Neuron studying chapter conspect

Health & Medicine, Body

chapter 2 chapter outline module 5 Neurons: The Basic Elements of Behavior The Structure of the Neuron How Neurons Fire Where Neurons Connect to One Another: Bridging the Gap Neurotransmitters: Multitalented Chemical Couriers module 6 module 7 The Brain The Nervous System and the Endocrine System: Communicating within the Body The Nervous System The Endocrine System: Of Chemicals and Glands

Studying the Brain's Structure and Functions: Spying on the Brain The Central Core: Our " Old Brain" The Limbic System: Beyond the Central Core The Cerebral Cortex: Our " New Brain" Neuroplasticity and the Brain The Specialization of the Hemispheres: Two Brains or One? Exploring Diversity: Human Diversity and the Brain Try It! Assessing Brain Lateralization The Split Brain: Exploring the Two Hemispheres Becoming an Informed Consumer ofPsychology: Learning to Control Your Heart—and Mind—through Biofeedback Psychology on the Web The Case of . . . The Fallen Athlete Full Circle: Neuroscience and Behavior 46

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The Deepest Cut Wendy Nissley carried her two-year-old daughter, Lacy, into O. R. 12 at Johns Hopkins Hospital to have half of her brain removed. Lacy suffers from a rare malformation of the brain, known as hemimegalencephaly, in which one hemisphere grows larger than the other. The condition causes seizures, and Lacy was having so many—up to forty in a day—that at an age when other toddlers were trying out sentences, she could produce only a few language-like sounds. As long as Lacy's malformed right hemisphere was attached to the rest of her brain, it would prevent her left hemisphere from functioning normally.

So Lacy's parents had brought her to Johns Hopkins for a hemispherectomy, which is probably the most radical procedure in neurosurgery. (Kenneally, 2006, p. 36) neuroscience and behavior It took nearly a day, but the surgery to remove half of Lacy's brain was a success. Within a few months, Lacy was crawling and beginning to speak. Although the long-term effects of the radical operation are still unclear, it brought substantial improvement to Lacy's life. The ability of surgeons to identify and remove damaged portions of the brain is little short of miraculous. The greater miracle, though, is the brain itself.

An organ roughly half the size of a loaf of bread, the brain controls our behavior through every waking and sleeping moment. Our movements, thoughts, hopes, aspirations, dreams—our very awareness that we are human—all depend on the brain and the nerves that extend throughout the body, constituting the nervous system. Because of the importance of the nervous system in controlling behavior, and because humans at their most basic level are biological beings, many researchers in psychology and other fields as diverse as computerscience, zoology, and medicine have made the biological underpinnings of behavior their specialty.

These experts collectively are called neuroscientists (Beatty, 2000; Posner & DiGirolamo, 2000; Gazzaniga, Ivry, & Mangun, 2002; Cartwright, 2006). Psychologists who specialize in considering the ways in which the biological structures and functions of the body affect behavior are known as Behavioral neuroscientists Psychologists who specialize in behavioral neuroscientists (or biopsychologists). They seek to answer sevconsidering the ways in which the eral key questions: How does the brain control the voluntary and involunbiological structures and functions tary functioning of the body?

How does the brain communicate with other of the body affect behavior. parts of the body? What is the physical structure of the brain, and how does this structure affect behavior? Are psychological disorders caused by biological factors, and how can such disorders be treated? As you consider the biological processes that we'll discuss in this chapter, it is important to keep in mind why behavioral neuroscience is an essential part of psychology: our understanding of human behavior requires knowledge of the brain and other parts of the nervous system.

Biological factors are central to our sensory experiences, states of consciousness, motivationand emotion, development throughout the life p, and physical and psychologicalhealth. Furthermore, advances in behavioral neuroscience have led to the creation of drugs and other treatments for psychological and physical disorders. In short, we cannot understand behavior without understanding our biological makeup (Plomin, 2003a; Compagni & Manderscheid, 2006; Plomin et al. , 2008). 47 looking ahe ad module 5 Neurons The Basic Elements of Behavior learning outcomes 5. 1 Explain the structure of a neuron.

The nervous system is the pathway for the instructions that permit our bodies to carry out everyday activities such as scratching an itch as well as more remarkable skills like climbing to the top of Mount Everest. Here we will look at the structure and function of neurons, the cells that make up the nervous system, including the brain. 5. 2 Describe how neurons fire. 5. 3

Summarize how messages travel from one neuron to another. 5. 4 Identify neurotransmitters. The Structure of the Neuron LO 1 Playing the piano, driving a car, or hitting a tennis ball depend, at one level, on exact muscle coordination.

But if we consider how the muscles can be activated so precisely, we see that there are more fundamental processes involved. For the muscles to produce the complex movements that make up any meaningful physical activity, the brain has to provide the right messages to them and coordinate those messages. Such messages—as well as those which enable us to think, remember, and experience emotion—are passed through specialized cells called neurons. Neurons Nerve cells, the basic Neurons, or nerve cells, are the basic elements of the nervous system. Their elements of the nervous system. uantity is staggering—perhaps as many as 1 trillion neurons throughout Dendrites A cluster of fibers at the body are involved in the control of behavior (Boahen, 2005). one end of the neuron that receives messages from other neurons. Although there are several types of neurons, they all have a similar strucAxon The part of the neuron that ture, as illustrated in Figure 1. In contrast to most other cells, however, carries messages destined for other neurons have a distinctive feature: the ability to communicate with other neurons. cells and transmit information across relatively long distances.

Many of the body's neurons receive signals from theenvironmentor relay the nervous system's messages to muscles and other target cells, but the vast majority of neurons communicate only with other neurons in the elaborate information system that regulates behavior. As you can see in Figure 1, a neuron has a cell body with a cluster of fibers called dendrites at one end. Those fibers, which look like the twisted Remember that Dendrites branches of a tree, receive messages from other neurons. On the opposite Detect messages from other of the cell body is a long, slim, tubelike extension called an axon.

The axon neurons; Axons carry signals carries messages received by the dendrites to other neurons. The axon is conAway from the cell body. siderably longer than the rest of the neuron. Although most axons are several s tudy aler t 48 Chapter 2 neuroscience and behavior Dendrites Terminal buttons Cell body M o ec vem tric ent of al i mpu lse el Myelin sheath Axon (inside myelin sheath) Figure 1 The primary components of the specialized cell called the neuron, the basic element of the nervous system (Van De Graaff, 2000).

A neuron, like most types of cells in the body, has a cell body and a nucleus, but it also contains structures that carry messages: the dendrites, which receive messages from other neurons, and the axon, which carries messages to other neurons or body cells. In this neuron, as in most neurons, the axon is protected by the sausagelike myelin sheath. What advantages does the treelike structure of the neuron provide? millimeters in length, some are as long as three feet. A xons end in small bulges called terminal buttons, which send messages to other neurons.

The messages that travel through a neuron are electrical in nature. Although there are exceptions, those electrical messages, or impulses, generally move across neurons in one direction only, as if they were traveling on a one-way street. Impulses follow a route that begins with the dendrites, continues into the cell body, and leads ultimately along the tubelike extension, the axon, to adjacent neurons. To prevent messages from short-circuiting one another, axons must be insulated in some fashion (just as electrical wires must be insulated).

Most axons are insulated by a myelin sheath, a protective coating of fat and protein that wraps around the axon like links of sausage. Terminal buttons Small bulges at the end of the axons that send messages to other neurons. Myelin sheath A protective coat of fat and protein that wraps around the axon. All-or-none law The rule that neurons are either on or off. Resting state The state in which there is a negative electrical charge of about 70 millivolts within a neuron. s tudy aler t Think of a neuron as a sausage, and the myelin sheath as the case around it.

LO 2 How Neurons Fire Like a gun, neurons either fire—that is, transmit an electrical impulse along the axon—or don't fire. There is no in-between stage, just as pulling harder on a gun trigger doesn't make the bullet travel faster. Similarly, neurons follow an all-or-none law: they are either on or off, with nothing in between the on state and the off state. Once there is enough force to pull the trigger, a neuron fires. Before a neuron is triggered—that is, when it is in a resting state—it has a negative electrical charge of about 70 millivolts.

When a message arrives at a neuron, gates along the cell membrane open briefly to allow positively charged ions to rush in at rates as high as 100 million ions per second. The sudden arrival of these positive ions causes the charge within the nearby part of the cell to change momentarily from negative to positive. When the positive charge reaches a critical level, the " trigger" is pulled, and an electrical impulse, known as an action potential, travels along the axon of the neuron (see Figure 2). psych 2. 0 www. mhhe. com/psychlife Neurons 49 Module 5 neurons: the basic elements of behavior

Figure 2 Movement of the action potential across the axon. Just before Time 1, positively charged ions enter the cell membrane, changing the charge in the nearby part of the neuron from negative to positive and triggering an action potential. The action potential travels along the axon, as illustrated in the changes occurring from Time 1 to Time 3 (from top to bottom in this drawing). Immediately after the action potential has passed through a section of the axon, positive ions are pumped out, restoring the charge in that section to negative.

Time 1 Voltage Time 2 ++ +++ – – – – – – Time 3 Voltage Voltage Positive charge Negative charge Direction of impulse Action potential An electric nerve impulse that travels through a neuron when it is set off by a " trigger," changing the neuron's charge from negative to positive. Mirror neurons Neurons that fire when a person enacts a particular behavior and also when a person views others' behavior. The action potential moves from one end of the axon to the other like a flame moving along a fuse.

Just after an action potential has occurred, a neuron cannot fire again immediately no matter how much stimulation it receives. It is as if the gun has to be reloaded after each shot. Eventually, though, the neuron is ready to fire once again. Neurons differ not only in terms of how quickly an impulse moves along the axon but also in their potential rate of firing. Some neurons are capable of firing as many as a thousand times per second; others fire at much slower rates. The intensity of a stimulus determines how much of a neuron's potential firing rate is reached.

A strong stimulus, such as a bright light or a loud sound, leads to a higher rate of firing than a less intense stimulus does. Thus, even though all impulses move at the same strength or speed through a particular axon—because of the all-or-none law—there is variation in the frequency of impulses, providing a mechanism by which we can distinguish the tickle of a feather from the weight of someone standing on our toes. Although all neurons operate through the firing of action potentials, there is significant specialization among different types of neurons.

For example, in the last decade, neuroscientists have discovered the existence of mirror neurons, neurons that fire not only when a person enacts a particular behavior, but also when a person simply observes another individual carrying out the same behavior (Lepage & Theoret, 2007; Schulte-Ruther et al. , 2007). 50 Chapter 2 neuroscience and behavior Mirror neurons may help explain how (and why) humans have the capacity to understand others' intentions. Specifically, mirror neurons may fire when we view others' behavior, helping us to predict what theirgoalsare and what hey may do next (Oberman, Pineda, & Ramachandran, 2007; Triesch, Jasso, & Deak, 2007). Mirror neurons may help explain how (and why) humans have the capacity to understand others' intentions. LO 3 Where Neurons Connect to One Another: Bridging the Gap Synapse The space between two If you have looked inside a computer, you've seen that each part is physically connected to another part. In contrast, evolution has produced a neural transmission system that at some points has no need for a structural connection between its components.

Instead, a chemical connection bridges the gap, known as a synapse, between two neurons (see Figure 3). The synapse is the space between two neurons where the axon of a sending neuron 1 Neurotransmitters are produced and stored in the axon. neurons where the axon of a sending neuron communicates with the dendrites of a receiving neuron by using chemical messages. 2 If an action potential arrives, the axon releases neurotransmitters. 3 Neurotransmitters travel across the synapse to receptor sites on another neuron's dendrite. Axon Axon Synapse Dendrite Synapse Neurotransmitter Neurotransmitter Synapse Receptor site

Receptor site 4 When a neurotransmitter fits into a receptor site, it delivers an excitatory or inhibitory message. If enough excitatory messages are delivered, the neuron will fire. A Neurotransmitter Dendrite B Figure 3 (A) A synapse is the junction between an axon and a dendrite. The gap between the axon and the dendrite is bridged by chemicals called neurotransmitters (Mader, 2000). (B) Just as the pieces of a jigsaw puzzle can fit in only one specific location in a puzzle, each kind of neurotransmitter has a distinctive configuration that allows it to fit into a specific type of receptor cell (Johnson, 2000).

Why is it advantageous for axons and dendrites to be linked by temporary chemical bridges rather than by the hard wiring typical of a radio connection or telephone hookup? Module 5 neurons: the basic elements of behavior 51 communicates with the dendrites of a receiving neuron by using chemical messages (Fanselow & Poulos, 2005; Dean & Dresbach, 2006). carry messages across the synapse to When a nerve impulse comes to the end of the axon and reaches a terminal the dendrite (and sometimes the cell button, the terminal button releases a chemical courier called a neurotransbody) of a receiver neuron. mitter.

Neurotransmitters are chemicals that carry messages across the Excitatory messages Chemical synapse to a dendrite (and sometimes the cell body) of a receiving neuron. messages that make it more likely that a receiving neuron will fire and an The chemical mode of message transmission that occurs between neurons is action potential will travel down its axon. strikingly different from the means by whichcommunicationoccurs inside Inhibitory messages Chemical neurons: although messages travel in electrical form within a neuron, they messages that prevent or decrease the move between neurons through a chemical transmission system. ikelihood that a receiving neuron will fire. There are several types of neurotransmitters, and not all neurons are Reuptake The reabsorption of capable of receiving the chemical message carried by a particular neuneurotransmitters by a terminal button. rotransmitter. In the same way that a jigsaw puzzle piece can fit in only one specific location in a puzzle, each kind of neurotransmitter has a distinctive configuration that allows it to fit into a specific type of receptor site on the receiving neuron (see Figure 3B). It is only when a neurotransmitter fits precisely into a receptor site that successful chemical communication is possible.

If a neurotransmitter does fit into a site on the receiving neuron, the chemical message it delivers is basically one of two types: excitatory or inhibitory. Excitatory messages make it more likely that a receiving neuron will fire and an action potential will travel down its axon. Inhibitory messages, in contrast, do just the opposite; they provide chemical information that prevents or decreases the likelihood that the receiving neuron will fire. Because the dendrites of a neuron receive both excitatory and inhibitory messages simultaneously, the neuron must integrate the messages by using a kind of chemical calculator.

Put simply, if the excitatory messages (“ fire! ”) outnumber psych 2. 0 the inhibitory ones (“ don’t fire! ”), the neuron fires. In contrast, if the inhibitory www. mhhe. com/psychlife messages outnumber the excitatory ones, nothing happens, and the neuron remains in its resting state (Mel, 2002; Flavell et al. , 2006). If neurotransmitters remained at the site of the synapse, receiving neurons would be awash in a continual chemical bath, producing constant stimulation or constant inhibition of the receiving neurons—and effective communication across the synapse would no longer be possible.

To solve this problem, neurotransmitters are either deactivated by enzymes or—more commonly— reabsorbed by the terminal button in an example of chemical recycling called reuptake. Like a vacuum cleaner sucking up dust, neurons reabsorb the neurotransmitters that are now clogging the synapse. All this activity Messages Traveling between Neurons occurs at lightning speed (Helmuth, 2000; Holt & Jahn, 2004). Neurotransmitters Chemicals that LO 4 Neurotransmitters: Multitalented Chemical Couriers Neurotransmitters are a particularly important link between the nervous system and behavior.

Not only are they important for maintaining vital brain and body functions, a deficiency or an excess of a neurotransmitter can produce severe behavior disorders. More than a hundred chemicals have been found to act as neurotransmitters, and neuroscientists believe that more may ultimately be identified (Penney, 2000; Schmidt, 2006). Neurotransmitters vary significantly in terms of how strong their concentration must be to trigger a neuron to fire. Furthermore, the effects of a particular neurotransmitter vary, depending on the area of the nervous system in 52 Chapter 2 neuroscience and behavior Dopamine Pathways Name Acetylcholine (ACh)

Location Brain, spinal cord, peripheral nervous system, especially some organs of the parasympathetic nervous system Brain, spinal cord Brain, spinal cord Effect Excitatory in brain and autonomic nervous system; inhibitory elsewhere Function Muscle movement, cognitive functioning Glutamate Gamma-amino butyric acid (GABA) Excitatory Main inhibitory neurotransmitter Memory Eating, aggression, sleeping Serotonin Pathways Dopamine (DA) Brain Inhibitory or excitatory Muscle disorders, mental disorders, Parkinson’s disease Sleeping, eating, mood, pain, depressionPain suppression, pleasurable feelings, appetities, placebos

Serotonin Brain, spinal cord Inhibitory Endorphins Brain, spinal cord Primarily inhibitory, except in hippocampus Figure 4 Some major neurotransmitters. which it is produced. The same neurotransmitter, then, can act as an excitatory message to a neuron located in one part of the brain and can inhibit firing in neurons located in another part. (The major neurotransmitters and their effects are described in Figure 4.) One of the most common neurotransmitters is acetylcholine (or ACh, its chemical symbol), which is found throughout the nervous system. ACh is Michael J.

Fox, who suffers from Parkinson’s disease, like Muhammad Ali, has become a strong advocate for research into the disorder. The pair is seen here asking Congress for additional funds for Parkinson’s research. Module 5 neurons: the basic elements of behavior 53 involved in our every move, because—among other things—it transmits messages relating to our skeletal muscles. ACh is also involved in memory capabilities, and diminished production of ACh may be related to Alzheimer’s disease (Mohapel et al. , 2005). Another major neurotransmitter is dopamine (DA), which is involved in movement, attention, and learning.

The discovery that certain drugs can have a significant effect on dopamine release has led to the development of effective treatments for a wide variety of physical and mental ailments. For instance, Parkinson’s disease, from which actor Michael J. Fox suffers, is caused by a deficiency of dopamine in the brain. Techniques for increasing the production of dopamine in From the perspective of . . . A Health Care Provider How might your understanding of the nervous system help you explain the symptoms of Parkinson’s disease to a patient with the disorder?

Parkinson’s patients are proving effective (Kaasinen & Rinne, 2002; Willis, 2005; Iversen & Iversen, 2007). In other instances, over production of dopamine produces negative consequences. For example, researchers have hypothesized that schizophrenia and some other severe mental disturbances are affected or perhaps even caused by the presence of unusually high levels of dopamine. Drugs that block the reception of dopamine reduce the symptoms displayed by some people diagnosed with schizophrenia

(Baumeister & Francis, 2002; Bolonna & Kerwin, 2005; Olijslagers, Werkman, & McCreary, 2006). recap

Explain the structure of a neuron. ¦ A neuron has a cell body (which contains a nucleus) with a cluster of fibers called dendrites, which receive messages from other neurons. On the opposite end of the cell body is a tubelike extension, an axon, which ends in a small bulge called a terminal button. Terminal buttons send messages to other neurons. (p. 48) message to fire, it releases an action potential, an electrical charge that travels through the axon. Neurons operate according to an all-ornone law: Either they are at rest, or an action potential is moving through them. There is no in-between state. p. 49) Summarize how messages travel from one neuron to another. ¦ Once a neuron fires, nerve impulses are carried to other neurons through the production of chemical substances, neurotransmitters, that actually bridge the gaps—known as synapses—between neurons. Neurotransmitters Describe how neurons fire. ¦ Most axons are insulated by a coating called the myelin sheath. When a neuron receives a 54 Chapter 2 neuroscience and behavior may be either excitatory, telling other neurons to fire, or inhibitory, preventing or decreasing the likelihood of other neurons firing. (p. 52) Identify neurotransmitters. Neurotransmitters are an important link between the nervous system and behavior. Common neurotransmitters include the following: acetylcholine, which transmits messages relating to our muscles and is involved in memory capabilities; glutamate, which plays a role in memory; gamma-amino butyric acid (GABA), which moderates behaviors from eating to aggression; dopamine, which is involved in movement, attention, and learning; serotonin, which is associated with the regulation of sleep, eating, mood, and pain; and endorphins, which seem to be involved in the brain’s effort to deal with pain and elevate mood. p. 53) evaluate 1. The is the fundamental element of the nervous system. and send messages through their 2. Neurons receive information through their . 3. Just as electrical wires have an outer coating, axons are insulated by a coating called the . 4. The gap between two neurons is bridged by a chemical connection called a 5. Endorphins are one kind of , the chemical “ messengers” between neurons. . rethink How might psychologists use drugs that mimic the effects of neurotransmitters to treat psychological disorders? Answers to Evaluate Questions 1. neuron; 2. dendrites, axons; 3. yelin sheath; 4. synapse; 5. neurotransmitter key terms Behavioral neuroscientists (or biopsychologists) p. 47 Neurons p. 48 Dendrites p. 48 Axon p. 48 Terminal buttons p. 49 Myelin sheath p. 49 All-or-none law p. 49 Resting state p. 49 Module 5 neurons: the basic elements of behavior Action potential p. 50 Mirror neurons p. 50 Synapse p. 51 Neurotransmitters p. 52 Excitatory messages p. 52 Inhibitory messages p. 52 Reuptake p. 52 55 module 6 The Nervous System and the Endocrine System Communicating within the Body learning outcomes 6. 1 Explain how the structures f the nervous system are linked together. The complexity of the nervous system is astounding. Estimates of the number of connections between neurons within the brain fall in the neighborhood of 10 quadrillion—a 1 followed by 16 zeros. Furthermore, connections among neurons are not the only means of communication within the body; as we’ll see, the endocrine system, which secretes chemical messages that circulate through the blood, also communicates messages that influence behavior and many aspects of biological functioning (Kandel, Schwartz, & Jessell, 2000; Forlenza & Baum, 2004; Boahen, 2005). . 2 Describe the operation of the endocrine system and how it affects behavior. Central nervous system (CNS) The part of the nervous system that includes the brain and spinal cord. Spinal cord A bundle of neurons LO 1 The Nervous System that leaves the brain and runs down the length of the back and is the main means of transmitting messages between the brain and the body. The human nervous system has both logic and elegance. We turn now to a discussion of its basic structures. Central and Peripheral Nervous Systems

As you can see from the schematic representation in Figure 1, the nervous system is divided into two main parts: the central nervous system and the peripheral nervous system. The central nervous system (CNS) is composed of the brain and spinal cord. The spinal cord, which is about the thickness of a pencil, contains a bundle of neurons that leaves the brain and runs down the length of the back (see Figure 2). As you can see in Figure 1, the spinal cord is the primary means for transmitting messages between the brain and the rest of the body. 56 Chapter 2 euroscience and behavior The Nervous System Consists of the brain and the neurons extending throughout the body Peripheral Nervous System Made up of long axons and dendrites, it contains all parts of the nervous system other than the brain and spinal cord Central Nervous System Consists of the brain and spinal cord Somatic Division (voluntary) Specializes in the control of voluntary movements and the communication of information to and from the sense organs Autonomic Division (involuntary) Concerned with the parts of the body that function involuntarily without our awareness

Brain An organ roughly half the size of a loaf of bread that constantly controls behavior Spinal Cord A bundle of nerves that leaves the brain and runs down the length of the back; transmits messages between the brain and the body Sympathetic Division Acts to prepare the body in stressful emergency situations, engaging resources to respond to a threat Parasympathetic Division Acts to calm the body after an emergency situation has engaged the sympathetic division; provides a means for the body to maintain storage of energy sources Figure 1 A schematic diagram of the relationship of the parts of the nervous system.

However, the spinal cord is not just a communication channel. It also Reflex An automatic, involuntary controls some simple behaviors on its own, without any help from the response to an incoming stimulus. brain. An example is the way the knee jerks forward when it is tapped with a rubber hammer. This behavior is a type of reflex, an automatic, involuntary response to an incoming stimulus. A reflex is also at work when psych 2. 0 you touch a hot stove and immediately withdraw your hand. Although the www. mhhe. com/psychlife brain eventually analyzes and reacts to the situation (“ Ouch—hot stove— pull away!), the initial withdrawal is directed only by neurons in the spinal cord. Three kinds of neurons are involved in reflexes. Sensory (afferent) neurons transmit information from the perimeter of the body to the central nervous system. Motor (efferent) neurons communicate information from the nervous system to muscles and glands. Interneurons connect sensory and motor neurons, carrying messages between the two. Organization of the Nervous System Module 6 the nervous system and the endocrine system 57 Central Nervous System Brain Spinal cord Peripheral Nervous System Spinal nerves

Figure 2 The central nervous system, consisting of the brain and spinal cord, and the peripheral nervous system. Sensory (afferent) neurons Neurons that transmit information from the perimeter of the body to the central nervous system. Motor (efferent) neurons Neurons that communicate information from the nervous system to muscles and glands. Interneurons Neurons that connect sensory and motor neurons, carrying messages between the two. Peripheral nervous system The part As suggested by its name, the peripheral nervous system branches out from the spinal cord and brain and reaches the extremities of the body.

Made up of neurons with long axons and dendrites, the peripheral nervous system encompasses all the parts of the nervous system other than the brain and spinal cord. There are two major divisions— the somatic division and the autonomic division— both of which connect the central nervous system with the sense organs, muscles, glands, and other organs. The somatic division specializes in the control of voluntary movements—such as the motion of the eyes to read this sentence or those of the hand to turn this page—and the communication of information to and from the sense organs.

On the other hand, the autonomic division controls the parts of the body that keep us alive—the heart, blood vessels, glands, lungs, and other organs that function involuntarily without our awareness. As you are reading at this moment, the autonomic division of the peripheral nervous system is pumping blood through your body, pushing your lungs in and out, and overseeing the digestion of your last meal. Activating the Divisions of the

Autonomic Nervous System The autonomic division plays a particularly crucial role during emergencies. Suppose that as you are reading in bed you suddenly sense that someone is outside your bedroom window.

As you look up, you see the glint of an object that might be a knife. As confusion and fear overcome you, what happens to your body? If you are like most people, you react immediately on a physiological level. Your heart rate increases, you begin to sweat, and you develop goose bumps all over your body. The physiological changes that occur during a crisis result from the activation of one of the two parts of the autonomic nervous system: the sympathetic division. The sympathetic division acts to prepare the body for action in stressful situations by engaging all of the organism's resources to run away or confront the threat.

This response is often called the " fight-orflight" response. In contrast, the parasympathetic division acts to calm the body after the emergency has ended. When you find, for instance, that the stranger at the window is actually your boyfriend who has lost his keys and is climbing in the window to avoid waking you, your parasympathetic division begins to predominate, lowering your heart rate, stopping your sweating, and returning your body to the state it was in before you became alarmed. The parasympathetic division also directs the body to store energy for use in emergencies.

The sympathetic and parasympathetic divisions work together to regulate many functions of the body (see Figure 3). of the nervous system that includes the autonomic and somatic subdivisions; made up of neurons with long axons and dendrites, it branches out from the spinal cord and brain and reaches the extremities of the body. Somatic division The part of the peripheral nervous system that specializes in the control of voluntary movements and the communication of information to and from the sense organs.

Autonomic division The part of the peripheral nervous system that controls involuntary movement of the heart, glands, lungs, and other organs. 58 Chapter 2 neuroscience and behavior Parasympathetic Sympathetic Eyes Contracts pupil Dilates pupil (enhanced vision) Heart Slow heartbeat Accelerates, strengthens heartbeat (increased oxygen) Lungs Constricts bronchi Relaxes bronchi (increased air to lungs) Stomach, Intestines Stimulates activity Inhibits activity (blood to muscles) Blood Vessels of Internal Organs Dilates vessels

Contracts vessels (increases blood pressure) Figure 3 The major functions of the autonomic nervous system. The sympathetic division acts to prepare certain organs of the body for stressful situations, and the parasympathetic division acts to calm the body after the emergency has passed. Can you explain why each response of the sympathetic division might be useful in an emergency? (Source: Adapted from Passer & Smith, 2001.) Behavioral Genetics Ourpersonalityand behavioral habits are affected in part by our genetic and evolutionary heritage.

Behavioral genetics studies the effects of heredity on behavior. Behavioral genetics researchers are finding increasing evidence that cognitive abilities, personality traits, sexual orientation, and psychological disorders are determined to some extent by genetic factors (Reif & Lesch, 2003; Viding et al. , 2005; Ilies, Arvey, & Bouchard, 2006). Behavioral genetics lies at the heart of the nature-nurture question, one of the key issues in the study of psychology. Although no one would argue that our behavior is determined solely by inherited factors, evidence

Sympathetic division The part of the autonomic division of the nervous system that acts to prepare the body for action in stressful situations, engaging all the organism's resources to respond to a threat. Parasympathetic division The part of the autonomic division of the nervous system that acts to calm the body after an emergency or a stressful situation has ended. Behavioral genetics The study of the effects of heredity on behavior. Module 6 the nervous system and the endocrine system 59 ollected by behavioral geneticists does suggest that our genetic inheritance predisposes us to respond in particular ways to our environment, and even to seek out particular kinds of environments. For instance, research indicates that genetic factors may be related to such diverse behaviors as level offamilyconflict, schizophrenia, learning disabilities, and general sociability (Harlaar et al. , 2005; Moffitt & Caspi, 2007). Furthermore, important human characteristics and behaviors are related to the presence (or absence) of particular genes, the inherited material that controls the transmission of traits.

For example, researchers have found evidence that novelty-seeking behavior is determined, at least in part, by a certain gene. As we will consider later in the book when we discuss human development, researchers have identified some 25, 000 individual genes, each of which appears in a specific sequence on a particular chromosome, a rod-shaped structure that transmits genetic informaGenetic testing can be done to determine potential risks to an unborn child based on family history of tion across generations. In 2003, after a decade of effort, illnesses. esearchers identified the sequence of the 3 billion chemical pairs that make up human DNA, the basic component of genes. Understanding the basic structure of the human genome—the “ map” of humans’ total genetic makeup—brings scientists a giant step closer to understanding the contributions of individual genes to specific human structures and functioning (Plomin et al. , 2003; Plomin & McGuffin, 2003; Andreasen, 2005). Our personality and behavioral habits are affected in part by our genetic and evolutionary heritage. s tudy aler t The endocrine system produces hormones, chemicals that circulate through the blood via the bloodstream.

Behavioral Genetics, Gene Therapy, and Genetic Counseling. Behavioral genetics also holds the promise of developing newdiagnosticand treatment techniques for genetic deficiencies that can lead to physical and psychological difficulties. In gene therapy, scientists inject genes meant to cure a particular disease into a patient’s bloodstream. When the genes arrive at the site of defective genes that are producing the illness, they trigger the production of chemicals that can treat the disease (Rattazzi, LaFuci, & Brown, 2004; Jaffe, Prasad, & Larcher, 2006; Plomin et al. 2008). The number of diseases that can be treated through gene therapy is growing, as we will see when we discuss human development. For example, gene therapy is now being used in experimental trials involving people with certain forms of cancer, leukemia, and blindness (Nakamura et al. , 2004; Wagner et al. , 2004; Hirschler, 2007). From the perspective of . . . A Physician’s Assistant How valuable would an understanding of the brain and neurosystem be in your job as a physician’s assistant? 60 Chapter 2 neuroscience and behavior

Advances in behavioral genetics also have led to the development of a profession that did not exist several decades ago: genetic counseling. Genetic counselors help people deal with issues related to inherited disorders. For example, genetic counselors provide advice to prospective parents about the potential risks in a future pregnancy, based on their family history of birth defects and hereditary illnesses. In addition, the counselor will consider the parents' age and problems with children they already have.

They also can take blood, skin, and urine samples to examine specificchromosomes. Endocrine system A chemical communication network that sends messages throughout the body via the bloodstream. Hormones Chemicals that circulate through the blood and regulate the functioning or growth of the body. Pituitary gland The major component of the endocrine system, or " master gland," which secretes hormones that control growth and other parts of the endocrine system. LO 2 The Endocrine System: Of Chemicals and Glands psych 2. www. mhhe. com/psychlife Another of the body's communication systems, the endocrine system is a chemical communication network that sends messages throughout the body via the bloodstream. Its job is to secrete hormones, chemicals that circulate through the blood and regulate the functioning or growth of the body. It also influences—and is influenced by—the functioning of the nervous system. As chemical messengers, hormones are like neurotransmitters, although their speed and mode of transmission are quite different.

Whereas neural messages are measured in thousandths of a second, hormonal communications may take minutes to reach their destination. Furthermore, neural messages move through neurons in specific lines (like a signal carried by wires strung along telephone poles), whereas hormones travel throughout the body, similar to the way radio waves are transmitted across the entire landscape. Just as radio waves evoke a response only when a radio is tuned to the correct station, hormones flowing through the bloodstream activate only those cells which are receptive and " tuned" to the appropriate hormonal message.

A key component of the endocrine system is the tiny pituitary gland. The pituitary gland has sometimes been called the " master gland" because it controls the functioning of the rest of the endocrine system. But the pituitary gland is more than just the taskmaster of other glands; it has important functions in its own right. For instance, hormones secreted by the pituitary gland control growth. Extremely short people and unusually tall ones usually have pituitary gland abnormalities. Other endocrine glands, shown in Figure 4, affect emotional reactions, sexual urges, and energy levels.

Although hormones are produced naturally by the endocrine system, there are a variety of artificial hormones that people may choose to take. For example, physicians sometimes prescribe hormone replacement therapy (HRT) to treat symptoms of menopause in older women. Other artificial hormones can be harmful. For example, some athletes use testosterone, a male hormone, and drugs known as steroids, which act like testosterone. For athletes and others who want to bulk up their appearance, steroids provide a way to add muscle weight and increase strength.

However, these drugs can lead to heart attacks, strokes, cancer, and even violent behavior, making them extremely dangerous (Kolata, 2002; Arangure, 2005; Klotz, Garle, & Granath, 2006; Pagonis, Angelopoulos, &

Koukoulis, 2006). The Endocrine System Steroids can provide added muscle strength, but they have dangerous side effects. A number of well-known athletes have been accused of using the drugs illegally. Jose Conseco is one of the few major league baseball players to admit steroid use. Module 6 the nervous system and the endocrine system 61 Anterior Pituitary Gland Produces 6 hormones with diverse actions

Hypothalamus Secretes several hormones that stimulate or inhibit anterior pituitary function Posterior Pituitary Gland Secretes oxytocin, which stimulates uterine contractions during birth; also secretes antidiuretic hormone, which increases water retention in the kidney Pineal Makes melatonin, which regulates daily rhythms Parathyroids (behind the thyroid) Make parathyroid hormone, which increases blood calcium Thyroid Regulates metabolic rate and growth Stomach and Small Intestine Secrete hormones that facilitate digestion and regulate pancreatic activity

Heart Makes atrial natriuretic peptide, which lowers blood sodium Adrenal Glands Medulla Makes epinephrine and norepinephrine, which mediate the " fight-or-flight" response Cortex Makes aldosterone, which regulates sodium and potassium balance in the blood; also makes glucocorticoids (such as cortisol), which regulate growth, metabolism, development, immune function, and the body's response tostressLiver and Kidneys Secrete erythropoietin, which regulates production of red blood cells Pancreas Makes insulin Ovaries Produce estrogens such as progesterone, which control reproduction in females

Adipose Tissue Produces adipokines (for example, leptin), which regulate appetite and metabolic rate Testes Produce androgens, such as testosterone, which control reproduction in males Figure 4 Location and function of the major endocrine glands. The pituitary gland controls the functioning of the other endocrine glands and in turn is regulated by the brain. Steroids can provide added muscle and strength, but they have dangerous side effects. (Source: Adapted from Brooker et al, 2008, p. 1062) recap Explain how the structures of the nervous system are linked together. The nervous system is made up of the central nervous system (the brain and spinal cord) and the peripheral nervous system. The peripheral 62 Chapter 2 neuroscience and behavior nervous system is made up of the somatic division, which controls voluntary movements and the communication of information to and from the sense organs, and the autonomic division, which controls involuntary functions such as those of the heart, blood vessels, and lungs. (p. 56) ¦ The autonomic division of the peripheral nervous system is further subdivided into the sympathetic and parasympathetic divisions.

The sympathetic division prepares the body in emergency situations, and the parasympathetic division helps the body return to its typical resting state. (p. 58) ¦ Behavioral genetics examines the hereditary basis of human personality traits and behavior. (p. 59) Describe the operation of the endocrine system and how it affects behavior. ¦ The endocrine system secretes hormones, chemicals that regulate the functioning of the body, via the bloodstream. The pituitary gland secretes growth hormones and influences the release of hormones by other endocrine glands, and in turn is regulated by the hypothalamus. (p. 61) valuate 1. If you put your hand on a red-hot piece of metal, the immediate response of pulling it away would be . an example of a(n) 2. The central nervous system is composed of the and .

3. In the peripheral nervous system, the division controls voluntary movements, whereas the division controls organs that keep us alive and function without our awareness. 4. Maria saw a young boy run into the street and get hit by a car. When she got to the fallen child, she was in a state of panic. She was sweating, and her heart was racing. Her biological state resulted from the activation of what division of the nervous system? . Parasympathetic b. Central c. Sympathetic rethink In what ways is the " fight-or-flight" response helpful to humans in emergency situations? Answers to Evaluate Questions 1. reflex; 2. brain, spinal cord; 3. somatic, autonomic; 4. sympathetic key terms Central nervous system (CNS) p. 56 Spinal cord p. 56 Reflex p. 57 Sensory (afferent) neurons p. 57 Motor (efferent) neurons p. 57 Interneurons p. 57 Peripheral nervous system p. 58 Somatic division p. 58 Module 6 the nervous system and the endocrine system 63 Autonomic division p. 58 Sympathetic division p. 58 Parasympathetic division p. 58 Behavioral genetics p. 9 Endocrine system p. 61 Hormones p. 61 Pituitary gland p. 61 module 7 The Brain learning outcomes 7. 1 Illustrate how researchers identify the major parts and functions of the brain. 7. 2 Describe the central core of the brain. 7. 3 Describe the limbic system of the brain. 7. 4 Describe the cerebral cortex of the brain. 7. 5 Recognize neuroplasticity and its implications. 7. 6 Explain how the two hemispheres of the brain operate interdependently and the implications for human behavior. It is not much to look at. Soft, spongy, mottled, and pinkish-gray in color, it hardly can be said to possess much in the way of physical beauty.

Despite its physical appearance, however, it ranks as the greatest natural marvel that we know and has a beauty and sophistication all its own. The object to which this description applies: the brain. The brain is responsible for our loftiest thoughts—and our most primitive urges. It is the overseer of the intricate workings of the human body. Many billions of neurons make up a structure weighing just three pounds in the average adult. However, it is not the number of cells that is the most astounding thing about the brain but its ability to allow the human intellect to flourish by guiding our behavior and thoughts.

We turn now to a consideration of the particular structures of the brain and the primary functions to which they are related. However, a caution is in order. Although we'll discuss specific areas of the brain in relation to specific behaviors, this approach is an oversimplification. No simple one-to-one correspondence exists between a distinct part of the brain and a particular behavior. Instead, behavior is produced by complex interconnections among sets of neurons in many areas of the brain: our behavior, emotions, thoughts, hopes, and dreams are produced by a variety of neurons throughout the nervous system working in concert.

LO 1 Studying the Brain's Structure and Functions: Spying on the Brain Modern brain-scanning techniques provide a window into the living brain. Using these techniques, investigators can take a " snapshot" of the interRemember that EEG, fMRI, nal workings of the brain without having to cut open a person's skull. The PET, and TMS differ in terms most important scanning techniques, illustrated in Figure 1, are the elecof whether they examine troencephalogram (EEG), positron emission tomography (PET), functional brain structures or brain magnetic resonance imaging (fMRI), and transcranial magnetic stimulation functioning. maging (TMS). The electroencephalogram (EEG) records electrical activity in the brain through electrodes placed on the outside of the skull. Although traditionally the EEG could produce only a graph of electrical wave patterns, new techniques are now used to transform the brain’s electrical activity into a pictorial representation of the brain that allows more precise diagnosis of disorders such as epilepsy and learning disabilities. s tudy aler t 64 Chapter 2 neuroscience and behavior A EEG B fMRI scan C TMS apparatus D PET scan Figure 1 Brain scans produced by different techniques. A) A computerproduced EEG image. (B) The fMRI scan uses a magnetic field to provide a detailed view of brain activity on a moment-by-moment basis. (C) Transcranial magnetic stimulation (TMS), the newest type of scan, produces a momentary disruption in an area of the brain, allowing researchers to see what activities are controlled by that area. TMS also has the potential to treat some psychological disorders. (D) The PET scan displays the functioning of the brain at a given moment. Positron emission tomography (PET) scans show biochemical activity within the brain at a given moment.

PET scans begin with the injection of a radioactive (but safe) liquid into the bloodstream, which makes its way to the brain. By locating radiation within the brain, a computer can determine which are the more active regions, providing a striking picture of the brain at work. Functional magnetic resonance imaging (fMRI) scans provide a detailed, three-dimensional computer-generated image of brain structures and activity by aiming a powerful magnetic field at the body. With fMRI scanning, it is possible to produce vivid, detailed images of the functioning of the brain.

Transcranial magnetic stimulation (TMS) is one of the newest types of scan. By exposing a tiny region of the brain to a strong magnetic field, TMS causes a momentary interruption of electrical activity. Researchers then are able to note the effects of this interruption on normal brain functioning. The procedure is sometimes called a “ virtual lesion” because it produces effects analogous to what would occur if areas The brain (shown here in cross section) may not be much to of the brain were physically cut. The enormous look at, but it represents one of the great marvels of human advantage of TMS, of course, is that the virtual development.

Why do most scientist believe that it will be difficult, if not impossible, to duplicate the brain’s abilities? cut is only temporary. Module 7 the brain 65 Cerebral cortex (the “ new brain”) LO 2 The Central Core: Our “ Old Brain” Although the capabilities of the human brain far exceed those of the brain of any other species, humans share some basic functions, such as breathing, eating, and sleeping, with more primitive animals. Not surprisingly, those activities are directed by a relatively primitive part of the brain.

A portion of the brain known as the central core (see Figure 2) is quite similar in all vertebrates Central core (species with backbones). The central core is sometimes referred to as the “ old (the “ old brain”) brain” because its evolution can be traced back some 500 million years to primFigure 2 The major itive structures found in nonhuman species. divisions of the brain: the If we were to move up the spinal cord from the base of the skull to locate cerebral cortex and the the structures of the central core of the brain, the first part we would come central core. Source: Seeley, to would be the hindbrain, which contains the medulla, pons, and cerebellum Stephens, &

Tate, 2000.) (see Figure 3). The medulla controls a number of critical body functions, the most important of which are breathing and heartbeat. The pons comes next, joining the two halves of the cerebellum, which lies adjacent to it. Containing large bundles of nerves, the pons acts as a transmitter of motor information, coordinating muscles and integrating movement between the right and left Central core The “ old brain,” which halves of the body.

It is also involved in regulating sleep. controls basic functions such as eating The cerebellum is found just above the medulla and behind the pons. and sleeping and is common to all Without the help of the cerebellum we would be unable to walk a straight vertebrates. line without staggering and lurching forward, for it is the job of the cerebelCerebellum (ser uh BELL um) The lum to control bodily balance. It constantly monitors feedback from the part of the brain that controls bodily muscles to coordinate their placement, movement, and tension. In fact, balance. rinking too much alcohol seems to depress the activity of the cerebellum, leading to the unsteady gait and movement characteristic of drunkenness. Hypothalamus Responsible for regulating basic biological needs: hunger, thirst, temperature control Cerebral Cortex Pituitary Gland “ Master” gland that regulates other endocrine glands Corpus Callosum Bridge of fibers passing information between the two cerebral hemispheres Pons Involved in sleep and arousal Thalamus Relay center for cortex; handles incoming and outgoing signals Reticular Formation A network of neurons related to sleep, arousal, and attention Cerebellum Controls bodily balance

Spinal Cord Responsible for communication between brain and rest of body; involved with simple reflexes Medulla Responsible for regulating largely unconscious functions such as breathing and circulation Figure 3 66 The major structures in the brain. (Source: Johnson, 2000.) Chapter 2 neuroscience and behavior The cerebellum is also involved in several intellectual functions, ranging from the analysis and Like an ever-vigilant guard, the coordination of sensory information to problem reticular formation is made up of solving (Bower & Parsons, 2004; Paquier & Marien, 2005; Vandervert, Schimpf, & Liu, 2007). roups of nerve cells that can activate The reticular formation extends from the other parts of the brain immediately medulla through the pons, passing through the middle section of the brain—or midbrain—and to produce general bodily arousal. into the front-most part of the brain, called the forebrain. Like an ever-vigilant guard, the reticular formation is made up of groups of nerve cells that can activate other parts of the brain immediately to produce general bodily arousal.

If, for example, we Reticular formation The part of the brain extending from the medulla are startled by a loud noise, the reticular formation can prompt a heightened through the pons and made up state of awareness to determine whether a response is necessary. The reticuof groups of nerve cells that can lar formation serves a different function when we are sleeping, seeming to immediately activate other parts of the brain to produce general bodily filter out background stimuli to allow us to sleep undisturbed. arousal.

Hidden within the forebrain, the thalamus acts primarily as a relay staThalamus The part of the brain tion for information about the senses. Messages from the eyes, ears, and skin located in the middle of the central travel to the thalamus to be communicated upward to higher parts of the core that acts primarily to relay brain. The thalamus also integrates information from higher parts of the information about the senses. brain, sorting it out so that it can be sent to the cerebellum and medulla. Hypothalamus A tiny part of the The hypothalamus is located just below the thalamus.

Although tiny— brain, located below the thalamus, that about the size of a fingertip—the hypothalamus plays an extremely impor- maintains homeostasis and produces tant role. One of its major functions is to maintain homeostasis, a steady and regulates vital behavior, such as eating, drinking, and sexual behavior. internal environment for the body. The hypothalamus helps provide a conLimbic system The part of the brain stant body temperature and monitors the amount of nutrients stored in the that controls eating, aggression, and cells.

A second major function is equally important: the hypothalamus produces and regulates behavior that is critical to the basic survival of the spe- reproduction. cies, such as eating, self-protection, and sex. LO 3 The Limbic System: Beyond the Central Core The limbic system of the brain consists of a series of doughnut-shaped structures that include the amygdala and hippocampus, the limbic system borders the top of the central core and has connections with the cerebral cortex (see Figure 4).

The structures of the limbic system jointly control a variety of basic functions relating to emotions and self-preservation, such as eating, aggression, and reproduction. Injury to the limbic sysFrontal lobe tem can produce striking changes in behavior. For example, injury to the amygdala, which is involved in fear and aggression, can turn animals that are usually docile and tame into belligerent savages. Conversely, animals that are usually wild and uncontrollable may become meek and obedient following injury to the amygdala (Bedard & Persinger, 1995; Amygdala Gontkovsky, 2005).

Hippocampus The limbic system is involved in Spinal cord several important functions, including Figure 4 The limbic system consists of a series of doughnut-shaped structures that are involved in selfpreservation, learning, memory, and the experience of pleasure. 67 Module 7 the brain self-preservation, learning, memory, and the experience of pleasure. These functions are hardly unique to humans; in fact, the limbic system is sometimes referred to as the “ animal brain” because its structures and functions are so similar to those of other mammals.

To identify the part of the brain that provides the complex and subtle capabilities that are uniquely human, we need to turn to another structure—the cerebral cortex. LO 4 Cerebral cortex The “ new brain,” responsible for the most sophisticated information processing in the brain; contains four lobes. The Cerebral Cortex: Our “ New Brain” As we have proceeded up the spinal cord and into the brain, our discussion has centered on areas of the brain that control functions similar to those found in less sophisticated organisms.

But where, you may be asking, are the Lobes The four major sections of portions of the brain that enable humans to do what they do best and that the cerebral cortex: frontal, parietal, distinguish humans from all other animals? Those unique features of the temporal, and occipital. human brain —indeed, the very capabilities that allow you to come up with Motor area

The part of the cortex that such a question in the first place—are embodied in the ability to think, evalis largely responsible for the body’s uate, and make complex judgments. The principal location of these abilities, voluntary movement. long with many others, is the cerebral cortex. The cerebral cortex is referred to as the “ new brain” because of its relatively recent evolution. It But where, you may be asking, are consists of a mass of deeply folded, rippled, convoluted tissue. Although only about one-twelfth of the portions of the brain that enable an inch thick, it would, if flattened out, cover an area more than two feet square. This configurahumans to do what they do best and tion allows the surface area of the cortex to be that distinguish humans from all considerably greater than it would be if it were smoother and more uniformly packed into the other animals? kull. The uneven shape also permits a high level of integration of neurons, allowing sophisticated information processing. The cortex has four major sections called lobes. If we take a side view of the psych 2. 0 brain, the frontal lobes lie at the front center of the cortex and the parietal lobes www. mhhe. com/psychlife lie behind them. The temporal lobes are found in the lower center portion of the cortex, with the occipital lobes lying behind them. These four sets of lobes are physically separated by deep grooves called sulci. Figure 5 shows the four areas.

Another way to describe the brain is in terms of the functions associated with a particular area. Figure 5 also shows the specialized regions within the lobes related to specific functions and areas of the body. Three major areas are known: the motor areas, the sensory areas, and the association areas. Although we will discuss these areas as though they were separate and independent, keep in mind that this is an oversimplification. In most instances, The Brain behavior is influenced simultaneously by several structures and areas within the brain, operating interdependently.

The Motor Area of the Cortex If you look at the frontal lobe in Figure 5, you will see a shaded portion labeled motor area. This part of the cortex is largely responsible for the body’s voluntary movement. Every portion of the motor area corresponds to a specific locale within the body. If we were to insert an electrode into a particular part of the motor area of the cortex and apply mild electrical stimulation, there would be involuntary 68 Chapter 2 neuroscience and behavior Somatosensory area Somatosensory association area Motor area Frontal Lobe Broca’s area

Parietal Lobe Primary auditory area Wernicke’s area Auditory association area Temporal Lobe Visual area Visual association area Occipital Lobe Figure 5 The cerebral cortex of the brain. The major physical structures of the cerebral cortex are called lobes. This figure also illustrates the functions as