CHAPTER 2

The Biology of Mind

Preview

Our nervous system plays a vital role in how we think, feel, and act. Neurons, the basic building blocks of the body's circuitry, receive signals through their branching dendrites and cell bodies and transmit electrical impulses down their axons. Chemical messengers called neurotransmitters traverse the tiny synaptic gap between neurons and pass on excitatory or inhibitory messages.

The central nervous system consists of the brain and spinal cord. The peripheral nervous system consists of the somatic nervous system, which directs voluntary movements and reflexes, and the autonomic nervous system, which controls the glands and muscles of our internal organs.

Hormones released by endocrine glands affect other tissues, including the brain. The most influential endocrine gland, the pituitary gland, releases hormones that influence growth, and its secretions also influence the release of hormones by other glands. The nervous system directs endocrine secretions, which then affect the nervous system.

The brain's increasing complexity arises from new brain systems built on top of old. Within the brainstem are the oldest regions, the medulla and the reticular formation. The thalamus sits atop the brainstem and the cerebellum extends from the rear. The limbic system includes the amygdala, the hippocampus, and the hypothalamus. The cerebral cortex, representing the highest level of brain development, is responsible for our most complex functions.

Each hemisphere of the cerebral cortex has four geographical areas: the frontal, parietal, occipital, and temporal lobes. Although small, well-defined regions within these lobes control muscle movement and receive information from the body senses, most of the cortex—its association areas—are free to process other information. Experiments on split-brain patients suggest that, for most people, the left hemisphere is the more verbal and the right hemisphere excels in visual perception. Studies of people with intact brains indicate that each hemisphere makes unique contributions to the integrated functions of the brain.

Introductory Exercise: Fact or Falsehood?

The correct answers to Handout 2–1 are as follows: 1. F 2. T 3. T 4. T 5. F 6. F 7. T 8. F 9. T 10. T

HANDOUT 2–1

Fact or Falsehood?

T F 1. Neural impulses travel through the human body at the same speed that electricity travels through a wire.

T F 2. The human brain produces its own natural opiates that elevate mood and ease pain.

T F 3. Electrically stimulating a cat's brain at a certain point can cause the animal to cower in terror in the presence of a small mouse.

T F 4. Both animals and humans seem to have reward centers located in the brain.

T F 5. We ordinarily use only 10 percent of our brains.

T F 6. Most people would advocate pushing someone in front of a runaway boxcar to save five others.

T F 7. If a blind person uses one finger to read Braille, the brain area dedicated to that finger expands.

T F 8. Adult humans cannot generate new brain cells.

T F 9. Some people have had the hemispheres of their brains split with no apparent ill effect.

T F 10. Hearing people usually use the left hemisphere of the brain to process language, and deaf people usually use the left hemisphere to process sign language.

Guide

Objectives

Every question in the Test Banks is keyed to one of these objectives.

Neural and Hormonal Systems

2-1. Explain why psychologists are concerned with human biology.
2-2. Describe neurons, and explain how they transmit information.
2-3. Describe how nerve cells communicate with other nerve cells.
2-4. Describe how neurotransmitters influence behavior, and explain how drugs and other chemicals affect neurotransmission.
2-5. Describe the functions of the nervous system's main divisions, and identify the three main types of neurons.
2-6. Describe how the endocrine system transmits information and interacts with the nervous system.

Tools of Discovery and Older Brain Structures

2-7. Describe how neuroscientists study the brain's connections to behavior and mind.
2-8. Describe the structures that make up the brainstem, and summarize the functions of the brainstem, thalamus, reticular formation, and cerebellum.
2-9. Describe the structures and functions of the limbic system.

The Cerebral Cortex and Our Divided Brain

2-10. Describe the functions of the various cerebral cortex regions.
2-11. Discuss the extent to which a damaged brain can reorganize itself, and define *neurogenesis*.
2-12. Describe what split brains reveal about the functions of our two brain hemispheres.
2-13. Describe what research tells us about being left-handed, and discuss whether it is advantageous to be right-handed.

Neural and Hormonal Systems

Biology, Behavior, and Mind

- Lecture: Phrenology

2-1. *Explain why psychologists are concerned with human biology.*

Everything psychological is simultaneously biological. We think, feel, and act with our bodies. By studying the links between biology and behavior, the ***biological perspective*** enables us to gain a better understanding of our experiences of sights and sounds, meanings and memories, pain and passion. In the 1800s, Franz Gall invented phrenology, a popular theory that claimed that bumps on the skull reveal our mental abilities and our character traits. Although bumps on the skull reveal nothing about the brain's underlying functions, Gall was accurate in supposing that various brain regions have particular functions.

Neural Communication

- Lecture: Multiple Sclerosis and Guillain-Barré Syndrome
- Exercise: Modeling a Neuron
- PsychSim 6: Neural Messages
- LaunchPad Video and Animation: *The Neuron: Basic Units of Communication; Animation: Ion Flow*

At all levels, researchers examine how we take in information and then how we organize, interpret, store, and use it. The information systems of humans and other animals operate similarly. This similarity permits researchers to study relatively simple animals to discover how our neural systems operate.

2-2. *Describe neurons, and explain how they transmit information.*

A ***neuron*** consists of a cell body and branching fibers: The ***dendrite*** fibers receive information from sensory receptors or other neurons, and the ***axon*** fibers pass that information along to other neurons. The axons of some neurons are encased by a ***myelin sheath,*** which helps speed their impulses.

A neural impulse, or ***action potential,*** fires when the neuron is stimulated by signals from the senses or when triggered by chemical signals from neighboring neurons. The action potential is a brief electrical charge that travels down the axon. Received signals trigger an impulse only if the excitatory signals minus the inhibitory signals exceeds a minimum intensity called the ***threshold.*** The neuron's reaction is an all-or-none response. During the *resting potential*, the fluid interior of the axon carries mostly negatively charged atoms (*ions*), while the fluid outside has mostly positively charged atoms. Then, the first bit of the axon is *depolarized* (its *selectively permeable* surface allows positive ions in), and the electrical impulse travels down the axon as channels open, admitting ions with a positive charge. During a resting pause (the *refractory period*), the neuron pumps the positively charged sodium ions back outside. Then it can fire again.

- Exercises: Neural Transmission; Crossing the Synaptic Gap; Reaction-Time Measure of Neural Transmission and Mental Processes
- Demonstration: The Action Potential
- LaunchPad Videos and Animations*: Neural Communication: Impulse Transmission Across the Synapse; Animation: Signal Transmission; Synaptic Activity*

2-3. *Describe how nerve cells communicate with other nerve cells.*

When electrical impulses reach the axon terminal, they stimulate the release of chemical messengers called ***neurotransmitters*** that cross the junction between neurons called the ***synapse.*** After these molecules traverse the tiny *synaptic gap* (*cleft*) between neurons, they bind to receptor sites on neighboring neurons, thus passing on their excitatory or inhibitory messages. Excess neurotransmitters are reabsorbed, in a process called ***reuptake***, drift away, or are broken down by enzymes.

- Lecture: Endorphins and Neurostimulation
- LaunchPad Videos: *Chemically Induced Hallucinations: Studies of Anesthetic Drugs; Parkinson's Disease: A Case Study*

2-4. *Describe how neurotransmitters influence behavior, and explain how drugs and other chemicals affect neurotransmission.*

Different neurotransmitters have different effects on behavior and emotion. For example, the neurotransmitter *acetylcholine (ACh)* plays a crucial role in learning and memory. Found at every junction between a motor neuron and skeletal muscle, ACh causes the muscle to contract. The brain's ***endorphins,*** natural opiates released in response to pain and vigorous exercise, explain the "runner's high" and the indifference to pain in some injured people.

When the brain is flooded with opiate drugs such as heroin and morphine, it may stop produc- ing its own natural opiates, and withdrawal of these drugs may result in intense discomfort until the brain resumes production of its natural opiates. Some drugs and other chemicals are ***agonists;*** they increase a neurotransmitter's action, either by increasing the production or release of the neurotransmitters or blocking reuptake in the synapse. Or, they may be similar enough to a neurotransmitter to bind to its receptor and mimic its effect. Some opiate drugs are agonists. Other drugs or chemicals are ***antagonists;*** they decrease a neurotransmitter's action by blocking production or release. Botulin, a poison that can form in improperly canned food, causes paralysis by blocking ACh release.

The Nervous System

- Lectures: Lou Gehrig's Disease; The Autonomic Nervous System and Sexual Functioning; The Sympathetic Nervous System and the Polygraph; The Sympathetic Nervous System and Performance
- Exercise: Drug Effects and the Nervous System
- LaunchPad Video: *The Central Nervous System: Spotlight on the Brain*

2-5. *Describe the functions of the nervous system's main divisions, and identify the three main types of neurons.*

Neurons communicating with other neurons form our body's primary system, the ***nervous system***. The brain and spinal cord form the ***central nervous system (CNS)***. The ***peripheral nervous system (PNS)*** links the central nervous system with the body's sense receptors, muscles, and glands. The axons carrying this PNS information are bundled into the electrical cables we know as ***nerves***.

Sensory neurons send information from the body's tissues and sensory organs inward to the brain and spinal cord, which process the information. ***Motor neurons*** carry outgoing information from the central nervous system to the body's tissues. ***Interneurons*** in the central nervous system communicate internally and intervene between the sensory inputs and the motor outputs.

The ***somatic nervous system*** of the peripheral nervous system enables voluntary control of our skeletal muscles. The ***autonomic nervous system*** of the peripheral nervous system is a dual self-regulating system that influences the glands and muscles of our internal organs. The ***sympathetic nervous system*** arouses; the ***parasympathetic nervous system*** calms.

The brain's neurons cluster into work groups called *neural networks.* The cells in each layer of a neural network interrelate with various cells in the next layer. Learning occurs as feedback strengthens the work groups.

Reflexes, which are simple, automatic responses to stimuli, illustrate the spinal cord's work. A simple reflex pathway is composed of a single sensory neuron and a single motor neuron, which often communicate through an interneuron. For example, when our fingers touch a candle's flame, information from the skin receptors travels inward via a sensory neuron to a spinal cord interneuron, which sends a signal outward to the arm muscles via a motor neuron. Because this reflex involves only the spinal cord, we jerk our hand away before the brain creates an experience of pain.

The Endocrine System

- Lectures: The Endocrine System; Oxytocin: The Hormone of Love, Bonding, and Generosity?

2-6. *Describe how the endocrine system transmits information and interacts with the nervous system.*

The ***endocrine system's*** glands secrete ***hormones,*** chemical messengers produced in one tissue that travel through the bloodstream and affect other tissues, including the brain. Compared with the speed at which messages move through the nervous system, endocrine messages move more slowly, but their effects usually last longer. The endocrine system's hormones influence many aspects of our lives, including growth, reproduction, metabolism, and mood, keeping everything in balance while responding to stress, exertion, and internal thoughts. In a moment of danger, the ***adrenal glands*** release the hormones *epinephrine* and *norepinephrine,* which increase heart rate, blood pressure, and blood sugar, providing us with increased energy. The ***pituitary gland*** is the endocrine system's most influential gland. Under the influence of the brain's hypothalamus, the pituitary's secretions influence growth and the release of hormones by other endocrine glands. These may in turn influence both the brain and behavior and thus reveal the intimate connection of the nervous and endocrine systems.

Tools of Discovery and Older Brain Structures

The Tools of Discovery: Having Our Head Examined

- Lectures: Neuroimaging Techniques; Assessing Awareness in Brain-Injured Patients; Concussions in Sports; Brain Puzzles, Models, and Molds
- Exercises: Building a Play-Doh Brain; A Portable Brain Model; Mastering Brain Structure; Case Studies in Neuroanatomy; Neuropsychology of Zombies
- Project: Color the Brain
- PsychSim 6: Brain and Behavior; Brain Treasure Hunt
- LaunchPad Videos and Animations: *Neuroimaging: Assessing What's Cool; Mapping the Brain Through Electrical Stimulation; Event-Related Potential (ERP) Research; Animation: Neuroimaging Techniques; Animation: Functional Imaging Techniques*

2-7. *Describe how neuroscientists study the brain's connections to behavior and mind.*

The oldest method of studying the brain involved observing the effects of brain diseases and injuries. Powerful new techniques now reveal brain structures and activities in the living brain. By surgically ***lesioning*** and electrically stimulating specific brain areas, by recording electrical activity on the brain's surface ***(electroencephalogram [EEG]),*** and by looking inside the living brain to see its activity (***PET, MRI,*** and ***fMRI***), neuroscientists examine the connections between brain, mind, and behavior.

Older Brain Structures

- Lecture: Conjoined Twins and a Shared Thalamus; Why Can't We Tickle Ourselves?
- Exercise: Individual Differences in Physiological Functioning and Behavior

2-8. *Describe the structures that make up the brainstem, and summarize the functions of the brainstem, thalamus, reticular formation, and cerebellum.*

The ***brainstem,*** the brain's oldest and innermost region, is responsible for automatic survival functions. It includes the ***medulla,*** which controls heartbeat and breathing, and the ***reticular formation,*** which plays an important role in controlling arousal. Just above the medulla is the *pons,* which helps coordinate movement and control sleep. Atop the brainstem is the ***thalamus,*** the brain's sensory switchboard. It receives information from all the senses, except smell, and sends it to the higher brain regions that deal with seeing, hearing, tasting, and touching. The ***cerebellum,*** which is attached to the rear of the brainstem (along with the *basal ganglia,* deep brain structures involved in motor movement) enables nonverbal learning and skill memory. It also helps us judge time, modulate our emotions, and discriminate sounds and textures.

- Lectures: The Case of Clive Wearing; H.M.'s Brain
- LaunchPad Videos: *Compulsive Gambling and the Brain's Pleasure Center; Self-Stimulation in Rats*

2-9. *Describe the structures and functions of the limbic system.*

The ***limbic system*** has been linked primarily to memory, emotions, and drives. For example, one of its neural centers, the ***hippocampus,*** processes conscious memory. Another, the ***amygdala,*** influences aggression and fear. A third, the ***hypothalamus,*** has been linked to various bodily maintenance functions and to pleasurable rewards. Its hormones influence the pituitary gland, and thus it provides a major link between the nervous and endocrine systems.

The Cerebral Cortex and Our Divided Brain

The Cerebral Cortex

- Lectures: Einstein's Brain and Genius; Kim Peek's Brain
- Exercises: Neuroscience and Moral Judgments; The Sensory Homunculus
- LaunchPad Videos and Animations: *Planning, Life Goals, and the Frontal Lobe; Brain and Behavior: Phineas Gage Revisited; Animation: Sensory Motor Cortex*

2-10. *Describe the functions of the various cerebral cortex regions.*

The ***cerebral cortex,*** a thin surface layer of interconnected neural cells, is our body's ultimate control and information-processing center. ***Glial cells*** support, nourish, and protect the nerve cells of the cerebral cortex. The ***frontal lobes,*** just behind the forehead, are involved in speaking, muscle movements, and planning and making judgments. The ***parietal lobes,*** at the top of head and toward the rear, receive sensory input for touch and body position. The ***occipital lobes,*** at the back of the head, include visual areas. The ***temporal lobes,*** just above the ears, include auditory areas. Each lobe performs many functions and interacts with other areas of the cortex.

The ***motor cortex,*** an arch-shaped region at the rear of the frontal lobes, controls voluntary muscle movements on the opposite side of the body. Body parts requiring the most precise control occupy the greatest amount of cortical space. In an effort to find the source of motor control, researchers have recorded messages from brain areas involved in planning and intention, leading to the testing of *cognitive neural prosthetics* for paralyzed patients. This *brain-computer interface* may one day result in humans being able to control machines with their thoughts. The ***sensory cortex,*** a region at the front of the parietal lobes, registers and processes body sensations. The most sensitive body parts require the largest amount of space in the sensory cortex.

The ***association areas*** are not involved in primary motor or sensory functions. Rather, they integrate and act on information processed by the sensory areas. They are involved in higher mental functions, such as learning, remembering, thinking, and speaking. Association areas are found in all four lobes. Complex human abilities, such as memory and language, result from the intricate coordination of many brain areas.

- Lecture: Hemispherectomy
- LaunchPad Videos: *Language and Brain Plasticity; Brain Plasticity: Rewiring the Visual Cortex; Achieving Hemispheric Balance: Improving Sports Performance; Experience and Exercise: Generating New Brain Cells*

2-11. *Discuss the extent to which a damaged brain can reorganize itself, and define* neurogenesis.

Research indicates that some neural tissue can reorganize in response to damage. When one brain area is damaged, others may in time take over some of its function. For example, if you lose a finger, the sensory cortex that received its input will begin to receive input from the adjacent fingers, which become more sensitive. Our brains are most ***plastic*** when we are young children. *Constraint-induced therapy* rewires the brain by restraining a fully functioning limb and forcing use of the "bad hand" or the uncooperative leg. Eventually, the therapy reprograms the brain, improving the dexterity of a brain-damaged child or even an adult stroke victim. New evidence reveals that adult humans can also generate new brain cells. Monkey brains illustrate ***neurogenesis*** by forming thousands of new neurons each day.

Our Divided Brain

- Lecture: The Wada Sodium Amobarbital Test
- Exercise: Behavioral Effects of the Split-Brain Operation
- Project/Exercise: Hemispheric Specialization
- LaunchPad Videos and Animation: *The Split Brain: Lessons on Language, Vision, and Free Will; The Split Brain: Lessons on Cognition and the Cerebral Hemispheres; Animation: Split Brain Functioning*
- PsychSim 6: Hemispheric Specialization

2-12. *Describe what split brains reveal about the functions of our two brain hemispheres.*

A ***split brain*** is one in which the ***corpus callosum,*** the wide band of axon fibers that connects the two brain hemispheres, has been severed. Experiments on split-brain patients have refined our knowledge of each hemisphere's special functions (called *lateralization*). In the laboratory, investigators ask a split-brain patient to look at a designated spot, then send information to either the left or right hemisphere (by flashing it to the right or left visual field). Quizzing each hemisphere separately, the researchers have confirmed that for most people, the left hemisphere is the more verbal and the right hemisphere excels in visual perception. Studies of people with intact brains have confirmed that the right and left hemispheres each make unique contributions. For example, the left hemisphere makes quick, literal interpretations of language, and the right hemisphere excels in making inferences.

2-13. *Describe what research tells us about being left-handed, and discuss whether it is advantageous to be right-handed.*

About 10 percent of us are left-handed. Almost all right-handers process speech primarily in the left hemisphere. Left-handers are more diverse. Seven in 10 process speech in the left hemisphere and the rest either process speech in the right hemisphere or use both hemispheres. Left-handers are more numerous among those with reading disabilities, allergies, and migraine headaches. Left-handedness is also more common among musicians, mathematicians, professional baseball and cricket players, architects, and artists. The advantages and disadvantages of being a lefty seem roughly equal.

Roger Sperry sees the mind and brain as a holistic system: The brain creates and controls the emergent mind, which in turn influences the brain.