01 - 2 Biological Foundations of Psychology

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CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY © PHOTOTAKE INC. / ALAMY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

I magine waking up one morning to discover that your sense of smell has intensified to such a degree that all other perceptual experiences pale in comparison. You soon discover that you can tell all your friends and acquaintances apart by just their body odor, and that you can find your way in your home town by the smell of the familiar shops and street corners. Excitement takes hold of you. You realize you are shivering with emotion, a yearning to take in the smell of everything and everyone that surrounds you, and a desire to touch it all as well. And although you are aware that your desires are not sexual, you resist these temptations when you are in the company of others – it would seem inappropriate to behave that way. These were actually the experiences of a young medical student named Stephen D., as recounted by Oliver Sacks in the story ‘The Dog Beneath the Skin’ in his famous book The Man Who Mistook His Wife for a Hat. Oliver Sacks is a neurologist whose writings of case histories have inspired many students of the human brain. Stephen, we are told, is a regular user of cocaine, PCP, and amphetamines. One night he has a very lively dream in which he is a dog and his world is rich with inspiring odors. He awakens to discover that his sense of smell has actually changed dramatically. And Stephen feels emotionally different. His longing to smell and touch everything comes with a sense of melancholia, a desire to return to a long-forgotten place. His thinking also seems to change. He enjoys the immediacy of every experience deeply and discovers that he is finding it more difficult than before to reflect on his experiences and think abstractly. After three weeks Stephen’s symptoms disappear and everything returns to normal, to his relief and regret. Olfaction is the term used for our sense of smell. Hyperosmia (the increased ability to smell), as well as anosmia (the inability to smell), can be the consequence of brain injury or infection, or caused by the use of certain medications. These changes in olfactory sensations have a remarkable impact on the emotional experiences of the patients. How can this be explained? Olfactory information is transmitted to a few different places in the brain, through multiple pathways. One pathway involves areas that are responsible for the perception and discrimination of odors, and damage to these areas results in the inability to discriminate odors.

Another pathway involves brain areas that are responsible for emotional and motivational aspects of behavior. This latter pathway sets the olfactory system apart from the other sensory systems: the emotional experience that accompanies the sensation of an odor is quite literally more direct than the emotion that might result from a visual or auditory experience. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk CHAPTER OUTLINE THE STUDY OF THE BIOLOGICAL BASES OF PSYCHOLOGY NEURONS, THE BUILDING BLOCKS OF THE NERVOUS SYSTEM Action potentials Synaptic transmission and neural coding Neurotransmitters THE ORGANIZATION OF THE BRAIN The hindbrain The midbrain The forebrain Mapping the brain Asymmetries in the brain CUTTING EDGE RESEARCH: THE ADOLESCENT BRAIN THE AUTONOMIC NERVOUS SYSTEM THE ENDOCRINE SYSTEM EVOLUTION, GENES, AND BEHAVIOR Evolution of behavior Chromosomes and genes Genetic studies of behavior SEEING BOTH SIDES: ARE MIRROR NEURONS INVOLVED IN THE EXPERIENCE OF EMPATHY? 33

34 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY We will see that many aspects of human behavior can be understood by taking a look at our biology. For example: exploring the consequences of certain brain injuries teaches us how the brain represents our experiences and behaviors. Similarly, the effects of medications THE STUDY OF THE BIOLOGICAL BASES OF PSYCHOLOGY The introduction illustrates that our perceptions, experiences and behaviors are based on the activation of our nervous system, and that an understanding of its functioning is important for the study of psychology. If this idea strikes you as mechanistic, as if to reduce a human being to some type of biological machine, you are not the first to have this response! The French philosopher René Descartes (1596–1650) proposed that all animal and human action was a mechanical response to an external stimulus: a reaction of a complex system consisting of tubes containing fluids and switching gears. But Descartes was well aware of the fact that denial of the existence of a human soul would have theological implications that would offend the Church and make his theory unacceptable. He was careful to leave room for the human soul and proposed that it is our soul that chooses a particular response from among a set of possible responses. It affords us our flexibility, so that we can have different responses to the same stimulus. Descartes' mind-body dualism proposes that the mind (or soul) exists separately from the physical body, and that both can influence each other. In this chapter, you will be introduced to our current understanding of our biological foundation. It will not be a story about a system of tubes and gears, but rather about the nervous system. This physical system consists of biological cells (neurons) that communicate with one another biochemically. As you study this chapter, some of the material might at first strike you as dry or perhaps as daunting. It is quite difficult to think of oneself in terms of a neural system: your unique human experiences (love, fear, bewilderment) seem impossible to reduce to something as prosaic as that. However, you might also find it quite stimulating. If the human experience is awe-inspiring, then the biological system that makes it possible for us to have these experiences must be rather complex and fascinating itself. And indeed, it is. Our brain might very well be the single most complex object that we know about. The study of the biological basis of our behavior involves considerations about its evolution. An important concept in evolutionary biology is that of pre-adaptation For more Cengage Learning textbooks, visit www.cengagebrain.co.uk or recreational drugs illustrate the role neurotransmitters play as the chemical messengers of the nervous system. In this chapter we will take a look at the nervous system, its building blocks and organization, as well as its evolutionary history. (Mayr, 1960). An example is the evolution of a voicing system: mouth, teeth and tongue gained a new function in producing sounds (and later, the pronunciation of language), even though they clearly

evolved initially for eating. Mayr's idea was that many evolutionary 'novelties' are the result of a process by which an existing system is co-opted, which means that it allows for the development of a new function. A similar mechanism is often proposed to explain the development of specific human abilities. Two compelling examples are the development of moral disgust and the development of our response to social exclusion. Paul Rozin, an American psychologist who likes to refer to himself as 'Dr. Disgust', proposes that moral disgust could develop because of the existence of a distaste and disgust system created by evolution to protect us from ingesting poisonous food (Rozin, Haidt, & McCaeley, 2000). The 'disgust face' was mentioned already by Darwin, who described the gape, the tongue extension, the nose wrinkle, and the dropping of the mouth corners as a response that would prevent food from entering the mouth, or encourage its discharge. Nausea, the physiological state that might accompany disgust, has a similar function, as does the associated response of increased salivation. We know that the disgust response is associated with brain activation in the right prefrontal area as well as the basal ganglia. Rozin proposes that disgust, which started its evolutionary life as response to avoid harm to the body, ultimately evolved to become a mechanism for avoiding harm to the soul. Moral offenses (such as sexual offenses or war atrocities) elicit an emotional response that is similar to the basic disgust response. Research shows that people shy away from contact with a morally offensive person as if the person has a contagious illness, even if that contact is indirect: Rozin's subjects found Adolf Hitler's sweater extremely aversive, as if it was contaminated. Exactly which behaviors are considered morally disgusting differs to some degree across different cultures, so that learning what is morally offensive and disgusting is part of an individual's socialization. Another human response that can be understood from within a model of pre-adaptation is our response to being socially excluded. For human beings it is of the utmost importance to be part of a social group because such connections provide safety, and it has been shown that

social exclusion poses a threat to an individual's physical and emotional health. Research has shown that human beings respond to social exclusion by becoming indifferent and apparently numb to emotional pain (DeWall & Baumeister, 2006). We may understand this if we realize that the evolution of a system of social interaction might have co-opted an evolutionarily older system: the system that allowed for responses to physical pain. A healthy reaction to a painful stimulus sometimes is to (defensively) increase the pain threshold, meaning that pain sensitivity is reduced. According to the pre-adaptation model, the physiological system that responds to physical pain evolved to accrete the function of responding to social pain. This leads to the prediction that social exclusion should influence how an individual responds to physical pain. This prediction was tested experimentally by Nathan deWall and Roy Baumeister (DeWall & Baumeister, 2006). The experimenters threatened half of their subjects with the prospect of a lonely future, whereas control subjects were told that they would have meaningful and lasting relationships. Subjects were made to believe that the experimenters based their predictions on the results of a personality test. In reality, subjects were randomly assigned to one of the two conditions. The researchers hypothesized that the physical pain thresholds of the subjects in the 'future alone' condition should be higher, and this is exactly what they found. Subjects in this condition also had higher physical pain tolerance (the ability to withstand pain) than subjects in the control condition. These results suggest that the emotional numbness reported by ostracized people might be part of a defensive response generated by a common physiological system that is responsible for physical as well as emotional pain. Further support for this comes from studies showing that certain areas in the brain are activated by distress associated with physical pain as well as with social exclusion. We have

seen that some human behaviors (the response to morally offensive behavior and to social exclusion) can be studied and understood from within a model that takes the evolutionary history of our nervous system into account. This insight is nicely underscored by the fact that we use similar words to refer to disgusting food items and disgusting acts (for example nauseating), and similar words for physical and social pain (it hurts) – and not just in English. At this point, it is important to introduce some basic terminology (see Figure 2.1). The term nervous system refers to all neural tissue. This system is divided into the central nervous system (CNS) and the peripheral nervous system (PNS). The central nervous system includes the brain (the part of the nervous system that resides in the skull) and the spinal cord. The peripheral nervous system includes the remainder of the neural tissue in the rest of the body. Afferent nerves carry signals from the body to the CNS, whereas efferent nerves carry signals from the CNS to the body. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk THE STUDY OF THE BIOLOGICAL BASES OF PSYCHOLOGY Brain Central nervous system Spinal cord Nervous system Somatic system Peripheral nervous system Autonomic system Figure 2.1 The organization of the nervous system. The PNS consists of the somatic system, which carries messages to and from the sense receptors, muscles, and the surface of the body (for conscious sensory functions and voluntary motor functions), and the autonomic system, which connects with the internal organs and glands (for automatic and involuntary functions, such as the beating of the heart). The sensory nerves of the somatic system transmit information about external stimulation from the skin, muscles, and joints to the central nervous system. That is how we become aware of pain, pressure, and temperature variations. The motor nerves of the somatic system carry impulses from the central nervous system to the muscles, where they initiate action. All the muscles we use in voluntary movements, as well as involuntary adjustments in posture and balance, are controlled by these nerves. The nerves of the autonomic system run to and from the internal organs, regulating processes such as respiration, heart rate, and digestion. In this chapter we will study these systems in detail by taking a look at specific parts of the nervous system (in particular: the brain and the autonomic system), as well as the endocrine system (the system of glands in charge of hormone secretion). The final section of this chapter concerns evolutionary biology and its relevance for the study of human behavior. We will start with the basic building blocks of the nervous system (neurons), and their communication system. INTERIM SUMMARY l Researchers have proposed that some human functions (such as moral disgust and our response to social exclusion) could develop through a process of preadaptation, by co-opting (‘hijacking’) existing systems (in these cases, the systems for physical disgust and physical pain). l The nervous system is divided into the central nervous system and the peripheral nervous system. The central nervous system includes the brain and the spinal cord. The peripheral nervous system includes the somatic system and the autonomic system.

 CRITICAL THINKING QUESTIONS 1 Can you think of another human function that might have developed by co-opting an existing function? 2 Most modern psychologists believe that it is important to study how the nervous system works. Do you agree? NEURONS, THE BUILDING BLOCKS OF THE NERVOUS SYSTEM The basic unit of the nervous system is the neuron, a specialized cell that transmits neural impulses or messages to other neurons, glands, and muscles. Neurons hold the secrets of how the brain works. We know the role they play in the transmission of nerve impulses, and we know how some neural circuits work, but we are just beginning to unravel their more complex functioning in memory, emotion, and thought. The many types of neurons in the nervous system differ markedly in size and appearance, but they all have certain common characteristics (see Figure 2.2). Projecting from the cell body, or

soma, are a number of short branches called dendrites (from the Greek word dendron, meaning ‘tree’), which receive neural impulses from other neurons. The axon is a slender tube that extends from the soma and transmits these messages to other neurons. At its end, the axon divides into a number of tiny branches that end Dendrites Terminal buttons Nucleus Soma (cell body) Myelin sheath Nodes of Ranvier Axon (inside myelin sheath) Direction of messages Figure 2.2 Schematic Diagram of a Neuron. Arrows indicate the direction of the nerve impulse. Some axons are branched; the branches are called collaterals. The axons of many neurons are covered with an insulating myelin sheath that helps increase the speed of the nerve impulse. (Adapted from Human Anatomy by Anthony J. Gaudin and Kenneth C. Jones. Copyright © 1988 by Anthony J. Gaudin and Kenneth C. Jones. Reprinted by permission of the authors.) For more Cengage Learning textbooks, visit www.cengagebrain.co.uk in small swellings called synaptic terminals or terminal buttons. The terminal buttons do not actually touch the adjacent neuron. There is a slight gap between the terminal button and the cell body or dendrites of the receiving neuron. This junction is called a synapse, and the gap itself is called the synaptic gap. When a neural impulse travels down the axon and arrives at the terminal buttons, it triggers the secretion of a neurotransmitter, a chemical that diffuses across the synaptic gap and stimulates the next neuron, thereby transmitting the impulse from one neuron to the next. The axons from a great many neurons form synapses on the dendrites and cell body of a single neuron (see Figure 2.3). In this way, the post-synaptic (receiving) neuron integrates information from multiple pre-synaptic neurons. Although all neurons have these general features, they vary greatly in size and shape (see Figure 2.4). A neuron in the spinal cord may have an axon up to a meter long, running from the end of the spine to the muscles of the big toe; a neuron in the brain may cover only a few thousandths of a centimeter. Neurons are classified into three categories, depending on their general function. Sensory neurons transmit impulses received by receptors to the central nervous system. The receptors are specialized cells in the sense organs, muscles, skin, and joints that detect physical or chemical changes and translate these events into impulses that travel along the sensory neurons. Motor neurons carry outgoing signals from the central nervous system to muscles and glands. Interneurons connect sensory (afferent) and motor (efferent) neurons. Interneurons are found only in the central nervous system and in the eyes. A nerve is a bundle of elongated axons belonging to hundreds or thousands of neurons. For example, the optic nerve carries the signals from the eye to the brain. A single nerve may contain axons from both sensory and motor neurons. The cell bodies of neurons are generally grouped together throughout the nervous system. In the brain and spinal cord, a group of cell bodies of neurons is referred to as a nucleus (plural: nuclei). A group of neuronal cell bodies found outside the brain and spinal cord is called a ganglion (plural: ganglia). In addition to neurons, the nervous system has a large number of nonneural cells, called glial cells, that are interspersed among – and often surround – neurons. Glial cells outnumber neurons by 9 to 1 and take up more than half the volume of the brain. The name glia, derived from the Greek word for ‘glue’, suggests one of their functions – namely, to hold neurons in place. In addition, they provide nutrients to the neurons and appear to ‘keep house’ in the brain by gathering and

packaging up waste products and taking up dead neurons and foreign substances, thereby maintaining the signaling capacity of neurons (Haydon, 2001). Action potentials One important term left unexplained thus far is the neural impulse. Information moves along a neuron in the form of a neural impulse called an action potential – an electrochemical impulse that travels from the cell body down to the end of the axon. Each action potential is the result of movements by electrically charged molecules, known as ions, in and out of the neuron. The key to understanding

the generation of the action potential lies in appreciating that neurons are normally very selective about what ions can flow in and out of the cell. That is, the cell membrane of the neuron (including its axon) is semi-permeable, which means that some ions can pass through the cell membrane easily and others are not allowed to pass through except when special passageways in the membrane are open. These passageways, called ion channels, are doughnut-shaped protein molecules that form pores across the Neuron from retina of eye Dendrite Cell body Axon Dendrite Dendrite Cell body Cell body Axon Axon Dendrite Cell body Axon Neuron from cortex of brain Neuron from spinal cord Neuron from olfactory area of brain Figure 2.4 Shapes and Relative Sizes of Neurons. The axon of a spinal cord neuron (not shown in its entirety in the figure) may be about a meter long. Axon Cell body Collateral Terminal buttons Dendrites Figure 2.3 Synapses at the Cell Body of a Neuron. Many different axons, each of which branches repeatedly, synapse on the dendrites and cell body of a single neuron. Each branch of an axon ends in terminal buttons that contain neurotransmitters. When released, neurotransmitters transmit the nerve impulse across the synapse to the dendrites or cell body of the receiving cell. NEURONS, THE BUILDING BLOCKS OF THE NERVOUS SYSTEM For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

38 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY Outside of cell Pore of ion channel Ions Closed ion channel Open ion channel Inside of cell Lipid molecules in membrane Figure 2.5 Ion Channels. Ions such as sodium (Naþ), potassium (Kþ), and chloride (Cl) pass through the cell membrane via doughnut-shaped protein molecules called ion channels. cell membrane (see Figure 2.5). These proteins regulate the flow of ions such as sodium (Naþ), potassium (Kþ), and chloride (Cl–) in and out of the neuron. (You may be more familiar with the terms natrium for Naþ, and kalium for Kþ.) Each ion channel is selective, permitting only one type of ion to flow through it when it is open. The importance of Naþ channels is shown by the effect of local anesthetic agents such as novocaine, which is routinely used to numb the mouth during dental procedures. Novocaine prevents Naþ channels from opening, thus preventing sensory signals from reaching the brain (Catterall, 2000). When a neuron is not generating an action potential, it is referred to as a resting. At rest, the cell membrane is not permeable to Naþ ions, and these ions are found at a high concentration outside the neuron. In contrast, the membrane is permeable to Kþ ions, which tend to concentrate inside the neuron. Certain protein structures, called ion pumps, help to maintain this uneven distribution of ions across the cell membrane by pumping them into or out of the cell. For example, the ion pumps transport Naþ out of the neuron whenever it leaks into the neuron and transports Kþ back into the neuron whenever it gets out. In this way the resting neuron maintains high concentrations of Naþ +40 Membrane potential (mV) −70 outside the cell and low concentrations inside it. The overall effect of these ion channels and pumps is to electrically polarize the cell membrane of the resting neuron, keeping the inside of the neuron more negative than the outside. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk The electrical potential of a neuron at rest is termed the resting potential. For most neurons, the resting potential is around –70 millivolts (mV). The resting potential of a neuron is similar to the charge held by a battery; both neurons and batteries use electrochemical gradients to store energy. The neuron’s energy can be used to generate action potentials. How does this happen? The electric potential across a neuron’s cell membrane will change if it is stimulated by other neurons. This stimulation is caused by the action of neurotransmitters that are released by the pre-synaptic neuron, and received by the post-synaptic neuron. If the change in electric potential is very small, nothing dramatic will happen. For example, if the potential is raised to about 60 mV or so, the neuron’s ion pumps will quickly restore the resting potential of 70 mV. However, if the change in

electric potential is large enough, a different set of events occurs. For most neurons, 55 mV constitutes the excitation threshold: if the electric potential is raised above this value, the cell membrane becomes temporarily unstable, resulting in an action potential. In other words: the initial depolarization caused by external stimulation raises the potential above threshold. This leads to a cascade of events that results in a temporary reversal (called depolarization) of the potential across the membrane. First, voltage-sensing Naþ channels located on the axon suddenly open so that Naþ ions can now cross the membrane into the cell. These positively charged sodium ions will flood into the cell because opposite charges attract one another and the inside of the cell is negatively charged. Now the inside of that area of the axon becomes positive relative to the outside, going up to about þ40 mV or so. Next, some other positively charged ions (in particular potassium ions, Kþ) are forced out, and the ion pumps begin to restore the electrical balance across the cell's membrane to its original state. This entire process takes only milliseconds, and the resulting spike in electric potential is called the action potential – see Figure 2.6. Action potential Resting potential 1 3 Time (msec) Figure 2.6 Action Potential.

Sodium ions – + + + – + Stimulus Axon membrane + – – – – Flow of charge + a) During an action potential, sodium gates in the neuron membrane open and sodium ions enter the axon, bringing a positive charge with them. Sodium ions + + + + + – – Stimulus Axon membrane – – – – Flow of charge – + + Potassium ions b) After an action potential occurs at one point along the axon, the sodium gates close at that point and open at the next point along the axon. When the sodium gates close, potassium gates open and potassium ions flow out of the axon, carrying a positive charge with them. Figure 2.7 Action Potential Propagating along the Axon. The action potential will propagate itself down the axon, in the direction of the terminal buttons. This is because neighboring Naþ channels sense the voltage drop and open, causing the adjacent area of the axon to depolarize. This process repeats itself down the length of the axon (see Figure 2.7). The reason that an action potential travels only in one direction and not backwards, is the result of a refractory period: after it has generated a 'spike,' the membrane cannot do so again for about one millisecond. The speed of the action potential as it travels down the axon can vary from about 1 to 120 meters per second. The speed is affected by whether the axon is covered with a myelin sheath. This sheath consists of specialized glial For more Cengage Learning textbooks, visit www.cengagebrain.co.uk NEURONS, THE BUILDING BLOCKS OF THE NERVOUS SYSTEM cells that wrap themselves around the axon, one after another, with small gaps between them (refer back to Figure 2-2). These tiny gaps are called nodes of Ranvier, named after the French anatomist. The insulation provided by the myelin sheath allows for saltatory conduction, in which the nerve impulse jumps from one node of Ranvier to the next. This greatly increases the speed of transmission of the action potential down the axon. (Saltatory comes from the Latin word saltare, which means 'to leap'.) The myelin sheath is particularly prevalent where rapid transmission of the action potential is critical – for example, along axons that stimulate skeletal muscles. In multiple sclerosis, a disorder in which symptoms first become evident between the ages of 16 and 30, the immune system attacks and destroys the body's own myelin sheaths, producing severe motor nerve dysfunction. Synaptic transmission and neural coding It is important to realize that, in terms of neural communication, firing off an action potential is all a neuron can do. The neuron fires an action potential in a single, brief pulse and then becomes inactive for a few thousandths of a second. It can only be triggered if the stimulation by pre-synaptic neurons reaches the threshold level. Thus, in response to any given synaptic input, a neuron either fires an action potential or it does not, and if it fires an action potential, the potential is always the same size. This is referred to

as the all-or-none law. You can think of neuronal action potentials as the binary signals (0's and 1's) computers use to implement software instructions. Neurons are either firing an action potential (1) or not (0). Once initiated, the action potential travels down the axon to its many axon terminals. But how can the nervous system code for (that is, represent) the complexity of our experiences, if the basic unit of communication is so very simple? Each 'coding question' has a different answer, revealing the complexity of the nervous system itself. But there are some basic principles. For example, imagine listening to a sound and noticing that it is becoming louder. This change in intensity is coded for at the level of the response of single neurons. Even though a neuron can only fire off action potentials, the frequency of its firing can change. In other words: a single neuron might respond to a particular sound with a response rate of 200 action potentials per

40 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY Response at low intensity Response at high intensity Time Figure 2.8 Response of a single neuron to a stimulus presented at low and high intensity. Each 'spike' is an action potential generated in response to the stimulus. For most neurons, the maximum rate of response is about 1,000 action potentials per second. second, and increase its response rate to 800 action potentials per second as the sound increases in intensity. This kind of frequency coding is depicted in Figure 2.8. Another way in which the nervous system might reflect something as simple as an increase in the intensity of a stimulus, is by involving a greater population of neurons in the response. Population coding can be powerful, because the synchronization (or lack thereof) in the response of the individual neurons often contains meaning as well. The consideration of coding questions reveals that the true power of the nervous system lies in the complexity of the connections between individual neurons. As mentioned earlier, neurons do not connect directly at a synapse, and the signal must travel across a slight gap (see Figure 2.9). When an action potential moves down the axon and arrives at the terminal buttons, it stimulates synaptic vesicles in the terminal buttons. The synaptic vesicles are small spherical structures that contain neurotransmitters. When they are stimulated, they discharge the neurotransmitters into the synapse. The neurotransmitters diffuse from the pre-synaptic neuron across the synaptic gap and bind to receptors, which are proteins lodged in the dendritic membrane of the postsynaptic neuron. Axon Neural impulse Terminal button Synaptic gap Binding site For more Cengage Learning textbooks, visit www.cengagebrain.co.uk The neurotransmitter and the receptor site fit together like the pieces of a jigsaw puzzle or a key and its lock. This lock-and-key action causes a change in the permeability of ion channels in the receiving neuron. The effect of this change might be either excitatory or inhibitory. An excitatory effect allows positively charged ions (such as Naþ) to enter the post-synaptic neuron, which depolarizes as a result (so that the inside is more positively charged than it was before). This makes the postsynaptic neuron more likely to reach its excitation threshold and thus more likely to generate an action potential. The change in permeability of the ion channels in the receiving neuron can also be inhibitory. In that case, positively charged ions (such as Kþ) leave the neuron, or negatively charged ions (such as Cl–) enter. Sending neuron Receiving neuron Sending neuron Synaptic vesicles Neurotransmitter molecule Postsynaptic membrane Figure 2.9 Release of Neurotransmitters Into a Synaptic Gap. The neurotransmitter is carried to the pre-synaptic membrane in synaptic vesicles, which fuse with the membrane and release their contents into the synaptic gap. The neurotransmitters diffuse across the gap and combine with receptor molecules in the postsynaptic membrane. Adapted from In Search of the Human Mind by Robert Sternberg (Wadsworth, 1995), © Robert Sternberg

ª OMICRON/SCIENCE SOURCE/PHOTO RESEARCHERS An electron micrograph of a neuron densely packed with synapses The post-synaptic neuron becomes hyperpolarized (the inside is more negatively charged than before). Consequently, it is less likely to reach its excitation threshold and therefore less likely to generate an action potential. Some of the most important neurotransmitters in our nervous system are described below. The effect of certain neurotransmitters is always excitatory, for others is it always inhibitory. However, for some neurotransmitters the effect can be either excitatory or inhibitory, depending on the receptor molecules in place. Any particular neuron may receive input from many pre-synaptic neurons. Some of this input might be excitatory, and some inhibitory. If – at a particular moment and at a particular place on the cell membrane – the excitatory effects are greater than the inhibitory effects so that threshold is reached, depolarization occurs and the neuron produces an action potential. In other words, the post-synaptic neuron summates the input it receives from its pre-synaptic neurons. Once a neurotransmitter substance is released and diffuses across the synaptic gap, its action must be very brief to maintain precise control. For some neurotransmitters, the synapse is almost immediately cleared by a process of reuptake: re-absorption of the neurotransmitter by the synaptic terminals from which it was released. Reuptake cuts off the action of the neurotransmitter and spares the axon terminals from having to manufacture more of the substance. For other neurotransmitters, the effect is terminated by degradation: enzymes in the synaptic gap chemically break up the neurotransmitter and make it inactive. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk NEURONS, THE BUILDING BLOCKS OF THE NERVOUS SYSTEM INTERIM SUMMARY l The basic unit of the nervous system is the neuron. l Neurons receive chemical signals on branches called dendrites and transmit electrochemical potentials down a tubelike extension called the axon. l Chemical neurotransmitters are released at synapses and carry messages between two neurons. Neurotransmitters exert their action by binding to receptors. l When a neuron is depolarized above its excitation threshold, it generates an all-or-none action potential. This action potential moves down the axon and initiates the release of neurotransmitter at the terminal buttons. CRITICAL THINKING QUESTIONS 1 Only about a tenth of the cells in your brain are neurons (the rest are glial cells). Does this mean that you use only 10 percent of your brain when you think? What else might this fact mean? 2 Local anesthetics, such as those dentists use, work by blocking Naþ gates in the neurons near the point of injection. Of course, dentists and physicians typically inject them in a part of the body near the source of pain. What do you think such a drug would do if it was injected into the brain? Would it still block pain and touch but nothing else, or would its effect be different? Neurotransmitters More than 70 different neurotransmitters have been identified, and others surely will be discovered. Some neurotransmitters can bind to more than one type of receptor and cause different effects on different types of receptors. For example, the neurotransmitter glutamate can activate at least ten types of receptor molecules, enabling neurons to respond in distinct ways to this same neurotransmitter (Madden, 2002). Certain neurotransmitters are excitatory at some sites and inhibitory at other sites because two types of receptor molecules are involved. In this chapter we obviously cannot discuss all of the neurotransmitters in the nervous system. Instead, we will focus on a few that influence behavior. Acetylcholine Acetylcholine is present at many synapses throughout the nervous system. It is usually excitatory, but it can

 also be inhibitory, depending on the type of receptor molecule in the membrane of the receiving neuron. Acetylcholine is particularly prevalent in an area of the forebrain called the hippocampus, which plays a key role in the formation of new memories (Eichenbaum, 2000). This neurotransmitter plays a prominent role in

Alzheimer’s disease, a devastating disorder that affects many older people by causing impairment of memory and other cognitive functions. Neurons in the forebrain that produce acetylcholine tend to degenerate in Alzheimer’s patients, who then produce less acetylcholine. The less acetylcholine is produced, the more serious the memory loss. Acetylcholine is also released at every synapse where a neuron terminates at a skeletal muscle fiber. The acetylcholine is directed onto small structures called end plates on the muscle cells. The end plates are covered with receptor molecules that, when activated by acetylcholine, trigger a molecular linkage inside the muscle cells that causes them to contract. Certain drugs that affect acetylcholine can produce muscle paralysis. For example, botulinum toxin, which forms from bacteria in improperly canned foods, blocks the release of acetylcholine at nerve-muscle synapses and can cause death by paralyzing the muscles used in breathing. Some nerve gases developed for warfare, as well as many pesticides, cause paralysis by destroying the enzyme that degrades acetylcholine once the neuron has fired. When the degradation process fails, there is an uncontrolled buildup of acetylcholine in the nervous system, and normal synaptic transmission becomes impossible. Norepinephrine Norepinephrine is a neurotransmitter that is produced mainly by neurons in the brainstem. Cocaine and amphetamines prolong the action of norepinephrine by slowing down its reuptake. Because of this delay, the receiving neurons are activated for a longer period, which causes these drugs’ stimulating psychological effects. In contrast, lithium speeds up the reuptake of norepinephrine, causing a person’s mood level to be depressed. Any drug that causes norepinephrine to increase or decrease in the brain is correlated with an increase or decrease in the individual’s mood level. Dopamine Dopamine is chemically very similar to norepinephrine. Release of dopamine in certain areas of the brain produces intense feelings of pleasure, and current research is investigating the role of dopamine in the development of addictions. Too much dopamine in some areas of the brain may cause schizophrenia, and too little in other areas may lead to Parkinson’s disease. Drugs used to treat schizophrenia, such as chlorpromazine or clozapine, block the receptors for dopamine. In contrast, L-dopa, a For more Cengage Learning textbooks, visit www.cengagebrain.co.uk drug commonly prescribed to treat Parkinson’s disease, increases dopamine in the brain. Serotonin Like norepinephrine, serotonin plays an important role in mood regulation. For example, low levels of serotonin have been associated with feelings of depression. Serotonin reuptake inhibitors are antidepressants that increase serotonin levels in the brain by blocking its uptake by neurons. Prozac, Zoloft, and Paxil, drugs that are commonly prescribed to treat depression, are serotonin reuptake inhibitors. Because serotonin is also important in the regulation of sleep and appetite, it is also used to treat the eating disorder bulimia. Interestingly, the hallucinogenic drug lysergic acid diethylamide (LSD) induces its effects by binding to serotonin receptors in the brain. Glutamate The excitatory neurotransmitter glutamate is present in more neurons of the central nervous system than any other transmitter. Glutamate is excitatory because it depolarizes neurons upon which it is released. Of the three or more subtypes of glutamate receptors, one in particular, the NMDA receptor, is thought to affect learning and memory. It is named for the chemical (N-methyl-D-aspartate) that is used to detect it. Neurons in the hippocampus are particularly rich in NMDA receptors, and this area seems to be critical in the formation of new memories (Eichenbaum, 2000; see Chapter 7). Disruptions in glutamate neurotransmission have been implicated in schizophrenia. GABA Another prominent amino acid neurotransmitter is gamma-aminobutyric acid (GABA). This substance is a major inhibitory transmitter; in fact, most synapses in the brain use GABA. The drug picrotoxin, which blocks GABA receptors, produces convulsions because muscle movement cannot be controlled by the brain without GABA’s inhibiting influence. The tranquilizing effects of certain antianxiety drugs, the benzodiazepines, are a result of GABA’s inhibitory action (see Chapter 15).

The functions of these neurotransmitters are summarized in the Concept Review Table. INTERIM SUMMARY l The most important neurotransmitters include acetylcholine, norepinephrine, dopamine, serotonin, gamma-aminobutyric acid (GABA), and glutamate. l Neurotransmitters have either excitatory or inhibitory effects on neurons, depending on the type of postsynaptic receptor they bind to.

CONCEPT REVIEW TABLE Neurotransmitters and Their Functions Neurotransmitter Function Acetylcholine Involved in memory and attention; decreases associated with Alzheimer's disease. Also transmits signals between nerve and muscle. Norepinephrine Increased by psycho-timulants. Low levels contribute to depression. Dopamine Mediates the effects of natural rewards (food and sex, for example) and drugs of abuse. Serotonin Important in mood and social behavior. Drugs that alleviate depression and anxiety increase serotonin levels in synapse. Glutamate Major excitatory neurotransmitter in brain. Involved in learning and memory. GABA Major inhibitory neurotransmitter in brain. Drugs that alleviate anxiety enhance activity of GABA. CRITICAL THINKING QUESTIONS 1 There are several different neurotransmitter systems in the brain. Why do you think there is such neurochemical diversity? 2 Why do you think Alzheimer's disease cannot be cured through the intake of a neurotransmitter? 3 What are some of the advantages provided by chemical signaling in the brain? What are some of the disadvantages? THE ORGANIZATION OF THE BRAIN There are a number of ways to conceptualize the structure of the brain. The most common approach is one that divides the brain into three main regions based on location (see Figure 2.10): (1) the hindbrain, which includes all the structures located in the hind ('posterior') part of the brain, closest to the spinal cord, (2) the midbrain, located in the middle of the brain, and (3) the forebrain, which includes the structures located in the front ('anterior') part of the brain. An alternative way to conceive of the organization of the brain is in terms of function. The Canadian For more Cengage Learning textbooks, visit www.cengagebrain.co.uk THE ORGANIZATION OF THE BRAIN investigator Paul MacLean (MacLean, 1973) proposed that we can think of the human brain as three concentric layers: (1) the central core, which regulates our most primitive behaviors, (2) the limbic system, which controls our emotions, and (3) the cerebrum, which regulates our higher intellectual processes. The central core, also known as the brainstem, controls involuntary behaviors such as coughing, sneezing, and gagging and 'primitive' behaviors that are under voluntary control, such as breathing, vomiting, sleeping, eating, drinking, temperature regulation, and sexual behavior. It includes all the structures in the hindbrain and midbrain and two structures in the forebrain: the hypothalamus and the thalamus. This means that the central core of the brain stretches from the hindbrain to the forebrain. McLean's functional division is obviously meaningful, but not easy to visualize. This is why we will use the division based on location, as we discuss different structures in the brain (see Figure 2.11). The hindbrain The hindbrain sits on top of the spinal cord, and it is crucial for basic life functions. Medulla The first slight enlargement of the spinal cord as it enters the skull is the medulla, a narrow structure that controls breathing and some reflexes that help maintain upright posture. Pons Above the medulla is the pons, which is important for the control of attentiveness, as well as the timing of sleep. At this point, the major nerve tracts coming up from the spinal cord cross over so that the right side of the brain is connected to the left side of the body, and the left side of the brain is connected to the right side of the body. Reticular formation A network of neural circuits that extends from the lower brainstem up to the thalamus in the forebrain, and traversing some of the other central core structures, is called the reticular formation. This network of neurons acts to control arousal. When an electric current of a certain voltage is sent through electrodes implanted in the reticular formation of a cat or dog, the animal goes to

sleep; stimulation by a current with a more rapidly changing waveform awakens the sleeping animal. The reticular formation also plays a role in our ability to focus attention on particular stimuli. All of the sense receptors have nerve fibers that feed into the reticular system, which appears to act as a filter. It allows some sensory messages to pass to the cerebral cortex (that is, to conscious awareness) while blocking others.

Medulla Pons Cerebellum Limbic system Thalamus Hypothalamus Pituitary gland Cerebrum Reticular formation Forebrain Brain Hindbrain The forebrain includes structures located in the anterior part of the brain The midbrain is located in the middle of the brain The hindbrain includes all structures located in the posterior part of the brain Superior and inferior colliculus Substantia nigra Midbrain Figure 2.10 Organization of the Brain. Medulla Pons Reticular formation Pituitary gland Cerebellum Midbrain Thalamus Hypothalamus Hippocampus Amygdala Cerebrum Corpus callosum Figure 2.11 The main structures of the human brain. CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

Cerebellum Attached to the rear of the brainstem slightly above the medulla is a convoluted structure called the cerebellum, which is concerned primarily with the coordination of movement. Specific movements may be initiated at higher levels, but the coordination of those movements depends on the cerebellum. Damage to the cerebellum results in jerky, uncoordinated movements. In addition to coordinating movement, the cerebellum is important for learning new motor responses (Thompson & Krupa, 1994; see Chapter 7). Direct neural connections between the cerebellum and frontal parts of the brain are involved in language, planning, and reasoning (Middleton & Strick, 1994). These connecting circuits are much larger in human beings than in monkeys and other animals. This and other evidence suggest that the cerebellum may play a role in the control and coordination of higher mental functions as well as in the coordination of movements. The midbrain The midbrain is relatively small in humans. It is found just above the pons, and surrounded by the forebrain. Superior and inferior colliculus The midbrain contains two small structures (the superior colliculus and the inferior colliculus) that are important for relaying sensory information to the brain, and for movement control (including eye movements). Substantia nigra Another important midbrain structure is the substantia nigra, a crucial part of the dopamine-containing pathway (also referred to as the ‘reward-pathway’). It is the substantia nigra that deteriorates in Parkinson’s disease. The forebrain In humans the forebrain is relatively large, and covers the midbrain and parts of the hindbrain. A large part of it, the cerebrum, is especially more highly developed in humans than in any other organism. The outer layer of the cerebrum is called the cerebral cortex (or simply cortex) from the Latin word for ‘bark’. Below, we will see that this is the most important region of the brain for many psychological functions. The other structures in the forebrain (the thalamus, the hypothalamus, and the areas comprising the limbic system) are found just underneath the cerebrum and are therefore called subcortical structures. Thalamus Located just above the midbrain inside the cerebral hemispheres are two egg-shaped groups of nerve cell nuclei, the thalamus. It acts as a sensory relay station, directing incoming information from the sense receptors (such as vision and hearing) to the cerebrum. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk THE ORGANIZATION OF THE BRAIN Hypothalamus The hypothalamus is a much smaller structure located just below the thalamus. Centers in the hypothalamus regulate eating, drinking, and sexual behavior. The hypothalamus is involved maintaining homeostasis by exerting control over the autonomic nervous system (discussed later).

Homeostasis is a term that refers to the level of functioning that is characteristic of a healthy organism, such as normal body temperature, heart rate, and blood pressure. When an organism is under stress, homeostasis is disturbed, and processes are set into motion to correct this lack of equilibrium. For example, if we are too warm, we perspire, and if we are too cool, we shiver. Both processes tend to restore normal temperature and are controlled by the hypothalamus. The hypothalamus also has an important role in the sensation of emotions and in our response to stress-producing situations. Mild electrical stimulation of certain areas in the hypothalamus produces feelings of pleasure; stimulation of adjacent regions produces unpleasant sensations. Pituitary gland The pituitary gland is the most important part of a system of glands called the endocrine system (to be discussed later). Through its influence on the pituitary gland, which lies just below it, the hypothalamus controls the endocrine system and thus the production of hormones. Limbic system Around the central core of the brain and closely interconnected with the hypothalamus is the limbic system, a set of structures that impose additional control over some of the instinctive behaviors regulated by the central core. Animals that have only rudimentary limbic systems, such as fish and reptiles, carry out activities such as feeding, attacking, fleeing, and mating by means of stereotyped behaviors. In mammals, the limbic system seems to inhibit some of these instinctive patterns and allow the organism to be more flexible and better able to adapt to changes in the environment. One part of the limbic system, the hippocampus, has a special role in memory. This role was discovered in people who had the structure surgically removed to treat their epilepsy in the 1950s. Upon recovery from such an operation, patients readily recognize old friends and recall earlier experiences, and they can read and perform skills learned earlier in life. However, they have little, if any, recall of events that occurred during the year before the operation, and they cannot remember events occurring after the operation. For example, they do not recognize a new person with whom they may have spent many hours earlier in the day. They can do the same jigsaw puzzle week after week without remembering having done it before, and they can read the same newspaper over and over without remembering the contents (Squire & Kandel, 2000).

46 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY The limbic system is also involved in emotional behavior. The amygdala, an almond-shaped structure deep within the brain, is critical in emotions such as fear (Maren, 2001). For example, monkeys with damage to the amygdala exhibit marked reduction in fear (Klüver & Bucy, 1937). Humans with such damage are unable to recognize facial expressions of fear or learn new fear responses (Bechara et al., 1995). Cerebral cortex Each of the sensory systems sends information to specific areas of the cerebral cortex. Motor responses, or movements of body parts, are controlled by specific areas of the cortex. The rest of the cortex, which is neither sensory nor motor, consists of association areas. These areas occupy the largest portion of the human cortex and are concerned with memory, thought, and language. The cortex of a preserved brain appears gray because it is largely nerve cell bodies and unmyelinated fibers – hence the term gray matter. The inside of the cerebrum, beneath the cortex, is mostly myelinated axons and appears white (also called white matter). The cortex is composed of two hemispheres on the left and right sides of the brain that are connected by the corpus callosum. They are basically symmetrical, with a deep division (the longitudinal fissure) between them. We therefore refer to the left and right hemispheres. Each hemisphere is divided into four lobes: the frontal, parietal, occipital, and temporal lobes. These are large regions of the cerebral cortex that perform diverse functions. The frontal lobe is separated from the parietal lobe by the central fissure, a groove that runs from near the top of the head sideways to the ears. The division between the parietal lobe and the occipital lobe is less clear-cut. For our purposes, we can say that

the parietal lobe is at the top of the brain behind the central fissure and that the occipital lobe is at the rear of the brain. A deep fissure at the side of the brain, the lateral fissure, sets off the temporal lobe (see Figure 2.13a). The primary motor area, just in front of the central fissure, controls voluntary movements of the body. Electrical © MARTIN ROTKER/PHOTOTAKE Parietal lobe Frontal lobe Occipital lobe Cerebellum Temporal lobe Figure 2.12 Photograph of human brain. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk stimulation at certain spots on the motor cortex causes specific parts of the body to move. When these same spots on the motor cortex are injured, movement is impaired. The body is represented on the motor cortex in approximately upside-down form. For example, movements of the toes are controlled from an area near the top of the head, but tongue and mouth movements are controlled from near the bottom of the motor area. Movements on the right side of the body are governed by the motor cortex of the left hemisphere; the right hemisphere governs movements on the left side. In the parietal lobe, separated from the motor area by the central fissure, lies an area that is responsible for sensory experiences: the primary somatosensory area. When this area is stimulated electrically, it produces a sensory experience somewhere on the opposite side of the body. Heat, cold, touch, pain, and the sense of body movement are represented here. In general, the amount of somatosensory area associated with a particular part of the body is related to its sensitivity and use. For example, among four-footed mammals, the dog has only a small amount of cortical tissue representing its forepaws, whereas the raccoon – which makes extensive use of its forepaws in exploring and manipulating its environment – has a much larger cortical area to control its forepaws, including regions for separate fingers. The rat, which learns a great deal about its environment by means of its sensitive whiskers, has a separate cortical area for each whisker. At the back of each occipital lobe in the cortex is the primary visual area. Figure 2.14 shows the optic nerve fibers and neural pathways leading from each eye to the visual cortex. Notice that some of the optic fibers from the right eye go to the right cerebral hemisphere, whereas others cross over at a junction called the optic chiasm and go to the opposite hemisphere; the same arrangement holds true for the left eye. Specifically, fibers from the right sides of both eyes go to the right hemisphere of the brain, and fibers from the left sides of both eyes go to the left hemisphere. As a result, the left visual field is represented in the right hemisphere, whereas the right visual field is represented in the left hemisphere. This fact is sometimes helpful in pinpointing the location of a brain tumor or other abnormalities. The primary auditory area, located on the surface of the temporal lobe at the side of each hemisphere, is involved in the analysis of complex auditory signals – particularly the temporal patterning of sound, as in human speech. Both ears are represented in the auditory areas on both sides of the cortex, but connections to the opposite side are stronger. The right ear sends information to both the right and left primary auditory areas, but it sends more information to the auditory area on the left side of the brain. The opposite is true of the left ear. As mentioned earlier, the areas of the cerebral cortex that are not directly concerned with sensory or motor

processes are association areas. The frontal association areas (the parts of the frontal lobes in front of the motor area) appear to play an important role in the memory processes required for problem solving (Miller & Cohen, 2001). In monkeys, for example, damage to the frontal lobes destroys their ability to solve a delayed-response problem. In this kind of problem, food is placed in one of two cups while the monkey watches, the cups are covered with identical objects, and an opaque screen is placed between the monkey and the cups. After a specified period, the screen is removed and the monkey is allowed to choose one of the cups. Normal monkeys can remember the correct cup after several minutes, but monkeys with frontal lobe damage cannot solve the problem if the delay

is more than a few seconds. Normal monkeys have neurons in the frontal lobe that fire action potentials during the delay, which possibly mediates memory of an event (Goldman-Rakic, 1996). The posterior association areas are located near primary sensory areas and appear to consist of subareas that each serve a particular sense. For example, the lower portion of the temporal lobe is related to visual perception. Lesions (that is, brain damage) in this area cause deficiencies in the ability to recognize and discriminate between different forms. A lesion here does not decrease visual acuity, as would a lesion in the primary visual area of the occipital lobe; the individual can 'see' the form and trace its outline but not identify the shape or distinguish it from a different form (Gallant, Shuop, & Mazer, 2000; Goodglass & Butters, 1988). Central fissure Central fissure Lateral fissure Longitudinal fissure Corpus callossum Frontal lobe Frontal lobe Left hemisphere Right hemisphere Primary motor area Primary motor area Parietal lobe Parietal lobe Occipital lobe Occipital lobe Primary somatosensory area Primary somatosensory area Primary visual area Primary visual area Primary auditory area Temporal lobe Figure 2.13a Cerebral cortex. (a) Lateral view Figure 2.13b Cerebral cortex. (b) Superior view Left eye Optic nerve Optic chiasm Visual area Corpus callosum Superior colliculus Right eye Figure 2.14 Visual Pathways. Nerve fibers from the inner, or nasal, half of the retina cross over at the optic chiasm and go to opposite sides of the brain. Nerve fibers from the outer, or temporal, half of the retina remain on the same side of the brain. Thus, stimuli falling on the right side of each retina are transmitted to the right hemisphere, and stimuli falling on the left side of each retina are transmitted to the left hemisphere. Also note that some of the input from the eyes is sent directly to the superior colliculus, for eye movement control. (Adapted from Human Anatomy by Anthony J. Gaudin and Kenneth C. Jones. Copyright © 1988 by Anthony J. Gaudin and Kenneth C. Jones. Reprinted by permission of the authors.) THE ORGANIZATION OF THE BRAIN For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

Mapping the brain To make the discoveries about the functions of different structures in the brain reviewed in this chapter, researchers have relied on multiple methods. The most important methods are reviewed in the Concept Review Table. Sophisticated computer methods (such as ERP, PET, and fMRI) have become feasible only in the last decades and can obtain detailed pictures of the living human brain without causing the patient distress or damage. Before these techniques were available, the precise location and identification of most types of brain injury could be determined only by exploratory neurosurgery, a complicated neurological diagnosis, or an autopsy after the patient's death. Asymmetries in the brain At first glance, the two halves of the brain look like mirror images. But when brains are measured during autopsies, the left hemisphere is almost always larger than the right hemisphere. The right hemisphere also contains many long neural fibers that connect widely separated areas of the brain, whereas the left hemisphere has many shorter fibers that provide large numbers of interconnections within a limited area (Hellige, 1993). CONCEPT REVIEW TABLE Studying the brain: methods of inquiry Name of method Procedure Notes Selective lesioning Studying the behavioral consequences of planned and selective lesioning (surgically removing or damaging a structure in the brain) Only used in animal studies Single-cell recordings Studying the activity of single neurons, by probing them with small microelectrodes to discover what stimulus or behavior triggers the cell's activity Only used in animal studies Post mortem dissection Examining patient's brain for lesions (damaged areas) after death Behavioral consequences must have been studied prior to the death of the patient Exploratory neurosurgery Examining patient's brain by electrically stimulating certain areas of the exposed brain Event-related potentials (ERPs) Recording the electrical activity of the brain at the scalp, using

electroencephalograms (EEGs), as it occurs in response to a stimulus or preceding a motor response (‘event-related’) Gives precise information on the timing of the brain activity, but less precise information on the location (since the recording occurs at the scalp only) Computerized axial tomography (CAT or CT) Mapping the brain using X-ray technique Used to scan the brain for large structural abnormalities Positron emission tomography (PET) Measuring brain activity using a radioactive tracer mixed with glucose; active neurons require the most glucose and will be most radioactive Gives precise information on the location of the brain activity, but less precise information on the timing (since glucose consumption is a relatively slow process) Functional magnetic resonance imaging (fMRI) Measuring brain activity by recording magnetic changes resulting from oxygen consumption Gives precise temporal and spatial information; is relatively expensive Transcranial magnetic stimulation (TMS) Examining the consequences of (temporary) disruptions of normal brain functioning caused by magnetic stimulation of small areas Used to study cognitive functioning Magnetoencephalography (MEG) Localizing brain activity by measuring magnetic changes Precise method used in surgical applications, alongside electrical stimulation of the exposed brain CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

ª MONKMEYER/LE DUC A technician administering a magnetic resonance imaging procedure. An image of the patient’s brain appears on the computer screen. COURTESY OF MARCUS E. RAICHLE PET scans in a human subject illustrating that different areas of the brain are involved in different modes of word processing. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk THE ORGANIZATION OF THE BRAIN Language Much of our information about brain mechanisms for language comes from observations of patients with brain damage. The damage may be due to tumors, penetrating head wounds, or the rupture of blood vessels. The term aphasia is used to describe language deficits caused by brain damage. As early as 1861, the French physician Paul Broca examined the brain of a deceased patient who had suffered speech loss. He found damage in an area of the left hemisphere just above the lateral fissure in the frontal lobe (see Figure 2.15). This region, now known as Broca’s area, is involved in speech production. People with damage to Broca’s area suffer from expressive aphasia: they have difficulty enunciating words correctly and speak in a slow, labored way. Their speech often makes sense, but it includes only key words. Nouns are generally expressed in the singular, and adjectives, adverbs, articles, and conjunctions are likely to be omitted. However, these individuals have no difficulty understanding either spoken or written language. Destruction of the equivalent region in the right hemisphere usually does not result in speech impairment. The areas involved in understanding speech and being able to write and understand written words are also usually located in the left hemisphere. A stroke that damages the left hemisphere is more likely to produce language impairment than one with damage confined to the right hemisphere. Not all people have left-hemisphere speech centers; some left-handed individuals have right-hemisphere speech centers. In 1874 a German investigator, Carl Wernicke, reported that damage to another site in the cortex – also in the left hemisphere but in the temporal lobe – is linked to a language disorder called receptive aphasia. People with damage in this location, known as Wernicke’s area (see Figure 2.15), are unable to comprehend words: they can hear words, but they do not know their meaning. They can produce strings of words without difficulty and with proper articulation, but they make errors in usage and their speech tends to be meaningless. Analyzing defects, Wernicke developed a model to explain how the brain functions in

50 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY Primary motor area Central fissure Primary somatosensory area Broca’s area Lateral fissure Primary visual area Wernicke’s area Primary auditory area Front of brain Figure 2.15 Specialization of Function in the Left Cortex. A major part of the cortex is involved in generating movements and analyzing sensory inputs. These areas (which include motor, somatosensory, visual, auditory, and olfactory areas) are present on both sides of the brain. Other functions are located on only one side of the brain. For example, Broca’s area and Wernicke’s area are involved in the production and understanding of language, and the angular gyrus helps in matching the visual form of a word with its auditory form; these functions are found on the left side of the human brain. producing and understanding language. Although his model is more than 100 years old, its general features still appear to be correct. Norman Geschwind built on these ideas in developing a theory that has come to be known as the Wernicke-Geschwind model (Geschwind, 1979). According to this model, Broca’s area stores articulatory codes, which specify the sequence of muscle actions required to pronounce a word. When these codes are transmitted to the motor area, they activate the muscles of the lips, tongue, and larynx in the proper sequence and produce a spoken word. Wernicke’s area, by contrast, is where auditory codes and the meanings of words are stored. For a word to be spoken, its auditory code must be activated in Wernicke’s area and transmitted to Broca’s area, where it activates the corresponding articulatory code. In turn, the articulatory code is transmitted to the motor area to activate the muscles that produce the spoken word. To understand a word spoken by someone else, it must be transmitted from the auditory area to Wernicke’s area. There the spoken form of the word is matched with its auditory code, which in turn activates the word’s meaning. When a written word is presented, it is first registered in the visual area and then relayed to the angular gyrus (see Figure 2.15), which associates the visual form of the For more Cengage Learning textbooks, visit www.cengagebrain.co.uk word with its auditory code in Wernicke’s area; once the word’s auditory code has been found, so has its meaning. Thus, the meanings of words are stored along with their acoustical codes in Wernicke’s area. Broca’s area stores articulatory codes, and the angular gyrus matches the written form of a word to its auditory code. Neither of these areas, however, stores information about word meaning. The meaning of a word is retrieved only when its acoustical code is activated in Wernicke’s area. The Wernicke-Geschwind model explains many of the language deficits aphasics show. Damage that is limited to Broca’s area disrupts speech production but has less effect on the comprehension of spoken or written language. Damage to Wernicke’s area disrupts all aspects of language comprehension, but the person can still articulate words properly (even though the output is meaningless) because Broca’s area is intact. The model also correctly predicts that individuals with damage in the angular gyrus are not able to read but have no difficulty speaking or comprehending speech. Finally, if damage is restricted to the auditory area, a person can read and speak normally but cannot comprehend speech. Angular gyrus Split-Brain research Although the left hemisphere’s role in language has been known for some time, only recently has it been possible to investigate what each hemisphere can do on its own. In a normal individual, the brain functions as an integrated whole. Information in one hemisphere is immediately transferred to the other via a broad band of connecting nerve fibers, the corpus callosum (see Figure 2.16). This connecting bridge is a problem in some forms of epilepsy because a seizure starting in one hemisphere may cross over and trigger a massive response in neurons in the other hemisphere. To try to prevent such generalized seizures, neurosurgeons have surgically severed the corpus callosum in individuals with severe epilepsy. These split-brain patients have yielded important insights into the functions of the left and right hemispheres. To understand what happens when the corpus callosum is severed, please take a

look at Figure 2.16. We have seen that the motor nerves cross over as they leave the brain, so that the left cerebral hemisphere controls the right side of the body, and the right hemisphere controls the left. We noted also that the speech production area (Broca's area) is located in the left hemisphere. Consider also that when the eyes are fixated directly ahead, images to the left of the fixation point go through both eyes to the right side of the brain, and images to the right of the

Right visual field Left visual field Fixation point L R Right hand Left hand Olfaction right nostril Olfaction left nostril Speech Writing Main language center Calculation Spacial construction Nonverbal ideation Left visual field Right visual field Severed corpus callosum Figure 2.16 Sensory Inputs to the Two Hemispheres. With the eyes fixated straight ahead, stimuli to the left of the fixation point go to the right cerebral hemisphere, and stimuli to the right go to the left hemisphere. The left hemisphere controls movements of the right hand, and the right hemisphere controls the left hand. Hearing is largely crossed in its input, but some sound representation goes to the hemisphere on the same side as the ear that registered it. The left hemisphere controls written and spoken language and mathematical calculations. The right hemisphere can understand only simple language; its main ability seems to involve spatial construction and pattern sense. (Reprinted from Neuropsychologia, Volume 9, by R. D. Nebes and W. Sperry, p. 247. Copyright © 1971, with kind permission of Elsevier Science Ltd., the Boulevard Langford Lane, Kidlington, Oxford, OX5 1DX, UK.) fixation point go to the left side of the brain. Each hemisphere therefore has a view of the half of the visual field in which 'its' hand normally functions; for example, the left hemisphere sees the right hand in the right visual field. In the normal brain, stimuli entering one hemisphere are rapidly communicated to the other, and the brain functions as a unit. Now, given these three facts about the brain, let us take a look at what happens when the corpus callosum is severed – leaving a split brain – and the two hemispheres cannot communicate with each other. Roger Sperry, who pioneered work in this field, was awarded the Nobel Prize in 1981. In one of Sperry's test For more Cengage Learning textbooks, visit www.cengagebrain.co.uk THE ORGANIZATION OF THE BRAIN situations, a person who has undergone split-brain surgery is seated in front of a screen that hides his hands from view (see Figure 2.17a). His gaze is fixed on a spot at the center of the screen. The word nut is flashed on the left side of the screen for a tenth of a second. Remember that this visual signal goes to the right side of the brain, which controls the left side of the body. With his left hand, the person can easily pick up a nut from a pile of objects hidden from view. But he cannot tell the experimenter what word flashed on the screen because speech is controlled by the left hemisphere and the visual image of 'nut' was not transmitted to that hemisphere. When questioned, he seems unaware of what his left hand is doing. Because the sensory input from the left hand goes to the right hemisphere, the left hemisphere receives no information about what the left hand is feeling or doing. All information is fed back to the right hemisphere, which received the original visual input of the word nut. In this experiment the word must be flashed on the screen for no more than a tenth of a second. If it remains longer, the person's eyes move, and the word is also projected to the left hemisphere. When people can move their eyes freely, information goes to both cerebral hemispheres; this is one reason why the deficiencies caused by severing the corpus callosum are not readily apparent in a person's daily activities. Further experiments demonstrate that a split-brain patient can communicate through speech only what is going on in the left hemisphere. Figure 2.17b shows another test situation. The word hatband was flashed on the screen so that hat went to the right hemisphere and band to the left. When asked what word he saw, the person replied, 'band'. When asked what kind of band, he made all sorts of guesses – 'rubber band', 'rock band', 'band of robbers', and so forth – and said

‘hatband’ only by chance. Tests with other compound words (such as keycase and suitcase) have shown similar results. What the right hemisphere perceives is not transferred to the conscious awareness of the left hemisphere. With the corpus callosum severed, each hemisphere seems oblivious to the experiences of the other. If split-brain patients are blindfolded and a familiar object (such as a comb, toothbrush, or keycase) is placed in the left hand, they appear to know what it is and can demonstrate its use by appropriate gestures. But they cannot express this knowledge in speech. If asked what is going on while they are manipulating the object, they have no idea as long as any sensory input from the object to the left (speaking) hemisphere is blocked. But if the patient’s right hand inadvertently touches the object or the object makes a characteristic sound (like the jingling of a keycase), the speaking hemisphere immediately gives the correct answer. Although the right hemisphere cannot produce speech, it does have some linguistic capabilities. It recognized the meaning of the word nut in our first

52 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY NUT HAT BAND BOOK Speech Left hand Speech Left hand ? Band Cup Nut a) A split-brain patient correctly retrieves

an object by touch with the left hand

when its name is flashed to the right

hemisphere, but he cannot name the

object or describe what he has done. b) The word ‘hatband’ is flashed so that

‘hat’ goes to the right cerebral hemisphere and ‘band’ goes to the left

hemisphere. The patient reports that

he sees the word ‘band’ but has no

idea what kind of band. Figure 2.17 Testing the Abilities of the Two Hemispheres. example, and it can produce writing. In the experiment illustrated in Figure 2.17c, split-brain patients are first shown a list of common objects, such as a cup, a knife, a book, and a glass. This list is displayed long enough for the words to be projected to both hemispheres. Next, the list is removed, and one of the words (for example, book) is flashed briefly on the left side of the screen so that it goes to the right hemisphere. When patients are asked to write what they saw, the left hand begins writing the word book. If asked what the left hand has written, they have no idea and guess any of the words on the original list. They know that they have written something because they feel the writing movements through their body. But because there is no communication between the right hemisphere that saw and wrote the word and the left hemisphere that controls speech, they cannot tell you what they wrote (Sperry, 1968, 1970; see also Gazzaniga, 1985; Hellige, 1990). Hemispheric specialization Studies with split-brain patients indicate that the two hemispheres function differently. The left hemisphere governs our ability to express ourselves in language. It can perform complicated logical activities and is skilled in mathematical computations. The right hemisphere can comprehend only very simple language. It can, for example, respond to simple nouns by selecting objects such as a nut or a comb, but it cannot comprehend more abstract linguistic forms. If it is presented with simple For more Cengage Learning textbooks, visit

www.cengagebrain.co.uk Speech Left hand Nut Book Band c) A list of common objects (including

‘book’ and ‘cup’) is initially shown

to both hemispheres. One word

from the list (‘book’) is then

projected to the right hemisphere.

When given the command to do so,

the left hand begins writing the word

‘book’, but when questioned, the

patient does not know what his left

hand has written and guesses ‘cup’. commands like ‘wink’, ‘nod’, ‘shake head’, or ‘smile’, it seldom responds. The right hemisphere, however, has a highly developed spatial and pattern sense. It is superior to the left hemisphere in constructing geometric and perspective drawings. It can assemble colored blocks to match a complex design much more effectively than the left hemisphere can. When split-brain patients are asked to use the right hand to assemble blocks to match a design shown in a picture, they make numerous mistakes. Sometimes they have trouble keeping the left hand from automatically correcting the right hand’s mistakes. Studies with normal individuals tend to confirm the different specializations of the two hemispheres. For example, verbal information (such as words or nonsense syllables) can be identified faster and more accurately when flashed briefly to the left hemisphere (that is, in the right visual field) than to the right hemisphere. In contrast, identification of faces, facial expressions of emotion, line slopes, or dot locations occurs more quickly when these are flashed to the right hemisphere (Hellige, 1990). Also, studies using electroencephalograms (EEGs) indicate that electrical activity from the left hemisphere increases during a verbal task, whereas during a spatial task, electrical activity increases in the right hemisphere (Kosslyn, 1988; Springer & Deutsch, 1989). This discussion does not mean that the two hemispheres work independently. Just the opposite is true. The hemispheres differ in their specializations, but they

CUTTING EDGE RESEARCH The adolescent brain One of the most famous brain-damaged patients in the history of brain research is Phineas Gage. He lost a large part of his left orbitofrontal cortex as a result of an explosion that drove an iron rod through his skull, entering just below the left eye and exiting at the top of his head. Amazingly, Gage survived the accident. However, his personality underwent a remarkable change: from being a friendly and capable man he changed into an impulsive and volatile person. The case of Phineas Gage is discussed in more detail in the Cutting Edge feature ‘Finding the Self in the Brain’ (Chapter 13). Gage’s accident occurred in 1848, but researchers have recently shown renewed interest in Gage and in other patients with orbitofrontal damage (see Damasio et al., 1994). The orbitofrontal cortex consist of the lower part of the frontal cortex (just behind the eyes). Patients with orbitofrontal damage generally do not have problems with memory, motor behavior, problem solving, or language. But, compared to undamaged

subjects, they seem to evaluate the consequences of their own actions on a different basis – as if they are driven by the desire to be satisfied in the short term, while ignoring long-term consequences. Some researchers have argued that the orbitofrontal cortex is involved in emotional 'gut reactions' that tell us whether our decisions are right or wrong (Damasio et al., 1994). Evidence for this comes from studies in which subjects play a card game that allows them one of two choices: they can either draw from decks of cards that will result in large pay-offs in the short term and losses in the long run, or from decks of cards that will result in smaller pay-offs in the short term, but no losses in the long run. Initially subjects don't know what the long-term pay-offs for the different decks of cards will be, so they select the decks that result in larger immediate winnings. After a little while, normal subjects show a physiological reaction (an increase in galvanic skin response, GSR) whenever they select from a 'dangerous' deck of cards – as if their 'gut' tells them that this is a dangerous thing to do. A short while later, these subjects switch continually integrate their activities. It is this interaction that enables mental processes that are greater than and different from each hemisphere's special contribution. As one researcher describes it, 'These differences are seen in the contrasting contributions each hemisphere makes to all cognitive activities. When a person reads a story, the right hemisphere may play a special role in decoding visual information, maintaining an integrated story structure, appreciating humor and emotional content, deriving meaning from past associations and understanding metaphor. At the same time, the left hemisphere plays a special role in understanding syntax, translating written words into their phonetic representations and For more Cengage Learning textbooks, visit www.cengagebrain.co.uk THE AUTONOMIC NERVOUS SYSTEM to drawing from the other decks. Patients with orbitofrontal damage do not show the GSR response to the dangerous decks of cards, nor do they make the switch to the other, safer, decks (Bechara et al., 1997). Recently, researchers have shown that young children as well as adolescents look remarkably similar to patients with orbitofrontal damage. Using a decision task similar to the task described above, Crone et al. (2007) were able to show that young children (ages 6–10) as well as adolescents (ages 16– 18) are more likely to opt for short-term winnings over longterm safety. The 'gut reaction' that served as a warning signal for adult subjects (the GSR response) was only found for subjects 16 years and older. For subjects between the ages 16–18 years, this GSR response was smaller than for subjects between the ages 20–25. Adolescence is defined as the period of development from childhood to adulthood, roughly the period from 10 to 22 years of age. Over the past ten years, brain researchers have made interesting discoveries showing that the adolescent brain is functioning differently from the adult brain (see, for example, work done in the 'Brain and Development Laboratory' at Leiden University in the Netherlands: www.libc-leiden.nl). Researchers have compared the behavior of different age groups (young children, adolescents, and adults), while at the same time scanning brain activity in different areas (for example: Adleman et al., 2002 and Crone et al., 2006). An interesting picture about the adolescent brain is beginning to emerge. Compared to younger children (and as a consequence of hormonal changes) adolescents have a very sensitive emotional system. In adults, emotional reactions are tempered by the regulating forces of the frontal cortex (Galvan et al., 2006). Such mitigating effects may be smaller in adolescents: research of gray matter density has shown that the frontal cortex (unlike other areas) continues to mature functionally until adolescence (Casey et al., 2005). These discoveries might help explain the risk-taking behavior and moody nature that seems so characteristic of adolescents. deriving meaning from complex relations among word concepts and syntax. But there is no activity in which only one hemisphere is involved or to which only one hemisphere makes a contribution'. (Levy, 1985, p. 44) THE AUTONOMIC NERVOUS SYSTEM We noted earlier that the

peripheral nervous system has two divisions. The somatic system controls the skeletal muscles and receives information from the skin,

muscles, and various sensory receptors. The autonomic system is a system of nerves outside the brain and spinal cord. It controls the glands and the smooth muscles, including the heart, the blood vessels, and the lining of the stomach and intestines. (These muscles are called ‘smooth’ because that is how they look under a microscope – skeletal muscles, in contrast, have a striped appearance.) The autonomic nervous system SYMPATHETIC PARASYMPATHETIC Pupils dilated Pupils constricted Decreased salivation Increased respiration Increased heart rate Digestion inhibited Bladder contracted Normal salivation Normal respiration Normal heart rate Digestion stimulated Bladder relaxed Figure 2.18 The Autonomic Nervous System. The sympathetic division mobilizes the body for an active response; the parasympathetic division restores the body and conserves its resources. CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

(ANS) derives its name from the fact that many of the activities it controls, such as digestion and circulation, are autonomous, or self-regulating, and continue even when a person is asleep or unconscious. ANS activity is controlled by the nervous system, in particular by the hypothalamus. The autonomic nervous system has two divisions, sympathetic and parasympathetic, whose actions are often antagonistic (reciprocal). The sympathetic nervous system typically is active during times of intense arousal, and the parasympathetic nervous system is associated with rest. Typically, the sympathetic division will be activated during ‘emergencies’, preparing the body for a response (often referred to as ‘fight or flight’). The parasympathetic division will restore the body afterwards. Figure 2.18 shows the contrasting effects of the two systems on some organs. The balance between these two systems maintains the normal (homeostatic) state of the body – somewhere between extreme excitement and vegetative placidity. INTERIM SUMMARY l The nervous system is divided into the central nervous system (the brain and spinal cord) and the peripheral nervous system (the nerves connecting the brain and spinal cord to other parts of the body). Subdivisions of the peripheral nervous system are the somatic system (which carries messages to and from the sense receptors, muscles, and the surface of the body) and the autonomic system (which connects with the internal organs and glands). l The human brain is composed of three functional divisions: the central core, the limbic system, and the cerebrum. l Anatomically, we divide the brain into the hindbrain, the midbrain, and the forebrain. l Severing the corpus callosum (the band of nerve fibers connecting the two cerebral hemispheres) causes significant differences in the functioning of the two hemispheres. The left hemisphere is skilled in language and mathematical abilities. The right hemisphere can understand some language but cannot communicate through speech; it has a highly developed spatial and pattern sense. l The autonomic nervous system consists of the sympathetic and parasympathetic divisions. The sympathetic division is active during excitement, and the parasympathetic system is dominant during quiescence. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk THE ENDOCRINE SYSTEM CRITICAL THINKING QUESTIONS 1 Why is your brain symmetrical (meaning that the left and right sides look alike)? You have a left and right motor cortex, a left and right hippocampus, a left and right cerebellum, and so on. In each case, the left side is a mirror image of the right side (just as, for example, your left eye is a mirror image of your right eye). Can you think of any reason why your brain is symmetrical in this way? 2 In split-brain patients, whose corpus callosum has been cut, the left and right sides of the brain seem to work independently after the operation. For example, a word shown to one side may

be read and responded to without the other side knowing what the word was. Does such a person have two minds, each capable of knowing different things, or does the patient still have only one mind? THE ENDOCRINE SYSTEM We can think of the nervous system as controlling the fastchanging activities of the body by directly activating muscles and glands. (Glands are organs located throughout the body that secrete special substances, such as sweat, milk, or a particular hormone.) The endocrine system acts more slowly, indirectly affecting the activities of cell groups throughout the body. It does so by means of hormones, chemicals secreted by the endocrine glands into the bloodstream and transported to other parts of the body, where they have specific effects on cells that recognize their message (see Figure 2.19). Hormones act in various ways on cells of different types. Each target cell is equipped with receptors that recognize only the hormone molecules that act on that cell. The receptors pull those molecules out of the bloodstream and into the cell. Some endocrine glands are activated by the nervous system, and others are activated by changes in the internal chemical state of the body. One of the major endocrine glands is the pituitary gland. This gland is partly an outgrowth of the brain and lies just below the hypothalamus (refer back to Figure 2.11). The pituitary has been called the ‘master gland’ because it produces the most different hormones and controls the secretion activity of other endocrine glands. One of the pituitary hormones, growth hormone, has the crucial job of controlling the body’s growth. Dwarfism is caused by too little of this hormone, and gigantism is caused by too much of it. Other hormones released by the pituitary trigger the action of other endocrine glands, such as the thyroid, the sex glands, and the outer layer of the adrenal gland. Courtship, mating, and reproductive behavior in many animals are based on a complex interaction between nervous system activity and the influence of the pituitary on the sex glands.

56 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY Hypothalamus Pituitary gland Thyroid Liver Adrenal gland Kidneys Pancreas Ovary (female) Testes (male) Figure 2.19 Major endocrine glands and hypothalamus. The relationship between the pituitary gland and the hypothalamus illustrates the complex interactions. In response to stress (fear, anxiety, pain, emotional events, and so forth), certain neurons in the hypothalamus secrete corticotropin-releasing factor (CRF), which is carried to the pituitary through a channel-like structure. CRF stimulates the pituitary to release adrenocorticotropic hormone (ACTH), the body’s major stress hormone. ACTH, in turn, is carried by the bloodstream to the adrenal glands and other organs, causing the release of some 30 hormones, each of which plays a role in the body’s adjustment to emergency situations. For example, the cellular demand for glucose increases in a state of emergency, and cortisol, an adrenal hormone that is released under stress, promotes liberation of glucose from fat stores in the body. Interestingly, cortisol has effects on cognitive function as well. At low levels, it enhances memory, but at high levels it causes memory impairments and neuronal death. The adrenal glands play an important role in determining a person’s mood, energy level, and ability to cope with stress. The inner core of the adrenal gland secretes epinephrine and norepinephrine (also known as adrenaline and noradrenaline). Epinephrine prepares the organism for an emergency. In conjunction with the sympathetic division of the autonomic nervous system, it For more Cengage Learning textbooks, visit www.cengagebrain.co.uk affects the smooth muscles and sweat glands. It also constricts the blood vessels in the stomach and intestines and makes the heart beat faster. Norepinephrine also prepares the organism for emergency action. It stimulates the pituitary to release a hormone that acts on the outer layer of the adrenal glands; this hormone, in turn, stimulates the liver to increase the blood sugar level to give the body the energy required for quick action. The hormones of the endocrine system and the neurotransmitters of neurons perform

similar functions: they both carry messages between cells. A neurotransmitter carries messages between adjacent neurons, and its effects are highly localized. In contrast, a hormone may travel a long distance through the body and act in various ways on many different types of cells. Despite these differences, some of these chemical messengers serve both functions. Epinephrine and norepinephrine, for example, act as neurotransmitters when they are released by neurons and as hormones when they are released by the adrenal gland. INTERIM SUMMARY l The endocrine glands secrete hormones into the bloodstream that travel through the body, acting in various ways on cells of different types. l The pituitary gland controls the secretion activity of other endocrine glands. CRITICAL THINKING QUESTIONS 1 When hormones are released into the bloodstream, they can reach every cell in the body. How then do hormones exert selective actions on certain bodily tissues? Can you think of analogies with synaptic transmission in the brain? 2 During winter, your furnace heats the air inside your house, and the thermostat detects when the indoor air temperature reaches the level you set. How might this principle be used in the endocrine system to maintain levels of hormones in the bloodstream? What master gland might serve as the endocrine system's 'thermostat'? EVOLUTION, GENES, AND BEHAVIOR To fully understand the biological foundations of psychology, we need to know something about evolutionary and genetic influences as well. All biological organisms

have evolved over millions of years, and environmental factors have played an important role in shaping the organization and function of their nervous systems. Natural selection, the process described by Charles Darwin to account for evolutionary change, plays an essential role in shaping both behavior and brain. Darwin's principle of natural selection states that it is those variations on inheritable traits that most contribute to an organism's survival that are passed on to the next generation. The field of behavior genetics combines the methods of genetics and psychology to study the inheritance of behavioral characteristics (Plomin, Owen, & McGuffin, 1994). We know that many physical characteristics – height, bone structure, hair and eye color, and the like – are inherited. Behavioral geneticists are interested in the degree to which psychological characteristics, including mental ability, temperament, and emotional stability, are transmitted from parent to offspring (Bouchard, 1984, 1995). Researchers led by Robert Plomin of London's Institute of Psychiatry have identified chromosomal markers that contribute to intelligence (Fisher et al., 1999). However, such findings are not conclusive. As we will see in this section, environmental conditions have a lot to do with the way a particular genetic factor is expressed in an individual as he or she matures. Evolution of behavior Any examination of behavior must include not only proximate causes of the behavior, such as the firing of spinal motor neurons that drives the knee jerk reflex, but also ultimate causes. Ultimate causes of behavior explain behavior in its evolutionary context. Whereas proximate causes explain how a behavior is generated, ultimate causes help us to understand why a behavior exists in the first place – that is, why it evolved by natural selection. Consider, for example, male aggression. In both humans and other mammals, males are typically more aggressive than females (Buss & Shackelford, 1997), particularly in samesex social interactions. In mammals whose sexual reproduction is seasonally regulated, intermale aggression is particularly pronounced during the breeding season. In red deer and elephant seals, for example, males attempt to control small groups of females ('harems') for mating and behave aggressively toward other males that attempt to mate with these females. The proximate causes of aggressive behavior are reasonably well understood. For example, circulating levels of the gonadal steroid, testosterone, are correlated with aggressive behavior, and damage to subcortical brain structures can reduce or potentiate aggressive behavior in animals. Recent

evidence indicates serotonin is important in aggressive behavior (Nelson & Chiavegatto, 2001), and olfactory cues, at least in rodents, appear to mediate male aggression (Stowers, Holy, Meister, Dulac, & Koenteges, 2002). Moreover, social context powerfully modulates the nature and pattern of aggressive behavior. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk EVOLUTION, GENES, AND BEHAVIOR During the breeding season, male red deer and elephant seals display to and attack other males that approach them but do not attack sexually receptive females. But why do aggressive behavior and the neural and hormonal systems underlying this behavior exist at all? What are the ultimate causes of aggressive behavior? From an evolutionary or functional point of view, aggressive behavior in breeding males is adaptive. It confers reproductive success, and reproductive success promotes the perpetuation of genes that control aggressive behavior. In red deer, aggressive males are more likely to secure and mate with receptive females and thereby increase the proportion of males in subsequent generations that carry genes for aggressiveness. Unaggressive male red deer are less likely to secure mates, and their genes become poorly represented in the population. This does not mean that male aggression is ‘good’ from an ethical or moral point of view. Rather, the behavior is adaptive in an evolutionary context. Aggressive behavior is said to be sexually selected because it is invoked by competition for mating opportunities. Sexual selection, a special case of natural selection, yields traits that promote reproductive success in the sex with the greater potential reproductive rate. In deer, the female reproductive rate is limited by gestation and nursing, but the male reproductive rate is limited only by available females. In some birds, the male reproductive rate is slower than that in females because the males brood over the nest to hatch the eggs while the females seek other males with which they mate. In this case, female birds show greater aggression than males. In either case, any trait that confers an advantage in securing mates will be selected for in the sex with the greatest reproductive potential. These traits are not limited to behavioral proclivities such as aggression but include physical traits such as body size and coloration. Chromosomes and genes Natural selection operates on genes, which are segments of deoxyribonucleic acid (DNA) molecules that form the fundamental hereditary unit. The genes we receive from our parents and transmit to our offspring are carried by chromosomes, structures in the nucleus of each cell in the body. Most body cells contain 46 chromosomes. At conception, the human being receives 23 chromosomes from the father’s sperm and 23 chromosomes from the mother’s ovum. These 46 chromosomes form 23 pairs, which are duplicated each time the cells divide (see Figure 2.20). As shown in Figure 2.21, the DNA molecule looks like a twisted ladder or a double-stranded helix (spiral). Each gene gives coded instructions to the cell, directing it to perform a specific function (usually to manufacture a particular protein). Although all cells in the body carry the same genes, each cell is specialized because only 5 percent to 10 percent of the genes in any given cell are active. In the process of developing from a fertilized egg,

58 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY Figure 2.20 Chromosomes. This photo (greatly enlarged) shows the 46 chromosomes of a normal human female. In a human male, pairs 1 through 22 would be the same as those in the female, but pair 23 would be XY rather than XX. each cell switches on some genes and switches off all others. When ‘nerve genes’ are active, for example, a cell develops as a neuron because the genes are directing the cell to make the products that allow it to perform neural functions (which would not be possible if irrelevant genes, such as ‘muscle genes’, were not switched off). Genes, like chromosomes, exist in pairs. One gene of each pair comes from the sperm chromosomes, and one gene comes from the ovum chromosomes. Thus, a child receives only half of each parent’s total genes. The total number of

genes in each human chromosome is about a thousand, perhaps higher. Because the number of genes is so high, two human beings, even siblings, are extremely unlikely to inherit exactly the same set of genes. The only exception is identical twins, who, because they developed from the same fertilized egg, have exactly the same genes. Dominant and recessive genes Either gene of a gene pair can be dominant or recessive. When both members of a gene pair are dominant, the individual manifests the form of the trait specified by these dominant genes. When one gene is dominant and the other recessive, the dominant gene again determines the form of the trait. Only if the genes contributed by both parents are recessive is the recessive form of the trait expressed. In the case of the genes determining eye color, for example, blue is recessive and brown is dominant. Thus, a blue-eyed child may have two blue-eyed parents, one blue-eyed parent and one brown-eyed parent (who For more Cengage Learning textbooks, visit www.cengagebrain.co.uk P P S S C G P P S T A S P P S S A T P P S S T A P P C G S S P P S S C G P P T A S S P P Figure 2.21 Structures of the DNA Molecule. Each strand of the molecule is made up of an alternating sequence of sugar (S) and phosphate (P); the rungs of the twisted ladder are made up of four bases (A, G, T, C). The double nature of the helix and the restriction on base pairings make possible the self-replication of DNA. In the process of cell division, the two strands of the DNA molecule come apart, with the base pairs separating, and one member of each base pair remains attached to each strand. Each strand then forms a new complementary strand using excess bases available in the cell. An A attached to a strand attracts a T, and so forth. By this process, two identical molecules of DNA come to exist where previously there was one. carries a recessive gene for blue eyes), or two brown-eyed parents (each of whom carries a recessive gene for blue eyes). A brown-eyed child, in contrast, never has two blue-eyed parents. Some other characteristics that are carried by recessive genes are baldness, albinism, hemophilia, and susceptibility to poison ivy. Most human characteristics are not determined by the actions of a single gene pair, but there are some striking exceptions in which a single gene has enormous importance. Of special interest from a psychological viewpoint are diseases like phenylketonuria (PKU) and Huntington’s disease (HD), both of which involve deterioration of the nervous system and associated behavioral and cognitive problems. Geneticists have identified the genes that cause both of these disorders.

PKU results from the action of a recessive gene inherited from both parents. The infant cannot digest an essential amino acid (phenylalanine), which then builds up in the body, poisons the nervous system, and causes irreversible brain damage. Children with PKU are severely retarded and usually die before reaching age 30. If the PKU disorder is discovered at birth and the infant is immediately placed on a diet that controls the level of phenylalanine, the chances of survival with good health and intelligence are fairly high. Until the PKU gene was located, the disorder could not be diagnosed until an infant was at least three weeks old. A single dominant gene causes Huntington’s disease. The long-term course of the disease is degeneration of certain areas in the brain and progressive deterioration over 10 to 15 years. Individuals with HD gradually lose the ability to talk and control their movements, and they show marked deterioration in memory and mental ability. The disease usually strikes when a person is 30 to 40 years old; before then, there is no evidence of the disease. Now that the Huntington’s disease gene has been isolated, geneticists can test individuals at risk for the disease and determine whether they carry the gene. As yet, there is no cure for HD, but the protein produced by the gene has been identified and may provide a key to treating the disease. Sex-linked genes A normal female has two similar-looking chromosomes in pair 23, called X chromosomes. A normal male has one X chromosome in pair 23 and one that looks slightly different, called a Y chromosome (refer back to ª THE EVERETT

COLLECTION The American folksinger Woody Guthrie (author of the lyrics of one of the most famous folk songs in the United States, 'This Land is Your Land') died of Huntington's disease at the age of 55. For more Cengage Learning textbooks, visit www.cengagebrain.co.uk EVOLUTION, GENES, AND BEHAVIOR Figure 2.20). Thus, the normal female chromosome pair is XX, and the normal male pair is XY. Women, who have two X chromosomes, are protected from recessive traits carried on the X chromosome. Men, who have only one X chromosome and one Y chromosome, express more recessive traits because a gene that is carried on one of these chromosomes will not be countered by a dominant gene on the other. Genetically determined characteristics and disorders that are linked to the twenty-third chromosome pair are called sex-linked traits. For example, color blindness is a recessive sexlinked trait. A male is color-blind if the X chromosome he received from his mother carries the gene for color blindness. Females are less likely to be color-blind, because a color-blind female has to have both a colorblind father and a mother who is either color-blind or carries a recessive gene for color blindness. Genetic studies of behavior Single genes determine some traits, but many genes combine to determine most human characteristics; they are polygenic. Traits such as intelligence, height, and emotionality do not fall into distinct categories but show continuous variation. Most people are neither dull nor bright. Intelligence is distributed over a broad range, with most individuals located near the middle. Sometimes a specific genetic defect can result in mental retardation, but in most cases a large number of genes influence the factors underlying the different abilities that determine a person's intellectual potential. Of course, as we will discuss shortly, what happens to this genetic potential depends on environmental conditions (Plomin, Owen, & McGuffin, 1994). Selective breeding One method of studying the inheritance of particular traits in animals is selective breeding. In selective breeding, animals that are high or low in a certain behavioral or physical trait are mated with each other. For example, in an early study of the inheritance of learning ability in rats, females that did poorly in learning to run a maze were mated with males that did poorly, and females that did well were mated with males that did well. The offspring of these matings were tested on the same maze. After a few rodent generations, 'bright' and 'dull' strains of rats were produced (see Figure 2.22). Such breeding may not necessarily yield more or less intelligent animals, however. A less fearful animal, for example, would be expected to perform better in the maze because it would be more likely to explore the apparatus. Selective breeding has been used to demonstrate the inheritance of a number of behavioral characteristics. Dogs have been bred to be excitable or lethargic; chickens, to be aggressive and sexually active; fruit flies, to be more or less attracted to light; and mice, to be more or

less attracted to alcohol. If a trait is influenced by heredity, changing it through selective breeding should be possible. If selective breeding does not alter a trait, we assume that the trait is dependent primarily on environmental factors (Plomin, 1989). Twin studies Because breeding experiments with human beings are obviously unethical, we must look instead at similarities in behavior among individuals who are related. Certain traits often run in families. But family members not only are linked genetically but also share the same environment. If musical talent 'runs in the family', we do not know whether inherited ability or parental emphasis on music is the primary influence. Sons of alcoholic fathers are more likely than others to develop alcoholism. Do genetic tendencies or environmental conditions play the major role? In an effort to answer questions of this sort, psychologists have turned to studies of twins, especially twins who have been adopted and raised in separate environments. Identical twins develop from a single fertilized egg and therefore share exactly the same genes – they are referred to as monozygotic because

they come from a single zygote, or fertilized egg. Fraternal twins develop from different egg cells and are no more alike genetically than ordinary siblings – they are referred to as dizygotic because they come from two zygotes. Studies that compare identical and fraternal twins help sort out the influences of environment and heredity. Identical twins are more similar in intelligence than fraternal twins, even when they are separated at birth and reared in different homes (see Chapter 13). Identical twins are also more similar than fraternal twins in some personality characteristics and in susceptibility to schizophrenia (see Chapter 15). A recent study shows that the amount of gray matter in the brain, as measured with MRI, is more correlated in identical twins than in fraternal twins, and it is also correlated with intelligence (Thompson et al., 2001). That is, smarter individuals have more gray matter in their brains, and the amount of gray matter appears to be strongly related to genetic factors (Plomin & Kosslyn, 2001). One surprising finding from studies of adopted children suggests that genetic influences may become stronger as people age. The psychological traits of young children are not particularly similar to those of either their biological parents or their adoptive parents. As they grow older, we might expect them to become more like their adoptive parents in traits such as general cognitive ability and verbal ability and less like their biological parents. Contrary to this expectation, as adopted children approach age 16, they become more similar to their biological parents than to their adopted parents in these traits (Plomin, Fulker, Corley, & Defries, 1997), suggesting an emerging role of genetic influences. Identical twins are referred to as monozygotic because they develop from a single fertilized egg. Fraternal or dizygotic twins develop from different egg cells and therefore are no more similar genetically than ordinary siblings. ª JAMES BLINN/DREAMSTIME.COM . ‘Dull’ rats ‘Bright’ rats 150 250 1 3 5 Mean errors Generations Figure 2.22 Inheritance of Maze Learning in Rats. Mean error scores of ‘bright’ (green line) and ‘dull’ (purple line) rats selectively bred for maze-running ability. (After Thompson, 1954) CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

Molecular genetics of behavior In recent years, some researchers have suggested that certain human traits, such as some aspects of personality, are influenced by specific genes, which are thought to affect particular neurotransmitter receptors (Zuckerman, 1995). In most studies of this sort, family members who have a certain psychological trait are identified and compared with family members who lack that trait. Using techniques of molecular genetics, the researchers attempt to find genes or chromosome segments that are correlated with the presence of the trait under study. For example, a combination of traits referred to as ‘novelty seeking’ (that is, a tendency to be impulsive, exploratory, and quicktempered, as measured by scores on personality scales) has been linked to a gene that controls the D4 receptor for dopamine (Benjamin et al., 1996). Occasionally this type of analysis has been applied to very specific behavioral traits. As mentioned earlier, sons of alcoholic fathers are more likely to be alcoholics themselves than are people chosen at random. When they drink alcohol, sons of alcoholics also tend to release more endorphin (the natural opiate neurotransmitter related to reward) than other people (Gianoulakis, Krishnan, & Thavundayil, 1996), suggesting a possible biological predisposition toward alcoholism. But these analyses can sometimes be misleading and must be viewed with caution. For example, it was once claimed that a gene for the D2 dopamine receptor occurred only in severe alcoholics and thus was a genetic basis for alcoholism. More recent studies of this gene, however, indicate that it also occurs in individuals who pursue many other types of pleasure and may be linked to drug abuse, obesity, compulsive gambling, and other forms of ‘unrestrained behavior’ (Blum, Cull, Braverman, & Comings, 1996). Our understanding of the role of this gene, and of its relationship to

behavior, clearly has changed in the years since its discovery and may change again as further evidence emerges. Such studies highlight the need to await further confirmation before concluding that the genetic basis for behavior of any kind has been identified. In several cases, what appeared at first to be a clear genetic explanation was later found to be spurious. Environmental influences on gene action The inherited potential with which an individual enters the world is very much influenced by the environment the infant encounters. One example is diabetes. The tendency to develop diabetes is hereditary, although the exact method of transmission is unknown. In diabetes, the pancreas does not produce enough insulin to burn carbohydrates and thus provide energy for the body. Scientists assume that genes determine the production of insulin. But people who carry the genetic potential for diabetes do not always develop the disease. If one For more Cengage Learning textbooks, visit www.cengagebrain.co.uk EVOLUTION, GENES, AND BEHAVIOR identical twin has diabetes, the other twin develops the disorder in only about half the cases. Not all of the environmental factors that contribute to diabetes are known, but one variable that is fairly well established is obesity. An overweight person requires more insulin to metabolize carbohydrates than a thin person does. Consequently, an individual who carries the genes for diabetes is more likely to develop the disorder if he or she is overweight. Schizophrenia presents a similar situation. As we will see in Chapter 15, substantial evidence suggests that this disorder has a hereditary component. If one identical twin is schizophrenic, chances are high that the other twin will exhibit some signs of mental disturbance. But whether or not the other twin develops full-blown schizophrenia depends on a number of environmental factors. Genes may predispose a person to schizophrenia, but the environment in which he or she grows up shapes the actual outcome. INTERIM SUMMARY l Chromosomes and genes, segments of DNA molecules that store genetic information, transmit an individual's hereditary potential. l Behavior depends on the interaction between heredity and environment: An individual's genes set the limits of his or her potential, but what happens to that potential depends on the environment in which he or she grows up. CRITICAL THINKING QUESTIONS 1 Every year seems to bring the discovery of a new gene for alcoholism or for drug dependence, schizophrenia, sexual orientation, impulsiveness, or some other complex psychological trait. But it often turns out after further studies that the gene is related to the trait in some people but not in everyone. And often the gene also turns out to be related to other behavioral traits in addition to the one to which it was originally linked. Can you think of any reasons why genes might affect psychological traits in this way? In other words, why is there not a perfect one-to-one match between the presence of a gene and the strength of a particular psychological trait? 2 Genes have an important influence on brain and behavior. But are genes responsible for everything? Can you think of examples of behavior that is not genetically programmed? How is this behavior transmitted across generations?

SEEING BOTH SIDES ARE MIRROR NEURONS INVOLVED IN THE EXPERIENCE OF EMPATHY? Mirror neurons are involved in the experience of empathy Laila Craighero, Institute of Human Physiology, University of Ferrara Humans are an exquisitely social species. They spend a large part of their time observing others and trying to understand what they are doing and why. How are such actions recognized? Two contrasting hypotheses may explain how this happens. The 'visual' hypothesis claims that action recognition is based exclusively on the visual system. The understanding of an action done by another individual depends on the activity of the highorder visual areas and, in particular, the superior temporal sulcus, where there are neurons that are selectively activated by biological motions (Perrett et al., 1989; Allison et al., 2000; Puce and Perrett, 2003). The 'motor' hypothesis claims that an action is recognized when its observation activates, in the observer's

brain, an analogous motor representation. This possibility derives from the discovery in the monkey brain, of a special class of neurons called ‘mirror neurons’, located in the premotor cortex, a region of the frontal lobe in front of the motor area. They are neither sensory nor motor, but they discharge both when the monkey executes an action and when it observes another individual execute that same action (Di Pellegrino et al., 1992). However, the monkey doesn’t move while observing others moving, since the neuron’s activity in the motor cortex never reaches the threshold to send outgoing signals to the muscles. So, what is the role of mirror neurons? It has been proposed that they represent the ‘idea’ of an action (Fadiga et al., 2000). This idea can be evoked when we have the intention to execute it, when we are executing it, and also when we see somebody else executing it. This idea is not only a ‘visual’, ‘cognitive’ or ‘verbal’ description; it actually involves the motor system necessary to execute the action. This means that whenever we see another person moving we feel ourselves as if we were executing that movement. The visual hypothesis describes a ‘third person’-style relationship between the observer and the observed action. The action is recognized, but without referring to the observer’s private knowledge of what doing that action means. In contrast, the motor hypothesis describes a ‘first person’ understanding of what the individual is seeing. The observed action enters into the observer’s motor representation and recalls his her similar experiences when doing that same action. It is an empathic recognition that makes the observer share the experience of the action agent. In social life, however, humans are required to understand not only actions but also to decipher emotions. Which mechanisms enable us to understand what others feel? Is there a mirror mechanism for emotions similar to that for understanding actions? It is reasonable to postulate that, as is the case for understanding action, there are two basic mechanisms for understanding emotion that are conceptually different one from another. The first consists of a cognitive elaboration of sensory aspects of others’ emotional behaviors. The second consists of a direct mapping of sensory aspects of the observed emotional behavior onto the motor structures that determine, in the observer, the experience of the observed emotion. These two ways of recognizing emotions are experientially radically different. With the first mechanism, the observer understands the emotions expressed by others but does not feel them, he, or she, deduces them. A certain facial or body pattern means fear, another happiness, and that is it, there is no emotional involvement. The sensory-motor mapping mechanism differs in this respect. In this case, the recognition occurs because the observed emotion triggers the feeling of the same emotion in the observing person. It is a direct first-person recognition. The emotion of the other penetrates the emotional life of the observer, evoking not only the observed emotion but also related emotional states and nuances of similar experiences. To test the two mechanisms, let’s review data on disgust for which rich empirical evidence has been recently acquired. Disgust is a very basic emotion indicating that something that the individual tastes or smells is bad and, most likely, dangerous. Because of its strong communicative value, disgust is an ideal emotion for testing the direct mapping hypothesis. When an individual is exposed to disgusting odors or tastes, there is an intense activation of two structures: the amygdala and the insula. Recently, Wicker et al. (2003) carried out a brain imaging study in which they tested whether the same insula sites that show signal increase during the experience of disgust also show signal increase during the observation of facial expressions of disgust. Results showed that precisely the same sector within the anterior insula that was activated by the exposure to disgusting odorants was also activated by the observation of disgust in others. These data strongly suggest that humans understand disgust, and most likely other emotions, through a direct mapping mechanism. The observation of emotionally laden actions activates those structures that give a first-person experience of the same actions. By means of this activation, a

bridge is created between ourselves and others. CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

SEEING BOTH SIDES ARE MIRROR NEURONS INVOLVED IN THE EXPERIENCE OF EMPATHY? Affective mirroring: emotional contagion or empathy Frédérique de Vignemont, Institut Jean-Nicod, Paris According to most accounts, empathy presupposes a rich prior knowledge of the person with whom one empathizes (Goldie, 1999). Consequently, it must be generated by high-level cognitive processes, such as imagination and perspective-taking. However, the recent discovery of so-called 'mirror systems' has offered a new possible account of empathy, which would be generated instead by low-level mechanisms of neural mimicry. Indeed, the same brain areas have been found to be active when one performs an action and when one observes another perform the same action (Rizzolatti et al., 1995), when one inhales disgusting odorants and when one observes disgust-expressive faces (Wicker at al., 2003), when one is being touched and when one sees another being touched (Keysers et al., 2004), and also when one feels pain and when one observes another in pain (Singer et al., 2004). As a result, the question has recently arisen whether mirroring could generate or constitute empathy (Gallese, 2001; Preston and de Waal, 2002). Individual X could not empathize with individual Y unless (i) X were in some affective state or other; (ii) X's affective state were homologous with Y's affective state (or target state) in some relevant aspects (e.g. same type of affective state); (iii) X's state were triggered by Y's state; and (iv) X were aware that Y is the source of X's own affective state (de Vignemont & Singer, 2006). The fourth condition is of particular interest for distinguishing emotional contagion and empathy. Both emotional contagion and empathy meet the first three conditions. However, unlike empathy, emotional contagion fails to meet the fourth condition. It falls short of understanding another's emotion. Suppose I become hysterical in the middle of a hysterical crowd. When I catch others' hysteria so to speak, I am locked within my own emotional state; I cannot care about others' emotions. In contrast, when I empathize with the distress you experience after your father's death, my empathetic distress helps me to better understand what you feel, and it may also motivate my trying to comfort you. Whereas emotional contagion is self-centered, empathy is other-centered. The awareness of the other's role in one's own emotion is thus a prerequisite of empathy (iv). Mirroring meets the first three conditions: (i) the mirror response may be an affective state (e.g., disgust, pain); (ii) it is part of the definition of the mirror state that it matches the target state, and (iii) the mirror state is caused by the target state. Thus, the mirroring account of both emotional contagion and empathy seems promising, but it is more promising for the former than for the latter. It is not clear, indeed, how mirroring per se can underlie one's emotional understanding of others, an understanding constitutive of empathy, but not of emotional contagion. How can I know that my mirroring state is triggered by your affective state? If mirroring constitutes emotional contagion and emotional contagion does not meet condition (iv), then it is unlikely that mirroring is either necessary or sufficient for emotional understanding of others. Instead, one needs to exploit higher-level cognitive processes in order to know the causal source of one's empathetic state. This view is in line with the top-down approach to empathy. Strictly speaking, there cannot be a mirroring route to empathy. Mirroring per se would only generate emotional contagion, not empathy. However, it is important to distinguish between two kinds of mirroring: strict mirroring based on low-level direct matching between one's state and the target state, and cognitively loaded mirroring. Consider the example of pain, which includes both a sensorimotor component (the intensity of pain and its bodily location) and an affective component (the unpleasantness of pain). Using one experimental paradigm, Avenanti et al. (2005) found that seeing a needle deeply penetrate another's hand

causes in the observer the same sensorimotor response (i.e. muscle-specific freeze) as in the person whose hand is being penetrated. By contrast, using a different experimental paradigm, Singer et al. (2004) found that experiencing pain and observing another's pain selectively activate the same affective part of the pain neural matrix. There are interesting contrasts between the two types of mirroring. Whereas the former is automatic (Avenanti et al., 2006), the latter is subject to top-down modulation by a wide range of factors: by the affective attitude toward the target (Singer et al., 2006), by the empathizer's expertise (Cheng et al., 2007), by information about therapeutic uses of pain (Lamm et al., 2007), and by perspective-taking (Jackson et al., 2006). Thus, affective pain mirroring is based on processes of context appraisal. As such, it can include one's awareness that the other is the source of one's affective state, and thus generate empathy. In contrast, sensorimotor pain mirroring fails to meet condition (iv). It is more direct and low-level and it can constitute the neural basis of emotional contagion. To conclude, strict mirroring is a low-level automatic mechanism that causes mere emotional contagion. It is only when mirroring is cognitively loaded that it can generate empathy. But it may then no longer qualify as a mirroring process. EVOLUTION, GENES, AND BEHAVIOR For more Cengage Learning textbooks, visit www.cengagebrain.co.uk

64 CHAPTER 2 BIOLOGICAL FOUNDATIONS OF PSYCHOLOGY CHAPTER SUMMARY The basic unit of the nervous system is a specialized type of cell called a neuron. Projecting from the cell body of a neuron are short branches called dendrites and a slender tubelike extension called the axon. Stimulation of the dendrites and cell body leads to a neural impulse that travels down the length of the axon. Sensory neurons transmit signals from sense organs to the brain and spinal cord; motor neurons transmit signals from the brain and spinal cord to muscles and glands. A nerve is a bundle of elongated axons belonging to hundreds or thousands of neurons. A stimulus moves along a neuron as an electrochemical impulse that travels from the dendrites to the end of the axon. This traveling impulse, or action potential, is caused by depolarization, an electrochemical process in which the voltage difference across cell mechanisms is changed at successive points along the neuron. Once started, an action potential travels down the axon to many small swellings at the end of the axon called terminal buttons. These terminal buttons release chemical substances called neurotransmitters, which are responsible for transferring the signal from one neuron to an adjacent one. The neurotransmitters diffuse across the synapse, a small gap between the juncture of the two neurons, and bind to receptors in the cell membrane of the receiving neuron. Some neurotransmitters have an excitatory effect, and others have an inhibitory effect. If the excitatory effects on the receiving neuron become large relative to the inhibitory effects, depolarization occurs, and the neuron fires an all-or-none impulse. There are many different kinds of neurotransmitter–receptor interactions, and they help explain a range of psychological phenomena. The most important neurotransmitters include acetylcholine, norepinephrine, dopamine, serotonin, gamma-aminobutyric acid (GABA), and glutamate. The nervous system is divided into the central nervous system (the brain and spinal cord) and the peripheral nervous system (the nerves connecting the brain and spinal cord to other parts of the body). Subdivisions of the peripheral nervous system are the somatic system (which carries messages to and from the sense receptors, muscles, and the surface of the body) and the autonomic For more Cengage Learning textbooks, visit www.cengagebrain.co.uk system (which connects with the internal organs and glands). The human brain is composed of three functional divisions: the central core, the limbic system, and the cerebrum. The central core includes the medulla, which is responsible for respiration and postural reflexes; the cerebellum, which is concerned with motor coordination; the thalamus, a relay station

for incoming sensory information; and the hypothalamus, which is important in emotion and in maintaining homeostasis. The reticular formation, which crosses through several of the other central core structures, controls the organism's state of arousal and consciousness. The limbic system controls some of the instinctive behaviors regulated by the hypothalamus, such as feeding, attacking, fleeing, and mating. It also plays an important role in emotion and memory. The cerebrum is divided into two cerebral hemispheres. The convoluted surface of these hemispheres, the cerebral cortex, plays a critical role in higher mental processes such as thinking, learning, and decision making. Certain areas of the cerebral cortex are associated with specific sensory inputs or control of specific movements. The remainder of the cerebral cortex consists of association areas concerned with memory, thought, and language. Techniques have been developed to obtain detailed pictures of the human brain without causing the patient undue distress or damage. They include computerized axial tomography (CAT or CT), magnetic resonance imaging (MRI), and positron emission tomography (PET). When the corpus callosum (the band of nerve fibers connecting the two cerebral hemispheres) is severed, significant differences in the functioning of the two hemispheres can be observed. The left hemisphere is skilled in language and mathematical abilities. The right hemisphere can understand some language but cannot communicate through speech. Instead, it has a highly developed spatial and pattern sense. The term aphasia is used to describe language deficits caused by brain damage. People with damage to Broca's area have difficulty enunciating words correctly and speak in a slow, labored way.

People with damage to Wernicke's area can hear words but do not know their meaning. The autonomic nervous system has sympathetic and parasympathetic divisions. Because it controls the action of the smooth muscles and the glands, the autonomic system is particularly important in emotional reactions. The sympathetic division is active during excitement, and the parasympathetic system is dominant during quiescence. The endocrine glands secrete hormones into the bloodstream that travel through the body, acting in various ways on cells of different types. The pituitary has been called the 'master gland' because it controls the secretion activity of other endocrine glands. The adrenal glands are important in determining mood, energy level, and ability to cope with stress. An individual's hereditary potential, which is transmitted by the chromosomes and genes, CORE CONCEPTS interneuron nerve nucleus ganglion glial cell action potential ion ion channel ion pump polarized resting potential excitation threshold depolarized refractory period myelin sheath nodes of ranvier saltatory conduction all-or-none law lock-and-key action excitatory inhibitory pain threshold pain tolerance nervous system brain spinal cord central nervous system peripheral nervous system afferent nerves efferent nerves somatic system autonomic system neuron dendrites axon terminal buttons synapse synaptic gap neurotransmitter sensory neuron receptor motor neuron For more Cengage Learning textbooks, visit www.cengagebrain.co.uk CORE CONCEPTS influences his or her psychological and physical characteristics. Genes are segments of DNA molecules, which store genetic information. Some genes are dominant, some recessive, and some sexlinked. Most human characteristics are polygenic; that is, they are determined by many genes acting together rather than by a single gene pair. Selective breeding (mating animals that are high or low in a certain trait) is one method of studying the influence of heredity. Another means of sorting out the effects of environment and heredity is twin studies, in which the characteristics of identical twins (who share the same heredity) are compared with those of fraternal twins (who are no more alike genetically than ordinary siblings). Behavior depends on the interaction between heredity and environment: An individual's genes set the limits of his or her potential, but what happens to that potential depends

on the environment in which he or she grows up. hyperpolarized reuptake degradation hindbrain midbrain forebrain central core limbic system cerebrum medulla pons reticular formation cerebellum superior and inferior colliculus substantia nigra cerebral cortex thalamus hypothalamus homeostasis pituitary gland limbic system

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