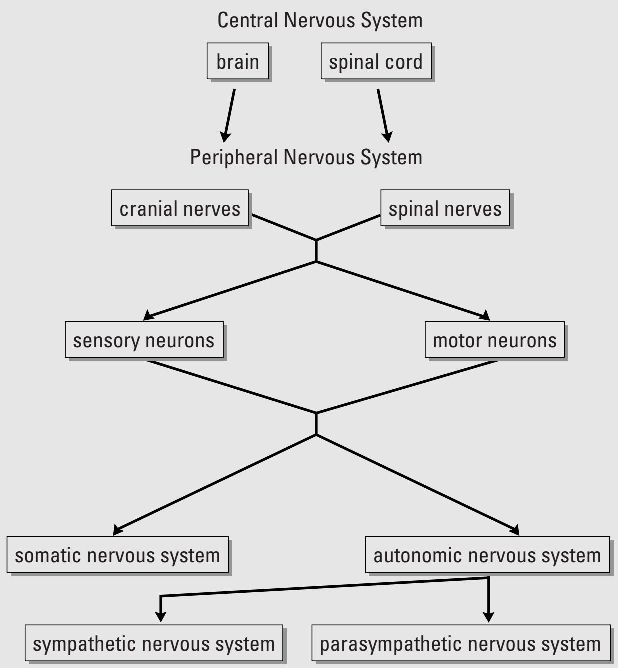
Chapter 11: Review Answers

Student Textbook pages 402–403

Answers to Understanding Concepts Questions

1. The following is a possible flow diagram showing the main divisions of the nervous system.



The central nervous system, composed of the brain and spinal cord, communicates with the peripheral nervous system, which contains the nerves. In the somatic system, nerves conduct impulses from sensory receptors to the central nervous system and motor impulses from the central nervous system to the skeletal muscles. In the autonomic system, consisting of the sympathetic and parasympathetic divisions, motor impulses travel to smooth muscle, cardiac muscle, and the glands.

2. If the right side of the motor cortex were damaged, the left side of the body would be affected. The right and left hemispheres communicate through nerve fibre bundles that cross from one side of the body to the other (through the corpus callosum). As a result, the right side of the brain controls the left side of the body and vice versa.

3.

Label	Structure	Brain functions that may be affected
A	parietal lobe	■ ability to distinguish specific sensations (depends on the exact location of the stroke)
B	occipital lobe	■ vision
C	frontal lobe	■ ability to move specific skeletal muscles (depends on the exact location of the stroke) ■ memory ■ ability to speak
D	temporal lobe	■ hearing and/or ability to understand speech

4. The sympathetic division of the autonomic nervous system sets off the fight-or-flight reaction that prepares the body to deal with an immediate threat. When this system is stimulated, heart rate and breathing rate increase and glucose is released from the liver into the bloodstream. These reactions are designed to deliver more oxygen and glucose to the skeletal muscles to provide the energy required to deal with the threat.

The parasympathetic division has an effect opposite to that of the sympathetic nervous system. When a threat has passed, the nerves of this system slow heart rate and breathing rate and reverse the effects of the sympathetic nervous system.

5. Scientists think that epilepsy can be caused by an overload of neurological electrical activities, and epileptic seizures may spread rapidly from one hemisphere to the other by way of the corpus callosum. Severing a part or all of the corpus callosum greatly reduces this spread.

6. Acetylcholine is a neurotransmitter that crosses a neuromuscular junction. When it binds to the receptor proteins in a muscle cell membrane, acetylcholine causes depolarization and contraction of the muscle fibre. An enzyme called cholinesterase is released into a synapse, where it breaks down acetylcholine. Cholinesterase is one of the fastest acting enzymes; it breaks down acetylcholine so that it can be removed from the protein receptors, thus allowing the ion channels to close and the membrane to repolarize in a fraction of a second.

7. If a person complains of a noticeable decrease in muscle coordination after an injury, one might expect that the cerebellum was damaged. The cerebellum sends motor impulses by way of the brain stem to the skeletal muscles. It ensures that all of the muscles work together to produce smooth, coordinated voluntary muscle movements. Damage to the frontal lobe of the cerebral cortex might also produce those symptoms.

8. Students' diagrams should represent a reflex arc as shown in Figure 11.8 on page 370. The diagram should indicate the following pathway:

pain receptor (stimulated by hammer) → sensory neuron (takes impulse to the spinal cord) → interneuron (integrates data from sensory neuron and relays signals to motor neurons) → motor neurons (convey nerve impulses from the spinal cord to skeletal muscles in the arm and hand) → skeletal muscles respond (drop hammer)

9. Spinal nerves are connected to the spinal cord (see Figure 11.23 on page 386 of the student textbook). Each spinal nerve contains sensory fibres that conduct impulses to the spinal cord from sensory receptors when a stimulus is applied. The sensory impulses travel up the spinal cord to the brain to process the information. However, if the spinal cord is damaged, the sensory information cannot get to the brain and the person does not detect any sensory stimuli applied below the injured area.

10. Compare to Figure 11.6 on page 369 of the student textbook.

Label	Structure	Functions
A	sensory neuron	takes messages from sensory receptors to the central nervous system
B	interneuron	■ receives input from sensory neurons and other interneurons in the CNS ■ sums up all messages received from these neurons before communicating with motor neurons
C	motor neuron	carries messages from the CNS to an effector (another neuron, muscle, or gland)
D	sensory receptor	responds to specific stimuli, i.e., pain, temperature, pressure
E	cell body	contains the nucleus as well as the other organelles required to keep the cell functioning
F	dendrite	receives signals from other neurons and sends them to the cell body
G	axon	conducts nerve impulses away from the cell body toward other neurons or other effectors
H	Schwann cell	forms the myelin sheath to protect the axon
I	node of Ranvier	appears as a gap where there is no myelin sheath; is involved in the saltatory conduction of the nerve impulse in myelinated neurons
J	effector (muscle)	carries out responses to motor impulses

11. The CNS is composed of two types of nervous tissue—grey matter and white matter. Grey matter is nervous tissue characterized by many nerve cell bodies and unmyelinated axons. White matter is composed of axonal nerve fibres, covered by a myelin sheath. In the brain, the white matter forms a central core and the grey matter forms a layer on the outside. In the spinal cord, the white matter is on the outside and the grey matter forms an H-shaped core. The myelinated axons in white matter run together in tracts and take nerve impulses to and from the brain. The grey matter includes regions of the brain involved in muscle control; sensory perceptions, such as seeing and hearing; memory; emotions; and speech.

12. Multiple sclerosis (MS) is a disease of the "white matter" tissue. The white matter is made up of myelinated nerve fibres responsible for transmitting communication signals both within the CNS and between the CNS and the nerves supplying the rest of the body. People with MS can experience partial or complete loss of any function that is controlled by, or passes through, the brain or spinal cord.

13. The diagram should resemble Figure 11.12 found on page 374. Yellow circles represent Na^+ and green circles represent K^+; yellow openings in the membrane represent Na^+ ion channels and green openings represent K^+ ion channels. The diagram should indicate that when a neuron is at rest, the outside of the membrane of the neuron is positively charged compared to the inside, which is at –70 mV. This is the result of the uneven distribution of positively and negatively charged ions. The diagram should show that outside the cell there is a high concentration of sodium (Na^+) ions and a lower concentration of potassium (K^+) ions. Inside the cell there is a high concentration of K^+ and a lower concentration of Na^+, as well as negatively charged ions such as chloride (Cl^-) and proteins (not shown in Figure 11.12). A neuron achieves this state in 3 ways: proteins and chloride ions (Cl^-) are trapped inside the cell and unable to diffuse out through the selectively permeable cell membrane; special membrane proteins can use the energy of ATP to pump charged particles across the membrane, but they move out 3 sodium ions for every 2 potassium ions pumped into the cell; and more ion-specific channels allow potassium ions to diffuse down their concentration gradient and out of the cell than channels allowing sodium ions to move into the cell.

14. The diagram of depolarization and the action potential should be similar to Figure 11.13 on page 376. When a neuron receives a stimulus, a wave of depolarization is triggered. When this occurs, the gates of the K^+ channels close and the gates of the Na^+ channels open. The number of channels that will open varies depending upon the strength of the stimulus. Sodium ions move into the axon until the charge inside the neuron reaches –55 mV; this is called the threshold potential. When the threshold potential is reached, large numbers of sodium ion channels open, causing the inside of the neuron to become positively charged at +35 mV. This change in charge is called the action potential. The depolarization of one part of the axon causes the Na^+ channels in the neighbouring region of the axon to open, and this depolarization continues along the length of the axon.

The diagram showing repolarization should resemble Figure 11.14 on page 376. Any specific region of the axon is only depolarized for a split second. Almost immediately after the Na^+ channels open, the gates of the K^+ channels re-open and K^+ ions move out of the neuron. The Na^+ channels close at the same time. This process, combined with rapid active transport of Na^+ ions out of the axon by the Na^+/K^+ ion pump, reestablishes the polarity of that region of the axon.

15. The axons of some neurons are enclosed in a fatty, insulating layer called the myelin sheath. (Schwann cells form the myelin sheath by wrapping themselves around the axon.) The myelin sheath is segmented, i.e., not a continuous layer like the plastic insulation surrounding a copper wire. Gaps, called nodes of Ranvier, exist between segments of myelin. A saltatory conduction takes place when the action potentials jump from one node of Ranvier to the next node. ("Saltatory" comes from the Latin word meaning to leap.)

The action potentials in an unmyelinated neuron occur all along the axon. Therefore, they occur beside one another. As a result of so many action potentials occurring all along the axon, the transmission of an impulse along an unmyelinated axon is much slower than the saltatory conduction along a myelinated axon.

16. If the neurotransmitter has an inhibitory effect, the receptor protein will trigger hyperpolarization of the membrane. This means that the inside of the axon will become even more negatively charged. As a result, the membrane will not depolarize and there is no action potential.

Answers to Applying Concepts Questions

17. (a) (Note: Make sure students understand that this question is asking about threshold potential of the neuron, not the threshold level of the size of the stimulus. It would be better to use the term "threshold" only for threshold potential here.) Threshold potential is the minimum change in the membrane potential that will allow an action potential to be generated; in mammals, the stimulus has to be strong enough to cause enough sodium channels to open to change the inside voltage of the neuron to at least –55 mV. In this neuron, the minimum size of the stimulus required for the neuron to reach threshold potential is 2 mV. (Note: Accept a student's answer with any voltage greater than 1 mV but less than or equal to 2 mV.)

(b) An axon is governed by the all-or-none principle. If an axon is stimulated sufficiently (above the threshold potential), the axon will trigger an impulse down the length of the axon. The strength of the response is uniform along the entire length of the axon. Also, the strength of response in a single neuron is independent of the strength of the stimulus. An axon cannot send a mild or a strong response; it can only respond or not respond. Increasing the strength of the stimulus will not affect the amount of mass that the muscle can lift. The muscle will lift a mass of 10 g no matter what the size of the stimulus is.

(c) An example of a sensory neuron is one that leads from a pain receptor in the finger to the spinal cord. A pin can be pressed against the skin without eliciting a response from the pain receptor; therefore an impulse is not generated in the sensory neuron. In other words, the size of the stimulus is not sufficient to cause the neuron to reach the threshold potential. However, if the pin is lightly jabbed into the finger, the pain receptor may be stimulated and an action potential generated in the sensory neuron heading toward the spinal cord. In other words, a threshold potential stimulus is applied and an action potential is generated in the neuron. If the pin is rammed into the finger, that one pain receptor responds and an action potential is generated in the sensory neuron. However, the strength of the action potential in that one neuron would be exactly the same. A neuron cannot send a mild or a strong response; it can only respond or not respond (all-or-none principle). The person would likely sense a greater level of pain in the last scenario, but that response would be due to more pain receptors being stimulated, thus generating action potentials in more neurons.

18. The frontal lobe of the cerebral cortex is most related to memory. Students' answers could name three other functions for this lobe from the following: conscious thought, intelligence, personality, voluntary muscle movements, and motor speech (Broca's area). One of the characteristics of Alzheimer's disease is the loss of short-term memory.

19. (a) The primary motor area in the frontal lobe would direct the movement of the robotic arm.

(b) Neural pathway: visual information (occipital lobe) → somatosensory area of the cerebral cortex → impulse from motor cortex → spinal cord → impulse travels down wires of robotic arm → skeletal muscles in robotic arm contract. Students should also note that the cerebellum coordinates the muscle movements ordered by the motor cortex.

Sensors in the artificial limb send messages back through wires to the spinal cord. Myelinated neurons in the spinal cord transmit this sensory information to the cerebellum and the parietal lobe of the brain. These impulses are interpreted in these areas so the monkey knows where and how its artificial arm is moving and what position it is in. This feedback results in smooth, coordinated motion.

(c) visual information (occipital lobe) → somatosensory area of the cerebral cortex → impulse from motor cortex → spinal cord → impulse travels down motor neuron of the peripheral nervous system → skeletal muscles in the arm contract

(d) Potential applications for this technology include providing so-called "intelligent" prosthetic devices for a person whose arm or leg has been amputated or whose motor function has been lost or impaired due to a spinal cord injury.

(e) The answer to this question will depend on the students' point of view. Some feel it is unethical to do any type of testing using animals. Others may feel that animal testing that provides a direct benefit to humans is acceptable.

20. There are two reasons why an action potential can travel in only one direction along the axon. The first reason is related to the depolarization and repolarization of the neural membrane and is explained below:

- An action potential generates local currents that tend to depolarize the membrane of the neuron immediately adjacent to the action potential.
- When depolarization caused by local currents reaches threshold levels, a new action potential is produced adjacent to the original one.
- Action potential propagation occurs in one direction because the recently depolarized area of the neural membrane is in an absolute refractory period and cannot generate an action potential.

The second reason is that nerve impulses can travel only from the axon of one neuron to the dendrite(s) of the next neuron. This can be explained as follows:

- The synapse is the gap between the axon of the first (presynaptic) neuron and the dendrite(s) of the second (postsynaptic) neuron.
- The end of every axon ends in a bulb.
- After an action potential arrives at the axon bulb, synaptic vesicles fuse with the membrane of the presynaptic neuron.
- Neurotransmitter molecules are released into the synapse and bind to receptors on the postsynaptic membrane.
- When a stimulatory neurotransmitter binds to a receptor on the postsynaptic membrane, an action potential is generated in the dendrites of the second neuron.

Nerve impulses travelling in both directions would be similar to vehicles going in both directions in the same lane of a freeway. It would be chaos!

21. (a) A stimulus large enough to cause the neuron to reach threshold potential is what starts the action potential in the neuron.

(b) This demonstrates part of the all-or-none response—the action potential is either generated by the stimulus or it isn't (just like the domino either falls or it doesn't).

(c) This would be described as the propagation of the action potential along the neuron in a real neuron.

(d) The impulse travels in one direction in a neuron as well.

(e) This event is also explained by the all-or-none response in a neuron. An axon cannot respond with a mild or a strong response; it can only respond or not respond. A stimulus that is strong enough to produce the threshold potential in the neuron will generate an action potential.

Answers to Making Connections Questions

22. Testing the blood would not provide any information about the meninges because of the blood-brain barrier. The meninges protect the central nervous system by preventing the direct circulation of blood through the cells of the brain and spinal cord. This separation of the blood and central nervous system is called the blood-brain barrier. Testing of the cerebrospinal fluid for the bacteria that cause meningitis, on the other hand, would provide the needed information. The cerebrospinal fluid transports hormones, white blood cells, and nutrients across the blood-brain barrier for cells of the brain and spinal cord. It also circulates between two layers of the meninges, the arachnoid and pia mater. The bacteria that cause meningitis would be found in this fluid.

23. The threshold potential is the minimum change in the membrane potential that is required to generate an action potential in a neuron (e.g., from –70 mV to –55 mV in mammals). People with a higher tolerance to pain must have sensory neurons that require a greater stimulus in order for the neurons to achieve the threshold potential than do those people with a lower tolerance for pain.

24. Acetylcholine is one of the prominent neurotransmitters of the somatic and the parasympathetic nervous systems. If botulinum toxin inhibits acetylcholine, the neurotransmitter that relays nerve signals to muscles, the nerves will be prevented from signalling the muscles to contract. The result is weakness and paralysis that descends from the cranium down, affecting, among other things, the muscles that regulate breathing.