that can think and solve problems as creatively as humans. Consider the case that opened this chapter. It was Dr. Wallace's knowledge of the chemicals in paint—which has no obvious connection to human body chemistry—that led her to figure out what was causing Laura McBride's illness. Computers are still not nearly as good as humans are at recognizing that information from one area can be used to solve a problem in a seemingly unrelated area. The ability to blend knowledge from many different domains is only one aspect of the creative thinking that humans display every day. People demonstrate **creativity** by producing original but useful solutions to all sorts of challenges (Simonton, 1999, 2004, 2012; Sternberg & Grigorenko, 2004a).

How do we know when people are thinking creatively? Psychologists have defined *creativity* as mental activity that can be inferred from performance on certain tests, as well as from the writings, computer programs, artwork, and other products resulting from the creative process (Sternberg & Dess, 2001). To measure creativity, some psychologists have generated tests of **divergent thinking**—the ability to think along many paths to generate multiple solutions to a problem (Diakidoy & Spanoudis, 2002). The Consequences Test is an example. It contains items such as "Imagine all of the things that might possibly happen if all national and local laws were suddenly abolished" (Guilford, 1959). Divergent-thinking tests are scored by counting the number of sensible responses that a person can give to each item and how many of these responses differ from those given by most people.

Only sensible responses to creativity tests are counted, because creativity involves divergent thinking that is appropriate for a given problem or situation. To be productive rather than just weird, a creative person must be firmly anchored in reality, understand society's needs, and learn from the experience and knowledge of others (Sternberg & Lubart, 1992). Theresa Amabile has identified three kinds of cognitive and personality characteristics necessary for creativity (Amabile, 1996; Amabile, Hennessey, & Grossman, 1986):

1. *Expertise* in the field of endeavor, which is directly tied to what a person has learned. For example, a painter or composer must know the paints, techniques, or instruments available.

creativity The capacity to produce original solutions or novel compositions.

divergent thinking The ability to generate many different solutions to a problem.

2. A set of *creative skills,* including persistence at problem solving, capacity for divergent thinking, ability to break out of old problem-solving habits (mental sets), and willingness to take risks. Amabile believes that training can influence many of these skills, some of which are closely linked to the strategies for problem solving discussed earlier.
3. The *motivation* to pursue creative work for internal reasons, such as satisfaction, rather than for external reasons, such as prize money. In fact, Amabile and her colleagues found that external rewards can deter creativity. They asked groups of children and adults to produce creative projects such as paintings or stories. Some were simply asked to work on these projects. Others were told that the projects would be judged for creativity and excellence and that rewards would be given or winners announced. Experts, who had no idea which products were created by which group, judged those from the "reward" group to be significantly less creative. Similar effects have been found in other studies (Byron & Khazanchi, 2012; Deci, Koestner, & Ryan, 2001; Murayama et al., 2010), though under some circumstances, rewarding people's creativity can strengthen it—in much the same way that positive reinforcement strengthens any other behavior (Eisenberger & Rhoades, 2001; Eisenberger & Shanock, 2003).

Is creativity inherited? To some extent, perhaps it is (Kéri, 2009; Lykken, 1998a), but evidence suggests that the social, economic, and political environment in which a person grows and lives also influences creative behavior (Amabile, 2001; Nakamura & Csikszentmihalyi, 2001). Do you have to be smart to be creative? Creativity does appear to require a certain degree of intelligence (Sternberg, 2001). For example, longitudinal studies have shown that individuals identified as particularly smart in adolescence were up to eight times more likely than other people to show creativity as adults by patenting inventions or producing scientific publications (Park, Lubinski, & Benbow, 2008; Wai, Lubinski, & Benbow, 2005). But you don't have to be a genius to be creative (Simonton, 1984, 2002; Sternberg, 2001). In fact, although correlations between scores on creativity tests and intelligence tests are almost always positive, they are relatively modest (Kim, 2008; Simonton, 1999). This finding is not surprising, because creativity involves divergent thinking about many solutions to a problem. As described later, high scores on most intelligence tests require **convergent thinking**, which uses logic and knowledge to narrow down the number of possible solutions to a problem. One result of research on this topic has been to see intelligence and creativity in the same person as contributing to the broader trait of *wisdom* (Baltes & Smith, 2008; Callahan, 2011; Sternberg, 2010).

The biological aspects of creativity are being investigated through the use of fMRI technology, which can identify the amount and location of brain activity that accompanies creative thinking (Chermahini & Hommel, 2010; Dietrich & Kanso, 2010). Other researchers are exploring the possibility of teaching creativity (e.g., Gupta et al., 2012; Jarosz, Colflesh, & Wiley, 2012). If it is successful, their work may someday enable all of us to think more creatively about life's problems, and perhaps about life in general (Glăveanu, 2012).

DECISION MAKING

How can I become a better decision maker?

Paper or plastic? Do I watch TV or study for the test? Should I get out of this relationship? Is it time to start thinking about a nursing home for Mom? Life is full of decisions. Some are quick and easy to make; others are painfully difficult and require considerable time, planning, and mental effort. Even carefully considered decisions can lead to undesirable outcomes, though, because the world is an uncertain place. Decisions made when the outcome is uncertain are called *risky decisions* or *decisions under uncertainty.* Chance aside, psychologists have discovered reasons why human decisions sometimes lead to unsatisfactory outcomes (Chandler & Pronin, 2012; Gifford, 2011). Let's consider some of these reasons.

convergent thinking The ability to apply the rules of logic and what one knows about the world to narrow down the possible solutions to a problem.

Analyzing your choices and the possible outcomes of each takes some time and effort, but the results are usually worth it. Like Dilbert's boss, many people prefer to make decisions more impulsively, and although their decisions sometimes turn out well, they often don't (Gladwell, 2005; Myers, 2004; Rubenwolf & Spörrle, 2011).

DILBERT: © Scott Adams/Dist. by United Feature Syndicate, Inc.

Evaluating Options

Suppose that you have to decide whether to pursue an academic major you love but that is less likely to lead to steady employment, or to choose a less interesting major that almost guarantees a high-paying job. The fact that each option has positive and negative features certainly complicates the decision making, doesn't it? Deciding which car to buy, which college to attend, or even how to spend the evening are all examples of choices that require you to weigh several options. Such choices are often based on the positive or negative value, or **utility**, that you place on each feature of each option. Listing the pros and cons of each option is a good way to keep them all in mind as you think about your decisions. You also have to estimate the probabilities and risks associated with the possible outcomes of each choice. For example, you must consider how likely it is that job opportunities in your chosen major will have faded by the time you graduate. In studying risky decision making, psychologists begin with the assumption that the best decision maximizes *expected value.* The **expected value** of a decision is the average benefit you could expect to receive if the decision were repeated on several occasions.

Biases and Flaws in Decision Making

Most people think of themselves as logical and rational, but in making decisions about everything from giving up smoking to investing in the stock market, they don't always act in ways that maximize expected value (Farmer, Patelli, & Zovko, 2005; Shiller, 2001; Tessari et al., 2011). Why not?

Gains, Losses, and Probabilities

For one thing, our pain over losing a certain amount is usually greater than the pleasure we feel after gaining the same amount (Kermer et al., 2006). This phenomenon is called *loss aversion* (Dawes, 1998; McGraw et al., 2010; Tversky & Kahneman, 1991). Because of loss aversion, you might go to more trouble to collect a \$100 debt than to win a \$100 prize. In addition, the value of a gain may not depend on the amount of the gain but on what you start with. Suppose you could have a \$10 gift certificate from a restaurant but you would have to drive 10 miles to pick it up. This gain has the same monetary value as having an extra \$10 added to your paycheck. However, most people tend to behave as if the difference between \$0 and \$10 is greater than the difference between, say, \$300 and \$310. So a person who won't drive across town after work to earn a \$10 bonus on next week's paycheck might gladly make the same trip to pick up a \$10 gift certificate. Understanding these biases and how they affect people's purchasing patterns and other economic decisions has proven so important that Daniel Kahneman received the 2002 Nobel Prize in economics for his research in this area.

People are also biased in how they think about probability. For example, we tend to overestimate the probability of rare events and to underestimate the probability of frequent ones (Kahneman & Tversky, 1984). This bias tends to be especially strong in relation to risky decisions (Glaser et al., 2012; Huber, 2012) and helps explain why people gamble in casinos and enter lotteries. The odds are against them and the decision to gamble has

utility In decision making, any subjective measure of value.

expected value The total benefit to be expected of a decision if it were repeated on several occasions.

a negative expected value, but because people overestimate the probability of winning, they associate a positive expected value with gambling. In one study, not even a course that highlighted gambling's mathematical disadvantages could change university students' gambling behavior (Williams & Connolly, 2006). The tendency to overestimate rare events is amplified by the availability heuristic: vivid memories of rare gambling successes and the publicity given to lottery winners encourage people to recall gains rather than losses.

Sometimes a bias in estimating probability costs more than money. For example, many people underestimate the risk of HIV and other sexually transmitted diseases and thus continue to engage in unprotected sex (Specter, 2005). And after the September 11, 2001, terrorist attacks on the United States, the risks of flying seemed so high that many more people than usual chose to travel by car instead. Yet driving is more dangerous overall than flying, so the decision to drive may actually have increased the risk of death, especially if stress associated with the attacks made drivers less careful (Su et al., 2008). With more cars on the road, there were 353 more traffic fatalities in the last three months of 2001 than there were during the same period in previous years (Gigerenzer, 2004). Similar bias in risk perception leads many people to buy a big, heavy sport utility vehicle that makes them feel safe, even though the chances of serious injury in an SUV are actually greater than in a minivan or family sedan (Gladwell, 2004). Their heightened sense of safety may even lead some SUV drivers to drive less carefully, which further increases the risk of injury (Bener et al., 2008; Thomas & Walton, 2007).

Another bias in estimating probability is called the *gambler's fallacy:* People believe that the probability of future events in a random process will change depending on past events. This belief is false. For example, if you flip a coin and it comes up heads ten times in a row, what is the likelihood of tails on the next flip? Although some people think otherwise, the chance that it will come up tails on the eleventh flip is still 50 percent, just as it was for the first ten flips. Yet many gamblers continue feeding a slot machine that has not paid off much for hours, because they wrongly believe it is "due."

A Highly Unlikely Outcome

Casinos and lotteries attract business by creating memorable images of big winners. They know that people's gambling and ticket buying will be influenced by the availability heuristic and the tendency to overestimate the probability of rare events. Did you ever notice that casino and lottery ads and websites never show or talk about the millions of players who lost money or whose tickets were worthless (McMullan & Miller, 2009)?

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Poor decision making can also stem from the human tendency to be unrealistically confident in the accuracy of our predictions. Baruch Fischoff and Donald MacGregor (1982) devised a clever way to study this bias. People were asked whether they believed a certain event would occur and then were asked to say how confident they were about their prediction. For example, they were asked whether a particular sports team would win an upcoming game. After the events were over, the accuracy of the people's forecasts was compared with their level of confidence. Sure enough, their confidence in their predictions was consistently greater than their accuracy. Investors, too—including professional stockbrokers—are usually confident about what to buy and sell even though many of their decisions turn out to be bad ones (Puetz & Ruenzi, 2011). Overconfidence operates even when people make predictions concerning the accuracy of their own memories (Bjork, 1999). The moral of the story is to be wary when people express confidence that a forecast or decision is correct. They will be wrong more often than they think.

How Biased Are We?

Almost everyone makes decisions that they later regret, but these outcomes may not entirely be due to biased thinking about gains, losses, and probabilities. Some decisions are not intended to maximize expected value but rather to satisfy other goals, such as minimizing expected loss, producing a quick and easy resolution, or preserving a moral principle (Arkes & Ayton, 1999; Galotti, 2007; McCaffery & Baron, 2006). Often decisions depend not just on how likely we are to gain or lose a particular amount of something but also on what that something is. A decision that could cost or save a human life may be made differently than one that could cost or gain a few dollars, even though the probabilities of each outcome are exactly the same in both cases.

The "goodness" or "badness" of decisions can be difficult to measure. Many decisions depend on personal values (utilities), which vary from person to person and across cultures (Weber & Morris, 2010; Yates, 2010). People in individualist cultures, for example,

Justice Is Served

Decision making can be affected by many factors, including motivational states such as hunger (e.g., Bos, van Baaren, & Dijksterhuis, 2011; Eskine, Kacinik, & Prinz, 2011). One study found, for example, that judges' courtroom decisions tended to be more lenient just after they had eaten, and became progressively harsher as the judges got hungrier (Danziger, Levav, & Avnaim-Pessoa, 2011).

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may tend to assign high utilities to attributes that promote personal goals, whereas people in collectivist cultures might place greater value on attributes that bring group harmony and the approval of family and friends (Markus, Kitayama, & Heiman, 1996; Varnum et al., 2010).

LINKAGES Do groups solve problems more effectively than individuals? (a link to Social Psychology)

LINKAGES

GROUP PROCESSES IN PROBLEM SOLVING AND DECISION MAKING

Problem solving and decision making often take place in groups. The factors that influence an individual's problem solving and decision making continue to operate when the individual is in a group, but group interactions also shape the outcome.

When groups are trying to make a decision, for example, they usually begin by considering the preferences or opinions stated by various members. Not all of these views have equal influence. Views that are shared by the greatest number of group members will have the greatest impact on the group's final decision (Tindale & Kameda, 2000). This means that extreme proposals or opinions will usually have less effect on group decisions than those that are more representative of the majority's views.

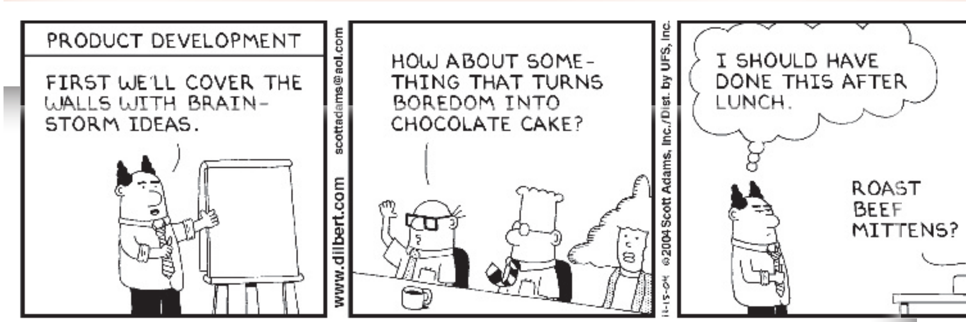
This is not always the case, though. Through a process called *group polarization*, discussions sometimes result in decisions that are more extreme than group members would make individually (Baron, Branscombe, & Byrne, 2008). Two mechanisms appear to underlie group polarization. First, most arguments presented during the discussion favor the majority view and most criticisms are directed at the minority view. In fact, confirmation bias leads group members to seek additional information that supports the majority position (Minson & Mueller, 2012; Schulz-Hardt et al., 2000). In this atmosphere, those who favor the majority view find it reasonable to adopt an even stronger version of it (Kassin, Fein, & Markus, 2010). Second, once some group members begin to agree that a particular decision is desirable, other members may try to associate themselves with it, perhaps by suggesting an even more extreme version (Kassin, Fein, & Markus, 2010).

(*continued*)

Are people better at problem solving and decision making when they work in groups or on their own? Research shows that shared decision making about health treatments can improve medical care outcomes and lower costs (Lee & Emanuel, 2013). However, two heads are not always better than one. This is one of the questions about human thinking that social psychologists study. In a typical experiment, a group of people is asked to solve a problem like the one in Figure 7.8 or to decide the guilt or innocence of the defendant in a fictional court case. Each person is asked to work alone and then to join with the others to try to agree on a decision. These studies have found that when problems have solutions that can be easily demonstrated to everyone, groups will usually outperform individuals at solving them (Laughlin, 1999). When problems have less obvious solutions, groups may be somewhat better at solving them than their average member but usually no better than their most talented member (Hackman, 1998). And because of phenomena such as *social loafing* and *groupthink* (discussed in the social psychology chapter), people working in a group are often less productive than people working alone (Cheshire & Antin, 2010; Williams & Sommer, 1997).

Other research suggests that a critical element in successful group problem solving is the sharing of individual members' unique information and expertise (e.g., Kohn, Paulus, & Choi, 2011; Puvathingal & Hantula, 2012). For example, when asked to diagnose an illness, groups of physicians were much more accurate when they pooled their knowledge (Larson et al., 1998). However, *brainstorming,* a popular strategy that supposedly encourages group members to generate new and innovative solutions to a problem, may actually produce fewer or less creative ideas than are generated by individuals working alone (Baumeister & Bushman, 2008). This result may occur because comments from other group members may interfere with some members' ability to think clearly and creatively (Nijstad, Stroebe, & Lodewijkx, 2003). Further, some participants in a brainstorming session may be reluctant to offer an idea, even a good one, for fear it will be rejected or ridiculed by the group (Mojzisch & Schulz-Hardt, 2010). To prevent these problems, some brainstorming groups are specifically instructed to come up with as many ideas as possible, without regard for quality or anything else, just to ensure that as many ideas as possible are considered (Paulus, Kohn, & Arditti, 2011). Following these procedures has been shown to elevate the level of performance by brainstorming groups significantly above what is typically found in such groups (Nemeth et al., 2004). Other researchers arrange for brainstorming groups to meet electronically using computer-based communication systems that allow group members to offer suggestions without being identified or interrupted yet still give everyone access to the ideas of all the other members. The levels of trust and the patterns of communication that develop in these groups appear comparable to those seen in face-to-face groups (Wilson, Straus, & McEvily, 2006), and because electronic brainstorming allows people to think more clearly and express themselves without fear, these groups may actually perform as well or better than those that meet in person (Englemann, Tergan, & Hesse, 2010).

As they work to solve a problem, group members experience their own thoughts as concepts, propositions, images, or other mental representations. How does each member share these private events to help the group perform its task? The answer lies in the use of language.



One disadvantage of brainstorming sessions is that running comments and bizarre ideas from some group members can interfere with the creative process in others (Nijstad, Stroebe, & Lodewijkx, 2003).

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LANGUAGE

How do babies learn to talk?

Our language abilities are usually well integrated with our memory, thinking, and other cognitive abilities (Boroditsky & Gaby, 2010). This integration allows us to use language to express everything from simple requests to abstract principles. We can speak about our thoughts and memories, think about what people tell us, and interact with each other in meaningful ways (Majid et al., 2011). We can create stories that pass on cultural information and traditions from one generation to the next. In fact, as described in the chapter on biological aspects of psychology, our brains process language so effectively that it is only when strokes or other forms of damage interfere with the brain's language areas that we are reminded that language is a very special kind of cognitive ability (Bedny et al., 2011; Kohnert, 2004; Stephens, Silbert, & Hasson, 2010).

The Elements of Language

A **language** has two basic elements: *symbols,* such as words, and *rules,* called **grammar**, for combining those symbols. With our knowledge of approximately 50,000 to 100,000 words (Miller, 1991), we humans can create and understand an infinite number of sentences. All of the sentences ever spoken are built from just a few dozen categories of sounds. The power of language comes from the way these rather unimpressive raw materials are organized according to certain rules. This organization occurs at several levels.

From Sounds to Sentences

Organization occurs first at the level of sounds. A **phoneme** is the smallest unit of sound that affects the meaning of speech. Changing a phoneme changes the meaning of a spoken word, much as changing a letter in a printed word changes its meaning. *Tea* has a meaning different from *sea,* and *sight* is different from *sigh.*

Although changing a phoneme affects the meaning of speech, phonemes themselves are not meaningful. We combine them to form a higher level of organization: morphemes. A **morpheme** is the smallest unit of language that has meaning. For example, because they have meaning, *dog* and *run* are morphemes; but so are prefixes such as *un-* and suffixes such as *-ed* because they, too, have meaning, even though they cannot stand alone.

Words are made up of one or more morphemes. Words, in turn, are combined to form phrases and sentences according to a set of grammatical rules called **syntax**. According to English syntax, a subject and a verb must be combined to form a sentence, adjectives typically appear before the nouns that they modify, and so on. Compare the following sentences:

Fatal accidents deter careful drivers.

Snows sudden floods melting cause.

The first sentence makes sense, but the second sentence violates English syntax. If the words were reordered, however, they would produce the perfectly acceptable sentence "Melting snows cause sudden floods."

Even if you use English phonemes combined in proper ways to form morphemes strung together according to the laws of English syntax, you may still not end up with an acceptable sentence. Consider the sentence "Rapid bouquets deter sudden neighbors." It somehow sounds right, but it is nonsense. Why? It has syntax, but it ignores the set of rules, called **semantics**, that govern the meaning of words and sentences. For example, because of its meaning, the noun *bouquets* cannot be modified by the word *rapid.*

Surface Structure and Deep Structure

In 1965, Noam Chomsky started a revolution in how we study language. He argued that if linguists looked only at the sentences people produce, they would never uncover all the

language Symbols (and a set of rules for combining them) that are used as a means of communicating.

grammar A set of rules for combining the symbols, such as words, used in a given language.

phoneme The smallest unit of sound that affects the meaning of speech.

morpheme The smallest unit of language that has meaning.

syntax The set of rules that govern the formation of phrases and sentences in a language.

semantics Rules governing the meaning of words and sentences.

Making sure that the surface structures we create accurately convey the deep structures we intend is one of the greatest challenges people face when communicating through language.

Danny Shanahan/The New Yorker Collection/www.cartoonbank.com

principles underlying language. Without looking deeper into language, he said, they could not explain, for example, why the sentence "This is my old friend" can have more than one meaning. Nor could they account for the similar meaning conveyed by such seemingly different sentences as "Don't give up just because things look bad" and "It ain't over till it's over."

To take these aspects of language into account, Chomsky chose a more abstract level of analysis. He suggested that behind the strings of words people produce, which he called **surface structures**, there is a **deep structure**, an abstract representation of the relationships expressed in a sentence. For example, the surface structure "The shooting of the psychologist was terrible" can represent either of two deep structures: (1) that the psychologist had terrible aim or (2) that it was terrible that someone shot the psychologist. Chomsky's analysis of deep and surface structures was important because it encouraged psychologists to analyze not just verbal behavior and grammatical rules but also mental representations.

Understanding Speech

When someone speaks to you in your own language, your sensory, perceptual, and other cognitive systems reconstruct the sounds of speech in a way that allows you to detect, recognize, and understand what the person is saying. The process may seem effortless, but it involves amazingly complex feats of information processing. Despite these challenges, humans can instantly recognize and understand the words and sentences produced by almost anyone speaking a familiar language. In contrast, even the best voice recognition software must learn to recognize words spoken by a new voice, and even then it may make many mistakes.

Scientists have yet to discover all the details about how people overcome the challenges of understanding speech, but some general answers are emerging. Just as we recognize objects by analyzing their visual features (as discussed in the chapter on sensation and perception), it appears that humans identify and recognize the specific—and changing—features of the sounds created when someone speaks. And as in visual perception, this *bottom-up processing* of stimulus features combines with *top-down processing* guided by knowledge-based factors, such as context and expectation, to aid understanding

surface structures The order in which words are arranged in sentences.

deep structure An abstract representation of the underlying meaning of a given sentence.

Understanding Spoken Language

The top-down perceptual processes described in the sensation and perception chapter help explain why people speaking an unfamiliar language seem to produce a continuous stream of abnormally rapid speech. The problem is that you don't know where each word starts and stops. Without any perceived gaps, the sounds of speech run together, creating the impression of rapid-fire "chatter." People unfamiliar with your language think you are speaking extremely fast, too!

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(Samuel, 2001). For example, knowing the general topic of conversation helps you to recognize individual words that might otherwise be hard to understand (Cole & Jakimik, 1978). People also use the visual cues provided by looking at a speaker's face, especially in noisy or distracting settings (Golumbic et al., 2013). This ability to use context is especially helpful for people with hearing impairments or when trying to understand what someone is saying at a loud party or in other noisy environments (Davis, Johnsrude, et al., 2005).

Learning to Speak: Stages of Language Development

Children the world over develop language with impressive speed; the average six-year-old already has a vocabulary of about 13,000 words (Pinker, 1994). But acquiring language involves more than just learning vocabulary. We also have to learn how words are combined and how to produce and understand sentences. Psychologists who study the development of language have found that the process begins in the earliest days of a child's life and follows some predictable steps (Parise & Csibra, 2012; Saffran, Senghas, & Trueswell, 2001).

The First Year

In their first year, infants become more and more attuned to the sounds that will be important in acquiring their native language (DePaolis, Vihman, & Nakai, 2013; Gomez et al., 2014). In fact, this early experience with language appears to be vital. Without it, language development can be impaired (Mayberry & Lock, 2003). The first year is also the time when babies begin to produce particular kinds of **infant vocalizations**, called **babblings**, patterns of meaningless sounds that first resemble speech. These alternating consonant and vowel sounds (such as "bababa," "dadada," and "mamimamima") appear at about four months of age, once the infant has developed the necessary coordination of the tongue and mouth. Though meaningless to the baby, babblings are a delight to parents. Infants everywhere begin with the same set of babbling sounds, but at about nine months of age, they begin to produce only the sounds that occur in the language they hear the most. At about the same time, their babbling becomes more complex and begins to sound like "sentences" in the babies' native language (Goldstein, King, & West, 2003). Infants who hear English, for example, begin to shorten some of their vocalizations to "da," "duh," and "ma." They use these sounds to convey joy, anger, interest, and other messages in specific contexts and with obvious purpose (Blake & de Boysson-Bardies, 1992).

By ten to twelve months of age, babies can understand several words—certainly more words than they can say (Fenson et al., 1994). Proper names and object words—such as *mama, daddy, cookie, doggy,* and *car* in English-speaking cultures—are among the earliest words they understand. These are also the first words children are likely to say when they begin to talk at around twelve months of age (some talk a little earlier and some a little later). Infants acquire nouns for simple object categories (*dog, flower*) before they acquire more general nouns (*animal, plant*) or more specific names (*collie, rose*) (Rosch et al., 1976).

Of course, these early words do not sound exactly like adult language. English-speaking babies usually reduce them to a shorter, easier form, like "duh" for *duck* or "mih" for *milk.* Children make themselves understood, however, by using gestures, voice tones, facial expressions, and endless repetitions (Özçalışkan & Dimitrova, 2013). Once they have a word for an object, they may "overextend" it to cover more ground. So they might use *doggy* to refer to cats, bears, and horses; they might use *fly* for all insects and perhaps for other small things such as raisins and M&Ms (Clark, 1983, 1993). Children make these "errors" because their vocabularies are limited, not because they fail to notice the difference between dogs and cats or because they want to eat flies (Fremgen & Fay, 1980; Rescorla, 1981). Being around people who don't understand these overextensions encourages children to learn and

infant vocalizations Early sounds, such as babblings, made by babies.

babblings Repetitions of syllables; the first sounds infants make that resemble speech.

Getting Ready to Talk

Long before they say their first words, babies are getting ready to talk. Laboratory studies show that even six-month-olds tend to look longer at faces whose lip movements match the sounds of spoken words. This tendency reflects babies' abilities to focus on, recognize, and discriminate the sounds of speech, especially in their native language. These abilities are crucial to the development of language (Lewkowicz & Hansen-Tift, 2012; Mayberry, Lock, & Kazmi, 2002).

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use more precise words (Markman, 1994). During this period, children build vocabularies one word at a time. They also use their limited vocabulary one word at a time. They cannot yet put words together into sentences. Their language skills will blossom during the years from two to four, and the richness of the vocabulary they eventually develop will be influenced by the richness of the language that they hear and the encouragement they receive for their earliest efforts to communicate using both words and gestures (Goldstein & Schwade, 2008; Özçalışkan & Dimitrova, 2013; Rowe & Goldin-Meadow, 2009).

The Second Year

The **one-word stage** of speech lasts for about six months. Then, some time around eighteen months of age, children's vocabularies expand dramatically (Gleitman & Landau, 1994). They may learn several new words each day, and by the age of two, most youngsters can use 50 to well over 100 words. They also start using two-word combinations to form efficient little sentences. These two-word sentences are called "telegraphic" because, like telegrams or text messages, they are brief and to the point, leaving out anything that is not absolutely essential. So if she wants her mother to give her a book, a twenty-month-old might first say, "Give book," then "Mommy give," and if that does not work, "Mommy book." The child also uses rising tones to indicate a question ("Go out?") and emphasizes certain words to indicate location ("Play *park*") or new information ("*Big* car").

Three-word sentences come next, and though still telegraphic, they are more nearly complete: "Mommy give book." The child's sentences begin to have the subject-verb-object form typical of adult sentences. Other words and word endings begin appearing, too. In English, these include the suffix *-ing,* the prepositions *in* and *on,* the plural *-s,* and irregular past tenses such as "It broke," and "I ate" (Brown, 1973; Dale, 1976). Children learn to use the suffix *-ed* for the past tense ("I walked"), but often overapply this rule to irregular verbs that they had previously used correctly, saying, for example, "It breaked," "It broked," or "I eated" (Marcus, 1996). Children also expand their sentences with adjectives, although at first they make some mistakes. For example, they are likely to use both *less* and *more* to mean "more" (Smith & Sera, 1992).

The Third Year and Beyond

By age three or so, children begin to use auxiliary verbs ("Adam is going") and to ask questions using what, where, who, and why. They begin to put together clauses to form complex sentences ("Here's the ball I was looking for"). By age five, children have acquired most of the grammatical rules of their native language.

How Is Language Acquired?

LINKAGES How do we learn to speak? (a link to Human Development)

Despite all that has been learned about the steps children follow in acquiring language, mystery and debate still surround the question of just how they do it. We know that children pick up the specific content of language from the speech they hear around them: English children learn English; French children learn French. But how do children come to follow the rules of grammar?

Conditioning, Imitation, and Rules

Perhaps children learn grammar because their parents reward them for using it. This idea sounds reasonable, but observational research suggests that positive reinforcement (which we describe in the learning chapter) is not the main character in the story of language acquisition. Parents are usually more concerned about what is said than about its grammatical form (Hirsch-Pasek, Treiman, & Schneiderman, 1984). So when the little boy with chocolate crumbs on his face says, "I not eat cookie," his mother is more likely to respond, "Yes, you did" than to ask the child to say, "I did not eat the cookie" and then praise him for his grammatical correctness.

one-word stage A stage of language development during which children tend to use one word at a time.

Learning through imitation appears to be more influential. Children learn grammar most rapidly when adult models demonstrate the correct form in the course of conversation (Zimmerman et al., 2009). For example:

Child: *Mommy fix.*

Mother: *Okay, Mommy will fix the truck.*

Child: *It breaked.*

Mother: *Yes, it broke.*

But if children learn grammar by imitation, why do children who at one time said "I went" later say "I goed"? Adults don't use this form of speech, so neither imitation nor reward can account for its sudden appearance. It appears more likely that children analyze for themselves the underlying patterns in the language they hear around them and then learn the rules governing those patterns (Bloom, 1995).

Biological Bases for Language Acquisition

The ease with which children the world over discover these patterns and develop language has led some to argue that language acquisition is at least partly innate, or automatic. Chomsky (1965) proposed that we are born with a built-in universal grammar, a mechanism that allows us to identify the basic dimensions of language (Baker, 2002; Chomsky, 1986; Nowak, Komarova, & Niyogi, 2001). According to this view, a child's universal grammar might tell the child that word order is important to the meaning of a sentence. In English, for example, word order tells us who is doing what to whom (the sentences "Heather teased Jason" and "Jason teased Heather" contain the same words, but they have different meanings). In Chomsky's view, then, we don't entirely learn language—we develop it as genetic predispositions interact with experience (Li & Bartlett, 2012). So a child's innate assumption that word order is important to grammar would change if the child heard language in which word order did not have much effect on the meaning of a sentence.

Those who disagree with Chomsky argue that language development comes about from the development of more general sensory, perceptual, and cognitive skills, not just unique, language-specific mechanisms (e.g., Bates, 1993; Gogate & Hollich, 2010; Goldstein et al., 2010). In other words, they say, we don't inherit a single, specific "grammar gene" (White, 2006). Still, other evidence supports the existence of biological factors in language acquisition (Peltola et al., 2012). For example, the unique properties of the human mouth and throat, the language-related brain regions described in the chapter on biological aspects of psychology, and genetic research all suggest that humans are innately "prewired," or biologically programmed, for language (Buxhoeveden et al., 2001; Dehaene-Lambertz et al., 2010; Lai et al., 2001). So even though a single gene does not fully bestow us with language capacity, certain genes do seem to affect brain development in ways that help make language possible (Sia, Clem, & Huganir, 2013). And researchers are beginning to uncover genetic mechanisms behind some speech and language disorders (e.g., Amarillo et al., 2014; Bates et al., 2011; Fisher, 2005). In addition, there appears to be a period in childhood during which we can learn language more easily than at any other time (Ridley, 2000). The existence of this *critical period* is supported by evidence from tragic cases in which children spent their early years isolated from human contact and the sound of adult language. Even after years of therapy and language training, these individuals are not able to combine ideas into sentences (Rymer, 1993). Such cases suggest that in order to acquire the complex features of language, we must be exposed to speech before a certain age.

Bilingualism

Does trying to learn two languages at once, even before the critical period for language learning is over, impair the learning of either? Research suggests just the opposite. Like some children in any situation, the early language of children from a bilingual environment may be confused or delayed, but they eventually show enhanced performance in each language (Bialystok & Craik, 2010; de Houwer, 1995; Garcia-Sierra et al., 2011). Early

Learning a Second Language

As these international students are discovering, people who learn a second language as adults do so more slowly, and with less proficiency, than younger people (Johnson & Newport, 1989; Patkowski, 1994) and virtually never learn to speak it without an accent (Lenneberg, 1967). Still, the window of opportunity for learning a second language remains open long after the end of the critical period in childhood during which first-language acquisition must occur (Hakuta, Bialystok, & Wiley, 2003).

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exposure to more than one language appears to help the brain maintain flexibility in recognizing the sounds and patterns of speech that monolingual children normally lose.

There is also some evidence that balanced bilinguals—those who have roughly equal mastery of two languages in childhood—enjoy some more general advantages in cognitive flexibility, concept formation, and creativity. Also, bilingual school-age children may be better at learning non-language topics when that learning rests heavily on the use of language (Kaushanskaya, Gross, & Buac, 2014). It is as if learning more than one language offers a person a slightly different perspective on thinking and that this dual perspective makes the brain more flexible and better able to learn new things (Bialystok & Craik, 2010; Krizman et al., 2012; Kroll, Bobb, & Hoshino, 2014; Poulin-Dubois et al., 2011). This flexibility may start very early; even six-month-old children in bilingual homes seem to have greater learning and memory capacity than is the case among infants in monolingual homes (Brito & Barr, 2013). Bilinguals also have an easier time than other people do in learning a third language later in life, even if the grammar of the new language is very different from the ones they already know (Kaushanskaya, 2009). The flexibility of thought developed by bilingual children also seems to provide a sort of *cognitive reserve* in old age, which may protect against the loss of cognitive abilities that is sometimes associated with aging, and may even delay the onset of Alzheimer's disease (Bialystok, Craik, & Luk, 2012; Craik, Bialystok, & Freedman, 2010; Luk et al., 2011).

THINKING CRITICALLY

CAN NONHUMANS USE LANGUAGE?

We have said that our ability to acquire and use language helps set humans apart from all other creatures. Yet those creatures, too, use symbols to communicate. Bees perform a dance that tells other bees where they found sources of nectar, killer whales signal one another as they hunt in groups, and the grunts and gestures of chimpanzees signify varying desires and emotions. These forms of communication do not necessarily have the grammatical characteristics of language, however. Are any nonhumans capable of learning language?

What am I being asked to believe or accept?

Over the past forty years, several researchers have claimed that nonhumans can master language. Chimpanzees and gorillas have been the most popular targets of study (e.g., Beran, Smith, & Perdue, 2013) because at maturity they are estimated to have intelligence similar to two- or three-year-old human children, who are usually well on their way to learning language. Dolphins have also been studied because they have a complex communication system and exceptionally large brains relative to their body size (Janik, 2013; Pack & Herman, 2007; Reiss & Marino, 2001). It would seem that if these animals were unable to learn language, their general intelligence could not be blamed. Instead, failure would be attributed to the absence of a genetic makeup that permits language learning.

What evidence is available to support the assertion?

Whether nonhuman mammals can learn to use language is not a simple question, for at least two reasons. First, language is not just communication, but defining just when animals are exhibiting that "something different" is a source of debate. A key factor that seems to set human language apart from the gestures, grunts, chirps, whistles, or cries of other animals is grammar—a formal set of rules for combining words, permitting the creation of an unlimited number of messages. Also, because of their anatomical structures, nonhuman mammals cannot "speak" in the same way that we humans do (Lieberman, 1991; Nishimura et al., 2003). To test these animals' ability to learn language, investigators must devise novel ways to allow them to communicate.

(continued)

David and Ann Premack taught a chimp, Sarah, to communicate by placing differently shaped chips, each symbolizing a word, on a magnetic board (Premack, 1971). Lana, a chimpanzee studied by Duane Rumbaugh (1977), learned to communicate by pressing keys on a specially designed computer. A simplified version of American Sign Language (ASL) has been used by Beatrice and Allen Gardner with the chimp Washoe, by Herbert Terrace with Nim Chimpsky (a chimp named after Noam Chomsky), and by Penny Patterson with a gorilla named Koko. Kanzi, a bonobo, or pygmy chimpanzee, studied by Sue Savage-Rumbaugh (1990; Savage-Rumbaugh et al., 1993), learned to recognize spoken words and to communicate by both gesturing and pressing word symbol keys on a computer that would "speak" them. Kanzi was a special case: He learned to communicate by listening and watching as his mother, Matata, was being taught and then used what he had learned to interact with her trainers.

Studies of these animals suggested that they could use combinations of words to refer to things that were not present. Washoe, Lana, Sarah, Nim, and Kanzi all mastered between 130 and 500 words. Their vocabulary included names for concrete objects, such as *apple* or *me*; verbs, such as *tickle* and *eat*; adjectives, such as *happy* and *big*; and adverbs, such as *again*. The animals combined the words to express wishes such as "You tickle me" or "If Sarah good, then apple." Sometimes their expressions referred to things in the past. When an investigator called attention to a wound that Kanzi had received, the animal responded with "Matata hurt," referring to a disciplinary bite his mother had recently given him (Savage-Rumbaugh, 1990). Finally, all these animals seemed to enjoy their communication tools and used them spontaneously to interact with their caretakers and with other animals.

Most of the investigators mentioned here have argued that their animals mastered a crude grammar (Premack & Premack, 1983; Savage-Rumbaugh, Shanker, & Taylor, 2001). For example, if Washoe wanted to be tickled, she would gesture, "You tickle Washoe." But if she wanted to do the tickling, she would gesture, "Washoe tickle you." The correct placement of object and subject in these sentences suggested that Washoe was following a set of rules for word combination—in other words, a grammar (Gardner & Gardner, 1978). Louis Herman and his colleagues documented similar grammatical sensitivity in dolphins, who rarely confused subject-verb order in following instructions given by human hand signals (Herman, Richards, & Wolz, 1984). Furthermore, Savage-Rumbaugh observed several hundred instances in which Kanzi understood sentences he had never heard before. Once, for example, while his back was turned to the speaker, Kanzi heard the sentence "Jeanie hid the pine needles in her shirt." He turned around, approached Jeanie, and searched her shirt to find the pine needles. His actions would seem to indicate that he understood this new sentence the first time he heard it.

Animal Language?

As demonstrated here by Nim Chimpsky, several chimpanzees and gorillas have been taught American Sign Language (ASL). Nim died in 2000 at the age of twenty-six, but Koko, the gorilla trained by Penny Patterson, is still with us. In one Internet chat session, Patterson relayed online questions to Koko in ASL, and a typist sent back Koko's signed responses. This procedure left some questioners wondering whether they were talking to Koko or to her trainer. (You can decide for yourself by reading the transcript of the session at www.koko.org/world/talk_aol.html.)

Susan Kuklin/Science Source

(*continued*)

Are there alternative ways of interpreting the evidence?

Many of the early conclusions about primate language learning were challenged by Herbert Terrace and his colleagues (1979) in their investigation of Nim and by other critics' responses to other cases. For example, Terrace noticed many characteristics of Nim's communications that seemed quite different from a child's use of language.

First, he said, Nim's sentences were always very short. For example, Nim could combine two or three gestures but never used strings that conveyed more sophisticated messages. The ape was never able to say anything equivalent to a three-year-old child's "I want to go to Wendy's for a hamburger, OK?" Others have noted that even the most intelligent of primates are unable to master the full grammatical possibilities of either ASL or specially developed artificial languages (Fitch & Hauser, 2004). Further, apes don't point at things, as humans do from a young age as they develop language and use it in joint communication (e.g., Tomasello, 2006). Second, Terrace questioned whether the animals' use of language demonstrated the spontaneity, creativity, and expanding complexity characteristic of children's language. Many of the animals' sentences were requests for food, tickling, baths, pets, and other pleasurable objects and experiences. Is such behavior really any different from the kind of behavior shown by the family dog who learns to sit up and beg for table scraps? Other researchers also pointed out that chimps are not naturally predisposed to associate seen objects with heard words, as human infants are (Savage-Rumbaugh et al., 1983). Finally, Terrace questioned whether experimenter bias influenced the reports of the chimps' communications. Consciously or not, experimenters who want to conclude that chimps learn language might tend to ignore strings of symbols that violate grammatical order or to reinterpret ambiguous strings so that they make grammatical sense. If Nim sees someone holding a banana and signs, "Nim banana," the experimenter might assume that the word order is correct and means "Nim wants the banana" rather than, for example, "That banana belongs to Nim," in which case the word order would be wrong.

Critics also point out that the results presented in support of animal language capabilities are usually only samples of an animal's behavior. They say that the unedited sequences of an animal's signing or other behavior presents a picture that is far more repetitious, chaotic, and random than one might expect on the basis of the selected samples (Aitchison, 2008).

What additional evidence would help evaluate the alternatives?

Studies of animals' ability to learn language are expensive and take many years. As a result, the amount of evidence in the area is small—just a handful of studies, each based on a few animals. Obviously, more data are needed from more studies that use a common methodology.

It is important, too, to study the extent to which limits on the length of primates' spontaneous sentences result from limits on short-term and working memory (Savage-Rumbaugh & Brakke, 1996). If memory is in fact the main limiting factor, then the failure to produce progressively longer sentences does not necessarily reflect an inability to master language.

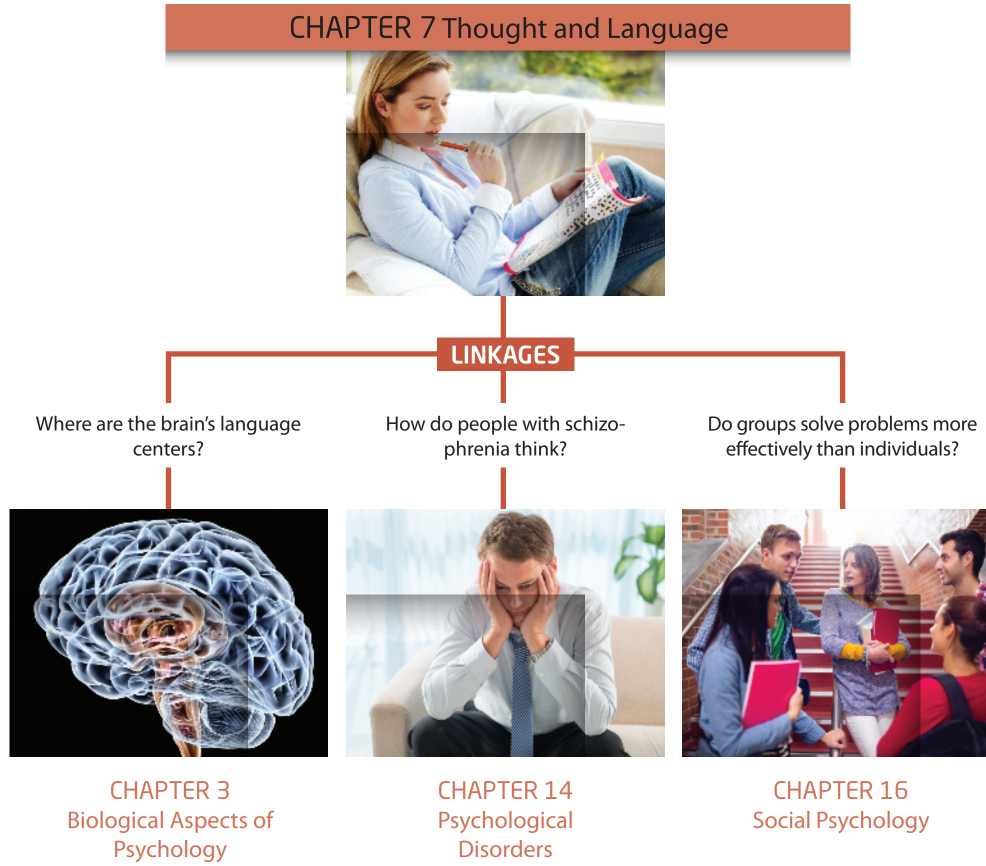
Research on how primates might spontaneously acquire language by listening and imitating, as Kanzi did, as well as naturalistic observations of communications among primates in their natural habitat, would also help scientists better understand primates' capacity to communicate (Savage-Rumbaugh, Shanker, & Taylor, 2001; Sevcik & Savage-Rumbaugh, 1994).

What conclusions are most reasonable?

There is still no full agreement about whether our sophisticated mammalian cousins can learn language. Two things are clear, however. First, whatever the chimp, gorilla, and dolphin have learned is a much more primitive and limited form of communication than that learned by children. Second, their level of communication does not do justice to their overall intelligence; these animals are smarter than their "language" production suggests. In short, the evidence to date favors the view that humans have language abilities that are unique (e.g., Povinelli & Bering, 2002; Zuberbühler, 2005), but that under the right circumstances and with the right tools, some nonhuman creatures can communicate using abstract symbols (e.g., Gillespie-Lynch et al., 2011; Lyn et al., 2011).

LINKAGES

As noted in the introductory chapter, all of psychology's subfields are related to one another. Our discussion of group problem solving illustrates just one way that the topic of this chapter—thought and language—is linked to the subfield of social psychology, which is described in the chapter by that name. The Linkages diagram shows ties to two other subfields, and there are many more ties throughout the book. Looking for linkages among subfields will help you see how they all fit together and help you better appreciate the big picture that is psychology.



SUMMARY

Basic Functions of Thought

What good is thinking, anyway?

The five core functions of thought are describing, elaborating, deciding, planning, and guiding action. Many psychologists think of the components of this circle of thought as constituting an ***information-processing system*** that receives, represents, transforms, and acts on incoming stimuli. ***Thinking***, then, is defined as the manipulation of mental representations by this system.

Mental Representations: The Ingredients of Thought

What are thoughts made of?

Mental representations take the form of concepts, propositions, schemas, scripts, mental models, images, and cognitive maps. ***Concepts*** are categories of objects, events, or ideas with common properties. They may be formal or natural. Formal concepts are precisely defined by the presence or absence of certain features. Natural concepts are fuzzy; no fixed set of defining properties determines membership in a natural concept. A member of a natural concept that displays all or most of the concept's characteristic features is called a ***prototype***.

Propositions are assertions that state how concepts are related. Propositions can be true or false. ***Schemas*** serve as generalized mental representations of concepts and generate expectations about them. ***Scripts*** are schemas about familiar sequences of events or activities. Experience creates accurate or inaccurate ***mental models*** that help guide our understanding of and interaction with the world. Mental ***images*** may also be manipulated when people think. ***Cognitive maps*** are mental representations of familiar parts of one's world.

Thinking Strategies

Do people always think logically?

By combining and transforming mental representations, our information-processing system makes it possible for us to engage in ***reasoning***, to solve problems, and to make decisions. ***Formal reasoning*** seeks valid conclusions through the application of rigorous procedures. It is guided by ***algorithms***, systematic methods that always reach a correct result (if there is one). To reach a sound conclusion, people should consider both the truth and falsity of their assumptions and whether the argument follows the rules of ***logic***. Unfortunately, people are prone to logical errors.

People use ***informal reasoning*** to assess the validity of a conclusion based on the evidence supporting it. Errors in informal reasoning often stem from the use of ***heuristics***, which are mental shortcuts or rules of thumb. Three important heuristics are the ***anchoring bias*** or ***anchoring heuristic*** (estimating the probability of an event by adjusting an earlier estimate), the ***representativeness heuristic*** (basing conclusions about whether something belongs in a certain class on how similar it is to other items in that class), and the ***availability heuristic*** (estimating probability by how available an event is in memory).

Problem Solving

What's the best way to solve a problem?

Steps in problem solving include diagnosing the problem and then planning, executing, and evaluating a solution. Especially when solutions are not obvious, problem solving can be aided by incubation and the use of strategies such as means-end analysis (also called decomposition), working backward, and finding analogies.

Many of the difficulties that people experience in solving problems arise when they are dealing with hypotheses. People do not easily consider multiple hypotheses. Because of ***mental sets***, they may stick to one hypothesis even when it is incorrect, and because of ***functional fixedness***, they may miss opportunities to use familiar objects in unusual ways. People may be reluctant to revise or change hypotheses on the basis of new data, partly because ***confirmation bias*** focuses their attention on evidence that supports their hypotheses. They may also fail to use the absence of symptoms or events as evidence in solving problems. Problem solving ability can be improved through deliberate practice.

Some specific problems can be solved by computer programs developed by researchers in the field of ***artificial intelligence (AI)***. There are two approaches to AI. One focuses on programming computers to imitate the logical manipulation of symbols that occurs in human thought; the other (involving connectionist, or neural network, models) attempts to imitate the connections among neurons in the human brain.

Tests of ***divergent thinking*** are used to measure differences in ***creativity***. In contrast, intelligence tests require ***convergent thinking***. Although creativity and intelligence are not highly correlated, creative behavior requires a certain amount of intelligence, along with expertise in a creative field, skill at problem solving and divergent thinking, and motivation to pursue a creative endeavor for its own sake.

Decision Making

How can I become a better decision maker?

Decisions are sometimes difficult because there are too many alternatives and too many features of each alternative to consider all at once. Furthermore, decisions often involve comparisons of subjective ***utility***, not of objective value. Decision making is also complicated by the fact that the world is unpredictable, which makes decisions risky.

People should act in ways that maximize the ***expected value*** of their decisions. They often fail to do so because losses are perceived differently from gains of equal size and because people tend to overestimate the probability of rare events, underestimate the probability of frequent events, and feel overconfident about the accuracy of their forecasts. The gambler's fallacy leads people to believe that events in a random process are affected by previous events. People also make decisions aimed at goals other than maximizing expected value; these goals may be determined by personal and cultural factors.

Group decisions tend to show group polarization, the selection of more extreme outcomes than would have been chosen by the average group member. Group performance in problem solving and decision making can be effective, but depending on the problem and the people involved, it may be less efficient than when individuals work alone.

Language

How do babies learn to talk?

Language consists of words or word symbols and rules for their combination—a ***grammar***. Spoken words are made up of ***phonemes***, which are combined to make ***morphemes***. Combinations of words must have both ***syntax*** (grammar) and ***semantics*** (meaning). Behind the word strings, or ***surface structures***, is an underlying representation, or ***deep structure***, that expresses the relationship among the ideas in a sentence. Ambiguous sentences occur when one surface structure reflects two or more deep structures. To understand language generally and conversations in particular, people use their knowledge of the context and of the world. In addition, understanding is guided by nonverbal cues.

Children develop grammar according to an orderly pattern. ***Infant vocalizations***, such as ***babblings***, come first, then a ***one-word stage*** of speech, and then two-word sentences. Next come three-word sentences and certain grammatical forms that appear in a somewhat predictable order. Once children learn certain regular verb forms and plural endings, they may overgeneralize rules. Children acquire most of the grammatical rules of their native language by the time they are five years old.

Both conditioning and imitation play a role in a child's acquisition of language, but neither can provide a complete explanation of how children acquire grammar. Humans may be biologically programmed to learn language. In any event, it appears that language must be learned during a certain critical period if normal language is to occur.

TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. Thinking is defined as the manipulation of __________.
   a. concepts
   b. mental models
   c. heuristics
   d. mental representations

2. While trying to describe an unusual bird he saw on his walk, Jarrod asks his friend to "think of a robin, but with blue tips on the wings and a tuft of hair on the head. That's what it looked like." Because "bird" is a __________ concept, Jarrod began with the image of a robin, which is the __________ of "bird." He hoped that his description would allow his friend to develop a __________ of the bird he saw.
   a. formal; concept; prototype
   b. natural; image; concept
   c. natural; prototype; mental model
   d. visual; mental model; script

3. Clint is frustrated. His uncle has been winning at checkers all night. During the next game he is going to base his strategy on an algorithm, not a heuristic. What problem will this strategy cause?
   a. Clint will not win the game.
   b. Clint and his uncle may be playing the same game of checkers for a long time.
   c. Clint will be ignoring overall probabilities.
   d. The representativeness heuristic will bias Clint's choice of strategy.

4. Alicia agreed to go to dinner and a movie with Adam but was surprised and angry when Adam expected her to pay for her half of the evening's expenses. Adam and Alicia apparently had different __________ for what is supposed to happen on a date.
   a. mental models
   b. propositions
   c. images
   d. scripts

5. Stephanie has worked for hours on a biochemistry problem without success. She decides to put it aside and work on her psychology homework in the hope that a solution might occur to her while she is thinking about something else. Stephanie is trying the __________ strategy to solve her problem.
   a. decomposition
   b. incubation
   c. working backward
   d. analogies

6. Ebony wanted to leave a note for her husband but couldn't find a pen, so she wrote the note with her lipstick. Ebony was able to overcome the obstacle to problem solving called __________.
   a. absence of information
   b. multiple hypotheses
   c. confirmation bias
   d. functional fixedness

7. Dr. Sand is sure that Ahmed has appendicitis and as a result he pays more attention to test results that are consistent with appendicitis than to results that suggest a different problem. Dr. Sand has fallen victim to __________.
   a. functional fixedness
   b. a mental model
   c. confirmation bias
   d. the availability heuristic

8. While playing a dominos game, Richard drew a tile at random and got a "double blank," which costs the most points during the first two rounds. At the start of the third round, he says, "There is no way I will draw the double blank tile next time!" Richard is being influenced by __________.
   a. the gambler's fallacy
   b. loss aversion
   c. a disregard of negative evidence
   d. confirmation bias

9. The fact that children learning language sometimes make errors, such as saying "I goed" instead of "I went," has been used to suggest which of the following?
   a. There is a critical period in language development.
   b. Children are born with a knowledge of grammar.
   c. Children do not learn language entirely through imitation.
   d. Speech is learned mainly through imitation.

10. Children who spend their early years isolated from human contact and the sound of adult language are unable to develop adult language skills despite extensive training efforts later. This phenomenon best provides evidence for the notion that __________.
    a. there is a critical period in language development
    b. children are born with a language acquisition device
    c. there are no fixed stages in language acquisition
    d. speech is acquired only through imitation

11. "All monsters are ugly. The Creature from the Black Lagoon is a monster. Therefore, the Creature is ugly." Together, these three statements are an example of __________.
    a. a premise
    b. a proposition
    c. a natural concept
    d. formal reasoning

12. When traveling by air to and from her hometown, Elisa always connects through Chicago's O'Hare airport, so she knows it well. On her last trip, even though she had only 35 minutes to make her connecting flight at a gate she had never used before, she had a __________ that helped her take the most efficient route to the correct gate.
- **a.** mental model
- **b.** schema
- **c.** cognitive map
- **d.** prototype

13. Theresa Amabile identified cognitive and personality characteristics necessary for creativity. Which of the following is not one of these characteristics?
- **a.** Capacity for focusing on the most important element in a problem, which is tied to convergent thinking.
- **b.** Expertise in the field of endeavor, which is tied to learning.
- **c.** A set of creative skills, including the capacity for divergent thinking.
- **d.** The motivation to pursue creative work for internal reasons.

14. Gulla was concerned about flying because he thought that the odds of being in a plane crash were around 1 in 100. Even after a pilot told him that the odds were actually less than 1 in a million, Gulla still believes that the chances of a crash are about 1 in 1,000. His new estimate is still far too high, suggesting that he has been affected by __________.
- **a.** confirmation bias
- **b.** the availability heuristic
- **c.** the representativeness heuristic
- **d.** the anchoring heuristic

15. The words "basket" and "casket" mean different things because of a single __________.
- **a.** syntax
- **b.** phoneme
- **c.** pivot word
- **d.** proposition

16. Matt cannot solve a difficult design problem for his architecture class. If he decides to use the problem-solving strategy called decomposition, Matt will __________.
- **a.** break the problem into smaller pieces and deal with each part separately
- **b.** begin with the finished design and work backwards to achieve it
- **c.** put the problem aside for a while and return to it later
- **d.** use an algorithm to plot all possible solutions

17. Seven-year-old Nunes speaks Hindi at home and English at school. His language skills will probably be __________ his classmates who speak only one language.
- **a.** inferior to
- **b.** superior to
- **c.** equal to
- **d.** less-developed than

18. Doris speaks no Spanish, so when she went to Mexico, she had the impression that everyone there speaks much faster than she does. This impression was probably caused by the fact that when listening to Spanish, she was unable to use __________ to identify individual words.
- **a.** bottom-up processing
- **b.** schemas
- **c.** top-down processing
- **d.** prototypes

19. When Wanda invites Tanya to join her in a cup of coffee Tanya laughs and says "That would have to be a very big cup!" She could make this joke by focusing on the __________ of Wanda's invitation.
- **a.** unconscious meaning
- **b.** deep structure
- **c.** surface structure
- **d.** context

20. Scientists who claim that nonhuman animals can use language base their assertions partly on the animals' ability to learn __________.
- **a.** chess
- **b.** American sign language
- **c.** typing skills
- **d.** basic human speech sounds

CHAPTER 8

Intelligence

Cathy Melloan / Alamy

Preview

Intelligence tests are used to guide decisions about which children need special education, which job applicants should be hired, which students will be admitted to college, which individuals should be classified as gifted or intellectually disabled, and whether mental functioning has been impaired by head injury or disease. Intelligence tests have even been used to determine who is eligible for the death penalty. With so many important decisions being based on the results of intelligence tests, it is no wonder that there is controversy about them. In theory, these tests measure intelligence, but what does that mean? What, exactly, is "intelligence," where does it come from, and how good are the tests that are designed to measure it? These are some of the questions that we explore in this chapter.

People who are good at using and understanding language and skilled at thinking, problem solving, and decision making are likely to be seen as *intelligent*. But intelligence is not limited to these abilities alone. Over the years, psychologists studying people in various cultures around the world have proposed that the concept of "intelligence" is a broad umbrella that can include many different kinds of attributes and abilities, from rapidly processing information to having a good sense of direction or displaying polished social skills (e.g., Berry & Bennett, 1992; Gardner, 1999; Hunt, 1983; Kush, Spring, & Barkand, 2012; Meyer & Salovey, 1997; Sternberg, Lautrey, & Lubart, 2003). We can't use x-rays or brain scans to see intelligence, so we have to draw conclusions about people's intelligence from what can be observed and measured in their actions (Borkenau et al., 2004). This usually means looking at scores on tests designed to measure intelligence.

TESTING FOR INTELLIGENCE

How is intelligence measured?

What, exactly is *intelligence?* The answer is hard to pin down. Though there is no single, universally accepted definition, most psychologists agree that **intelligence** includes three main characteristics: (1) abstract thinking or reasoning abilities, (2) problem-solving abilities, and (3) the capacity to acquire knowledge (Gottfredson, 1997b; Snyderman & Rothman, 1987). Standard tests of intelligence measure some of these characteristics, but they don't address all of them. That is why some psychologists argue that these tests fail to provide a complete picture of someone's intelligence in its broadest sense. Others say that broadening the definition of intelligence too much makes it meaningless. Still others suggest dropping the term altogether in favor of the more descriptive and less emotionally charged concept of *cognitive ability.* To better understand the controversy, let's look at how standard intelligence tests were created, what they are designed to measure, and how well they do their job. Later, we will consider some alternative intelligence tests that have been proposed by those who find fault with traditional ones.

A Brief History of Intelligence Tests

The story of modern intelligence tests begins in France in 1904, when the French government appointed a psychologist named Alfred Binet (pronounced "bee-NAY") to a committee whose job was to identify, study, and provide special educational programs for children who were not doing well in school. As part of his work, Binet developed a set of test items that provided the model for today's intelligence tests. Binet assumed that reasoning, thinking, and problem solving all depend on intelligence, so he looked for tasks that would highlight differences in children's ability to do these things (Binet & Simon, 1905). His test included tasks such as unwrapping a piece of candy, repeating numbers or sentences from memory, and identifying familiar objects (Rogers, 1995).

Binet also assumed that children's abilities increase with age. With this in mind, he tried out his test items on children of various ages and, in later versions of his test, categorized each item according to the age at which the typical child could respond correctly. For example, a "six-year-old item" was one that half of six-year-olds could answer. In other words, Binet's test contained a set of *age-graded* items. It measured a child's "mental level"—later called **mental age**—by determining the age level of the most-advanced items a child could consistently answer correctly. Children whose mental age equaled their actual age, or *chronological age,* were considered to be of "regular" intelligence (Schultz & Schultz, 2000).

At about the time Binet published his test, Lewis Terman at Stanford University began to develop an English-language version that has come to be known as the **Stanford-Binet Intelligence Scale** (Terman, 1906, 1916). Table 8.1 gives examples of the kinds of items included on the Stanford-Binet test. Terman added items to measure the intelligence of adults and, following a formula devised by William Stern (1914), revised the scoring procedure. Mental age was divided by chronological age, and the result, multiplied

intelligence Personal attributes that center around skill at information processing, problem solving, and adapting to new or changing environments.

mental age A score corresponding to the age level of the most-advanced items a child could answer correctly on Alfred Binet's first intelligence test.

Stanford-Binet Intelligence Scale A test for determining a person's intelligence quotient, or IQ.

TABLE 8.1 THE STANFORD-BINET INTELLIGENCE SCALE

Here are samples of the types of items included on Lewis Terman's original Stanford-Binet Intelligence Scale. As in Alfred Binet's test, an age level was assigned to each item.

Age	Task
2	Place geometric shapes into corresponding openings; identify body parts; stack blocks; identify common objects.
4	Name objects from memory; complete analogies (e.g., fire is hot; ice is ___); identify objects of similar shape; answer simple questions (e.g., "Why do we have schools?").
6	Define simple words; explain differences (e.g., between a fish and a horse); identify missing parts of a picture; count out objects.
8	Answer questions about a simple story; identify absurdities (e.g., in statements such as "John had to walk on crutches because he hurt his arm"); explain similarities and differences among objects; tell how to handle certain situations (e.g., finding a stray puppy).
10	Define more difficult words; give explanations (e.g., about why people should wait their turn to be served in a store); list as many words as possible; repeat six-digit numbers.
12	Identify more difficult verbal and pictured absurdities; repeat five-digit numbers in reverse order; define abstract words (e.g., *sorrow*); fill in a missing word in a sentence.
14	Solve reasoning problems; identify relationships among points of the compass; find similarities in apparently opposite concepts (e.g., "high" and "low"); predict the number of holes that will appear when folded paper is cut and then opened.
Adult	Supply several missing words for incomplete sentences; repeat six-digit numbers in reverse order; create a sentence using several unrelated words (e.g., *forest, businesslike,* and *dismayed*); describe similarities between concepts (e.g., "teaching" and "business").

by 100, was called the *intelligence quotient* (*IQ*). So a child whose mental age and chronological age were equal would have an IQ of 100, which defined an expected "average" intelligence. A ten-year-old who scored at the mental age of a twelve-year-old would have an IQ of $12/10 \times 100 = 120$. In the ensuing years, the term *IQ test* has come to be applied to any test designed to measure intelligence on an objective, standardized scale.

This scoring method allowed testers to rank people on IQ, which was seen as an important advantage by Terman and others who promoted the test in the United States. Unlike Binet—who believed that intelligence improved with education and training—they saw intelligence as a fixed and inherited entity, and so they said IQ tests could pinpoint who did and who did not have a suitable "amount" of intelligence. These beliefs were controversial because they were not supported by empirical evidence and in some instances served to reinforce prejudices against certain people. In other words, enthusiasm for testing outpaced understanding of what was being tested.

For example, in 1917, as the United States moved closer to entering World War I, the government asked a team of psychologists to develop the first group-administered intelligence tests to assess the cognitive abilities of military recruits. One of these tests, called the Army Alpha test, presented arithmetic problems, verbal analogies (e.g., hot is to cold as high is to ___), and general knowledge questions to all recruits who could read English. The Army Beta test was developed for recruits who could not read or speak English; it presented nonverbal tasks, such as visualizing three-dimensional objects and solving mazes. Unfortunately, the verbal tests contained items that were unfamiliar to many recruits. Further, the tests were often given under stressful conditions in crowded rooms where instructions were

Coming to America

Early in the twentieth century, immigrants to the United States, including these new arrivals at Ellis Island in New York harbor, were tested for both physical and mental weaknesses. Especially for those who could not read, speak, or understand English, the intelligence tests they took tended to greatly underestimate their intellectual capacity. Today, psychologists recognize that cognitive abilities are developed partly through education and experience (Cronbach, 1975; Lohmann, 2004; Martinez, 2000), and they take much greater care in administering and interpreting intelligence tests.

Records of the Public Health Service/National Archives

not always audible or (for those who did not speak English) understandable. Nevertheless, when 47 percent of the recruits scored at a mental age of thirteen years or lower (Yerkes, 1921), some psychologists incorrectly concluded that these recruits—even those who did not speak English—lacked normal intelligence (Brigham, 1923).

In the late 1930s, David Wechsler (1939, 1949) developed new tests designed to improve on the earlier ones in three important ways. First, the new tests included both verbal and nonverbal subtests. Second, these tests were designed so that success depended less on having formal schooling. Third, each subtest was scored separately, resulting in a profile that described an individual's performance on all subtests. Special versions of these tests were developed for adults (the Wechsler Adult Intelligence Scale, WAIS) and for children (the Wechsler Intelligence Scale for Children, WISC).

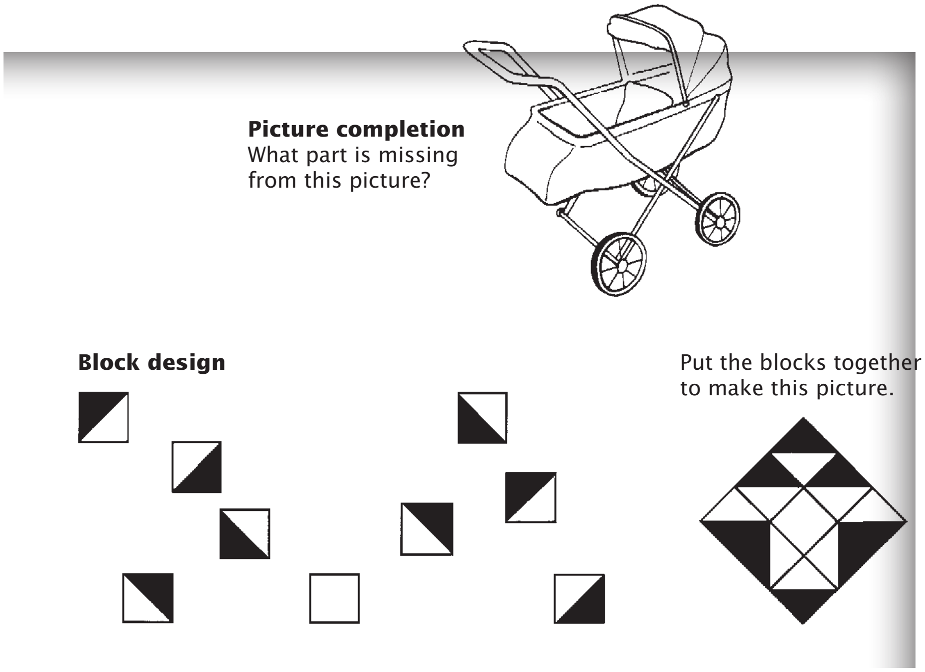
Intelligence Tests Today

Today's revised editions of the Wechsler tests and the Stanford-Binet Intelligence Scale are the most widely used, individually administered intelligence tests. The Wechsler Adult Intelligence Scale (WAIS IV; Wechsler, 2008) contains fifteen subtests that include items such as remembering a series of digits, solving arithmetic problems, defining vocabulary words, understanding and answering general-knowledge questions, assembling blocks, solving visual puzzles, and completing unfinished pictures. Scores on these subtests can be grouped to indicate a person's performance on each of four intellectual factors: mental processing speed, memory ability, perceptual skills, and understanding of verbal information. A full-scale IQ can be calculated by combining scores on all four of these factors. The latest edition of the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2003) yields four similar index scores, along with an overall IQ (see Figure 8.1).

Like the WISC-IV, the fifth edition of the Stanford-Binet (SB5; Roid, 2003) also consists of ten main subtests. However, the SB5 subtests are designed to measure five different abilities: *fluid reasoning* (e.g., completing verbal analogies), *knowledge* (e.g., defining words, detecting absurdities in pictures), *quantitative reasoning* (e.g., solving math problems),

FIGURE 8.1
Items Similar to Those on the Wechsler Intelligence Scale for Children (WISC-IV)

The WISC-IV is made up of ten standard and five supplemental subtests, grouped into four clusters. The *perceptual reasoning* cluster includes tasks, such as those shown here, that involve assembling blocks, solving mazes, and reasoning about pictures. Tests in the *verbal comprehension* cluster require defining words, explaining the meaning of sentences, and identifying similarities between words. Tests in the *working memory* cluster ask children to recall a series of numbers, put a random sequence of numbers into logical order, and the like. The *processing speed* cluster tests children's ability to search for symbols on a page and to decode simple coded messages.



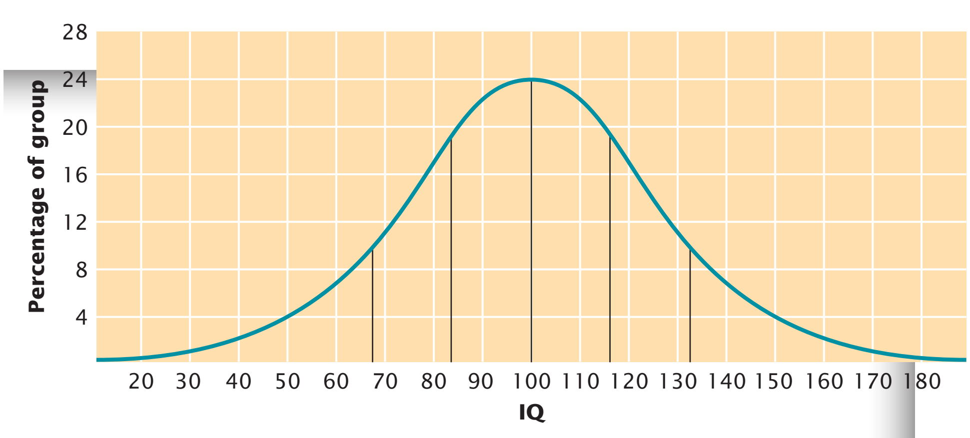
visual-spatial processing (e.g., assembling a puzzle), and *working memory* (e.g., repeating a sentence). Each of these five abilities is measured by one verbal and one nonverbal subtest, so it is possible to calculate a score for each of the five abilities, a total score on all the verbal tests, a total score on all the nonverbal tests, and an overall score for all ten tests combined.

Calculating IQ

IQs are no longer calculated by dividing mental age by chronological age. If you take an IQ test today, the points you earn for each correct answer are added up. That total score is then compared with the scores earned by other people. The average score obtained by people at each age level is assigned an IQ value of 100. Other scores are given IQ values that reflect how far each score deviates from that average. If you do better on the test than the average person in your age group, you will receive an IQ above 100; how far above depends on how much better than average you do. Similarly, a person scoring below the age-group average will have an IQ below 100. This procedure is based on a well-documented aspect of many characteristics: Most people's scores fall in the middle of the range of possible scores, creating a bell-shaped curve that approximates the normal distribution shown in Figure 8.2.

FIGURE 8.2
The Normal Distribution of IQ Scores in a Population

When IQs in the general population are plotted on a graph, a bell-shaped curve appears. The average IQ of any given age group is 100. Half are higher than 100, and half are lower than 100. Approximately 68 percent of the IQs of any age group fall between 84 and 116; about 16 percent fall below 84, and about 16 percent fall above 116.



(The statistics appendix provides a fuller explanation of the normal distribution and how IQ tests are scored.) As a result of this scoring method, your **intelligence quotient (IQ)**, reflects your relative standing within a population of your age.

EVALUATING INTELLIGENCE TESTS

How good are IQ tests?

We have said that no intelligence test can accurately measure all aspects of what various people think of as intelligence. So just what does your IQ say about you? Can it predict your performance in school or on the job? Is it a fair summary of your cognitive abilities? To answer questions such as these scientifically, we must measure the quality of the tests that yield IQs, using the same criteria that apply to tests of personality, language skills, driving, or anything else. Let's review these criteria and then see how they are used to evaluate IQ tests.

A **test** is a systematic procedure for observing behavior in a standard situation and describing it with the help of a numerical scale or system of categories (Cronbach, 1990). Tests are *standardized,* meaning that they present the same tasks, under similar conditions, to each person who takes them. Standardization helps ensure that test results will not be significantly affected by factors such as who gives and scores the test. Because the biases of those giving and scoring a test are minimized, a standardized test is said to be *objective*. Test scores can be used to calculate **norms**, which are descriptions of the frequency of particular scores. Norms tell us, for example, what percentage of high school students obtained each possible score on a college entrance exam. They also allow us to say whether a particular IQ or entrance-exam score is above or below the average score. Any test, including IQ tests, should fairly and accurately measure a person's performance. The two most important things to know about when determining the value of a test are its *statistical reliability* and *validity*.

Defining Statistical Reliability

If you stepped on a scale, checked your weight, stepped off, stepped back on, and found that your weight had increased by twenty pounds, you would know it was time to buy a new scale. A good scale, like a good test, must have **statistical reliability**; in other words, the results must be repeatable or stable. The test must measure the same thing in the same way every time it is used. Let's suppose you receive a very high score on a test of reasoning, but when you take the same test the next day, you get a very low score. Your reasoning ability probably didn't change much overnight, so the test is probably unreliable. The higher the reliability of a test, the less likely it is that its results will be affected by temperature, hunger, or other random and irrelevant changes in the environment or the test taker.

Defining Statistical Validity

Most scales reliably measure your weight, giving you about the same reading day after day. But what if you use these readings as a measure of your height? This far-fetched example illustrates that a reliable scale reading can be incorrect, or invalid, if it is misinterpreted. The same is true of tests. Even the most reliable test might not provide a correct, or valid, measure of intelligence, of anxiety, of typing skill, or of anything else if those are not the things the test really measures. In other words, we can't say that a test itself is "valid" or "invalid." Instead, **statistical validity** refers to the degree to which test scores are interpreted appropriately and used properly (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999; Messick, 1989). As in our scale example, a test can be valid for one purpose but invalid for another.

Researchers evaluate the statistical reliability of a test by obtaining two sets of scores on the same test from the same people. They then calculate a correlation coefficient between the two sets of scores (see the introductory chapter). When the correlation is high

intelligence quotient (IQ) An index of intelligence that reflects the degree to which a person's score on an intelligence test deviates from the average score of others in the same age group.

test A systematic procedure for observing behavior in a standard situation and describing it with the help of a numerical scale or a category system.

norms Descriptions of the frequency at which particular scores occur, allowing scores to be compared statistically.

statistical reliability The degree to which a test can be repeated with the same results.

statistical validity The degree to which test scores are interpreted correctly and used appropriately.

If only measuring intelligence were this easy!

J.B. Handelsman The New Yorker Collection/The Cartoon Bank

and positive (usually above +.80), the test is considered reliable. Evaluating a test's statistical validity usually means calculating a correlation coefficient between test scores and something else. What that "something else" is depends on what the test is designed to measure. Suppose, for example, you wanted to know if a creativity test is valid for identifying creative people. You could do so by computing the correlation between people's scores on the creativity test and experts' judgments about the quality of those same people's artistic creations. If the correlation is high, the test has high validity as a measure of creativity.

The Statistical Reliability and Validity of Intelligence Tests

The statistical reliability of intelligence tests is generally evaluated on the basis of their stability, or consistency. The statistical validity of intelligence tests is usually based on their accuracy in guiding statements and predictions about people's cognitive abilities.

How Reliable Are Intelligence Tests?

IQs obtained before the age of seven are only moderately correlated with scores on intelligence tests given later (e.g., Fagan, Holland, & Wheeler, 2007). There are two key reasons. First, the test items used with very young children are different from those used with older children. Second, cognitive abilities change rapidly in the early years (see the chapter on human development). During the school years, IQs tend to remain stable (Allen & Thorndike, 1995; Mayer & Sutton, 1996). So for teenagers and adults, the reliability of intelligence tests is high, as seen in correlation coefficients that are generally between +.85 and +.95 (Deary et al., 2000, 2004).

Of course, a person's score may vary from one occasion to another if there are significant changes in the person's motivation, anxiety, health, or other factors. Overall, though, modern IQ tests usually provide exceptionally consistent results, especially compared with most other kinds of mental tests.

How Valid Are Intelligence Tests?

If everyone agreed on exactly what intelligence is (having a good memory, for example), we could evaluate the statistical validity of IQ tests simply by correlating people's IQs with their performance on various tasks (in this case, memory tasks). IQ tests whose scores correlated most highly with scores on memory tests would be the most valid measures of intelligence. But because psychologists do not fully agree on a single definition of intelligence, they don't have a single standard against which to compare intelligence tests. Therefore, the validity of intelligence tests is best examined by correlating IQ test scores with a variety of performance measures. Because intelligence is always displayed in the course of specific tasks and specific social, educational, and work situations, psychologists assess the validity of intelligence tests for specific purposes.

The results of their research suggest that intelligence test scores are most valid for assessing aspects of intelligence that are related to schoolwork, such as abstract reasoning and understanding verbal material. Their validity—as measured by correlating IQs with high school grades—is reasonably good, about +.50 (Brody & Erlichman, 1998). Scores on tests that focus more specifically on reasoning skills show even higher correlations with school performance (Kuncel, Hezlett, & Ones, 2004; Lohman & Hagen, 2001). For example, the correlation between people's intelligence test scores and the level of education they achieve ranges from +.60 to +.80 (e.g., Colom & Flores-Mendoza, 2007; Judge, Ilies, & Dimotakis, 2010; Lynn & Mikk, 2007).

There is also evidence that employees who score high on verbal and mathematical reasoning tests tend to perform better at work than those who earn lower scores (e.g., Arneson, Sackett, & Beatty, 2011; Kuncel & Hezlett, 2010), especially if their jobs require complex reasoning and judgment skills (Schmidt & Hunter, 2004). One study kept track of people for 70 years and found that those who had high IQs as children tended to be

IQ and Job Performance

IQ is a reasonably good predictor of the ability to learn job-relevant information and to deal with unpredictable, changing aspects of the work environment—characteristics that are needed for success in complex jobs such as this one.

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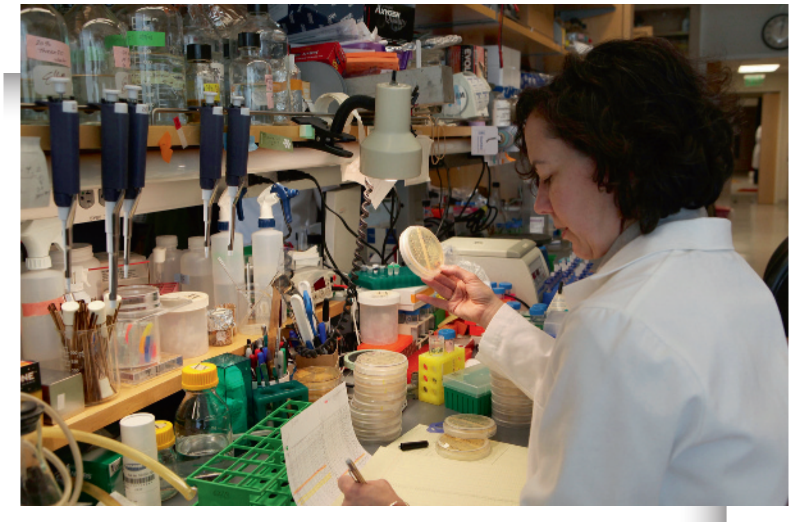


well above average in terms of academic and financial success in adulthood (Oden, 1968; Terman & Oden, 1947). IQs also appear to be highly correlated with performance on routine tasks such as following instructions on medicine labels and using reference material (Gottfredson, 1997b, 2004).

So, in summary, by the standard measures for judging psychological tests, scores on intelligence tests have good reliability and good validity for predicting success in school and in many life situations and occupations (Firkowska-Mankiewicz, 2011; Sackett, Borneman, & Connelly, 2008).

How Fair Are IQ Tests?

As noted earlier, IQ is not a perfect measure of how "smart" a person is. For example, the average intelligence of children appears to have risen in recent decades, but some psychologists suggest that this may be partly due to the use of deviation scores instead of the old MA/CA × 100 formula for calculating IQ (McDonald, 2010). Further, because intelligence tests do not measure the full array of cognitive abilities, a particular test score tells only part of the story, and even that part may be distorted. Many factors other than cognitive ability, including self-control and reactions to the testing situation, can affect test performance (Chapell et al., 2005; Duckworth, Quinn, & Tsukayama, 2012; Onyper et al., 2011). So if children are suspicious of strangers and adults and fear making mistakes, they may become anxious and fail even to try answering certain questions, thus artificially lowering their IQ scores (Fagan, 2000). Scores may also be depressed artificially if individuals are not motivated to take a particular test (Duckworth et al., 2011).

Test scores can also be affected by anxiety, physical disabilities, and language differences and other cultural barriers (Fagan, 2000; Steele, 1997). For example, consider this multiple-choice question: Which is most similar to a xylophone? (violin, tuba, drum, marimba, piano). No matter how intelligent children are, if they have never seen an orchestra or learned about these instruments, they may miss this question. Accordingly, test designers have developed sophisticated procedures to detect and eliminate obviously biased questions. Furthermore, because intelligence tests now include more than one scale, areas that are most influenced by culture, such as vocabulary, can be assessed separately from areas that are less influenced by cultural factors.

However, the solutions to many of the technical problems in intelligence tests have not resolved the controversy over the fairness of intelligence *testing.* The debate continues partly because the results of intelligence tests can have important consequences. Some students who score well above average on these tests may receive advanced educational opportunities that set them on the road to further high achievement. Those whose relatively low test scores identify them as having special educational needs may find themselves in separate classes that isolate them from other students and carry negative social labels. Obviously, the social consequences of testing can be evaluated separately from the quality of the tests themselves; but those consequences cannot be ignored, especially if they tend to affect some groups more than others.

LINKAGES How does excessive emotional arousal affect scores on cognitive ability tests? (a link to Motivation and Emotion)

LINKAGES

EMOTIONALITY AND THE MEASUREMENT OF INTELLIGENCE

What noncognitive factors might influence scores on tests of intelligence and other cognitive abilities? One of the most important factors is emotional arousal. As described in the chapter on motivation and emotion, people tend to perform best when their arousal level is moderate. Too little arousal tends to result in decreased performance, and so does too much. People whose overarousal impairs their ability to do well in testing situations are said to suffer from *test anxiety*.

Some of these people fear that they will do poorly on the test and that others will think they are "stupid." Some may have other unrealistic thoughts, such as that they must be perfect (Eum & Rice, 2011). When people with test anxiety approach a testing situation, they may experience physical symptoms such as heart palpitations and sweating, as well as negative thoughts such as "I am going to blow this exam" (Chapell et al., 2005). In the most severe cases of test anxiety, individuals may be so distressed that they are unable to complete a test.

Test anxiety may affect up to 40 percent of elementary school students and about the same percentage of college students. It is seen in both males and females (Baghurst & Kelley, 2013; Devine et al., 2012). High test anxiety is correlated with lower IQ, but even among people with high IQ, those who experience severe test anxiety tend to do poorly on tests such as college entrance exams. Test-anxious elementary school students are likely to receive low grades and to perform poorly on evaluated tasks and on those that require new learning (Campbell, 1986). Some children with test anxiety refuse to attend school or "play sick" on test days, creating a vicious circle that further harms their performance on standardized achievement tests.

Anxiety, frustration, and other emotions may also be at work in a testing phenomenon that Claude Steele and his colleagues have identified as *stereotype threat* (Steele & Aronson, 2000). According to Steele, concern over negative stereotypes about the cognitive abilities of the group to which they belong can impair the performance of some women and some members of ethnic minorities. As a result, the test scores they earn, in laboratory settings at least, may underestimate those abilities (e.g., Cadinu et al., 2005; Mazerolle et al., 2012; Murphy, Steele, & Gross, 2007; Schmader, 2010). In one study, bright African American students read test instructions designed to make them more sensitive to negative stereotypes about the intelligence of their ethnic group. These students performed less well on a standardized test than equally bright African American students whose sensitivity to the stereotypes had not been increased (Steele & Aronson, 2000). In another study, women with good math skills were randomly assigned to one of two groups. The first group was given information intended to create concern over the stereotype that women aren't as good as men at math. In fact, they were told that men usually do better than women on the difficult math test they were about to take. The second group was not given this information. The women in the second group performed much better on the test than those in the first. In fact, their performance was equal to that of men who took the same test (Spencer, Steele, & Quinn, 1997).

Studies such as these suggest that stereotype threat can lead to reduced scores on tests—possibly by impairing test preparation and test-taking strategies (e.g., Appel, Kronberger, & Aronson, 2011; Mangels et al., 2012; Martiny et al., 2012; Robinson-Cimpian et al., 2014). However, other research on the performance of females and minority group members on high-stakes tests has found no such effects or only a weak effect (e.g., Cullen, Waters, & Sackett, 2006; Fischer & Massey, 2007; Grand et al., 2011). It may be that some people—such as girls whose parents reject gender stereotypes—are more resistant to stereotype threat than others (Tomasetto, Alparone, & Cadinu, 2011). In any case, the extent to which stereotype threat

(*continued*)

impairs performance on cognitive abilities tests in real-world settings remains uncertain (Stoet & Geary, 2012).

Test anxiety is associated with lower performance on cognitive ability tests (e.g., Gass & Curiel, 2011), but it does not appear to decrease the accuracy of predictions made on the basis of the tests' scores (Reeve & Bonaccio, 2008; Wicherts & Scholten, 2010). In other words, if people's performance is hampered by anxiety in a testing situation, it may be hampered in other stressful situations as well. The good news for people who suffer from test anxiety is that counseling centers at most colleges and universities have effective programs for dealing with it (Brown et al., 2011; Nemati, 2013).

These and other research findings indicate that the relationship between anxiety and test performance is complex, but one generalization seems to hold true: People who are severely test-anxious do not perform to the best of their ability on intelligence tests (Lang & Lang, 2010).

IQ As a Measure of Inherited Ability

Concern over the fairness of intelligence tests is based partly on what many people assume to be true about these tests. A good intelligence test, they believe, should be able to see through the surface ripples created by an individual's cultural background, experience, and motivation to discover the innate cognitive abilities that lie beneath. But years of study have led psychologists to conclude that intelligence is a *developed ability,* influenced partly by genetics but also by educational, cultural, and other life experiences that shape the very knowledge, reasoning, and other skills that intelligence tests measure (e.g., Hunt, 2012; Nisbett et al., 2012; Plomin & Spinath, 2004; Rattan, Good, & Dweck, 2012). For example, when brighter, more curious children ask more questions of their parents and teachers, they are generating a more enriching environment for themselves. Their innate abilities are allowing these children to take better advantage of their environment (Scarr, 1997; Scarr & Carter-Saltzman, 1982). The parents of these children are likely to be bright too. If so, their own biologically influenced intelligence probably helped them acquire resources that enrich their children's environment. That enriched environment helps develop the children's intelligence, so these children are favored by both heredity and environment.

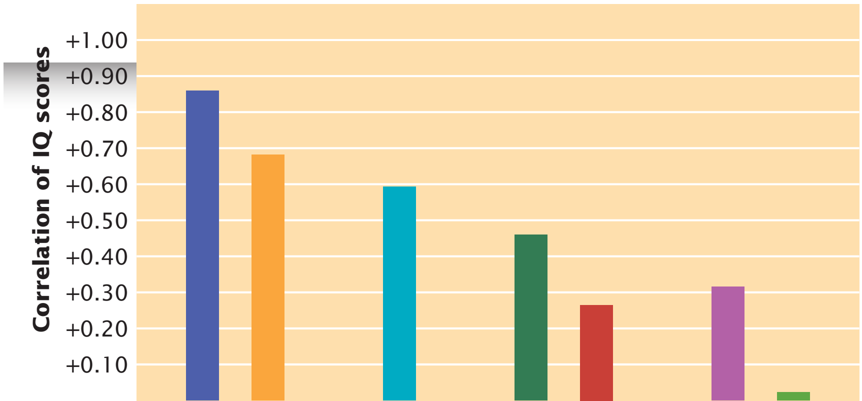
Psychologists have explored the influence of genetics on individual differences in intelligence by comparing the correlation between the IQs of people who have differing degrees of similarity in their genetic makeup and environment. For example, they have examined the IQs of identical twins—pairs with exactly the same genes—who were separated when very young and raised in different environments. They have also examined the IQs of identical twins raised together.

These studies find, first, that hereditary factors are strongly related to IQ. When identical twins who were separated at birth and adopted by different families are tested many years later, the correlation between their scores is usually at least +.60 (e.g., Bouchard, 1999). That is, if one twin scores high on an IQ test, the other probably will too; if one twin's IQ is low, the other's is likely to be low as well. However, studies of IQ correlations also highlight the importance of the environment (Scarr, 1998). Consider any two people—twins, siblings, or unrelated children—brought up together in a foster home. No matter what the degree of genetic similarity in these pairs, the correlation between their IQs is higher if they share the same home than if they are raised in different environments, as Figure 8.3 shows (Scarr & Carter-Saltzman, 1982).

The role of environmental influences is also seen in the results of studies that compare children's IQs before and after environmental changes such as adoption (van IJzendoorn & Juffer, 2005). Generally, when children from relatively impoverished backgrounds were adopted into homes offering a more enriching intellectual environment—including interesting materials and experiences, as well as a supportive, responsive adult—they show twelve- to eighteen-point increases in their IQs (e.g., Capron & Duyme, 1989;

FIGURE 8.3
Correlations of IQ Scores

The correlation in IQ between pairs increases with increasing similarity in heredity or environment.



Nisbett et al., 2012; Weinberg, Scarr, & Waldman, 1992; Zhai, Brooks-Gunn, & Waldfogel, 2011; Zhai, Raver, & Jones, 2012).

A study of French children who were adopted soon after birth demonstrates the importance of both genetic and environmental influences. These children were tested after years of living in their adopted homes. Children whose biological parents were from upper socioeconomic groups (in which higher IQs are more common) had higher IQs than children whose biological parents came from lower socioeconomic groups, regardless of the socioeconomic status of the adoptive homes (Capron & Duyme, 1989, 1996). These findings were supported by data from the Colorado Adoption Project (Cardon & Fulker, 1993; Cardon et al., 1992), and they suggest that a genetic component of children's cognitive abilities continues to exert an influence even in their adoptive environment.

Programs designed to enhance young children's school readiness and academic ability have also been associated with improved scores on tests of intelligence and academic success (Bulotsky-Shearer, Dominguez, & Bell, 2012; McWayne et al., 2012; Neisser et al., 1996). The same is true of enrichment programs that focus on musical training and improving memory capacity (e.g., Moreno et al., 2011; Morrison & Chein, 2011; Shipstead, Redick, & Engle, 2012). These early intervention programs may be partly responsible for the steady increase of children's average IQs mentioned earlier (Flynn, 1999; Neisser, 1998).

Research on genetic and environmental influences can help us understand the differences we see *among* people in terms of cognitive abilities and other characteristics, but it cannot tell us how strong each influence is in any *particular* person, including in this person.

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Some researchers have concluded that the influence of heredity and environment on differences in cognitive abilities appears to be roughly equal. Others see a somewhat larger role for heredity (Herrnstein & Murray, 1994; Loehlin, 1989; Plomin, 1994), and they are working to identify specific groups of genes that might be associated with variations in cognitive abilities (Posthuma & de Geus, 2006). However, the effects of genetics and the environment are intertwined in complex ways, so the influence of either factor may change across developmental stages, in particular situations, and across some cultures (Kan et al., 2013; Tucker-Drob et al., 2011). It is also important to understand that estimates of the relative contributions of heredity and environment apply only to groups, not to individuals. It would not be correct to say that about 50 percent of your IQ is inherited and about 50 percent learned. It is far more accurate to say that about half of the *variability* in the IQs of a group of people can be attributed to hereditary influences. The other half can be attributed to environmental influences and measurement error. Intelligence provides yet another example of nature and nurture working together to shape human behavior and mental processes.

Group Differences in IQ

Much of the controversy over the roles played by genes and the environment in intelligence has been sparked by efforts to explain differences in the average IQs seen in particular groups of people. For example, the average IQ of Asian Americans is typically the highest among the various ethnic groups in the United States, followed, in order, by European Americans, Hispanic Americans, and African Americans (e.g., Fagan, 2000; Herrnstein & Murray, 1994; Lynn, 2006). Similar patterns appear on a number of other tests of cognitive ability and achievement (e.g., Koretz, Lynch, & Lynch, 2000; Sackett et al., 2001). Further, the average IQ of people from high-income areas in the United States and elsewhere is consistently higher than that of people from low-income communities with the same ethnic makeup (McLoyd, 1998; Rowe, Jacobson, & Van den Oord, 1999).

To understand these differences and where they come from, we must remember two things. First, group scores are just that; they do not describe individuals. Although the mean IQ of Asian Americans is higher than the mean IQ of European Americans, there will still be large numbers of European Americans who score well above the Asian American mean and large numbers of Asian Americans who score below the European American mean (see Figure 8.4).

Second, increases in average IQ in recent decades, and other similar findings, suggest that inherited characteristics are not necessarily fixed. As already mentioned, a favorable environment can improve a child's performance somewhat, even if the inherited influences on that child's IQ are negative (Humphreys, 1984). There is also evidence that living in an impoverished environment can impair the development of cognitive skills (Turkheimer et al., 2003) and that environmental influences can magnify the effects of genetic influences (Bates, Lewis, & Weiss, 2013).

LINKAGES How does motivation affect IQ scores? (a link to Motivation and Emotion)

Socioeconomic Differences

We have already mentioned that there is a positive correlation between socioeconomic status (SES) and scores on IQ and other cognitive ability tests (e.g., Sackett et al., 2009). Why should this be? Four factors seem to be involved. First, parents' jobs and status depend on characteristics related to their own intelligence. This intelligence is partly determined by a genetic component that in turn contributes to their children's IQ. Second, parents' income affects their children's environment in ways that can increase or decrease IQ (Bacharach & Baumeister, 1998; Suzuki & Valencia, 1997). Third, motivational differences may play a role. Parents in upper- and middle-income families tend to provide more financial and psychological support for their children's motivation to succeed and excel in academic endeavors (Erikson et al., 2005; Nelson-LeGall & Resnick, 1998). As a result, children from

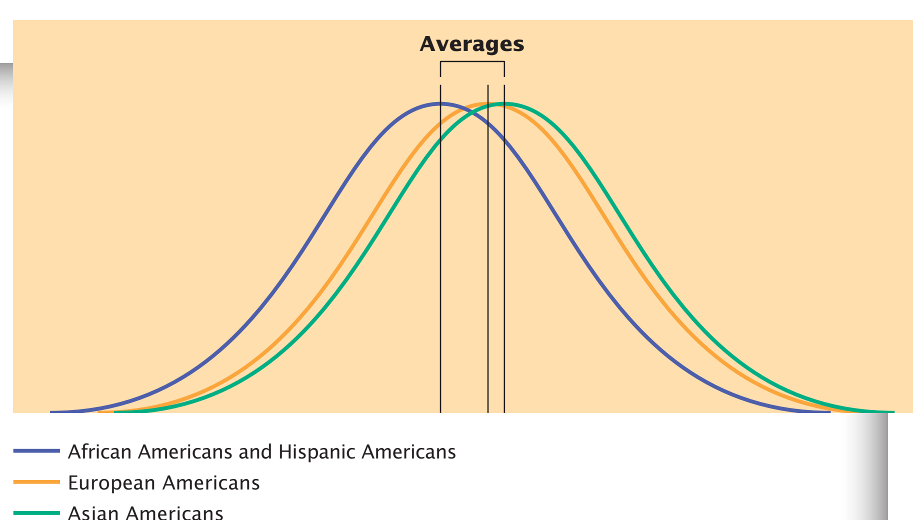


FIGURE 8.4
A Representation of Ethnic Group Differences in IQ Scores

The average IQ of Asian Americans is about four to six points higher than the average IQ of European Americans, who average twelve to fifteen points higher than African Americans and Hispanic Americans. Notice, though, that there is much more variation *within* these groups than there is among their average scores.

middle- and upper-income families may exert more effort in testing situations and therefore obtain higher scores (Bradley-Johnson, Graham, & Johnson, 1986; Robbins et al., 2004; Zigler & Seitz, 1982). Fourth, because colleges, universities, and businesses usually select people who score high on various cognitive ability tests, those with higher IQs—who tend to do better on such tests—may have greater opportunities to earn more money (Sackett et al., 2001).

Ethnic Differences

Some experts have argued that the average differences in IQ among ethnic groups in the United States are due at least partly to heredity (Rowe, 2005; Rushton & Jensen, 2005). Remember, though, that the existence of hereditary differences among individuals *within* groups does not indicate whether differences *between* groups result from similar genetic causes (Lewontin, 1976). As shown in Figure 8.4, variation within ethnic groups is much greater than variation among the mean scores of those groups (Zuckerman, 1990).

We must also take into account the significantly different environments in which average children in various ethnic groups grow up. To take only the most blatant evidence, recent Census Bureau figures show 27.2 percent of African American families and 25.6 percent of Hispanic American families living below the poverty level, compared with 11.7 percent of Asian American families and 9.7 percent of European American families (Gabe, 2013). Compared with European Americans, African Americans are more likely to have parents with less extensive educational backgrounds and to have less access to good nutrition, health care, and schools (Evans, 2004; W. J. Wilson, 1997). All of these conditions are likely to pull down scores on intelligence tests (e.g., Englund, Luckner, & Whaley, 2004; Lemos et al., 2011). Cultural factors may also contribute to differences among the average scores of various ethnic groups. For example, those differing averages may partly reflect differences in the degree to which parents in each group tend to encourage their children's academic achievement (Ryan et al., 2010; Steinberg, Dornbusch, & Brown, 1992).

The influence of environmental factors on the average black-white difference in IQ is supported by data from adoption studies. One such study involved African American children from disadvantaged homes who were adopted by middle- to upper-class European American families in the first years of their lives (Scarr & Weinberg, 1976). When measured

Helping with Homework

There are differences in the average IQs of European Americans and African Americans, but these differences are due in large measure to various environmental, social, and other nongenetic factors.

Andy Sacks/Stone/Getty Images

a few years later, the mean IQ of these children was 110. A comparison of this mean score with that of nonadopted children from similar backgrounds suggests that the new environment raised the children's IQs at least ten points. A ten-year follow-up study of these youngsters showed that their average IQ was still higher than the average of African American children raised in disadvantaged homes (Weinberg, Scarr, & Waldman, 1992).

As discussed in the chapter on human development, cultural factors may also contribute to differences among the mean scores of various ethnic groups. For example, those differing averages may partly reflect differences in the degree to which parents in each group tend to encourage their children's academic achievement (Al-Fadhli & Kersen, 2010; Ryan et al., 2010; Steinberg, Dornbusch, & Brown, 1992).

In short, it appears that some important nongenetic factors decrease the mean scores of African American and Hispanic American children. Whatever heredity might contribute to children's performance, under the right conditions it may be possible for them to improve.

Conditions That Can Raise IQ

As noted, environmental conditions can help or deter cognitive development (see the chapter on human development). For example, lack of caring attention or of normal intellectual stimulation can inhibit a child's mental growth. Low test scores have been linked to poverty, chaos, and noise in the home; poor schools; and inadequate nutrition and health care (Alaimo, Olson, & Frongillo, 2001; Kwate, 2001; Morrissey et al., 2014). Can the effects of bad environments be reversed? Not always, but efforts to intervene in the lives of children and enrich their environments have had some limited success. Conditions for improving children's performance include rewards for progress, encouragement of effort, and creation of expectations for success.

In the United States, the best-known attempt to enrich children's environments is Project Head Start, a set of programs established by the federal government in the 1960s to help preschoolers from lower-income backgrounds. In some of these programs, teachers visit the home and work with the child and parents on cognitive skills. In others, the children attend classes in nursery schools. Some programs emphasize health and nutrition and family mental health and social skills as well. Head Start has brought measurable benefits to children's health (Abbot-Shim, Lambert, & McCarty, 2003; Spernak et al., 2006), as well as improvements in their academic, intellectual, and language skills (e.g., Bierman, Domitrovich, et al., 2008; Bierman, Nix, et al., 2008).

Project Head Start

This teacher is working in Project Head Start, a U.S. government program designed to enrich the academic environments of preschoolers from lower-income backgrounds and improve their chances of succeeding in grade school.

Mark Richard/PhotoEdit

Do the gains achieved by preschool enrichment programs last? Although program developers sometimes claim long-term benefits (e.g., Christensen et al., 2014), these claims are disputed (e.g., Caputo, 2004; Mehr et al., 2013). Various findings from more than a thousand such programs are often contradictory, but the effect on IQ typically diminishes after a year or two (Woodhead, 1988). A study evaluating two of the better preschool programs concluded that their effects are at best only temporary (Locurto, 1991). These fading effects reflect the fact that IQ describes a person's performance compared with others of the same age. To keep the same IQ, a child must keep improving at the same rate as other children in the same age group (Kanaya, Scullin, & Ceci, 2003). So IQ will drop from year to year in children whose rate of cognitive growth falls behind that of their age-mates. This slowing in the cognitive growth rate is often seen when children leave special preschool programs and enter the substandard schools that often serve the poor (Finn-Stevenson & Zigler, 1999; Zigler & Muenchow, 1992).

Some beneficial effects have also been seen in programs such as the Abecedarian Project (Ramey, 1992). Children at risk for intellectual disabilities were identified while they were still in the womb. They then received five years of intense interventions to improve their chances of academic success. When they started school, children in this enrichment program had IQs that were seven points higher than those of at-risk children who were not in the program. At age twelve, they still scored higher on IQ tests, but the size of the difference at that time was just five points. Clear benefits in educational achievement, income, and social-emotional outcomes were still evident nearly two decades later (Campbell et al., 2012).

The primary benefit of early-enrichment programs probably lies in improving children's attitudes toward school (Woodhead, 1988). This can be an important benefit because, especially in borderline cases, children with favorable attitudes toward school may be less likely to be held back or placed in special education classes. Avoiding these experiences may in turn help children retain positive attitudes about school and enter a cycle in which gains due to early enrichment are maintained and amplified on a long-term basis.

THINKING CRITICALLY

ARE INTELLIGENCE TESTS UNFAIRLY BIASED AGAINST CERTAIN GROUPS?

We have seen that intelligence tests can have great value but also that IQ can be negatively affected by poverty, inferior educational opportunities, and other environmental factors. So there is concern that members of ethnic minorities and other disadvantaged groups have not had an equal chance to develop the knowledge and skills that are required to achieve high scores on IQ tests.

What am I being asked to believe or accept?

Some critics claim that standard intelligence tests are not fair. They argue that a disproportionately large number of people in some ethnic minority groups receive low scores on intelligence tests for reasons that are unrelated to cognitive ability, job potential, or other criteria that the tests are supposed to predict (Helms, 1997; Kwate, 2001; Neisser et al., 1996). They say that using ability and aptitude measures to make decisions about people—such as assigning them to particular jobs or special classes—may unfairly deprive members of some ethnic minority groups of equal employment or educational opportunities.

What evidence is available to support the assertion?

Research reveals several possible sources of bias in tests of cognitive abilities. First, as noted earlier, noncognitive factors such as anxiety, lack of motivation, or distrust can impair test performance and may put certain individuals at a disadvantage. For example, children from some minority groups may be less motivated to perform well on standardized tests and less

(*continued*)

likely to trust the adult tester (Steele, 1997). So differences in test scores may partly reflect motivational or emotional differences among various groups, not intellectual ones.

Second, many intelligence test items still reflect the vocabulary and experiences of the dominant middle-class culture in the United States. Individuals who are less familiar with the knowledge and skills valued by that culture will not score as well as those who are more familiar with them. Not all cultures value the same things, however (Sternberg & Grigorenko, 2004b). A study of Cree Indians in northern Canada revealed that words and phrases associated with *competence* included "good sense of direction"; at the *incompetent* end of the scale was the phrase "lives like a white person" (Berry & Bennett, 1992). A European American might not perform well on a Cree intelligence test based on these criteria. In fact, as illustrated in Table 8.2, poor performance on a culture-specific test is probably due more to unfamiliarity with culture-based concepts than to lack of cognitive ability. Compared with more traditional measures, "culture-fair" tests—such as the Universal Nonverbal Intelligence Test—that reduce dependence on oral skills do produce smaller differences between native English speakers and English-language learners (Bracken & McCallum, 1998).

TABLE 8.2 AN INTELLIGENCE TEST?

TRY THIS Take a minute to answer each of the following questions on this "intelligence test," and check your answers against the key at the bottom of page 277. If, like most people, you are unfamiliar with the material being tested by these rather obscure questions, your score will probably be low. Would it be fair to say, then, that you are not very intelligent?

1. What fictional detective was created by Leslie Charteris?
2. What dwarf planet travels around the sun every 248 years?
3. What vegetable yields the most pounds of produce per acre?
4. What was the infamous pseudonym of broadcaster Iva Toguri d'Aquino?
5. What kind of animal is Dr. Dolittle's pushmi-pullyu?

Third, some tests may reward individuals who interpret questions as expected by the test designer. Conventional intelligence tests have clearly defined "right" and "wrong" answers. Yet a person may interpret test questions in a manner that is "intelligent" or "correct" but that produces a "wrong" answer. For example, when one child was asked, "In what way are an apple and a banana alike?" he replied, "They both give me diarrhea." And when Liberian rice farmers were asked to sort objects, they tended to put a knife in the same group as vegetables. This was the clever way to do it, they said, because the knife is used to cut vegetables. When asked to sort the objects as a "stupid" person would, the farmers grouped the cutting tools together, the vegetables together, and so on, as most North Americans would (Segall et al., 1990). In other words, the fact that people don't give the answer that the test designer was looking for does not mean that they *can't* (which is why well-trained test administrators would ask for another answer before moving on).

Are there alternative ways of interpreting the evidence?

This same evidence might be interpreted as showing that although intelligence tests do not provide a pure measure of innate cognitive ability, they do provide a fair picture of whether a person has developed the skills necessary to succeed in school or in certain jobs. When some people have had more opportunity than others to develop their abilities, the difference will be reflected in their IQs. From this point of view, intelligence tests are fair measures of the cognitive abilities developed by people living in a society that, unfortunately, contains some unfair elements. In other words, the tests may be accurately detecting knowledge and skills

(*continued*)

that are not represented equally in all groups, but this doesn't mean that the tests discriminate *unfairly* among those groups.

To some observers, concern over cultural bias in intelligence tests stems from a tendency to think of IQ as a measure of innate ability. These psychologists suggest instead that intelligence tests are measuring ability that is developed and expressed in a cultural context—much as athletes develop the physical skills needed to play certain sports (Lohman, 2004). Eliminating language and other cultural elements from intelligence tests, they say, would eliminate a vital part of what the term *intelligence* means in any culture (Sternberg, 2004). This may be why "culture-fair" tests do not predict academic achievement as well as conventional intelligence tests do (Aiken, 1994; Lohman, 2005). Perhaps familiarity with the culture reflected in intelligence tests is just as important for success at school or work in that culture as it is for success on the tests themselves. After all, the ranking among groups on measures of academic achievement is similar to the ranking for average IQs (Sue & Okazaki, 1990).

What additional evidence would help evaluate the alternatives?

If the problem of test bias is really a reflection of differences between various groups' opportunities to develop their cognitive skills, it will be important to conduct research on interventions that can reduce those differences. Making "unfair" cultures fairer by enhancing the skill development opportunities of traditionally disadvantaged groups should lead to smaller differences between groups on tests of cognitive ability (Martinez, 2000). It will also be important to find better ways to encourage members of disadvantaged groups to take advantage of those opportunities (Sowell, 2005).

At the same time, alternative tests of cognitive ability must also be explored, particularly those that include assessment of problem-solving skills and other abilities not measured by most intelligence tests (e.g., Sternberg & Kaufman, 1998). If new tests show smaller between-group differences than traditional tests but have equal or better predictive validity, many of the issues discussed in this section will have been resolved. So far, efforts in this direction have not been successful.

What conclusions are most reasonable?

The effort to reduce unfair cultural biases in tests is well founded, but "culture-fair" tests will be of little benefit if they fail to predict academic or occupational success as well as traditional tests do (Anastasi & Urbina, 1997; Sternberg, 1985). Whether one considers this situation good or bad, fair or unfair, the fact remains that it is important for people to have the information and skills that are valued by the culture in which they live and work. So it seems reasonable to continue using conventional cognitive ability tests as long as they accurately measure the skills and knowledge that people need for success in their culture.

In other words, there is probably no value-free, experience-free, or culture-free way to measure the construct known as intelligence when that construct is defined by the behaviors that a culture values and that are developed through experience in that culture (Sternberg, 1985, 2004). This conclusion has led some researchers to worry less about how cultural influences might "contaminate" tests of innate cognitive abilities and to focus instead on how to help people develop the abilities that are required for success in school and society. As mentioned earlier, if more attention were focused on combating poverty, poor schools, inadequate nutrition, lack of health care, and other conditions that result in lower average IQs and reduced economic opportunities for certain groups of people, many of the reasons for concern about test bias might be eliminated.

The Bottom Line on IQ Tests

IQ tests have been criticized for being biased and for labeling people on the basis of scores or profiles. ("In Review: Influences on IQ" lists the factors that can shape IQ.) "Summarizing" a person with a score on an IQ test does indeed run the risk of oversimplifying reality and making errors. But intelligence tests can also *prevent* errors. Specifically, they can reduce the chances that inaccurate stereotypes, false preconceptions, and faulty generalizations will influence important educational and employment decisions. For example, boredom or lack of motivation at school might make a child appear mentally slow or perhaps even intellectually disabled. But a test of cognitive abilities conducted under the right conditions is likely to reveal the child's potential. The test can prevent the mistake of moving a child of average intelligence to a class for children with intellectual disabilities. And as Alfred Binet had hoped, intelligence tests have been enormously helpful in identifying children who need special educational attention. So despite their limitations and potential for bias, IQ tests can minimize the likelihood of assigning children to remedial work they do not need or to advanced work they cannot yet handle.

IN REVIEW

INFLUENCES ON IQ

Source of Effect	Description	Examples of Evidence for Effect
Genetics	Genes appear to play a significant role in differences among people on intelligence test performance.	The IQs of siblings who share no common environment are positively correlated. There is a greater correlation between scores of identical twins than between those of nonidentical twins.
Environment	Environmental conditions interact with genetic inheritance. Nutrition, medical care, sensory and intellectual stimulation, educational experiences, interpersonal relations, and influences on motivation are all significant features of the environment.	IQs have risen among children who are adopted into homes that offer a stimulating, enriching environment. Correlations between IQs of identical twins reared together are higher than for those reared apart.

1. Intelligence is influenced by both __________ and __________.
2. Children living in poverty tend to have __________ IQs than those in middle-income families.
3. IQs of children whose parents encourage learning tend to be __________ than those of children whose parents do not.

DIVERSITY IN INTELLIGENCE

Is there more than one type of intelligence?

Intelligence test scores can tell us some things—and predict some things—about people, but we have seen that they don't tell the whole story of intelligence. Let's see how diverse intelligence can be by looking at some of the ways in which psychological scientists have approached it.

The Psychometric Approach

Standard intelligence tests are associated with **psychometrics**, the scientific study and measurement of knowledge, abilities, attitudes, personality, and other psychological characteristics. The **psychometric approach** to intelligence focuses on the *products* of

psychometrics The scientific study and measurement of knowledge, abilities, attitudes, personality, and other psychological characteristics.

psychometric approach A way of studying intelligence that emphasizes analysis of the products of intelligence, especially scores on intelligence tests.

Answers to Table 8.2: (1) Simon Templar; (2) Pluto; (3) cabbage; (4) Tokyo Rose; (5) a two-headed llama.

intelligence, including scores on IQ tests. Researchers taking this approach ask whether intelligence is one general trait or a bundle of more specific abilities. The answer matters, because if intelligence is a single trait, then an employer might assume that someone with a low IQ could not do any tasks well. But if intelligence is composed of many abilities that are somewhat independent of one another, then a poor showing in one area—say, imagining the rotation of objects in space—would not rule out good performance in others, such as understanding information or solving mathematical word problems.

Early in the twentieth century, the writings of statistician Charles Spearman began the modern debate about the nature of intelligence. Spearman noticed that scores on almost all tests of cognitive abilities were positively correlated (Spearman, 1904, 1927). That is, people who did well on one test also tended to do well on all of the others. Spearman concluded that these correlations were created by general cognitive ability, which he called ***g***, for *general intelligence*, and a group of special intelligences, which he collectively referred to as ***s***. The *s* factors, he said, are the specific information and skills needed for particular tasks. Raymond B. Cattell (1963) agreed with Spearman, but his own factor analyses suggested two kinds of *g*. **Fluid intelligence**, he said, is the basic power of reasoning and problem solving. **Crystallized intelligence**, in contrast, involves specific knowledge gained as a result of applying fluid intelligence. It produces, for example, a good vocabulary and familiarity with the multiplication tables.

After decades of research and debate, most psychologists today agree that there is a positive correlation among various tests of cognitive ability, a correlation that is attributed to the *g* factor (e.g., Carroll, 1993; Frey & Detterman, 2004). Further, it appears that the *g* factor can be measured by many different groups of cognitive tests, even if the tests in each group are entirely different (Johnson et al., 2004). However, the brain probably does not contain some unified "thing" corresponding to what people call intelligence. Instead, cognitive abilities appear to be organized in "layers," beginning with as many as fifty or sixty narrow and specific skills that can be grouped into seven or eight more general ability factors, all of which combine into *g*, the broadest and most general of all (e.g., Carroll, 1993; Kievit et al., 2012; Lubinski, 2004; Unsworth et al., 2014). Understanding *g* and how it arises is a major goal of research in cognitive psychology and brain research (e.g., Bouchard, 2014; Garlick, 2002; Hampshire et al., 2012; Reynolds, 2013).

Intelligence as Information Processing

As described in the chapter on thought and language, many cognitive psychologists see the brain as an information-processing system that receives and works on information in ways that allow us to think, remember, and engage in other cognitive activities. When applied to the concept of intelligence, this **information-processing model** focuses on identifying the mental *processes* involved in intelligent behavior, not the abilities that result in test scores and other *products* of intelligence. Researchers taking this information-processing approach ask, What mental operations are necessary to perform intellectual tasks? What aspects depend on past learning, and what aspects depend on attention, working memory, and processing speed? Are there individual differences in these processes that correlate with measures of intelligence? More specifically, are measures of intelligence related to differences in the amount of attention people have available for basic mental processes or in the speed of those processes?

As discussed in the chapter on sensation and perception, attention represents a pool of resources or mental energy. When people perform difficult tasks or perform more than one task at a time, they must call on greater amounts of these resources. Early research by Earl Hunt (1980) suggests that people with greater intellectual ability have more attentional resources available. There is also evidence of a positive correlation between IQ and performance on tasks requiring attention, such as silently counting the number of words in the "animal" category while reading a list of varied terms aloud (Stankov, 1989).

Another possible link between differences in information processing and differences in intelligence relates to processing speed. Perhaps more intelligent people just have "faster

g A general intelligence factor that Charles Spearman postulated as accounting for positive correlations between people's scores on all sorts of cognitive ability tests.

s A group of special abilities that Charles Spearman saw as accompanying general intelligence (*g*).

fluid intelligence The basic power of reasoning and problem solving.

crystallized intelligence The specific knowledge gained as a result of applying fluid intelligence.

information-processing model An approach to the study of intelligence that focuses on mental operations, such as attention and memory, that underlie intelligent behavior.

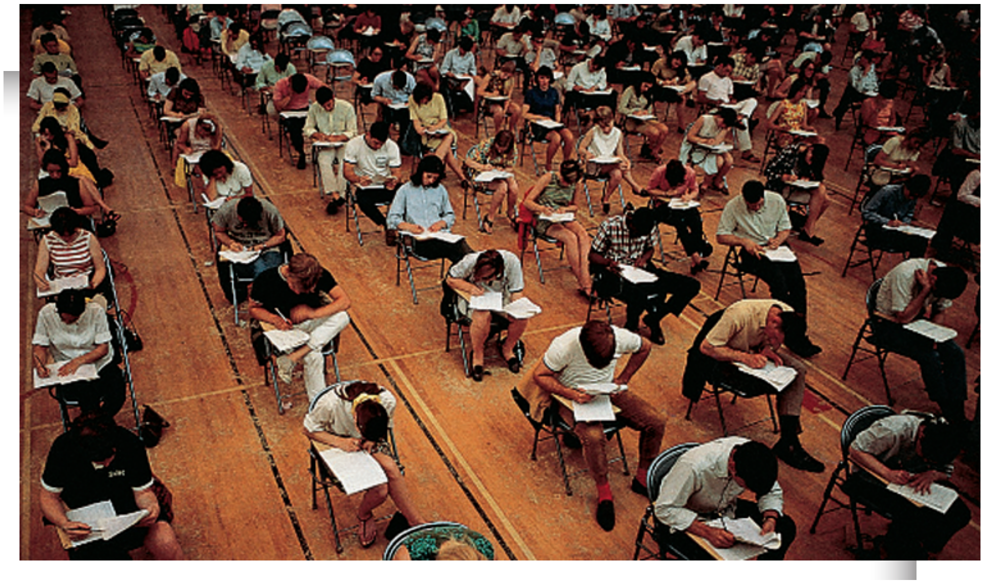
brains." When a task is complex, having a "fast brain" might reduce the chance that information will fade from memory before it can be used (Jensen, 1993; Larson & Saccuzzo, 1989). With this view in mind, some researchers have attempted to measure various aspects of intelligence by looking at activity in particular parts of the brain (e.g., Colom, Jung, & Haier, 2006; Gläscher et al., 2010; Koten et al., 2009).

Evidence that better performance on intellectual tasks is related to more efficient information processing (Koten et al., 2009; Neubauer & Fink, 2009; Rypma & Prabhakaran, 2009) highlights the role of brain processes in intelligence, but it probably doesn't tell the whole story. Other research suggests that only a portion of the variation seen in people's performance on cognitive abilities tests can be accounted for by differences in their speed of access to long-term memory, the capacity of short-term and working memory, or other information-processing abilities (Baker, Vernon, & Ho, 1991; Friedman et al., 2006; Miller & Vernon, 1992).

The Triarchic Theory of Intelligence

Robert Sternberg's *triarchic theory* of intelligence (1988b, 1999) proposes three different types of intelligence: analytic, creative, and practical. *Analytic intelligence,* the kind that is measured by traditional intelligence tests, would help you solve a physics problem; *creative intelligence* is what you would use to compose music; and you would draw on *practical intelligence* to figure out what to do if you were stranded on a lonely road during a blizzard.

Sternberg recognizes that analytic intelligence is important for success at school and in other areas, but he argues that universities and employers should not select people solely on the basis of tests of this kind of intelligence (Sternberg, 1996; Sternberg & Williams, 1997). Why? Because the tasks posed by tests of analytic intelligence are often of little interest to the people taking them and typically have little relationship to their daily experience. For one thing, each task is usually clearly defined and comes with all the information needed to find the one right answer (Neisser et al., 1996), a situation that seldom occurs in the real world. The practical problems people face every day are generally of personal interest and are related to more common life experiences. That is, they are ill defined and do not contain all the information necessary to solve them, they typically have more than one correct solution, and there may be several paths to a solution (Sternberg et al., 1995).



Brainpower and Intelligence

The information-processing model of intelligence suggests that people with the most rapid information processors—the "fastest" brains—should do best on cognitive ability tests, including intelligence tests and college entrance exams. Research suggests that there is more to intelligent behavior than sheer processing speed, though.

Stephen Collins/Science Source

It is no wonder, then, that some children who do poorly in school may nevertheless show high degrees of practical intelligence, including—as in the case of Brazilian street children—the ability to live by their wits in hostile environments (Carraher, Carraher, & Schliemann, 1985). Some racetrack bettors whose IQs are as low as 82 are experts at predicting race odds at post time by combining many different kinds of complex information about horses, jockeys, and track conditions (Ceci & Liker, 1986). In these particular cases, practical intelligence appears almost unrelated to the analytic intelligence measured by traditional cognitive tests, but research with larger populations shows that there is actually a significant correlation between the two (Gottfredson, 2003).

Sternberg's theory is important because it extends the concept of intelligence into areas that most psychologists have traditionally not examined and because it emphasizes what intelligence means in everyday life. The theory is so broad, however, that many parts of it are difficult to test. For example, methods for measuring practical "street smarts" have been proposed (Sternberg, 2001; Sternberg et al., 1995), but they remain controversial (Brody, 2003; Gottfredson, 2003). Sternberg and his colleagues have also developed new intelligence tests designed to assess analytic, practical, and creative intelligence (see Figure 8.5), and they offer evidence that scores on these tests can predict success in college and at some jobs at least as well as standard intelligence tests (Sternberg & Kaufman, 1998; Sternberg & Rainbow Project, 2006). Other researchers have questioned this interpretation (Brody, 2003). The value of these newer tests, they say, may be due in part to the correlation between practical and analytic intelligence. To some extent, the newer tests may be measuring the same thing as the older ones (Gottfredson, 2003).

FIGURE 8.5
Testing for Practical and Creative Intelligence

TRY THIS Robert Sternberg argues that traditional tests measure mainly analytic intelligence. Here are sample items from tests he developed to test both practical and creative intelligence. Try answering them before you check the answers at the bottom of page 283. How did you do?

PRACTICAL

1. Think of a problem that you are currently experiencing in real life. Briefly describe the problem, including how long it has been present and who else is involved (if anyone). Then describe three different practical things you could do to try to solve the problem. *(Students are given up to 15 minutes and up to 2 pages.)*

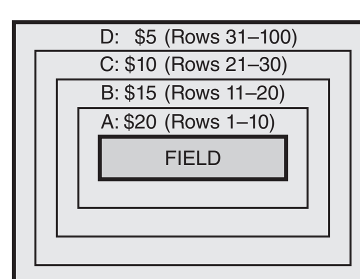
2. Choose the answer that provides the **best** solution, given the specific situation and desired outcome.

John's family moved to Iowa from Arizona during his junior year in high school. He enrolled as a new student in the local high school two months ago but still has not made friends and feels bored and lonely. One of his favorite activities is writing stories. What is likely to be the most effective solution to this problem?

A. Volunteer to work on the school newspaper staff.
B. Spend more time at home writing columns for the school newsletter.
C. Try to convince his parents to move back to Arizona.
D. Invite a friend from Arizona to visit during Christmas break.

3. This question asks you to use information about everyday things. Read the question carefully and choose the best answer.

Mike wants to buy two seats together and is told there are pairs of seats available only in Rows 8, 12, 49, and 95–100. Which of the following is not one of his choices for the total price of the two tickets?



A. $10. **B.** $20. **C.** $30. **D.** $40.

FIGURE 8.5 (*continued*)

CREATIVE

1. Suppose you are the student representative to a committee that has the power and the money to reform your school system. Describe your ideal school system, including buildings, teachers, curriculum, and any other aspects you feel are important. *(Students are given up to 15 minutes and up to 2 pages.)*

2. Each question has a "Pretend" statement. You must suppose that this statement is true. Decide which word goes with the third underlined word in the same way that the first two underlined words go together.

Colors are audible.

flavor is to tongue as shade is to

A. ear. **B.** light. **C.** sound. **D.** hue.

3. First, read how the operation is defined. Then, decide what is the correct answer to the question.

There is a new mathematical operation called **flix.**
It is defined as follows:

A flix B = A + B, if A > B

but A flix B = A x B, if A < B

and A flix B = A / B, if A = B

How much is 4 flix 7?

A. 28. **B.** 11. **C.** 3. **D.** –11.

Multiple Intelligences

Some people whose IQs are only average, or even below average, may have exceptional ability in certain specific areas. One child whose IQ was just 50 could correctly state the day of the week for any date between 1880 and 1950 (Scheerer, Rothmann, & Goldstein, 1945). He could also play melodies on the piano by ear and sing Italian operatic pieces he had heard. In addition, he could spell—forward or backward—any word spoken to him and could memorize long speeches, although he had no understanding of what he was doing.

Cases such as this are part of the evidence cited by Howard Gardner in support of his theory of *multiple intelligences* (Gardner, 1993, 2002). To study intelligence, Gardner focuses on how people learn and use symbol systems such as language, mathematics, and music. He asks, Do these systems all require the same abilities and processes, the same "intelligence"? According to Gardner, the answer is no. All people, he says, possess a number of intellectual potentials, or intelligences, each of which involves a somewhat different set of skills. Biology provides raw capacities; cultures provide symbolic systems—such as language—to use those raw capacities. Although the intelligences normally interact, they can function with some independence, and individuals may develop certain intelligences further than others. ("In Review: Approaches to Intelligence" summarizes Gardner's theory, along with the other views of intelligence we have discussed.)

The specific intelligences that Gardner (1999) proposes are (1) *linguistic* intelligence (reflected in good vocabulary and reading comprehension), (2) *logical-mathematical*

A Musical Prodigy?

According to Gardner's theory of multiple intelligences, skilled artists, athletes, and musicians—such as the young flutist shown here—display forms of intelligence not assessed by standard intelligence tests.

Comstock Images/Alamy

intelligence (as indicated by skill at arithmetic and certain kinds of reasoning), (3) *spatial* intelligence (seen in the ability to visualize relationships among objects in the environment), (4) *musical* intelligence (as in abilities involving rhythm, tempo, and sound identification), (5) *body-kinesthetic* intelligence (reflected in skill at dancing, athletics, and eye-hand coordination), (6) *intrapersonal* intelligence (displayed by self-understanding), (7) *interpersonal* intelligence (seen in the ability to understand and interact with others), and (8) *naturalistic* intelligence (the ability to see patterns in nature). Other researchers have suggested that people also possess *emotional* intelligence, which involves the capacity to perceive, use, understand, and manage their emotions (Meyer & Salovey, 1997; Salovey & Grewal, 2005). Gardner says that traditional intelligence tests sample only the first three of these intelligences, mainly because these are the forms of intelligence most valued in school. To measure intelligences not tapped by standard tests, Gardner suggests collecting samples of children's writing, assessing their ability to appreciate or produce music, and obtaining teacher reports of their strengths and weaknesses in athletic and social skills (Gardner, 1991).

Gardner's view of intelligence is appealing, partly because it allows virtually everyone to be highly intelligent in at least one way. However, his critics argue that including athletic or musical skill dilutes the validity and usefulness of the intelligence concept, especially as it is applied in school and in many kinds of jobs. They suggest that intrapersonal, interpersonal, body-kinesthetic, and naturalistic abilities are best described as collections of specific skills. Therefore, it makes more sense to speak of, say, "interpersonal skills" rather than "interpersonal intelligence." At the moment, Gardner's theory lacks the empirical evidence necessary to challenge other, more established theories of intelligence (Klein, 1997; Waterhouse, 2006a, 2006b). This is true in part because there are still no dependable measures of the various intelligences he proposes (Lubinski & Benbow, 1995; Visser, Ashton, & Vernon, 2006). Until and unless such measures are developed, say Gardner's critics, his theory will be of little scientific value.

IN REVIEW

APPROACHES TO INTELLIGENCE

Approach	Method	Key Findings or Propositions
Psychometric	Define the structure of intelligence by examining factor analyses of the correlations between scores on tests of cognitive abilities.	Performance on many tests of cognitive abilities is highly correlated, but this correlation, represented by g, reflects a bundle of abilities, not just one trait.

(*continued*)

IN REVIEW

APPROACHES TO INTELLIGENCE (CONT.)

Approach	Method	Key Findings or Propositions
Information processing	Understand intelligence by examining the mental operations involved in intelligent behavior.	The speed of basic cognitive processes and the amount of attentional resources available make significant contributions to performance on intelligence tests.
Sternberg's triarchic theory	Understand intelligence by examining the information processing involved in thinking, changes with experience, and effects in different environments.	There are three distinct kinds of intelligence: analytic, creative, and practical. Intelligence tests measure only analytic intelligence, but creative intelligence (which involves dealing with new problems) and practical intelligence (which involves adapting to one's environment) may also be important to success in school and at work.
Gardner's theory of multiple intelligences	Understand intelligence by examining test scores, information processing, biological and developmental research, the skills valued by different cultures, and exceptional people.	Biology provides the capacity for eight distinct "intelligences": linguistic, logical-mathematical, spatial, musical, body-kinesthetic, intrapersonal, interpersonal, and naturalistic.

In Review Questions

1. The concepts of fluid and crystallized intelligence developed from research on the ___________ approach to intelligence.
2. Using fMRI scanning to relate memory skills to intelligence reflects the ___________ approach to intelligence.
3. Which theory of intelligence highlights the fact that some people with low IQs can still succeed at complex tasks of daily living?

FOCUS ON RESEARCH METHODS

TRACKING COGNITIVE ABILITIES OVER THE LIFE SPAN

LINKAGES Which research designs are best for studying changes in cognitive abilities as people age? (a link to Research in Psychology)

As described in the chapter on human development, significant changes in cognitive abilities occur from infancy through adolescence, but development does not stop there. One major study has focused specifically on the changes in cognitive abilities that occur during adulthood.

What was the researchers' question?

The researchers began by asking what appears to be a relatively simple question: How do adults' cognitive abilities change over time?

(*continued*)

Answers to Figure 8.5: Practical (2) A, (3) B. Creative: (2) A, (3) A.

How did the researchers answer the question?

Answering this question is extremely difficult because findings about age-related changes in cognitive abilities depend to some extent on the methods that are used to observe those changes. None of the methods include true experiments, because psychologists cannot randomly assign people to be a certain age and then give them mental tests. So changes in cognitive abilities must be explored through a number of other research designs.

One of these, the *cross-sectional study,* compares data collected at the same point in time from people of different ages. However, cross-sectional studies contain a major confounding variable: Because people are born at different times, they may have had very different educational, cultural, nutritional, and medical experiences. This confounding variable is referred to as a *cohort effect.* Suppose that two cohorts, or age groups, are tested on their ability to imagine the rotation of an object in space. The cohort born around 1940 might not do as well as the one born around 1980, but does the difference reflect declining spatial ability in the older people? It might, but it might also be due in part to the younger group's greater experience with video games and other spatial tasks. In other words, differences in experience, and not just age, could account for differences in ability between older and younger people in a cross-sectional study.

Changes associated with age can also be examined through *longitudinal studies,* in which people are repeatedly tested as they grow older. But longitudinal designs, too, have some built-in problems. For one thing, fewer and fewer members of an age cohort can be tested over time as death, physical disability, relocation, and lack of interest reduce the sample size. Researchers call this problem the *mortality effect.* Further, the remaining members are likely to be the healthiest in the group and may also have retained better mental powers than the dropouts. As a result, longitudinal studies may underestimate the degree to which abilities decline with age. Another confounding factor can come from the *history effect.* Here, some event—such as a reduction in health care benefits for senior citizens—might have an effect on cognitive ability scores that is mistakenly attributed to age. Finally, longitudinal studies may be confounded by *testing effects,* meaning that participants may improve over time because of what they learn during repeated testing procedures.

As part of the Seattle Longitudinal Study of cognitive aging, K. Warner Schaie (1993) developed a research design that measures the impact of the confounding variables we have discussed and allows corrections to be made for them. In 1956, Schaie identified a random sample of five thousand members of a health maintenance organization (HMO) and invited some of them to volunteer for his study. The volunteers, who ranged in age from twenty to eighty, were given a set of intelligence tests designed to measure certain primary mental abilities (PMA). The cross-sectional comparisons allowed by this first step were, of course, confounded by cohort effects. To control for those effects, the researchers retested the same participants seven years later, in 1963. This design allowed the researchers to compare the size of the *difference* in PMA scores between, say, the twenty-year-olds and twenty-seven-year-olds tested in 1956 with the size of the *change* in PMA scores for these same people as they aged from twenty to twenty-seven and from twenty-seven to thirty-four. Schaie reasoned that if the size of the longitudinal change was about the same as the size of the cross-sectional difference, the cross-sectional difference could probably be attributed to aging, not to the era in which the participants were born.

To measure the impact of testing effects, the researchers randomly drew a new set of participants from their original pool of five thousand. These people were of the same age range as the first sample, but they had not yet been tested. If people from the first sample did better on their second PMA testing than the people of the same age who now took the PMA for the first time, a testing effect would be suggested. To control for history effects, the researchers examined the scores of people who were the same age in different years. For example, they compared people who were thirty in 1956 with those who were thirty in 1963, people who were forty in 1956 with those who were forty in 1963, and so on. If PMA scores were the same for people of the same age no matter what year they were tested, it is unlikely that events that happened in any particular year would have influenced test results. The researchers tested participants multiple times between 1956 and 1999 (Gerstorf et al., 2011). On each occasion, they retested some previous participants and tested others for the first time.

(*continued*)

The Voice of Experience

Even in old age, people's crystallized intelligence may remain intact. Their extensive storehouse of knowledge, experience, and wisdom makes older people a valuable resource for the young.

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What did the researchers find?

The results of the Seattle Longitudinal Study and other, more limited longitudinal studies suggest a reasonably consistent conclusion: Unless people are impaired by Alzheimer's disease or other brain disorders, most of their cognitive abilities usually decline very slightly between early adulthood and old age. Some aspects of crystallized intelligence, which depends on retrieving information and facts about the world from long-term memory, may remain robust well into old age. Other components of intelligence, however, may have failed quite noticeably by the time people reach sixty-five or seventy. Fluid intelligence, which involves rapid and flexible manipulations of ideas and symbols, is the most likely to decline (Bugg et al., 2006; Gilmore, Spinks, & Thomas, 2006; Schaie, 1996). The decline shows up in the following areas:

1. *Working memory*. The ability to hold and organize material in working memory declines beyond age fifty or sixty, particularly when attention must be redirected (e.g., Fandakova et al., 2014).
2. *Processing speed*. There is a general slowing of all mental processes (e.g., Manard et al., 2014; Stawski, Silwinski, & Hofer, 2013).
3. *Organization*. Older people seem to be less likely to solve problems by adopting specific strategies, or mental shortcuts (Charness, 2000). The tests carried out by older people tend to be more random and haphazard (Young, 1971). This result may occur partly because many older people are out of practice at solving such problems.
4. *Flexibility*. Older people tend to be less flexible than younger people in problem solving (Johnco, Wuthrich, & Rapee, 2013).
5. *Control of attention*. The ability to direct or control attention declines with age (Kramer et al., 1999). Older adults tend to be overwhelmed by distracting information, which may help account for many of the cognitive problems accompanying aging (Gazzaley et al., 2005).

What do the results mean?

This study indicates that different kinds of cognitive abilities change in different ways throughout our lifetimes. In general, there is a gradual, continual accumulation of knowledge about the world, some systematic changes in the limits of cognitive processes, and changes

(*continued*)

in the way those processes are carried out. This finding suggests that a general decline in cognitive abilities during adulthood is neither inevitable nor universal (Richards et al., 2004).

What do we still need to know?

There is an important question that Schaie's study doesn't answer: Why do age-related changes in cognitive abilities occur? Some researchers suggest that these changes are largely due to a decline in the speed and accuracy with which older people process information (Li et al., 2004; Salthouse, 2000). If this interpretation is correct, it would explain why some older people are less successful than younger ones at tasks that require rapidly integrating several pieces of information in working memory prior to making a choice or a decision.

It is also vital to learn why some people do *not* show declines in cognitive abilities, even when they reach their eighties. By understanding the biological and psychological factors responsible for these exceptions to the general rule, we might be able to reverse or delay some of the intellectual consequences of growing old.

Unusual Intelligence

Psychologists' understanding of intelligence has been advanced by studying people whose intelligence is unusual—especially the gifted and the intellectually disabled (Robinson, Zigler, & Gallagher, 2000).

Giftedness

People who show remarkably high levels of accomplishment in particular areas are often referred to as gifted (Guénolé et al., 2013). Giftedness is typically measured by school achievement. A child's potential for high achievement is usually measured by intelligence tests, but researchers warn that it is risky to predict academic potential from a single measure, such as IQ (Hagen, 1980; Lohman & Hagen, 2001; Thorndike & Hagen, 1996).

For one thing, not all people with unusually high IQs become famous and successful in their chosen fields, although they are more likely than others to do so. One of the best-known studies of the intellectually gifted was conducted by Lewis Terman and his colleagues (Oden, 1968; Terman & Oden, 1947, 1959). This study began in 1921 with the identification of more than 1,500 boys and girls whose IQs were very high—most higher than 135 by age ten. Periodic interviews and tests over the next seventy years revealed that few, if any, became world-famous scientists, inventors, authors, artists, or composers. But only eleven failed to graduate from high school, and more than two-thirds graduated from college—this at a time when completing a college education was relatively rare, particularly for women. Ninety-seven went on to earn Ph.D.s; ninety-two, law degrees; and fifty-seven, medical degrees. In 1955, their median family income was well above the national average (Terman & Oden, 1959).

In general, people with higher IQs were physically and mentally healthier than the general population and appeared to have led happier lives (Ali et al., 2013; Cronbach, 1996). Several more recent studies also show that people with higher IQs tend to live longer (e.g., Deary & Batty, 2011; Ghirlanda, Enquist, & Lind, 2014; Hagger-Johnson et al., 2012), perhaps because they have the reasoning and problem-solving skills that lead them to take better care of themselves and avoid danger (e.g., Calvin et al., 2011; Deary & Der, 2005b; Hall et al., 2009; see the Focus on Research Methods section in the chapter on health, stress, and coping).

In other words, higher IQs tend to predict greater success in life (Lubinski et al., 2006; Simonton & Song, 2009), but an extremely high IQ does not guarantee special distinction. Some research suggests that gifted children are not fundamentally different kinds of people. They just have more of the same basic cognitive abilities seen in all children (Dark & Benbow, 1993; Singh & O'Boyle, 2004). Other work suggests that gifted people may be different in other ways, too, such as having unusually intense curiosity or motivation to master certain tasks or areas of intellectual endeavor (e.g., Lubinski et al., 2001; Nicpon & Pfeiffer, 2011). Whatever the case, there is broad support for the idea that giftedness is something that can and should be encouraged and developed (Dai, Swanson, & Cheng, 2011; Subotnik, Olszewski-Kubilius, & Worrell, 2011).

Intellectual Disability

intellectual development disorder Defined in DSM-5 as an IQ at or below 70, starting in childhood, and affecting a person's ability to function as compared to other people of the same age.

People whose IQs are lower than about 70 and who fail to display the skills at daily living, communication, and other tasks that are expected of those their age were once described as mentally retarded (American Psychiatric Association, 1994). They might now more often be said to be mentally challenged or to have a developmental disability, an intellectual disability, or a developmental delay (Schalock et al., 2009). The new Diagnostic and Statistical Manual (DSM-5, American Psychiatric Association) describes these people as having an **intellectual development disorder**. This diagnosis is given not only on the basis of a low measured IQ, but also on whether that measurement was made in childhood and whether there is evidence of impairment in day-to-day functioning. As a result, people in this very broad category differ greatly in their cognitive abilities and in their ability to function independently in daily life (see Table 8.3).

TABLE 8.3 CATEGORIES OF INTELLECTUAL DISABILITY

These categories are approximate. Especially at the upper end of the scale, many intellectually disabled people can learn to handle tasks well beyond what their IQ might have predicted. Thus, a given IQ score does not automatically guarantee a certain level of function in society. Many people with IQs lower than 70 can function adequately in their communities and so would not be diagnosed with an intellectual development disorder.

Level of Intellectual Disability	IQ Range	Characteristics
Mild	50–70	A majority of all intellectually disabled people. Many live independently, marry, and maintain skilled employment with training. May have difficulty with academics, abstract reasoning, risk evaluation, and problem solving. May need support for complex tasks such as home organization, money management, child care, and health care.
Moderate	35–49	With extended training and time, some people can manage personal needs (hygiene, eating) and household tasks independently. May maintain employment with limited responsibilities, but could need help with ancillary job-related duties (scheduling, transportation, money management), as well as with other personal responsibilities such as health care, social judgments, communication, and decision making.
Severe	20–34	Can participate in household tasks with ongoing training and supervision. Most need support for much of their self-care. Relationships usually limited to family and caregivers. Speech is usually limited to simple vocabulary, focused on immediate circumstances. Most require constant supervision.
Profound	Below 20	Dependent on caregivers for self-care and for household tasks, but may be able to participate in some tasks if assisted. Motor and sensory impairments limit many goal-directed actions. Sometimes can understand simple verbal communication, but self-expression is mostly nonverbal. Can often enjoy close familial and caregiver relationships. Require constant supervision.

The Eagle Has Landed

In February 2000, Richard Keebler, twenty-seven, became an Eagle Scout, the highest rank in the Boy Scouts of America. His achievement is notable not only because only 4 percent of all Scouts reach this pinnacle but also because Keebler has Down syndrome. As we come to better understand the potential, not just the limitations, of people with intellectual disabilities, their opportunities and their role in society will continue to expand.

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Some cases of intellectual disability have a clearly identifiable cause. The best-known example is *Down syndrome*, which occurs when an abnormality during conception results in an extra copy of chromosome 21 (Kleschevnikov et al., 2012). Children with Down syndrome typically have IQs in the range of 40 to 55, though some may score higher than that. There are also several inherited causes of intellectual disability. The most common of these is *fragile X syndrome,* a defect on chromosome 23 (known as the *X chromosome*) (Hunter et al., 2014). More rarely, intellectual disability is caused by inheriting *Williams syndrome* (a defect on chromosome 7) or by inheriting a gene for *phenylketonuria,* or PKU (which causes the body to create toxins out of milk and other foods). Intellectual disability can also result from environmental causes, such as exposure to German measles (rubella), alcohol, or other toxins before birth; oxygen deprivation during birth; and head injuries, brain tumors, and infectious diseases (such as meningitis or encephalitis) in childhood (U.S. Surgeon General, 1999).

Psychosocial intellectual disability refers to the 30 to 40 percent of (usually mild) cases of intellectual disability that have no obvious genetic or environmental cause (American Psychiatric Association, 1994). These cases appear to result from a complex and as yet unknown interaction between heredity and environment that researchers are continuing to explore (Croen, Grether, & Selvin, 2001; Spinath, Harlaar et al., 2004).

People who have mild intellectual disability differ from other people in three important ways (Campione, Brown, & Ferrara, 1982):

1. They perform certain mental operations more slowly, such as retrieving information from long-term memory. When asked to repeat something they have learned, they are not as quick as a person of normal intelligence.
2. They know fewer facts about the world. It is likely that this deficiency is a consequence of the problem listed next.
3. They are not very good at using certain mental strategies that may be important in learning and problem solving. For example, they do not remember to rehearse material that must be held in short-term memory, even though they know how to do so.

Despite such difficulties, the cognitive abilities of intellectually disabled people can be improved to some extent. One program that emphasized positive parent-child communications began when the children were as young as two and a half years old. It helped children with Down syndrome to eventually master reading skills at a second-grade level, providing the foundation for further achievement (Rynders & Horrobin, 1980; Turkington, 1987). However, designing effective programs for children who are intellectually disabled is complicated by the fact that learning does not depend on cognitive skills alone. It also depends on social and emotional factors, including where children learn. Much debate has focused on *mainstreaming* and *inclusive education*, which involve teaching children with disabilities, including those who are intellectually disabled, in regular classrooms alongside children without disabilities. A number of studies comparing the cognitive and social skills of children who have been mainstreamed and those who were separated show few significant differences overall. However, it does appear that students at higher ability levels may gain more from being mainstreamed than their less mentally able peers. There are also advantages for them in terms of self-esteem, friendships, and social support (e.g., Huck, Kemp, & Carter, 2010; Mills et al., 1998; Pati, 2011; Vianello & Lanfranchi, 2011).

psychosocial intellectual disability Cases of mild cognitive disability for which there is no obvious genetic or environmental cause.

LINKAGES

As noted in the chapter on introducing psychology, all of psychology's many subfields are related to one another. Our discussion of test anxiety illustrates just one way in which the topic of this chapter, intelligence, is linked to the subfield of motivation and emotion (which is the focus of the chapter by that name). The Linkages diagram shows ties to two other subfields as well, and there are many more ties throughout the book. Looking for linkages among subfields will help you see how they all fit together and better appreciate the big picture that is psychology.

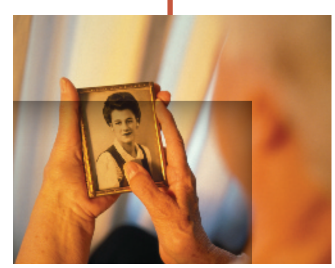
CHAPTER 8 Intelligence

LINKAGES

Which research designs are best for studying changes in cognitive abilities as people age?

CHAPTER 2
Research Methods in Psychology

Is intellectual disability mainly a matter of poor memory?



CHAPTER 6
Memory

How does excessive emotional arousal affect scores on tests of cognitive ability?

CHAPTER 10
Motivation and Emotion

SUMMARY

Intelligence refers to the capacity to perform higher mental processes, such as reasoning, remembering, understanding, problem solving, and decision making.

Testing for Intelligence

How is intelligence measured?

Psychologists have not reached a consensus on how best to define intelligence. A working definition describes ***intelligence*** in terms of reasoning, problem solving, and dealing with changing environments.

Alfred Binet's pioneering test of intelligence included questions that required reasoning and problem solving of varying levels of difficulty, graded by age and resulting in a ***mental age*** score. Lewis Terman developed a revision of Binet's test that became known as the ***Stanford-Binet Intelligence Scale***; it included items designed to assess the intelligence of adults as well as children and became the model for IQ tests. David Wechsler's tests remedied some of the deficiencies of the earlier IQ tests. Made up of subtests, some of which have little verbal content, these tests allowed testers to generate scores for different aspects of cognitive ability.

The Stanford-Binet and Wechsler tests are the most popular individually administered intelligence tests. Both include subtests and provide scores for parts of the test, as well as an overall score. For example, in addition to a full-scale IQ, the Wechsler tests yield scores for verbal comprehension, perceptual reasoning, working memory, and processing speed. Currently, a person's ***intelligence quotient***, or ***IQ***, reflects how far that person's performance on the test deviates from the average performance of people in the same age group. An average performance is assigned an IQ of 100.

Evaluating Intelligence Tests

How good are IQ tests?

A ***test*** has two key advantages over other techniques of evaluation. First, they are standardized, which means that the conditions surrounding a test are as similar as possible for everyone who takes it. Second, they produce scores that can be compared with ***norms***, thus allowing people's strengths or weaknesses in various areas to be compared with those of other people. A good test must have ***statistical reliability***, which means that the results for each person are consistent, or stable. ***Statistical validity*** refers to the degree to which test scores are interpreted appropriately and used properly.

Intelligence tests are reasonably reliable, and they do a good job of predicting academic success. However, these tests assess only some of the abilities that might be considered aspects of intelligence, and they tend to favor people most familiar with middle-class culture. Nonetheless, this familiarity is important for academic and occupational success.

Both heredity and the environment influence IQ, and their effects interact. The influence of heredity is shown by the high correlation between the IQs of identical twins raised in separate households and by the similarity in the IQs of children adopted at birth and their biological parents. The influence of the environment is revealed by the higher correlation of IQs among siblings who share the same environment than among siblings who do not, as well as by the effects of environmental changes such as adoption.

Average IQs differ across socioeconomic and ethnic groups. These differences appear to be due to numerous factors, including differences in educational opportunity, motivation to achieve, family support for cognitive development, and other environmental conditions.

An enriched environment sometimes raises preschool children's IQs. Initial gains in cognitive performance that result from interventions such as Project Head Start may decline over time, but the programs may improve children's attitudes toward school.

Diversity in Intelligence

Is there more than one type of intelligence?

Researchers have taken several approaches to understanding the concept of intelligence. Based on the field of ***psychometrics***, the ***psychometric approach*** to intelligence attempts to analyze the structure of intelligence by examining correlations between tests of cognitive ability. Because scores on almost all tests of cognitive ability are positively correlated, Charles Spearman concluded that such tests measure a general factor of mental ability, called ***g***, as well as more specific factors, called ***s***. As a result of factor analysis, other researchers have concluded that intelligence is not a single general ability but a collection of abilities and subskills needed to succeed on any test of intelligence. Raymond B. Cattell distinguished between ***fluid intelligence***, the basic power of reasoning and problem solving, and ***crystallized intelligence***, the specific knowledge gained as a result of applying fluid intelligence. Modern psychometric theories of intelligence describe it as a hierarchy that is based on a host of specific abilities that fit into about eight groups that themselves combine into a single, general category of cognitive ability.

The ***information-processing model*** of intelligence focuses on the processes underlying intelligent behavior. Varying degrees of correlation have been found between IQ and measures of the flexibility and capacity of attention and between IQ and measures of the speed of information processing. This model has helped deepen our understanding of the processes that create individual differences in intelligence.

According to Robert Sternberg's triarchic theory of intelligence, there are three different types of intelligence: analytic, creative, and practical. Intelligence tests typically focus on analytic intelligence, but recent research has suggested ways to assess practical and creative intelligence too.

Howard Gardner's approach to intelligence suggests that biology equips us with the capacities for multiple intelligences that can function with some independence—specifically, linguistic, logical-mathematical, spatial, musical, body-kinesthetic, intrapersonal, interpersonal, and naturalistic intelligences.

Knowledge about intelligence has been expanded by research on giftedness and intellectual disabilities. Gifted people, those with very high IQs, tend to be healthier and more successful, but they are not necessarily geniuses. People are considered to have an intellectual development disorder if as children they have IQs below about 70 and if their functioning is less than expected for people their age. Some cases of intellectual disability have a known cause; in ***psychosocial intellectual disability***, the mix of genetic and environmental causes is unknown. Compared with people of normal intelligence, intellectually disabled people process information more slowly, know fewer facts, and are deficient at knowing and using mental strategies. Despite such difficulties, the cognitive skills of some intellectually disabled people can be improved to some extent.

TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. Binet's intelligence test was developed to __________.
   - **a.** identify children who needed special educational programs
   - **b.** help the armed forces make appropriate assignments of recruits
   - **c.** identify which immigrants were mentally defective and thus should not be allowed into the United States
   - **d.** help employers decide which employees were most appropriate for the available jobs

2. Jonah's parents are told that their son has an IQ of 100. According to the intelligence test scoring method used today, this means that Jonah __________.
   - **a.** has a mental age that is higher than his chronological age
   - **b.** scored higher than half the children in his age group
   - **c.** is considered to be a gifted child
   - **d.** shows about average skill at divergent thinking

3. Like all other applicants to medical school, Lavinia took the MCAT admission test. Later, researchers compared all the successful applicants' medical school grades with

their MCAT scores. The researchers were obviously trying to measure the MCAT's __________.
  a. statistical reliability
  b. standardization
  c. statistical validity
  d. norms

4. When Jerrica first took the Handy Dandy Intelligence test, her score was 140. When she took the same test six weeks later, her score was only 102. If other people showed similarly changing score patterns, the Handy Dandy Intelligence test would appear to lack __________.
   a. statistical reliability
   b. statistical validity
   c. standardization
   d. norms

5. Research shows that today's standardized intelligence tests __________.
   a. have good reliability and reasonably good validity for predicting success in school
   b. do not do a good job of predicting success on the job
   c. are not correlated with performance on "real-life" tasks
   d. measure the full array of cognitive abilities

6. There are two sets of twins in the Mullis family. Louise and Lanie are identical twins; Andy and Adrian are not. According to research on heredity and intelligence, which pair of twins is likely to show the most similarity in IQs?
   a. Andy and Adrian, because they are male siblings.
   b. Andy and Adrian, because they are fraternal twins.
   c. Louise and Lanie, because they are female siblings.
   d. Louise and Lanie, because they are identical twins.

7. Rowena is mildly intellectually disabled, but she is attending regular classes at a public school. Rowena most likely __________ and she will __________ from being mainstreamed.
   a. knows fewer facts about the world than others; benefit
   b. knows fewer facts about the world than others; not benefit
   c. learns just as fast as other children, but forgets it faster; not benefit
   d. has little or no potential for employment; benefit

8. Betsey took an intelligence test that included items requiring her to say what she would do if she were stranded in a large city with no money and how she would teach music to children who had no musical instruments. This test was most likely based on __________.
   a. Sternberg's triarchic theory of intelligence
   b. Gardner's concept of multiple intelligences
   c. Terman's giftedness theory
   d. The Wechsler Adult Intelligence Scale

9. Your cousin Alix is enrolled in a preschool program for "at-risk" children designed to enrich his learning environment. Based on research on programs such as Project Head Start, you tell his parents that the program will most likely positively influence Alix's __________, but might have little or no influence on his __________ in the long-term.
   a. attitudes toward school; IQ
   b. IQ; attitudes toward school
   c. spatial ability; mathematical ability
   d. mathematical ability; spatial ability

10. Mrs. Linder, a high school teacher, believes that students who are good at math will also be good in English, history, and music. Mrs. Linder most likely subscribes to the __________ theory of intelligence.
    a. *g*
    b. triarchic
    c. genetic
    d. multiple intelligences

11. Eugene, 77, is retired now, but he has worked crossword puzzles every day since he was a teenager. He no longer finishes the puzzles as quickly as he used to, but he can complete more difficult puzzles. Eugene's puzzle performance reflects the fact that his __________ intelligence has remained relatively intact.
    a. spatial
    b. fluid
    c. crystallized
    d. flexible

12. Although many successful musical artists don't appear to have "book smarts," they certainly have the "street smarts" needed to succeed in the music industry. Which theory of intelligence best accounts for this observation?
    a. *g* theory
    b. triarchic theory
    c. information processing theory
    d. crystallized intelligence theory

13. Dr. Armstrong is conducting an experiment on the possible effects of stereotype threat on women's math test performance. Which of the following independent variables would Dr. Armstrong manipulate in his experiment?
    a. age of the participants
    b. age and ethnic background of the participants
    c. information about alleged sex differences in math ability
    d. sex of the participants

14. Differences in the average IQ scores of various ethnic groups
    a. are not statistically significant.
    b. reflect mainly genetic differences.
    c. reflect mainly differing environmental factors.
    d. reflect both genetic and environmental factors.

15. If the influence of heredity and environment on differences in intelligence is about equal, it would mean that __________.
    a. about 50 percent of your IQ is inherited and 50 percent learned
    b. about half of the IQ variability seen in a group of people is attributed to heredity
    c. about half of the IQ variability seen in a group of people is attributed to environment
    d. both b and c are correct

16. Today, your IQ score would be determined by
- **a.** the total number of test items you answered correctly.
- **b.** how much your score deviates from others of the same age.
- **c.** dividing your mental age by your chronological age and multiplying by 100.
- **d.** dividing your chronological age by your mental age and multiplying by 100.

17. People whose scores on intelligence tests identify them as gifted are more often
- **a.** troubled during their teenage years.
- **b.** troubled during adulthood.
- **c.** world famous for some achievement.
- **d.** more successful than the average person.

18. Paul has a terrible time with academic exams, but he is a great dancer and a highly skilled mechanic who can take apart, repair, and fix almost anything. The __________ approach would be most likely to label these skills as intelligent?
- **a.** psychometric
- **b.** triarchic
- **c.** multiple intelligence
- **d.** information processing

19. __________ is an important environmental influence on children's IQ scores.
- **a.** Parents' socioeconomic status
- **b.** Parents' support for children's motivation to succeed at school
- **c.** Parents' age and marital status
- **d.** both a and b are correct

20. Research on intelligence has established that __________.
- **a.** once set by genetics, intelligence cannot change much
- **b.** once set by environmental factors, intelligence cannot change much
- **c.** environmental factors can improve or impair intelligence test performance
- **d.** environmental factors can impair IQ scores, but not improve them

Consciousness

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Preview

Have you ever "spaced out" while driving on a boring highway? Has your mind wandered far and wide during a dull lecture? These experiences contrast sharply with how it feels to focus your attention on playing a video game or to concentrate on a complicated recipe, but all of them represent differing versions of consciousness. In this chapter, we delve into both "normal" and altered states of consciousness. Most of the altered states—sleep, dreaming, hypnosis, meditation—differ psychologically and physiologically from normal waking consciousness. We will examine how they differ, and we will also look at the effects of psychoactive drugs, which, in addition to altering consciousness, have complex physiological effects.

In an old *Sesame Street* episode, Ernie is trying to find out whether Bert is asleep or awake. Ernie observes that Bert's eyes are closed, and comments that Bert usually closes his eyes when he is asleep. Ernie also notes that Bert doesn't respond to pokes when he's asleep, so naturally he delivers a few pokes. At first, Bert doesn't respond, but after being poked a few times, he awakes, very annoyed, and yells at Ernie for waking him. Ernie then informs Bert that he just wanted to let him know that it was time for his nap.

Doctors face a similar situation in dealing with the more than 30 million people each year who receive general anesthesia during surgery. These patients certainly seem unresponsive, but there's no reliable way of knowing whether they actually are unconscious (Alkire, Hudetz, & Tononi, 2008). It turns out that about 1 in 500 people may retain some degree of consciousness during surgical procedures (Pandit et al., 2013). In rare cases, patients actually are aware of surgical pain and remember the trauma. Although their surgical wounds heal, these people may be psychologically scarred by the experience and may even show symptoms of posttraumatic stress disorder (Leslie et al., 2010). To reduce the possibility of operating on someone who appears unconscious but may not be, some physicians suggest monitoring patients' brain activity during every surgery (Jameson & Sloan, 2006). Unfortunately, even this precaution may not eliminate the problem in every case (Avidan et al., 2011).

If people can be aware yet appear to be unconscious, you can see how difficult it can be to define consciousness (Sarà & Pistoia, 2009). One way that medical doctors chose to define consciousness is awareness that is demonstrated by an ability to recall an experience (Schwender et al., 1995). Psychologists use a somewhat broader definition: **Consciousness** is generally defined as your awareness of the outside world and of your mental processes, thoughts, feelings, and perceptions (Metzinger, 2000; Zeman, 2001). Let's see how this definition applies as we explore the scope of consciousness and various states of consciousness.

Keeping an Eye Out

Humans are not the only creatures capable of processing information while apparently unconscious. While ducks sleep, one hemisphere of their brains can process visual information from an eye that remains open. Birds positioned where they are most vulnerable to predators, such as at the end of a row, may spend twice as much time in this "alert" sleep than do birds in more protected positions (Rattenborg, Lima, & Amlaner, 1999).

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consciousness The awareness of external stimuli and our own mental activity.

consciousness state The characteristics of consciousness at any particular moment.

THE SCOPE OF CONSCIOUSNESS

Can unconscious thoughts affect your behavior?

Mental activity changes constantly. The features of consciousness at any instant—what reaches your awareness, the decisions you make, and so on—make up what is called your **consciousness state** at that moment (Tassi & Muzet, 2001). Possible *states of consciousness* include coma, deep sleep, hypnosis, meditation, daydreaming, and alert wakefulness. Consciousness can also be altered by drugs and other influences.

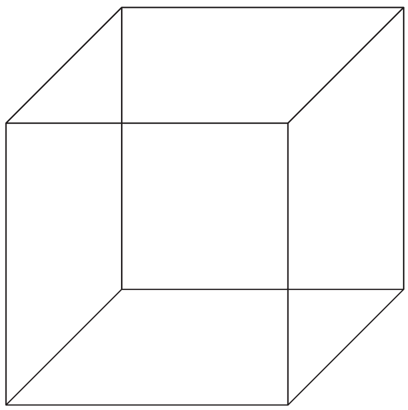


FIGURE 9.1
The Necker Cube

TRY THIS Each of the two squares in the Necker cube can be perceived as either the front or rear surface of the cube. Try to see the cube switch back and forth between these two orientations. Now try to see only one orientation. You probably cannot maintain the whole cube in consciousness for longer than about three seconds before it "flips" from one orientation to the other.

Consciousness States

Consciousness states can be viewed as different points along a scale or continuum of consciousness (Cavanna et al., 2011). For example, suppose you're aboard an airliner flying from New York to Los Angeles. The pilot calmly scans instrument displays while talking to an air traffic controller. In the seat next to you, a lawyer finishes her second cocktail while planning a courtroom strategy. Across the aisle, a young father gazes out the window, daydreaming, while his small daughter sleeps in his lap, dreaming dreams of her own. All these people are experiencing different states of consciousness. Some states are active and some are passive. The daydreaming father lets his mind wander, passively noticing images, memories, and other mental events that come to mind. Like the pilot, the lawyer actively directs her mental processes. In her case, though, as she evaluates various options and considers their likely outcomes, she is altering her state of consciousness by sipping alcohol.

Generally, people spend most of their time in a *waking* consciousness state. Mental processing in this state varies with changes in attention or arousal (Taylor, 2002). While reading, for example, you may temporarily ignore sounds around you. Similarly, if you're upset or bored or talking on a cell phone, you may tune out important cues from the environment, making it dangerous to perform complex activities, such as driving a car.

Levels of Consciousness

The events and mental processes that you are aware of at any given moment are said to exist at the **conscious level**. For example, look at the Necker cube in Figure 9.1. If you're like most people, you can hold the cube in one orientation for only a few seconds before the other version "pops out" at you. The version that you experience at any moment is at your conscious level of awareness for that moment.

Some events, however, cannot be experienced consciously. For example, you are not directly aware of your brain regulating your blood pressure or controlling the dilation of the pupils in your eyes (Laeng, Sirois, & Gredebäck, 2012). Mental processes that control our biological functions occur at the **nonconscious level**, totally removed from conscious awareness. People can learn to alter a nonconscious process through *biofeedback training*, receiving information about their biological processes in order to control them. Usually special equipment is required, but you can approximate a biofeedback session by having a friend take your pulse at one-minute intervals while you sit quietly. First, establish a baseline pulse, then imagine a peaceful scene or think about lowering your pulse rate. Then ask your friend to softly say whether your pulse is higher or lower compared with the baseline. After four or five minutes of having this information "fed back" to you, you will probably be able to keep your pulse rate below the original baseline. Yet the pulse-regulating processes themselves remain out of consciousness.

TRY THIS

Some mental events are not conscious but can become conscious or can influence conscious experience. These mental events make up the *cognitive unconscious* (Reber, 1992), which includes the preconscious and the subconscious. Mental events that are outside awareness but that can easily be brought into awareness are said to exist at the **preconscious level**. What did you have for dinner last night? The information you needed to answer this question probably wasn't already in your conscious awareness, but it was at the preconscious level. So when you read the question, you could answer it immediately. Similarly, when you play trivia games, you draw on your large storehouse of preconscious memories to come up with obscure facts.

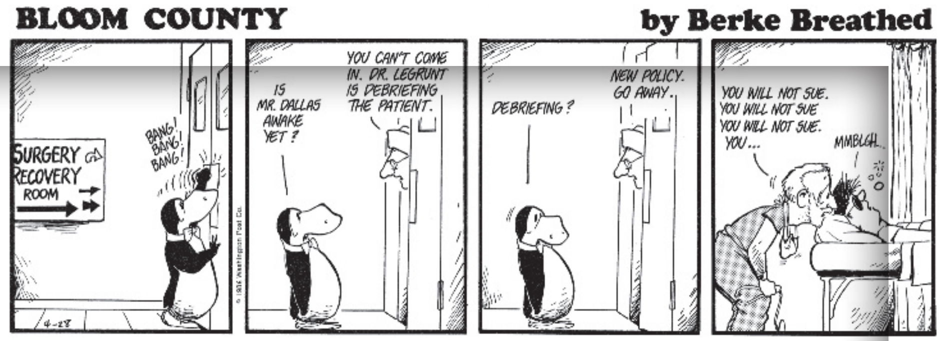
Other mental activities can alter thoughts, feelings, and actions but are more difficult to bring into awareness. Sigmund Freud suggested that these **unconscious** activities, especially those involving unacceptable sexual and aggressive urges, are actively kept out of consciousness. Most psychologists do not accept Freud's view, but they still

conscious level The level of consciousness at which mental activities accessible to awareness occur.

nonconscious level The level of consciousness at which reside processes that are totally inaccessible to conscious awareness.

preconscious level The level of consciousness at which reside mental events that are not currently conscious but can become conscious at will.

unconscious The term used to describe a level of mental activity said by Freud to contain unacceptable sexual, aggressive, and other impulses of which an individual is unaware.



Research shows that some surgery patients can hear, and later comply with, instructions or suggestions given while they were under anesthesia, even though they have no memory of what they were told (Bennett, Giannini, & Davis, 1985). People also have physiological responses to emotionally charged words even when they are not paying attention to them (Von Wright, Anderson, & Stenman, 1975). These and other similar studies provide evidence for the operation of subconscious mental processing (Deeprose & Andrade, 2006).

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use the term *unconscious*, or **subconscious**, to describe mental activity that influences us in various ways but that occurs outside of awareness (Dijksterhuis & Nordgren, 2006).

Mental Processing without Awareness

A fascinating demonstration of mental processing without awareness was provided by an experiment with patients who had surgery under general anesthesia. After their operations but while the patients were still unconscious from the anesthesia, a recording of fifteen word pairs was played over and over for them in the recovery room. After regaining consciousness, the patients could not say what words were on the recording or even whether a recording had been played at all. However, when given one word from each of the word pairs and asked to say the first word that came to mind, the patients came up with the other member of the word pair from the recording (Cork, Kihlstrom, & Hameroff, 1992).

Even when conscious and alert, you sometimes process and use information without being aware of it (Fu, Fu, & Dienes, 2008; Mudrick et al., 2011). In one study, participants watched a computer screen as an X flashed in one of four locations. The task was to indicate as quickly as possible where the X appeared. The location of the X seemed to vary randomly, but actually followed a set of complex rules. (One such rule was "If the X moves horizontally twice in succession, its next move will be vertical.") Participants' responses became progressively faster and more accurate. Then, unknown to the participants, the rules were abandoned and the X appeared in *truly* random locations. Instantly, participants' accuracy and speed deteriorated. Apparently, the participants had learned the rules without knowing what they were, and this learning improved performance! However, even when offered $100 to state the rules that had guided the location sequence, they could not do so, nor were they sure that any such rules existed (Lewicki, 1992).

Visual processing without awareness may even occur in some blind people. When blindness is caused by damage only to the brain's primary visual cortex, pathways from the eyes are still connected to other brain areas that process visual information (Garrido, 2012). Such connections may permit visual processing without awareness—a condition called *blindsight* (Stoerig & Cowey, 1997). People who experience blindsight say they see nothing, but if forced to guess, they may still locate visual targets, identify the direction of moving images, reach for objects, name the color of lights, and even discriminate happy from fearful faces (Azzopardi & Hock, 2011; Cowey, 2010a). The same blindsight phenomenon has been created in visually normal volunteers using magnetic brain stimulation to temporarily disable the primary visual cortex (Allen, Sumner, & Chambers, 2014).

subconscious Another term that describes the mental level at which influential but normally inaccessible mental processes take place.

Research on *priming* also demonstrates mental processing without awareness. In a typical priming study, people respond faster or more accurately to the stimuli they have seen before, even if they do not consciously recall those stimuli (Abrams & Greenwald, 2000; Breuer et al., 2009; Kouider & Dupoux, 2005). In one study, for example, people

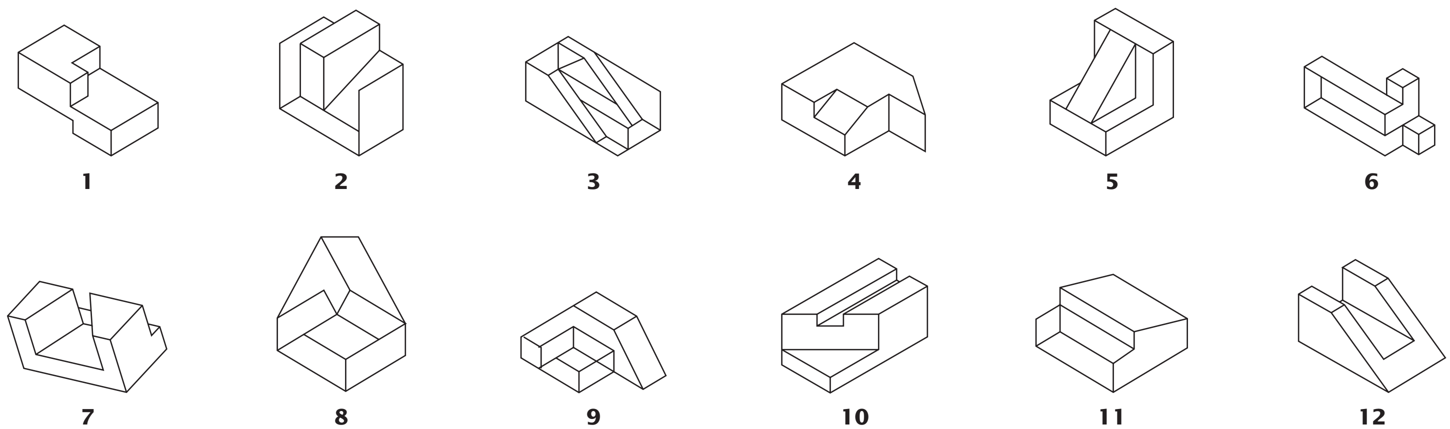


FIGURE 9.2
Stimuli Used in a Priming Experiment

TRY THIS Look at these figures and decide, as quickly as you can, whether each can actually exist. Priming studies show that this task would be easier for figures you have seen in the past, even if you don't recall seeing them. How did you do? The correct answers appear at the bottom of page 301.

looked at figures like those in Figure 9.2. They had to decide which figures could possibly exist in three-dimensional space and which could not. Participants were better at classifying pictures they had seen before, even when they couldn't remember seeing them (Schacter et al., 1991). Some priming effects are short lived, but others can last for years (Mitchell, 2006).

To some degree, decisions and choices we make in our everyday lives may be guided by mental processes without our awareness (e.g., Hassin, 2013; Galdi, Arcuri, & Gawronski, 2008; Mealor & Dienes, 2012). For example, your "lucky" choice of the fastest-moving supermarket checkout line might seem to have been based on nothing more than a hunch, a gut feeling, or intuition, but previous visits to that store might have given you useful information that you didn't know you had about the various clerks (Adolphs et al., 2005). In a laboratory study that supports this notion, people watched videotaped television commercials while the changing stock prices of fictional companies crawled across the bottom of the screen. Later, these people were asked to choose which of these companies they liked best. They couldn't recall anything they had seen about the companies' stock, so they had to make their choice on the basis of their gut reaction to the company names. Nevertheless, their choices were not random; they more often chose companies whose stock prices had been rising rather than those whose stock had been falling (Betch et al., 2003).

THINKING CRITICALLY

CAN SUBLIMINAL MESSAGES CHANGE YOUR BEHAVIOR?

The research we have described shows that we don't always have to be aware of information in order for it to affect us. How strong can this influence be? In 1957, an adman named James Vicary claimed that a New Jersey theater flashed messages such as "buy popcorn" and "drink Coke" on a movie screen, too briefly to be noticed, while customers watched the movie *Picnic*. He said that these messages caused a 15 percent rise in sales of Coca-Cola and a 58 percent increase in popcorn sales. Can messages perceived at a *subliminal* level—that is, below conscious awareness—act as a form of "mind control"? Many people seem to think so. Each year, they spend millions of dollars on video and audio products whose subliminal messages are promised to help people lose weight, raise self-esteem, quit smoking, make more money, or achieve other goals.

LINKAGES Can subliminal messages help you lose weight? (a link to Sensation and Perception)

What am I being asked to believe or accept?

Two types of claims have been made about subliminal stimuli. The more general one is that subliminal stimuli influence people's behavior. A second, more specific claim is that subliminal stimuli effectively change people's buying habits, political opinions, self-confidence, and other complex attitudes and behaviors, without their awareness or consent.

(*continued*)

What evidence is available to support the assertion?

Evidence that subliminal messages can affect conscious judgments comes in part from laboratory studies that present visual stimuli too briefly to be perceived consciously. In one such study, participants saw slides showing people performing ordinary acts such as washing dishes. Unknown to the participants, each slide was preceded by a subliminal exposure to a photo of "positive" stimuli (such as a child playing) or "negative" stimuli (such as a monster). Later, participants rated the people on the visible slides that had been preceded by a positive subliminal photo as being more likable, polite, friendly, successful, and reputable (Krosnick et al., 1992). The subliminal photos not only affected participants' liking of the people they saw but also shaped beliefs about their personalities.

In another study, participants were exposed to subliminal presentations of slides showing snakes, spiders, flowers, and mushrooms. Even though the slides were impossible to perceive at a conscious level, participants who were afraid of snakes or spiders showed physiological arousal (and reported feeling fear) in response to slides of snakes and spiders (Öhman & Soares, 1994).

The results of studies such as these support the notion that subliminal information can have an impact on judgments and emotion, but they say little or nothing about the value of subliminal recordings for achieving self-help goals. In fact, no laboratory evidence exists to support the effectiveness of these recordings. Their promoters offer only the reports of satisfied customers.

Are there alternative ways of interpreting the evidence?

Many claims for subliminal advertising—including the New Jersey movie theater case—have been unmasked as publicity stunts using phony data (Haberstroh, 1995; Pratkanis, 1992). And testimonials from satisfied customers could be biased by what these people would like to believe about the subliminal recordings they bought. In one study designed to test this possibility, half the participants were told that they would hear recordings containing subliminal messages for improving memory. The rest were told that the subliminal messages would promote self-esteem. However, half the participants in the memory group actually got self-esteem messages, and half of the self-esteem group actually got memory messages. Regardless of which version they received, participants who thought they had heard memory enhancement messages reported improved memory; those who thought they had received self-esteem messages said their self-esteem had improved (Pratkanis, Eskenazi, & Greenwald, 1994). In other words, the effects of the recordings were determined by the listeners' expectations, not by the subliminal content of the recordings. These results suggest that customers' reports about the value of subliminal self-help recordings may reflect placebo effects based on optimistic expectations rather than the effects of subliminal messages.

What additional evidence would help evaluate the alternatives?

The effectiveness of self-help recordings and other subliminal products must be evaluated through further experiments, such as the one just mentioned, that carefully control for expectations. Those who support and sell subliminal-influence methods are responsible for conducting those experiments, but as long as customers are willing to buy subliminal products on the basis of testimonials alone, scientific evaluation efforts will probably come only from those interested in protecting consumers from fraud.

What conclusions are most reasonable?

The available evidence suggests that subliminal perception occurs but that it has no potential for "mind control" (Greenwald, Klinger, & Schuh, 1995). Subliminal effects are usually small and short-lived, and they mainly affect simple judgments and general measures of overall arousal. The effects also tend to be related to temporary conditions such as fatigue or motivation (Bermeitinger et al., 2009). For example, a subliminal message about a beverage is more likely to influence a person who is thirsty than one who is not (Karremans, Stroebe, & Klaus, 2006). As for subliminal messages aimed at long-term behavior change, most researchers agree that such messages have no special power to create needs, goals, skills, or actions (Pratkanis & Aronson, 2001; Randolph-Seng & Mather, 2009; Strahan et al., 2005). In fact, advertisements, political speeches, and other messages that we *can* perceive consciously have far stronger persuasive effects.

FOCUS ON RESEARCH METHODS

SUBLIMINAL MESSAGES IN POPULAR MUSIC

Would the persuasive power of subliminal messages be increased if they were presented at normal speed but in reverse, so that we could not understand them consciously? According to numerous websites, this is how secret messages have been hidden in the recorded music of Lady Gaga, Marilyn Manson, Eminem, Nine Inch Nails, Pink Floyd, the Rolling Stones, and hundreds of other performers. Some contend that these "back masked" *subliminal* messages caused listeners to commit suicide or murder. However, for this claim to be true, subliminal backward messages would have to be perceived at some level of consciousness.

What was the researchers' question?

There is no clear evidence that secret backward messages exist in most of the music cited. However, John R. Vokey and J. Don Read (1985) wondered if any backward messages had existed, could they be perceived and understood while the music was playing forward. They also asked whether such a message would affect a listener's behavior.

How did the researchers answer the question?

First, Vokey and Read made tape recordings of a person reading portions of the Twenty-third Psalm and Lewis Carroll's poem "Jabberwocky." This poem includes many nonsense words, but it follows the rules of grammar (e.g., "Twas brillig, and the slithy toves …"). The recordings were then played backward to college students, who judged whether what they heard would have been meaningful or nonsensical if played forward.

What did the researchers find?

When the students heard the readings being played backward, they could not discriminate sense from nonsense. They could not tell the difference between declarative sentences and questions. They couldn't even identify the original material on which the recordings were based. In short, the participants couldn't understand the backward messages at a conscious level. Could they do so subconsciously? To find out, the researchers asked the participants to sort the backward statements they heard into one of five categories: nursery rhymes, Christian, satanic, pornographic, or advertising. They reasoned that if some sort of meaning could be subconsciously understood, the participants might sort the statements nonrandomly. Yet participants did no better at this task than random chance would predict.

Perhaps backward messages might influence people's behavior even if the messages were not perceived consciously. To check on this possibility, Vokey and Read (1985) conducted another study. This time, they presented a backward version of a message whose sentences contained homophones (words that sound alike but have two spellings and two different meanings, such as "feat" and "feet"). When heard in the normal forward direction, such messages affect people's spelling of ambiguous words that are read aloud to them at a later time. (For example, they tend to spell out f-e-a-t rather than f-e-e-t if they had previously heard the sentence "It was a great feat of strength.") This example of priming occurs even if people do not recall having heard the message. After hearing a *backward* version of the message, however, the participants in this study did not produce the expected spelling bias.

What do the results mean?

It wasn't possible for the participants to understand meaning in the backward messages at a subconscious level. It seems that backward messages are not consciously or unconsciously understood, nor do they influence behavior (Vokey, 2002).

What do we still need to know?

Why does the incorrect idea persist that backward messages can influence behavior? Beliefs and suspicions do not simply disappear in the face of contrary scientific evidence (Vyse, 2000; Winer et al., 2002). Perhaps such evidence needs to be publicized more widely in order to lay the misconceptions to rest. Perhaps, though, some people so deeply want to believe in the existence and power of backward messages in popular music that such beliefs will forever grip folk myth in Western culture.

Altered States and Cultural Values

Cultures differ in their definitions of which altered states of consciousness are approved and which are inappropriate. Here we see members of a Brazilian spirit possession cult in various stages of trance and, in Peru, a Moche curandero, or "curer," attempting to heal an ailing patient by using fumes from a potion—and a drug from the San Pedro cactus—to put himself in an altered state of consciousness.

Nacho Doce/Reuters /Landov; Nathan Benn/National Geographic Creative

Altered States of Consciousness

When changes in mental processes are great enough for you or others to notice significant differences in how you function, you are said to have entered an **altered state of consciousness**. In an altered state, mental processing shows distinct changes unique to that state. Cognitive processes or perceptions of yourself or the world may change, and normal inhibitions or self-control may weaken (Vaitl et al., 2005).

The phrase *altered states of consciousness* recognizes waking consciousness as the most common state, a baseline against which altered states are compared. However, this is not to say that waking consciousness is universally considered more normal, proper, or valued than other states. In fact, judgments about the status and meaning of certain states of consciousness vary considerably across cultures (Ward, 1994).

Consider, for instance, *hallucinations,* which are perceptual experiences (such as hearing voices) that occur without sensory stimulation from the outside world. In the United States, hallucinations are usually viewed as so undesirable that even if they are caused by nothing more than an eye disorder people may be ashamed to seek the medical help they need to solve the problem (Menon et al., 2003). If mental patients hallucinate, they may feel such stress or self-blame and so choose not to report their hallucinations (Karidi et al., 2014). Those who do report them tend to be considered more disturbed and may receive more drastic treatments than patients who keep their hallucinations to themselves (Wilson et al., 1996). Among the Moche of Peru, however, hallucinations have a culturally approved place. When someone experiences illness or misfortune, a healer conducts an elaborate ritual to find causes and treatments. During the ceremony, the healer takes mescaline, a drug that causes hallucinations. These hallucinations are thought to give the healer spiritual insight into the patient's problems (de Rios, 1992). In many other tribal cultures, too, purposeful hallucinations are respected, not rejected (Grob & Dobkin de Rios, 1992).

In other words, states of consciousness differ not only in their characteristics but also in their value to members of particular cultures. In the sections that follow, we describe some of the most interesting altered states of consciousness, beginning with the most common one: sleep.

SLEEPING AND DREAMING

Does your brain go to sleep when you do?

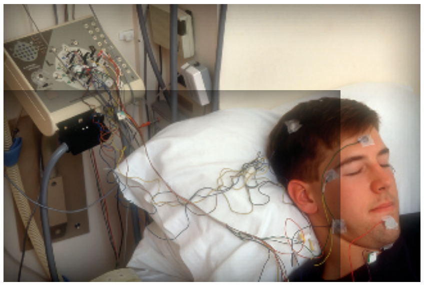
According to ancient myths, sleepers lose control of their minds and flirt with death as their souls wander freely. Early researchers thought sleep was a time of mental inactivity, but sleep is actually an active, complex state (Hobson, 2005).

altered state of consciousness A condition that exists when changes in mental processes are extensive enough to produce noticeable differences in psychological and behavioral functioning.

Stages of Sleep

Sleep researchers study the brain's electrical activity during sleep using an *electroencephalograph (EEG).* EEG recordings, often called *brain waves,* vary in height (amplitude)

Answers for Figure 9.2: Figures 1, 4, 5, 7, 10, and 12 can exist in three-dimensional space.



A Sleep Lab

The electroencephalograph (EEG) allows scientists to record brain activity through electrodes attached to the scalp. The development of this technology in the 1950s opened the door to the scientific study of sleep.

Hank Morgan-Rainbow/Science Faction/Corbis

LINKAGES Does the brain shut down when we sleep? (a link to Biological Aspects of Psychology)

and speed (frequency) as behavior or mental processes change. The brain waves of an awake, alert person are irregular, small, and closely spaced; that is, high frequency and low amplitude. A relaxed person with closed eyes shows more rhythmic brain waves occurring at slower speeds, about eight to twelve cycles per second (cps). During a normal night's sleep, your brain waves show distinctive and systematic changes in amplitude and frequency as you pass through various stages of sleep (Shatzmiller, 2010; Silber et al., 2007).

Non-REM Sleep

Imagine that you are participating in a sleep study. You're hooked up to an EEG and various monitors, and a video camera watches as you sleep through the night. If you were to view the results, here's what you'd see: At first, you are relaxed, with your eyes closed, but you are still awake. At this point, your muscle tone and eye movements are normal and your EEG shows the slow brain waves associated with relaxation. Then, as you drift into sleep, your breathing deepens, your heartbeat slows, and your blood pressure falls. Over the next half-hour, you descend through three stages of sleep—N1, N2, and N3—that are characterized by even slower brain waves with even higher amplitude (see Figure 9.3). Together, these three stages are called **NREM**, or **non-REM sleep** because they do not include the rapid eye movements (REM) described in the next section (Iber et al., 2007). The deepest of the NREM stages, N3, is also known as *slow-wave sleep*. When you reach stage N3, it's quite difficult to wake up. If you were roused from this stage of deep sleep, you'd be groggy and slow to answer questions.

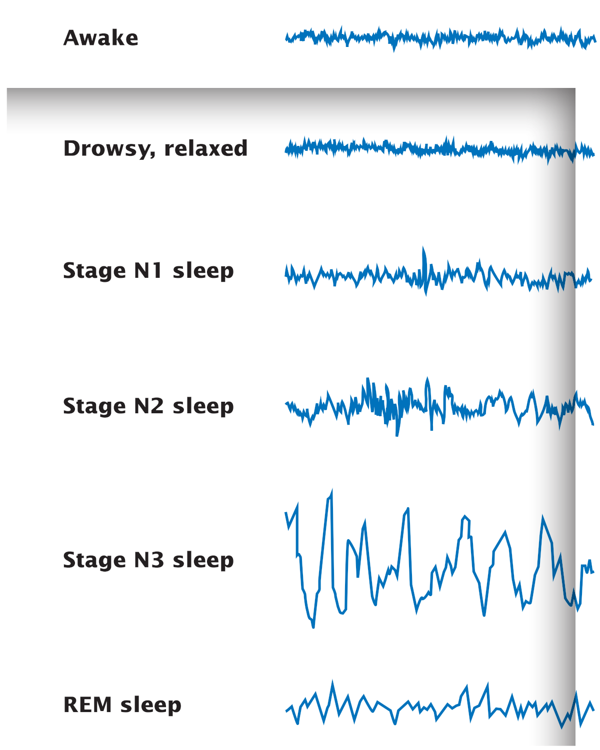


FIGURE 9.3
EEG during Sleep

EEG recordings of brain wave activity show three relatively distinct stages of sleep. Notice the regular patterns of brain waves that occur just before a person goes to sleep, followed by even slower waves as sleep becomes deeper in non-REM stages N1 through N3. In REM (rapid eye movement) sleep, the frequency of brain waves increases dramatically. In some ways the brain waves of REM sleep resemble patterns seen in people who are awake.

REM Sleep

After thirty to forty-five minutes in stage N3, you quickly return to stage N2 and then enter a unique stage in which your eyes move rapidly under your closed eyelids. This is called **REM (rapid eye movement) sleep**, or paradoxical sleep. It's called paradoxical because its characteristics contain a paradox, or contradiction. In REM sleep, your EEG looks like an awake, alert person, and your physiological arousal—heart rate, breathing, and blood pressure—is also similar to when you are awake. However, most of your muscles are nearly paralyzed. Thus, REM sleep and NREM sleep are very different types of sleep (Silber et al., 2007).

NREM (non-rapid eye movement) sleep Sleep stages N1, N2, and N3; they are accompanied by gradually slower and deeper breathing; a calm, regular heartbeat; reduced blood pressure; and slower brain waves. (Stage N3 is called slow-wave sleep.)

REM (rapid eye movement) sleep The stage of sleep during which muscle tone decreases dramatically but the EEG resembles that of someone who is awake.

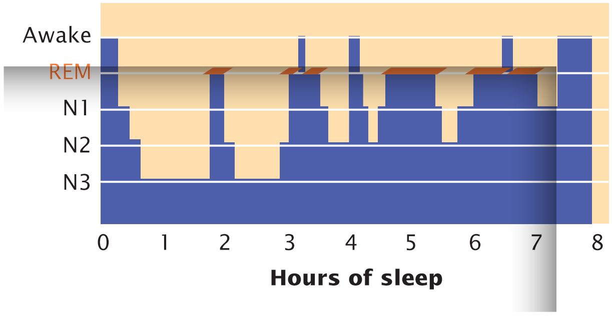


FIGURE 9.4
A Night's Sleep

During a typical night, a sleeper goes through this sequence of EEG stages. Notice that sleep is deepest during the first part of the night and shallower later on, when REM sleep (highlighted in orange here) becomes more prominent.

A Night's Sleep

Most people pass through the cycle of sleep stages four to six times each night. Each cycle lasts about ninety minutes, but the pattern of stages and length of the stages change somewhat. Early in the night, most time is spent in NREM with only a few minutes in REM (see Figure 9.4). As sleep continues, though, it is dominated by stage N2 and REM sleep, from which sleepers finally awaken. Sleep patterns change with age. An infant averages thirteen hours of sleep a day (Williams, Zimmerman, & Bell, 2013), but a seventy-year-old sleeps only about six hours (Roffwarg, Muzio, & Dement, 1966). Elderly people also tend to wake more often during the night than younger people do (Floyd, 2002; Roenneberg et al., 2007). The "architecture," or composition of sleep, also changes with age. REM accounts for half of a newborn's sleep but less than 25 percent in young adults and even less in the elderly (Darchia, Campbell, & Feinberg, 2003). Elderly people spend more time in N1 and N2, the lighter stages of sleep (Espiritu, 2008). Though the National Sleep Foundation (www.sleepfoundation.org) recommends that most adults should sleep seven to nine hours each night, individual needs vary widely. Some people feel rested after four hours of sleep, while others of similar age need ten hours or more (Clausen, Sersen, & Lidsky, 1974).

Sleep Disorders

Most people have sleep-related problems at some time (Silber, 2001). These can range from grogginess after a late night out to occasional nights of tossing and turning to more serious and long-term *sleep disorders* that affect perhaps 70 million people in the United States alone (Institute of Medicine, 2006; Morin et al., 2009).

The most common sleep disorder is **insomnia**, in which people feel fatigue during waking hours because they do not get enough sleep to feel rested. If, for a month or more, you have difficulty getting to sleep or staying asleep, you may be suffering from insomnia. Besides being tiring, insomnia may cause mental distress, health problems, and impairments in daily functioning (Hamilton et al., 2007; Rajaratnam et al., 2011). Fatigue-related workplace accidents and errors are estimated to cost the U.S. economy $31.1 billion annually (Shahly et al., 2012), and a study in Norway found that people with insomnia were nearly five times more likely than others to develop a permanent work disability (Sivertsen et al., 2009). Overall, people with insomnia are three times more likely to show a mental disorder than those with no sleep complaints (Ohayon & Roth, 2003). Insomnia is especially associated with depression and anxiety disorders (Baglioni et al., 2010). It is not clear from such correlations, however, whether insomnia causes mental disorders, mental disorders cause insomnia, or some other factor causes both.

Stimulus Control Therapy

Insomnia can often be reduced through a combination of relaxation techniques and stimulus control therapy, in which the person goes to bed only when sleepy and gets out of bed if sleep does not come within fifteen to twenty minutes. The goal is to have the bed become a stimulus associated with sleeping, and perhaps sex, but not with reading, eating, watching television, worrying, or anything else that is incompatible with sleep (Edinger et al., 2001).

Jupiterimages/Getty Images

insomnia A sleep disorder in which a person does not get enough sleep to feel rested.

narcolepsy A daytime sleep disorder in which a person suddenly switches from an active waking state into REM sleep.

Some medications may relieve insomnia temporarily (Saper & Scammell, 2013); however, they may have unwanted side effects, reduce REM sleep, and lead to dependency and increased sleeplessness down the line (Curry, Eisenstein, & Walsh, 2006; Poyares et al., 2004). In the long run, an approach including learning-based treatments is best (Neubauer, 2013). Such treatments include the cognitive behavior therapy methods described in the chapter on treatment of psychological disorders, and the progressive relaxation training techniques mentioned in the chapter on health, stress, and coping (Bootzin & Epstein, 2011). Both of these treatments promote better sleeping by reducing anxiety, tension, and other stress reactions (Bernstein, Borkovec, & Hazlett-Stevens, 2000; Jacobs et al., 2004). Short daytime naps and moderate evening exercise also help some people fall sleep more easily and sleep better, with better mood and performance the next day (Tanaka et al., 2001).

Narcolepsy is a disturbing daytime sleep disorder that is typically first seen in people between fifteen and twenty-five years old (Dyken & Yamada, 2005; Zeman et al., 2004). People with narcolepsy suddenly enter REM sleep directly from a waking state, often as they laugh or experience another emotional state (Ahmed & Thorpy, 2011). Because of the loss of muscle tone in REM, narcoleptics may have *cataplexy,* meaning that they collapse and remain briefly immobile even after awakening. These attacks appear to come from the brain's lateral hypothalamus (Nishino, 2011). The most common cause of narcolepsy appears to be the absence or deficiency of the neurotransmitter *orexin,* also called *hypocretin* (Caylak, 2009; Miyagawa et al., 2008). Because medications that block orexin help insomnia sufferers fall asleep (Herring et al., 2012), it is hoped that new medications that mimic orexin will make narcolepsy sufferers feel more alert (Mieda & Sakuri, 2013). One helpful medication is modafinil, taken in the morning, since this helps both the fatigue in narcolepsy and in those suffering from sleep deprivation (Lavault et al., 2011). Another drug, gamma hydroxybutyrate (GHB), taken at night, reduces daytime narcoleptic attacks of fatigue (Boscolo-Berto et al., 2011).

Sudden Infant Death Syndrome (SIDS)

In SIDS cases, seemingly healthy infants stop breathing while asleep in their cribs. All the causes of SIDS are not known, but health authorities now urge parents to ensure that infants sleep on their backs, as this baby demonstrates.

JGI/Blend Images/Corbis

People who suffer from **sleep apnea** briefly stop breathing hundreds of times each night, waking each time long enough to resume breathing. In the morning, they don't recall the awakenings, but they feel tired and tend to have headaches, learning difficulties, and reduced attention (Jackson, Howard, & Barnes, 2011). The daytime fatigue and inattention caused by sleep apnea also increase the risk for accidents (Tregear et al., 2009). In one tragic case, two members of a train crew—both of whom had apnea—fell asleep on the job, resulting in a crash that killed two people (Pickler, 2002). Sleep apnea also increases risks for stroke and high blood pressure (Barone & Kriefer, 2013). Apnea has many causes, including genetic predisposition, obesity, problems with brain mechanisms that control breathing, and compression of the windpipe (White & Younes, 2013). Effective treatments include weight loss and use of sleep masks like CPAP (continuous positive airway pressure) to help keep breathing passages open (Antonescu-Turcu & Parthasarathy, 2010). In some cases, surgery may widen the air passageway in the upper throat (Lin et al., 2013).

In cases of **sudden infant death syndrome (SIDS)**, sleeping infants stop breathing and die. SIDS is the most common cause of unexpected infant death in Western countries (Hunt & Hauck, 2006). In the United States, it strikes about six of every ten thousand infants (Balayla, Azoulay, & Abenhaim, 2011), especially very low birthweight babies, usually when they are two to four months old (Smith & White, 2006; Vernacchio et al., 2003).

Some SIDS cases may be caused by exposure to cigarette smoke, problems with brain systems that regulate breathing, or genetic factors (e.g., Klintschar & Heimbold, 2012; Machaalani, Say, & Waters, 2011; Trachtenberg et al., 2012). However, the most important causes may be related to how and where infants sleep at night (Moon & Fu, 2012). SIDS rates appear to be lower in some countries where infants and parents sleep in the same bed (Li, Petitti, et al., 2003) but higher in others, including the United States and Ireland (McGarvey et al., 2006; Ostfeld et al., 2006). The differing risks may have to do with the kinds of bedding used or with sleeping position. Correlational evidence suggests that about half of apparent SIDS cases might actually be accidental suffocations that occur when infants sleep face down on a soft surface. In the United States, for example, SIDS may be particularly common when caregivers place babies in the face-down position (e.g., Dwyer & Ponsonby, 2009). The danger of the face-down position is especially great for babies who don't usually sleep in that position, who are not breastfed, or who don't sleep with a pacifier in their mouths (Vennemann et al., 2009a, 2009b). In 1992, a new health campaign was started, called "back to sleep," in which doctors urged parents to be sure their babies sleep face up (Task Force on Sudden Infant Death Syndrome, 2011). Since then, the number of infants dying from SIDS in the United States and United Kingdom has dropped by 50 to 90 percent (Moon, Horn, & Hauk, 2007).

Sleepwalking occurs in NREM sleep, affecting up to 14 percent of children and 4 percent of adults (Remulla & Guilleminault, 2004). By morning, most sleepwalkers have forgotten their travels and their sometimes bizarre activities. One sleepwalking man had no recollection of tying his four-month-old daughter to a clothesline in his attic (Pillmann, 2009). Sleepwalking has been associated with several possible causes, including genetic predisposition, sleep deprivation, and the side effects of some drugs (Zadra et al., 2013). Walking around while asleep can lead to injury, so affected individuals are advised to

sleep apnea A sleep disorder in which a person briefly but repeatedly stops breathing during the night.

sudden infant death syndrome (SIDS) A disorder in which a sleeping baby stops breathing, does not awaken, and dies.

sleepwalking A phenomenon that starts primarily in NREM sleep, especially in stage N3, and involves walking while asleep.

remove fall risks in the bedroom. Otherwise, there are no consistently effective medical treatments for sleepwalking (Harris & Grunstein, 2009), although sleepwalkers who also have sleep apnea often find relief for both conditions by wearing a CPAP mask at night (Guilleminault et al., 2005). Most children simply outgrow the problem. One adult sleepwalker was cured when his wife blew a whistle whenever he began a nighttime stroll (Meyer, 1975). Despite myths to the contrary, waking a sleepwalker is not harmful.

Nightmares are frightening REM dreams that occur in 4 to 8 percent of the general population. Adult women report more nightmares than men (Schredl & Reinhard, 2011), and they are especially common in people who suffer from posttraumatic stress disorder following military combat, torture, rape, or other horrific events (e.g., Hinton et al., 2009). Drugs have proved helpful in reducing the frequency of nightmares (Aurora et al., 2010), as has imagery therapy, in which people repeatedly imagine new and less frightening outcomes to their nightmares (Hansen et al., 2013). **Sleep terror disorder** (also known as **night terrors**) involves frightful dream images during stage N3 sleep (Derry et al., 2009). Sleepers often awaken from a night terror with a bloodcurdling scream and remain intensely afraid for up to 30 minutes, yet they may not recall the episode in the morning (Snyder et al., 2008). Sleep terror disorder is especially common in children, but adults can suffer milder versions, and it appears to be partly inherited (Nguyen et al., 2008). The condition is sometimes treatable with drugs or psychotherapy (Jan et al., 2004; Sadeh 2005).

In **REM behavior disorder**, sleepers enter REM sleep without the near-paralysis that normally accompanies it (Arnulf, 2012). As a result, they can act out their dreams. If the dreams are violent, the disorder can be dangerous to the dreamer or those nearby (Schenck, Gittings, & Colussi-Mas, 2009). One nine-year-old boy in New York City was seriously injured when he jumped from a third-floor window while dreaming that his parents were being murdered. In another case, a man shot his wife to death while dreaming that burglars were invading their home (de Bruxelles, 2009). Although he was acquitted of murder charges, most defendants who offer a REM behavior disorder or sleepwalking defense are convicted (Lyon, 2009). REM behavior disorder, which sometimes occurs in tandem with daytime narcolepsy (Billiard, 2009; Schenck & Mahowald, 1992), can be caused by the side effects of medication (Morrison, Frangulyan, & Riha, 2011), and in one case was caused by a brain tumor (Zambelis, Paparrigopoulos, & Soldatos, 2002). Most often, REM behavior disorder has no obvious cause at first, but over many years the affected person may go on to develop Parkinson's disease or other similar brain disorders (Zanigni et al., 2011). Fortunately, prescription drugs are usually effective in treating REM behavior disorder (Ramar & Olson, 2013).

Why Do People Sleep?

People need a certain amount of uninterrupted sleep to function normally. In fact, most living creatures sleep. In trying to understand why people sleep, psychologists have studied what sleep does for us and how the brain shapes the characteristics of sleep (Siegel, 2005).

Sleep as a Circadian Rhythm

Humans and almost all animals display cycles of behavior and physiology that repeat about every 24 hours (Mazzoccoli, 2011). These patterns are called **circadian rhythms** (also known as **human biological rhythms**). (*Circadian,* pronounced "sir-KAY-dee-en," comes from the Latin *circa dies,* meaning "about a day.") Longer and shorter rhythms also occur, but they are less common.

Circadian rhythms are linked to signals such as the light of day and the dark of night (Ohta, Yamazaki, & McMahon, 2005). However, most of these rhythms continue even when no time signals are available. People living for months without external light and dark cues maintain daily rhythms in sleeping and waking, eating, urination, hormone release, and other physiological functions. Under such conditions, these cycles repeat about every twenty-four hours (Czeisler et al., 1999).

nightmares Frightening dreams that take place during REM sleep.

sleep terror disorder (night terrors) The occurrence of horrific dream images during N3 sleep, followed by a rapid awakening and a state of intense fear.

REM behavior disorder A sleep disorder in which the decreased muscle tone normally seen in REM sleep does not appear, thus allowing dreams to be acted out.

circadian rhythm (human biological rhythm) A cycle, such as waking and sleeping, that repeats about once a day.

The Cost of Jet Lag

Twice a year, exhibitors freshly arrived from around the world groggily set up displays at Asia's largest jewelry show. Then they try to wait on customers while keeping track of their treasures. Taking advantage of these jet-lagged travelers' inattentiveness, thieves steal millions of dollars' worth of merchandise at every show (Fowler, 2004).

Jodi Cobb/National Geographic Creative

Trying to change our sleep-wake cycle can create problems. A common example is air travel across several time zones, which may cause **jet lag**, a pattern of fatigue, irritability, inattention, and sleeping problems that can last for several days (Weingarten & Collop, 2013). The traveler's body feels ready to sleep at the wrong time for the new location. It tends to be easier to stay awake longer than usual than to go to sleep earlier than usual. That explains why jet lag symptoms are usually more intense after a long eastward trip (when time is lost) than after a long westward journey (when time is gained; Doane et al., 2010; Lemmer et al., 2002). Symptoms similar to those of jet lag also occur when workers repeatedly change between day and night shifts, or when people who try to go to sleep early on a Sunday night after a weekend of later-than-usual bedtimes (Czeisler et al., 2005; Di Milia, 2006). For these people, Monday morning "blues" may actually be symptoms of a disrupted sleep-wake cycle (Yang & Spielman, 2001).

The timing of circadian sleep rhythms varies from person to person. Most people fall into one of two patterns (Roenneberg et al., 2007)—some have a natural tendency to stay up later at night ("owls") while others normally tend to wake up earlier in the morning ("larks"). These different *chronotypes* may occur because of "clock genes," genetic codes that help set the daily peaks and valleys in a person's sleepiness and wakefulness, hormone levels, and body temperature (Zhang et al., 2011). These clock genes appear less effective, though, when people have disorders such as Alzheimer's disease, depression, and certain cancers (Kishi et al., 2011; Yang et al., 2011; Yesavage et al., 2011), perhaps helping to explain why sleep may be disrupted in certain illnesses.

Because our sleep-wake rhythms stay about the same even without external cues about light and dark, we must have an internal biological clock that keeps track of time. This clock is in the *suprachiasmatic nuclei* (*SCN*) of the hypothalamus (Honma et al., 2012), as shown in Figure 9.5. The SCN receives light information from a special set of photoreceptors in the eyes and then sends signals to hindbrain areas that initiate sleep or wakefulness (Reinoso-Suárez, de Andrés, & Garzón, 2011). When animals with SCN damage receive transplanted SCN cells, their circadian rhythms become like those of the donor animal (Menaker & Vogelbaum, 1993). SCN neurons appear to respond to the hormone vasopressin (Yamaguchi et al, 2013) and also regulate the release of the hormone *melatonin* (Hardeland, 2013). Melatonin rises during periods of darkness, and appears to be important in maintaining circadian rhythms (Zawilska, Skene, & Arendt, 2009). Many symptoms associated with jet lag and other disruptions in sleep-wake cycles can be prevented or treated by taking melatonin (Brown et al., 2009), although for some people,

jet lag Fatigue, irritability, inattention, and sleeping problems caused by air travel across several time zones.

FIGURE 9.5
Sleep, Dreaming, and the Brain

This diagram shows the location of some of the brain structures thought to be involved in sleep and dreaming, as well as in other altered states discussed later in the chapter. For example, one area near the suprachiasmatic nuclei acts as a "master switch" to promote sleep (Saper, Chou, & Scammell, 2001). If it is damaged, sleep may be nearly impossible. Another nearby area promotes wakefulness; individuals with damage to this area sleep virtually all the time (Salin-Pascual et al., 2001).

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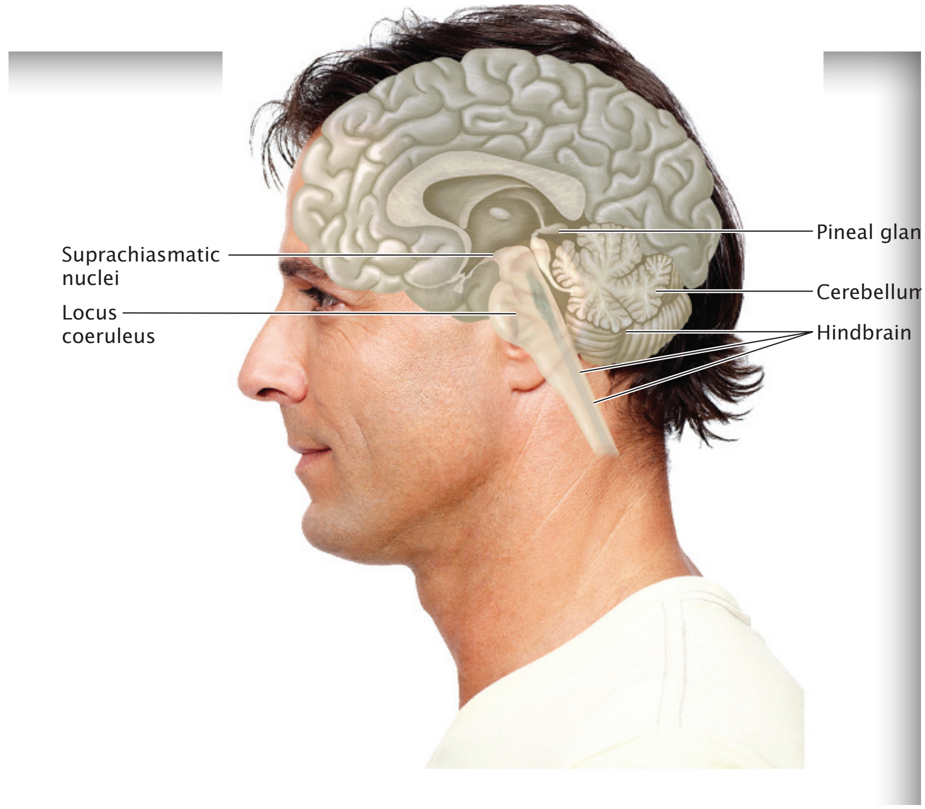

such as commercial airline crewmembers, regular use is not recommended (Simons & Valk, 2009). It may also be possible to reduce jet lag through diet, exercise, and exposure to natural lighting conditions upon daytime arrival or to dim light upon nighttime arrival (Armstrong, 2006; Edwards, Reilly, & Waterhouse, 2009; Evans, Elliott, & Gorman, 2009).

The Value of Sleep

One way to explore what sleep does for us is to study what happens when we are prevented from sleeping. After being deprived of sleep, people don't need to make up every hour of lost sleep. Instead, they sleep about 50 percent more than usual, then wake up feeling rested. But their "recovery" night includes an unusually high percentage of REM sleep (Feinberg & Campbell, 1993). And if people are deprived *only* of REM sleep, they compensate even more specifically. In one study, sleep subjects were awakened whenever their EEGs showed REM. When allowed to sleep normally the next night, they "rebounded," nearly doubling the percentage of time spent in REM (Dement, 1960). Such research suggests we have a specific need for REM sleep, perhaps because it has its own special functions. What might those functions be? There are several interesting possibilities.

One idea is that REM improves the functioning of neurons that use norepinephrine (Siegel & Rogawski, 1988), a neurotransmitter released by cells in the *locus coeruleus* (pronounced "lo-kus seh-ROO-lee-us"; see Figure 9.5). During waking hours, the locus coeruleus affects alertness and mood. But neurons respond less to norepinephrine if it is released continuously for too long. REM sleep deprivation causes unusually high norepinephrine levels and decreased daytime alertness (Mallick and Singh, 2011). Researchers suggest that because the locus coeruleus is almost completely inactive during REM sleep, REM helps restore sensitivity to norepinephrine and thus its ability to keep us alert (Steriade & McCarley, 1990).

REM sleep may help your brain "consolidate" what you learned from the day before, by improving the connections that form between nerve cells in the brain (Diekelmann &

Born, 2010). Such a function might explain why infants and young children—whose brains are still developing—spend so much time in REM sleep, or why preschoolers appear to learn better if they take afternoon naps (Mednick, 2013). Evidence for such a mechanism includes animal research showing that REM sleep increases neural connections after new learning experiences (Frank et al., 2001; Scullin & McDaniel, 2010). Also, memory for a learning task is improved when odors or other sensory cues present during the task again appear in REM sleep, suggesting that REM helped make memories stronger (Rudoy et al., 2009). So, if your psychology class meets in a flower garden, a vase of fragrant roses next to your bed at night may help your test scores the next day (Bendor, 2013)! Evidence also suggests that REM sleep deprivation slows the creation of nerve cell connections formed during learning (Kim, Mahmoud, & Grover, 2005). Such findings argue that REM sleep may help to solidify and absorb the day's experiences and skills (Fenn, Nusbaum, & Margoliash, 2003; Ishikawa et al., 2006; Stickgold, James, & Hobson, 2000). There is evidence, too, that REM sleep may improve daytime creativity (Cai et al., 2009).

Other studies have found that information, including emotional information or certain aspects of language, is remembered better and longer when followed immediately by sleep, especially REM sleep (e.g., Djonlagic et al., 2009; Gaskell et al., 2014; Payne & Kensinger, 2010). Even sixty- to ninety-minute naps in which REM sleep occurs can be enough to solidify the learning of visual information (Mednick, Nakayama, & Stickgold, 2003). When people are deprived of REM sleep, their performance at a skill they had learned the day before suffers when compared with people who were either deprived of NREM sleep or had slept normally (Karni et al., 1994). However, if people are given a medication that increases the activity of acetylcholine in the brain, REM sleep deprivation does not have the same disruptive effect on learning (Aleisa, Alzoubi, & Alkadhi, 2011). This suggests that the learning impairments seen after REM sleep deprivation may be caused by its effects on brain circuits that use acetylcholine. If REM sleep deprivation can interfere with learning, could it be used to help people forget traumatic events? Some researchers have suggested that sleep deprivation immediately after a trauma mightreduce the risk of posttraumatic stress disorder (Wagner et al., 2006), but others disagree (van der Helm et al., 2011). Further research will be needed to evaluate this claim.

What are the effects of total **sleep deprivation**? People who go without sleep for as long as a week usually don't suffer serious long-term effects. However, extended sleeplessness does lead to fatigue, irritability, memory problems, and inattention (van der Kloet et al., 2012). Even short-term sleep deprivation—a common condition among busy adolescents and adults—can take its toll (Caldwell, 2012; Lim & Dinges, 2010). For example, sleep deprivation can reduce the ability of the body's immune system to fight off colds (Cohen et al., 2009), and serious mistakes in patient care are more likely when doctors work sleep-disrupting extended hospital shifts than when they work more normal hours (Lockley et al., 2007). By one estimate, sleep deprivation was involved in 23.7 percent of all workplace accidents in the United States (Shahly et al., 2012). For example, thirty-two passengers were injured on March 24, 2014, when a Chicago Transit Authority train slammed into a station at the end of the line because the train operator had fallen asleep. She had been overtired after working a lot of overtime (Esposito & Rossi, 2014). Most fatal car crashes in the United States occur during the "fatigue hazard" hours of midnight to 6 a.m. (Coleman, 1992), and sleepiness resulting from long work shifts or other causes is a major factor in up to 25 percent of all auto accidents (Barger et al., 2005; Filtness, Reyner, & Horne, 2012). Young drivers (ages seventeen to twenty-four) who sleep less are more likely to get into a car accident, too, especially on weekends (Martiniuk et al., 2013). Fatigue has also been identified as a major cause of car accidents in Asia, South America, and Europe (Abe et al., 2010; de Pinho et al., 2006; Pizza et al., 2010; Sagaspe et al., 2010). The fact that "sleepy driving" can be as dangerous as drunk driving led the state of New Jersey to expand the definition of reckless driving to include "driving while fatigued" (i.e., having had no sleep in the previous twenty-four hours). Fatigue also plays a role in many injuries suffered by sleepy young children at play or in day care (Boto et al., 2011). Learning and performance on IQ tests are also impaired after sleep deprivation (Gruber et al., 2010; Yoo et al., 2007), but certain parts of the cerebral cortex actually increase their activity

sleep deprivation A condition in which people do not get enough sleep; it may result in reduced cognitive abilities, inattention, and increased risk of accidents.

when a sleep-deprived person faces a learning task, so we're able to compensate for a while (Drummond et al., 2000).

Scientists are looking for drugs that can combat the effects of sleep deprivation, but there seems to be no substitute for sleep itself. It appears to help restore the body and the brain for future activity and to help consolidate memories of newly learned facts (Korman et al., 2007; Racsmány, Conway, & Demeter, 2010; Walker & Stickgold, 2006). The restorative function is especially associated with NREM sleep, which would help explain why most people get their NREM sleep in the first part of the night (see Figure 9.4).

IN REVIEW

SLEEP AND SLEEP DISORDERS

Sleep Disorders	Characteristics	Possible Causes
NREM (non–rapid eye movement) Stage N3 is also called slow-wave sleep	Includes the deepest stages of sleep, characterized by slowed heart rate and breathing, reduced blood pressure, and low-frequency, high-amplitude brain waves	Refreshes body and brain; consolidates memory
REM (rapid eye movement) sleep	Characterized by eye movements, waking levels of heart rate, breathing, blood pressure, and brain waves, but near-paralysis in muscles	Restores sensitivity to norepinephrine, thus improving waking alertness; creates and solidifies nerve cell connections; consolidates memories and new skills
Insomnia	Difficulty (lasting at least a month) in falling asleep or staying asleep	Worry, anxiety
Narcolepsy	Sudden switching from a waking state to REM sleep	Absence or deficiency in orexin (*hypocretin*)
Sleep apnea	Frequent episodes of interrupted breathing while asleep	Genetic predisposition, obesity, faulty breathing-related brain mechanisms, windpipe compression
Sudden infant death syndrome (SIDS)	Interruption of an infant's breathing, resulting in death	Genetic predisposition, faulty breathing-related brain mechanisms, exposure to cigarette smoke
Sleepwalking	Engaging in walking or other waking behaviors during NREM sleep	Genetic predisposition, drug side effects, and sleep deprivation
Nightmares	Frightening dreams during REM sleep	Stressful or traumatic events or experiences
Sleep terror disorder (night terrors)	Frightening dream images during NREM sleep	Stressful or traumatic events or experiences
REM behavior disorder	Lack of paralysis during REM sleep allows dreams to be enacted, sometimes with harmful consequences	Malfunction of brain mechanism normally creating REM paralysis

In Review Questions

1. Jet lag occurs because of a disruption in a traveler's ___________.
2. The importance of NREM sleep is suggested by its appearance ___________ in the night.
3. The safest sleeping position for babies is ___________.

Dreams and Dreaming

We have seen that the brain is active in all sleep stages (for a summary of our discussion, see "In Review: Sleep and Sleep Disorders"). Some of this brain activity during sleep produces the storylike experiences known as **dreaming**. Dreams may be as short as a few seconds or last for many minutes. They may be organized or chaotic, realistic or fantastic, peaceful or exciting (Schredl, 2010).

Some dreaming occurs during NREM sleep, but most dreams—and the most bizarre and vivid ones—happen in REM (Dement & Kleitman, 1957; Eiser, 2005). Even when they seem to make no sense, dreams may contain a certain kind of logic. For example, people can tell the difference between written dream reports whose sentences had been randomly rearranged and those that had been left alone (Stickgold, Rittenhouse, & Hobson, 1994). And although dreams often involve one person transforming into another or one object turning into another object, it is rare that objects become people or vice versa (Cicogna et al., 2006).

Daytime activities affect dream content (Blagrove et al., 2011). In one study, an unusually high number of animal characters appeared in the dreams reported by people who had just attended an animal rights conference (Lewis, 2008). In another, people with health problems reported more dreams that included illness or injury (King & DiCicco, 2007), and several studies have found that dream images of violence, terrorism, and disaster became more common in the days and weeks following the September 11, 2001, terrorist attacks in the United States (Bulkeley & Kahan, 2008). Sounds and odors influence dreams, too. In one study, sleeping research participants were exposed to the smell of roses or rotten eggs. Those who had smelled the roses reported happier dreams than those who had smelled the rotten eggs (Schredly et al., 2010). It is even possible to intentionally direct dream content. This is called **lucid dreaming**, because the sleeper is aware of dreaming while it occurs (Stumbrys et al., 2012).

Research leaves little doubt that everyone dreams during every night of normal sleep (e.g., Saurat et al., 2011; Voss et al., 2011). Whether you remember a dream depends on how you sleep and wake up. You'll remember more if you awaken abruptly and lie quietly while writing or recording your recollections.

Why do we dream? Theories abound. Some see dreaming as a process through which all species with complex brains analyze and consolidate information that is personally important or has survival value (Payne & Nadel, 2004; Zadra, Desjardins, & Marcotte, 2006). This view is supported by the fact that most mammals have REM sleep, and they are probably dreaming when they do. Such a conclusion was suggested with researchers studying sleep in cats. When the animals had damage to the neurons that cause REM sleep paralysis, the cats ran around and attacked or seemed alarmed by unseen objects, presumably the images from dreams (Winson, 1990).

Sigmund Freud (1900), whose ideas we describe more in the chapter on personality, argued that dreams are a disguised form of *wish fulfillment,* a way to satisfy unconscious urges or resolve unconscious conflicts that are too upsetting to deal with consciously. For example, a person's sexual desires might appear in a dream as the rhythmic motions of a horseback ride. Conflicting feelings about a parent might appear as a dream about a fight. Seeing his patients' dreams as a "royal road to a knowledge of the unconscious," Freud interpreted their meaning as part of his psychoanalytic therapy methods (see the chapter on the treatment of psychological disorders).

In contrast, the *activation-synthesis theory* describes dreams as meaningless byproducts of REM sleep (Eiser, 2005; Hobson, 1997). According to this theory, random signals from the hindbrain occur during REM sleep, and these signals *activate* the brain's cerebral cortex. Dreams may result when the cortex tries to make sense of

dreaming The production during sleep of storylike sequences of images, sensations, and perceptions that last from several seconds to many minutes; it occurs mainly during REM sleep.

lucid dreaming Being aware that a dream is a dream while it is occurring.

these random signals, using stored memories and current feelings to *synthesize* something more coherent. From this perspective, dreams represent the brain's attempt to impose sensibility onto meaningless stimulation during sleep (Bernstein & Roberts, 1995; Tierney, 2009).

Even if dreams arise from random brain activity, their content may show something psychologically significant (Bulkeley & Domhoff, 2010). Some psychologists see dreams as giving people a chance to review and address some of the problems they face during waking hours (Cartwright, 1993). This view is supported by evidence suggesting that people's current concerns can affect both the content of their dreams and the way in which dreams are organized and recalled (e.g., Domhoff & Schneider, 2008). However, neuroimaging studies show that while we are in REM sleep, brain areas involved in emotion tend to be overactivated, whereas those areas controlling logical thought tend to be suppressed (Miyauchi et al., 2009). In fact, as we reach deeper sleep stages and then enter REM sleep, logical thinking subsides and unusual perceptions increase (Fosse, Stickgold, & Hobson, 2001). This is probably why dreams rarely provide realistic, logical solutions to our problems (Blagrove, 1996).

Inducing Hypnosis

In the late 1700s, Austrian physician Franz Anton Mesmer used a forerunner of hypnosis to treat physical disorders. His procedure, known as mesmerism, included elaborate trance-induction rituals, but we now know that hypnosis can be induced far more easily, often simply by staring at an object, as this woman did.

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HYPNOSIS

Can you be hypnotized against your will?

The word *hypnosis* comes from the Greek word *hypnos,* meaning "sleep." However, hypnotized people are not sleeping. Even those who say afterward that their bodies felt "asleep" also report that their minds were active and alert. **Hypnosis** has been defined as an altered state of consciousness that is brought on by special techniques and produces responsiveness to suggestions for changes in experience and behavior (Kirsch, 1994a). Most hypnotized people do not feel forced to follow the hypnotist's instructions. They simply see no reason to refuse (Hilgard, 1965). In fact, the more that people want to cooperate with the hypnotist, the more likely it is they will experience hypnosis (Lynn et al., 2002). People cannot be hypnotized against their will.

Experiencing Hypnosis

Hypnosis often begins with suggesting that the person feels relaxed and sleepy. The hypnotist then gradually focuses the person's attention on a particular and often monotonous set of stimuli, such as a swinging pendant. The hypnotist asks that the individual ignore everything else and imagine certain feelings.

There are tests to measure **hypnotic susceptibility**, the degree to which people respond to hypnotic suggestions (Kumar & Farley, 2009). In general, they show that about 10 percent of adults are difficult or impossible to hypnotize (Hilgard, 1982). At the other extreme are people whose hypnotic experiences are so vivid that they can't tell the difference between images the hypnotist asked them to imagine and images shown on a screen (Bryant & Mallard, 2003). Brain scans of people who are highly susceptible to hypnosis may show unusually active interactions between attention-regulating regions of cerebral cortex, even in a normal waking state of consciousness (Hoeff et al., 2013). Perhaps this is why hypnotically susceptible people typically differ from others in having a better ability to focus attention and ignore distractions (e.g., Iani et al., 2006). They also tend to have more active imaginations (Spanos, Burnley, & Cross, 1993), a tendency to fantasize (Lynn & Rhue, 1986), a capacity for processing information quickly and easily (Dixon, Brunet, & Laurence, 1990), a tendency to be suggestible (Kirsch & Braffman, 2001), and positive attitudes and expectations about hypnosis (Benham et al., 2006; Fassler, Lynn, & Knox, 2008).

hypnotic susceptibility The degree to which a person responds to hypnotic suggestion.

hypnosis A phenomenon that is brought on by special techniques and is characterized by varying degrees of responsiveness to suggestions for changes in a person's behavior and experiences.

The results of hypnosis are fascinating. People told that their eyes are locked shut may struggle unsuccessfully to open them. They may appear deaf or blind or insensitive to pain. They may seem to forget their own names. Some claim to remember forgotten things. Others show *age regression,* seeming to recall or reenact their childhoods (see Figure 9.6). Hypnotic effects can be extended for hours or days through *posthypnotic suggestions,* which are instructions about how to behave after hypnosis has ended (such as smiling whenever someone says "Paris"). Some individuals show *posthypnotic amnesia,* an inability to recall what happened while they were hypnotized, even after being told what happened (Sutcher, 2008; Wark, 2008).

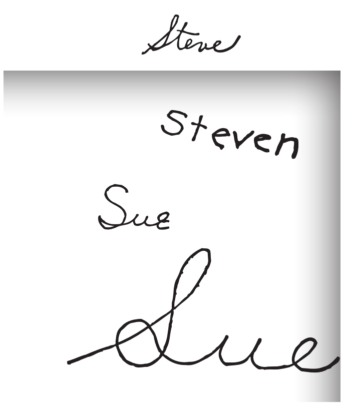

FIGURE 9.6
Hypnotic Age Regression

TRY THIS Here are the signatures of two adults before hypnotically induced age regression (top of each pair) and while age regressed (bottom of each pair). The lower signature in each pair looks less mature, but was the change due to hypnosis? To find out, ask a friend to sign a blank sheet of paper, first as usual, and then as if he or she were five years old. If the two signatures look significantly different, what does this say about the cause of certain age-regression effects?

Ernest Hilgard (1965, 1992) described the main changes that people display during hypnosis. First, hypnotized people *tend not to begin actions on their own,* waiting instead for the hypnotist's instructions. One participant said, "I was trying to decide if my legs were crossed, but I couldn't tell, and didn't quite have the initiative to move to find out" (Hilgard, 1965). Second, hypnotized people tend to ignore all but the hypnotist's voice and whatever it points out: Their *attention is redistributed.* Third, hypnosis *enhances the ability to fantasize.* Participants more vividly imagine a scene or relive a memory. Fourth, hypnotized people *readily take on roles.* They more easily act as though they were people of a different age or sex than nonhypnotized people do. Fifth, hypnotized individuals show *reduced reality testing.* They tend not to question whether statements are true, and they are more willing to accept distortions of reality. So a hypnotized person might shiver in a warm room if a hypnotist says it is snowing.

Explaining Hypnosis

Hypnotized people look and act differently from nonhypnotized people (Hilgard, 1965). Do these differences indicate an altered state of consciousness?

Advocates of **state theories of hypnosis** say that they do. They point to the changes in brain activity that occur during hypnosis (Burgmer et al., 2013) and to the dramatic effects that hypnosis can produce, including insensitivity to pain and the disappearance of warts (Noll, 1994). They also note that there are slight differences in the way hypnotized and nonhypnotized people carry out suggestions. In one study, hypnotized people and those pretending to be hypnotized were told to run their hands through their hair whenever they heard the word "experiment" (Orne, Sheehan, & Evans, 1968). The pretenders did so only when the hypnotist said the cue word. Hypnotized participants complied no matter who said it. Another study found that hypnotized people complied more often than pretenders with a posthypnotic suggestion to mail postcards to the experimenter (Barnier & McConkey, 1998).

By contrast, there are also several **nonstate theories of hypnosis**. Supporters of *role theory*, for example, maintain that hypnosis is not a special state of consciousness. They point out that some of the changes in brain activity associated with hypnosis can also be created by other means (McGeown et al., 2012; Mohr, Binkofski, et al., 2005). Advocates for the role theory of hypnosis suggest that hypnotized people are simply complying with the demands of a situation that asks them to act out a special social role (Kirsch, 1994b). From this perspective, hypnosis just gives a socially acceptable reason to follow someone's suggestions, much as a checkup at your doctor's office provides a socially acceptable reason to remove your clothing on request. Support for role theory comes from several sources. First, nonhypnotized people sometimes show behaviors like some that are seen with hypnosis. For example, contestants on television game shows and reality shows do lots of odd, silly, disgusting, or even dangerous things without first being hypnotized. Second, laboratory studies show that motivated but nonhypnotized volunteers can duplicate many aspects of hypnotic behavior, from arm rigidity to age regression (Dasgupta et al., 1995; Mazzoni et al., 2009; Orne & Evans, 1965). Other studies have found that people rendered blind or deaf by hypnosis can

state theories of hypnosis Theories proposing that hypnosis creates an altered state of consciousness.

nonstate theories of hypnosis Theories, such as role theory, proposing that hypnosis does not create an altered state of consciousness.

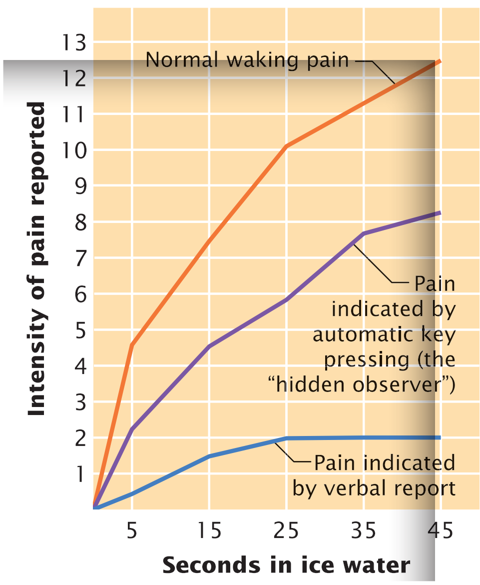

FIGURE 9.7
Reports of Pain in Hypnosis

This graph compares the intensity of pain reported by three groups of participants while one of their hands was immersed in ice water. The orange line represents nonhypnotized participants. The blue line represents hypnotized participants who were told they would feel no pain. The purple line shows the reports of hypnotized participants who were told they would feel no pain but were asked to press a key if "any part of them" felt pain. The key pressing by this "hidden observer" suggests that under hypnosis, the experience of pain was dissociated from conscious awareness.

still see or hear, even though their actions and beliefs suggest that they cannot (Bryant & McConkey, 1989). Still others indicate that people's responses to hypnotic suggestions can vary from one occasion to the next, depending on situational factors (Fassler, Lynn, & Knox, 2008).

Hilgard's (1992) *dissociation theory* blends role and state theories. He suggested that hypnosis is not one specific state but a general condition that temporarily reorganizes or breaks down our normal control over thoughts and actions (Holmes et al., 2005). By this view, hypnosis creates a *dissociation,* meaning a split in consciousness (Hilgard, 1979). Dissociation allows body movements normally under voluntary control to occur on their own and normally involuntary processes (such as overt reactions to pain) to be controlled voluntarily. This relaxation of control depends on a social agreement between the hypnotized person and the hypnotist to share control. In other words, people usually decide for themselves how to act or what to attend to, perceive, or remember. During hypnosis, the hypnotist is given permission to control some of these experiences and actions. Compliance with a social role may tell part of the story, Hilgard said, but hypnosis also leads to significant changes in mental processes.

Support for Hilgard's theory comes from brain-imaging studies showing that the ability to dissociate certain mental processes is greater in people who are more hypnotically susceptible (Bob, 2008; Egner, Jamieson, & Gruzelier, 2005). Dissociation was also demonstrated behaviorally by asking hypnotized participants to keep a hand in ice water (Hilgard, Morgan, & MacDonald, 1975). They were told that they would feel no pain but were asked to press a key with their other hand if "any part of them" felt pain. The results are shown in Figure 9.7. The participants' oral reports indicated almost no pain, but their key-pressing told a different story. Hilgard concluded that a "hidden observer" was reporting on pain that was reaching these people but that had been separated, or dissociated, from conscious awareness (Hilgard, 1977).

Applications of Hypnosis

Whatever hypnosis is, it has proven useful, especially in relation to pain (Patterson, 2010). Functional magnetic resonance imaging (fMRI) studies of hypnotized pain patients show reduced activity in brain regions that normally process the emotional aspects of pain (Vanhaudenhuyse et al., 2009). For some people, hypnosis can block the pain of dental work (Gow, 2010), childbirth (Landolt & Milling, 2011), burns (Askay et al., 2007), and surgery (Hammond, 2008). For others, hypnosis has been shown to relieve chronic pain from arthritis, nerve damage, migraine headaches, and cancer (Stewart, 2005), help eliminate diarrhea (Tan, Hammond, & Joseph, 2005), reduce chemotherapy related nausea and vomiting (Richardson et al., 2007), limit surgical bleeding (Gerschman, Reade, & Burrows, 1980), and speed up postoperative recovery (Astin, 2004). Hypnosis has even helped reduce stress-related hair loss (Willemsen & Vanderlinden, 2008)!

Some applications of hypnosis remain quite controversial (Loftus & Davis, 2006). For example, hypnotic age regression is claimed to help people recover lost memories. One problem with this claim, however, is that the memories of past events reported by age-regressed individuals are not as accurate as those of nonhypnotized individuals (Lynn, Myers, & Malinoski, 1997). Similarly, it is doubtful that hypnosis truly helps most witnesses recall the details of a crime. In fact, their positive expectations about the value of hypnosis may lead them to unintentionally distort or reconstruct memories of what they saw and heard (Garry & Loftus, 1994; Wells & Olson, 2003). Being hypnotized may also make witnesses more confident about even inaccurate reports.

Surgery under Hypnosis

Bernadine Coady of Wimblington, England, has a condition that makes general anesthesia dangerous for her. In April 1999, she faced a foot operation that would have been extremely painful without anesthesia. She arranged for a hypnotherapist to help her through the procedure, but when he failed to show up, she was forced to rely on self-hypnosis as her only anesthetic. She said she imagined the pain as "waves lashing against a sea wall … [and] going away, like the tide." Coady's report that the operation was painless is believable because, in December 2000, she had the same operation on her other foot, again using only self-hypnosis for pain control (Morris, 2000).

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LINKAGES Can meditation relieve stress? (a link to Health, Stress, and Coping)

LINKAGES

MEDITATION, HEALTH, AND STRESS

Meditation uses a set of techniques to create an altered state of consciousness characterized by inner peace and tranquility (Chiesa & Serretti, 2009; Walsh & Shapiro, 2006). Techniques to achieve a meditative state differ, depending on belief and philosophy (e.g., Eastern meditation, Sufism, yoga, or prayer). In the most common meditation methods, a person focuses attention on just one thing until he or she stops thinking about anything else and experiences nothing but "pure awareness" (Benson, 1975; Perlman et al., 2010). In this way, the individual becomes more fully aware of the present moment rather than being caught up in the past or the future.

To organize their attention, meditators may focus on the sound or tempo of their breathing or slowly repeat a soothing word or phrase, called a mantra. During a typical meditation session, breathing, heart rate, muscle tension, blood pressure, and oxygen consumption decrease, whereas blood flow in the brain to the thalamus and frontal lobes increases (Cahn & Polich, 2006; Newberg et al., 2001; Wallace & Benson, 1972). The effects of meditation on the brain are complex (Austin, 2006; Hölzel et al., 2011). During most forms of meditation, EEG activity is similar to that seen in a relaxed, eyes-closed, waking state (see Figure 9.3). Meditation is also associated with increased activity of dopamine (Kjaer et al., 2002), a neurotransmitter involved in the experience of reward or pleasure, and fMRI scans show that during meditation, activity increases in brain areas involved in concentrated attention (Brefczynski-Lewis et al., 2007; Hölzel et al., 2011). Neuroimaging studies have shown, too, that meditation is associated with increased connectivity among brain cells (Luders et al., 2011; Moyer et al., 2011).

Some people claim that meditation improves awareness and understanding of themselves and their environment. It is also associated with better immune system function, reductions in high blood pressure and anxiety, improved sleep, longer life span, and better performance in everything from work to tennis (e.g., Dakwar & Levin, 2009; Goyal et al., 2014; Lee et al., 2009; MacLean et al., 2010; Schutte & Malouff, 2014;). Even a brief meditation session makes it easier to quit smoking (Tang, Tang, & Posner, 2013). More generally, meditators' scores on personality tests indicate increases in overall mental health, happiness, self-esteem, and social openness (e.g., Hofmann, Grossman, & Hinton, 2011; Tang et al., 2007). We still do not know exactly how meditation produces these benefits, though its activation of dopamine brain systems may be an important part of the story. Whatever the mechanism, it is probably not unique to meditation. Many of the benefits associated with meditation have also been reported in with biofeedback, hypnosis, tai chi, or just relaxing (Bernstein et al., 2000; Beyerstein, 1999; Wang, Collet, & Lau, 2004).

PSYCHOACTIVE DRUGS

How do drugs affect the brain?

The altered states we have discussed so far serve a biological need (sleep) or rely on the chemistry of the brain and body (hypnosis and meditation). Other altered states are brought on by outside agents, namely drugs. Every day most people in the world use drugs that alter brain activity and consciousness (Levinthal, 2001). For example, 80 to 90 percent of people in North America use caffeine, the stimulant found in coffee, tea, and energy drinks. A *drug* is a chemical that is not required for normal physiological functioning yet has an effect on the body. You may say that you "need" a cup of coffee in the morning, but you'll still wake up without it; accordingly, the caffeine in coffee is defined as a drug. Drugs whose effects on the brain alter consciousness and

meditation A set of techniques used to focus on the "present moment," which create an altered state of consciousness characterized by inner peace and tranquility other psychological processes are called **psychoactive drugs** (Julien, 2008). The study of psychoactive drugs is called **psychopharmacology**.

Psychopharmacology

Most psychoactive drugs affect the brain by changing the behavior of neurotransmitters or receptors, topics we describe in the chapter on biological aspects of psychology. To create their effects, psychoactive drugs must cross the **blood-brain barrier**, a feature of blood vessels in the brain that prevents some substances from entering brain tissue (Urquhart & Kim, 2009). If a drug can pass this barrier, its psychoactive effects depend on several factors, such as with which neurotransmitter systems the drug interacts, how the drug affects those neurotransmitters and their receptors, and the psychological functions normally affected by the brain systems that use those neurotransmitters.

Drugs can affect neurotransmitters or their receptors through several mechanisms. As mentioned in the biological aspects of psychology chapter, neurotransmitters fit into their own receptors (see Figure 9.8). Some drugs, such as morphine, are similar enough to a particular neurotransmitter to fool its receptors. These drugs, called **agonists**, bind to receptors and imitate, or mimic, the effects of the normal neurotransmitter. Other drugs, called **antagonists**, are similar enough to a neurotransmitter to occupy its receptors but cannot mimic its effects. When they bind to receptors, they prevent the normal neurotransmitter from binding. Still other drugs work by increasing or decreasing the release of a specific neurotransmitter. Finally, some drugs work by speeding or slowing the *removal* of a neurotransmitter from synapses.

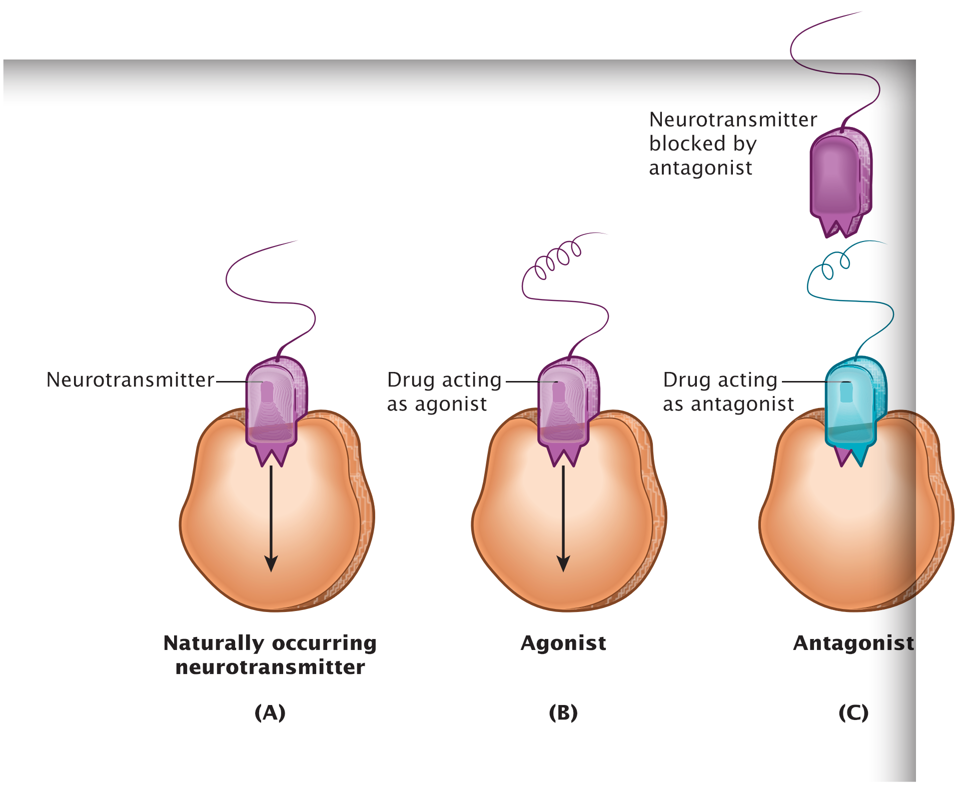

FIGURE 9.8
Agonists and Antagonists

In Part A, a molecule of neurotransmitter interacts with a receptor on a neuron's dendrite by fitting into and stimulating it. Part B shows a drug molecule acting as an agonist, affecting the receptor in the same way a neurotransmitter would. Part C depicts an antagonist drug molecule blocking a natural neurotransmitter from reaching and acting on the receptor.

psychoactive drugs Chemical substances that act on the brain to create psychological effects.

psychopharmacology The study of psychoactive drugs and their effects.

blood-brain barrier A characteristic of blood vessels in the brain that prevents some substances from entering brain tissue.

agonists Drugs that bind to a receptor and mimic the effects of the neurotransmitter that normally fits that receptor.

antagonists Drugs that bind to a receptor and prevent the normal neurotransmitter from binding.

Predicting a psychoactive drug's effects on behavior is complicated. For one thing, most of these drugs interact with many neurotransmitter systems. Also, the nervous system may compensate for a given drug's effects. For instance, repeated exposure to a drug that blocks receptors for a certain neurotransmitter often leads to an increase in the number of receptors available to accept that neurotransmitter.

The Varying Effects of Drugs

The chemical properties that give drugs their medically desirable main effects, such as pain relief, often create undesirable side effects as well.

Drug Abuse

One side effect may be the potential for abuse. **Drug abuse** (sometimes called a **substance use disorder**) is a pattern of use that causes serious social, legal, or interpersonal problems for the user (American Psychiatric Association, 2013). Of course, as a culture changes, which drugs cause a person social and legal problems may also change, as Figure 9.9 illustrates.

FIGURE 9.9
Changing Views of Drugs

The legal and social status of a drug can vary across cultures and over time (Weiss & Moore, 1990). For example, in the United States cocaine was once a respectable, commercially available drug; today it is illegal. Marijuana, once illegal throughout the United States, is now legal in some states. Meanwhile, alcohol, which is legal in the United States and many other nations, is banned in countries such as Kuwait, Iran, and Saudi Arabia.

The William H. Helfand Collection, New York Academy of Medicine; Thinkstock/Getty Images

drug abuse (substance use disorder) The use of psychoactive drugs in ways that deviate from cultural norms and cause serious problems for the user.

Substance abuse can lead to psychological or physical *dependence*. People displaying *psychological dependence* on a drug will continue to use it even though it has harmful effects. They need the drug for a sense of well-being and become preoccupied with getting the drug if it is no longer available. However, they can still function without the drug. Psychological dependence can occur with or without addiction. **Addiction** (also known as *physical dependence*) is a physiological state in which there is not only a strong craving for the drug but also in which using the drug becomes necessary to prevent the unpleasant experience of **drug withdrawal** (sometimes called a *withdrawal syndrome*). Withdrawal symptoms vary depending on the drug, but they often include an intense desire for the drug and physical effects often opposite to those of the drug itself. Eventually, drug use may produce **drug tolerance**, a condition in which increasingly larger drug doses are required to produce the same effects. With the development of drug tolerance, many addicts need the drug just to prevent the negative effects of not taking it. However, a craving for the positive effects of drugs is mainly what keeps addicts coming back to them (Blum et al., 2011).

You may be tempted to think of "addicts" as being different from the rest of us, but we should not underestimate the ease with which drug dependence can develop in any person. Physical dependence develops gradually and may do so without our awareness. In fact, scientists believe that the changes in the brain that underlie addiction may be similar to those that occur during learning (Koob & Kreek, 2007; Nestler, 2001; Ross & Peselow, 2009). All addictive drugs stimulate the brain's "pleasure centers," regions that are sensitive to the neurotransmitter dopamine (Quintero, 2013). Activity of neurons in these areas creates intensely pleasurable feelings, including those associated with a good meal, "runner's high," gambling, or sex (Haber & Knutson, 2010; Reuter et al., 2005). When addictive drugs affect dopamine regulation in these "pleasure centers," they, too, produce tremendously rewarding effects in most people. In fact, the changes created in the brain by drug addiction can remain long after drug use ends (Diana, Spiqa, & Acquas, 2006), which is one reason that people who succeed in giving up addictive drugs may still be in danger of relapse even years later. The risk of relapse is also elevated because of epigenetic effects (see the introductory chapter); for some people, exposure to addictive drugs changes gene expression such that the pleasure a drug creates becomes more intense as use continues (Ponomarev, 2013).

Expectations and Drug Effects

Drug effects are not determined by biochemistry alone (Crombag & Robinson, 2004). The *expectations* we learn through experience with drugs and/or drug users also play a role (Pollo & Benedetti, 2009; Siegel, 2005). So just expecting to drink alcohol, for example, can create neural activity in the same brain areas that are affected by actually drinking it (Gundersen et al., 2008). Several experiments have shown that research participants who consume nonalcoholic drinks that they *think* contain alcohol are likely to behave in line with their expectations about alcohol's effects. So they tend to feel drunk and to become more aggressive, more interested in violent and sexual material, and more easily sexually aroused (Darkes & Goldman, 1993; George & Marlatt, 1986; Lang et al., 1975). And because they know that alcohol impairs memory, these participants are more vulnerable to developing false memories about a crime they witnessed on videotape (Assefi & Garry, 2003). The effects of expectancy are not limited to alcohol. Other research shows that people may feel and act "high" after smoking a cigarette that they believe contains marijuana, even if it doesn't (Metrik et al., 2009).

We build expectations about drug effects in part by watching how other people, especially parents, react to drugs (Cranford et al., 2010; Sher et al., 1996). Such expectations can influence how much of a drug a user will consume. Of course, what a person sees can differ from one individual and culture to the next, so drug effects vary greatly throughout the world (Lin, Smith, & Ortiz, 2001; MacAndrew & Edgerton, 1969). In the United States, for example, drinking alcohol is often associated with uninhibited behavior, including impulsiveness, anger, violence, and sexual promiscuity. But these effects are not seen in all cultures. In Bolivia's Camba culture, for example, people sometimes engage in extended bouts of drinking a brew that is 89 percent alcohol (178 proof). During these binges, the

addiction Development of a physical need for a psychoactive drug.

drug withdrawal A set of symptoms associated with ending the use of an addictive substance.

drug tolerance A condition in which increasingly larger drug doses are needed to produce a given effect.

Camba repeatedly pass out, wake up, and start drinking again—all the while maintaining friendly social relations.

In short, the effects of psychoactive drugs are complex and variable. Let's now consider several major categories of psychoactive drugs that people use primarily to produce altered states of consciousness. They include depressant drugs, stimulating drugs, opiates, hallucinogenic drugs, and dissociative drugs.

CNS Depressant Drugs

Drugs such as alcohol and barbiturates are called **CNS depressant drugs** because they reduce or depress activity in the central nervous system (CNS), mainly in the brain. They do so partly by increasing the effects of the neurotransmitter GABA. As described in the chapter on biological aspects of psychology, GABA reduces the activity of neurons in various brain circuits. So if a drug increases the amount of GABA available, activity in those circuits will be lower than usual, creating feelings of relaxation, drowsiness, and sometimes depression (Hanson & Venturelli, 1995).

Alcohol

The most common CNS depressant drug by far is alcohol. In the United States, more than 100 million people drink it, and alcohol is equally popular worldwide (Leigh & Stacy, 2004; Swendsen et al., 2012). Alcohol affects several neurotransmitters, including glutamate, serotonin, and GABA (Daglish & Nutt, 2003; Enoch, 2003; Vinod et al., 2006). Alcohol also enhances the effect of endorphins, the body's natural painkillers. The fact that endorphins produce a sense of well-being may explain why people initially feel "high" when drinking alcohol. It may also explain why drugs that block endorphins effectively reduce alcohol cravings and relapse rates in recovering alcoholics (Soyka, 2013). Alcohol's pleasurable effects are partly due to its interaction with the dopamine systems that are part of the brain's reward mechanisms (Morikawa & Morrisett, 2010). Prolonged alcohol use can have lasting effects on the brain's ability to regulate dopamine levels (Tiihonen et al., 1995). Dopamine agonists reduce alcohol cravings and the effects of alcohol withdrawal (Swift et al., 2010).

Alcohol affects some brain regions more than others. It depresses activity in the locus coeruleus, an area that, as described in our discussion of sleep, normally helps activate the cerebral cortex (Koob & Bloom, 1988). The resulting reduction in cortical activity, in turn, may cause cognitive changes that can cause a loosening of control over normally inhibited behaviors (Casbon et al., 2003). Some drinkers begin talking loudly, acting silly, or telling others what they think of them. Emotional reactions range from giddy happiness to despair. Normally shy people may become impulsive or violent (Giancola & Corman, 2007). Alcohol also impairs the hippocampus, making it more difficult to process information and form new memories (Anderson et al., 2012). Chronic alcohol use appears to damage the hippocampus permanently, making it smaller and less functional in heavy drinkers as compared to nondrinkers (Beresford et al., 2006; McClintick et al., 2013). Elsewhere in the brain, alcohol's suppression of the cerebellum causes poor motor coordination, including difficulty in walking (Rogers et al., 1986). Excessive use can permanently damage the cerebellum (Manto, 2012). Alcohol's ability to depress hindbrain mechanisms required for breathing and heartbeat is probably why very high doses become fatal.

As mentioned earlier, some effects of alcohol—such as anger and aggressiveness—depend on not only biochemical factors but also learned expectations (Goldman, Darkes, & Del Boca, 1999; Kushner et al., 2000). Other effects—especially disruptions in motor coordination, speech, and thought—result from biochemical factors alone. These biological effects depend on the amount of alcohol the blood carries to the brain. It takes the liver about an hour to break down one ounce of alcohol (the amount in one typical drink), so alcohol has milder effects if consumed slowly (Zakhari, 2006). Faster drinking or drinking on an empty stomach speeds absorption of alcohol into the blood and heightens its effects. Even after allowing for differences in average male and female body weight, metabolic differences allow male bodies to tolerate somewhat greater amounts of alcohol. So a given quantity of alcohol may have a stronger effect on the average woman than on

CNS depressant drugs Psychoactive drugs that inhibit the functioning of the central nervous system.

Drinking and Driving Don't Mix

Though practice makes it seem easy, driving a car is a complex information-processing task. As described in the chapter on thought and language, such tasks require constant vigilance, quick decisions, and skillful execution of responses. Alcohol can impair all these processes, as well as the ability to judge the degree of impairment—thus making drinking and driving a deadly combination that results in almost 11,000 deaths each year in the United States alone (National Highway Traffic Safety Administration, 2010).

Luis Santana/Photos.com

the average man (York & Welte, 1994). Overindulgence by either sex results in unpleasant physical hangover effects that are not effectively prevented or relieved by aspirin, bananas, vitamins, coffee, eggs, exercise, fresh air, honey, pizza, herbal remedies, more alcohol, or any of dozens of other "surefire" hangover cures (Pittler, Verster, & Ernst, 2005).

Genetics helps determine the biochemical effects of alcohol (Rietschel & Treutlein, 2013). Evidence suggests that some people have a genetic predisposition toward alcohol dependence (Kimura & Higuchi, 2011), though the genes involved have not yet been identified. Other groups (the Japanese, for example) may have inherited metabolic characteristics that enhance the adverse effects of alcohol, possibly inhibiting the development of alcohol abuse (Iwahashi et al., 1995).

Barbiturates

Sometimes called "downers" or sleeping pills, *barbiturates* are highly addictive. In small doses, their psychoactive effects include relaxation, mild pleasure, loss of muscle coordination, and reduced attention. Higher doses cause deep sleep, but continued use actually distorts sleep patterns (Zammit, 2007), so long-term use of barbiturates as sleeping pills may be unwise. Overdoses can be fatal. Withdrawal symptoms are among the most severe for any drug and can include intense agitation, violent outbursts, seizures, hallucinations, and even sudden death.

GHB

Gamma hydroxybutyrate (GHB) is a naturally occurring substance similar to the neurotransmitter GABA (Drasbek, Christensen, & Jensen, 2006; Wong, Gibson, & Snead, 2004). As mentioned earlier, it is sometimes used by physicians in the treatment of narcolepsy. However, a laboratory-manufactured version of GHB (also known as "G") has become a popular "club drug," meaning that it is often used at nightclubs, concerts, raves, or dance parties (Gahlinger, 2004). GHB is known for creating relaxation, feelings of elation, loss of inhibitions, and increased sex drive (Schuman-Oliver et al., 2011). It can also cause nausea and vomiting, headaches, memory loss, dizziness, loss of muscle control or paralysis, breathing problems, loss of consciousness, and even death—especially when combined with alcohol or other drugs (Miotto et al., 2001; Stillwell, 2002). As with other CNS depressants, long-term use of GHB can lead to dependence (Carter et al., 2006). Dependent users who abruptly stop taking the drug may experience withdrawal symptoms that can include seizures, hallucinations, agitation, coma, or death (Van Noorden et al., 2009).

Flunitrazepam

A drug related to the prescription medications Xanax and Valium, *flunitrazepam* has been used by physicians to treat insomnia, but those who abuse it risk becoming dependent, and acute intoxication can be fatal (Druid, Holmgren, & Ahlner, 2001). Flunitrazepam relaxes muscles, produces sedation, but also impairs decision making and may cause a person to forget the drug experience. This amnesic effect, combined with the drug's reputation for making people more willing to engage in sex (Britt & McCance-Katz, 2005), makes it one of several club drugs, including GHB, that are used in drug-facilitated sexual assault or "date rape" (Beynon et al., 2008).

CNS Stimulating Drugs

Whereas depressants slow down central nervous system activity, **CNS stimulating drugs** speed it up. Amphetamines, cocaine, caffeine, and nicotine are all examples of CNS stimulating drugs.

Deadly Drug Use

Singer Whitney Houston's death in 2012 was due in part to her chronic use of cocaine. She joined a long list of celebrities (including Corey Monteith, Lisa Robin Kelly, Amy Winehouse, Chris Kelley, Heath Ledger, and Phillip Seymour Hoffman) and an even longer list of non-celebrities whose lives have been destroyed by the abuse of alcohol, cocaine, or other addictive drugs.

Ian West/PA Photos /Landov

CNS stimulating drugs Psychoactive drugs that increase behavioral and mental activity.

Amphetamines

Often called "uppers" or "speed," *amphetamines* increase the release of norepinephrine and dopamine into synapses, affecting sleep, learning, and mood (Bonci et al., 2003; Kolb et al., 2003). Amphetamines also slow the removal of both substances at synapses, leaving more of them there, ready to work. The increased activity at these neurotransmitters' receptors results in alertness, arousal, and appetite suppression. These effects are amplified by the fact that amphetamines also reduce activity of the inhibitory neurotransmitter GABA (Vlachou & Markou, 2010). Amphetamines' rewarding properties are probably associated with their effect on dopamine activity, because taking dopamine antagonists reduces amphetamine use (Higley et al., 2011).

Amphetamine abuse usually begins after taking these drugs to lose weight, increase alertness, stay awake, or "get high." Repeated use leads to anxiety and insomnia. Continued use often causes heart problems, brain damage, movement disorders, confusion, paranoia, nonstop talking, and psychological and physical dependence (Rusyniak, 2011). In some cases, symptoms of amphetamine abuse are almost identical to those of paranoid schizophrenia (Salo, Ravizza, & Fassbender, 2011), a serious mental disorder linked to dopamine malfunction.

Cocaine

Like amphetamines, *cocaine* increases norepinephrine and dopamine activity and decreases GABA activity, so it produces many amphetamine-like effects (Ciccarone, 2011; Vlachou & Markou, 2010). Cocaine has a particularly powerful and rapid effect on dopamine activity and so is remarkably addictive (Wise & Kiyatkin, 2011). In fact, most drugs with rapid onset and short duration are more addictive than others (Kato, Wakasa, & Yamagita, 1987), which helps explain why *crack*—a purified, fast-acting, highly potent, smokable form of cocaine—is especially addictive (Falck, Wang, & Carlson, 2007). In the United States, about 5.3 million people over the age of twelve have used cocaine and about 1.1 million have used crack at least once in the last year (Substance Abuse and Mental Health Services Administration, 2009).

Cocaine stimulates self-confidence, a sense of well-being, and optimism. Continued use brings nausea, overactivity, insomnia, paranoia, a sudden depressive "crash," hallucinations, sexual dysfunction, and seizures (Lacayo, 1995). However, every time it is used, immediate effects on the heart and brain are unpredictable; even small doses can cause a fatal heart attack or stroke (Maraj, Figueredo, & Lynn, 2010). Using cocaine during pregnancy harms the fetus (Hurt et al., 1995) and is known to leave lasting cognitive and behavioral problems for the child (Salisbury et al., 2009). Nonetheless, many of the severe, long-term behavioral problems seen in "cocaine babies" may stem from poverty and neglect after birth and not just the mother's cocaine use (Ackerman, Riggins, & Black, 2010). Early intervention can reduce some of the effects of both cocaine and the hostile environment that confronts cocaine babies (Bada, 2012).

Caffeine

Caffeine may be the world's most popular drug. It is found in chocolate, many soft drinks, tea, and coffee, which is consumed worldwide more than any other beverage except water (Butt & Sultan, 2011). A typical cup of coffee has 58 to 259 mg of caffeine, and even "decaffeinated" coffee may contain up to 15.8 mg (McCusker, Goldberger, & Cone, 2003; McCusker et al., 2006). Energy drinks have up to 505 mg per can (Reissig, Strain, & Griffiths, 2009). Caffeine reduces drowsiness, can create temporary improvements in cognitive performance, including problem solving and vigilance (Snel & Lorist, 2011). In modest quantities, caffeine may help people form memories. In one study, participants viewed a series of images, then received either caffeine or a placebo. The next day, those who had received mild to moderate elevations in their caffeine levels performed better when trying to remember the images they had seen. Those who had the highest caffeine levels did not do as well, suggesting that a "medium" dose may work best (Borota et al., 2014). Indeed, at high doses, caffeine causes anxiety and tremors. People can develop tolerance to caffeine, and it is physically addictive (Ogawa & Ueki, 2007; Strain et al., 1994). Withdrawal symptoms—including headache, fatigue, anxiety, shakiness, and craving—appear on the first day of abstinence and last about a week (Silverman et al., 1992). Caffeine may also slightly raise the risk of breast cancer in women (Jiang, Wu, & Jiang, 2013). Whereas heavy caffeine use may increase the risk of miscarriage, stillbirth, or having a low birth weight baby (Kuczkowski, 2009), it is unclear if mild to moderate caffeine use poses a pregnancy risk (Jahanfar & Jaafar, 2013). Moderate daily use may cause slight increases in blood pressure (Geleijnse, 2008), but otherwise appears to have few, if any, negative effects (e.g., Lopez-Garcia et al., 2008; Winkelmayer et al., 2005). Caffeine consumption may even be associated with a decreased risk of developing Alzheimer's disease (Marques et al., 2011).

Nicotine

A powerful autonomic nervous system stimulant, *nicotine* is the main psychoactive ingredient in tobacco. It enhances the action of acetylcholine (Penton & Lester, 2009) and increases the availability of glutamate, the brain's primary excitatory neurotransmitter (Liechti & Markou, 2008). It also activates the brain's dopamine-related pleasure systems (Herman et al., 2014). Nicotine has many psychoactive effects, including elevated mood and improved memory and attention (Domino, 2003; Ernst et al., 2001).

Like cocaine, nicotine can be physically addictive (White, 1998), and teenagers who smoke cigarettes are more likely to go on to use illegal addictive drugs (Mayet et al., 2011). Some people are more vulnerable to nicotine addiction than others (Hiroi & Scott, 2009), and the tendency to become physically dependent on nicotine appears to be at least partly inherited (Russo et al., 2011). Nicotine doesn't create the "rush" noted in many drugs of abuse, yet quitting smoking causes a potent withdrawal syndrome, with craving, irritability, anxiety, reduced heart rate, and lower activity in the brain's reward pathways (Epping-Jordan et al., 1998; Hughes, Higgins, & Bickel, 1994). This is partly why smoking tobacco can be a difficult habit to break (Crane, 2007). Today, so-called electronic cigarettes are touted as a safer alternative to tobacco cigarettes, but their safety remains in question (Palazzolo, 2013). Use of various forms of smokeless nicotine replacement may help some people quit smoking (Stead et al., 2012), as can medications such as varenicline and buproprion (Carson et al., 2013). An antismoking vaccine is being proposed as well (Fahim, Kesser, & Kalnik, 2013). By whatever means, quitting is worthwhile. Although smoking is a major risk factor for death from cancer, heart disease, and respiratory disorders, smokers who quit before the age of thirty-five have long-term mortality rates similar to those who never smoked (Centers for Disease Control and Prevention, 2008, 2011a).

MDMA

The stimulant "ecstasy," or *MDMA* (short for methylenedioxymethamphetamine)—also known as "XTC," "clarity," "essence," "E," and "Adam"—is another club drug that is popular on college campuses in the United States. MDMA acts on dopamine pathways in the brain (Schenk, Gittings, & Colussi-Mas, 2011), so it leads to some of the same effects as those produced by cocaine and amphetamines (Steele, McCann, & Ricaurte, 1994). These include emotional changes with a sense of well-being, increased sex drive, and a feeling of greater closeness to others. Undesirable effects of MDMA may include dry mouth, hyperactivity, jaw muscle spasms that may result in "lockjaw," elevated blood pressure, fever, and dangerous heart rhythms (Baylen & Rosenberg, 2006). Hallucinations from MDMA are probably because MDMA acts as a serotonin agonist and it increases serotonin release (Green, Cross, & Goodwin, 1995). On the day after using MDMA, people often report muscle aches, fatigue, depression, and poor concentration.

MDMA does not appear to be physically addictive, but it is dangerous and potentially deadly, especially when taken by women (Liechti, Gamma, & Vollenweider, 2001; National Institute on Drug Abuse, 2000). It permanently damages the brain (Sarkar & Schmued, 2010), killing serotonin-sensitive and dopamine-using neurons. As you might expect, the danger of brain damage increases with higher doses and continued use. MDMA users may develop the symptoms of panic disorder, with intense anxiety and a sense of impending death (see the chapter on psychological disorders). When given to pregnant animals, MDMA produces permanent behavioral changes in their offspring (Thompson et al., 2009). Research on humans and nonhumans indicates that many of the MDMA's effects remain even after its use is discontinued (Kalechstein et al., 2007; Smith, Tivarus, et al., 2006).

Another Drug Danger

Oxycodone, a morphine-like drug prescribed by doctors under the label OxyContin, is popular among recreational substance abusers. It was designed as a timed-release painkiller, but when people crush OxyContin tablets and then inject or inhale the drug, they get a much stronger and potentially lethal dose, especially when they are also using other drugs such as alcohol or cocaine (Cone et al., 2004). Deaths from OxyContin abuse have been on the rise in the United States in recent years (Centers for Disease Control and Prevention, 2011b).

Stockbyte/Thinsktock

Opiates

The **opiates** (opium, morphine, heroin, and codeine) are unique in their capacity for inducing sleep and relieving pain (Julien, 2008). *Opium,* which comes from the poppy plant, relieves pain and creates feelings of euphoria and relaxation (Cowan et al., 2001). One of its most active ingredients, *morphine,* was first isolated in the early 1800s. It is used worldwide for pain relief. Percocet, Vicodin, and OxyContin are some common morphine-like drugs. *Heroin* is made from morphine but is three times more powerful, causing intensely pleasurable reactions. Opiates have complex effects on consciousness (Gruber, Silveri, & Yurgelun-Todd, 2007). Drowsy, cloudy feelings occur because opiates depress activity in some areas of the cerebral cortex. They also create excitation in other parts, causing some users to experience euphoria, or elation (Bozarth & Wise, 1984). Opiates exert many of their effects by stimulating the receptors normally stimulated by endorphins, the body's own painkillers. This action "tricks" the brain into an exaggerated activation of its pain-killing and mood-altering systems (Julien, 2008).

Opiates are highly addictive, largely because of their actions on the dopamine reward system (Kreek et al., 2009), but also partly because they affect both glutamate and GABA receptors in a way that changes how nerve cells communicate with each other (Dacher & Nugent, 2011). It may be, then, that opiates alter neurons so that they come to require the drug (Christie, 2008). Beyond the hazard of addiction itself, heroin addicts risk death through overdoses, contaminated drugs, or AIDS contracted through sharing needles (Hser et al., 2001).

opiates Psychoactive drugs that produce both sleep-inducing and pain-relieving effects.

hallucinogenic drugs Psychoactive drugs that alter consciousness by producing a temporary loss of contact with reality and changes in emotion, perception, and thought.

Hallucinogenic Drugs

Hallucinogenic drugs, also called *psychedelic drugs,* create a loss of contact with reality and alter other aspects of emotion, perception, and thought. They can cause distortions in body image (the user may feel gigantic or tiny), loss of identity (uncertainty about who one actually is), dreamlike fantasies, and hallucinations. Because these effects resemble many severe forms of mental disorder, hallucinogenic drugs are also called *psychotomimetics* ("mimicking psychosis").

LSD

One of the most powerful hallucinogenic drugs is *lysergic acid diethylamide* (LSD). It was first synthesized from a rye fungus by Swiss chemist Albert Hofmann. In 1938, after Hofmann accidentally ingested a tiny amount of the substance, he discovered the drug's strange effects in the world's first LSD "trip" (Julien, 2008). LSD hallucinations can be quite bizarre. Time may seem distorted, sounds may cause visual sensations, and users may feel as if they have left their bodies. LSD's hallucinations may stem from its ability to stimulate a specific type of serotonin receptor (Halberstadt & Geyer, 2011). This possibility is supported by evidence that serotonin antagonists reduce LSD's hallucinatory effects (Passie et al, 2008). The strangeness of LSD hallucinations may occur because the drug activates slightly different brain areas than those activated when we are correctly sensing the world around us (Iaria et al., 2010).

The effects of LSD on a particular person are unpredictable. Unpleasant hallucinations and delusions can occur during a person's first—or two hundredth—LSD experience. Although LSD is not addictive, tolerance to its effects does develop. Some users suffer lasting side effects, including severe short-term memory loss, paranoia, violent outbursts, nightmares, and panic attacks (Gold, 1994). Sometimes "flashbacks" can occur, in which a person suddenly returns to an LSD-like state of consciousness weeks or even years after using the drug.

Ketamine

Ketamine is an anesthetic used by veterinarians to ease pain in animals (Hirota, 2006; Robakis & Hirsch, 2006), but because it also has hallucinogenic effects, it is used as a recreational drug known as "Special K." Its effects include dissociative feelings that create an "out-of-body" or "near-death" experience. Ketamine intoxication can create thought problems similar to those seen in schizophrenia (Neill et al., 2011), and long-term use causes lasting memory impairments (Venâncio et al., 2011), probably because the drug damages memory-related brain structures such as the hippocampus (Jevtovic-Todorovic et al., 2001).

Marijuana

A mixture of crushed leaves, flowers, and stems from the hemp plant (*Cannabis sativa*) makes up *marijuana*. The active ingredient is *tetrahydrocannabinol* (THC) (Fisar, 2009). When inhaled, THC is absorbed in minutes by many organs, including the brain (Martin-Santos et al., 2010), and it continues to affect consciousness for a few hours (O'Leary et al., 2002). THC tends to collect in fatty deposits of the brain and reproductive organs, where it can remain for weeks. Low doses of marijuana may initially create restlessness and hilarity, followed by a dreamy, carefree relaxation, an expanded sense of space and time, more vivid sensations, food cravings, and subtle changes in thinking (Kelly et al., 1990).

For some time now, marijuana has been legally prescribed by physicians in the District of Columbia, in several U.S. states, and in Canada and several other countries, and has been successful in the treatment of asthma, glaucoma, epilepsy, chronic pain, and nausea from cancer chemotherapy; it may even help in treating some types of cancer (Grevdanus et al., 2013). While opponents of medical marijuana point to its possible health and safety risks and argue that other medications may be equally effective and less dangerous (e.g., Campbell et al., 2001; Fox et al., 2004; Hall & Degenhardt, 2003), some U.S. states are bypassing the medical debate by legalizing the sale, purchase, and use of marijuana for any purpose, including recreation.

Even if marijuana becomes legal everywhere, controversy over its use will likely continue. Proponents argue that, unlike tobacco, marijuana does not harm the lungs (Sidney, Feng, & Kertesz, 2011). Opponents point to findings that withdrawal from marijuana may be accompanied by increases in anxiety, depression, irritability, restlessness, and aggressiveness (Allsop et al., 2011; Levin et al., 2010). And because marijuana interacts with the same dopamine and opiate receptors as heroin (Cadoni et al., 2013), some researchers speculate that, like tobacco, marijuana may act as a "gateway" to using more addictive drugs (Mayet et al., 2012). Others point out, though, that the rewarding effects of sex and chocolate occur by activating these same receptors, and that those pleasures are not generally viewed as gateways to drug addiction.

Regardless of whether marijuana is addicting or leads to opiate use, like all drugs, it can create problems, including in the cardiovascular and immune systems (Hall & Degenhardt, 2009; Jayanthi et al., 2010). Marijuana also disrupts memory formation, making it difficult to carry out mental or physical tasks and, despite many users' impressions, it actually reduces creativity (Bourassa & Vaugeois, 2001). Because marijuana disrupts muscle coordination, driving under its influence is dangerous (Asbridge, Hayden, & Cartwright, 2012). Marijuana easily reaches a developing fetus, and while the risk to a pregnancy is not clear (Jaques et al., 2013), pregnant women's use of marijuana has been associated with behavioral problems in their children (Day, Leech, & Goldschmidt, 2011). Finally, long-term use can lead to psychological dependence (Stephens, Roffman, & Simpson, 1994) as well as to impairments in reasoning and memory that last for months or years after marijuana use stops (Sofuoglu, Sugarman, & Carroll, 2010).

These effects are especially strong in people who start using marijuana before the age of fifteen (Fontes et al., 2011). In fact, heavy use by teenagers has been associated with smaller than normal volume in brain areas involved in emotion and memory as well as with the later appearance of anxiety, depression, and other even more serious symptoms of mental disorder (e.g., Moore et al., 2007; Yücel et al., 2008). Some research suggests that frequent marijuana users also show lower IQ scores as individuals move from childhood to adulthood (Meier et al., 2012). Still, these correlations cannot establish cause and effect. For example, some research suggests that the relationship between marijuana use and lower IQ may be caused by a third factor, such as educational or socioeconomic status (Rogeberg, 2013).

Further complicating the scientific and legal controversy surrounding marijuana is the recent emergence of several forms of "legal pot." These synthetic substances, such as "spice" and "K2," are being marketed as marijuana alternatives, and because their chemical makeup differs from the THC molecules they mimic, they are not yet illegal. Nevertheless, these compounds and their effects are not well understood, and so potential new dangers arise for users each time a new one is synthesized.

("In Review: Major Classes of Psychoactive Drugs" summarizes our discussion of these substances.)

IN REVIEW

MAJOR CLASSES OF PSYCHOACTIVE DRUGS

Drug	Trade/Street Name	Main Effects	Potential for Physical/ Psychological Dependence
CNS Depressant Drugs			
Alcohol	"booze"	Relaxation, anxiety reduction, sleep	High/high
Barbiturates	Seconal, Tuinal, Nembutal ("downers")	Relaxation, anxiety reduction, sleep	High/high
GHB	"G," "jib," "scoop," "GH buddy"	Relaxation, euphoria	High/high

(continued)

IN REVIEW

MAJOR CLASSES OF PSYCHOACTIVE DRUGS (CONT.)

Drug	Trade/Street Name	Main Effects	Potential for Physical/ Psychological Dependence
Flunitrazepam	"R2," "roofie," "roach"	relaxation, impaired decision making, memory loss	High/high
CNS Stimulating Drugs			
Amphetamines	Benzedrine, Dexedrine, Methadrine ("speed," "uppers," "ice")	Alertness, euphoria	Moderate/high
Cocaine	"coke," "crack"	Alertness, euphoria	Moderate to high/high
Caffeine		Alertness	Moderate/ moderate
Nicotine	"smokes," "coffin nails"	Alertness	High (?)/high
MDMA	"ecstasy," "clarity"	Hallucinations	Low/(?)
Opiates			
Opium		Euphoria	High/high
Morphine	Percodan, Demerol	Euphoria, pain control	High/high
Heroin	"junk," "smack"	Euphoria, pain control	High/high
Hallucinogenic Drugs			
LSD/ketamine	"acid"/"special K"	Altered perceptions, hallucinations	Low/low
Marijuana (cannabis)	"pot," "dope," "reefer," "weed"	Euphoria, relaxation	Low/moderate

In Review Questions

1. Physical dependence on a drug is a condition more commonly known as __________ .
2. Drugs that act as antagonists __________ the interaction of neurotransmitters and receptors.
3. Drug effects are determined partly by what we learn to __________ the effects to be.

LINKAGES

As noted in the introductory chapter, all of psychology's subfields are related to one another. Our discussion of meditation, health, and stress illustrates just one way that the topic of this chapter, consciousness, is linked to the subfield of health psychology, which is described in the chapter on health, stress, and coping. The Linkages diagram shows ties to two other subfields, and there are many more ties throughout the book. Looking for linkages among subfields will help you see how they all fit together and help you better appreciate the big picture that is psychology.

CHAPTER 9 Consciousness

LINKAGES

Do forgotten memories remain in consciousness?

Can meditation relieve stress?

Can subconscious processes alter our reaction to people?

CHAPTER 6
Memory

CHAPTER 12
Health, Stress, and Coping

CHAPTER 16
Social Psychology

SUMMARY

Consciousness can be defined as awareness of the outside world and of one's own thoughts, feelings, perceptions, and other mental processes.

The Scope of Consciousness

Can unconscious thoughts affect your behavior?

A person's ***consciousness state*** is constantly changing. When the changes are particularly noticeable, they are called ***altered states of consciousness***. Examples of altered states include sleep, hypnosis, meditation, and some drug-induced conditions. Cultures differ in the value they place on particular states of consciousness.

Differing levels of consciousness are described as variations in awareness of your own mental functions. The ***preconscious level*** includes mental activities that are outside awareness but that can easily be brought to the ***conscious level***. ***Subconscious*** and ***unconscious*** mental activity is said to involve thoughts, memories, and processes that are more difficult to bring to awareness. Mental processes that cannot be brought into awareness are said to occur at the ***nonconscious level***.

Awareness is not always required for mental operations. For example, research on priming shows that people's responses to stimuli speed up and improve as stimuli are repeated, even when there is no conscious memory of which stimuli are old and which are new. And some decisions that seem intuitive may be guided by information that is outside of awareness.

Sleeping and Dreaming

Does your brain go to sleep when you do?

Sleep is an active and complex state. Different stages of sleep are defined on the basis of changes in brain activity (as measured by an electroencephalograph, or EEG) and physiological arousal. Sleep normally begins with stage N1 sleep and progresses gradually through stage N2 to stage N3 sleep. The deepest stage of this ***NREM* (*non-rapid eye movement*)** sleep is also called slow-wave sleep. After passing back to stage N2, people enter ***REM (rapid eye movement) sleep***, or paradoxical sleep. The sleeper passes through these stages several times each night, gradually spending more time in stage N2 and REM sleep later in the night.

Sleep disorders can disrupt the natural rhythm of sleep. Among the most common is ***insomnia***, a condition in which one has trouble falling asleep or staying asleep. ***Narcolepsy*** produces sudden daytime sleeping episodes. In cases of ***sleep apnea***, people briefly but repeatedly stop breathing during sleep. ***Sudden infant death syndrome* (*SIDS*)** may be due to brain abnormalities or accidental suffocation. ***Sleepwalking*** happens most frequently during childhood. ***Nightmares*** and ***sleep terror disorder* (*night terrors*)** involve different kinds of frightening dreams. ***REM behavior disorder*** is potentially dangerous because it allows people to act out REM dreams.

The cycle of waking and sleeping is a natural ***circadian rhythm*** or ***human biological rhythm***, controlled by the suprachiasmatic nuclei of the brain. ***Jet lag*** can be one result of disrupting the normal sleep-wake cycle.

The purpose of sleep is still unclear. NREM sleep may aid bodily rest and repair. REM sleep may help maintain activity in brain areas that provide daytime alertness or it may allow the brain to "check circuits," eliminate useless information, and solidify learning from the previous day. ***Sleep deprivation*** leads to fatigue, irritability, and inattention and is a major factor in poor decision making, learning and memory difficulties, and traffic accidents.

Dreaming is the production of storylike sequences of images, sensations, and perceptions that occur during sleep. Most dreams occur during REM sleep. Evidence from research on ***lucid dreaming*** suggests that people may be able to control their own dreams. Some claim that dreams are the meaningless by-products of brain activity, but our recall of dreams may still have psychological significance.

Hypnosis

Can you be hypnotized against your will?

Hypnosis is a well-known but still poorly understood phenomenon. Tests of ***hypnotic susceptibility*** suggest that some people cannot be hypnotized and that others are hypnotized easily. Hypnotized people tend to focus attention on the hypnotist and passively follow instructions. They become better at fantasizing and role taking. They may exhibit apparent age regression, experience posthypnotic amnesia, and obey posthypnotic suggestions.

State theories of hypnosis see hypnosis as a special state of consciousness. ***Nonstate theories of hypnosis*** such as role theory suggest that hypnosis creates a special social role that frees people to act in unusual ways. *Dissociation theory* combines aspects of role and state theories, suggesting that hypnotized individuals enter into a social contract with the hypnotist to allow normally integrated mental processes to become dissociated and to share control over these processes. Hypnosis is useful in the control of pain and the reduction of nausea associated with cancer chemotherapy.

Meditation is a set of techniques designed to create an altered state of consciousness characterized by inner peace and increased awareness. The consistent practice of meditation has been associated with reductions in stress-related problems such as anxiety and high blood pressure.

Psychoactive Drugs

How do drugs affect the brain?

Psychoactive drugs affect the brain, changing consciousness and other psychological processes. ***Psychopharmacology*** is the field that studies drug effects and their mechanisms. Psychoactive drugs exert their effects primarily by influencing specific neurotransmitter systems and hence certain brain activities. To reach brain tissue, drugs must cross the ***blood-brain barrier***. Drugs that mimic the receptor effects of a neurotransmitter are called ***agonists***; drugs that block the receptor effects of a neurotransmitter are called ***antagonists***. Some drugs alter the release or removal of specific neurotransmitters, thus affecting the amount of neurotransmitter available for receptor effects.

Adverse effects such as ***drug abuse (substance use disorder)*** often accompany the use of psychoactive drugs. Psychological dependence, ***addiction*** (physical dependence), ***drug tolerance***, and symptoms of ***drug withdrawal*** (withdrawal syndrome) may result. Drugs that produce dependence share the property of directly stimulating certain dopamine-sensitive areas of the brain known as pleasure centers. The consequences of using a psychoactive drug depend both on how the drug affects neurotransmitters and on the user's expectations.

Alcohol, barbiturates, GHB, and flunitrazepam are examples of ***CNS depressant drugs***. They reduce activity in the central nervous system, often by enhancing the action of inhibitory neurotransmitters. They have considerable potential for producing both psychological and physical dependence.

CNS stimulating drugs, such as amphetamines and cocaine, increase behavioral and mental activity mainly by increasing the action of dopamine and norepinephrine. These drugs can produce both psychological and physical dependence. Caffeine, one of the world's most popular stimulants, may also create dependence. Nicotine is a potent stimulant. And MDMA, which has both stimulant and hallucinogenic properties, is one of several psychoactive drugs that can permanently damage brain tissue.

Opiates such as opium, morphine, and heroin are highly addictive drugs that induce sleep and relieve pain.

LSD and marijuana are examples of ***hallucinogenic drugs***, or psychedelic drugs. They alter consciousness by producing a temporary loss of contact with reality and changes in emotion, perception, and thought.

TEST YOUR KNOWLEDGE

Select the best answer for each of the following questions. Then check your responses against the Answer Key at the end of the book.

1. Tyrrell is undergoing biofeedback training to help him regulate his blood pressure, a bodily function typically regulated at which level of consciousness?
   a. Nonconscious
   b. Preconscious
   c. Subconscious
   d. Unconscious

2. Dr. Eplort is staying in a cave for several months with no external light cues and no way to keep time. He goes to sleep when he feels sleepy and gets up when he is awake. Dr. Eplort will most likely sleep __________.
   a. fewer hours than he did before
   b. more hours than he did before
   c. about the same as he did before
   d. on a varying and unpredictable schedule

3. Zandra knew nothing about art, and during her first semester on campus she had not noticed the framed Rembrandt prints in the hallway of her classroom building. But when she took an art appreciation class the next semester, she found that the paintings she liked best were those same Rembrandt images. Her preference was most likely affected by __________.
   a. the prosopagnosia effect
   b. supraliminal perception
   c. priming
   d. visual masking

4. Edie has purchased a tape that contains subliminal messages designed to help her lose weight. According to the Thinking Critically section in this chapter, Edie's success in losing weight most likely depends on __________.
   a. the content of the subliminal messages
   b. her expectation that the subliminal messages will help
   c. how relaxed the subliminal messages make her feel
   d. the number of times the subliminal messages occur

5. Mitch noticed that after his friends smoked marijuana, they soon began giggling, acting silly, and singing "We're Off to See the Wizard." After he smoked marijuana himself for the first time, he found himself doing the very same things. Mitch's specific responses to marijuana were most likely due to __________.
   a. an altered state of consciousness
   b. reversion to a preconscious state
   c. priming
   d. learned expectations

6. The telephone rang several hours after Leroy fell asleep. It takes Leroy a while to locate the phone, and he is so groggy when he answers that in the morning, he can't remember who called or what was said. When the phone rang, Leroy was most likely in __________ sleep.
   a. stage N1
   b. stage N2
   c. stage N3
   d. REM

7. Alan's wife is concerned because he often gets out of bed during the night and acts out his dreams. One night he boxed with an invisible opponent, and last night he was fighting a phantom bull. Alan most likely would be diagnosed as having __________.
   a. sleep apnea
   b. narcolepsy
   c. REM behavior disorder
   d. sleep terror disorder

8. The "back to sleep" program, which advises parents to have their babies sleep face up, has greatly reduced the incidence of __________ in the United States.
   a. SIDS
   b. sleep terror disorder
   c. REM behavior disorder
   d. insomnia

9. Dr. Franklin was flying from Los Angeles to Paris, where he was to give a speech shortly after arrival. To minimize the effects of jet lag, his physician would most likely recommend that Dr. Franklin should __________.
   a. be sure to sleep eight hours a night for at least a week before his trip
   b. take melatonin
   c. stay awake for 24 hours before departure, then sleep throughout the flight
   d. reverse his sleep-wake cycle for a week before departure

10. Sleep research suggests that REM sleep may be important for all of the following *except* __________.
    a. improving the functioning of neurons that use norepinephrine
    b. improving the connections that form between nerve cells in the brain
    c. restoring the body's and brain's energy stores for the next day's activity
    d. establishing memories of emotional information

11. According to the activation-synthesis theory, dreams __________.
    a. help our brains analyze and consolidate information
    b. satisfy unconscious urges and resolve unconscious conflicts
    c. are hallucinations
    d. are meaningless, random by-products of REM sleep

12. Lavonne, a hypnotist, wanted to present a dramatic demonstration of hypnosis. Which of the following people should she select as her hypnotic subject?
a. Alex, who is easily distracted.
b. Bobbi, who doesn't believe in hypnosis.
c. Dellena, whose imagination is limited.
d. Carl, who is good at focusing his attention.

13. Hypnosis has been especially effective in __________.
a. connecting with past lives
b. improving memory
c. pain control
d. lowering cholesterol

14. Norman has been meditating for over a year. By now, according to this chapter, we would expect Norman to __________.
a. be less anxious
b. need less sleep to feel refreshed
c. have a better memory
d. daydream more

15. Candice was given morphine to ease the pain of back surgery. Her doctor explained that morphine occupies the same receptors and has the same effect as endorphins, the body's natural painkillers. In other words, morphine is an endorphin __________.
a. reuptake blocker
b. placebo
c. antagonist
d. agonist

16. Vincent has been using heroin for some time, and now he finds that he needs larger amounts of the drug to achieve the same effect he used to get from smaller doses. Vincent is experiencing __________.
a. drug tolerance
b. learned expectations
c. withdrawal
d. synaptic potential

17. Which of the following is true about alcohol?
a. A given amount of alcohol will affect a man more than a woman.
b. Alcohol's effects are the same whether it is consumed slowly or quickly.
c. There are no genetic predispositions toward alcohol abuse.
d. Dopamine agonists reduce alcohol cravings.

18. A woman is brought to a hospital emergency room after an apparent date rape. Which of the following drugs would her doctor suspect was used by her attacker?
a. Amphetamine
b. Marijuana
c. Flunitrazepam
d. LSD

19. Abel took a drug to reduce the pain in his broken arm. The drug Abel took to reduce his pain would be classified as a(n) __________.
a. depressant
b. opiate
c. hallucinogen
d. stimulant

20. Yeh is doing research for a term paper about legalizing the use of marijuana in the United States. If her research is accurate, she is likely to learn all of the following *except* which one?
a. Marijuana has been used successfully in treating asthma, glaucoma, chronic pain, and nausea from chemotherapy.
b. Marijuana increases memory function and creativity.
c. It is legal to grow and use marijuana for medicinal purposes in many U.S. states.
d. Doctors have found that marijuana may help treat some types of cancer.