Chapter 2 *The Biological Perspective*

TABLE OF CONTENTS

CHAPTER AT A GLANCE

Detailed Outline	*Instructor Resources*	*Revel Features*
Neurons and Neurotransmitters Structure of the Neuron: The Nervous System's Building Block Generating the Message Within the Neuron: The Neural Impulse Neurotransmission Neurotransmitters: Messengers of the Network Cleaning up the Synapse: Reuptake and Enzymes	**Learning Objectives:** 2.1, 2.2, 2.3 **Lecture Launchers:** 2.1, 2.2, 2.3 **Activities & Exercises:** 2.1, 2.2	Opening Video: *The Biological Perspective* Video: *Figure 2.1: The Structure of the Neuron* Video: *Figure 2.2: The Neural Impulse Action Potential* Video: *Figure 2.3: The Synapse* Video: *Figure 2.4: Neurotransmitters: Reuptake*
Looking Inside the Living Brain Methods for Studying Specific Regions of the Brain Neuroimaging Techniques	**Learning Objectives:** 2.4, 2.5 **Lecture Launchers:** 2.7, 2.8, 2.9, 2.10, 2.11 **Activities & Exercises:** 2.12	
From the Bottom Up: The Structures of the Brain The Hindbrain Structures Under the Cortex: The Limbic System The Cortex The Association Areas of the Cortex The Cerebral Hemispheres	**Learning Objectives:** 2.6, 2.7, 2.8, 2.9, 2.10 **Lecture Launchers:** 2.12, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19 **Activities & Exercises:** 2.6, 2.7, 2.8, 2.9 **Handout:** 2.1	Video: *Parts of the Brain* Video: *Figure 2.13: The Split-Brain Experiment*
The Nervous System: The Rest of the Story The Central Nervous System: The "Central Processing Unit" The Peripheral Nervous System: Nerves on the Edge	**Learning Objectives:** 2.11, 2.12 **Lecture Launchers:** 2.4, 2.5, 2.20 **Activities & Exercises:** 2.3, 2.4, 2.5	Video: *Figure 2.15: The Spinal Cord Reflex* Video: *Overview of Neuroplasticity*
The Endocrine Glands The Pituitary: Master of the Hormonal Universe Other Endocrine Glands	**Learning Objectives:** 2.13, 2.14 **Lecture Launcher:** 2.6	
Applying Psychology to Everyday Life: Minimizing the Impact of Adult Attention-Deficit/Hyperactivity Disorder	**Learning Objective:** 2.15	Video: *Applying Psychology to Everyday Life: Minimizing the Impact of Adult Attention-Deficit/Hyperactivity Disorder* Shared Writing: APA Goal 3: Ethical and Social Responsibility: The Biological Perspective

LEARNING OBJECTIVES

2.1 Identify the parts of a neuron and the function of each.

2.2 Explain the action potential.

2.3 Describe how neurons use neurotransmitters to communicate with each other and with the body.

2.4 Describe how lesioning studies and brain stimulation are used to study the brain.

2.5 Compare and contrast neuroimaging techniques for mapping the brain’s structure and function.

2.6 Identify the different structures of the hindbrain and the function of each.

2.7 Identify the structures of the brain that are involved in emotion, learning, memory, and motivation.

2.8 Identify the parts of the cortex that process the different senses and those that control movement of the body.

2.9 Recall the function of association areas of the cortex, including those especially crucial for language.

2.10 Explain how some brain functions differ between the left and right hemispheres.

2.11 Describe how the components of the central nervous system interact and how they may respond to experiences or injury.

2.12 Differentiate the roles of the somatic and autonomic nervous systems.

2.13 Explain why the pituitary gland is known as the “master gland.”

2.14 Recall the role of various endocrine glands.

2.15 Identify potential strategies for coping with attention-deficit/hyperactivity disorder.

RAPID REVIEW

The **nervous system** is composed of a complex network of cells throughout the body. The cells in the nervous system that carry information are called **neurons**. Information enters at the **dendrites**, flows through the cell body (or **soma**) and down the **axon**. Although neurons are the cells that carry the information, most of the nervous system consists of **glial cells** that provide food, support, and insulation to the neuron cells. The insulation around the neuron is called **myelin** and works in a way similar to the plastic coating on an electrical wire. Bundles of myelin-coated axons are wrapped together in cable-like structures called **nerves**. The movement of an electrical signal across a neuron is called the **action potential**. During the action potential, ions are exchanged across the membrane due to diffusion and electrostatic pressure. A neuron fires the action potential in an **all-or-none** manner: The neuron is either firing at full strength or it is not firing at all. When the electrical signal travels down the axon and reaches the other end of the neuron called the **axon terminal**, it causes the **neurotransmitters** in the **synaptic vesicles** to be released into the fluid-filled **synapse** between the two cells. Neurotransmitters can have either an excitatory or inhibitory effect on the receiving cell and, once neurotransmission occurs, it is terminated through reuptake and the action of enzymes.

Two techniques used to study the brain involve either destroying a specific area of the brain (**lesioning**) or stimulating a specific brain area to see the effect. Researchers have developed several methods such as **CT**, **MEG**, **MRI**, **EEG**, **PET**, **fMRI**, **NIRS, tDCS,** and **rTMS**.

The brain can be roughly divided into three sections: the forebrain, the midbrain, and the hindbrain. Various structures within the brain include the **brain stem**, **medulla**, **pons,** **reticular formation**, **cerebellum,** **limbic system**, which includes the **thalamus**, **hypothalamus**, **hippocampus**, **amygdala**, and **cingulate cortex**, **cortex,** **cerebral hemispheres**, **corpus callosum**, **occipital lobes**, **parietal lobes**, **temporal lobes**, and **frontal lobes**. **Mirror neurons**, neurons that fire when we perform an action and also when we see someone else perform that action, may explain a great deal of the social learning that takes place in humans starting in infancy. **Association areas** are the areas within each of the lobes that are responsible for "making sense" of all the incoming information. **Broca's area** is located in the left frontal lobe and **Wernicke's area** is located in the left temporal lobe; both play a role in language. The **cerebrum** is made up of the two cerebral hemispheres and the structures connecting them. **Split-brain research** helped scientists understand that the two cerebral hemispheres are not identical.

The **central nervous system (CNS)** is made up of the brain and the **spinal cord**. **Afferent (sensory) neurons** send information from the senses to the spinal cord, whereas **efferent (motor) neurons** send commands from the spinal cord to the muscles. **Interneurons** connect sensory and motor neurons and help coordinate the signals. The **peripheral nervous system (PNS)** is made up of all the nerves and neurons that are not in the brain or spinal cord and is divided into two parts: the **somatic nervous system** and the **autonomic nervous system**. The autonomic nervous system is in turn divided into two parts: the **sympathetic division** and the **parasympathetic division**.

The **endocrine glands** represent a second communication system in the body. The endocrine glands secrete chemicals called **hormones** directly into the bloodstream. The **pituitary gland** is located in the brain and secretes the hormones that control milk production, salt levels, and the activity of other glands. The **pineal gland** is also located in the brain and regulates the sleep cycle through the secretion of melatonin. The **thyroid gland** is located in the neck and releases a hormone that regulates metabolism. The **pancreas** controls the level of blood sugar in the body, whereas the **gonad** sex glands regulate sexual behavior and reproduction. The **adrenal glands** play a critical role in regulating the body's response to stress.

LECTURE GUIDE

I. NEURONS AND NEUROTRANSMITTERS

Lecture Launchers and Discussion Topics

- 2.1 Neurotransmitters: Chemical Communicators of the Nervous System
- 2.2 Exceptions to the Rules
- 2.3 The Glue of Life: Neuroglial Cells

Classroom Activities, Demonstrations, and Exercises

- 2.1 Using Dominoes to Understand the Action Potential
- 2.2 Environmental Influences on the Brain

Learning Objective 2.1 Identify the parts of a neuron and the function of each.

A. Structure of the neuron: The nervous system's building block

1. The **nervous system** is an extensive network of specialized cells that carries information to and from all parts of the body. **Neuroscience** is a branch of the life sciences that deals with the structure and function of neurons, nerves, and nervous tissue. **Biological psychology** or behavioral neuroscience is a branch of neuroscience that focuses on the biological bases of psychological processes, behavior, and learning.

2. The **neuron** is the basic cell that makes up the nervous system and that receives and sends messages within that system. **Dendrites** are branchlike structures of a neuron that receive messages from other neurons. The **soma** is the cell body of the neuron responsible for maintaining the life of the cell. The **axon** is a tubelike structure of a neuron that carries the neural message from the cell body to the **axon terminals,** enlarged ends of axonal branches, specialized for communication with other cells.

3. **Glial cells** provide support for the neurons to grow on and around, deliver nutrients to neurons, produce myelin to coat axons, clean up waste products and dead neurons, influence information processing, and influence the generation of new neurons during prenatal development. **Myelin** is a layer of fatty substances produced by certain glial cells that coat the axons of neurons to insulate, protect, and speed up the neural impulse. **Nerves** are bundles of axons coated in myelin that travel together through the body.

Learning Objective 2.2 Explain the action potential.

B. Generating the message within the neuron: The neural impulse

1. At rest, the neuron is negatively charged inside and positively charged outside. **Diffusion** is the process of molecules moving from areas of high concentration to areas of low concentration. The **resting potential** is the state of the neuron when not firing a neural impulse.

2. The **action potential**, consisting of a reversal of the electrical charge within the axon, releases the neural impulse. When a neuron fires, it fires in an **all-or-none** fashion, meaning that it fires completely or does not fire at all.

Learning Objective 2.3 Describe how neurons use neurotransmitters to communicate with each other and with the body.

C. Neurotransmission

1. Sending the message to other cells: The synapse

   a. The **synaptic vesicles** are saclike structures found inside the synaptic knob containing chemicals. A **neurotransmitter** is a chemical found in the synaptic vesicles that, when released, has an effect on the next cell. The **synapse (synaptic gap)** is microscopic fluid-filled space between the axon terminal of one cell and the dendrites or soma of the next cell. **Receptor sites** are three-dimensional proteins on the surface of the dendrites or certain cells of the muscles and glands, which are shaped to fit only certain neurotransmitters.

   b. An **excitatory synapse** is a synapse at which a neurotransmitter causes the receiving cell to fire, whereas an **inhibitory synapse** is a synapse at which a neurotransmitter causes the receiving cell to stop firing.

2. Neurotransmitters: Messengers of the network

   a. **Antagonists** are chemical substances that block or reduce a cell's response to the action of other chemicals or neurotransmitters. **Agonists** are chemical substances that mimic or enhance the effects of a neurotransmitter on the receptor sites of the next cell, increasing or decreasing the activity of that cell.

   b. Important neurotransmitters include acetylcholine (ACh), norepinephrine (NE), serotonin, gamma-aminobutyric acid (GABA), glutamate, and endorphins.

3. Cleaning up the synapse: Reuptake and enzymes

   a. **Reuptake** is the process by which neurotransmitters are taken back into the synaptic vesicles.

   b. In a process of **enzyme degradation**, the structure of a neurotransmitter is altered so it can no longer act on a receptor.

II. LOOKING INSIDE THE LIVING BRAIN

Lecture Launchers and Discussion Topics

- 2.7 Psychophysiological Measurement
- 2.8 Berger's Wave
- 2.9 Lie Detectors 2.0
- 2.10 Women, Men, and PETs
- 2.11 Using fMRI and MEG to Study Phantom Limb Pain

Classroom Activities, Demonstrations, and Exercises

- 2.12 Diagnostic Brain Imaging or Electrophysiology

Learning Objective 2.4 Describe how lesioning studies and brain stimulation are used to study the brain.

A. Methods for studying specific regions of the brain

1. Lesioning studies

a. **Lesioning** involves the insertion of a thin, insulated electrode into the brain through which an electrical current is sent, destroying the brain cells at the tip of the wire.

b. By studying areas of brain damage we learn the functions that various areas of the brain control.

2. Brain stimulation

a. Invasive techniques: Stimulating from the inside. Deep brain stimulation (DBS) is an invasive technique; optogenetics may offer a comparable alternative.

b. Noninvasive techniques: Stimulating from the outside. Transcranial magnetic stimulation (TMS), repetitive TMS (rTMS), and transcranial direct current stimulation (tDCS) are noninvasive procedures.

Learning Objective 2.5 Compare and contrast neuroimaging techniques for mapping the brain's structure and function.

B. Neuroimaging techniques

1. Mapping structure

a. **Computed tomography (CT)** is a brain-imaging method using computer-controlled X-rays of the brain.

b. **Magnetic resonance imaging (MRI)** is a brain-imaging method using radio waves and magnetic fields of the body to produce detailed images of the brain.

2. Mapping function

a. The **electroencephalogram (EEG)** is a recording of the electrical activity of large groups of cortical neurons just below the skull, most often using scalp electrodes.

b. Magnetoencephalography (MEG) is used to explore information processing differences in language disorders.

c. **Positron emission tomography (PET)** is a brain-imaging method in which a radioactive sugar is injected into the subject and a computer compiles a color-coded image of the activity of the brain.

d. **Functional MRI (fMRI)** is an MRI-based brain-imaging method that allows for functional examination of brain areas through changes in brain oxygenation.

e. Near-infrared spectroscopy (NIRS) is another noninvasive brain-imaging technique.

III. FROM THE BOTTOM UP: THE STRUCTURES OF THE BRAIN

Lecture Launchers and Discussion Topics

- 2.12 The Importance of a Wrinkled Cortex
- 2.13 Brain's Bilingual Broca
- 2.14 A New Look at Phineas Gage
- 2.15 Freak Accidents and Brain Injuries
- 2.16 Understanding Hemispheric Function
- 2.17 Handedness, Eyedness, Footedness, Facedness
- 2.18 Workplace Problems: Left-Handedness
- 2.19 The Results of a Hemispherectomy

Classroom Activities, Demonstrations, and Exercises

- 2.6 Mapping the Brain
- 2.7 Football and Brain Damage
- 2.8 Hemispheric Lateralization
- 2.9 Hemispheric Communication and the Split Brain

Learning Objective 2.6 Identify the different structures of the hindbrain and the function of each.

A. The hindbrain

1. Medulla: The **medulla** is the first large swelling at the top of the spinal cord, forming the lowest part of the brain, which is responsible for life-sustaining functions such as breathing, swallowing, and heart rate.

2. Pons: The **pons** is the larger swelling above the medulla that connects the top of the brain to the bottom and that plays a part in sleep, dreaming, left-right body coordination, and arousal.

3. Reticular formation: The **reticular formation (RF)** is an area of neurons running through the middle of the medulla and the pons and slightly beyond that is responsible for general attention, alertness, and arousal.

4. Cerebellum: The **cerebellum** is part of the lower brain located behind the pons that controls and coordinates involuntary, rapid, fine motor movement and may have some cognitive functions.

Learning Objective 2.7 Identify the structures of the brain that are involved in emotion, learning, memory, and motivation.

B. Structures under the cortex: The limbic system

1. The **limbic system** is a group of several brain structures located primarily under the cortex and involved in learning, emotion, memory, and motivation.

2. Thalamus

    a. The **thalamus** is part of the limbic system located in the center of the brain, this structure relays sensory information from the lower part of the brain to the proper areas of the cortex and processes some sensory information before sending it to its proper area.

    b. **Olfactory bulbs** are two bulblike projections of the brain located just above the sinus cavity and just below the frontal lobes that receive information from the olfactory receptor cells. Smell is the only sense that does not have to first pass through the thalamus.

3. Hypothalamus: The **hypothalamus** is a small structure in the brain located below the thalamus and directly above the pituitary gland, responsible for motivational behavior such as sleep, hunger, thirst, and sex.

4. Hippocampus: The **hippocampus** is a curved structure located within each temporal lobe, responsible for the formation of long-term declarative memories.

5. Amygdala: The **amygdala** is a brain structure located near the hippocampus, responsible for fear responses and memory of fear.

6. Cingulate cortex: This structure plays an important role in emotional and cognitive processing.

Learning Objective 2.8 Identify the parts of the cortex that process the different senses and those that control movement of the body.

C. The cortex

1. The **cortex** is the outermost covering of the brain consisting of densely packed neurons, responsible for higher thought processes and interpretation of sensory input.

2. Cerebral hemispheres

   a. The **cerebrum** is the upper part of the brain consisting of the two hemispheres and the structures that connect them.

   b. The **cerebral hemispheres** are the two sections of the cortex on the left and right sides of the brain.

   c. The **corpus callosum** is the thick band of neurons that connects the right and left cerebral hemispheres.

3. Occipital lobes: The **occipital lobe** is a section of the brain located at the rear and bottom of each cerebral hemisphere containing the primary visual centers of the brain.

4. Parietal lobes

   a. The **parietal lobes** are sections of the brain located at the top and back of each cerebral hemisphere containing the centers for touch, temperature, and body position.

   b. The **somatosensory cortex** is an area of cortex at the front of the parietal lobes responsible for processing information from the skin and internal body receptors for touch, temperature, and body position.

   c. **Spatial neglect** is a condition produced most often by damage to the parietal lobe association areas of the right hemisphere, resulting in an inability to recognize objects or body parts in the left visual field.

5. Temporal lobes: The **temporal lobes** are areas of the cortex located along the side of the brain, starting just behind the temples, containing the neurons responsible for the sense of hearing and meaningful speech.

6. Frontal lobes

   a. **Frontal lobes** are areas of the brain located in the front and top, responsible for higher mental processes and decision making as well as the production of fluent speech.

   b. The **motor cortex** is the rear section of the frontal lobe, responsible for sending motor commands to the muscles of the somatic nervous system.

   c. **Mirror neurons** are neurons that fire when an animal or person performs an action and also when an animal or person observes that same action being performed by another.

Learning Objective 2.9 Recall the function of association areas of the cortex, including those especially crucial for language.

D. The association areas of the cortex

1. **Association areas** are areas within each lobe of the cortex responsible for the coordination and interpretation of information, as well as higher mental processing.

2. Broca's area

   a. Broca's area is responsible for producing fluent, understandable speech.

   b. **Broca's aphasia** is a condition resulting from damage to Broca's area, causing the affected person to be unable to speak fluently, to mispronounce words, and to speak haltingly.

3. Wernicke's area

   a. Wernicke's area is responsible for the understanding of language.

   b. **Wernicke's aphasia** is a condition resulting from damage to Wernicke's area, causing the affected person to be unable to understand or produce meaningful language.

Learning Objective 2.10 Explain how some brain functions differ between the left and right hemispheres.

E. The cerebral hemispheres

1. Split-brain research

a. Research has shown that the left hemisphere specializes in language, speech, handwriting, math calculation, sense of time and rhythm (mathematical in nature), and analytical thinking.

b. The right side of the brain processes information globally and controls emotional expression, spatial perception, and recognition of faces, patterns, melodies, and emotions.

2. Handedness

a. Handedness is the tendency to use one hand for most fine motor skills.

b. Roughly 90 percent of individuals are right-handed; handedness appears to be largely influenced by genetics.

IV. THE NERVOUS SYSTEM: THE REST OF THE STORY

Lecture Launchers and Discussion Topics

- 2.4 Brain Metaphors
- 2.5 The Cranial Nerves
- 2.20 Stressed? Not Much!!

Classroom Activities, Demonstrations, and Exercises

- 2.3 Demonstrating Neural Conduction: The Class as a Neural Network
- 2.4 The Dollar Bill Drop
- 2.5 Reaction Time and Neural Processing

Learning Objective 2.11 Describe how the components of the central nervous system interact and how they may respond to experiences or injury.

A. The central nervous system: The “central processing unit”

1. The **central nervous system (CNS)** is part of the nervous system consisting of the brain and the spinal cord.

2. The brain

3. The spinal cord

a. The **spinal cord** is a long bundle of neurons that carries messages between the body and the brain and is responsible for very fast, lifesaving reflexes.

b. **Afferent (sensory) neurons** carry information from the senses to the central nervous system. **Efferent (motor) neurons** carry messages from the central nervous system to the muscles of the body.

c. **Interneurons** are found in the center of the spinal cord and receive information from the afferent neurons and send commands to the muscles through the efferent neurons. Interneurons also make up the bulk of the neurons in the brain. The **reflex arc** is the connection of the afferent neurons to the interneurons to the efferent neurons, resulting in a reflex action.

4. Damage to the central nervous system, neuroplasticity, and neurogenesis

a. **Neuroplasticity** is the ability within the brain to constantly change both the structure and function of many cells in response to experience or trauma.

b. **Neurogenesis** is the formation of new neurons that occurs primarily during prenatal development but may also occur at lesser levels in some brain areas during adulthood.

c. **Stem cells** are special cells found in all the tissues of the body that are capable of becoming other cell types when those cells need to be replaced due to damage or wear and tear.

d. **Epigenetics** is the interaction between genes and environmental factors influencing gene activity; environmental factors include diet, life experiences, and physical surroundings.

Learning Objective 2.12 Differentiate the roles of the somatic and autonomic nervous systems.

B. The peripheral nervous system: Nerves on the edge

1. The **peripheral nervous system (PNS)** all nerves and neurons that are not contained in the brain and spinal cord but that run through the body itself. The PNS can be divided into the **somatic nervous system,** which consists of nerves that carry information from the senses to the CNS and from the CNS to the voluntary muscles of the body, and the **autonomic nervous system (ANS)**, which consists of nerves that control all of the involuntary muscles, organs, and glands.

2. The somatic nervous system

a. The **sensory pathway** involves nerves coming from the sensory organs to the CNS containing afferent neurons.

b. The **motor pathway** involves nerves coming from the CNS to the voluntary muscles, containing efferent neurons.

3. The autonomic nervous system

a. The sympathetic division: The **sympathetic division (fight-or-flight system)**, also called the sympathetic nervous system (SNS), is part of the ANS that is responsible for reacting to stressful events and bodily arousal.

b. The parasympathetic division: The **parasympathetic division (eat-drink-and-rest system)**, also called the parasympathetic nervous system (PNS), is part of the ANS that restores the body to normal functioning after arousal and is responsible for the day-to-day functioning of the organs and glands.

V. THE ENDOCRINE GLANDS

Lecture Launchers and Discussion Topics

- 2.6 Hormone Imbalances

Learning Objective 2.13 Explain why the pituitary gland is known as the "master gland."

A. The pituitary: Master of the hormonal universe

1. E**ndocrine glands** have no ducts and secrete chemicals called **hormones** directly into the bloodstream.

2. The **pituitary gland** located in the brain secretes human growth hormone and influences all other hormone-secreting glands (also known as the master gland). In women**, oxytocin** is a hormone released by the posterior pituitary gland that is involved in reproductive and parental behaviors.

Learning Objective 2.14 Recall the role of various endocrine glands.

B. Other endocrine glands

1. The pineal gland: **pineal gland** is an endocrine gland located near the base of the cerebrum and secretes melatonin.

2. The thyroid gland: **thyroid gland** is an endocrine gland found in the neck and regulates metabolism by secreting thyroxin.

3. The pancreas: the **pancreas** is an endocrine gland that controls the levels of sugar in the blood by secreting insulin and glucagons.

4. The gonads: the **gonads** are the sex glands, including **ovaries** (female gonads or sex glands) and **testicles** (male gonads or sex glands), that secrete hormones that regulate sexual development and behavior as well as reproduction.

5. The adrenal glands: the **adrenal glands** are endocrine glands located on top of each kidney that secrete over 30 different hormones to deal with stress, regulate salt intake, and provide a secondary source of sex hormones affecting the sexual changes that occur during adolescence.

VI. APPLYING PSYCHOLOGY TO EVERYDAY LIFE: MINIMIZING THE IMPACT OF ADULT ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

Learning Objective 2.15 Identify potential strategies for positively coping with attention-deficit/hyperactivity disorder.

A. Attention-deficit/hyperactivity disorder (ADHD) involves behavioral and cognitive aspects of inattention, impulsivity, and hyperactivity that people likely do not outgrow.

B. Positive coping strategies may include both behavioral and cognitive strategies.

VII. CHAPTER SUMMARY

Classroom Activities, Demonstrations, and Exercises

- 2.10 Crossword Puzzle
- 2.11 Fill in the Blanks

LECTURE LAUNCHERS AND DISCUSSION TOPICS

- 2.1 Neurotransmitters: Chemical Communicators of the Nervous System
- 2.2 Exceptions to the Rules
- 2.3 The Glue of Life: Neuroglial Cells
- 2.4 Brain Metaphors
- 2.5 The Cranial Nerves
- 2.6 Hormone Imbalances
- 2.7 Psychophysiological Measurement
- 2.8 Berger's Wave
- 2.9 Lie Detectors 2.0
- 2.10 Women, Men, and PETs
- 2.11 Using fMRI and MEG to Study Phantom Limb Pain
- 2.12 The Importance of a Wrinkled Cortex
- 2.13 Brain's Bilingual Broca
- 2.14 A New Look at Phineas Gage
- 2.15 Freak Accidents and Brain Injuries
- 2.16 Understanding Hemispheric Function
- 2.17 Handedness, Eyedness, Footedness, Facedness
- 2.18 Workplace Problems: Left-Handedness
- 2.19 The Results of a Hemispherectomy
- 2.20 Stressed? Not Much!!

Lecture Launcher 2.1 Neurotransmitters: Chemical Communicators of the Nervous System

In 1921, a scientist in Austria put two living hearts in a fluid bath that kept them beating. He then stimulated the vagus nerve of one heart. This bundle of neurons that serves the parasympathetic nervous system caused a reduction in the heart's rate of beating. A substance was released by the nerve of the first heart and transported through the fluid to the second heart. The second heart reduced its rate of beating. The substance released from the vagus nerve of the first heart was later identified as acetylcholine, one of the first neurotransmitters to be identified. Although many other neurotransmitters have now been identified, we continue to think of acetylcholine as one of the most important neurotransmitters. Curare is a poison that was discovered by South American Indians. They put it on the tips of the darts they shoot from their blowguns. Curare blocks acetylcholine receptors, and paralysis of internal organs results. The victim is unable to breathe and eventually dies. A substance in the venom of black widow spiders stimulates release of acetylcholine at synapses. Botulism toxin, found in improperly canned foods, blocks release of acetylcholine at the synapses and has a deadly effect. It takes less than one millionth of a gram of this toxin to kill a person. A deficit of acetylcholine is associated with Alzheimer's disease, which afflicts a high percentage of older adults.

Many neurotransmitters have been identified in the years since 1921, and there is increasing evidence of their importance in human behavior. Psychoactive drugs affect consciousness because of their effects on synaptic transmission. For example, cocaine and the amphetamines prolong the action of certain neurotransmitters and opiates imitate the action of natural neuromodulators called the endorphins. It appears that the neurotransmitters dopamine, norepinephrine, and serotonin are associated with some of the most severe forms of mental illness.

There are probably only a few ounces of these substances in the body, but they may have a profound effect on mood, memory, perception, and behavior. Could intelligence be primarily a matter of having plenty of the right neurotransmitter at the right synapses?

Background information and videos can be found online by searching “Otto Loewi.”

Lecture Launcher 2.2 Exceptions to the Rules

In an introductory psychology class, students learn the basic rules that generally govern neuronal communication. In many cases, however, the exceptions to these rules may be as important as the rules themselves. Several of these exceptions are described below.

Rule 1: Neuron-to-neuron signaling is chemical, not electrical.
Exception: Gap junctions

Although it is generally the case that a neuron's electrical signal must first be converted to a chemical signal to excite or inhibit another neuron, this is not always the case. Some neurons have gap junctions, which connect their intracellular fluids. This means that the electrical signal can flow directly from one neuron to another. Unlike chemical synapses, most electrical synapses formed by gap junctions are bidirectional, meaning that electrical signals can travel in both directions through the gap junctions. Gap junctions also contain gates, which can be closed to prevent the electrical signal from being passed to the neighboring neuron.

Rule 2: Axons always synapse on dendrites.
Exception: Axo-axonic and axosomatic synapses

Axons can form synapses on all parts of a postsynaptic neuron. Synapses located on the soma (i.e., cell body) of a neuron are often inhibitory. In other words, transmitters released at these axosomatic synapses make it harder for the postsynaptic neuron to reach the threshold for generating an action potential. When an axon synapses on the axon of another neuron, it is called an axo-axonic synapse. Because these synapses usually occur near the end of the axon, they have no effect on whether the postsynaptic cell generates an axon potential. Instead, axo-axonic synapses usually modulate how much neurotransmitter is released from the postsynaptic neuron.

Rule 3: Action potentials only travel in one direction.
Exception: Back-propagating action potentials

Action potentials begin at the axon hillock, where the axon emerges from the soma. From there, the action potential travels down the axon and away from the soma. At the same time, however, a back-propagating action potential can travel from the axon hillock, through the soma, and into the dendrites. Back-propagating action potentials are thought to affect the functioning of receptors located in the soma and dendrites.

Kandel, E., Schwartz, J., & Jessell, T. (2012). *Principles of neural science* (5th ed.). New York: McGraw-Hill.

Lecture Launcher 2.3 The Glue of Life: Neuroglial Cells

Glia is derived from the Greek word for glue and is an appropriate name for the cells that surround all neurons, sealing them together. Glial cells outnumber neurons ten to one and, although tiny in size, still make up half of the brain's bulk. Unlike neurons, glia cells do not possess excitable membranes and so cannot transmit information in the way neurons do. Yet so many thousands of cells must be there for some purpose.

Researchers studying the brain have suggested that glia can take up, manufacture, and release chemical transmitters and so may help maintain or regulate synaptic transmission. Other researchers suggest that glia can manufacture and possibly transmit other kinds of molecules, such as proteins. The anatomy of some glial cells is striking in this regard, for they seem to form a conduit between blood vessels and neurons, and so may bring nourishment to the neurons. It is thought that these cells may have important functions during prenatal development and recovery from brain injury. One role of the glia is known definitely: Certain kinds of glia, called by the tongue-twisting name *oligodendroglia,* form the myelin sheath that insulates central nervous system axons and speeds conduction of the nerve impulse. A counterpart called a Schwann cell performs the same role for the neurons that make up peripheral nerves.

The study of glia is difficult because these tiny cells are inextricably entwined with neurons. As the most numerous cell type in the brain, their potential importance is vast, and investigation of their function is currently yielding amazing results.

Lecture Launcher 2.4 Brain Metaphors

Metaphors can help us understand systems we cannot directly observable through reference to things that are more familiar and perhaps better understood (Weiner, 1991). Our understanding of the human brain and its activity has been helped through a reliance on metaphor. The metaphors used, however, have changed over time.

Hydraulic models. Thinkers such as Galen and Descartes described the brain as a pneumatic/hydraulic system, relying on the "newfangled" plumbing systems dominant during their lifetimes. Galen, for example, believed that the liver generated "spirits" or gases that flowed to the brain, where they then formed "animal spirits" that flowed throughout the nervous system. Descartes expanded on this view, adding that the pineal gland (the supposed seat of the soul) acted on the animal spirits to direct reasoning and other behaviors. In short, the brain was a septic tank, storing, mixing, and directing the flow of spirit gases throughout the body for the purposes of behavior and action.

Mechanical and telephone models. With the advent of new technology came new metaphors for the brain. During the Industrial Revolution, machine metaphors dominated and, in particular, the brain was conceived as a complex mechanical apparatus involving (metaphorical) levers, gears, trip-hammers, and pulleys. During the 1920s, the brain developed into a slightly more sophisticated machine resembling a switchboard; the new technology of the telephone provided a new metaphor. Inputs, patch cords, outputs, and busy signals (though no "call waiting") dominated explanations of brain activity. This metaphor, however, faltered by viewing the brain as a system that shut down periodically, as when no one was dialing a number. We now know, of course, that the brain is continually active.

Computer models. Starting in the late 1950s, metaphors for the brain have relied on computer technology. Input, output, memory, storage, information processing, and circuitry were all terms that seemed equally suited to talking about computer chips and neurons. Although perhaps a better metaphor than plumbing or telephones, the computer model eventually showed its shortcomings. As a descriptive device, however, this metaphor can at least suggest limits in our understanding and point the way to profitable areas of research.

Weiner, B. (1991). Metaphors in motivation and attribution. *American Psychologist*, *46*, 921–930.

Lecture Launcher 2.5 The Cranial Nerves

The textbook discusses various divisions of the nervous system. You may want to add a description of the cranial nerves to your outline of the nervous system. Although the function of the cranial nerves is not different from that of the sensory and motor nerves in the spinal cord, they do not enter and leave the brain through the spinal cord. There are 12 cranial nerves (numbered 1 to 12 and ordered from the front to the back of the brain) that primarily transmit sensory information and control motor movements of the face and head. The 12 cranial nerves are the following:

1. *Olfactory*. A sensory nerve that transmits odor information from the olfactory receptors to the brain.
2. *Optic*. A sensory nerve that transmits information from the retina to the brain.
3. *Oculomotor*. A motor nerve that controls eye movements, the iris (and therefore pupil size), lens accommodation, and tear production.
4. *Trochlear*. A motor nerve that is also involved in controlling eye movements.
5. *Trigeminal*. A sensory and motor nerve that conveys somatosensory information from receptors in the face and head and controls muscles involved in chewing.
6. *Abducens*. Another motor nerve involved in controlling eye movements.
7. *Facial*. A nerve that conveys sensory information and controls motor and parasympathetic functions associated with facial muscles, taste, and the salivary glands.
8. *Auditory-vestibular*. A sensory nerve with two branches, one of which transmits information from the auditory receptors in the cochlea and the other conveys information concerning balance from the vestibular receptors in the inner ear.
9. *Glossopharyngeal*. A nerve that conveys sensory information and controls motor and parasympathetic functions associated with the taste receptors, throat muscles, and salivary glands.
10. *Vagus*. A nerve that primarily transmits sensory information and controls autonomic functions of the internal organs in the thoracic and abdominal cavities.
11. *Spinal accessory*. A motor nerve that controls head and neck muscles.

12. *Hypoglossal*. A motor nerve that controls tongue and neck muscles.

As is their custom, medical students have developed several mnemonics for memorizing the cranial nerves. Some of the family-friendly ones include the following:

On **O**ld **O**lympus' **T**iny **T**ops, **A** **F**riendly **V**iking **G**rew **V**ines **A**nd **H**ops

Oh **O**nce **O**ne **T**akes **T**he **A**natomy **F**inal **V**ery **G**ood **V**acations **A**re **H**eavenly

One **O**f **O**ur **T**wo **T**iming **A**dults **F**ound **V**ery **G**ood **V**alues **A**t **H**ome

On **O**ccasion **O**ur **T**rusty **T**ruck **A**cts **F**unny. **V**ery **G**ood **V**ehicle **A**ny **H**ow

Orlando's **O**verweight **O**ctopuses **T**ry **T**o **A**void **F**uddrucker's **A**nd **G**rabbing **V**ienna **S**ausage **H**amburgers

On **O**ur **O**verseas **T**rip **T**o **A**rgentina **F**ound **V**ery **G**rand **V**illas **A**nd **H**uts

Lecture Launcher 2.6 Hormone Imbalances

Various problems are caused by imbalances within the endocrine system. The following disorders and medical problems are associated with abnormal levels within the pituitary, thyroid, and adrenal glands.

<u>Pituitary Malfunctions</u>

Hypopituitary Dwarfism

If the pituitary secretes too little of its growth hormone during childhood, the person will be very small although normally proportioned.

Giantism

If the pituitary gland secretes too much growth hormone while a child is still in the growth period, the long bones of the body in the legs and other areas grow very, very long—a height of 9 feet is not unheard of. The organs of the body also increase in size, and the person may have health problems associated with both the extreme height and the organ size.

Acromegaly

If too much growth hormone is secreted after the major growth period is ended, the person's long bones will not get longer, but the bones in the face, hands, and feet will increase in size, producing abnormally large hands, feet, and facial bone structure. The famous wrestler/actor, Andre the Giant (Andre Rousimoff), had this condition, as did the great actor Rondo Hatton.

<u>Thyroid Malfunctions</u>

Hypothyroidism

In hypothyroidism, the thyroid does not secrete enough thyroxin, resulting in a slower than normal metabolism. The person with this condition will feel sluggish and lethargic, have little energy, and tend to be obese.

Hyperthyroidism

In hyperthyroidism, the thyroid secretes too much thyroxin, resulting in an overly active metabolism. This person will be thin, nervous, tense, and excitable. He or she will also be able to eat large quantities of food without gaining weight (oh, if only we came equipped with thyroid control knobs!).

Adrenal Gland Malfunctions

Among the disorders that can result from malfunctioning of the adrenal glands are Addison's disease (which is caused by adrenal insufficiency) and Cushing's syndrome (caused by elevated levels of cortisol). In the former, fatigue, low blood pressure, weight loss, nausea, diarrhea, and muscle weakness are some of the symptoms, whereas for the latter, obesity, high blood pressure, a "moon" face, and poor healing of skin wounds are common. John F. Kennedy, Helen Reddy, and (perhaps) Osama bin Laden were well-known Addisonians.

If there is a problem with too much secretion of the sex hormones in the adrenals, virilism and premature puberty are possible problems. Virilism results in women with beards on their faces and men with exceptionally low, deep voices. Premature puberty, or full sexual development while still a child, is a result of too many sex hormones during childhood. (Puberty is considered premature if it occurs before age 8 in girls and age 9 in boys.) Treatment is possible using hormones to control the appearance of symptoms but must begin early in the disorder.

Lecture Launcher 2.7 Psychophysiological Measurement

Various strategies exist for measuring activity in the brain, including techniques such as PET (positron emission tomography), TMS (transcranial magnetic stimulation), and MRI (magnetic resonance imaging). There are, of course, other bodily systems and other techniques for measuring them, many of which rely on the electrophysical activity of the body.

EMG—Electromyography. An electromyogram records the action potential given off by contracting muscle fibers. A common example is the recording of facial EMG, in which either inserted electrodes or surface electrodes record the activity of muscles as they pose various expressions.

EGG—Electrogastrography. Electrogastrograms provide a record of smooth muscle activity in the abdomen. The contractions of the stomach or intestines, for example, can be measured by comparing the readings from a surface electrode attached to the abdomen with those of an electrode attached to the forearm. In the special case of measuring contractions in the esophagus, surface electrodes are attached to a balloon, which is “swallowed” by the person being measured. EGG may be used successfully to gain information about fear, anxiety, or other emotional states.

EOG—Electrooculography. Readings from electrodes placed around the posterior of the eyes are the basis for EOG. Electrical signals result from small saccadic eye movements as well as more gross movements that can be directly observed. EOG can be used for measuring rapid eye movements during sleep.

EKG—Electrocardiography. EKG records changes in electrical potential associated with the heartbeat. Electrodes are placed at various locations on the body, and their recordings yield five waves that can be analyzed: P-waves, Q-waves, R-waves, S-waves, and T-waves. EKG may be used by psychologists to supplement observations relevant to stress, heart disease, or Type A behavior patterns.

EDA—Electrodermal Activity. Formerly called *galvanic skin response, skin resistance,* and *skin conductance,* EDA refers to the electrical activity of the skin. As activity in the sympathetic nervous system increases, it causes the eccrine glands to produce sweat. This activity of the eccrine glands can be measured by EDA, regardless of whether or not sweat actually rises to the skin surface. The folklore of “sweaty palms” associated with a liar might be measured using this technique.

EEG—Electroencephalography. EEG provides information about the electrical activity of the brain, as recorded by surface electrodes attached to the scalp. EEG has been used in a variety of ways to gather information about brain activity under a wide range of circumstances.

Pneumography. Pneumographs measure the frequency and amplitude of breathing and are obtained through a relatively straightforward procedure. A rubber tube placed around the chest expands and contracts in response to the person’s inhalations and exhalations. These changes can then be recorded with either an ink pen or electrical signal.

Lecture Launcher 2.8 Berger’s Wave

Ask if anyone knows what is meant by the term *Berger’s wave*. Explain that the study of electrical activity in the brain was once limited to studies in which different kinds of measuring devices were attached to the exposed brains of animals. Studies involving humans were rare; researchers could only measure the electrical activity of the living human brain in individuals who had genetic defects of their skull bones that caused the skin of their scalps to be in direct contact with the surfaces of their brains. Yuck!

All this changed when a German physicist named Hans Berger, after several years of painstaking research, discovered that it was possible to amplify and measure the electrical activity of the brain by attaching special electrodes to the scalp that, in turn, sent impulses to a machine that graphed them. In his research, Berger discovered several types of waves, one of which he called the "alpha" wave for no other reason than it was the first one he discovered (alpha is the first letter of the Greek alphabet). He kept his research a secret until he published an article about it in 1929. The alpha wave is also sometimes called *Berger's wave* in honor of Berger's discovery.

Although Berger achieved one of the most important discoveries in the history of neuroscience, his life was not a happy one. Shortly after his article was published, the Nazis rose to power in Germany, which greatly distressed him. In addition, his work was not valued in Germany; he was far better known in the United States. As a result, Berger fell into a deep depression in 1941 and hanged himself.

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Millett, D. (2001). Hans Berger: From psychic energy to the EEG. *Perspectives in Biological Medicine*, *44*(4), 522–542.

Wiedemann, H. R. (1994). Hans Berger (1873–1941). *European Journal of Pediatrics*, *153*(10), 705.

Lecture Launcher 2.9 Lie Detectors 2.0

A staple of police and lawyer television shows is the "lie detector" scene, in which the suspect is hooked up to a polygraph machine and asked a series of questions about a crime. As the questions are asked, the needles on the polygraph record the suspect's heart rate, breathing, skin conductance, and other physiological responses to the questions. Polygraph machines have been used in this way by law enforcement agencies for many years. The principle behind the test is that the act of lying causes an involuntary change in the autonomic nervous system, which can be detected by the polygraph. The accuracy of polygraph machines, however, is controversial, and in many courts they are inadmissible as evidence. More recently, some researchers have tried to create a new generation of lie detectors that can measure activity in the brain directly. These techniques look for patterns in the brain that, at least in theory, correlate with lying.

One technique that might be adapted to the use of lie detectors is electroencephalography, more commonly referred to as EEG. During an EEG recording, electrodes are placed at various locations on the scalp. These electrodes are capable of picking up the electrical activity produced by neurons located in different parts of the brain. Although the activity of individual neurons cannot be identified, the patterns of electrical activity produced by thousands of neurons working together can be a sign that the brain is functioning in a particular way. EEGs may be useful as lie detectors by identifying event-related potentials (ERPs). An ERP is a brief electrical change that occurs at a reliable point in time relative to a specific event. For example, it has been found that

300 to 500 ms after a person has been shown something that is unexpected or novel, there is a brief electrical change in that person's EEG. Theoretically, this ERP could be used to determine if a subject has previous knowledge of a piece of evidence. For instance, an ERP occurring 300 ms after being shown a picture of the murder weapon might indicate that the suspect had not seen the murder weapon before.

More recently, functional magnetic resonance imaging (fMRI) has been suggested as a potential method for lie detection. fMRI works by detecting the increase in blood flow to more active regions in the brain. This is not to be confused with structural MRIs, which can only create an image of tissues, bones, and so on. When a person performs a task in an fMRI (e.g., adding two numbers together), the brain regions required to perform the task will become active. This activity will cause a change in blood flow that the fMRI can detect. Because different brain regions are involved in recounting an actual event than are involved in making up a story, it is possible that fMRI is capable of determining whether someone is lying or telling the truth. Some researchers have found that, even if a lie is well rehearsed, it still appears to activate different brain regions than telling the truth does.

Despite media interest in new forms of lie detection, many experts agree that the EEG and fMRI approaches currently suffer from the same issues that polygraphs do. For example, although the newer techniques measure brain activity much more directly, there is concern about their reliability. Although certain brain activity might suggest that a person is lying, unless the technology can deliver accuracy of almost 100 percent, innocent people may be convicted of crimes they did not commit. It is also unclear whether people could find ways to "trick" the machines by performing certain mental tasks during testing. Until these questions can be answered, it is unlikely that the polygraph will be replaced anytime soon.

Farah, M. J., Hutchinson, J. B., Phelps, E. A., & Wagner, A. D. (2014). Functional MRI-based lie detection: Scientific and societal challenges. *Nature Reviews | Neuroscience*, *15*, 123–131.

Ganis, G., Kosslyn, S., Stose, S., Thompson, W., & Yurgelun-Todd, D. (2003). Neural correlates of different types of deception: An fMRI investigation. *Cerebral Cortex*, *13*(8), 830–836.

Wolpe, P., Foster K., & Langleben, D. (2005). Emerging neurotechnologies for lie detection: Promises and perils. *American Journal of Bioethics*, *5*(2), 39–49.

Lecture Launcher 2.10 Women, Men, and PETs

The 1990s were dubbed "the decade of the brain," and it is true that remarkable advances have been made by the neurosciences in discovering how the brain operates. Several studies suggest that the operation of men's and women's brains may differ in significant ways.

For example, Ruben Gur and his colleagues at the University of Pennsylvania recorded positron emission tomography (PET) scans of men and women who were asked to think of nothing in particular. That is, the research participants were instructed to relax and let their brains idle as they exerted as little mental effort as possible. The researchers found that for most participants the task was difficult to complete; PET scans revealed that these idle minds nonetheless hummed with activity. The locus of that activity, however, differed between the sexes. Men's brains often showed activity in the limbic system, whereas women often showed activity in the posterior cingulate gyrus. The meaning of these differences is difficult to interpret; the difficulty is compounded by the 13 men and 4 women who showed patterns of activity characteristic of their opposite sex peers. As an early peek into the brain, however, they hint that the centers of activity for "blank" brains differ for women and men.

In a separate study, researchers at the University of California, Irvine, asked 22 men and 22 women to solve SAT math problems while undergoing a PET scan. Half of each group had SAT math scores above 700, whereas the other half had scores below 540. The temporal lobes of the 700+ men showed heightened activity during the math task, although this was not true for the women; the 700+ women's temporal lobes were no more intensively used than those of the women scoring below 540. Richard Haier, who helped lead the study, speculates that women in the top group might be using their brains more efficiently than women in the average-scoring group. More generally, although both men and women did well at the task, their brains were operating differently to accomplish it.

Ruben and Raquel Gur also studied men's and women's brains in response to emotional expressions (Erwin et al., 1992). Shown pictures of either happy or sad faces, both men and women were quite adept at spotting happiness. Women, however, could identify sadness about 90 percent of the time, regardless of whether it was on the face of a man or a woman. By comparison, men were accurate in spotting sadness 90 percent of the time on a man's face but only 70 percent of the time if the expression was on a woman's face. Once again, PET scans revealed that women's brains did not have to work as hard at this task as did men's brains; in fact, women's limbic systems were less active than the limbic systems of the poor-scoring men.

There are a number of other differences between women's and men's brains. Women tend to have a larger corpus callosum than men, for example. Women may also have a higher concentration of neurons in their cortexes than men. But the meaning behind these differences is a matter that is far from decided.

Begley, S. (1995, March 27). Gray matters. *Newsweek*, 48–54.

Erwin, R. J., Gur, R. C., Gur, R. E., Skolnick, B. et al. (1992). Facial emotion discrimination I: Task construction and behavioral findings in normal subjects. *Psychiatry Research*, *42*, 231–240.

Zaldi, Z. (2010). Gender differences in human brain: A review. *The Open Anatomy Journal*, *2*, 37–55.

Lecture Launcher 2.11 Using fMRI and MEG to Study Phantom Limb Pain

The concept of pain sensation means different things to different people. Many students are aware of phantom pain sensation and are very curious about it. Medical professionals have recorded many cases of what has come to be called “phantom limbs.” Phantom limb phenomenon occurs when a person who has had an amputation of some body part, such as an arm or leg, reports feeling sensations from the missing limb. Phantom limb refers to the subjective sensory awareness of an amputated body part and may include numbness, itchiness, temperature, posture, volume, or movement. For example, one man whose left arm was amputated just above the elbow during a horrific car accident claimed that he could still feel the arm as a kind of ghostly presence. He could feel himself wiggling nonexistent fingers and “grabbing” objects that would have been in his reach had his arm still been there (Ramachandran & Blakeslee, 1998). Phantom sensations may take years to fade and usually do so from the end of the limb up to the body—in other words, a phantom arm seems to get shorter and shorter until it can no longer be felt. In addition to legs and arms there have been cases of phantom breasts, bladders, rectums, vision, hearing, and internal organs.

Phantom limb pain refers to the specific case of painful sensations that appear to reside in the amputated body part. Patients have variously reported pins-and-needles sensations, burning sensations, shooting pains that seem to travel up and down the limb, and cramps, as though the severed limb was in an uncomfortable and unnatural position. Many amputees often experience several types of pain; others report that the sensations are unlike other pain they’ve experienced. Unfortunately, some estimates suggest that over 70 percent of amputees still experience intense pain even 25 years after amputation. Most treatments for phantom limb pain (there are over 50 types of therapy) help only about 7 percent of sufferers.

What causes these phantom sensations? Researchers at Humboldt University in Berlin have suggested that the most severe type of this pain occurs in amputees whose brains undergo extensive sensory reorganization. Magnetic responses were measured in the brains of 13 arm amputees in response to light pressure on their intact thumbs, pinkies, lower lips, and chins. These responses were then mapped onto the somatosensory cortex controlling that side of the body. Because of the brain’s contralateral control over the body, the researchers were able to estimate the location of the somatosensory sites for the missing limb. They found that those amputees who reported the most phantom limb pain also showed the greatest cortical reorganization. Somatosensory areas for the face encroached into regions previously reserved for the amputated fingers.

Renowned neuroscientist Dr. V. S. Ramachandran has investigated many cases of phantom limb sensations in his career. He believes that using the noninvasive techniques of magnetoencephalograms and functional MRIs to examine people who experience these phenomena can teach us much about the relationship between sensory experience and consciousness. Researchers have long known that touching certain points on the stump of the amputation (and in some cases on the person's face) can produce phantom sensations in a missing arm or fingers (Ramachandran & Hirstein, 1998). Older explanations of phantom limb sensations have called it an illusion brought on by the irritation of the nerve endings in the stump due to scar tissue. But using anesthesia on the stump does not remove the phantom limb sensations or the pain experienced by some patients in the missing limb, so that explanation is not adequate. Ramachandran and colleagues suggest instead that phantom limb sensations may occur because areas of the face and body near the stump "take over" the nerve functions that were once in the control of the living limb, creating the false impression that the limb is still there, feeling and moving. This "remapping" of the limb functions, along with the sensations from the neurons ending at the stump, and the person's mental "body image" work together to produce phantom limb sensations.

Although these findings do not by themselves solve the riddle of phantom limb pain, they do offer avenues for future research. For example, damage to the nervous system may cause a strengthening of connections between somatosensory cells and the formation of new ones. Phantom limb pain may result due to an imbalance of pain messages from other parts of the brain. As another possibility, pain may result from a remapping of somatosensory areas that infringes on pain centers close by.

Boas, R. A., Schug, S. A., & Acland, R. H. (1993). Perineal pain after rectal amputation: A 5-year follow-up. *Pain*, 52, 67–70.

Bower, B. (1995). Brain changes linked to phantom-limb pain. *Science News, 147,* 357.

Brena, S. F., & Sammons, E. E. (1979). Phantom urinary bladder pain – Case report. *Pain, 7,* 197–201.

Bressler, B., Cohen, S. I., & Magnussen, F. (1955). Bilateral breast phantom and breast phantom pain. *Journal of Nervous and Mental Disease*, *122*, 315–320.

Dorpat, T. L. (1971). Phantom sensations of internal organs. *Comprehensive Psychiatry*, *12*, 27–35.

Katz, J. (1993). The reality of phantom limbs. *Motivation and Emotion*, *17,* 147–179.

Ramachandran, V. S., & Blakeslee, S. (1998). *Phantoms in the brain.* New York: William Morrow.

Ramachandran, V. S., & Hirstein, W. (1998). The perception of phantom limbs: The D. O. Hebb lecture. *Brain*, *121*, 1603–1630.

Shreeve, J. (1993, June). Touching the phantom. *Discover*, 35–42.

Lecture Launcher 2.12 The Importance of a Wrinkled Cortex

At the beginning of your lecture on the structure and function of the brain, ask students to explain why the cerebral cortex is wrinkled. There are always a few students who correctly answer that the wrinkled appearance of the cerebral cortex allows it to have a greater surface area while fitting in a relatively small space (i.e., the head). To demonstrate this point to your class, hold a plain, white sheet of paper in your hand and then crumple it into a small, wrinkled ball.

Note that the paper retains the same surface area yet is now able to fit into a much smaller space, such as your hand. You can then mention that the brain's actual surface area, if flattened out, would be roughly the size of a newspaper page. Laughs usually erupt when the class imagines what our heads would look like if we had to accommodate an unwrinkled, newspaper-sized cerebral cortex!

Lecture Launcher 2.13 Brain's Bilingual Broca

Se potete parlare Italiano, allore potete capire questa sentenza. Of course, if you only speak English, you probably only understand *this* sentence. If you speak both languages, then by this point in the paragraph you should be really bored.

Bilingual speakers who come to their bilingualism in different ways show different patterns of brain activity. Joy Hirsch of Memorial Sloan-Kettering Cancer Center in New York and her colleagues monitored the activity in Broca's area in the brains of bilingual speakers who acquired their second language starting in infancy and compared it to the activity of bilingual speakers who adopted a second language in their teens. Participants were asked to silently recite brief descriptions of an event from the previous day, first in one language and then in the other. A functional magnetic resonance image (fMRI) was taken during this task. All of the 12 adult speakers were equally fluent in both languages, used both languages equally often, and represented speakers of English, French, and Turkish, among other tongues.

Hirsch and her colleagues found that among the infancy-trained speakers, the same region of Broca's area was active, regardless of the language they used. Among the teenage-trained speakers, however, a different region of Broca's area was activated when using the acquired language. Similar results were found in Wernicke's area in both groups. Although the full meaning of these results is a matter of some debate (i.e., do they reflect sensitivity in Broca's area to language exposure or pronounced differences in adult versus childhood language learning?), they nonetheless reveal an intriguing link between *la testa e le parole*.

Bower, B. (1997, July 12). Brains show signs of two bilingual roads. *Science News*, *152*, 23.

Lecture Launcher 2.14 A New Look at Phineas Gage

For over 30 years, Jack and Beverly Wilgus had a daguerreotype portrait (i.e., a type of early photograph) of a well-dressed young man with one eye closed. Because the photograph showed the young man holding what appeared to be part of a harpoon, the Wilguses believed that the man was a nineteenth-century whaler who had lost his eye, perhaps in a whaling accident. It was only after a copy of the portrait was posted online that the couple was told that the object in the man's hands did not appear to be a harpoon. Then, in 2008, a person viewing the image online posted a comment that the young man may be Phineas Gage, making the "harpoon" the infamous tamping rod that was blasted through his skull and brain. By carefully examining the rod in the daguerreotype and by comparing the young man's face to the cast made of Gage's head after his death, the Wilguses were able to confirm that the portrait is almost certainly that of Phineas Gage, made sometime after his accident. Importantly, this is the only known photograph of the man who became one of the most famous case studies in psychology.

One of the consequences of the portrait's discovery has been a renewed debate about how Gage's injuries affected his personality and behavior. Many psychology textbooks explain that the accident left Gage a permanently changed man with his once well-balanced, gregarious, and hardworking personality replaced with profane, inconsiderate, and impulsive behavior for the rest of his life. This, however, is not necessarily supported by the few original sources researchers have to go on. For example, although the evidence clearly indicates that Gage had major psychological changes for a period after his accident, we also know that Gage later spent many years driving stagecoaches before he died in 1860, 12 years after the accident. Many have questioned whether the postaccident Phineas Gage commonly described in introductory psychology classes could have performed the tasks required to drive a stagecoach, interact with passengers, and be reliable enough to maintain employment for long periods at a time. Does this indicate that many of the psychological changes Gage suffered were temporary? Certainly the newly discovered daguerreotype of a healthy-looking and well-kept Phineas Gage lends further support to the idea that Phineas was able to largely recover from his accident, both physically and mentally. If true, the case of Phineas Gage may be as much a story about the incredible plasticity of the brain and its ability to compensate for the loss of specific brain regions as it is about the localization of specific functions.

The newly discovered portrait of Phineas Gage can be found by searching online for "Phineas Gage daguerreotype."

Macmillan, M. (2008). Phineas Gage–Unraveling the myth. *The Psychologist, 21*(9), 828–831.

Lecture Launcher 2.15 Freak Accidents and Brain Injuries

Students may be interested in the unusual cases of individuals who have experienced bizarre brain injuries due to freak accidents with nail guns. The most fascinating example involved Isidro Mejia, a construction worker in southern California, who had six nails driven into his head when he fell from a roof onto his coworker who was using a nail gun. (X-ray images of the embedded nails can be found at several sites online.) Incredibly, none of the nails caused serious damage to Mejia's brain. One nail lodged near his spinal cord, and another came very close to his brain stem. Immediate surgery and treatment with antibiotics prevented deadly infections that could have been caused by the nails. In a similar accident, a construction worker in Colorado ended up with a nail lodged in his head due to a nail gun mishap. Unlike Mejia, Patrick Lawler didn't realize he had a nail in his head for 6 days. The nail was discovered when he visited a dentist due to a "toothache." It appears that Lawler fired a nail into the roof of his mouth. The nail barely missed his brain and the back of his eye.

Nail Gun /Victim Lives. (2004, September 10). *Current Science, 90*(1), 14.
Additional resources can be found by searching "Isidro Mejia" or "Patrick Lawler" online.

Lecture Launcher 2.16 Understanding Hemispheric Function

A variation on the rather dubious statement that "we only use one tenth of our brain" is that "we only use one half (hemisphere) of our brain." Research suggests that each cerebral hemisphere is specialized to perform certain tasks (e.g., left hemisphere/language; right hemisphere/ visuospatial relationships) with the abilities of one hemisphere being complementary to the other. From this claim came numerous distortions, oversimplifications, and unwarranted extensions, many of which are discussed in two interesting reviews of this trend toward "dichotomania" (Corballis, 1980; Levy, 1985). For example, the left hemisphere has been described variously as logical, intellectual, deductive, convergent, and "Western," whereas the right hemisphere has been described as intuitive or creative, sensuous, imaginative, divergent, and "Eastern." Even complex tasks are described as right or left hemispheric because of their language component. In every individual one hemisphere supposedly dominates, affecting that person's mode of thought, skills, and approach to life. One commonly cited but questionable test for dominance is to note the direction of gaze when a person is asked a question (left gaze signaling right-hemispheric activity, right gaze showing left-hemispheric activity). Advertisements have claimed that artistic abilities can be improved if the right hemisphere is freed, and public schools have been blamed for stifling creativity by emphasizing left-hemispheric skills and by neglecting to teach to the children's right hemisphere.

Corballis and Levy explode these myths and trace their development. In reality, the two hemispheres are quite similar and can function remarkably well even if separated by split-brain surgery. Each hemisphere does have specialized abilities, but the two hemispheres work together in all complex tasks. For example, writing a story involves left-hemispheric input concerning syntax but right-hemispheric input for developing an integrated structure and for using humor or metaphor. The left hemisphere is neither the sole determinant of logic nor is the right hemisphere essential for creativity. Disturbances of logic are more prevalent with right-hemispheric damage, and creativity is not necessarily affected. Although one hemisphere can be somewhat more active than the other, no individual is purely "right brained" or "left brained." Also, eye movement and hemispheric activity patterns poorly correlate with cognitive style or occupation. Finally, because of the coordinated, interactive manner of the functioning of both hemispheres, educating or using only the right or left hemisphere is impossible (without split-brain surgery).

Corballis, M. C. (1980). Laterality and myth. *American Psychologist*, *35*, 284–295.
Levy, J. (1985). Right brain, left brain: Fact or fiction? *Psychology Today*, *19*, 38–45.

Lecture Launcher 2.17 Handedness, Eyedness, Footedness, Facedness

Although the title sounds like a Dr. Seuss rhyme, it actually does make sense to neuropsychologists. Most people are familiar with the concept of handedness. The human population is distributed across many people who are adept at using their right hands for most tasks, some who have greater skill using the left hand, and a smaller proportion of those who are equally skilled using either hand (or who alternate hands for certain tasks). The concepts of footedness, leggedness, eyedness, and facedness may be less familiar to the layperson, although they stem from the same principle as handedness.

The basis of these distinctions lies in the concept of laterality. Just as the cerebral hemispheres show specialization (e.g., left hemisphere for language functions, right hemisphere for visual-spatial functions), so too are there preferences or asymmetries in other body regions. The concept of eyedness, then, refers to the preference for using one eye over another, such as when squinting to site down the crosshairs of a rifle or to thread a needle. Footedness and leggedness similarly refer to a preference for one limb over the other; drummers and soccer players will attest to the importance of being equally adept at using either foot and to the difficulty in achieving that skill. Finally, facedness refers to the strength with which information is conveyed by the right or left side of the face. It has been suggested that verbal information shows a right-face bias whereas emotional expressions are more strongly shown on the left side of the face, although these conclusions remain somewhat controversial.

Why are these distinctions useful? They play their largest role in the areas of sensation and perception, engineering psychology, and neuropsychology. Studies of reaction time, human-machine interaction, ergonomic design, and so on, take into account the preferences and dominance of some body systems over others. In the case of facedness and emotional expression, researchers are working to illuminate the link between facial expressions and cerebral laterality. Given the right hemisphere's greater role in emotional activities, the contralateral control between the right hemisphere and the left hemiface becomes an important proving ground for investigating both brain functions and the qualities of expression.

Borod, J. C., Caron, H. S., & Koff, E. (1981). Asymmetry of facial expression related to handedness, footedness, and eyedness: A quantitative study. *Cortex*, *17*, 381–390.
Ekman, P., Hagar, C. J., & Friesen, W. V. (1981). The symmetry of emotional and deliberate facial actions. *Psychophysiology*, *18*, 101–106.
Friedlander, W. J. (1971). Some aspects of eyedness. *Cortex*, *7*, 357–371.
McGuigan, F. J. (1994). *Biological psychology: A cybernetic science.* Englewood Cliffs, NJ: Prentice Hall.
Sackheim, H. A., Gur, R. C., & Saucy, M. C. (1978). Emotions are expressed more intensely on the left side of the face. *Science*, *202*, 434–436.

Lecture Launcher 2.18 Workplace Problems: Left-Handedness

Within Canada and the United States, there are approximately 33 million people who are left-handed. This presents a significant detriment to workplace safety. It has been shown that left-handed individuals are 25 percent more likely in general and 51 percent more likely if working with tools and machinery to have accidents at work than are right-handed individuals. Accommodations such as being able to rearrange the work area and having tools available that are both left- and right-handed would make the workplace safer. Have students suggest ways that the workplace could be made safer or even what could be done in the classroom to make it easier for students who are left-handed to take notes or tests. What about the mouse on computers? The mouse is actually made for people who are right-handed. How adaptable must a left-handed person become in order not to be frustrated by using a right-handed mouse?

Resources can be found by searching handedness and safety online.

Lecture Launcher 2.19 The Results of a Hemispherectomy

When Matthew was 6 years old, surgeons removed half of his brain.

His first 3 years of life were completely normal. Just before he turned 4, however, Matthew began to experience seizures that did not respond to drug treatment. The seizures were both life threatening and frequent (as often as every 3 minutes). The eventual diagnosis was Rasmussen's encephalitis, a rare and incurable condition of unknown origin.

The surgery, a hemispherectomy, was performed at Johns Hopkins Hospital in Baltimore. A few dozen such operations are performed each year in the United States, usually as a treatment for Rasmussen's and for forms of epilepsy that destroy the cortex but do not cross the corpus callosum. After surgeons removed Matthew's left hemisphere, the empty space quickly filled with cerebrospinal fluid.

Although the surgery left a scar that ran along one ear and disappeared under his hair, his face had no lopsidedness. The only other visible effects of the operation were a slight limp and limited use of his right arm and hand. Matthew had no right peripheral vision in either eye. He had weekly speech and language therapy sessions. For example, a therapist displayed cards that might say "fast things" and Matthew had to name as many fast things as he could in 20 seconds. He did not offer as many examples as other children his age. However, he made progress in the use of language, perhaps as a result of fostering and accelerating the growth of dendrites.

Matthew's case indicates the brain's remarkable plasticity. Furthermore, it is interesting to note that Matthew's personality never changed throughout the seizures and surgery.

Boyle, M. (1997, August 1). Surgery to remove half of brain reduces seizures. *Austin American-Statesman*,

A18.
Rasmussen, T., Olszewski, J., & Lloyd-Smith, D. (1958). Focal seizures due to chronic localized encephalitis. *Neurology*, *8*(6), 435–445.
Swerdlow, J. L. (1995, June). Quiet miracles of the brain. *National Geographic*, *87*, 2–41.
Vining, E. P., Freeman, J. M., Pillas, D. J., Uematsu, S., Carson, B. S., Brandt, J., Boatman, D., Pulsifer, M. B., & Zuckerberg, A. (1997). Why would you remove half a brain? The outcome of 58 children after hemispherectomy—the Johns Hopkins experience: 1968 to 1996. *Pediatrics*, *100*(2 Pt 1), 163–171.

Lecture Launcher 2.20 Stressed? Not Much!

When beginning a discussion on the parts of the nervous system, remind students that the autonomic nervous system is set up to provide balance between excitation and relaxation in the body. Ask students to describe the last time they felt stress and trace it back to the functions of the sympathetic nervous system. Ask them to think about the last time a long-term stressor finally was gone and they felt the calming effects of the parasympathetic nervous system. The sympathetic nervous system is set up to prepare us to fight or flee a major stressor. Use that to explain the changes in the body seen when the sympathetic nervous system is activated. Changes such as dilated pupils, increased heart rate, decreased digestion, and increased glucose release all are parts of sympathetic nervous system activation that helps us prepare to fight or flee. Ask students to predict the effects of parasympathetic activation in the body.

CLASSROOM ACTIVITIES, DEMONSTRATIONS, AND EXERCISES

- 2.1 Using Dominoes to Understand the Action Potential
- 2.2 Environmental Influences on the Brain
- 2.3 Demonstrating Neural Conduction: The Class as a Neural Network
- 2.4 The Dollar Bill Drop
- 2.5 Reaction Time and Neural Processing
- 2.6 Mapping the Brain
- 2.7 Football and Brain Damage
- 2.8 Hemispheric Lateralization
- 2.9 Hemispheric Communication and the Split Brain
- 2.10 Crossword Puzzle
- 2.11 Fill in the Blanks
- 2.12 Diagnostic Brain Imaging or Electrophysiology

Activity 2.1 Using Dominoes to Understand the Action Potential

Walter Wagor suggests using real dominoes to demonstrate the so-called domino effect of the action potential as it travels along the axon. For this demonstration, you'll need a smooth tabletop surface (at least 5 feet long) and one or two sets of dominoes. Set up the dominoes beforehand, on their ends and about an inch apart, so that you can push the first one over and cause the rest to fall in sequence. Proceed to knock down the first domino in the row and students should clearly see how the "action potential" is passed along the entire length of the axon. You can then point out the concept of refractory period by showing that, no matter how hard you push on the first domino, you will not be able to repeat the domino effect until you take the time to set the dominoes back up (i.e., the resetting time for the dominoes is analogous to the refractory period for neurons). You can then demonstrate the all-or-none characteristic of the axon by resetting the dominoes and pushing so lightly on the first domino that it does not fall. Just as the force on the first domino has to be strong enough to knock it down before the rest of the dominoes will fall, the action potential must be there in order to perpetuate itself along the entire axon. Finally, you can demonstrate the advantage of the myelin sheath in axonal transmission. For this demonstration, you'll need to set up two rows of dominoes (approximately 3 or 4 feet long) next to each other. The second row of dominoes should have foot-long sticks (e.g., plastic rulers) placed end to end in sequence on top of the dominoes. By placing the all-domino row and the stick-domino row parallel to each other and pushing the first domino in each, you can demonstrate how much faster the action potential can travel if it can jump from node to node rather than having to be passed on sequentially, single domino by single domino. Ask your students to discuss how this effect relates to myelinization.

Wagor, W. F. (1990). Using dominoes to help explain the action potential. In V. P. Makosky, C. C. Sileo, L. G. Whittemore, C. P. Landry, & M. L. Skutley (Eds.), *Activities handbook for the teaching of psychology: Vol. 3* (pp. 72–73). Washington, DC: American Psychological Association.

Activity 2.2 Environmental Influences on the Brain

You might want to remind students that brain function and structure are subject to environmental influences. Ask students to identify the behaviors that are important for keeping the brain healthy and functioning well. The following are some possibilities:

Good nutrition, especially during childhood. Adequate nutrition is vital for proper brain development. Even in adults, diet may influence brain function. Studies show that although high levels of cholesterol may be bad for your heart, low levels of cholesterol may be bad for your brain. Low cholesterol may be associated with low levels of the neurotransmitter serotonin, which can result in higher levels of aggression and depression.

Mental stimulation. High levels of stimulation help to form neural connections that in turn enhance brain function.

Physical fitness. Studies have shown that aerobic fitness has an impact on the density of capillaries in the brain. More capillaries result in greater blood flow to the brain.

Maternal health during pregnancy. The uterine environment can have an enormous impact on the brain development of a fetus. Women who do not have adequate nutrition, who drink, smoke, or do drugs, or who are exposed to certain environmental toxins are more likely to have children with lower IQs and learning disabilities.

Stress management. When we are highly stressed, it interferes with brain function and has been shown to actually promote the death of brain cells involved in memory.

Activity 2.3 Demonstrating Neural Conduction: The Class as a Neural Network

In this engaging exercise suggested by Paul Rozin and John Jonides, students in the class simulate a neural network and get a valuable lesson in the speed of neural transmission. Depending on your class size, arrange 15 to 40 students so that students can place their right hand on the right shoulder of the person in front of them. Note that students in every other row will have to face backward to form a snaking chain so that all students (playing the role of individual neurons) are connected to each other. Explain to students that their task as a neural network is to send a neural impulse from one end of the room to the other. The first student in the chain will squeeze the shoulder of the next person who, upon receiving this “message,” will deliver (i.e., “fire”) a squeeze to the next person’s shoulder and so on, until the last person receives the message. Before starting the neural impulse, ask students (as “neurons”) to label their parts; they typically have no trouble stating that their arms are axons, their fingers are axon terminals, and their shoulders are dendrites.

To start the conduction, the instructor should start the timer on a stopwatch while simultaneously squeezing the shoulder of the first student. The instructor should then keep time as the neural impulse travels around the room, stopping the timer when the last student/neuron calls out “stop.” This process should be repeated once or twice until the time required to send the message stabilizes (i.e., students will be much slower the first time around as they adjust to the task). Next, explain to students that you want them to again send a neural impulse, but this time you want them to use their ankles as dendrites. That is, each student will “fire” by squeezing the ankle of the person in front of them. While students are busy shifting themselves into position for this exercise, ask them if they expect transmission by ankle squeezing to be faster or slower than transmission by shoulder squeezing. Most students will immediately recognize that the ankle squeezing will take longer because of the greater distance the message (from the ankle as opposed to the shoulder) has to travel to reach the brain. Repeat this transmission once or twice and verify that it indeed takes longer than the shoulder squeeze.

This exercise—a student favorite—is highly recommended as a great icebreaker during the first few weeks of the semester, and it also makes the somewhat dry subject of neural processing come alive.

Rozin, P., & Jonides, J. (1977). Mass reaction time measurement of the speed of the nerve impulse and the duration of mental processes in class. *Teaching of Psychology*, *4*, 91–94.

Activity 2.4 The Dollar Bill Drop

After engaging in the neural network exercise, follow it up with the "dollar bill drop" (Fisher, 1979), which not only delights students but also clearly illustrates the speed of neural transmission. Ask students to get into pairs and to come up with one crisp, flat, one-dollar bill between them (or something larger, if they trust their fellow classmates!). First, each member of the pair should take turns trying to catch the dollar bill with their nondominant (for most people, the left) hand as they drop it from their dominant (typically right) hand. To do this, they should hold the bill vertically so that the top center of the bill is held by the thumb and middle finger of their dominant hand. Next, they should place the thumb and middle finger of their nondominant hand around the dead center of the bill, as close as they can get without touching it. When students drop the bill from one hand, they should be able to easily catch it with the other before it falls to the ground.

Now that students are thoroughly unimpressed, ask them to replicate the drop, only this time one person should try to catch the bill (i.e., with the thumb and middle finger of the nondominant hand) while the other person drops it (i.e., from the top center of the bill). Student "droppers" are instructed to release the bill without warning, and "catchers" are warned not to grab before the bill is dropped. (Students should take turns playing dropper and catcher.) There will be stunned looks all around as dollar bills whiz to the ground. Ask students to explain why it is so much harder to catch it from someone other than themselves. Most will instantly understand that when catching from ourselves, the brain can simultaneously signal us to release and catch the bill, but when trying to catch it from someone else, the signal to catch the bill can't be sent until the eyes (which see the drop) signal the brain to do so, which is unfortunately a little too late.

Fisher, J. (1979). *Body magic*. Briarcliff Manor, NY: Stein and Day.

Activity 2.5 Reaction Time and Neural Processing

Yet another exercise that illustrates the speed of neural processing is suggested by E. Rae Harcum. The point made by this simple but effective exercise is that reaction times increase as more response choices become available (i.e., because more difficult choices in responses involve more neuronal paths and more synapses, both of which slow neural transmission). Depending on your class size, recruit two equal groups of students (10 to 20 per group is ideal) and have each group stand together at the front of the room. First, explain that all subjects are to respond as quickly as possible to the name of a U.S. president. Then give written instructions to each group so that neither group knows the instructions given to the other. One group should be instructed to raise their right hands if the president served before Abraham Lincoln and to raise their left hands if the president served after Lincoln. The other group should be instructed simply to raise their left hands when they hear a president’s name. Ask participants and audience members to note which group reacts more quickly. When all students are poised and ready to go (i.e., hands level with shoulders and ready to raise), say “ready” and then “Reagan.” The group with the simpler reaction time task should be faster than the group whose task requires a choice.

Harcum, E. R. (1988). Reaction time as a behavioral demonstration of neural mechanisms for a large introductory psychology class. *Teaching of Psychology*, *4*, 208–209.

Activity 2.6 Mapping the Brain

To engage students in learning brain anatomy, search online for some simple coloring pages that contain the lobes of the brain, Broca’s and Wernicke’s areas, and the primary motor cortex and somatosensory cortex. Ask students to color in the regions and, using their color coding, list the function of each of the areas they colored.

Activity 2.7 Football and Brain Damage

Coaches and medical experts have known for a while that the severe hits that football players take on the field can lead to concussions, blackouts, and even permanent damage. More recently, however, there has been increasing concern that the effects of repeated hits to the head may not manifest themselves until decades later. Early studies suggest that former National Football League (NFL) players suffer high rates of memory and other cognitive problems years after retiring and that they also may develop these problems earlier than non-football players do. NFL players may also be vulnerable to higher rates of depression and Alzheimer’s disease.

To investigate this problem, groups like the Sports Legacy Institute have begun to encourage former NFL players to donate their brains to science when they die. Already, the brains of a handful of players have been examined with shocking results. Almost all of the brains show high levels of a protein called *tau*, which is suspected of being involved in several neurodegenerative disorders including Alzheimer's disease. The presence of high levels of tau may explain why football players have a tendency to develop cognitive impairments long after their playing days are over. More disturbing still, high levels of tau were also found in the brain of an 18-year-old high school football player who died.

After introducing students to this issue, have the class discuss the possible implications for social and sports policy. Should football playing be stopped? Should the rules of the game be changed to eliminate hard hitting? If necessary, pose the following additional questions to stimulate discussion: Everyone knows football is dangerous, but does the fact that these cognitive impairments may take decades to develop make them somehow different? Is the risk of permanent cognitive disability different than the risk of permanent physical disability? Wrestlers, soccer players, boxers, and other types of athletes are also at risk for long-term brain damage. Should these sports be changed or banned?

After discussing the issue in class, have students respond to the following writing prompt.

Writing prompt: Describe a longitudinal and then a cross-sectional study that could be used to determine if professional football players show higher than normal rates of cognitive impairment. Explain some of the advantages and disadvantages of the two designs.

Sample answer: A longitudinal study might choose a few football players and test them every 10 years using the same cognitive tests to see how their abilities change over time. A cross-sectional study might find a group of 65-year-old retired football players and compare their cognitive functioning to 65-year-olds who did not play football. The longitudinal study would provide a more complete view of how cognitive function might decline but would take decades to complete and may suffer from attrition. The cross-sectional study would be a lot easier to perform but would only offer a "snapshot" of cognitive function. You could not tell, for example, if football players develop cognitive impairment earlier than non-football players typically do.

Miller, G. (2009). A late hit for pro football players. *Science, 7*, 670–672.

Activity 2.8 Hemispheric Lateralization

Hemispheric lateralization results in eyedness, handedness, footedness, earedness, facedness, and other silly-sounding words with important implications (see related Lecture Launcher 2.17). Lateralization results from the specialization of each hemisphere for different tasks, such as reading facial expressions, speaking, solving spatial problems, or performing analytic tasks. Although neuropsychologists use sophisticated measures to determine this lateralization, this simple exercise allows students to gauge their own brain organization.

With both eyes open, have students hold up their right thumbs at arm's length under an object across the room directly in front of them. As they alternately close their left and right eyes, their thumbs should appear to jump to the right or to the left with respect to the distant object. For those who are right-eyed, their thumbs should jump to the right when they close their right eyes but stay as is when they close their left eyes. The opposite pattern should occur among those who are left-eyed. Students who see little or no jumping are among the 41 percent of the population who are neither strongly left-eyed nor right-eyed.

As a second test, ask for a volunteer. Present the student with the first paragraph of this exercise (or any suitable short passage) to memorize, a yardstick, a clock with a second hand, a pencil, and a pad of paper. First, time how long the volunteer can balance the yardstick on the tip of his or her right index finger while standing on the right foot. Next, measure the time as the volunteer balances the yardstick on his or her left index finger while standing on the left foot. Finally, repeat these tests while the volunteer recites the memorized passage. Speech will be localized on the side of the brain opposite the hand that is most disrupted by the memorization task.

Another demonstration, suggested by Morton Ann Gernsbacher, requires students to move their right hand and right foot simultaneously in a clockwise direction for a few seconds. Next ask that the right hand and left foot be moved in a clockwise direction. Then have students make circular movements in opposite directions with the right hand and the left foot. Finally, have students attempt to move the right hand and right foot in opposite directions. This generally produces laughter as students discover that this procedure is most difficult to do even though they are sure before they try it that it would be no problem to perform. A simple alternative activity is to ask students to pat their heads and to rub their stomachs clockwise and then switch to a counterclockwise motion. The pat will show slight signs of rotation as well.

The brain is lateralized to some extent, which makes some activities difficult to perform. Challenge your students to explain why activities of these types are difficult to execute. This will generally lead to interesting discussions and the assertion by some students that this type of behavior is no problem. Students who have been trained in martial arts, dance, drumming, or gymnastics generally have less difficulty completing these activities due to their rigorous physical training.

Haseltine, E. (1999, June). Brain works: Your better half. *Discover*, 112.

Kemble, E. D. (1987). Cerebral lateralization. In V. P. Makosky, L. G. Whittemore, and A. M. Rogers (Eds.), *Activities handbook for the teaching of psychology* (Vol. 2) (pp. 33–36). Washington, DC: American Psychological Association.

Kemble, E. D., Filipi, T., & Gravlin, L. (1985). Some simple classroom experiments on cerebral lateralization. *Teaching of Psychology, 12*, 81–83.

Activity 2.9 Hemispheric Communication and the Split Brain

Even after reading the textbook and listening to your lecture, many students may have difficulty conceptualizing the effects of a split-brain operation on an individual's behavior. Morris (1991) described five activities designed to simulate the behavior of split-brain patients. All of the activities have the same basic setup. You will need to solicit two right-handed volunteers and seat them next to each other at a table, preferably in the same chair. The volunteer on the left represents the left hemisphere, and the other student is the right hemisphere. The students are instructed to place their outer hands behind their backs and their inner hands on the table with their hands crossed, representing the right and left hands of the split-brain patient. Finally, the student representing the right hemisphere is instructed to remain silent for the remainder of the activity. In one of the activities described by Morris, both students are blindfolded and a familiar object (Morris suggested a retractable ballpoint pen) is placed in the left hand of the "split-brain patient" (the hand associated with the right hemisphere). Then ask the "right hemisphere" student if he or she can identify the object, reminding him or her that they must do so nonverbally. Next, ask the "right hemisphere" to try to communicate, without using language, what the object is to the "left hemisphere." Your more creative volunteers may engage in behaviors that attempt to communicate what the object is through sound or touch. If your "right hemisphere" has difficulty in figuring out how to communicate, ask the class for suggestions. This demonstration can be used to elicit discussion about why only the "left hemisphere" student can talk, the laterality of the different senses, and how split-brain patients are able to adjust their behavior to accommodate. You should refer to Morris's original article for descriptions of the other activities.

Morris, E. J. (1991). Classroom demonstration of behavioral effects of the split-brain operation. *Teaching of Psychology*, *18*, 226–228.

Activity 2.10 Crossword Puzzle

Copy and distribute **Handout Master 2.1** to students as a homework or in-class review assignment.

Answers for the crossword puzzle:

Across

1. Neurotransmitter that causes the receiving cell to stop firing. **inhibitory**
3. The cell body of the neuron, responsible for maintaining the life of the cell. **soma**
4. Endocrine gland located near the base of the cerebrum that secretes melatonin. **pineal**
7. Glands that secrete chemicals called hormones directly into the bloodstream. **endocrine**
8. Long tubelike structure that carries the neural message to other cells. **axon**
10. Chemical found in the synaptic vesicles that, when released, has an effect on the next cell. **neurotransmitter**

13. Bundles of axons coated in myelin that travel together through the body. **nerves**
14. Branchlike structures that receive messages from other neurons. **dendrites**
15. Endocrine gland found in the neck that regulates metabolism. **thyroid**
17. Thick band of neurons that connects the right and left cerebral hemispheres. **corpus callosum**
19. Part of the nervous system consisting of the brain and spinal cord. **central**

Down
2. Part of the limbic system located in the center of the brain that acts as a relay from the lower part of the brain to the proper areas of the cortex. **thalamus**
4. Endocrine gland that controls the levels of sugar in the blood. p**ancreas**
5. Layer of fatty substances produced by certain glial cells that coats the axons of neurons to insulate, protect, and speed up the neural impulse. **myelin**
6. The basic cell that makes up the nervous system and receives and sends messages within that system. **neuron**
8. Chemical substances that mimic or enhance the effects of a neurotransmitter on the receptor sites of the next cell. **agonists**
9. Part of the lower brain that controls and coordinates involuntary, rapid, fine motor movement. **cerebellum**
11. Process by which neurotransmitters are taken back into the synaptic vesicles. **reuptake**
12. A group of several brain structures located under the cortex and involved in learning, emotion, memory, and motivation. **limbic**
16. Chemicals released into the bloodstream by endocrine glands. **hormones**
18. Brain structure located near the hippocampus, responsible for fear responses and memory of fear. **amygdala**

Activity 2.11 Fill in the Blanks

Copy and distribute **Master Handout 2.2** to students as a homework or in-class review assignment.

Answers for Fill in the Blanks

1. nervous system
2. neuron
3. axon
4. dendrites
5. soma
6. myelin

7. nerves
8. ions
9. resting potential
10. synaptic vesicles
11. neurotransmitters
12. excitatory
13. agonists
14. spinal cord
15. sensory neuron
16. peripheral nervous
17. somatic nervous
18. autonomic nervous
19. sympathetic division
20. electroencephalograph
21. cerebellum
22. thalamus
23. pons
24. reticular formation
25. hippocampus
26. amygdala
27. cortex
28. corpus callosum
29. occipital cortex
30. parietal cortex
31. temporal lobes
32. frontal lobes
33. endocrine
34. adrenal glands

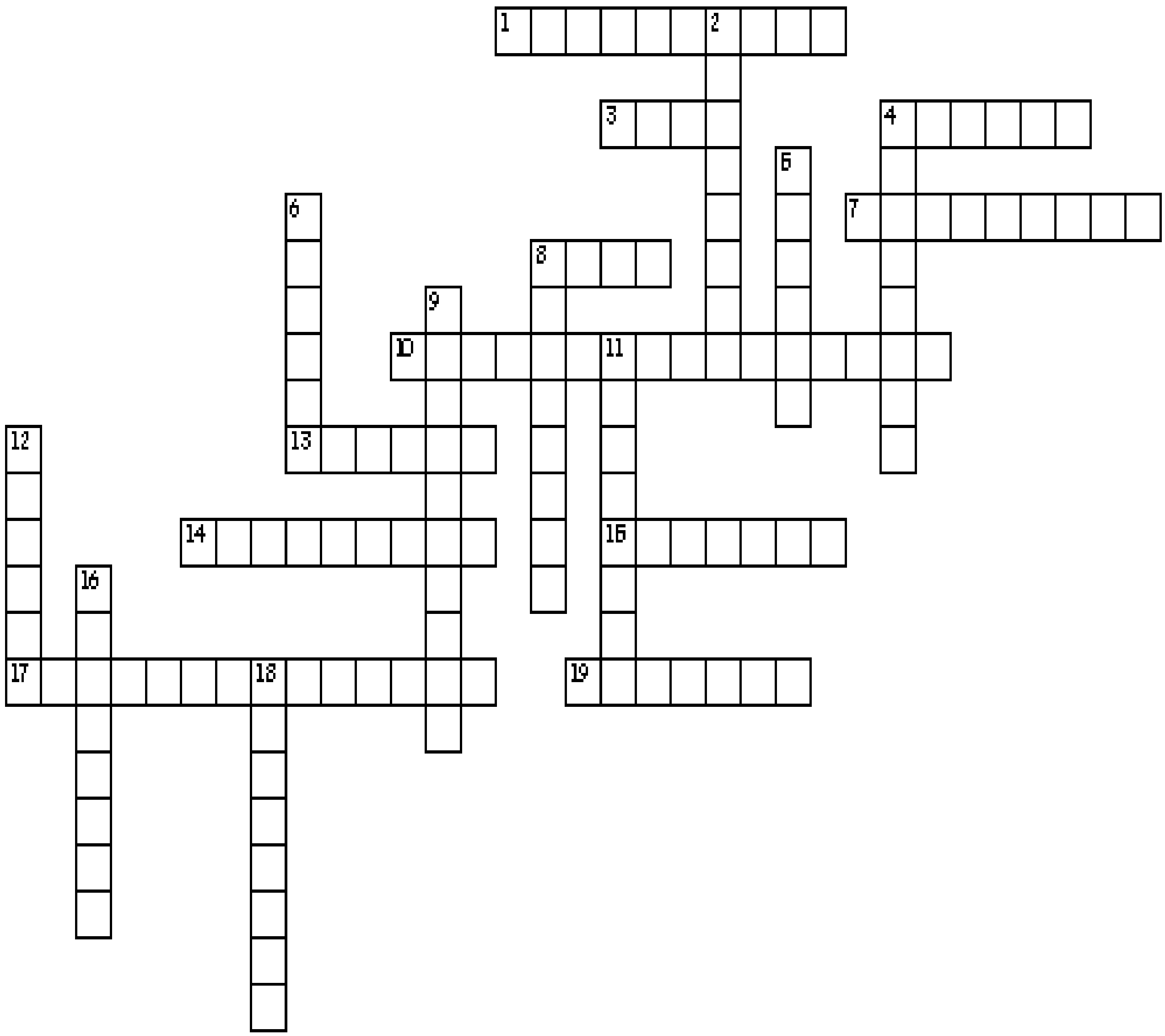
Activity 2.12 Diagnostic Brain Imaging or Electrophysiology

To help students begin to understand the powerful tools neurologists and neuroscientists have to learn about the brain and to help in diagnosing conditions of the brain, provide them with **Handout Master 2.3**. This handout describes people who are struggling with brain disorders who might present themselves to a doctor or clinic. Students are asked to review the section on brain-imaging technologies and determine a method they might be able to use to help in the diagnosis of the patient. There are no right or wrong answers for rookie neuroscientists, and some students may consider costs, patient condition, and other factors as well as what procedure works best in their decisions. Encouraging students to explain their reasons for selecting a specific diagnostic technology can lead into a discussion on the pros and cons of each of the brain-imaging technologies discussed in the text.

HANDOUT MASTERS

- 2.1 Crossword Puzzle
- 2.2 Fill in the Blanks
- 2.3 Diagnostic Brain Imaging

Handout Master 2.1
Crossword Puzzle



Across

1. Neurotransmitter that causes the receiving cell to stop firing.
3. The cell body of the neuron, responsible for maintaining the life of the cell.
4. Endocrine gland located near the base of the cerebrum that secretes melatonin.
7. Glands that secrete chemicals called hormones directly into the bloodstream.
8. Long tubelike structure that carries the neural message to other cells.
10. Chemical found in the synaptic vesicles that, when released, has an effect on the next cell.
13. Bundles of axons coated in myelin that travel together through the body.
14. Branchlike structures that receive messages from other neurons.
15. Endocrine gland found in the neck that regulates metabolism.
17. Thick band of neurons that connects the right and left cerebral hemispheres.
19. Part of the nervous system consisting of the brain and spinal cord.

Down

2. Part of the limbic system located in the center of the brain that acts as a relay from the lower part of the brain to the proper areas of the cortex.
4. Endocrine gland that controls the levels of sugar in the blood.
5. Layer of fatty substances produced by certain glial cells that coats the axons of neurons to insulate, protect, and speed up the neural impulse.
6. The basic cell that makes up the nervous system and receives and sends messages within that system.
8. Chemical substances that mimic or enhance the effects of a neurotransmitter on the receptor sites of the next cell.
9. Part of the lower brain that controls and coordinates involuntary, rapid, fine motor movement.
11. Process by which neurotransmitters are taken back into the synaptic vesicles.
12. A group of several brain structures located under the cortex and involved in learning, emotion, memory, and motivation.
16. Chemicals released into the bloodstream by endocrine glands.
18. Brain structure located near the hippocampus, responsible for fear responses and memory of fear.

Handout Master 2.2
Fill in the Blanks

1. An extensive network of specialized cells that carries information to and from all parts of the body is called the ________________ ______________.
2. The basic cell that makes up the nervous system and receives and sends messages within that system is called a __________________.
3. The long tubelike structure that carries the neural message to other cells on the neuron is the _______________
4. On a neuron, the branchlike structures that receive messages from other neurons are the ___________________.
5. The cell body of the neuron responsible for maintaining the life of the cell and containing the mitochondria is the _________________.
6. The fatty substance produced by certain glial cells that coats the axons of neurons to insulate, protect, and speed up the neural impulse is the _________________.
7. The bundles of axons in the body that travel together through the body are known as the ______________.
8. The charged particles located inside and outside of the neuron are called ____________.
9. The state of the neuron when not firing a neural impulse is known as the ________________ ____________________.
10. The _____________ _____________ are sacklike structures found inside the synaptic knob containing chemicals.
11. __________________________ are chemicals found in the synaptic vesicles that, when released, have an effect on the next cell.
12. The ______________________ neurotransmitter causes the receiving cell to fire.
13. The __________________________ mimic or enhance the effects of a neurotransmitter on the receptor sites of the next cell, increasing or decreasing the activity of that cell.
14. The __________________ _______________ is a long bundle of neurons that carries messages to and from the body to the brain and is responsible for very fast, lifesaving reflexes.

15. A neuron that carries information from the senses to the central nervous system and is also known as the afferent is called a ____________________ ________________.
16. All nerves and neurons that are not contained in the brain and spinal cord but that run through the body itself are in the __________________ ____________________ system.
17. The division of the PNS consisting of nerves that carry information from the senses to the CNS and from the CNS to the voluntary muscles of the body is the ______________ ________________ system.
18. The ___________________ _________________ system division of the PNS consisting of nerves that control all of the involuntary muscles, organs, and glands.
19. The part of the ANS that is responsible for reacting to stressful events and bodily arousal is called the _______________________ __________________ of the nervous system.
20. A machine designed to record the brain wave patterns produced by electrical activity of the surface of the brain is called an _________________________.
21. The part of the lower brain located behind the pons that controls and coordinates involuntary, rapid, fine motor movement is called the ______________________.
22. Part of the limbic system located in the center of the brain, this structure relays sensory information from the lower part of the brain to the proper areas of the cortex and processes some sensory information before sending it to its proper area and is called the _______________________.
23. The larger swelling above the medulla that connects the top of the brain to the bottom and that plays a part in sleep, dreaming, left-right body coordination, and arousal is called the _____________________.
24. The _____________________ ________________ is an area of neurons running through the middle of the medulla and the pons and slightly beyond that is responsible for selective attention.
25. The _______________________ is a curved structure located within each temporal lobe responsible for the formation of long-term memories and the storage of memory for location of objects.

26. The ____________________ is a brain structure located near the hippocampus responsible for fear responses and memory of fear.
27. The _______________ is the outermost covering of the brain consisting of densely packed neurons that is responsible for higher thought processes and interpretation of sensory input.
28. The thick band of neurons that connects the right and left cerebral hemispheres is called the _________________ _______________.
29. The section of the brain located at the rear and bottom of each cerebral hemisphere containing the visual centers of the brain is the called the ________________ _______________.
30. The section of the brain located at the top and back of each cerebral hemisphere containing the centers for touch, taste, and temperature sensations is called the _______________________ ____________________________.
31. The __________________ _________________ are the areas of the cortex located just behind the temples containing the neurons responsible for the sense of hearing and meaningful speech.
32. The ____________________ ______________________ are areas of the cortex located in the front and top of the brain that are responsible for higher mental processes and decision making as well as the production of fluent speech.
33. The _____________________ glands secrete chemicals called hormones directly into the bloodstream.
34. The endocrine glands located on top of each kidney that secrete over 30 different hormones to deal with stress, regulate salt intake, and provide a secondary source of sex hormones affecting the sexual changes that occur during adolescence are called the ___________________ ____________________.

Word List for Fill in the Blanks

adrenal glands
agonists
amygdala
autonomic nervous

axon
cerebellum
corpus callosum
cortex
dendrites
electroencephalograph
endocrine
excitatory
frontal lobes
hippocampus
ions
myelin
nerves
nervous system
neuron
neurotransmitters
occipital cortex
parietal cortex
peripheral nervous
pons
resting potential
reticular formation
sensory neuron
soma
somatic nervous
spinal cord
sympathetic division
synaptic vesicles
temporal lobes
thalamus

Handout Master 2.3
Diagnostic Brain Imaging

For each of the following patients, use the information provided to determine which procedure or technology would be most helpful in determining a diagnosis. There are no perfectly right or wrong answers, but you are asked to provide a justification for why you chose each methodology.

1. Chris has seizures every day that involve his entire body. They are not helped by medication and now neurologists want to investigate where in the brain the seizures are starting so that they can consider if surgical removal might be an option. What procedure would you recommend they use and why?

2. Suttuchi has been having headaches and on occasion has gotten dizzy and has had to sit down to avoid passing out. The neurologists working with her believe that she may have a tumor that is pressing on critical areas of the brain. What procedure would you recommend they use and why?

3. Fayeed has been having problems moving the left side of his body for about 2 weeks. When asked about his experience, he remembered a day 2 or 3 weeks ago when he felt weak and for a little time had great difficulty finding the words he needed to tell his wife what he was feeling. His neurologists suspect that he has had a stroke or a series of strokes and want to determine how extensive the damage might be in the brain if that is the case. What procedure would you recommend they use to determine the potential damage in the brain?

4. Barrow is a youngster who is having extreme difficulty reading his schoolwork. He is in the fifth grade and should be fairly proficient now at reading. Doctors have thoroughly investigated his eyesight, eye tracking, and phonetic processing, but they believe that when he views the words, the right parts of the brain are not being used to decode the words. How might they further investigate these issues? Remember to defend your selection of procedure.

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REVEL FEATURES

Videos:

Opening Video: *The Biological Perspective*
Figure 2.1: The Structure of the Neuron
Figure 2.2: The Neural Impulse Action Potential
Figure 2.3: The Synapse
Figure 2.4: Neurotransmitters: Reuptake
Parts of the Brain
Figure 2.13: The Split-Brain Experiment
Figure 2.15: The Spinal Cord Reflex
Overview of Neuroplasticity
Applying Psychology to Everyday Life: Minimizing the Impact of Adult Attention-Deficit/Hyperactivity Disorder

Interactives:

Concept Map: 2.1–2.3 Neurons and Neurotransmitters
Concept Map: 2.4–2.5 Looking Inside the Living Brain
Concept Map: 2.6–2.10 The Structures of the Brain
Concept Map: 2.11–2.12 The Nervous System
Concept Map: 2.13–2.14 The Endocrine Glands

Social Explorer Survey: Do You Fight or Fly?

Journal Prompts:

[Module 2.2]

Thinking Critically 2.1
You may see a lot of brain imaging studies in the news or online. Thinking back to the research methods discussed in Chapter 1 (Learning Objectives 1.6–1.11), what kinds of questions should you ask about these studies before accepting the findings as valid?

[Module 2.5]
Thinking Critically 2.2
Some people think that taking human growth hormone (HGH) supplements will help reverse the effects of aging. If this were true, what would you expect to see in the news media or medical journals? How would you expect HGH supplements to be marketed as a result?

[Module 2.6]

Thinking Critically 2.3

1. What type of questions should you ask yourself when referring to case studies? Do the questions differ based on the case studies being modern or historical?
2. What kind of supports and structure might have been provided to Phineas through his post-accident jobs that would have possibly helped him with his recovery?
3. How might the modern study of psychology help us better understand other historical case studies?

Shared Writing Prompt:

Shared Writing: APA Goal 3: Ethical and Social Responsibility: The Biological Perspective
Dr. Z is conducting research on ADHD and is requiring members of his psychology class to participate. As part of the study, students are learning to control their brain activity by using feedback during an EEG. In doing so, half of the class is learning to enhance brain activity associated with improved attention. The other half is learning to increase brain activity associated with the inattentive symptoms of ADHD. He asks both groups to complete tests of attention and he shares the individual results of students in class, calling them by name and displaying their individual results. He did not gain approval from his university's institutional review board to conduct this study, claiming it was simply a pilot investigation. Refer back to the APA Ethical Guidelines discussed in Chapter 1. What guidelines and standards are being violated?

Experiment Simulations:

Simulation: Examples of Aphasia

PRACTICE QUIZZES ANSWER KEY

Chapter 2 Answer Key

2.1–2.3 Practice Quiz Answer Key:

1. c; 2. d; 3. b; 4. b; 5. b; 6. c

2.4–2.5 Practice Quiz Answer Key:

1. c; 2. b; 3. b; 4. d

2.6–2.10 Practice Quiz Answer Key:

1. b; 2. d; 3. c; 4. b; 5. b

2.11–2.12 Practice Quiz Answer Key:

1. c; 2. c; 3. b; 4. b; 5. c

2.13–2.14 Practice Quiz Answer Key:

1. b; 2. b; 3. c; 4. c

TEST YOURSELF ANSWER KEY

Chapter 2 Answer Key

Test Yourself
1. b; 2. c; 3. b; 4. c; 5. b; 6. d; 7. c; 8. b; 9. d; 10. c; 11. d; 12. d; 13. b; 14. d;
15. d; 16. b; 17. b; 18. a; 19. d; 20. d