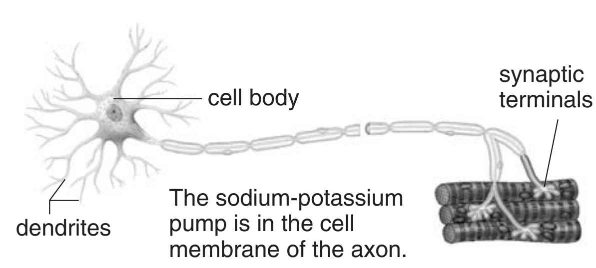
Unit 5: Review Answers

Student Textbook pages 466–469

Answers to Understanding Concepts Questions

1. Students' answers should be similar to the illustration below.



2. The Schwann cell is the glial cell that is responsible for increasing the speed of a nerve impulse. The Schwann cell produces the myelin sheath. The myelin sheath greatly enhances the speed of impulse conduction by forcing the

impulse to jump from node to node along the axon, a process known as saltatory conduction.

3. (a) Neuron 2—sensory neuron; takes sensory impulse from sensory receptor to the central nervous system

Neuron 3—connector neuron; conducts impulse from primary somatosensory area of the parietal lobe to the primary motor area of the frontal lobe

Neuron 5—motor neuron; takes motor impulse from the brain to the muscle (effector) in the hand

(b) (1) pain receptor is stimulated by pain (the stimulus) and generates action potential

(2) sensory neuron is stimulated and conducts a nerve impulse to the spinal cord

(3) the sensory impulse is analyzed by neurons in the primary somatosensory area of the brain; neurons send information to the primary motor area in the frontal lobe

(4) thalamus is the major relay for all incoming sensory stimuli

(5) motor neuron brings an impulse from the central nervous system to an effector (muscle)

(6) muscles in the finger receive the impulse from the cerebral cortex and respond (pull away from the door)

(c) The two brain structures at number 3 are the primary somatosensory area found in the parietal lobe (right on diagram) and the primary motor area found in the frontal lobe (left on diagram).

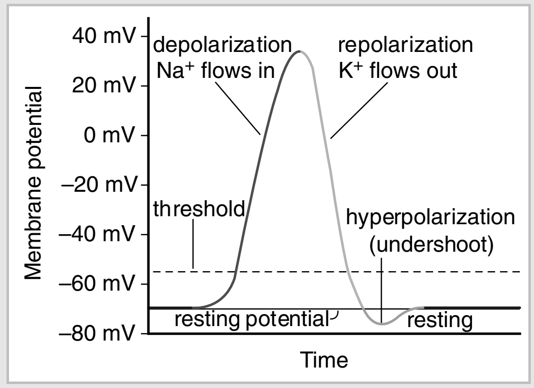
(d) Number 4 is the thalamus, and it is the primary relay centre for incoming sensory impulses.

(e) This nerve pathway involves sensory information travelling to the cerebral cortex where the pain sensation is perceived by the sensory areas of the brain and where impulses controlling voluntary body movement are generated. Reflex arcs, on the other hand, are simple connections of neurons. Withdrawal reflexes, for example, depend on only three neurons. Receptors in the skin sense the pressure of the door closing on the finger and initiate an impulse in a sensory neuron. The impulse is carried by the sensory neuron and then activates the interneuron in the spinal cord. The interneuron signals the motor neuron to instruct the muscle to contract and withdraw the hand. Responses to many pain stimuli (such as touching a hot stove) involve the reflex arc rather than the nerve pathway shown in the diagram.

(f) If the tissue in the finger is damaged, special cells release chemicals that trigger pain receptors to send impulses to the brain. Painkillers such as Aspirin™ block the release of these chemicals, which helps to alleviate the pain.

4. If the BSE is affecting co-ordination, students would infer that the cerebellum and/or the primary motor cortex of the brain has been affected by this disease.

5.



6. In this flowchart,

A—represents the central nervous system; integrates and processes information sent by nerves

B—represents the brain (or spinal cord, whichever wasn't identified as C)

C—represents the spinal cord (or brain, whichever wasn't identified as B)

D—represents the peripheral nervous system

E—represents the somatic nervous system; relays information to and from skin and skeletal muscles under conscious control

F—represents the autonomic nervous system; relays information to internal organs not under conscious control

G—represents the sympathetic or parasympathetic nervous system (whichever wasn't identified as H); sympathetic controls organs in times of stress (fight or flight) while parasympathetic causes return to state of rest and controls organs when body is at rest

H—represents the parasympathetic or sympathetic nervous system (whichever wasn't identified as G); sympathetic controls organs in times of stress (fight or flight) while parasympathetic causes return to state of rest and controls organs when body is at rest

7. Students can select any three of the following:

(1) eye—photoreceptors (rods and cones) relay information that is interpreted by neurons in the occipital lobe (primary visual area and the visual association area)

(2) ear—mechanoreceptors (hair cells) in the inner ear relay information that is interpreted by neurons in the auditory association area of the temporal lobe

(3) ear—mechanoreceptors (hair cells) in the inner ear relay information that is interpreted by neurons in the cerebellum and in the primary motor area of the frontal lobe

(4) nose—chemoreceptors (olfactory receptors) in the nose relay information that is interpreted by neurons in the olfactory bulb

(5) tongue—chemoreceptors (taste buds) in the tongue relay information that is interpreted by neurons in the primary taste area of the parietal lobe

(6) skin—thermoreceptors (heat and cold receptors) in the skin relay information that is interpreted by neurons in the primary somatosensory and somatosensory association area in the parietal lobe

8. Mechanoreceptors transduce mechanical pressure, sound waves, fluid movement, or muscle contraction into electrochemical impulses. The human senses that rely on this type of receptor include touch, pressure, pain, hearing, balance, and body position.

Photoreceptors transduce visible light energy into electrochemical impulses. The human sense that relies on this type of receptor is vision.

Chemoreceptors transduce food particles in saliva, odour molecules, low blood volume, or blood pH into electrochemical impulses. The human senses that rely on this type of receptor include taste, smell, and internal senses.

Thermoreceptors transduce changes in radiant energy into electrochemical impulses. Heat and cold are detected by these sensory receptors.

9. The structures of the eye that light passes through on its way to the photoreceptors are:

- cornea—the transparent part of the sclera at the front of the eye
- anterior chamber—the chamber in front of the lens containing a clear, watery fluid called the aqueous humour
- pupil—opening in the iris for light to enter the inner eye
- lens—structure for focussing light onto the retina
- posterior chamber—the chamber behind the lens containing a clear, jelly-like fluid called the vitreous humour
- retina—thin layer of tissue containing photoreceptors and other cells
- axons of ganglion cells—form the optic nerve that exits the eye
- ganglion cell layer
- bipolar cell layer
- photoreceptors (rods and cones)

The light-detecting cells (photoreceptors) of the retina are the rods and cones. The rods are sensitive to dim light while the cones are sensitive to different wavelengths of light (colour vision).

10. The semicircular canals contain mechanoreceptors that detect head and body rotation while the person is dancing. These receptors help to maintain rotational equilibrium.

The balance required while moving the head forward and backward (watching birds fly overhead) is called gravitational equilibrium. Gravitational equilibrium depends on the utricle and saccule, which together make up the fluid-filled vestibule of the inner ear.

The semicircular canals are three fluid-filled loops, arranged in three different planes. The base of each semicircular canal contains a gelatinous material called a cupula. The stereocilia of the hair cells in the semicircular canals stick into the cupula. When the head rotates, the material inside the semicircular canals moves and bends the stereocilia, causing hair cells to send rotational information to the brain.

Both the utricle and saccule contain calcium carbonate granules, called otoliths. The otoliths lie in a cupula over a layer of hair cells. When the head dips forward or back, gravity pulls on the otoliths. This puts pressure on some of the hair cells, causing them to send a neural impulse to the brain, indicating the position of the head.

11. The structures of the outer ear include the pinna and auditory canal. The auditory canal amplifies sound waves, effectively making sounds louder.

The middle ear is an air-filled space that is bordered on one side by the tympanum. The tympanum vibrates in response to sound waves. When sound waves push the tympanum, its vibrations are passed on and amplified by the neighbouring ossicles: three tiny, interconnected bones in the middle ear. The ossicles amplify the sound waves. The stapes concentrates vibrations onto the bony wall of the inner ear, called the oval window. The middle ear can significantly amplify and concentrate vibrations.

The cochlea is found in the inner ear. It is within the structures of the cochlea that the mechanical energy of sound is converted into electrochemical impulses that are transmitted to the brain.

12. The following flowchart shows how light is transformed into a nerve impulse:

light is focussed on photoreceptors (rods and cones) → reaction stops the release of inhibitory neurotransmitters into the synapse → bipolar cells transfer a neural impulse to the ganglion cells → axons of ganglion cells form the optic nerve

13. The aqueous humour helps to maintain the shape of the cornea and provides oxygen and nutrients for the surrounding cells. The vitreous humour maintains the shape of the eyeball and provides support for the cells of the eye.

14. The process is called light adaptation. In bright light, the iris constricts, which shrinks the pupil to let in less light. In dim light, the iris dilates, which widens the pupil and lets in more light.

15. The similarities between neurotransmitters and hormones include:

- both are stored in cells for later release
- stimulation of cells prompts release
- many molecules function as both a hormone and a neurotransmitter
- both require a specific receptor for action
- both can act through second messenger systems
- both include responses that are regulated by negative feedback loops

The differences between neurotransmitters and hormones include:

- neurotransmitters act more rapidly than hormones
- neurotransmitters are released in precise locations, whereas hormones are secreted into the blood, where they are transported to their target cells
- the actions of hormones are longer acting and hormones affect a broader range of cell types

16. The table below summarizes the ways in which the sympathetic and parasympathetic nervous systems act antagonistically.

Category	Sympathetic nervous system	Parasympathetic nervous system
neurotransmitter	norepinephrine	acetylcholine
tear glands	inhibits tears	stimulates tears
pupils	dilates pupils	constricts pupils
salivary glands	inhibits salivation	stimulates salivation
air passages	dilates air passages	constricts air passages
heart	increases heart rate	slows heart rate
intestines	decreases intestinal activity	increases intestinal activity
bladder	inhibits urination	stimulates urination

Note: The sympathetic nervous system also affects the liver (stimulates it to release glucose), adrenal glands (stimulates the adrenal medulla), and kidney (inhibits its activity), but there are no corresponding antagonistic effects by the parasympathetic nervous system.

17. The human system that would be most important in each of the following activities is:

(a) The nervous system would be most important when driving a car. The sense of vision, the making of rapid decisions, and the voluntary control of muscles in the arms and legs are all under control of the nervous system and are all required to drive a car.

(b) The endocrine system is more important for raising your blood glucose levels when you are hungry. As blood glucose levels drop, the pancreas secretes the hormone glucagon into the bloodstream. Glucagon stimulates the liver to convert glycogen back into glucose, which is released into the blood. Glucagon also breaks down fat in adipose tissue to form glucose. Both of these events increase blood glucose levels.

(c) The nervous and endocrine systems would play a role in regulating your blood glucose levels when you are playing soccer. The fight-or-flight response of the sympathetic nervous system would be stimulated in a competitive situation. The adrenal glands would be stimulated to release epinephrine, which raises blood glucose levels. The adrenal glands would secrete cortisol, which also raises blood glucose levels. Cortisol does this by promoting the breakdown of fat cells, which releases glucose.

18. Note: Refer students to Section 9.3, page 316 if they do not remember how ADH works.

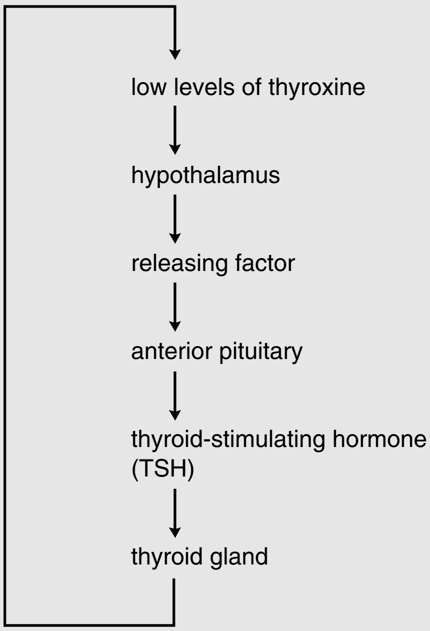
Being active on a hot day can result in your body's becoming dehydrated, which increases the concentration of the blood. When blood plasma becomes too concentrated, osmoreceptors in the hypothalamus respond by sending nerve impulses to the posterior pituitary gland. The posterior pituitary releases antidiuretic hormone (ADH). ADH increases the permeability of the distal tubule and the collecting duct, allowing more water to be reabsorbed into the blood. This produces more concentrated urine (less water is lost in the urine).

As well, if you are perspiring, you are losing sodium (Na^+ ions). A drop in blood Na^+ concentration is normally compensated for by the kidneys under the influence of the hormone aldosterone. This hormone stimulates the distal tubules and collecting ducts to reabsorb more Na^+ ions. Because the reabsorption of Na^+ ions is followed passively by chloride (Cl^-) ions and water, aldosterone has the net effect of retaining both salt and water.

19. The short-term response to the fire alarm is called the fight-or-flight response. The adrenal medulla produces two closely related hormones: epinephrine and norepinephrine. The effects of these hormones on the body are similar to those caused by the sympathetic nervous system. Like the sympathetic nervous system, the hormones of the adrenal medulla prepare the body for fight-or flight by increasing metabolism. In response to the fire alarm, neurons from the sympathetic nervous system carry a signal from the hypothalamus directly to the adrenal medulla. These neurons stimulate the adrenal medulla to secrete epinephrine and norepinephrine. These hormones trigger an increase in breathing rate, blood pressure, blood flow to the heart and muscles, and the conversion of glycogen to glucose in the liver.

20. The lack of iodine in the diet can result in the formation of an enlarged thyroid gland (goitre). Iodine is required

for the formation of the thyroid hormone called thyroxine. The following feedback loop can be used to explain how this happens.



If there was sufficient iodine in the diet, the thyroid gland would release thyroxine. The higher levels of thyroxine would cause negative feedback on the pituitary and hypothalamus, shutting down the production of TSH. However, without iodine, the thyroid gland cannot produce thyroxine and there will be no signal to stop the secretion of TSH. The relentless stimulation of the thyroid gland by TSH causes a goitre (enlargement of the thyroid gland).

21. The challenges faced by early endocrine researchers included the following:

- The removal by researchers of specific endocrine glands did not always provide useful results because different hormones often work together; in fact, another gland or hormone can compensate for one that is missing.
- The concentration of most hormones in the bloodstream is extremely low.
- Some hormones are not released continuously, so they are difficult to measure.

22. Each target cell contains receptor proteins embedded in the cell membrane. Circulating hormones bind to their specific receptor proteins, much like a key fits into a lock. When the hormone binds to its receptor, it triggers other reactions in the target cell.

23. The sympathetic nervous system and the adrenal medulla produce hormones that regulate a short-term response to stress, commonly referred to as the fight-or-flight response. In response to a stressor, neurons of the sympathetic nervous system release a neurotransmitter called norepinephrine. Other neurons from the sympathetic nervous system carry a signal from the hypothalamus directly to the adrenal medulla. These neurons (rather than hormones) stimulate the adrenal medulla to secrete epinephrine and norepinephrine. The combined action of the neurotransmitter and the hormones triggers an increase in breathing rate, heart rate, blood pressure, blood flow to the heart and muscles, and the conversion of glycogen to glucose in the liver.

24. The alpha cells in the pancreas of a person with type 1 diabetes degenerate and are unable to produce insulin. This condition is treated by regular injections of insulin. A diabetic's blood glucose level can drop dangerously low if he/she injects too much insulin or has not eaten properly. The juice or candy bar can provide the sugar required to bring blood glucose up to normal levels.

25. **(a)** The pituitary gland is often referred to as the "master gland" because it releases tropic hormones that actually regulate the action of other endocrine glands.

(b) Neurosecretory cells produce releasing and release-inhibiting hormones. These hormones are secreted into a portal system. Each type of hypothalamic hormone either stimulates or inhibits production and secretion of an anterior pituitary hormone. The anterior pituitary secretes its hormones into the bloodstream.

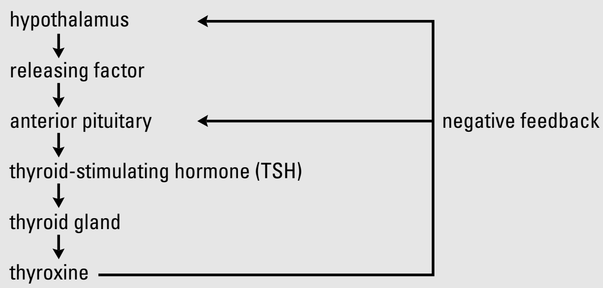
Students' answers could either support or reject the "master gland" label assigned to the pituitary gland. Some students might argue that the hypothalamus is part of the brain and not a separate endocrine gland. In this case, the name "master gland" given to the pituitary gland is suitable. Other students might argue that the hypothalamus should be called the "master gland" because it is actually controlling the pituitary gland.

26. Diabetes insipidus develops when the hypothalamus does not produce sufficient quantities of antidiuretic hormone (ADH). ADH controls the amount of water reabsorbed from the tubules and collecting ducts of the nephron. Without ADH, less water is reabsorbed and the person produces large volumes of urine. People with this disorder are also thirsty most of the time because they are losing so much water in their urine.

27. **(a)** Human growth hormone, epinephrine, cortisol, and glucagon are hormones that increase blood glucose levels. Insulin is the hormone that lowers blood glucose levels.

(b) One possible hypothesis is that because the regulation of blood glucose levels is critical to human health, the human body has evolved a number of glands to regulate this process. Another possible hypothesis is that if one gland is damaged or destroyed, then hormones from other glands can compensate for the loss.

28. A possible flowchart for TSH is shown below:



TSH is a tropic hormone because it stimulates another endocrine gland (the thyroid gland) to release a hormone (thyroxine).

29. The three groups of hormones produced by the adrenal cortex are:

- glucocorticoids (cortisol), which raise blood glucose levels
- mineralocorticoids (aldosterone), which stimulate the nephrons of the kidneys to increase the absorption of sodium into the bloodstream. This increases the solute concentration of the blood, which then draws more water from the nephrons, raising blood pressure.
- gonadocorticoids (female and male sex hormones), which supplement the hormones produced by the gonads (testes and ovaries)

30. The following chart is one type of graphic organizer that could be used to organize the endocrine structures and their functions listed in the question.

Controlling structure or tropic hormone	Endocrine gland	Hormone secreted	Target tissues/organs and the function/action of the hormone
hypothalamus	anterior pituitary	human growth hormone (hGH)	stimulates cell division, bone and muscle growth, and metabolic functions
hypothalamus	anterior pituitary	thyroid-stimulating hormone (TSH)	stimulates the thyroid gland to release thyroxine
hypothalamus	anterior pituitary	adrenocorticotropic hormone (ACTH)	stimulates the adrenal cortex to secrete glucocorticoids such as cortisol
hypothalamus	posterior pituitary	antidiuretic hormone (ADH)	promotes the retention of water by the kidneys
TSH	thyroid	thyroxine	affects all tissues; increases metabolic rate and regulates growth and development
ACTH	adrenal cortex	cortisol	stimulates tissues to raise blood glucose and break down protein
short-term stress (danger)	adrenal medulla	epinephrine and norepinephrine	fight-or-flight hormones, raise blood glucose levels
low blood glucose levels	pancreas	glucagon	raises blood glucose levels
high blood glucose levels	pancreas	insulin	lowers blood glucose levels

Answers to Applying Concept Questions

31. Five possible physiological conditions that were probably not operating at homeostasis in Chris Legh's body at the end of the race include the following:

- Dehydration becomes likely when a race is run in extreme heat and humidity. Dehydration causes an increase in blood osmotic pressure that stimulates osmoreceptors in the hypothalamus, triggering the thirst reflex. Osmoreceptors in the hypothalamus would also signal the posterior pituitary to release ADH in an attempt to reabsorb water from the kidney tubules. The adrenal cortex would also release aldosterone. Aldosterone stimulates the nephrons of the kidneys to increase the absorption of sodium into the bloodstream. This increases the solute concentration of the blood, which then draws more water from the nephrons.
- Difficulty regulating body temperature is possible. If the athlete was competing on a hot, humid day, then heat stroke is a possibility. In Biology 20, students learned that an important function of the blood is to maintain homeostasis, especially in relation to temperature regulation. When the body's internal environment becomes too warm, blood transports heat from where it is formed by cellular respiration and muscle activity to the blood vessels of the skin. Under the control of the nervous system, these blood vessels dilate (vasodilation) to increase the amount of blood flowing to the skin, which, in turn, results in more heat being lost from the skin.
- Difficulty regulating blood glucose levels could develop. These athletes are using tremendous quantities of glucose to provide the energy required by their muscles. This could result in hypoglycemia (low blood sugar).

Hypoglycemia can cause dizziness, confusion, and loss of consciousness. Glucagon from the pancreas, as well as epinephrine and cortisol from the adrenal glands, would be released in an attempt to raise blood glucose levels. However, the result would be a depletion in muscle glycogen supplies, which would contribute to muscle fatigue and cramping.

- Difficulties with the gastrointestinal tract are likely in Ironman Triathletes. These disorders are likely linked to the reduction of blood flow to the intestines. Stimulation of the sympathetic nervous system can result in decreased activity of the intestines, which could contribute to this problem.
- Overhydration (drinking too much water) can result in low sodium in the blood, a condition known as hyponatremia. This condition can result in serious consequences such as death. (Note: See also the answer to Unit Review question #41.) Students may be interested in the following details: Hyponatremia is a disorder in fluid-electrolyte balance that results in an abnormally low plasma sodium concentration. A sustained decrease in plasma sodium concentration disrupts the osmotic balance across the blood-brain barrier, resulting in a rapid influx of water into the brain. This causes brain swelling and a cascade of increasingly severe neurological responses (confusion, seizure, coma) that can culminate in death from rupture of the brainstem.

32. A tumour on the anterior pituitary can cause an oversecretion of human growth hormone (hGH). hGH stimulates the growth of muscles, connective tissue, and the growth plates at the ends of the long bones. If this disorder is not corrected, an excessive amount of hGH during childhood can result in a condition called gigantism.

33. The outline of the student's nervous system should include the brain, spinal cord, and the peripheral nervous system. The diagram should also include sensory receptors such as in the eye, ear, and skin. The structures being used to complete the questions would be the eyes (to see the question) and the cerebral cortex (to process the information and formulate an answer). As well, the motor area of the cerebral cortex controls the muscles used to write or type out the answers.

34. The initial reaction is a reflex arc. A flowchart of the reflex arc should include the following:

pain receptors in the toe → sensory neuron → interneuron → motor neuron → effector (muscles in the foot)

A reflex arc enables the body to react rapidly in times of danger, even before the person is consciously aware of the threat.

The perception of pain is felt only after sensory impulses are processed in the thalamus and then received by the neurons in the somatosensory area of the parietal lobe.

35. Responses during brain probe:

Area probed	Person's response	Area of brain stimulated
A	"I can hear a radio playing."	temporal lobe
B	"I see a flash of bright light."	occipital lobe
C	"I can smell the flowers in my garden."	parietal lobe
D	"I remember a happy moment from my childhood."	frontal lobe
E	"I can feel pain in my foot."	parietal lobe
F	"My finger just twitched."	frontal lobe

36. (a) If the membrane is at resting membrane potential (–70 mV), the addition of Na^+ ions to the fluid surrounding the axon would likely increase the difference in electric potential across the membrane at this point. This would hyperpolarize the membrane, bringing the membrane potential to below –70 mV. Students may add that, where the membrane is hyperpolarized, a stronger stimulus will be needed in order to depolarize the membrane.

(b) The –70 mV resting membrane potential is partly due to the difference in the K^+ ion concentration on either side of the membrane. If the membrane is at resting membrane potential (–70 mV), the addition of K^+ ions would likely increase the difference in electric potential across the membrane at this point. This would hyperpolarize the membrane, bringing the membrane potential to below –70 mV. Students may add that, where the membrane is hyperpolarized, a stronger stimulus will be needed in order to depolarize the membrane.

37. (a) The high concentration of sodium ions outside the neuron and the high concentration of potassium ions inside is indicative of a neuron at rest. (In contrast, there is a rapid influx of sodium ions when the membrane is depolarized.) If the membrane is at rest, students should recognize that the resting membrane potential of a neuron is approximately –70 mV.

A neuron establishes this charge difference across the membrane because of three factors:

- Large, negatively charged molecules such as proteins are found inside the neuron. These anions normally do not diffuse out of the cell.
- The sodium-potassium ion pump in the cell membrane of a neuron brings only 2 potassium ions into the cell for every 3 sodium ions that it pumps out.
- Ion-specific channels in the cell membrane allow more potassium ions to diffuse out of the cell than sodium ions to diffuse into the cell.

(b) A sufficiently strong stimulus would cause sodium ion channels to open, allowing sodium to diffuse into the neuron. The charge across the membrane would become less negative (the membrane would depolarize). If the membrane depolarizes to the threshold potential (–55 mV), large numbers of sodium ion channels simultaneously open, allowing for an influx of sodium ions, therefore leading to a higher concentration of sodium ions inside the neuron and rapid depolarization of the membrane. This rapid change in the membrane potential from –70 mV to about +35 mV initiates a response called an action potential, or nerve impulse.

(c) Once a charge of +35 mV has been achieved and an action potential has been generated, K^+ channels that were previously closed begin to open. With the K^+ channels open, repolarization occurs because of the rapid diffusion of K^+ ions out of the axon. This begins to restore the negative membrane potential inside the neuron. Students may also add that when the neuron begins to repolarize, the sodium-potassium pump is reactivated. Once again, sodium ions are pumped out of the neuron. In addition, ion-specific channels open, allowing chloride to diffuse into the cell. The combination of sodium and potassium ions on the outside of the neural membrane and chloride ions on the inside causes a rapid drop in membrane potential from +35 mV to –90 mV. The drop in membrane potential below resting membrane potential is called hyperpolarization.

38. (a) and **(b)** Students' diagrams should resemble Figure 11.19 found on page 380 of the student textbook.

(c) Botox® injections block the release of the neurotransmitter acetylcholine at the synapse between the nerves and facial muscles. Botulinum toxin works by disrupting the normal acetylcholine release process, resulting in chemical denervation and ultimately paralysis of the specific muscles that are causing the wrinkles. (Hint: See page 430 of the student textbook.)

39. The densely packed cones in the retina would increase the visual acuity of the eagle. This would allow the eagle to locate prey and identify potential predators at greater distances.

40. A key feature of an action potential in a neuron is that it is an all-or-none response. Each depolarization event either reaches the threshold potential, causing an action potential, or does not. For an action potential (and therefore nerve impulse) to be generated, 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. This minimum change in the membrane potential is called the threshold potential. Furthermore, an action potential has only one strength or magnitude. The axon cannot fire a stronger action potential or a weaker action potential.

In terms of the neuron in the elephant, a stimulus less than 1 Hz is not strong enough to generate an action potential. However, a stimulus of 1 Hz or greater is strong enough to generate an action potential. Because an action potential in a neuron has only one strength or magnitude, increasing the frequency of sound will not have any effect on this individual neuron. In terms of the neuron in the human, the strength of a stimulus required to generate an action potential is somewhere between 1 Hz and 20 Hz (although most students will likely indicate that it is 20 Hz, based on the chart). Because an action potential in a neuron has only one strength or magnitude, increasing the frequency of sound will not have any effect on this individual neuron.

41. Drinking large volumes of water would reduce the concentration of sodium ions in the blood. In response, the hypothalamus would prevent the release of ADH from the posterior pituitary gland. As a result, the distal tubule and the collecting duct would become less permeable to water. This would allow more water to be excreted in the urine, and the osmotic pressure of the plasma and tissue fluid would return to normal.

As well, a drop in blood sodium ion concentration is compensated for by the kidneys under the influence of aldosterone. This hormone stimulates the distal tubules and collecting ducts to reabsorb Na^+ ions. Because the reabsorption of Na^+ ions is followed passively by chloride ions and water, aldosterone has the net effect of retaining both salts and water.

Note to the teacher: Although students will not likely be aware of this, you might want to use this question to mention hyponatremia (see also the answer to Unit Review question #31). What happens when too much water is consumed is a consequence of the drive to osmotic equilibrium. Water is absorbed from the gut into the bloodstream, and when it gets to the capillaries it quickly moves into the cells' exterior milieu (called the interstitium). Interstitial fluid now becomes dilute relative to the fluid inside cells, so water moves into cells until the osmolality in the cell, interstitium and blood plasma are all equal. The movement of water into cells causes them to swell, a result which is particularly problematic in the brain because the skull is almost completely closed, allowing for very little expansion. Consequently, the symptoms of too-much-water hyponatremia are those of brain dysfunction: change in mental status, sensory distortion, confusion, lack of co-ordination, bizarre behaviour, and, ultimately, seizures, coma and death.)

42. (a) At 5 hours, the person's blood glucose levels started to increase after the ingestion of food.

(b) The hormone released at 7 hours was insulin. Insulin is produced in the pancreas and is released into the bloodstream in response to high levels of glucose in the blood.

(c) At 8 hours, the hormone glucagon was released. Glucagon is produced in the pancreas and released into the bloodstream in response to low levels of glucose in the blood.

(d) During strenuous exercise, the blood glucose levels would decrease and the hormone glucagon would be released.

(e) The pancreas of a person with type 1 diabetes cannot produce insulin. Therefore, this person would have to take insulin just after eating.

43. (a) The readings were taken 3 hours after eating, when blood glucose levels should be back to normal levels. Students should also recognize that sampling time is one of the variables controlled in this investigation.

(b) Averaging 10 readings helps to eliminate anomalies that might appear in single trials.

(c) Blood glucose levels increased over 40 years.

(d) Based on this data, you could infer that this person has type 2 diabetes. Type 2 diabetes tends to develop gradually, and has two potential causes: the body's cells may stop responding to insulin, or the beta cells of the pancreas may produce less and less insulin over time.

(e) She can try to control her type 2 diabetes with diet and exercise.

44. The student having trouble seeing the chalkboard may be nearsighted (has myopia). The eyeball of a person with myopia is elongated, so the focussed light falls in front of the retina instead of on the photoreceptors. To see distant objects, nearsighted people can wear concave lenses, which diverge incoming light rays so that the image falls directly on the retina. Students' drawings should be similar to Figure 12.12 on page 413 of the student textbook.

Answers to Making Connections Questions

45. Different areas in the organ of Corti are sensitive to different frequencies of sound. High frequencies most strongly stimulate hair cells that are closest to the oval window. Low frequencies most strongly stimulate hair cells that are farthest from the oval window. People who work with heavy equipment likely experience sound frequencies in a range that damages the hair cells in only one area of the cochlea, resulting in an inability to hear sounds only in that range.

46. The frontal lobe of the brain is associated with conscious thought, intelligence, memory, and personality. It also controls voluntary muscle movements. The neurons in the child's frontal lobe are making new connections as the child learns to walk, develops fine motor skills, and learns new things. These neurons would require a great deal of energy to make these new connections. The frontal lobe in the adult brain does not require as much energy because it is not making/growing as many new connections.

47. A PET scan can be used to diagnose conditions such as a stroke or Alzheimer's disease, in which the deterioration of the brain leads to memory loss and confusion, and eventual lack of conscious movement. Students' answers should provide practical examples of where brain research is being used and identify both the pros and the cons of this type of research. For example, brain research into Alzheimer's disease could lead to the development of a treatment that would prevent this debilitating disease from developing. On the other hand, this type of research may provide a way for doctors to identify individuals who will develop Alzheimer's disease later in life and this information could be sold to insurance companies.

48. Multiple sclerosis is a disease that affects the white matter of the central nervous system. The neurons that form the white matter of the CNS are covered with a fatty tissue called myelin. Myelin is an insulating layer that forms around nerves. It is made up of protein and fatty substances. The purpose of the myelin sheath is to allow rapid and efficient transmission of impulses along the nerve cells. In MS, myelin is lost in multiple areas, leaving scar tissue called sclerosis. These damaged areas are also known as plaques or lesions. Sometimes the nerve fibre itself is damaged or broken. Myelin not only protects nerve fibres, but makes their job possible. When myelin or the nerve fibre is destroyed or damaged, the ability of the nerves to conduct electrical impulses to and from the brain is disrupted, and this produces the various symptoms of MS.

Alzheimer's disease is progressive and irreversible. Abnormal changes in the brain worsen over time, eventually interfering with many aspects of brain function. Memory loss is one of the earliest symptoms, along with a gradual decline of other intellectual and thinking abilities, called cognitive functions, and changes in personality or behaviour.

Creutzfeldt-Jakob disease is a rare, fatal brain disorder that causes a rapid, progressive dementia and associated neuromuscular disturbances. This disease is believed to be caused by prions. Prions are abnormal forms of protein that are extremely hardy and cannot be eradicated by normal sterilization procedures. Their presence in the brain results in spongiform encephalopathy, so-called because areas of the brain in which cells have died take on a sponge-like appearance when viewed under the microscope.

Students could argue that research dollars for either one could produce new technologies for the treatment or even the cure for the disease.

49. Dopamine is a neurotransmitter that is commonly associated with the pleasure system in the brain. The release of this neurotransmitter provides feelings of enjoyment and reinforcement to motivate us to do, or continue doing, certain activities.

Students' answers should include the following:

(1) Dopamine is produced in the presynaptic neuron and packaged in containers called vesicles. As an electrical impulse arrives at the neuron's terminal, the vesicle moves to the neural membrane and releases its load of dopamine into the synaptic cleft.

(2) The dopamine crosses the gap and binds to receiver sites, or receptors, on the membrane of the postsynaptic neuron. When dopamine occupies a receptor, a new electrical impulse is generated in the postsynaptic neuron and the impulse continues on.

(3) After the dopamine has bound to the receptor and generated the impulse, it is released from the receptor, removed from the synaptic cleft, and returned to the presynaptic neuron by reuptake pumps. It is important for normal nerve transmission that the dopamine be removed from the cleft.

(4) Cocaine is a drug that prevents the reuptake of the neurotransmitter dopamine. By compeittively inhibiting dopamine reuptake, cocaine increases the amount of dopamine in the synaptic cleft, resulting in feelings of intense pleasure. Repeated use causes tolerance for the drug: withdrawal results in low levels of dopamine being produced; continuous use is required to keep dopamine at normal levels, and even higher doses are required to obtain the same "high" levels as during initial use. Cocaine withdrawal is often accompanied by mental and physical symptoms.

(5) A drug that binds and interferes with dopamine could trick the body into thinking there are low levels of dopamine; this could stimulate the presynaptic neurons to produce more dopamine, thereby curing the addiction and reducing the withdrawal symptoms.

Students' answers to the question of forced treatment should reflect the rights of the individual compared to the rights of society. Arguments could include the cost of drug dependency in terms of crime, health care for treatment, and the disruption of families.

50. The stress hormones produced by the adrenal cortex trigger the sustained physiological responses that make up the long-term stress response. The glucocorticoids (cortisol) increase blood sugar, and the mineralocorticoids (aldosterone) increase blood pressure. The long-term stress response includes the following:

- sodium ions and water are absorbed by the kidney;
- blood volume and blood pressure increase;
- protein and fat metabolism increases to release glucose
- inflammation is reduced and cells of the immune system are suppressed.

In long-term stress, sustained high levels of cortisol can impair thinking, damage the heart, cause high blood pressure, lead to diabetes, increase susceptibility to infection, and even cause early death.

The campaign should teach ways to reduce stress because this response is not under conscious control. Drugs may be able to control certain symptoms such as high blood pressure. However, the endocrine system produces these responses in times of stress and the only way to stop this response is to reduce the stress.

51. This girl is exhibiting the symptoms of hypothyroidism. Her body is unable to produce sufficient quantities of the hormone thyroxine. Her diet is the likely cause for the lack of thyroxine.

A sodium-free diet is not only reducing levels of sodium in her body, it is reducing levels of iodine (iodine is added to salt in many countries). The thyroid gland needs iodine in order to make the hormone thyroxine.

The thyroid gland is enlarged because there is no signal (negative feedback) to stop the secretion of TSH from the anterior pituitary gland. The relentless stimulation of the thyroid gland by TSH causes a goitre (an enlargement of the thyroid gland). The lack of thyroxine slows down the girl's metabolism, which explains why she is tired, cold, and gaining weight.

The girl should see a doctor because hypothyroidism can lead to an enlarged heart and an accumulation of fluid in the lungs.