CHAPTER 3

Chapter Summary

What analogies have been used to describe the brain through the ages?

The ancient Romans described the brain as being like a pump that propels fluids. In the eighteenth century, scientists suggested that the brain and the body are like a machine. In the nineteenth century, psychologists and physicians such as Freud proposed that the brain is an energy system. Over the past half-century, psychologists have suggested that the brain is like a computer.

What valuable points are highlighted by using a brain-as-tool analogy?

First, you can use a tool for tasks that didn't exist in the evolutionary past (e.g., reading). Second, when you use a tool to perform a job, it is you—not the tool—who is responsible for completing the job.

How have researchers demonstrated that the brain is like muscle?

Like a muscle, the brain grows with experience. Researchers found that among people who learned to juggle, there was growth in an area of the brain related to processing visual information, whereas no changes occurred in the brains of nonjugglers.

What can brain damage tell us about the structure and function of the brain?

Brain damage helps to identify which structures are associated with which functions. When the brain is damaged, some thinking abilities remain completely intact, whereas others are lost.

How does Aristotle's model of the brain compare to more recent conceptualizations of the brain?

In Aristotle's model, the vegetative mind is responsible for growth and reproduction; the animal mind is responsible for feelings of pleasure and pain; and the rational mind enables people to engage in logical thought. In MacLean's triune brain, a model proposed in the twentieth century, the reptilian brain, similar to the vegetative mind, executes simple functions like regulating body temperature and breathing; the paleomammalian brain, similar to the animal brain, produces emotions; and the neomammalian brain, similar to the rational mind, enables us to put experiences into words.

What did MacLean mean when he said that we have "three brains in one"?

MacLean, in his triune brain model, suggested that our contemporary human brains have three main parts that evolved at different points in history and that each performs unique functions. Each is, in a sense, a brain.

What are the structures of the lowest level of the brain and their functions?

The brain stem is made up of the medulla, the pons, and the midbrain. The medulla plays a major role in homeostasis. The pons contains structures that control your rate of breathing and also conveys signals among other brain regions. One region of the midbrain protects the organism by generating defensive reactions to threatening events. The reticular formation is a system that influences arousal. The cerebellum is involved in motor movement.

What are the structures of the middle level of the brain and their functions?

The limbic system includes the hypothalamus, the hippocampus, and the amygdala. The hypothalamus plays a critical role in the regulation of bodily states and behaviors such as eating, drinking, and sexual response. The hippocampus is a structure that you need for remembering and for spatial memory. The amygdala contributes to the processing of information about danger in risky situations.

Other structures in the limbic system include the fornix, the olfactory bulbs, and the cingulate gyrus. The fornix connects the hippocampus and the hypothalamus and helps them to work as a system. The olfactory bulbs are required for a sense of smell. The cingulate gyrus contributes to people's ability to stop themselves from doing one thing and to switch to something else.

What are the structures of the highest level of the brain and their functions?

The cerebral cortex consists of four lobes: occipital, parietal, temporal, and frontal. The occipital lobe, commonly called the visual cortex, is heavily involved in the processing of visual information and also becomes active when you engage in mental imagery. The parietal lobes contain brain matter needed for somatosensory processing. The sensory cortex of the parietal lobe receives sensory information from all parts of the body, which are, in essence, "mapped" onto the cortex. The temporal lobe is crucial to hearing and to memory. The auditory cortex of the temporal lobe is active whenever you listen to sounds, detecting their pitch, volume, and timing in relation to one another.

The frontal lobes enable humans to think about themselves; to set goals and stick to them; to control their emotions; and to recognize themselves as social beings who are evaluated by others. The frontal lobes also contain the motor cortex, which sends out signals that move the body's muscles. The association areas of the cerebral cortex receive sensory information and connect it to stored knowledge of the world. The prefrontal cortex contributes to the ability to concentrate on facts, focus attention, and manipulate information in the mind; and to the ability to align behavior with social rules and conventions.

What is the relation between the left and right sides of the brain?

Information from the left side of the body reaches the right cerebral hemisphere, and information from the body's right side reaches the left cerebral hemisphere. Similarly, commands sent out from the brain to the body switch sides. The hemispheres are connected through the corpus callosum, a structure containing more than 200 million cells that transmit signals from one side of the brain to the other.

As discussed in Cultural Opportunities: Arithmetic and the Brain, there are cultural variations in which parts of the left cerebral hemisphere are active during tasks such as arithmetic. Among native English speakers, an addition task activated the visual–spatial region and Broca's area; among Chinese speakers, Broca's area was almost entirely *in*active during arithmetic.

For what functions are the left and right sides of the brain specialized?

The left hemisphere specializes in analytic tasks, including arithmetic and the ability to produce and understand spoken language. The right hemisphere is specialized for spatial thinking, the ability to create images in your mind.

If the left and right sides of the brain were cut off from each other, would you have two brains? How do we know?

If the corpus callosum were severed, your left and right hemispheres would function as if they were two separate brains. Sperry and his colleagues placed patients in front of a projection screen, asked them to concentrate on a dot in the middle of the screen, and then briefly flashed words, simultaneously, on the screen’s left and right sides. When split brain patients were asked what word or words they saw, they inevitably named only the word on the right, though they were aware the other word had been shown and could even identify it by reaching for the correct object, as long as they did so with their left hand.

How does the architecture of our brains enable us to process large amounts of information simultaneously?

Even though different parts of the brain are specialized, the brain is organized into networks that enable communication between different regions. Many of these transmissions run through a brain structure known as the thalamus, which serves as a “relay station” for connections among brain regions.

What distinguishes nerve cells from other cells of the body?

Two features distinguish neurons from other cells: (1) their shape, which is unique due to the presence of dendrites and axons, and (2) their ability to communicate with one another, due to specialized structures found at synapses.

How do neurons communicate electrochemically?

Neurons produce action potentials, electrochemical events in which an electrical current travels down the length of the axon, from the soma to the axon terminals. When at rest, the neuron’s interior mostly contains substances that are charged negatively. On the outside of the cell are positively charged sodium ions. During an action potential, the sodium ions briefly enter the neuron through channels in the neuron's cell wall. This flow of charged particles generates an electric impulse. The electrical impulse moves down the length of the axon and is sped along by the myelin sheath, a fatty substance that surrounds the axon and acts as an electrical insulator.

How do neurons send signals from the axon terminal of one neuron to the dendrites of another?

A sending neuron stores neurotransmitters in small sacs known as synaptic vesicles, which move within the neuron, down the length of the axon. They reach the end of the axon and "dock" with the outer edge of the axon terminal, where they are able to release their neurotransmitters into the synapse. Some of these neurotransmitters reach receptors on dendrites of the receiving neuron. When a neurotransmitter from the sending neuron binds to the receptor of a receiving neuron, one bit of communication between neurons is complete.

As discussed in This Just In, neural communication can also occur outside of the synapse.

What determines whether a neuron will fire?

Neurotransmitters determine whether a receiving neuron will fire. Some neurotransmitters bind to receptors that increase the likelihood the neuron will fire, whereas others bind to receptors that decrease this likelihood. The receiving neuron integrates these inputs to determine whether to fire.

How do neurons stay in place?

Glial cells hold neurons in place, as well as support the biological functioning of neurons, supplying them with nutrients and disposing of the brain's biological waste matter.

What are the structures of the central nervous system and their functions?

The central nervous system consists of the brain and the spinal cord. The spinal cord participates in communications between the brain and body. In one direction, information from the environment is directed into the spinal cord and then passed on to the brain via sensory neurons. After outgoing messages from the brain reach the spinal cord, motor neurons send out signals to the body's muscles.

What are the structures of the peripheral nervous system and their functions?

The peripheral nervous system consists of the somatic nervous system and the autonomic nervous system. The somatic nervous system provides the brain-to-periphery communications that enable you to control your bodily movement. The autonomic nervous system provides the communications that control bodily functions generally *not* under your control. The autonomic nervous system is further divided into the sympathetic nervous system, which prepares you for action by activating the biological systems required for "fight" or "flight" responses, and the parasympathetic nervous system, which maintains normal functioning of the body when you are not under threat or stress.

What is the endocrine system and how does it differ from the nervous system?

The endocrine system is a collection of glands that produce and secrete hormones, which carry messages from the brain to organs via the bloodstream. The nervous system is fast and specific, whereas the endocrine system is slow with lingering effects. The nervous system communicates electrically, whereas the endocrine system's communications are entirely chemical.

What are the major endocrine glands and their functions?

The pineal gland produces a hormone called melatonin that influences patterns of sleeping and wakefulness. The pituitary gland releases hormones that influence biological activity in several other glands, including those that respond to stress, contribute to reproduction, and regulate the body's use of energy. It is also the point of contact between the nervous systems and endocrine system via the hypothalamus. The thyroid gland releases hormones that regulate the body's metabolic rate. The thymus produces hormones that influence the development and functioning of the immune system. The adrenal glands produce hormones that respond to stress, as well as sex hormones, which are produced also by the gonads. The pancreas releases hormones that include insulin, which regulates the level of sugar in the bloodstream. The gonads are the organs that produce reproductive cells; the ovaries in women produce ova (eggs) and the testes in men produce sperm. The gonads also produce hormones. The ovaries produce estrogens and progesterone; the testes produce testosterone.

How does estrogen affect memory and behavior?

The research of Pauline Maki and colleagues indicated that memory varied across the menstrual cycle; when estrogen levels were high, memory was superior. Martie Haselton and colleagues' research indicated that during high-fertility periods, women tended to wear more fashionable clothes that showed more skin—presumably to make themselves more sexually attractive.

Answers to What Do You Know?

1. analogies/metaphors

2. The statement is incorrect because the brain-as-tool analogy reminds us that it is the *person using the tool* (in this case, the brain) who performs the tasks.

3. Plasticity refers to how the brain changes physically as a result of experiences. In this way, it is like a muscle that increases in strength when used.

4. If parts of the brain were not specialized, Phineas Gage may have lost his ability to think or his thinking may have been impaired.

5. functional; blood

6. 1e, 2f, 3i, 4h, 5b, 6c, 7a, 8k, 9g, 10j, 11d

7. b. What is the right hemisphere?
   c. What is the corpus callosum?
   d. What is the right hemisphere?
   e. What is the field of vision on the right?

8. a. The brain's networks enable these functions.
   b. It is the thalamus that acts as a relay station.

9. The statement is incorrect because it was only among the native English speakers that Broca's area became active when they solved an arithmetic problem, illustrating that culture does, in fact, play a role in brain development.

10. 1c, 2g, 3i, 4h, 5d, 6a, 7b, 8f, 9e
11. synapse
12. a. What are sensory neurons?
    b. What are motor neurons?
    c. What are reflexes?
13. somatic; sympathetic; parasympathetic
14. Whereas the nervous system is fast and specific and communicates electrically, the endocrine system is slow and less specific and communicates chemically via hormones, which travel through the bloodstream.
15. 1b, 2d, 3g, 4f, 5a, 6e, 7c
16. fashionably/sexily/attractively

Answers to Self-Test

1. c
2. b
3. c
4. c
5. b
6. b
7. a
8. d
9. d
10. c
11. d
12. a
13. a
14. d
15. d