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UNIT 5

The Nervous and Endocrine Systems

Teaching Unit 5: The Nervous and Endocrine Systems

(25% percent of the course time; approximately 30 hours)

Student Textbook pages 360-471

General Outcomes

- explore how the nervous system regulates physiological processes in the body
- explain how the endocrine system contributes to homeostasis in the body

Curriculum Fit (See the Curriculum Correlation for Full Listing)

Background: This unit builds on concepts from *Science 8*, Unit B: Cells and Systems; *Science 10*, Unit C: Flow of Matter in Living Systems; and *Biology 20*, Unit D: Human Systems.

Contents

- Chapter 11 The Nervous System
- Chapter 12 Sensory Reception
- Chapter 13 Hormonal Regulation of Homeostasis

The themes of this unit are Equilibrium and Systems.

Content Summary

Unit 5 focusses on the role that the nervous and endocrine systems play in maintaining homeostasis in the human body. Chapter 11 is an in-depth study of the structure and function of the nervous system. Chapter 12 is about the structure and function of the sense organs. Chapter 13 looks at the endocrine system, and how it contributes to homeostasis. That chapter (and the unit) end with sections dealing with the top endocrine-related health issues in the West: the effects of stress and the effects of an inability to manage blood sugar levels (diabetes).

Chapter 11 deals with the structures and processes of the nervous system. Students learn how the human body reacts to changes in its internal and external environment. The Launch Lab sets the context by giving students a look at how impairment of the senses affects their ability to function efficiently. The chapter looks at the roles of the human brain and nervous system in maintaining homeostasis. In particular, students examine the structure and function of the neuron, the central nervous system (brain and spinal cord), and the peripheral nervous system.

Section 11.1 introduces the nervous system. Students will learn about the two principal divisions: the central nervous system (CNS) and the peripheral nervous system (PNS) and be able to describe the structure and the function of the reflex arc, as well as identify the parts of a neuron. This section also describes how electrical impulses carry information along the axon of a neuron, and how this information is passed from one neuron to another through the release of chemical neurotransmitters. Investigations in this section allow exploration of reflex responses (Move Fast! Reflex Responses), resting membrane potential (Modelling Resting Membrane Potential), and neural tissue (Examining Neural Tissue). The section ends with a thought lab on the effects of various recreational drugs on the nervous system.

Section 11.2 is an exploration of the Central Nervous System (CNS), including the principal structure and function of the brain and spinal cord. The investigation in this section is the dissection of the mammalian brain, either hands-on or virtual. The section ends with a quick look at technologies used to study the brain and solve some problems related to brain function.

Section 11.3 identifies the principal components of the peripheral nervous system and explains the role of the peripheral nervous system in regulating the somatic (voluntary) and autonomic (involuntary) systems. In addition, the functions of the sympathetic division and the parasympathetic division of the autonomic nervous system are compared. The Connections feature looks at neurological disorders and the treatment of them when they occur in animals.

Chapter 12 is about sensory receptors (the sense organs) and sensation and perception (which happen in the brain). The information gathered by sensory receptors is essential to guide the brain in maintaining homeostasis.

In Section 12.1, students learn the difference between sensory reception, sensation, and perception. They will describe the process of sensory adaptation and distinguish among the major sensory receptors in the human body.

The eye receives an in-depth treatment in Section 12.2, as students learn the principal structures of the human eye and how this organ converts light energy into electrochemical energy that can be processed by the central nervous system. Students observe the principal features of the mammalian eye in Investigation 12.A: Dissection of an Eye. They also learn about several eye disorders, such as glaucoma, myopia, and hyperopia, and identify possible treatments for each disorder.

Section 12.3 deals with other key sensory organs: the ear, nose, tongue, and skin. Students will be able to describe the structure and function of each, and explain how they give us our various senses, including balance. Investigations 12.B: Distinguishing Sights and Sounds and 12.C: Feel, Taste, or Smell: Design Your Own Investigation allow students to test various senses and discover the variation in perception of sensation among themselves. The Connections feature looks at pain receptors and the possibility of using natural (but quite deadly) neurotoxins for targeted pain relief in cases of chronic conditions.

Chapter 13 completes the study of homeostasis with a look at the glands and hormones of the endocrine system. Students learn how the endocrine system works with the nervous system to regulate and maintain homeostasis.

Section 13.1 is a comparison of the nervous and endocrine systems, with an explanation of the principal structures of the endocrine system, the hormones that are secreted and their role in maintaining homeostasis. The concept of hormonal regulation through negative feedback mechanisms is revisited. The Connections feature looks at the role of hormones (melatonin) in Seasonal Affective Disorder.

Section 13.2 focusses on the structure of the pituitary gland and explains how it functions and is regulated. A key pituitary hormone—human growth hormone (hGH)—is the focus. (The hormones involved in the male and female reproductive systems are not included in this unit. They are the subject of Unit 6.) Then the role of the thyroid and parathyroid glands are studied, in the context of maintaining homeostasis. Negative feedback loops again figure in the regulation of these hormones. The investigation in this section, 13.A: Evaluating Potential Uses for Human Growth Hormone, encourages students to consider the impact of artificial hormones on the human body and do some critical thinking about the use of this substance.

Section 13.3 describes how the nervous system and endocrine system act together to regulate the stress response in humans. Stress response hormones such as epinephrine and norepinephrine are identified and their roles in the response are defined. The effects of cortisol and aldosterone on the human body during a long-term stress response are featured, and the physiological effects of chronic stress or an imbalance in the stress hormones are described.

Section 13.4 looks at another key player in homeostasis: the pancreas and its role in regulating blood sugar through the hormones insulin and glucagon. Thought Lab 13.1: Blood Glucose Regulation and Homeostasis gives students data to analyze and interpret in an effort to see how levels of blood glucose fluctuate in those with and without diabetes. Investigation 13.B: Analyzing Endocrine Disorders gives students more data to analyze in an effort to identify patients with endocrine disorders. The role of medical technology in regulating hormonal imbalances is discussed at the end of the section.

Activities and Related Target Skills

Activity	Target Skills
Chapter 11: The Nervous System	
Launch Lab: You, Robot?, p. 365	■ Comparing human neural capabilities to those of an advance robot
Investigation 11.A: Move Fast! Reflex Response, p. 371	■ Performing an experiment to investigate the physiology of reflex arcs ■ Identifying a reflex arc not discussed in the textbook, and designing an experiment to investigate the physiology of this reflex arc
Investigation 11. B: Modelling Resting Membrane Potential, p. 375	■ Gathering and analyzing data from a model of a neuron ■ Working as a team to carry out experimental procedures and assess results
Investigation 11.C: Examining Neural Tissue, p. 381	■ Observing neurons and neuromuscular junctions with a microscope ■ Identifying the principal structures in different types of neurons, and relating these structures to their functions
Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses, p. 383	■ Analyzing and explaining how different drugs affect neural impulses ■ Working cooperatively to investigate the effects of a drug on neurons or neural synapses ■ Hypothesizing what might make some drugs addictive
Investigation 11.D: The Brain, p. 393	■ Observing and identifying the principal features of a mammalian brain using dissections or other means ■ Compiling and displaying data in appropriate forms ■ Working cooperatively as a team to investigate a neurological disorder
Chapter 12: Sensory Reception	
Launch Lab: Sense It, p. 405	■ Identifying familiar objects while one or more senses are inhibited
Investigation 12.A: Dissection of an Eye, p. 417	■ Observing and describing the major structures of the mammalian eye

Activities and Related Target Skills

Activity	Target Skills
Investigation 12.B: Distinguishing Sights and Sounds, p. 422	■ Performing experiments to measure the ability to discriminate objects visually and to hear a range of sounds ■ Gathering and recording data ■ Compiling and displaying data in an appropriate form
Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428	■ Asking questions about observed relationships ■ Designing an experiment to investigate various sensory receptors ■ Analyzing data to show interrelationships between the different senses
Chapter 13: Hormonal Regulation of Homeostasis	
Launch Lab: Modern Stress!, p. 435	■ Monitoring physiological changes that occur in response to a stressful situation
Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone, p. 447	■ Evaluating the use of synthetic hGH treatment of humans ■ Working with a team in addressing an issue and communicating findings
Thought Lab 13.1: Blood Glucose Regulation and Homeostasis, p. 458	■ Analyzing and interpreting collected data on blood glucose levels ■ Identifying healthy patterns of changing blood glucose levels ■ Inferring the effects of diabetes mellitus on blood glucose levels
Investigation 13.B: Analyzing Endocrine Disorders, pp. 460-461	■ Analyzing and comparing data collected from simulated blood and urine samples ■ Interpreting data and identifying hormonal imbalances suggested by the data
Investigation 15.A: Comparing Embryonic Structures, p. 519	■ Observing changes during embryo development ■ Comparing extra-embryonic membranes of human and chicken embryos
Thought Lab 15.1: Folic Acid and Neural Tube Defects, p. 524	■ Investigating the effects of folic acid on embryonic and fetal development ■ Discussing the societal impact of folic acid consumption on fetal development
Thought Lab 15.2: Evaluating Reproductive Technologies: Safety and Effectiveness, p. 533	■ Evaluating, from published data, the effectiveness and safety of various reproductive technologies ■ Justifying, through the use of clear and logical arguments, a decision about the effectiveness and safety of reproductive technologies

Conceptual Challenges

- Unit 5 has a large volume of material to master, particularly in the area of vocabulary of relating body parts, functions, disorders, and related hormones. Encourage students, particularly those with language challenges, to create a vocabulary builder that works for them. On-line puzzle makers are available as free downloads. Alternatively, students could create electronic flash cards or compile their own electronic glossary or dictionary. (Or a paper one, if they prefer.) A number of BLMs have been prepared to give them practice labelling art from the student text and including descriptions and functions in their own words.

Chapter 11

- The nerve impulse process (pages 372 to 382) is complex, and the topic is usually a challenge for students. Stress the importance of understanding the process to students and note that it includes concepts (such as active transport) that they have already seen. The key for the student is to proceed slowly and ensure that the vocabulary terms are understood.
- The Student Edition of the Online Learning Centre at **www.albertabiology.ca** includes a tutorial on the concept of action potential. You may want to review this in class. In addition, the BLMs listed below are included on the CD or can be downloaded from the Instructor's Edition at the Online Learning Centre at **www.albertabiology.ca**. These are reproductions of the illustrations from the student text, with the opportunity to fill in terms or definitions in the handout (HAND) version or to be used as overheads or simply class notes in the overhead (ANS/OH) version. Investigation 11.B: Modelling Resting Membrane Potential, particularly the "Conclusions" questions, will also assist the students in understanding this process.

11.1.6 (HAND) Parts of a Neuron
11.1.6A (ANS/OH) Parts of a Neuron Answer Key
11.1.7 (HAND) Establishing The Resting Membrane Potential in a Neuron
11.1.7A (ANS/OH) Establishing The Resting Membrane Potential in a Neuron Answer Key
11.1.8 (HAND) Investigation 11.B: Modelling Resting Membrane Potential
11.1.8A (HAND) Investigation 11.B: Modelling Resting Membrane Potential Answer Key
11.1.9 (HAND) Depolarization and Repolarization of a Neuron
11.1.9A (ANS/OH) Depolarization and Repolarization of a Neuron Answer Key
11.1.10 (HAND) Action Potential
11.1.10A (ANS/OH) Action Potential Answer Key
11.1.11 (HAND) Saltatory Conduction
11.1.11A (ANS/OH) Saltatory Conduction Answer Key
11.1.12 (HAND) Neural Synapse
11.1.12A (ANS/OH) Neural Synapse Answer Key
11.1.13 (HAND) Neuromuscular Junction
11.1.13A (ANS/OH) Neuromuscular Junction Answer Key
11.1.15 (HAND) Neurotransmitters and Their Functions
11.1.15A (ANS) Neurotransmitters and Their Functions Answer Key

Chapter 12

- The structure and function of the ear can be intimidating for some students. **BLMs 12.3.1 (HAND) The Human Ear/12.3.1A (ANS/OH) The Human Ear Answer Key** and **12.3.2 (HAND) The Inner Ear and Cochlea/12.3.2A (ANS/OH) The Inner Ear and Cochlea Answer Key** will give students an opportunity to use the related vocabulary as they identify the parts of the ear. Animations such as "The Effect of Sound Waves on the Cochlear Structure" are available at the Student Edition section of the Online Learning Centre at **www.albertabiology.ca.**

Chapter 13

- Negative feedback loops were introduced in Biology 20, Unit 4 Preparation on page 203. These pages could be revisited to refresh the information. The concept appears in this chapter in connection with the endocrine system, where various organs act as control centres that can assess incoming data and respond to changes. Overhead **BLM 6.0.2 Homeostasis** can be used to illustrate the concept.
- Students may have an easier time understanding a negative feedback loop if they first consider a positive feedback loop. Positive feedback loops result in unlimited growth—"a vicious circle" is a good descriptor for such a loop. Global warming could be used as an example, as more warming will trigger events that lead to more warming.

  In contrast, a negative feedback loop operates to stop a process. A thermostat is a good example of a control centre in a negative feedback loop. It has a sensor to monitor conditions, an ability to assess the conditions in question (room temperature) and can trigger a response that will stop the escalating change (turning a heat source on or off to keep the temperature within a desire range). A negative feedback loop therefore operates to control conditions within an often narrow set of parameters.

Using the Unit 5 Opener and Unit 5 Preparation Feature

Student Textbook pages 360–363

The Unit 5 opener puts students at the heart—of a forest fire—of the kind of situation that gets the heart pumping and puts all the senses on high alert.

Teaching Strategies

- Students may have experienced similar circumstances when they had reached exhaustion but circumstances gave them a jolt of energy—perhaps at the end of a race or a hiking or canoe trip. Consideration of these experiences could lead into a discussion of the Focussing Questions. Question 1 asks students to suggest how the more obvious physical reactions to changes in the external environment, for example, shivering, happen. Question 2 links the senses to these reactions, and question 3 asks students to speculate on the role of hormones in the reactions.
- The Unit Preparation feature is a brief review of human body systems, last considered at the end of Unit 4 in Biology 20. Students may benefit from a refresher on the relevant systems before starting the unit.
- Encourage students to take the Unit Prequiz (found at the Online Learning Centre at **www.albertabiology.ca,** under Student Edition) to gauge their recall, noting that if they are familiar with the background science, their experience with this unit will be much easier.

UNIT 5: COURSE MATERIALS

Chapter, Section	Item Description	Suggested Quantity	Text Activity
Chapters 11, 12, 13	safety goggles	40 pairs	Investigations: 11.B, 11.C, 11.D, 12.A, 13.B
Chapters 11, 12, 13	nonlatex disposable gloves	40 pairs × 4 investigations	Investigations: 11.B, 11.D, 12.A, 13.B
Chapters 11, 12, 13	aprons	40	Investigations: 11.B, 11.C, 11.D, 12.A, 13.B
Chapter 11, Chapter Opener	shoes with laces tongue depressors masking tape heavy gloves pairs of pliers blindfold new ear plugs or cotton batting stopwatch	each student's shoes 1 per student 4 rolls 1 pair per group 2 per group 1 per group 1 pair per student 1 per group	Launch Lab: You, Robot?, p. 365
Chapter 11, Section 11.1	cotton balls 20 cm by 20 cm clear plastic sheet (or piece of wire mesh) room light chair	500 1 per group 1 per group 1 per group	Investigation 11.A: Move Fast! Reflex Responses, p. 371
Chapter 11, Section 11.1	3 mol/L sodium chloride solution 3 mol/L potassium chloride solution 22 cm of moistened dialysis tubing strips of uninsulated copper wire, each 40 cm long string elastic band pen DC millivolt meter 400 mL beaker	325 mL per group 100 mL per group (estimate) 1 per group 2 per group 2 balls 1 per group 1 per group 1 per group 1 per group	Investigation 11.B: Modelling Resting Membrane Potential, p. 375
Chapter 11, Section 11.1	microscopes prepared neural slides similar to, but not limited to, the ones shown in the textbook	1 per student 1 per student	Investigation 11.C: Examining Neural Tissue, p. 381
Chapter 11, Section 11.2	preserved sheep brains paper towels dissecting trays dissecting kits 10% bleach solution (to clean the dissecting tray) tongs	1 per student 5 rolls 1 per student 1 per student 2 L 1 pair	Investigation 11.D: The Brain, pp. 393–394

Chapter, Section	Item Description	Suggested Quantity	Text Activity
Chapter 12, Chapter Opener	ear plugs (new) blindfold unknowns (e.g., wet piece of raw potato, small piece of wet soap, pine needles, bristles from a brush, wet coffee grounds, wet coarse sand, granulated sugar)	1 pair per student 1 per pair to be determined by teacher	Launch Lab: Sense It, p. 405
Chapter 12, Section 12.1	preserved cow eye paper towels 10% bleach solution dissecting trays dissection kits dissecting microscope (optional)	1 per group 5 rolls 2 L 1 per group 1 per group 1 per group	Investigation 12.A: Dissection of an Eye, p. 417
Chapter 12, Section 12.3	liquid food colouring water 100 ml beakers (or other clear containers of equal size)	 5	Investigation 12.B: Distinguishing Sights and Sounds, Part 1: Distinguishing Shades of Colour, p. 422
Chapter 12, Section 12.3	devices that produce a wide range of sound frequencies, which could include: -tuning forks -frequency signal generator -Vernier or Pasco computer program that aids in analyzing different sound frequencies -Internet site that provides different tone frequencies frequency sensor (optional)	1 per group 1	Investigation 12.B: Distinguishing Sights and Sounds, Part 2: Distinguishing Sound Frequencies, pp. 422–423
Chapter 12, Section 12.3	500 mL beaker of hot water (60 °C) 500 mL beaker of ice water (0–2 °C) non-permanent pen for marking gridlines of different areas of the body finishing nails alcohol thermometer	1 per group 1 per group 5 1 per group 5	Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, Topic 1, p. 428
Chapter 12, Section 12.3	samples: -salty water -sugary water or sweet candy -lemon juice -onion juice or tonic water clean toothpicks or cotton swabs garbage bin blindfold	 40–50 1 per group 1 per group	Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, Topic 2, p. 428
Chapter 12, Section 12.3	samples: -ginger -lemon -menthol -peppermint -pine needles -vanilla -vinegar -perfume blindfold	 1 per group	Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, Topic 3, p. 428
Chapter 13, Chapter Opener	test questions stopwatch	 1 per pair	Launch Lab: Modern Stress!, p. 435

Chapter, Section	Item Description	Suggested Quantity	Text Activity
Chapter 13, Section 13.4	simulated samples of blood simulated samples of urine Benedict's solution (if not using a monitor) cotton swabs digital blood glucose monitor (if available) blood and urine test strips (if using a monitor) medicine dropper 10 mL test tubes test-tube rack 10 mL graduated cylinder 400 mL beaker hot plate test-tube clamp beaker tongs Bunsen burner or small propane torch heat-insulated gloves	5 samples per group (specified in text), 75 drops of each sample 5 samples per group (specified in text), 75 drops of each sample 50 mL per group 100 1 per group 10 strips per group 1 per group 10 per group 1 per group 1 per group 1 per group 1 per group 1 per group 1 per group 1 per group 1 pair per group	Investigation 13.B: Analyzing Endocrine Disorders, pp. 460–461

CHAPTER 11 THE NERVOUS SYSTEM

Curriculum Correlation

General Outcome 1: Students will explain how the nervous system controls physiological processes.

NOTE: The curriculum correlation for this outcome covers two chapters. The references for Chapter 11 are in boldface.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
30–A1.1k describe the structure and function of a neuron and myelin sheath, explaining the formation and transmission of an action potential and the transmission of a signal across a synapse or neuromuscular junction and the main chemicals and transmitters involved, i.e., norepinephrine, acetylcholine and cholinesterase	**Section 11.1: Cells of the Nervous System, p. 368** **The Structure of a Neuron, p. 370** **The Nerve Impulse, p. 372** **Investigation 11.B: Modelling Resting Action Potential, p. 374** **Membrane Potential, p. 375** **Nerve Impulse, p. 377** **Signal Transmission Across a Synapse, p. 378** **Neural Transmitters in Action, p. 380** **Investigation 11.C: Examining Neural Tissue, p. 381** **Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses, p. 383** **Section 11.2: The Autonomic System, p. 397**	**Chapter 11 Questions for Comprehension:** **4–6, p. 370** **7, 8, p. 372** **9, 10, p. 374** **11–13, p. 377** **14–16, p. 380** **17, 18, p. 382** **30–32, p. 399** **Investigation 11.B: Analysis, Conclusions, p. 375** **Investigation 11.C: Analysis 2-6, p. 381** **Thought Lab 11.1: Analysis, p. 383** **Section 11.1 Review: 1–8, p. 384** **Chapter 11 Review: 1, 6, 8, 10, 13–17, 19–21, 23, pp. 402–403** **Chapter 11 Test** Unit 5 Review: 1, 2, 5, 7, 36–38, pp. 468–470

	Student Textbook	Assessment Options
30–A1.2k identify the principal structures of the central and peripheral nervous systems and explain their functions in regulating the voluntary (somatic) and involuntary (autonomic) systems of the human organism, i.e., cerebral hemispheres and lobes, cerebellum, pons, medulla oblongata, hypothalamus, spinal cord, sympathetic and parasympathetic nervous systems, and the sensory–somatic nervous system	**Section 11.1: Organization of the Nervous System, p. 367** **Section 11.2:** **The Spinal Cord, p. 385** **The Brain, p. 386** **The Structure and Function of the Cerebrum, p. 389** **Mapping Brain Functions, p. 392** **Imaging Techniques Used to Study the Brain, p. 392** **Investigation 11.D: The Brain, Parts 1 & 2, p. 393–394** **Section 11.3:** **The Somatic System, p. 396** **The Autonomic System, p. 397** Throughout Section 12.1, p. 406–409 Section 12.2: The Photoreceptors: Rods and Cones, p. 414	**Chapter 11 Questions for Comprehension:** **1–3, p. 367** **19–22, p. 389** **23–25, p.392** **28, 29, p. 399** **30–32, p. 399** **Investigation 11.D, Parts 1 & 2: Analysis, pp. 393–394** **Sect 11.1 Review: 1, p. 384** **Section 11.2 Review: 1–7, p. 395** **Section 11.3 Review: 1–5, p. 399** **Chapter 11 Review: 1–5, 7–9, 11, 18, 19, 22, 24, pp. 402–403** **Chapter 11 Test** Chapter 12 Questions for Comprehension: 1–2, p. 406 3–4, p. 407 5–6, p. 409 15, p. 416 17, p. 416 22, p. 424 25, p. 425 Section 12.1 Review: 1–5, p. 409 Chapter 12 Review 1–2, 4–7, 11, 13, 17, 18, p. 432 Chapter 12 Test Unit 5 Review: 3–7, 16, 23, 35, 46, pp. 468–471
30–A1.3k describe the composition and function of a simple reflex arc and the organization of neurons into nerves	**Section 11.1: Cells of the Nervous System, p. 368** **The Reflex Arc, p. 369** **Investigation 11.A: Move Fast! Reflex Responses, p. 371**	**Chapter 11 Questions for Comprehension: 4–6, p. 370** **Investigation 11.A: Analysis, p. 371** **Chapter 11 Test** Unit 5 Review: 3, 6, p. 468
30–A1.4k describe the structure and function of the human eye, i.e., cornea, lens, sclera, choroid, retina, rods and cones, pupil, iris, and optic nerve	Section 12.1: Sensory Receptors, p. 407 Throughout Section 12.2, pp. 410–418 Investigation 12.A: Dissection of an Eye, p. 417 Investigation 12.B: Distinguishing Sights and Sounds, Part 1 Distinguishing Shades of Colour, p. 422	Chapter 12 Questions for Comprehension: 7–9, p. 412 10–12, p. 414 13–17, p. 416 Investigation 12.A: Analysis, Conclusion, Application, p. 417 Investigation 12.B, Part 1: Analysis, Conclusion, p. 422 Section 12.1 Review: 1(b), p. 409 Section 12.2 Review: 1–7, p. 418 Chapter 12 Review: 3, 8–12, 14, 16–17, 21, 22, 23–25, 27, 31, pp. 432-433 Chapter 12 Test Unit 5 Review: 8, 9, 12–14, 44, p. 468-471

	Student Textbook	Assessment Options
30–A1.5k describe the structure and function of the human ear, i.e., pinna, auditory canal, tympanum, ossicles, cochlea, organ of Corti, auditory nerve, semicircular canals and Eustachian tube	Section 12.3: Hearing and Balance, p. 419 Capturing Sound, p. 419 Frequencies of Sound, p. 421 Hearing Loss, p. 423 The Perception of Sound, p. 424 Investigation 12.B: Distinguishing Sights and Sounds, Part 2: Distinguishing Sound Frequencies, p. 422–423	Chapter 12 Questions for Comprehension: 18–20, p. 421 21–22, p. 424 23–25, p. 425 Investigation 12.B, Part 2: Analysis, Conclusion, Extension, p. 423 Section 12.3 Review: 1–5, p. 429 Chapter 12 Review: 6, 15, 17–20, p. 432 Chapter 12 Test Unit 5 Review: 10, 11, p. 468
30–A1.6k explain other ways that human organisms sense their environment and their spatial orientation in it, e.g., *skin receptors, olfactory receptors, proprioceptors, taste receptors.*	Throughout Section 12.1, p. 406–409 Section 12.3: Hearing and Balance, p. 419 Taste, p. 425 Smell, p. 426 Touch, p. 427 Sensation and Homeostasis, p. 427 Summary, p. 429 Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428	Chapter 12 Questions for Comprehension: 5–6, p. 409 26, p. 426 27–30, p 427 Investigation 12.C: Analysis, Conclusion, p. 428 Section 12.1 Review: 1 (a), 2–5, p. 409 Chapter 12 Review: 13, 15, 29 pp. 432–433 Chapter 12 Test Unit 5 Review: 8, 31, 35, pp. 468–470
Outcomes for Science, Technology, and Society (Emphasis on the nature of Science)		
30–A1.1sts explain that scientific knowledge and theories develop through hypotheses, collection of evidence through experimentation and the ability to provide explanations by ■ *discussing the biological basis of neurological diseases and how this relates to its treatment, e.g., Alzheimer's disease, Parkinson's disease*	**Section 11.1: The Nerve Impulse, p. 377** **Neurotransmitters in Action, p. 380** **Section 11.2: Imaging Techniques Used to Study the Brain, p. 392** **The Somatic System, p. 396** **Investigation 11.D: The Brain, Parts 1 & 2, pp. 393–394** **Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, p. 400**	**Investigation 11.D, Parts 1 & 2: Analysis, pp. 389–390** **Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, questions 1–4, p. 400** **Chapter 11 Review: 12, 18, 20, pp. 402–403** Unit 5 Review: 36, 45, 47, 48, pp. 470–471
■ *evaluating the impact of photoperiod (light wavelength and duration) on the human organism*	e.g., Investigation 12.B, Distinguishing Sights and Sounds Part 1: Distinguishing Shades of Colour, p. 422	Chapter 12 Questions for Comprehension: e.g., 8, p. 412 e.g., Investigation 12.B, Part 1: Analysis, Conclusions, p. 422 e.g., Chapter 12 Review: 8, 11, p. 432 e.g., Unit 5 Review: 14, p. 468

	Student Textbook	Assessment Options
30–A1.2sts explain that scientific investigation includes the process of analyzing evidence and providing explanations based on scientific theories and concepts by ■ *analyzing experimental evidence on the influence of anesthetics, drugs and chemicals, natural and synthetic, on the functioning of the nervous system and their relationship to addiction theories*	**Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses, p. 383**	**Thought Lab 11.1: Analysis, p. 383** **Section 11.1 Review: 8, p. 384** **Section 11.3 Review: 5, p. 399** Unit 5 Review: 49, p. 471
■ *analyzing the contribution of technological developments and physiological knowledge to longevity and quality of life*	**Section 11.2: Imaging Techniques Used to Study the Brain, p. 392** **Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, p. 400** Section 12.1: Sensory Receptors, p. 407 Section 12.2: Focussing, p. 412 Conditions Affecting the Cornea and Lens, p. 412 Section 12.3: Hearing Loss, p. 423	**Section 11.2 Review: 7, p. 391** **Chapter 11 Questions for Comprehension: 26, 27, p. 394** **Chapter 11 Connections: Social and Environmental Contexts, 1–4, p. 400** Chapter 12 Review: 23, 31, p. 433 Unit 5 Review: 31–35, 41–51 , pp. 469-471
30–A1.3sts explain that the goal of technology is to provide solutions to practical problems by ■ *investigating the technologies available to correct eye and ear defects*	Section 12.1: Sensory Receptors, p. 407 Section 12.2: Photoreceptors, p. 414 Focussing, p. 412 Conditions Affecting the Cornea and Lens, p. 412 Preventing Vision Loss, p. 418 Investigation 12.B: Distinguishing Sights and Sounds, pp. 422-423 Section 12.3: Hearing Loss, p. 423	Chapter 12 Questions for Comprehension 9, p. 412 11, p. 414 21, p. 424 Investigation 12.B, Extension, p. 423 Section 12.2 Review: 5, 6, p. 418 Chapter 12 Review: 24, p. 431
■ *investigating the biological basis of neurotoxin action and their antidotes, e.g., snake venom, box jellyfish, botulin, reserpine* (Rauwolfia serpentina)	Chapter 12 Connections: Nature of Science: Pain Relievers or Deadly Neurotoxins? p. 430	**Chapter 11 Review: 24, p. 403** Chapter 12 Connections: Nature of Science, 1–3, p. 430 Chapter 12 Review: 31, p. 433
■ *discussing how advances in science have contributed to technologies that increase access to the world beyond normal sensory limits.*	Section 12.1: Sensory Receptors, p. 407	Section 12.2 Review: 2, 6, p. 418 Chapter 12 Review: 22, 23, 31, pp. 432–433
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
30–A1.1s ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues by ■ designing an experiment to investigate heat, cold, pressure and touch receptors	Chapter 12 Launch Lab: Sense It, p. 405 Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428	Chapter 12 Launch Lab: Analysis, p. 405 Investigation 12.C: Analysis, Conclusion, p. 428

	Student Textbook	Assessment Options
Performing and Recording		
30–A1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by ■ designing and performing an experiment to investigate the physiology of reflex arcs	**Investigation 11.A: Move Fast! Reflex Responses, p. 371**	**Investigation 11.A: Analysis, p. 371**
■ performing experiments to measure the ability to discriminate objects visually and to hear a range of sounds	**Chapter 11 Launch Lab: You, Robot?, p. 365** Investigation 12.B: Distinguishing Sights and Sounds Parts 1–2, pp. 422–423	**Chapter 11 Launch Lab: Analysis, p. 365** Investigation 12.B, Parts 1–2: Analysis, Conclusion, Extension, pp. 422–423 Unit 5 Review: 40, p. 470
■ using a microscope and prepared slides to observe neurons and neuromuscular junctions	**Investigation 11.C: Examining Neural Tissue, p. 381**	**Investigation 11.C: Analysis, p. 381**
■ observing the principal features of a mammalian brain, ear and eye, using models, computer simulations or dissections, and identifying the major visible structures of those organs	**Investigation 11.D: The Brain, Parts 1 & 2, pp. 393–394** Section 12.2: Photoreceptors, p. 410 Focussing, p. 412 The Photoreceptors: the Rods and Cones, p. 414 Investigation 12.A: Dissection of an Eye, p. 417 Section 12.3: Capturing Sound, p. 419	**Investigation 11.D, Parts 1 & 2: Analysis, pp. 393–394** Investigation 12.A: Analysis, Conclusions and Application, p. 417
■ *investigating and integrating, from library and electronic sources, information on the impact of photoperiod and wavelength on humans*	Investigation 12.B, Distinguishing Sights and Sounds, Part 1: Distinguishing Shades of Colour, p. 422	Investigation 12.B, Part 1: Analysis, Conclusion, p. 422 Chapter 12 Review: 8, 11, 16, p. 432 Unit 5 Review: 9, 14, p. 468
■ *compiling and displaying, in appropriate format, data collected for investigations on auditory range, reflex arcs and/or stimulus strength versus force of muscle contraction*	**Investigation 11.A: Move Fast! Reflex Responses, p. 371**	**Investigation 11.A: Analysis, p. 371** Unit 5 Review: 36, 37, 40, p. 470
Analyzing and Interpreting		
30–A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ *interpreting patterns and trends in data on strength of stimuli versus force of muscle contraction*	**Investigation 11.A: Move Fast! Reflex Responses, p. 371** Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428	**Investigation 11.A: Analysis, p. 371** **Chapter 11 Review: 17, p. 403** Investigation 12.C: Analysis, Conclusion, p. 428 Unit 5 Review: 36, 37, p. 470
■ *providing a statement that explains the blind spot*	Section 12.2: Visual Interpretation, p. 416 Summary, p. 418	Chapter 12 Questions for Comprehension: 16, p. 416 Chapter 12 Review: 10, p. 432
■ *explaining how data supports or refutes a hypothesis or prediction on strength of stimulus versus force of muscle contraction*	**Investigation 11.A: Move Fast! Reflex Responses, p. 371**	**Investigation 11.A: Analysis, p. 371** Unit 5 Review: 36, 37, p. 470
■ *analyzing a hearing aid as a device that simulates a sensory function*	Investigation 12.B: Distinguishing Sights and Sounds, pp. 422-423 Section 12.3: Hearing Loss, p. 423	Investigation 12.B: Extension, p. 423

	Student Textbook	Assessment Options
■ *posing new questions, e.g., why some people are more tolerant to pain than others*	**Investigation 11.A: Move Fast! Reflex Responses, p. 371** Throughout Section 12.1, pp. 406–409	**Investigation 11.A: Applications, 4, p. 371** **Chapter 11 Review: 23, p. 403** Chapter 12 Review: 28, p. 433 Unit 5 Review: 34, p. 469
■ *collecting and analyzing class data on colour charts*	Investigation 12.B, Distinguishing Sights and Sounds, Part 1: Distinguishing Shades of Colour, p. 422	Investigation 12.B, Part 1: Analysis, Conclusion, p.422
■ *analyzing data to show the interrelationship between taste and smell receptors*	Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428	Investigation 12.C: Analysis, Conclusion, p. 428
Communication and Teamwork		
30–A1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *working cooperatively with group members to investigate neurological disorders such as Alzheimer's disease and Parkinson's disease*	**Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses, p. 383** **Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, 1–4, p. 400** e.g., Investigation 12.B, Distinguishing Sights and Sounds, Part 1–2, p. 422 e.g., Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428	**Thought Lab 11.1: Analysis, p. 383** **Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, 1–4, p. 400** **Chapter 11 Review: 18, p. 403** e.g., Investigation 12.B, Analysis, Conclusion, Extension, p. 422 e.g., Investigation 12.C: Analysis, Conclusion; p. 428 Unit 5 Review: 48, 50, p. 471

Chapter 11

The Nervous System

Student Textbook pages 364–403

Chapter Concepts

11.1 Structures and Processes of the Nervous System

- Homeostasis is maintained in the human body by the various parts of the nervous system.
- Neural transmission occurs along axons, due to an action potential that causes depolarization of the neuron.
- Electrochemical communication occurs between cells at the synapse.

11.2 The Central Nervous System

- The central nervous system is the body's control centre. It consists of the brain and spinal cord.
- The brain includes centres that control involuntary responses and voluntary responses.
- The cerebrum is the largest part of the brain. It contains four pairs of lobes, each of which is associated with particular functions.

11.3 The Peripheral Nervous System

- The peripheral nervous system is comprised of the somatic (voluntary) system and the autonomic (involuntary) system.
- The autonomic system is divided into the sympathetic and parasympathetic nervous systems.

Common Misconceptions

- Although normal changes occur with age in the brain and nervous system, many people have misconceptions about the nature and extent of these changes. A common but erroneous belief is that all elderly people become senile. Many people blame increased confusion on "getting old" when it may, in fact, be caused by an illness.
- Many people have misconceptions about pain in children. These myths have been pervasive and have endured, even though there is now evidence that they are not true. According to The Hospital for Sick Children in Toronto, Ontario, the most common misconceptions on pain in children include the following:
  - Myth: Infants cannot feel pain.
  - Fact: Decades ago, it was thought that a newborn's nervous system had not developed enough to process pain messages and therefore a newborn could not feel pain. Surgery without anaesthetic was not uncommon, and the use of pain medicine was thought unnecessary for what are now known to be painful procedures. Today, we know that a 26-week-old fetus has a nervous system sufficiently developed to feel pain.
  - Myth: Children are less sensitive to pain than adults are.
  - Fact: Younger children experience higher levels of pain than do older children and adults. For some, pain sensitivity seems to decrease with age. (For more information, visit **www.sickkids.ca/mediaRoom/custom/painmyths05.pdf**.)
- That a pain receptor "feels pain" is another common misconception. Pain is actually the result of sensory impulses reaching the brain. Here is one explanation: The interpretation of pain occurs when the nociceptors (pain receptors) are stimulated and subsequently transmit signals through sensory neurons in the spinal cord. The spinal cord releases glutamate, a major excitatory neurotransmitter that relays signals from one neuron to another and ultimately to the thalamus, in which pain perception occurs. From the thalamus, the signal travels to the cerebrum, at which point the individual becomes fully aware of the pain.

Helpful Resources

Books and Journal Articles

- Austin, P. "Why Can't He Walk?" *Discover* 25, no. 5 (May 2004): 24.
- Fink, S. "How Did He Get So Weak?" *Discover* 24, no. 12 (December 2003): 27.
- Grim, P. "Mysteries of the Mind." *Discover* 25, no. 7 (July 2004): 26.
- Ozgur, B. "Why Can't He Speak?" *Discover* 26, no. 8 (August 2005): 20.
- Ripley, A. "Who Says a Woman Can't Be Einstein?" *Time* 165, no. 10 (March 7, 2005): 35.

Web Sites

Web links related to the human nervous system can be found at **www.albertabiology.ca.** Log on for the Instructor Edition at the Online Learning Centre and and follow the links to Chapter 11.

List of BLMs

Blackline masters (BLMs) have been prepared to support the material in this chapter. The BLMs are either for assessment (AST); use as overheads (OH); use as handouts (HAND), in particular to support activities; or to supply answers (ANS) for assessment or handouts. The BLMs are in digital form, stored on the CD that accompanies this Teacher's Resource or on the web site at **www.albertabiology.ca**, after logging on to the Instructor Edition at the Online Learning Centre.

Number (Type)

11.0.1 Launch Lab: You, Robot?
11.0.1A Launch Lab: You, Robot? Answer Key
11.1.1 (OH) Organization of the Human Nervous System
11.1.2 (OH) Neuron Bundles
11.1.3 (HAND) From Sensor to Muscle Action
11.1.3A (ANS/OH) From Sensor to Muscle Action Answer Key

11.1.4 (HAND) The Reflex Arc
11.1.4A (ANS/OH) The Reflex Arc Answer Key
11.1.5 (HAND) Investigation 11.A: Move Fast! Reflex Responses
11.1.5A (ANS) Investigation 11.A: Move Fast! Reflex Responses Answer Key
11.1.6 (HAND) Parts of a Neuron
11.1.6A (ANS/OH) Parts of a Neuron Answer Key
11.1.7 (HAND) Establishing the Resting Membrane Potential in a Neuron
11.1.7A (ANS/OH) Establishing the Resting Membrane Potential in a Neuron Answer Key
11.1.8 (HAND) Investigation 11.B: Modelling Resting Membrane Potential
11.1.8A (HAND) Investigation 11.B: Modelling Resting Membrane Potential Answer Key
11.1.9 (HAND) Depolarization and Repolarization of a Neuron
11.1.9A (ANS/OH) Depolarization and Repolarization of a Neuron Answer Key
11.1.10 (HAND) Action Potential
11.1.10A (ANS/OH) Action Potential Answer Key
11.1.11 (HAND) Saltatory Conduction
11.1.11A (ANS/OH) Saltatory Conduction Answer Key
11.1.12 (HAND) Neural Synapse
11.1.12A (ANS/OH) Neural Synapse Answer Key
11.1.13 (HAND) Neuromuscular Junction
11.1.13A (ANS/OH) Neuromuscular Junction Answer Key
11.1.14 (HAND) Investigation 11.C: Examining Neural Tissue
11.1.14A (ANS) Investigation 11.C: Examining Neural Tissue Answer Key
11.1.15 (AST) Neurotransmitters and Their Functions Quiz
11.1.15A (ANS) Neurotransmitters and Their Functions Answer Key
11.1.16 (HAND) Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses
11.1.16A (ANS) Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses Answer Key

11.2.1 (OH) Cross-section of a Human Brain
11.2.2 (HAND) The Spinal Cord
11.2.2A (ANS/OH) The Spinal Cord Answer Key
11.2.3 (HAND) The Structure of the Human Brain
11.2.3A (ANS/OH) The Structure of the Human Brain Answer Key
11.2.4 (HAND) Protection for the Brain
11.2.4A (ANS/OH) Protection for the Brain Answer Key
11.2.5 (HAND) The Cerebral Cortex
11.2.5A (ANS/OH) The Cerebral Cortex Answer Key
11.2.6 (OH) Map of the Motor Cortex
11.2.7 (HAND) Investigation 11.D: The Brain
11.2.7A (ANS) Investigation 11.D: The Brain Answer Key

11.3.1 (HAND) Map of the Spinal Nerves
11.3.1A (ANS/OH) Map of the Spinal Nerves Answer Key
11.3.2 (OH) Sympathetic and Parasympathetic Nervous Systems
11.4.1 (AST) Chapter 11 Test
11.4.1A (ANS) Chapter 11 Test Answer Key

Using the Chapter 11 Opener

Student Textbook pages 364-365

- While robots have been playing chess (and beating human opponents) for a number of years, designers have not been as successful in creating a robot that can mimic the human sensory system. Students could begin the Launch Lab by contrasting the work done by artificial intelligence that plays chess with one that can, for example, detect odours of dangerous chemicals.

Teaching Strategies

- Cut paper into strips large enough to be seen by all students. Ask students to tell you everything that they know about the nervous system. Write down key points on the strips of paper—1 key point per strip. When students have exhausted their ideas, have 2 or 3 students come up to the front and, as a large group, try to organize the information into categories. Staple the paper strips to the bulletin board under those categories when finished. Possible categories include the brain, spinal cord, sense organs, and nerves (reflexes). Refer to this "concept map" throughout this chapter.
- Take a few minutes to review with students the flow of electric current in a simple circuit (from *Science 9*). This analogy can be used to compare the flow of electric current to the transmission of a nerve impulse.

Launch Lab: You, Robot?

Student Textbook page 365

Purpose

Students will experience the complex nature of the human nervous system.

Outcome

30-A1.2s

Advance Preparation

When to Begin	What to Do
3 or 4 days before	■ Gather up the materials for this activity. ■ Request that students bring a pair of pliers from home. ■ Use paper bags to organize these materials into 1 set of materials per group.

When to Begin	What to Do
3 or 4 days before	■ Photocopy **BLM 11.0.1: Launch Lab**

Materials
■ shoes with laces ■ stopwatch ■ heavy gloves ■ 2 pairs of pliers ■ blindfold ■ tongue depressor ■ masking tape ■ ear plugs or cotton batting

Time Required

30 minutes

Helpful Tips

- Use **BLM 11.0.1: Launch Lab** to support this activity. Modify as necessry.
- Organizing one set of materials per group will save time when it comes to distributing the materials to each group.
- Remind students that they should not reuse ear plugs or the cotton batting. (Certain types of ear plugs can be sterilized before being used by another student.)
- Asking students to bring a set of pliers from home will save on your budget.

Safety Precautions

- Remind students that it is not sanitary to "share" cotton batting or the ear plugs. Ask them to dispose of the cotton batting in the garbage and return the ear plugs to a special area for sterilization.
- Remind students that wearing a blindfold while walking around can lead to injury.

Answers to Analysis Questions

1. The following table lists the senses that are impaired and how each impairment affects the ability to process sensory information.

Number of the Procedure	Senses Impaired	Effects of Impairment on Integrating and Processing Sensory Information
Step 3	no senses impaired	serves as the control test and provides baseline data
Step 4	sight and hearing	subject is now not able to receive auditory information from partner about task, and cannot see if task is being done accurately
Step 5	touch and pressure	now subject can receive visual and audio input, but cannot receive sensory input from touch and pressure receptors in the skin
Step 6	touch, pressure, and spatial	processing of sensory information is impaired because the extension of the fingers makes it difficult for the brain to recognize where these structures are in space
Step 7	touch, pressure, spatial, and different muscle receptors	sensory information is now being received about a different task—using pliers rather than fingers

2. The following chart describes the effect on the ability to perform a simple motor output task.

Number of the Procedure	Senses Impaired	Effects of Impairment on Ability to Perform a Simple Motor Output Task
Step 3	no senses impaired	serves as the control test and provides baseline data
Step 4	sight and hearing	motor output not affected greatly because the task is learned already, and not much visual or auditory information is required
Step 5	touch and pressure	motor output is affected because of the lack of sensory input from touch and pressure receptors in the skin; it would take time for the nervous system to adapt to this impairment
Step 6	touch, pressure, and spatial	motor output is affected; the extension of the fingers makes it difficult for the brain to recognize where these structures are in space; it would take time for the nervous system to adapt to this impairment

Number of the Procedure	Senses Impaired	Effects of Impairment on Ability to Perform a Simple Motor Output Task
Step 7	touch, pressure, spatial, and different muscle receptors	motor output is affected; using the pliers would require re-training the nervous system and the muscle system—this is a completely different task than that done using fingers

3. Students' impressions would depend on the degree of success or failure that they had in completing the task.

Assessment Options

- Consider completing this activity without any type of formal assessment.
- Assess answers to Analysis questions.
- Use Assessment Checklist 4: Performance Task Group Assessment from Appendix A.

11.1 Structures and Processes of the Nervous System

Student Textbook pages 366-384

Section Outcomes

Students will:

- describe the role of the nervous system in homeostasis
- describe and observe the organization of neurons into nerves
- describe the structure and function of a reflex arc, and design and perform an investigation to study reflex arcs
- explain the transmission of an action potential along a neuron and from one neuron to another, and perform investigations that demonstrate the structure and function of neurons
- analyze and explain the effects of various drugs on the nervous system

Key Terms

homeostasis
nervous system
central nervous system
peripheral nervous system
neurons
glial cells
nerves
reflex arcs
dendrites
cell body
axon
myelin sheath
Schwann cells
membrane potential
resting membrane potential
polarization
sodium-potassium exchange pump
depolarization
nodes of Ranvier
action potential
threshold potential
repolarization
refractory period
synapse
neuromuscular junction
neurotransmitters
acetylcholine
cholinesterase

Biology Background

- Homeostasis is maintained in the human body by the various parts of the nervous system.
- Neural transmission occurs along axons, due to an action potential that causes depolarization of the neuron. The wave of depolarization is primarily caused by the movement of two positive ions (Na^+ and K^+) from one side of the axon's cell membrane to the other.
- Reflex arcs are simple connections of neurons that explain reflexive behaviours. The impulse travels to the spinal cord from the affected body part, crosses to a small interneuron, and then moves to a motor neuron that transmits the impulse to an effector (muscle). The brain becomes aware of the reflex only after it occurs.
- Electrochemical communication occurs between nerve cells at the synapse. Transmission across a synapse is dependent on the release of neurotransmitters, which diffuse across the synaptic cleft from one neuron to the next.

Teaching Strategies

- Introduce this unit by showing an introductory video on the human nervous system. Select a video that provides an overview of the entire nervous system including the neuron, brain, and sense organs.
- Use **BLM 11.1.1: Organization of the Nervous System** to help students summarize the organization of the nervous system.
- Locate the web resources provided on the McGraw-Hill web site (described under Helpful Resources in this Teacher's Resource). These web sites include animations of resting membrane potential, the action potential, repolarizing a neuron, and the synapse. Arrange to have a computer with Internet access connected to a data projector in the classroom. Use these animations to help your students visualize these very difficult concepts.
- A number of overhead masters that can double as handouts and reinforcement activities have been prepared for this section. These are in addition to the BLMs supporting the activities. In particular, art illustrating the various structures and processes are available in BLM format for use in labelling structures and tracing and/or describing

processes. You will find them with the Chapter 11 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging on to the Instructor Edition at the Online Learning Centre.

Number (Type)
11.1.1 (OH) Organization of the Human Nervous System
11.1.2 (OH) Neuron Bundles
11.1.3 (HAND) From Sensor to Muscle Action
11.1.3A (ANS/OH) From Sensor to Muscle Action Answer Key
11.1.4 (HAND) The Reflex Arc
11.1.4A (ANS/OH) The Reflex Arc Answer Key
11.1.6 (HAND) Parts of a Neuron
11.1.6A (ANS/OH) Parts of a Neuron Answer Key
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11.1.7A (ANS/OH) Establishing the Resting Membrane Potential in a Neuron Answer Key
11.1.9 (HAND) Depolarization and Repolarization of a Neuron
11.1.9A (ANS/OH) Depolarization and Repolarization of a Neuron Answer Key
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11.1.12A (ANS/OH) Neural Synapse Answer Key
11.1.13 (HAND) Neuromuscular Junction
11.1.13A (ANS/OH) Neuromuscular Junction Answer Key
11.1.15 (AST) Neurotransmitters and Their Functions Quiz
11.1.15A (ANS) Neurotransmitters and Their Functions Answer Key

SUPPORTING DIVERSE STUDENT NEEDS

- The terminology introduced in this section could pose a challenge for some students, especially those whose first language is not English. Consider allowing these students to express their ideas initially in their first language and then translate these ideas into English.
- Ask students to start a vocabulary list. Their list should include the name of a structure, its function, and an illustration. They can add terms to their list as well as modifying and refining existing terms as they work through the chapter.
- Struggling learners may grasp an idea better by looking at diagrams or pictures. Use the various blackline masters provided in this Teacher's Resource to help these students.
- The rich array of materials available through the Internet makes it relatively easy to differentiate materials for your students. For example, ESL students might benefit from making their own crossword puzzle dealing with the neuron. Or the interactive nature of many of the recommended web sites could help students visualize the concepts presented in this section.
- Create a 2- or 3-page study guide of ideas in the section. This guide can be of great assistance to students who struggle with print materials, lectures, or even organization of information. The guide could be in paragraph form, point form, a graphic organizer, or a combination. It might also spotlight key vocabulary and provide essential questions that the section is designed to address. Advanced students could be encouraged to make a digital version of this guide using presentation software.
- Making models of the neuron as well as the electrochemical events that take place during the transmission of a nervous impulse can help all students visualize these concepts.

Figure 11.1

Student Textbook page 366

Students may remember this information from previous biology classes. Sensory receptors are found throughout every body organ and tissue. The function of the sensory receptors is to send nerve impulses to the brain in response to environmental information (stimuli). When the body's temperature begins to drop or rise, specialized receptors in the skin detect the change and signal the hypothalamus.

The brain, similar to the thermostat in a house, is an integrator—it sends messages to effectors (analogous to the furnace or air conditioner in a house). Effectors, in turn, cause a change in the internal conditions. In this case, the brain sends messages to various tissues and organs that cause the body to either generate or conserve heat. These messages can be transmitted by the nervous system or by chemical messengers known as hormones.

Answers to Questions for Comprehension

Student Textbook page 367

Q1. Homeostasis is the maintenance of a constant internal environment. Slight fluctuations above and below these "normal" levels are common, so our internal systems are often said to be in a state of dynamic equilibrium.

Q2. The human nervous system can regulate tens of thousands of activities simultaneously. Its overall function is to collect information about the external conditions in relation to the body's internal state, to analyze this information, and to initiate appropriate responses to maintain homeostasis.

Q3.

System	Structure	Function
Central Nervous System	■ brain ■ spinal cord	■ The spinal cord carries messages from the body to the brain. ■ The brain analyzes and interprets these messages. ■ The brain then passes response messages through the spinal cord to the target structure—a muscle, a gland, or another neuron.
Peripheral Nervous System	■ somatic nervous system ■ autonomic nervous system	■ This system relays information to and from the skin and skeletal muscles under conscious control. ■ The sympathetic nervous system controls organs in times of stress (fight or flight). ■ The parasympathetic nervous system causes a return to a state of rest and controls organs when the body is at rest.

Student Textbook page 370

Q4. Neurons are the basic structural and functional units of the nervous system. They are specialized to respond to physical and chemical stimuli, to conduct electrochemical signals, and to release chemicals that regulate various body processes.

Glial cells support neurons. These cells nourish the neurons, remove their wastes, and defend against infection. Glial cells also provide a supporting framework for all of the nervous-system tissue.

Q5. The three types of neuron are the sensory neuron, interneuron, and motor neuron.

- Sensory neurons gather information from sensory receptors and transmit these impulses to the central nervous system.
- Interneurons are found entirely within the central nervous system. They act as a link between the sensory and motor neurons. They process and integrate incoming sensory information, and relay outgoing motor information.
- Motor neurons transmit information from the central nervous system to muscles, glands, or other organs (effectors).

Q6. The basic neural pathway used is a reflex arc, which is a withdrawal reflex in this example.

Sense organ (eye) detects the ball → sensory neuron → spinal cord (interneuron) → motor neuron → causes muscle to act to withdraw (move the head) out of the way of the ball

Investigation 11.A: Move Fast! Reflex Responses

Student Textbook page 371

Purpose

Students will design and perform an investigation to study reflex arcs.

Outcomes

- 30-A1.2s
- 30-A1.4s

Advance Preparation

When to Begin	What to Do
1 or 2 days before	■ Check to make sure that you have all of the materials required for this investigation. ■ Photocopy **BLM 11.1.5: Investigation 11.A**

Materials
■ chair (1 per group) ■ room light ■ 20 cm by 20 cm clear plastic sheet (1 per group) ■ cotton balls (1 or 2 per group)

Time Required

- 30 minutes to complete Parts 1 to 3 of this activity
- 30 minutes to complete Application question 5

Helpful Tips

- Review and demonstrate the procedure for Parts 1 to 3. As you are demonstrating each part, reinforce the safety precautions for this investigation.
- Distribute **BLM 11.1.5: Investigation 11.A** prior to the lab. Modify it as necessary.
- Have students work in groups of 3. One student can act as the experimenter, the second student as the subject, and the third student as the timer/data recorder. Make sure that students assume different roles as they complete the 3 parts of this investigation.
- If you ask students to design their own investigation (Application question 5), make sure that you clearly explain what is and is not acceptable. Pay particular

attention to the safety precautions that students include in their experimental design. Also make sure that the students are actually investigating a reflex in the human body.

Safety Precautions

- Remind students that they do not have to hit hard when testing for the knee-jerk (patellar) reflex.
- Caution students that even a cotton ball can cause damage to the eye, including scratching the cornea. Make sure they understand that they should not throw the cotton ball hard and that the subject's eyes should be protected by the plastic shield during this part of the activity.

Answers to Analysis Questions

1. Students' answers should be similar to Figure 11.8 on page 370 of the student textbook. Make sure that students label the stimulus, sensory neuron, cell body of the sensory neuron, interneuron in the spinal cord, cell body of the motor neuron in the grey matter of the spinal cord, the motor neuron, and the effector (muscle).

2. Because reflex arcs use very few neurons to transmit messages, reflexes can be rapid and a response can happen before there is an awareness that a reaction is necessary. This means that contact with a dangerous stimulus is minimized.

Answer to Conclusion Question

3. The pupillary reflex will protect the retina from bright light. The blink reflex will protect the cornea and other structures of the eyeball from contact with objects. The knee-jerk reflex can be used by doctors to diagnose certain neurological disorders or an injury to the muscles in the thigh (i.e., a pulled hamstring muscle).

Answers to Extension Questions

4. When a student moves her hand upon touching a hot glass, it is an example of the withdrawal reflex. Receptors in the skin sense the heat and initiate an impulse in the sensory neurons. The impulse carried by the sensory neuron then activates the interneuron in the spinal cord. The interneuron signals the motor neuron to instruct the muscle to contract and withdraw the hand. A reflex arc initiates a reaction before the brain has had a chance to process the sensory information. However, once the brain has interpreted the sensory information, the student will feel pain.

5. Students can now build on their previous experiences and learn more about reflex arcs. Students can quantify their data by measuring the distance the foot moved during the knee reaction by marking the starting and ending points on a piece of cardboard. Alternatively, they could use a protractor to measure the angle of change in the knee. Eye pupil data may be scored as a plus or minus to indicate whether the reaction occurred in a number of students.

Once again, make sure that students are conducting investigations that do not cause harm to sense organs. For example, if you are going to allow them to "pop" a balloon near an unsuspecting student, make sure that they do not pop the balloon close to the other person's ear.

Assessment Options

- Collect and assess students' answers to Analysis questions 1 and 2, Conclusion question 3, and Extension question 4.
- Use Assessment Checklist 4: Performance Task Group Assessment for Appendix A.

Answers to Questions for Comprehension

Student Textbook page 372

Q7. Students' drawings should be similar to the motor neurons shown in Figure 11.9 on page 372 of the student textbook. The diagram should include the following labels: dendrites, cell body, axon, Schwann cell, and the node of Ranvier.

Q8. The axons of some neurons are enclosed in a fatty, insulating layer called the myelin sheath, which gives the axons a glistening white appearance. These axons are said to be myelinated. The myelin sheath protects myelinated neurons and speeds the rate of nerve impulse transmission. Schwann cells, a type of glial cell, produce myelin in certain parts of the CNS and PNS.

Figure 11.10

Student Textbook page 373

Much of what neurologists have learned about how neurons function comes from experiments done with a giant squid, *Loligo*. The neuron used for rapid tail movements has an axon that reaches from the head of the squid to the end of its tail. The axon is about 1 mm in diameter, or 100 to 1000 times the diameter of a human axon. The size of the axon allows scientists to measure the charge difference across the cell membrane quite easily by inserting tiny electrodes into the axon and then reading the charge difference from a specialized voltmeter. This technique has provided extensive information about how a voltage gradient is established across the axon membrane and how a neural impulse is generated.

Answers to Questions for Comprehension

Student Textbook page 374

Q9. The charge difference across the membrane in a resting neuron is called the resting membrane potential. The resting membrane potential of most unstimulated neurons is –70 mV (millivolts), and it is more negative on the inside. The resting membrane potential provides energy for the generation of a nerve impulse in response to an appropriate stimulus.

Q10. Neurons achieve polarization (i.e., generate resting membrane potential) in 3 ways:

1. Some negatively charged substances, such as proteins and chloride ions (Cl^-), are trapped inside the cell and unable to diffuse out through the selectively permeable cell membrane.
2. Sodium ions (Na^+) and potassium ions (K^+) cannot diffuse unaided from one side of the cell membrane to the other. Special membrane proteins, however, can use the energy of ATP to pump charged particles across the membrane. This **s**odium-potassium pump pumps out *3* sodium ions for every *2* potassium ions pumped into the cell, which results in an unequal distribution of positive charges on either side of the membrane. The buildup of positive charges on the outside of the cell creates an electric potential.
3. Special transport proteins form ion-specific channels that allow potassium ions to diffuse down their concentration gradient and out of the cell. There are sodium ion channels as well, but, in a resting neuron, there are more open channels for potassium ions than for sodium ions. As a result, more potassium ions diffuse out of the cell relative to the number of sodium ions diffusing in, which contributes to the buildup of positive charges on the outside of the membrane.

Investigation 11.B: Modelling Resting Membrane Potential

Student Textbook pages 375

Purpose

Students will build a model of the neural membrane to demonstrate how the resting membrane potential is established.

Outcomes

- 30-A1.2s
- 30-A1.3s
- 30-A1.4s

Advance Preparation

When to Begin	What to Do
1 or 2 days before	■ Photocopy **BLM 11.1.8: Investigation 11.B** ■ Gather the materials and prepare the sodium chloride and potassium chloride solutions.
1 or 2 days before	■ Photocopy Assessment Checklist 2: Laboratory Report from Appendix A if you want your students to generate a full lab report for this activity.

Materials

- 22 cm of moistened dialysis tubing
- 2 strips of uninsulated copper wire, each 40 cm long
- string
- elastic band
- pen
- DC millivolt meter
- 400 mL beaker
- 3 mol/L sodium chloride (NaCl) solution (500 mL per group)
- 3 mol/L potassium chloride (KCl) solution (100 mL per group)

Time Required

45 minutes

Helpful Tips

- Use **BLM 11.1.8: Investigation 11.B** to support this activity. Modify as necessary.
- To make 500 mL of the 3 mol/L solution of NaCl, add 58.44 grams of sodium chloride to a 500 mL volumetric flask. Add distilled water to bring the volume in the flask up to 500 mL. This is a very concentrated solution and it may take several minutes for all of the NaCl to dissolve.
- To make 100 mL of 3 mol/L solution of KCl, add 22.36 grams of potassium chloride to a 100 mL volumetric flask. Add distilled water to bring the volume in the flask up to 100 mL. This is also a very concentrated solution and it may take several minutes for all of the KCl to dissolve.
- Make sure that the students clean the copper wire with steel wool or sandpaper to remove any insulation or signs of oxidation.
- Strips of copper metal can be substituted for the copper wire. The key thing is to provide maximum surface area for the chemical reaction.
- Demonstrate how to open the dialysis tubing and how to secure it with a knot at the end as well as securing it tightly with the piece of string. If the dialysis bag is not tied securely, the potassium chloride solution will leak out before the students can attach their voltmeter to the copper strips.
- Demonstrate how to set up and use the DC millivolt meter (multimeter) before students begin the activity.
- Assign students to groups of three or four. Two students can set up the equipment, a third student can time the experiment, and a fourth student can record the results.

- This investigation does require a significant quantity of sodium chloride solution. If your budget is tight, consider doing this activity as a demonstration. Use a couple of students as helpers.
- Students should connect the multimeter to the copper wires before lowering the dialysis bag of potassium chloride into the sodium chloride solution. They should begin timing as soon as the dialysis bag is lowered into the sodium chloride solution. Have students record the voltage in 10-second intervals. It should take 2 to 3 minutes. It should take a few minutes for the potassium to diffuse out of the semi-permeable (selectively permeable) dialysis tubing. The movement of the potassium ions creates a voltage gradient similar to the one generated in the neuron.
- This activity is ideally suited for using lab probeware. The voltage should be set in the range of 0 mV to 100 mV and the sampling rate should be set for once per 10-second interval.
- *Expected Results:* Students' graphs should have a "bell-shape" with a maximum of approximately 20 mV. It will also take some time for the voltage to return back to the original level because sodium ions do not diffuse through the dialysis membrane as quickly.

Safety Precautions



Remind students that they must wear safety goggles and aprons at all times.


Remind students that they are using two very concentrated salt solutions. They must wash their hands immediately if they spill either solution on their skin.

- If the students are making their own solutions in a volumetric flask, warn them not to place their thumb over the opening when trying to dissolve the sodium chloride and potassium chloride.

Answers to Analysis Questions

1. Students should graph the number of millivolts produced vs. the time. The graph should have a "bell-shape" with a maximum voltage difference of approximately 20 mV. It will also take some time for the voltage to return to the original level because sodium ions do not diffuse through the dialysis membrane as quickly as do potassium ions.

2. The dialysis tubing is semi-permeable and is analogous to the membrane of the neuron. The K^+ ions in the potassium chloride solution are analogous to the K^+ ions that are inside the neuron. The Na^+ ions in the sodium chloride solution are analogous to the Na^+ ions that are outside the neuron. However, the dialysis tubing does not have the sodium-potassium pump that a neuron has. All movement of ions into and out of the dialysis bag is as a result of simple diffusion.

3. The resting membrane potential of the model neuron will be zero prior to lowering the dialysis tubing into the sodium chloride solution. An electric current cannot be produced in the model until the dialysis tubing is lowered into the sodium chloride solution. The resting membrane potential of a neuron is approximately –70 mV. This negative electric potential of a living neuron is the result of the sodium-potassium pump. ATP is used to pump 3 sodium ions out for every 2 potassium ions that are pumped into the neuron. This results in an unequal distribution of positive charges on either side of the neuron. The buildup of positive charges on the outside of the cell creates an electric potential. In addition, potassium ions also diffuse out of the membrane and sodium ions into the membrane, but this diffusion is unequal: more potassium diffuses out of the membrane, and less sodium diffuses into the membrane.

4. Possible sources of discrepancies could include allowing leaks in the dialysis tubing, not removing all of the insulation or oxidized material from the copper metal, using warmer or colder solutions, not connecting the multimeter correctly, or not timing accurately.

5. One possible hypothesis would be to use solutions with higher or lower concentrations. For example, if you increase the concentration of potassium chloride, you will get a greater electric potential across the dialysis tubing. Accept any reasonable hypothesis.

Answers to Conclusion Questions

6. (a) The electric potential was zero at the beginning of the activity, gradually increased to approximately 20 mV, and then decreased back to zero. The electric potential was created by the diffusion of ions across the semi-permeable membrane, and then it returns to zero as ions diffuse back.

(b) A neuron would be able to generate only one action potential. The neuron has to have a way of quickly repolarizing in order to transmit the next action potential.

7. (a) Ions moving by facilitated diffusion can move across a plasma membrane through channels created by proteins embedded in the cell membrane. These proteins allow for the formation of a concentration gradient between the fluids inside and outside the cell. Facilitated diffusion cannot occur in this model because dialysis tubing is non-living and does not have special protein molecules to carry out this process. In this model, K^+ ions diffuse out of the dialysis bag into the sodium chloride solution. This creates a separation of charge because the K^+ ions moved into the sodium solution. The corresponding Cl^- ions are in equal concentration on both sides of the membrane. As a result, the sodium chloride solution becomes more positive than the potassium chloride solution inside the dialysis tubing. The charge then returns to zero as the Na^+ ions diffuse into the tubing. However, sodium ions take a longer

time to diffuse into the dialysis tube than potassium ions take to diffuse out.

(b) The factors that establish a negative resting membrane potential in a neuron are as follows:

1. Some negatively charged substances, such as proteins and chloride ions (Cl^-), are trapped inside the cell and unable to diffuse out through the selectively permeable cell membrane.
2. Sodium ions (Na^+) and potassium ions (K^+) cannot diffuse unaided from one side of the cell membrane to the other. Special membrane proteins, however, can use the energy of ATP to pump charged particles across the membrane. This sodium-potassium pump moves out *3* sodium ions for every *2* potassium ions pumped into the cell, which results in an unequal distribution of positive charges on either side of the membrane. The buildup of positive charges on the outside of the cell creates an electric potential.
3. Special transport proteins form ion-specific channels that allow potassium ions to diffuse down their concentration gradient and out of the cell. There are sodium ion channels as well, but, in a resting neuron, there are more open channels for potassium ions than for sodium ions. As a result, more potassium ions diffuse out of the cell relative to the number of sodium ions diffusing in, which contributes to the buildup of positive charges on the outside of the membrane.

Assessment Options

- Collect and assess the answers to the Analysis and Conclusion questions.
- Use Assessment Checklist 2: Laboratory Report from Appendix A if you want your students to generate a full lab report for this activity.

Figure 11.14

Student Textbook page 376

The membrane is depolarized and the neuron is in its refractory period. The neuron will not be able to fire again until the –70 mV resting potential is reestablished. Repolarization is the event that helps to restore the resting membrane potential.

Answers to Questions for Comprehension

Student Textbook page 377

Q11. Depolarization of the neuron takes place if the stimulus is weak. In this case only a small number of channels will open and some sodium will start to diffuse down its concentration gradient and into the neuron. This process changes the membrane potential, causing depolarization of the membrane. If the charge inside the cell stays close to –70 mV; however, no impulse will be generated.

An action potential is a wave of depolarization that sweeps along the neuron. If a threshold potential is reached, large numbers of sodium ion channels simultaneously open, allowing for an influx of sodium ions and rapid depolarization of the membrane. This rapid change in the membrane potential from –70 mV to about +35 mV initiates a nerve impulse, called an action potential.

Q12. An action potential has an all-or-none response. Each depolarization event either reaches the threshold potential, causing an action potential, or does not. Furthermore, an action potential has only one strength or magnitude. In other words, the axon cannot fire a stronger or weaker action potential.

Q13. Immediately after the sodium ion channels open, the change in membrane potential to +35 mV triggers certain potassium ion channels to open. The potassium ions rush out of the membrane, down their concentration gradient to the outside of the neuron. This event, which helps to restore the resting membrane potential, is called repolarization.

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.

The voltage-activated potassium ion channels then close, and the membrane returns to its resting state of –70 mV. The return to resting membrane potential following the initial depolarization is called the refractory period. Until the neuron goes through the refractory period, it cannot be stimulated again.

Biology File: Web Link

Student Textbook page 378

Animations of an action potential spreading along the axon of a neuron look like a wave spreading out when a pebble is dropped in a puddle of water.

Answers to Questions for Comprehension

Student Textbook page 380

Q14. A neural impulse is the movement of action potentials and the consequent repolarization along the neuron. The impulse begins as a movement of ions across a localized

area of the cell membrane, which reverses the polarity of the membrane potential in the area. This reversal of polarity results in depolarization in the neighbouring area of the membrane, which has the same effect on the next area of the membrane, and so on. In this way, the impulse propagates in one direction along the length of the neuron, with sodium ion channels and then potassium ion channels opening up in one area after another.

Q15. An action potential travels the length of the axon until it reaches the far end, called the synaptic terminal. Synaptic vesicles move toward and fuse with the presynaptic membrane. Neurotransmitters are released into the synaptic cleft and diffuse across the cleft to the postsynaptic membrane where they bind to receptor proteins and affect the postsynaptic neuron.

Q16. Neurotransmitters carry the neural signal from one neuron to another. Neurotransmitters can also carry the neural signal from a neuron to an effector, such as a gland or a muscle fibre.

Biology File: Web Link

Student Textbook page 380

When an action potential arrives at the end of a presynaptic neuron, the impulse causes sacs that contain neurotransmitters to fuse with the cell membrane of the axon. These sacs, called synaptic vesicles, release their contents into the synaptic cleft by exocytosis. Upon reaching the postsynaptic membrane, the neurotransmitters bind to specific receptor proteins in this membrane.

Investigation 11.C: Examining Neural Tissue

Student Textbook page 381

Purpose

Students will observe neurons and neuromuscular junctions with a microscope, identify the principal structures in different types of neurons, and relate these structures to their functions.

Outcome

- 30-A1.2s

Advance Preparation

When to Begin	What to Do
3 to 4 weeks before	■ Check supply of prepared microscope slides and order those required to complete the activity.
1 day before	■ Photocopy **BLM 11.1.14 Investigation 11.C**

Materials

- microscope
- prepared neural slides of the following:
  - cross section of brain showing white and grey matter
  - cross section of a nerve showing that a number of neurons make up a single nerve
  - cross section of the spinal cord showing a sensory neuron, a motor neuron, and the interneuron
  - unmyelinated neurons showing the dendrites, cell body, and axon
  - myelinated axons
  - neuromuscular junction

Time Required

45 minutes

Helpful Tips

- To reduce the number of microscopes and prepared slides, arrange your students into teams of 3. Set up the microscopes in "stations." Have an instruction card at each station that outlines what the students should be looking for in each slide. While one student is actually looking at the slide, the other two can be working on their drawings and answering the question. Use a stop watch or egg timer to let students know when it is time to move to the next station.
- A number of sites on the Internet show labelled histology slides of neurological tissue. Web links related to this activity can be found at **www.albertabiology.ca**. Select Student Edition and follow the links to Chapter 11. Arrange for a computer in your classroom to be connected to the Internet. Use a data projector to display each image on the screen or white board. Point out the key structures on each slide and then have your students complete the Analysis questions.
- Review the proper procedure for focussing a microscope. This will reduce the likelihood that students will damage the objective lens of the microscopes or break the prepared slides.
- Group students into teams of 3 or 4 and assign each group one of the neural tissues shown in this activity. Have the teams prepare drawings and detailed answers to their respective Analysis question. Provide time for each group to present the results of its research to the rest of the class.

Answers to Analysis Questions

1. Students' drawings will likely show a difference in colour (grey vs. white). Grey matter is a category of nervous

tissue characterized by many nerve cell bodies and very few myelinated axons. Grey matter looks reddish grey on a freshly removed brain. White matter is composed of axon nerve fibres that are covered by a myelin sheath.

2. Students' drawings should show numerous neurons enclosed in a sheath. The neurons are the functional units of the nervous system. These cells transmit regulatory information in the form of electrochemical impulses.
3. Students' drawings should be similar to Figure 11.6 on page 369 of the student textbook. A stimulus causes sensory receptors to generate a nervous impulse that travels along sensory axons to the spinal cord. Interneurons integrate data from sensory neurons and then relay signals to motor neurons. Motor axons convey nerve impulses from the spinal cord to an effector such as a skeletal muscle.
4. Students' drawings should include the dendrites, cell body, and axon. The impulse should indicate that dendrites transmit the nervous impulse to the cell body while the axon transmits the nerve impulse away from the cell body.
5. Students' drawings should include the axon, the myelin sheath, a Schwann cell (including the nucleus), and a node of Ranvier. The myelin sheath protects the myelinated neuron and speeds the rate of nerve impulse transmission.
6. Students' drawings should include the end plates of a motor neuron, the synapse, and the muscle fibre. Students will be learning that special chemical messengers (neurotransmitters) carry the neural signal from the neuron to the muscle fibre.
7. Students' answers will depend on the slide or slides that you have provided.

Assessment Options

- Collect and assess students' answers to the Analysis questions, including their drawings.

Answers to Questions for Comprehension

Student Textbook page 382

Q17. Neurotransmitters have either excitatory or inhibitory effects on the postsynaptic membrane. If the effect is excitatory, the receptor proteins will trigger the opening of ion channels that allow positive ions, such as sodium, to flow into the postsynaptic neuron. This depolarizes the postsynaptic membrane and, if the threshold potential is reached, initiates an action potential. The impulse that is initiated will travel along the axon to the next neuron or effector.

If, however, 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 will be no action potential.

Q18. Acetylcholine is a neurotransmitter that crosses a neuromuscular junction. Acetylcholine excites the muscle cell membrane, causing depolarization and contraction of the muscle fibre.

Cholinesterase is an enzyme that is released into a synapse to break down acetylcholine. Cholinesterase is one of the fastest acting enzymes; in a fraction of a second it breaks down acetylcholine and removes it from the protein receptors, thus allowing the ion channels to close and the membrane to repolarize.

Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses

Student Textbook page 383

Purpose

Students will analyze and explain how different drugs affect neural impulses, work cooperatively to investigate the effects of a drug on neurons or neural synapses, and hypothesize what might make some drugs addictive.

Outcomes

- 30-A1.2sts
- 30-A1.4s

Advance Preparation

When to Begin	What to Do
3 to 4 weeks before	■ Contact agencies such as Alberta Alcohol and Drug Addiction Commission (AADAC) to obtain print resources that discuss drug dependency. ■ Contact agencies such as AADAC to request one of their counsellors to talk to your students. ■ Book the computer lab and/or library for two class periods. ■ Talk to your school's Resource Officer to see if he/she has any information on drug dependency. ■ Find out whether a local doctor would be willing to present to your students on the effects of drugs on the nervous system.

When to Begin	What to Do
1–2 days before	■ Photocopy **BLM 11.1.16: Thought Lab 1.1**

Materials
■ print and electronic information on the effects of drugs on the nervous system

Time Required

- 1 class period for students to conduct their research
- 1 class period for students to make their pamphlet
- 1 class period for students to present their findings

Helpful Tips

- Use **BLM 11.1.16** to support this activity. Modify as necessary.
- To save some time, organize the groups ahead of time and assign each group one drug to research.
- Identify the topics that you want students to research. Set specific limits on the size of the pamphlet, the amount of time students will have to research their assigned drug, the amount of time students will have to make their pamphlet, and the length of their presentations.

Answer to Analysis Question

1. Addictive properties are unique to each drug. However, one area students may focus on is the action of drugs at a synapse. A drug can affect a neurotransmitter in these ways:

(a) it can cause leakage of the neurotransmitter out of a synaptic vesicle into the axon terminal;

(b) it can prevent release of the neurotransmitter into the synaptic cleft;

(c) it can promote release of the neurotransmitter into the synaptic cleft;

(d) it can prevent the re-uptake of the neurotransmitter by the presynaptic membrane;

(e) it can block the enzyme that breaks down the neurotransmitter; or

(f) it can bind to a receptor protein, mimicking the action or preventing the uptake of a neurotransmitter.

Taking drugs that affect the nervous system leads to physical dependence and withdrawal symptoms if the drug is not taken regularly.

Answer to Extension Question

2. This question challenges students to debate the effects of drug use on society as a whole. Caution students to form their arguments for or against based on facts—not on emotion or urban legends. Establish guidelines for presenting their point of view, and protocols for rebuttal to ensure that the debate does not get out of control.

Assessment Options

- Design a rubric to evaluate the pamphlet produced by the group and their presentation. Provide this rubric to the students prior to the activity. This will ensure that students know how they are going to be evaluated.

Section 11.1: Review Answers

Student Textbook page 384

1. A – central nervous system

B – peripheral nervous system

C – sensory pathways

D – motor pathways

E – somatic nervous system

F – autonomic nervous system

G – sympathetic nervous system

H – parasympathetic nervous system

2. Students' answers will depend on what they remember about electricity from Science 9.

Criteria	Electric Current in a Wire	Nerve Impulse
conductor	Electric currents travel along a conductor such as copper wire.	Electrochemical action causes the action potential to travel along the axon of a neuron.
propagation	Movement of an electric pulse along a wire involves the movement of electrons along the wire.	A nerve impulse is the result of ion concentration differences across the axon membrane.
strength of the impulse	The strength of an electrical current diminishes the farther you get from the source.	The strength of the action potential is the same along the entire length of the neuron.

Criteria	Electric Current in a Wire	Nerve Impulse
contact	Wires have to be in direct contact with each other in order for electricity to flow from one to the next.	Neurons are not in direct contact with each other. Neurotransmitters transmit the action potential from one neuron to another.
speed	Electricity in a wire travels much faster than the action potential in a neuron.	The action potential in a neuron travels much more slowly than electricity in a wire.
all-or-none	A switch regulates the flow of electrons through a circuit.	Once threshold potential is reached, an action potential will be generated in the neuron and will propagate the entire length of the neuron.

3. Myelinated neurons have a white, glistening appearance. The myelin sheath is an excellent insulator, protects myelinated neurons, and 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. The fastest impulses, such as those in a reflex arc, travel at about 120 m/s. Schwann cells, a type of glial cell, produce myelin in certain parts of the nervous system. In the central nervous system, myelinated neurons form what is known as white matter. In the peripheral nervous system, most neurons are myelinated. Unmyelinated neurons form the grey matter in the central nervous system. The nerve impulses in unmyelinated neurons, such as those that stimulate smooth muscle in the digestive tract, travel at only about 2 m/s.

4. Students' answers should resemble Figure 11.12 on page 374 of the student textbook. 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. 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 3 sodium ions move out for every 2 potassium ions pumped into the cell; 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. The value of this is that the resting membrane potential provides energy for the generation of a nerve impulse in response to an appropriate stimulus.

5. (a) The event occurring at Region 1 is that the membrane achieves resting potential. At Region 2, the neuron becomes depolarized. At Region 3, the neuron becomes repolarized.

(b) At Region 2 (depolarization), sodium ions are entering the neuron.

(c) At Region 3 (repolarization), potassium ions are leaving the neuron.

(d) At Regions 1 and 4 (resting membrane potential), the sodium ion concentration is higher outside than inside the neuron.

6. Acetylcholine is a neurotransmitter that crosses a neuromuscular junction. Acetylcholine excites the muscle cell membrane, causing depolarization and contraction of the muscle fibre. Cholinesterase is the enzyme released into a synapse to break down acetylcholine. Breaking down acetylcholine removes it from the protein receptors, thus allowing the ion channels to close and the membrane to repolarize in a fraction of a second. One possible hypothesis is that if there is an overproduction of cholinesterase, acetylcholine will not be permitted to fulfill its function. This could affect muscle activity.

7. Neurotransmitters have either excitatory or inhibitory effects on the postsynaptic membrane. If the effect is excitatory, the receptor proteins will trigger ion channels that open to allow positive ions, such as sodium, to flow into the postsynaptic neuron. This depolarizes the postsynaptic membrane and, if the threshold potential is reached, initiates an action potential. The impulse will travel along the axon to the next neuron or effector.

If, however, the effect is inhibitory, 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.

8. (a) An action potential travels along an axon to the synaptic terminal. Synaptic vesicles move toward and fuse with the presynaptic membrane, releasing neurotransmitters into the synaptic cleft. Neurotransmitters bind to receptor proteins on the postsynaptic neuron and affect the movement of ions across the membrane, either causing an action potential or not. After the neurotransmitter has had its effect, enzymes inactivate it so that its components can be reabsorbed by the presynaptic cell. The postsynaptic neuron will then return to resting potential.

(b) Cocaine acts by blocking the re-uptake of certain neurotransmitters such as dopamine. By binding to the transporters that normally remove the excess of this neurotransmitter from the synaptic gap, cocaine prevents dopamine from being reabsorbed by presynaptic neurons, resulting in an increased concentration of dopamine in these synapses. As a result, the natural effect of dopamine on the postsynaptic neurons is amplified and produces the feeling of euphoria typically experienced by people who take cocaine.

(c) (Note: Students may be able to obtain some of this information from the group presentations or pamphlets on drugs from Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses.) Dopamine has a number of roles. In terms of cocaine addiction, dopamine is commonly associated with the "pleasure system" of the brain, providing feelings of enjoyment and reinforcement to motivate us to do, or continue doing, certain activities. Students may also include the other roles that dopamine has in the brain. For example, dopamine is critical to the way the brain controls our movements. Shortage of dopamine causes Parkinson's disease, in which a person loses the ability to execute smooth, controlled movements. In the frontal lobes, dopamine controls the flow of information from other areas of the brain. Dopamine disorders in this region of the brain can cause a decline in cognitive functions, especially memory, attention and problem solving.

(d) From their research, students may hypothesize that cocaine causes extreme physical dependence because, with continued cocaine use, the body begins to make less dopamine to compensate for a seemingly endless supply. The user, therefore, experiences increased tolerance, withdrawal symptoms, and intense cravings for cocaine.

11.2 The Central Nervous System

Student Textbook pages 385-395

Section Outcomes

Students will:

- identify the principal structures of the central nervous system
- explain the functions of the spinal cord and various regions of the brain
- observe the principal features of the mammalian brain
- explain how technological advances in neuroscience can provide solutions to practical problems

Key Terms

grey matter
white matter
meninges
cerebellum
medulla oblongata
pons
midbrain
thalamus
hypothalamus
cerebrum
blood-brain barrier
cerebrospinal fluid
cerebral cortex
corpus callosum
occipital lobes
temporal lobes
parietal lobes
frontal lobes
Broca's area
Wernicke's area

Biology Background

- The central nervous system (CNS) consists of the brain and spinal cord.
- The spinal cord is a vital communication link between the brain and the peripheral nervous system.
- The brain includes centres that control involuntary and voluntary responses.
- The brain can be divided into three general regions: the hindbrain, the midbrain, and the forebrain.
- The cerebrum is the largest part of the brain. It contains four lobes, each of which is associated with particular functions.

Teaching Strategies

- Check with your local media resource centre to find an intermediate-level video that provides an overview of the human brain. Try to find one that does not provide too much detail, but simply gives your students a broad introduction to this organ.
- Most students are fascinated (or grossed out) by Phineas Gage's story (as recounted in Figure 11.31 on page 392 and discussed under "Mapping Brain Functions" on the same page). Phineas Gage was the foreman of a railway construction gang working for the contractors preparing the bed for the Rutland and Burlington Rail Road near Cavendish, Vermont. On 13 September 1848, an accidental explosion of a charge he had set blew his tamping iron through his head. Phineas was knocked over but was believed not to have lost consciousness even though most of the front part of the left side of his brain was destroyed. Students may wish to explore web sites that describe what happened to Mr. Gage over the longer term and the information that the medical community was able to learn from him about the function of the brain. They can also find out more information about the work of Canadian doctor Wilder Penfield.

- Consider asking your students to design and create a computer presentation on the human brain that describes the different regions and their respective functions.
- A number of overhead masters and reinforcement tools, such as handouts that can be used as worksheets, have been prepared for this section. These are in addition to the BLMs supporting activities in the section. You will find them with the Chapter 11 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging on to the Instructor Edition at the Online Learning Centre.

Number (Type)
11.2.1 (OH) Cross-section of a Human Brain
11.2.2 (HAND) The Spinal Cord
11.2.2A (ANS/OH) The Spinal Cord Answer Key
11.2.3 (HAND) The Structure of the Human Brain
11.2.3A (ANS/OH) The Structure of the Human Brain Answer Key
11.2.4 (HAND) Protection for the Brain
11.2.4A (ANS/OH) Protection for the Brain Answer Key
11.2.5 (HAND) The Cerebral Cortex
11.2.5A (ANS/OH) The Cerebral Cortex Answer Key
11.2.6 (OH) Map of the Motor Cortex

SUPPORTING DIVERSE STUDENT NEEDS

- Struggling learners may grasp an idea better by looking at diagrams or pictures. Use the various blackline masters provided in this Teacher's Resource to help these students.
- Locate the web resources provided on the McGraw-Hill web site (described under Helpful Resources in this Teacher's Resource). These web sites include information on the brain and spinal cord. Provide a list of these URLs to your students for individual study at home or in the library.
- Create a 2- or 3-page study guide of ideas in the section. This guide can be of great assistance to students who struggle with print materials, lectures, or even organization of information. The digest could be in paragraph form, point form, a graphic organizer, or a combination. It might also spotlight key vocabulary and provide essential questions that the section is designed to address. Advanced students could be encouraged to make a digital version of this guide using presentation software.
- Making models of the human brain can help all students visualize the different regions of the brain and their respective functions.

Answers to Questions for Comprehension

Student Textbook page 389

Q19. The spinal cord and the brain make up the central nervous system, where sensory information is received and motor control is initiated. The central nervous system (brain and spinal cord) receives information from the senses, evaluates this information, and initiates outgoing responses to the body. The spinal cord is a column of nerve tissue that extends out of the skull from the brain and downward through a canal within the backbone. The spinal cord serves as a means of communication between the brain and the peripheral nervous system. The spinal cord is also a centre for reflex actions. The brain maintains homeostasis within the body: the brain processes information transmitted through the senses so the body can deal with changes in the external and internal environment. The brain is also responsible for reasoning, learning, memory, language, and speech.

Q20. The meninges protect the CNS by preventing the direct circulation of blood through the cells of the brain and spinal cord. The blood-brain barrier both protects the brain and supplies the brain with nutrients and oxygen. The blood capillaries that lead to the brain are made up of tightly fused epithelial cells. Thus, the capillary walls form a barrier that blocks many toxins and infectious agents. Some substances, such as glucose and oxygen, can still pass through the barrier using special transport mechanisms. Other lipid-soluble substances are able to pass directly through the lipid bilayer of the cell membrane. Circulating throughout the spaces, or ventricles, within the brain and spinal cord is the cerebrospinal fluid. It circulates between two layers of the meninges, the arachnoid and pia mater, and acts as a shock absorber to cushion the brain.

Q21. The hypothalamus helps to maintain homeostasis by:

- controlling blood pressure
- controlling heart rate
- controlling body temperature
- coordinating the actions of the pituitary gland, by producing and regulating the release of many hormones that maintain homeostasis.

The medulla oblongata regulates involuntary actions such as heart rate, constriction or dilation of blood vessels to control blood pressure, and rate and depth of breathing.

Q22. The following chart can be used to summarize the information required to answer this question.

Region	Structure	Function
hindbrain	cerebellum	■ unconscious control of posture, reflexes, and body movements ■ control of fine, voluntary motor skills ■ receives information from specialized sensors

Region	Structure	Function
	medulla oblongata	■ controls automatic, involuntary responses such as heart rate, blood pressure, breathing, swallowing, and coughing
	pons	■ a relay centre between the neurons of the right and left hemispheres of the cerebrum, the cerebellum, and the rest of the brain
midbrain	midbrain	■ relays visual and auditory information between areas of the hindbrain and forebrain ■ plays important role in eye movement and control of skeletal muscles
forebrain	thalamus	■ provides connections between the forebrain and hindbrain, and between areas of the sensory system and cerebellum
	hypothalamus	■ controls blood pressure, heart rate, body temperature, basic drives, emotions ■ major link between the nervous and endocrine systems
	cerebrum	■ contains centres for intellect, memory, consciousness, and language ■ interprets and controls the response to sensory information

Biology File: Try This

Student Textbook page 389

The water in the first container should provide some degree of protection for the egg. The egg in the empty container will probably break almost immediately. This demonstrates the protective function of the cerebrospinal fluid for the brain. Students should note, however, that if shaken hard enough, even the egg in the water-filled container will break.

Figure 11.27

Student Textbook page 389

At this point, students will not likely be able to identify the specific functions of the cerebral cortex. They may have some idea that the right side of the brain controls the left side of the body and vice versa. Students will learn more about the specific areas of the brain later in this section. However, if time permits, you might want them to explore the idea of cerebral dominance. For example, some scientists believe that each hemisphere of the brain is dominant for different behaviours. It appears that the right brain is dominant for spatial abilities, face recognition, visual imagery, and music. The left brain may be more dominant for calculations, math and logical abilities. The cerebral cortex contains many ridges called gyri and grooves called sulci. These structures provide the brain with a greater surface area to fit more neurons into a smaller space.

Figure 11.30

Student Textbook page 391

The muscles of the face, lips, jaw, and tongue, and the muscles of the hands have a relatively larger area of the cerebral cortex devoted to their movement compared to the muscles in other areas of the body. This is why the girl's face and hands in the illustration are drawn so large.

It is also interesting to note that this closely parallels the amount of sensory cortex devoted to certain sensory areas of the body: The face, lips, tongue, hands, and genitals also have a comparatively large amount of sensory cortex devoted to them. So these areas of the body not only are the most sensitive to touch, but also have the greatest amount of motor control.

Biology File: Try This

Student Textbook page 392

A theory is that one side of the brain is involved with muscle movements, like moving your leg, while the other side is involved with such as mathematic task activities and drawing numbers. When you try to do both activities at once, the left brain and right brain are conflicted, and the signals get confused.

Answers to Questions for Comprehension

Student Textbook page 392

Q23. The following chart identifies the 4 lobes of the cerebrum and describes the function of each.

Lobes of the Cerebrum	Functions
frontal lobe	associated with conscious thought, intelligence, memory, and personality; controls voluntary muscle movements
temporal lobe	involved in auditory reception
parietal lobe	receives sensory information from the skin, and processes information about body position
occipital lobe	processes visual information

Q24. The areas of the brain responsible for fine motor control of the muscles are the frontal lobe of the cerebrum and

the cerebellum. The area that processes sensory information from the skin is the parietal lobe of the cerebrum.

Q25. The process of speech involves several areas of the cerebrum. Two important areas are on the left side of the cerebrum: Broca's area (in the frontal lobe) and Wernicke's area (in the temporal lobe). Broca's area coordinates the muscles for speaking and translates thought into speech. Damage to this area results in an inability to speak. It does not, however, affect the understanding of language. Wernicke's area stores the information involved in language comprehension. The ability to utter words is not affected if this area is damaged, but the words make little sense.

Biology File: Web Link

Student Textbook page 392

There are a number of arguments for and against the use of virtual dissections in the classroom. Those in favour of virtual dissection argue that computer simulations are better suited for dissection because the cost is lower, the animals are protected, and students are guided through the process. Those who are not in favour of virtual dissection argue that actual dissections are better because they provide a 3-dimensional view of the organism and students gain an appreciation for the complexity of organisms.

Investigation 11.D: The Brain

Student Textbook pages 393–394

Purpose

Students will observe and identify the principal structures and functions of a mammalian brain using dissections or other means.

Outcomes

- 30-A1.1sts
- 30-A1.2s
- 30-A1.4s

Advance Preparation

Please note that the following information pertains to the hands-on dissection of an actual mammalian brain.

When to Begin	What to Do
3 to 4 weeks before	■ Check supply of mammalian brains; order as required. ■ Check local policies for information on the proper disposal of mammalian organs.
3 to 4 weeks before	■ Check supply of safety equipment (gloves, aprons, goggles) and replace if needed.
2 days before	■ Photocopy **BLM 11.2.7: Investigation 11.D** ■ Organize dissecting tools and instruments

Materials
■ goggles ■ apron ■ tongs ■ dissecting tray ■ dissecting kit ■ preserved sheep brain ■ paper towel ■ disposable plastic gloves ■ 10% bleach solution (to clean the dissecting tray)

Time Required

1 hour

Helpful Tips

- Use **BLM 11.2.7: Investigation 11.D** to support this activity. Modify it as necessary.
- This investigation can be done either as a hands-on activity or as a virtual experience. Web links related to a virtual dissection of the mammalian brain can be found at **www.albertabiology.ca**. Select Instructor Edition and follow the links to Chapter 11.
- Before students start the dissection, remind them of all safety precautions.
- Remind students that dissection involves the careful and systematic examination of the structures of an organism.
- If you are planning to use a fresh mammalian brain, make sure that it has been properly inspected for infectious agents and that it is refrigerated. For more information, refer to Alberta Education's publication *Safety in the Science Classroom.* The web link can be found at **www.albertabiology.ca**. Select Teacher Resources and follow the links to Chapter 11.
- Group your students in teams of 4 to reduce the number of specimens that you have to purchase.
- Have students make "flags" out of straight pins and masking tape. They can write on the masking tape the names of the different regions and lobes of the mammalian brain and then insert the pin in the appropriate structure. This will ensure that they have taken the time to actually find each region of the brain. It could also be used as a formative evaluation tool for this activity.

- The Extension for this investigation is actually another activity. The Extension encourages the students to make a labelled model of a human brain. You may want to have your students build the model instead of doing the dissection.

Safety Precautions


Extreme care must be taken when students are using dissecting instruments, particularly scalpels. Make sure that students make cuts away from their bodies.


Students must wear plastic gloves, goggles, and aprons at all times and work in a well-ventilated area if using preserved specimens.

- Use tongs and wear gloves when removing specimens from shipping containers.
- Provide time for students to thoroughly wash hands at the end of the activity.


Follow Alberta Education guidelines for the proper disposal of all hazardous materials. (See reference to Alberta Education's publication *Safety in the Science Classroom* under Helpful Tips.)

SUPPORTING DIVERSE STUDENT NEEDS

- Some students may object to touching animal organs or may have cultural or ethical concerns about doing a dissection. Provide these students with the opportunity to do the virtual dissection in a supervised area of the school.
- Students with visual or motor disabilities should be teamed with students who can complete the investigation safely.

Answers to Part 1 Analysis Questions

1. This table summarizes the functions of the structures of the cerebrum that are visible when looking at the whole brain.

Cerebrum structure	Major functions
frontal lobe	associated with conscious thought, intelligence, memory, and personality; controls voluntary muscle movements
temporal lobe	involved in auditory reception
parietal lobe	receives sensory information from the skin, and processes information about body position
occipital lobe	processes visual information

2. The right cerebral hemisphere is associated with creativity and artistic ability. The left cerebral hemisphere is associated with analytical and mathematical ability.

Answer to Part 2 Analysis Question

1. This chart summarizes the function of the structures visible in a cross section of the brain.

Brain structure	Major functions
spinal cord	the spinal cord serves as a means of communication between the brain and much of the body (the peripheral nervous system); is also a centre for reflex actions
cerebellum	controls muscle coordination and balance
medulla oblongata	controls subconscious activities, such as heart rate, blood pressure, breathing, swallowing, and vomiting
pons	relays information between the cerebellum and cerebral cortex
midbrain	receives specific sensory input; connects the hindbrain to the forebrain
thalamus	connects various parts of the brain; relays information from the senses
hypothalamus	regulates the pituitary gland, heart rate, blood pressure, and temperature; controls drives such as hunger, thirst, and sexual desire
pituitary gland	secretes hormones to regulate a variety of bodily functions; regulated by the hypothalamus
corpus callosum	connects the right and left cerebral hemispheres through nerve tracts

Answer to Conclusion Question

2. The sheep brain is very similar to the mammalian brain in terms of structures. The human brain is larger and has a different shape. The cerebrum of the human brain is notably larger.

Answer to Extension Question

3. Please note that the Extension for this investigation is actually another activity. This activity could be used as a replacement for the actual dissection.

Assessment Options

- Collect and assess **BLM 112.7: Investigation 11.D**. This BLM has space for students to draw their diagrams as well as to answer the Analysis and Conclusion questions found in the student textbook.
- One of the Helpful Tips provided for this investigation was to mark structures using flags made out of straight pins

and masking tape. Test each group's knowledge of the structures and the functions of the brain while the other students are working on the Section 11.2 Review questions.

Figure 11.32

Student Textbook page 394

- Hearing is associated with the temporal lobe.
- Seeing is associated with the occipital lobe.
- Speaking is associated with the frontal lobe.
- Thinking is associated with the frontal lobe.

Answers to Questions for Comprehension

Student Textbook page 394

Q26. Scientists first learned about brain functions by studying the brains of people with brain injuries or diseases. For example, injured soldiers would sometimes have damage to certain areas of the brain, but still survive. Researchers could then link the injured area of the brain to loss of functions in other areas of the body. Brain mapping, or operating on the brain of a conscious person, was one way to determine the function of different regions of the cerebral cortex.

Q27. PET can show different levels of activity in the brain, and 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, confusion, and eventual lack of conscious movement. Because active areas of the brain have higher energy demands, radioactively labelled glucose fed to patients shows up on a screen as different colours representing different activity levels in the brain.

MRI can produce very clear and detailed images of brain structure, and can be used to identify various brain disorders, such as brain tumours. A giant magnet surrounds the patient's head, and changes in the direction of the magnetic field induce hydrogen atoms in the brain to emit radio signals. These signals can then be detected, translated, and displayed as a structural or functional image.

Biology File: Web Link

Student Textbook page 395

Students' answers should cite the particular part or parts of the brain and link the loss of function to their knowledge of the part of the brain. Information on current research should be related to the part of the brain and its function. Students could be encouraged to go beyond the high-profile disorders of Alzheimer's and Parkinson's diseases.

Students should use more than one source for their research and include appropriate documentation. This task can be expanded to include a discussion of how to evaluate reputable sites. Findings could be summarized in a comparison chart or spreadsheet to help students evaluate the sources, with a summary paragraph on areas of agreement and disagreement. Students could be asked to offer opinions on the areas of disagreement.

Good sources to begin the exercise are the Mayo Clinic (students can look under disorders), WebMD, and perhaps a non-profit organization designed to support those who have the disease. Beyond simply being able to find information on the Internet, students can be coached on the importance of evaluating that information, particularly when it is related to health issues.

Section 11.2: Review Answers

Student Textbook page 395

1. Scientists estimate that there are more neurons in the human brain than stars in the Milky Way Galaxy. The brain therefore requires a constant supply of nutrients and oxygen to feed these cells. In fact, the brain, which comprises only 2% of the body's total weight, uses at least 20% of the body's oxygen and energy supplies. If the oxygen supply to the brain is disrupted for even a few minutes, massive damage can occur in the brain. One function that requires nutrients and oxygen is the transmission of nerve impulses, which requires ATP in order to establish the resting membrane potential (see Section 11.1 of the student textbook). Cellular respiration is the process that produces ATP for all cells—including the neurons. Cellular respiration requires a continual supply of nutrients (glucose) and oxygen. Therefore, in order to continually supply brain cells with ATP, the brain must have a continual supply of oxygen and glucose.

2. The 3 structures that support and protect the central nervous system are

- bone—the vertebral column protects the spinal cord; the skull protects the brain
- meninges—these layers of tough, elastic tissues are found in both the spinal cord and brain. The meninges protect the central nervous system by preventing the direct circulation of blood through the cells of the brain and spinal cord.
- cerebrospinal fluid—the fluid circulates throughout the spaces within the brain and spinal cord. It acts as a shock absorber to cushion the brain.

3. Bacterial meningitis is a potentially fatal disease. A doctor will perform a spinal tap if he/she suspects meningitis. A spinal tap allows the doctor to withdraw a small amount of the cerebrospinal fluid and send it to a lab for testing. Bacterial cultures of the cerebrospinal fluid can be used to diagnose this disease.

4.

Label	Structure	Functional Problems
A	primary motor area of the frontal lobe	Damage to this area could result in loss of motor function.
B	thalamus	Damage to this area could result in impaired vision, hearing, and senses such as touch.
C	cerebellum	Damage to this area could result in loss of balance or lack of muscle coordination.
D	medulla oblongata	Damage to this area could result in the body's inability to regulate heart rate, blood pressure, breathing, swallowing, and vomiting
E	corpus callosum	Damage to this area could result in loss of communication between the two hemispheres of the cerebral cortex.
F	hypothalamus	Damage to this area can result in the inability to control homeostatic mechanisms including hormones, heart rate, blood pressure, body temperature, and drives such as hunger, thirst, and sexual desire.
G	pons	Damage to this area could result in a lack of communication between the right and left halves of the cerebrum, the cerebellum, and the rest of the brain.

5. (a) Seeing this question is the responsibility of the occipital lobes because they receive and analyze visual information.

(b) Thinking about this question is the responsibility of the frontal lobes because they control reasoning and critical thinking.

(c) Hearing the question read by someone else is the responsibility of the temporal lobes because their main function is auditory reception.

(d) Reading this question to someone else is the responsibility of the frontal lobes, specifically Broca's area because it coordinates the muscles for speaking and translates thought into speech.

(e) The parietal lobe of the cerebral cortex of a person using Braille would be stimulated. The parietal lobes receive and process sensory information from the skin. The proportion of a parietal lobe devoted to a particular part of the body is related to the importance of sensory information for this part of the body.

6. The doctor would suspect that the stroke has damaged Wernicke's area of the temporal lobe and the primary motor area on the right side of the brain. The right side of the brain controls the left side of the body, so damage to the primary motor cortex on the right side of the brain will result in paralysis on the left side of the body. Wernicke's area stores the information involved in language comprehension. The ability to utter words is not affected if this area is damaged, but the words make little sense.

7. PET scans can detect active areas of the brain, so they can be used to diagnose conditions such as stroke or Alzheimer's disease, in which there is deterioration of the brain.

MRI can produce very clear and detailed images of brain structure and can be used to identify various brain disorders, such as brain tumours.

11.3 The Peripheral Nervous System

Student Textbook pages 396-400

Section Outcomes

Students will:

- identify the principal components of the peripheral nervous system
- explain the role of the peripheral nervous system in regulating the somatic (voluntary) and autonomic (involuntary) systems
- compare the functions of the sympathetic division and the parasympathetic division of the autonomic nervous system

Key Terms

somatic system
autonomic system
sympathetic nervous system
norepinephrine
parasympathetic nervous system

Biology Background

- The peripheral nervous system is composed of the somatic (voluntary) system and the autonomic (involuntary) system.
- In the peripheral nervous system, cranial nerves take impulses to and from the brain, and spinal nerves take impulses to and from the spinal cord.
- In the somatic system, nerves take messages from external sensory receptors to the CNS and take motor commands to the skeletal muscles. The reflex arc is included in the somatic system.
- The autonomic system is divided into the sympathetic and parasympathetic nervous systems. The sympathetic division

brings about those responses associated with "fight-or flight" and the parasympathetic division brings about those responses associated with "rest-and-digest."

Teaching Strategies

- This is a brief section that brings the information in the previous two into the bigger picture of how the nervous system co-ordinates both voluntary and involuntary activity in the body.
- The Connections feature on neurological disorders among pets can be used to spark debate on pet care or the more contentious subject of animal research (as an extension of question 2: If co-incidental insights are helpful, is it ethical to purposely use animals to learn more about conditions or potential treatments for humans?)
- Two BLMs have been prepared to support the information in this section. You will find them with the Chapter 11 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging in to the Instructor Edition at the Online Learning Centre.

Number (Type)
11.3.1 (HAND) Map of the Spinal Nerves
11.3.1A (ANS/OH) Map of the Spinal Nerves Answer Key
11.3.2 (OH) Sympathetic and Parasympathetic Nervous Systems

- Although this is a very short section, some of the terminology introduced in this section could pose a challenge, especially for those students whose first language is not English. Students could add key terms to their personal vocabulary list.
- Some learners may grasp an idea better by looking at diagrams or pictures. Use the various blackline masters provided in this Teacher's Resource to help these students.
- Create a 2- or 3-page study guide of ideas in the section. This guide can be of great assistance to students who struggle with print materials, lectures, or even organization of information. The guide could be in paragraph form, point form, a graphic organizer, or a combination. It might also spotlight key vocabulary and provide essential questions the section is designed to address.

Figure 11.34

Student Textbook page 396

In order for a football player to catch a ball, motor neurons to the muscles of the arms, shoulders, and fingers would have to work in conjunction with motor neurons that maintain balance and posture. Signals to these motor neurons would originate in the primary motor cortex and in the cerebellum and be transmitted to the muscles by motor neurons that leave the spinal cord.

Answers to Questions for Comprehension

Student Textbook page 396

Q28. The major structures of the somatic nervous system are 12 pairs of myelinated cranial nerves and 31 pairs of myelinated spinal nerves.

Q29. The somatic system is largely under voluntary control, and its neurons service the head, trunk, and limbs. Its sensory neurons carry information about the external environment inward to the brain, from the receptors in the skin, tendons, and skeletal muscles. Its motor neurons carry information to the skeletal muscles.

Answers to Questions for Comprehension

Student Textbook page 399

Q30. The motor neurons involved in the autonomic nervous system are part of either the sympathetic nervous system or the parasympathetic nervous system, and either stimulate or inhibit the glands or the cardiac or smooth muscle.

Q31. Stress or danger is likely to trigger a response from the sympathetic nervous system, sometimes called a "fight-or-flight" response. The sympathetic neurons release a neurotransmitter called norepinephrine, which has an excitatory effect on its target muscles. As well, the sympathetic nerves trigger the adrenal glands to release epinephrine and norepinephrine, both of which also function as hormones that activate the stress response. At the same time, the sympathetic nervous system inhibits some areas of the body. For example, in order for someone to be able to run from danger, the skeletal muscles need a boost of energy. Therefore, blood pressure increases and the heart beats faster, while digestion slows down and the sphincter controlling the bladder relaxes.

Q32. The parasympathetic nervous system is activated when the body is calm and at rest. Sometimes referred to as the "rest-and-digest" response, the parasympathetic nervous system slows the heart rate, reduces blood pressure, promotes the digestion of food, and stimulates the reproductive organs by dilating blood vessels to the genitals. The parasympathetic system uses a neurotransmitter called acetylcholine to control organ responses.

Section 11.3: Review Answers

Student Textbook page 399

1. The peripheral nervous system lies outside of the central nervous system. Sensory neurons carry information to the CNS, and motor neurons carry information away from the CNS. The central nervous system receives the sensory information and initiates an appropriate motor response.

2. The somatic system is largely under voluntary control, and its neurons service the head, trunk, and limbs. Its sensory neurons carry information about the external environment inward, from the receptors in the skin, tendons, and skeletal muscles. Its motor neurons carry information to the skeletal muscles.

In contrast to the somatic system, the autonomic system is under automatic, or involuntary, control. Its nerves either stimulate or inhibit the glands or the cardiac or smooth muscle. The autonomic system maintains homeostasis by adjusting the body to variations in the external and internal environments.

3. (a) Seeing the bear and cubs would likely cause a response from the sympathetic nervous system—the "fight-or-flight" response.

(b) The physiological responses to this situation would include some of the following: blood pressure increases, the heart beats faster, breathing rate increases, air passages dilate, the liver releases glucose into the blood stream, while digestion slows down, and the sphincter controlling the bladder constricts.

(c) The parasympathetic nervous system would return the body to equilibrium.

4.

Body Structures	Sympathetic Stimulation Effect	Parasympathetic Stimulation Effect
eyes	■ inhibits tears ■ dilates pupils	■ stimulates tears ■ constricts pupils
salivary glands	inhibits salivation	stimulates salivation
bronchioles	dilates air passages	constricts bronchioles
heart	increases heart rate	slows heart rate
liver	stimulates liver to release glucose	stimulates gall bladder to release bile
adrenal glands	stimulates adrenal glands to release epinephrine and norepinephrine	does not affect adrenal glands (parasympathetic nerves do not go to the adrenal glands)
kidneys	inhibits activity	does not affect kidney (parasympathetic nerves do not go to the kidneys)
stomach	inhibits activity	increases activity
pancreas	inhibits activity	increases activity
intestines	decreases activity	increases activity
bladder	inhibits urination by constricting the sphincter and relaxing the wall	stimulates urination by relaxing the sphincter and contracting the wall
genitals	causes erection of genitals	causes orgasmic contractions of the genitals

5. Depressants act on the parasympathetic nervous system to relax the body and slow the heart rate whereas stimulants do the opposite by causing the sympathetic nervous system to increase the heart rate and blood pressure. A commonly used stimulant is caffeine.

Connections: Science and Technology

Neurological Disorders

Student Textbook page 400

Teaching Tips

- To debate this issue, students will need one or two class periods to research the topic. Book the library and/or the computer lab well ahead of time to ensure students have access to both print and electronic sources of information.
- Provide students with a list of rules used in formal debates.
- Set clear guidelines including how much time students will have to present their point of view and how to respond to the comments made by their opponents.

Answers to Questions

1. There are specific rules that students should use in a formal debate. These rules are called the World Schools Style Debate. More information on these rules can be found at **www.albertabiology.ca**. Select Teacher Resources and follow the links to Chapter 11.

2. Because horses and humans have similar muscular structures, and fall victim to many of the same neuromuscular diseases, research into horses will provide valuable information about diseases and treatments in humans. Specific treatments and drugs could be tested on many horses over a varying period of time before such treatments are allowed in humans. Research into these conditions in horses may be easier than in humans because horses don't have the same psychological or emotional responses as humans do under the same stressful conditions.

3. Students will find literally hundreds of web resources by simply keying in "blind and deaf pets" into their favourite search engine. They will find everything from toys that make noise for blind dogs to training advice from so-called experts in the field.

4. Students will find many web resources by keying in "adaptive devices for pets that can't use their back legs." A

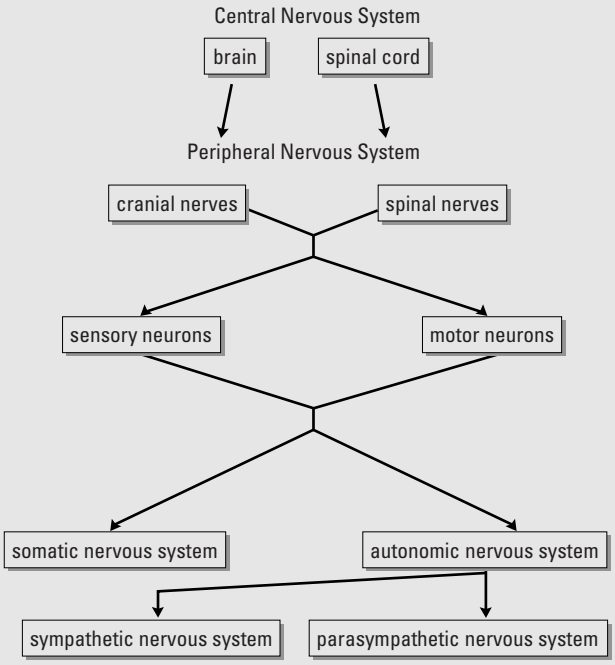
K-9 cart, for example, can cost over $500 U.S. while a Quad Wheelchair for dogs can cost nearly $1000 U.S.

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.

CHAPTER 12 SENSORY RECEPTION

Curriculum Correlation

General Outcome 1: Students will explain how the nervous system controls physiological processes.

NOTE: The curriculum correlation for this outcome covers two chapters. The references for Chapter 12 are in boldface.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
30–A1.1k describe the structure and function of a neuron and myelin sheath, explaining the formation and transmission of an action potential and the transmission of a signal across a synapse or neuromuscular junction and the main chemicals and transmitters involved, i.e., norepinephrine, acetylcholine and cholinesterase	Section 11.1: Cells of the Nervous System, p. 368 The Structure of a Neuron, p. 370 The Nerve Impulse, p. 372 Investigation 11.B: Modelling Resting Action Potential, p. 374 Membrane Potential, p. 375 Nerve Impulse, p. 377 Signal Transmission Across a Synapse, p. 378 Neural Transmitters in Action, p. 380 Investigation 11.C: Examining Neural Tissue, p. 381 Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses, p. 383 Section 11.2: The Autonomic System, p. 397	Chapter 11 Questions for Comprehension: 4–6, p. 370 7, 8, p. 372 9, 10, p. 374 11–13, p. 377 14–16, p. 380 17, 18, p. 382 30–32, p. 399 Investigation 11.B: Analysis, Conclusions, p. 375 Investigation 11.C: Analysis 2-6, p. 381 Thought Lab 11.1: Analysis, p. 383 Section 11.1 Review: 1–8, p. 384 Chapter 11 Review: 1, 6, 8, 10, 13–17, 19–21, 23, pp. 402–403 Chapter 11 Test Unit 5 Review: 1, 2, 5, 7, 36–38, pp. 468–470

	Student Textbook	Assessment Options
30–A1.2k identify the principal structures of the central and peripheral nervous systems and explain their functions in regulating the voluntary (somatic) and involuntary (autonomic) systems of the human organism, i.e., cerebral hemispheres and lobes, cerebellum, pons, medulla oblongata, hypothalamus, spinal cord, sympathetic and parasympathetic nervous systems, and the sensory–somatic nervous system	Section 11.1: Organization of the Nervous System, p. 367 Section 11.2: The Spinal Cord, p. 385 The Brain, p. 386 The Structure and Function of the Cerebrum, p. 389 Mapping Brain Functions, p. 392 Imaging Techniques Used to Study the Brain, p. 392 Investigation 11.D: The Brain, Parts 1 & 2, p. 393–394 Section 11.3: The Somatic System, p. 396 The Autonomic System, p. 397 **Throughout Section 12.1, p. 406–409** **Section 12.2: The Photoreceptors: Rods and Cones, p. 414**	Chapter 11 Questions for Comprehension: 1–3, p. 367 19–22, p. 389 23–25, p.392 28, 29, p. 399 30–32, p. 399 Investigation 11.D, Parts 1 & 2: Analysis, pp. 393–394 Sect 11.1 Review: 1, p. 384 Section 11.2 Review: 1–7, p. 395 Section 11.3 Review: 1–5, p. 399 Chapter 11 Review: 1–5, 7–9, 11, 18, 19, 22, 24, pp. 402–403 Chapter 11 Test **Chapter 12 Questions for Comprehension:** **1–2, p. 406** **3–4, p. 407** **5–6, p. 409** **15, p. 416** **17, p. 416** **22, p. 424** **25, p. 425** **Section 12.1 Review: 1–5, p. 409** **Chapter 12 Review 1–2, 4–7, 11, 13, 17, 18, p. 432** **Chapter 12 Test** Unit 5 Review: 3–7, 16, 23, 35, 46, pp. 468–471
30–A1.3k describe the composition and function of a simple reflex arc and the organization of neurons into nerves	Section 11.1: Cells of the Nervous System, p. 368 The Reflex Arc, p. 369 Investigation 11.A: Move Fast! Reflex Responses, p. 371	Chapter 11 Questions for Comprehension: 4–6, p. 370 Investigation 11.A: Analysis, p. 371 Chapter 11 Test Unit 5 Review: 3, 6, p. 468
30–A1.4k describe the structure and function of the human eye, i.e., cornea, lens, sclera, choroid, retina, rods and cones, pupil, iris, and optic nerve	**Section 12.1:** **Sensory Receptors, p. 407** **Throughout Section 12.2, pp. 410–418** **Investigation 12.A: Dissection of an Eye, p. 417** **Investigation 12.B: Distinguishing Sights and Sounds, Part 1 Distinguishing Shades of Colour, p. 422**	**Chapter 12 Questions for Comprehension:** **7–9, p. 412** **10–12, p. 414** **13–17, p. 416** **Investigation 12.A: Analysis, Conclusion, Application, p. 417** **Investigation 12.B, Part 1: Analysis, Conclusion, p. 422** **Section 12.1 Review: 1(b), p. 409** **Section 12.2 Review: 1–7, p. 418** **Chapter 12 Review: 3, 8–12, 14, 16–17, 21, 22, 23–25, 27, 31, pp. 432-433** **Chapter 12 Test** Unit 5 Review: 8, 9, 12–14, 44, p. 468-471

	Student Textbook	Assessment Options
30–A1.5k describe the structure and function of the human ear, i.e., pinna, auditory canal, tympanum, ossicles, cochlea, organ of Corti, auditory nerve, semicircular canals and Eustachian tube	**Section 12.3: Hearing and Balance, p. 419** **Capturing Sound, p. 419** **Frequencies of Sound, p. 421** **Hearing Loss, p. 423** **The Perception of Sound, p. 424** **Investigation 12.B: Distinguishing Sights and Sounds, Part 2: Distinguishing Sound Frequencies, p. 422–423**	**Chapter 12 Questions for Comprehension: 18–20, p. 421** **21–22, p. 424** **23–25, p. 425** **Investigation 12.B, Part 2: Analysis, Conclusion, Extension, p. 423** **Section 12.3 Review: 1–5, p. 429** **Chapter 12 Review: 6, 15, 17–20, p. 432** **Chapter 12 Test** Unit 5 Review: 10, 11, p. 468
30–A1.6k explain other ways that human organisms sense their environment and their spatial orientation in it, e.g., *skin receptors, olfactory receptors, proprioceptors, taste receptors.*	**Throughout Section 12.1, p. 406–409** **Section 12.3:** **Hearing and Balance, p. 419** **Taste, p. 425** **Smell, p. 426** **Touch, p. 427** **Sensation and Homeostasis, p. 427** **Summary, p. 429** **Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428**	**Chapter 12 Questions for Comprehension: 5–6, p. 409** **26, p. 426** **27–30, p 427** **Investigation 12.C: Analysis, Conclusion, p. 428** **Section 12.1 Review: 1 (a), 2–5, p. 409** **Chapter 12 Review: 13, 15, 29 pp. 432–433** **Chapter 12 Test** Unit 5 Review: 8, 31, 35, pp. 468–470
Outcomes for Science, Technology, and Society (Emphasis on the nature of Science)		
30–A1.1sts explain that scientific knowledge and theories develop through hypotheses, collection of evidence through experimentation and the ability to provide explanations by ■ *discussing the biological basis of neurological diseases and how this relates to its treatment, e.g., Alzheimer's disease, Parkinson's disease*	Section 11.1: The Nerve Impulse, p. 377 Neurotransmitters in Action, p. 380 Section 11.2: Imaging Techniques Used to Study the Brain, p. 392 The Somatic System, p. 396 Investigation 11.D: The Brain, Parts 1 & 2, pp. 393–394 Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, p. 400	Investigation 11.D, Parts 1 & 2: Analysis, pp. 389–390 Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, questions 1–4, p. 400 Chapter 11 Review: 12, 18, 20, pp. 402–403 Unit 5 Review: 36, 45, 47, 48, pp. 470–471
■ *evaluating the impact of photoperiod (light wavelength and duration) on the human organism*	**e.g., Investigation 12.B, Distinguishing Sights and Sounds Part 1: Distinguishing Shades of Colour, p. 422**	**e.g., Chapter 12 Questions for Comprehension: e.g., 8, p. 412** **e.g., Investigation 12.B, Part 1: Analysis, Conclusions, p. 422** **e.g., Chapter 12 Review: 8, 11, p. 432** e.g., Unit 5 Review: 14, p. 468

	Student Textbook	Assessment Options
30–A1.2sts explain that scientific investigation includes the process of analyzing evidence and providing explanations based on scientific theories and concepts by ■ *analyzing experimental evidence on the influence of anesthetics, drugs and chemicals, natural and synthetic, on the functioning of the nervous system and their relationship to addiction theories*	Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses, p. 383	Thought Lab 11.1: Analysis, p. 383 Section 11.1 Review: 8, p. 384 Section 11.3 Review: 5, p. 399 Unit 5 Review: 49, p. 471
■ *analyzing the contribution of technological developments and physiological knowledge to longevity and quality of life*	Section 11.2: Imaging Techniques Used to Study the Brain, p. 392 Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, p. 400 **Section 12.1: Sensory Receptors, p. 407** **Section 12.2: Focussing, p. 412** **Conditions Affecting the Cornea and Lens, p. 412** **Section 12.3: Hearing Loss, p. 423**	Section 11.2 Review: 7, p. 391 Chapter 11 Questions for Comprehension: 26, 27, p. 394 Chapter 11 Connections: Social and Environmental Contexts, 1–4, p. 400 **Chapter 12 Review: 23, 31, p. 433** Unit 5 Review: 31–35, 41–51 , pp. 469-471
30–A1.3sts explain that the goal of technology is to provide solutions to practical problems by ■ *investigating the technologies available to correct eye and ear defects*	**Section 12.1: Sensory Receptors, p. 407** **Section 12.2:** **Photoreceptors, p. 414** **Focussing, p. 412** **Conditions Affecting the Cornea and Lens, p. 412** **Preventing Vision Loss, p. 418** **Investigation 12.B: Distinguishing Sights and Sounds, pp. 422-423** **Section 12.3: Hearing Loss, p. 423**	**Chapter 12 Questions for Comprehension** **9, p. 412** **11, p. 414** **21, p. 424** **Investigation 12.B, Extension, p. 423** **Section 12.2 Review: 5, 6, p. 418** **Chapter 12 Review: 24, p. 431**
■ *investigating the biological basis of neurotoxin action and their antidotes, e.g., snake venom, box jellyfish, botulin, reserpine* (Rauwolfia serpentina)	**Chapter 12 Connections: Nature of Science: Pain Relievers or Deadly Neurotoxins? p. 430**	Chapter 11 Review: 24, p. 403 **Chapter 12 Connections: Nature of Science, 1–3, p. 430** **Chapter 12 Review: 31, p. 433**
■ *discussing how advances in science have contributed to technologies that increase access to the world beyond normal sensory limits.*	**Section 12.1: Sensory Receptors, p. 407**	**Section 12.2 Review: 2, 6, p. 418** **Chapter 12 Review: 22, 23, 31, pp. 432–433**
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
30–A1.1s ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues by ■ designing an experiment to investigate heat, cold, pressure and touch receptors	**Chapter 12 Launch Lab: Sense It, p. 405** **Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428**	**Chapter 12 Launch Lab: Analysis, p. 405** **Investigation 12.C: Analysis, Conclusion, p. 428**

	Student Textbook	Assessment Options
Performing and Recording		
30–A1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by ■ designing and performing an experiment to investigate the physiology of reflex arcs	Investigation 11.A: Move Fast! Reflex Responses, p. 371	Investigation 11.A: Analysis, p. 371
■ performing experiments to measure the ability to discriminate objects visually and to hear a range of sounds	Chapter 11 Launch Lab: You, Robot?, p. 365 **Investigation 12.B: Distinguishing Sights and Sounds Parts 1–2, pp. 422–423**	Chapter 11 Launch Lab: Analysis, p. 365 **Investigation 12.B, Parts 1–2: Analysis, Conclusion, Extension, pp. 422–423** Unit 5 Review: 40, p. 470
■ using a microscope and prepared slides to observe neurons and neuromuscular junctions	Investigation 11.C: Examining Neural Tissue, p. 381	Investigation 11.C: Analysis, p. 381
■ observing the principal features of a mammalian brain, ear and eye, using models, computer simulations or dissections, and identifying the major visible structures of those organs	Investigation 11.D: The Brain, Parts 1 & 2, pp. 393–394 **Section 12.2: Photoreceptors, p. 410** **Focussing, p. 412** **The Photoreceptors: the Rods and Cones, p. 414** **Investigation 12.A: Dissection of an Eye, p. 417** **Section 12.3: Capturing Sound, p. 419**	Investigation 11.D, Parts 1 & 2: Analysis, pp. 393–394 **Investigation 12.A: Analysis, Conclusions and Application, p. 417**
■ *investigating and integrating, from library and electronic sources, information on the impact of photoperiod and wavelength on humans*	**Investigation 12.B, Distinguishing Sights and Sounds, Part 1: Distinguishing Shades of Colour, p. 422**	**Investigation 12.B, Part 1: Analysis, Conclusion, p. 422** **Chapter 12 Review: 8, 11, 16, p. 432** Unit 5 Review: 9, 14, p. 468
■ *compiling and displaying, in appropriate format, data collected for investigations on auditory range, reflex arcs and/or stimulus strength versus force of muscle contraction*	Investigation 11.A: Move Fast! Reflex Responses, p. 371	Investigation 11.A: Analysis, p. 371 Unit 5 Review: 36, 37, 40, p. 470
Analyzing and Interpreting		
30–A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ *interpreting patterns and trends in data on strength of stimuli versus force of muscle contraction*	Investigation 11.A: Move Fast! Reflex Responses, p. 371 **Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428**	Investigation 11.A: Analysis, p. 371 Chapter 11 Review: 17, p. 403 **Investigation 12.C: Analysis, Conclusion, p. 428** **Unit 5 Review: 36, 37, p. 470**
■ *providing a statement that explains the blind spot*	**Section 12.2: Visual Interpretation, p. 416** **Summary, p. 418**	**Chapter 12 Questions for Comprehension: 16, p. 416** **Chapter 12 Review: 10, p. 432**
■ *explaining how data supports or refutes a hypothesis or prediction on strength of stimulus versus force of muscle contraction*	Investigation 11.A: Move Fast! Reflex Responses, p. 371	Investigation 11.A: Analysis, p. 371 Unit 5 Review: 36, 37, p. 470
■ *analyzing a hearing aid as a device that simulates a sensory function*	**Investigation 12.B: Distinguishing Sights and Sounds, pp. 422-423** **Section 12.3: Hearing Loss, p. 423**	**Investigation 12.B: Extension, p. 423**

	Student Textbook	Assessment Options
■ *posing new questions, e.g., why some people are more tolerant to pain than others*	Investigation 11.A: Move Fast! Reflex Responses, p. 371 **Throughout Section 12.1, pp. 406–409**	Investigation 11.A: Applications, 4, p. 371 Chapter 11 Review: 23, p. 403 **Chapter 12 Review: 28, p. 433** Unit 5 Review: 34, p. 469
■ *collecting and analyzing class data on colour charts*	**Investigation 12.B, Distinguishing Sights and Sounds, Part 1: Distinguishing Shades of Colour, p. 422**	**Investigation 12.B, Part 1: Analysis, Conclusion, p.422**
■ *analyzing data to show the interrelationship between taste and smell receptors*	**Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428**	**Investigation 12.C: Analysis, Conclusion, p. 428**
Communication and Teamwork		
30–A1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *working cooperatively with group members to investigate neurological disorders such as Alzheimer's disease and Parkinson's disease*	Thought Lab 11.1: The Effect of Drugs on Neurons and Synapses, p. 383 Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, 1–4, p. 400 **e.g., Investigation 12.B, Distinguishing Sights and Sounds, Part 1–2, p. 422** **e.g., Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation, p. 428**	Thought Lab 11.1: Analysis, p. 383 Chapter 11 Connections: Social and Environmental Contexts: Neurological Disorders, 1–4, p. 400 Chapter 11 Review: 18, p. 403 **e.g., Investigation 12.B, Analysis, Conclusion, Extension, p. 422** **e.g., Investigation 12.C: Analysis, Conclusion; p. 428** Unit 5 Review: 48, 50, p. 471

Chapter 12

Sensory Reception

Student Textbook pages 404–433

Chapter Concepts

12.1 Sensory Receptors and Sensation

- Sensory reception occurs at the senses. Sensation and perception occur in the brain.
- Various sensory receptors detect information in the internal and external environments.

12.2 Photoreception

- The human eye is similar to a camera. It contains a lens that focusses light, a pupil that lets in light, and a dark interior that contains light receptors.
- The retina contains rods and cones. Rods function in dim light and produce black and white images. Cones function in bright light and produce colour images.

12.3 Mechanoreception and Chemoreception

- The outer ear and middle ear transmit the energy of sound waves to the inner ear.
- The inner ear contains mechanoreceptors for hearing and balance.
- Tastes are detected by chemoreceptors in the taste buds of the tongue. Smells are detected by chemoreceptors in the nose.
- The skin contains receptors for light touch, pressure, pain, heat, and cold.

Common Misconceptions

- Scientists now know that tongue taste maps showing large regional differences in sensitivity across the human tongue are incorrect. In reality, all qualities of taste can be elicited from all the regions of the tongue that contain taste buds.
- Myth: Eating carrots will improve your eyesight.

  False! Carrots are rich in beta-carotene, which the liver converts to Vitamin A. This vitamin is important for healthy eyesight, skin, growth, and resisting infection. However, eating a lot of carrots won't specifically improve vision unless you are severely deficient. In fact, eating excessive amounts of Vitamin A or any other fat-soluble vitamin can be harmful. The rumour that carrots were good for night vision is believed to have been started by the Royal Air Force to cover up its use of night radar during WWII.
- Myth: Sitting too close to the television will hurt your eyes.

  False! Children have a greater ability to focus up close without strain than do adults and often develop the habit of sitting close to the television. Children and adults who are nearsighted may sit close to enable them to see the picture more clearly. There is no evidence that sitting close to the television will damage your eyes. Eyes may become tired if someone sits too close for long periods, if the light in the room is too dim, or if the picture is out of focus.
- Students may think that there are only 5 senses: touch, taste, smell, hearing, and sight. This list should be expanded to include proprioceptors that provide information about body position as well as movement and vestibular senses that provide information about body and head positions.
- Some students may think that their sense organs (eyes, ears, nose) not only receive but perceive the actual sensation. These sense organs contain sensory receptors that transduce one of several types of energy from a specific stimulus into electrochemical energy, which can be processed by the brain and/or spinal cord. Perception is the actual interpretation of the meaning of the sensory impulses, and it takes place in the cerebral cortex.
- Some common misconceptions about the ear and hearing are:
  - Misconception: Loud sound is not dangerous, as long as you don't feel any pain in your ears.

    Not true: The human threshold for pain is at about 120–140 dB, but sound begins to damage our hearing when it is above 85 dB for more than 8 hours.
  - Misconception: Hearing loss after loud sound exposure is temporary.

    Not true: Some of the hearing loss will be permanent. Indications of damage are ringing and noise in the ears (called tinnitus) after loud sound exposure. This is a clear indication that exposure to damaging sound took place.

    Another indication is difficulty communicating on the phone or in a noisy place.
  - Misconception: If you have a hearing loss already, you don't have to protect your hearing anymore.

    Not true: Hearing loss accumulates. More exposure to loud sounds leads to more hearing loss.

Helpful Resources

Books and Journal Articles

- Abrams, Michael. "Sight Unseen." *Discover* 23, no. 6 (June 2002): 55.
- Austin, Paul. "Headaches to Worry About." *Discover* 24, no. 1 (January 2003): 21.
- Cohen, Mark. "Why Are His Eyes Crossed?" *Discover* 24, no. 4 (April 2003): 23.
- Grim, Pamela. "Why Does This Belly Ache?" *Discover* 23, no. 4 (April 2002): 24.
- Horgan, John. "Can a Single Brain Cell Recognize Bill Clinton?" *Discover* 26, no. 6 (June 2005): 64.
- Kunzig, Robert. "The Chemistry of Perfume: A Fragrant Revolution." *Discover* 21, no. 2 (February 2000): 22.
- Lemley, Brad. "Isn't She Lovely?" *Discover* 21, no. 2 (February 2000): 42.

- McCarthy, Susan. "Do We Kill Whales with Sound?" *Discover* 23, no. 4 (April 2002): 61.
- Shier, David. *Hole's Essentials of Human Anatomy and Physiology 9/e*. Whitby: McGraw-Hill Ryerson, 2006.

Web Sites

Web links related to sensory reception and perception can be found at **www.albertabiology.ca**. Log on for the Instructor Edition and follow the links to Chapter 12.

List of BLMs

Blackline masters (BLMs) have been prepared to support the material in this chapter. The BLMs are either for assessment (AST); use as overheads (OH); use as handouts (HAND), in particular to support activities; or to supply answers (ANS) for assessment or handouts. The BLMs are in digital form, stored on the CD that accompanies this Teacher's Resource or on the web site at **www.albertabiology.ca**, after logging in to the Instructor Edition at the Online Learning Centre.

Number (Type)
12.0.1 (HAND) Launch Lab: Sense It
12.0.1A (ANS) Launch Lab: Sense It Answer Key
12.1.1 (HAND) Major Sensory Receptors in the Human Body
12.2.1 (HAND) The Human Eye
12.2.1A (ANS) The Human Eye Answer Key
12.2.2 (HAND) Focussing
12.2.3 (HAND) Out of Focus
12.2.4 (OH) Rods and Cones
12.2.5 (HAND) The Retina
12.2.5A (ANS/OH) The Retina Answer Key
12.2.6 (OH) The Neural Pathway of the Optic Nerve
12.2.7 (HAND) Investigation 12.A: Dissection of an Eye
12.2.7A (ANS) Investigation 12.A: Dissection of an Eye Answer Key
12.3.1 (HAND) The Human Ear
12.3.1A (ANS/OH) The Human Ear Answer Key
12.3.2 (HAND) The Inner Ear and Cochlea
12.3.2A (ANS/OH) The Inner Ear and Cochlea Answer Key
12.3.3 (HAND) Investigation 12.B: Distinguishing Sights and Sounds
12.3.3A (ANS) Investigation 12.B: Distinguishing Sights and Sounds Answer Key
12.3.4 (HAND) Balancing Act
12.3.4A (ANS/OH) Balancing Act Answer Key
12.3.5 (HAND) Taste Test
12.3.5A (ANS/OH) Taste Test Answer Key
12.3.6 (HAND) Identifying a Smell
12.3.6A (ANS/OH) Identifying a Smell Answer Key
12.3.7 (HAND) Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation
12.3.7A (ANS/OH) Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation Answer Key
12.3.8 (OH) The Sensory Neurons
12.4.1 (AST) Chapter 12 Test
12.4.1A (ANS) Chapter 12 Test Answer Key

Using the Chapter 12 Opener

Student Textbook pages 404-405

- Sensory deprivation through meditation or other techniques may be a foreign concept to many students. North American culture is largely characterized by stimuli, with "louder, faster, brighter" being considered desirable. This chapter opener can be revisited at the beginning of Chapter 13 in the context of hormonal (stress-related) responses to stimuli.

Teaching Strategies

- "Sensory overload" is usually defined as the stimulation of more than one sense at once or the over-stimulation of one sense that makes it difficult to register something with the other senses. Students may consider themselves adept at watching TV or listening to music while studying or doing homework. Ask if they have experienced "sensory overload"—for example when a parent comes in to ask them to do something and they don't hear the request. (Is this really sensory overload or just selective hearing?)
- There is a great deal of information in this chapter; however, gifted students may be interested in pursuing inquiries into conditions such as autism or related disorders that are now believed to be related to oversensitive sensory reception.
- Review the reflex arc that was discussed in Chapter 11, pages 369-370 or use **BLM 11.1.4A**. Ask students to explain the connection between the reflex arc and sensory reception.

Launch Lab: Sense It

Student Textbook page 405

Purpose

Students will attempt to identify common objects while one or more of their senses are inhibited.

Outcome

- 30-A1.1s

Advance Preparation

When to Begin	What to Do
2 or 3 weeks before	■ Purchase enough ear plugs for your class. ■ Make or purchase clean rags that can be used as blindfolds. ■ Purchase or bring in samples of familiar objects. Some options are suggested under Materials, below.
1–2 days before	■ Photocopy **BLM 12.0.1: Launch Lab**

Materials

- new ear plugs (one set for every student)
- blindfolds (one for every student)
- wet piece of raw potato
- small piece of wet soap
- pine needles
- bristles from a brush
- wet coffee grounds
- wet coarse sand
- granulated sugar

Time Required

30 minutes

Helpful Tips

- Use **BLM 12.0.1: Launch Lab** to support this activity. Modify it as necessary.
- Organize students in teams of 3 to save time. One student can be the tester, the second student the subject, and the third student the recorder.
- You may wish to do this as a demonstration. Ask 4 or 5 volunteers to come to the front of the room as the subjects. Ask another 4 or 5 volunteers to be the testers and assign 1 or 2 students the job of recording their observations.
- Set up materials in individual containers or on trays. This will save time when it comes to distributing the materials for this activity.
- To help prevent the spread of bacteria and viruses, purchase new ear plugs and provide a recently laundered blindfold for every student who is going to be the "subject" for this activity.

Safety Precautions

- Remind students not to eat anything in the science lab.
- Make sure that you are aware of students who may have a food or chemical allergy.
- Make sure that students do not share ear plugs or blindfolds. For information on all safety precautions for this investigation, refer to Alberta Education's publication ***Safety in the Science Classroom***. The web link can be found at **www.albertabiology.ca**. Log on for the Instructor Edition.

Answers to Analysis Questions

1. Students will likely have more difficulty distinguishing materials that have a shape and texture similar to other materials (e.g., salt and sugar).
2. Under normal circumstances, the senses that would be used to identify most of the samples would be sense of touch, vision, and possibly smell.
3. **(a)** You would use your sense of smell and vision to check if milk is sour.
   (b) You would use your sense of touch and vision to separate rocks from lentils.
   (c) You would use your sense of balance to stand on one leg without falling over.
4. Sensory experiences include touch, movement, body awareness, sight, sound, and the pull of gravity. Sensory integration is the process that allows our brain to interpret sensory stimulation from a variety of these senses to tell us what we need to know about what is going on around us. This experiment demonstrates that sometimes one sense is not enough to provide all the information needed.

Assessment Options

- Collect and assess students' answers to the Analysis questions.
- You may wish to use Socratic questioning strategies to assess students' understanding of the concepts developed in this activity by asking students to explain their basic assumptions, their reasoning, and their use of any terms that are not clear.

12.1 Sensory Receptors and Sensation

Student Textbook pages 406-409

Section Outcomes

Students will:

- explain the difference between sensory reception, sensation, and perception
- describe the process of sensory adaptation
- distinguish among the major sensory receptors in the human body

Key Terms

sensory receptors
sensation
perception
sensory adaptation

photoreceptors
chemoreceptors
mechanoreceptors
thermoreceptors

Biology Background

- Sensory receptors are specialized cells or neurons that detect specific stimuli. Human sensory receptors can be classified into four categories: photoreceptors, chemoreceptors, mechanoreceptors, and thermoreceptors. Each type of receptor is able to transduce (convert) one form of energy from a stimulus into electrochemical energy that can be processed by the brain.
- Light is the stimulus for photoreceptors in the eyes.
- Certain chemicals are the stimulus for chemoreceptors in the tongue and nose.
- Mechanoreceptors in the inner ear respond to mechanical forces of the pressure waves associated with sound, while mechanoreceptors in the skin respond to forms of pressure, from light touch to moderate pressure or pressure that causes pain.
- Thermoreceptors in the skin detect heat and cold.
- Sensation occurs when nerve impulses reach the cerebral cortex, and perception is an interpretation of the meaning of sensations.
- A massive amount of sensory information coming from various neural pathways bombards the brain. Sometimes the brain can filter out redundant, insignificant information in a process called sensory adaptation.

Teaching Strategies

- If required, arrange to get a computer with Internet access and a digital projector in your classroom. Web links related to optical illusions can be found at **www.albertabiology.ca.** The links can be accessed through the Student Edition or by logging in to the Instructor Edition at the Online Learning Centre and following the links to Chapter 12. Project several of these illusions on a screen or white board and discuss each illusion with your students.
- Have students recall their experiences with the Chapter 11 Launch Lab: You, Robot? on page 365 of the student textbook. Ask them how impairing their senses affected their ability to tie shoelaces. Consider having your students complete this activity if you did not do it in Chapter 11.
- Photocopy and distribute **BLM 12.1.1: Major Sensory Receptors in the Human Body**. This information handout is a copy of Table 12.1 on page 409 of the student textbook.
- Set up a mock incident in your classroom. Ask a stranger to come into your classroom during class and to do something that attracts students' attention. This event should last only a few seconds. After the person has left the room, have the students describe the individual, including hair colour, clothing, height, approximate weight, etc. They should write this information down without discussing it with anyone else in the room. Discuss how different people perceive the same situation. Ask the "stranger" to come back into the room and have students compare their initial perception with reality. Note that the same variety of interpretation of sensory stimuli can happen with the other senses, e.g., those who feel hot and cold differently, those who experience loud and quiet differently, etc.

- Suggest that all students set up their own vocabulary list. Students may wish to create their own "flash cards" with the term on one side of the card and its definition or description on the other side.

Figure 12.1

Student Textbook page 406

Your senses would detect the bright lights, the noise of the fireworks, noises coming from the midway rides, and the smells of food cooking. Your senses of sight, hearing, taste, smell, and touch keep you informed about the world around you and allow your body to respond to your external environment.

Answers to Questions for Comprehension

Student Textbook page 406

Q1. Sensory reception refers to the detection of sensory information by the receptors, which are the nerve endings. These sensory receptors initiate neural impulses.

Sensation occurs when the neural impulses arrive at the cerebral cortex. The resulting sensation depends on the area of the brain that has interpreted this information.

Q2. Each type of sensory receptor initiates nerve impulses that travel through the spinal cord to a certain part of the brain; the sensation that results depends on which part of the brain receives the nerve impulses. Perception, which also occurs in the cerebral cortex, occurs when the brain processes the sensations and interprets their meaning.

Student Textbook page 407

Q3. Sensory adaptation occurs when you no longer notice the ticking of a clock, feel the clothes on your skin, or notice an odour in the room. The brain filters out redundant and insignificant information. Students may recognize that constantly hearing and feeling every stimulus would be too much information for the brain to process.

Q4. To quickly process information from significant stimuli, the brain *parallels* or splits up this input to various areas of the brain—a form of neural multi-tasking. Sometimes the input information does not get reintegrated precisely, and what we sense is not necessarily what we perceive.

Figure 12.3

Student Textbook page 407

Keeping hands in warm or cold water will allow the temperature receptors to become adapted to water at that temperature. Perceptions of cold and hot do not come directly from temperature but from the difference between the temperature your thermal receptors have become used to and the warmth or coolness of the objects stimulating them. Since your hand adapted to the cold water, the room temperature water seemed warm in comparison. The hand that adapted to the hot water perceived the room temperature water as cold in comparison.

Biology File: Web Link

Student Textbook page 408

Student answers may include the following details:

– Most forms of RP first cause the degeneration of rod cells.
– Retinal cells are among the most specialized cells in the human body and depend on a number of unique genes to create vision. A disease-causing mutation in any one of these genes can lead to vision loss. To date, researchers have discovered over 100 genes that can contain mutations leading to the disease.

Research:

– Gene therapy researchers have developed ways to deliver altered genes to the retina. This process may also be used to deliver potential cell rescue agents, such as growth factors to the retina. Cell transplantation techniques perfected to implant retinal cells may also be used to assist in cell rescue.
– The discovery of stem cells that survive in the human retina may provide cells to replace dying photoreceptors.

Answers to Questions for Comprehension

Student Textbook page 409

Q5. Students may answer with any five of the following external senses and their corresponding sensory receptors (also see Table 12.1 on page 405 of the student textbook):

- vision—rods and cones in the eyes
- taste—taste buds on the tongue
- hearing—hair cells in the inner ear
- touch/pressure/pain—receptors in the skin
- smell—olfactory receptors in the nose
- temperature—heat and cold receptors in the skin

Q6. Students may answer with any three of the following internal sensory receptors and their functions:

- osmoreceptors—regulate volume of blood
- pH receptors—regulate pH levels in the blood
- proprioceptors in the muscles and tendons and at the joints—regulate body position
- hair cells in the inner ear—control balance

Biology File: Web Link

Student Textbook page 409

Synesthesia means "joined sensation" (Greek: *syn* = together + *aisthesis* = perception). It refers to an involuntary physical experience in which the stimulation of one sense causes an additional perception in a different sense or senses. For example, someone with synesthesia, known as a synesthete, might describe the colour, shape, and flavour of someone's voice, or, upon seeing the colour red, might detect the "scent" of red as well.

Section 12.1: Review Answers

Student Textbook page 409

1. (a) Thermoreceptors in the skin are stimulated by radiant energy.

(b) Photoreceptors are stimulated by visible light energy.

2. Mechanoreceptors (touch, pressure, pain, balance, and body position) would be stimulated by a person performing a complicated yoga pose.

3. Each person's unique perception results from the interpretation of the meaning of sensory information by the cerebral cortex. Perception is the active process of selecting, organizing, and interpreting the information brought to the brain by the senses. The brain of each individual organizes and translates this information differently.

4. Your perception of the way your boots feel changes because of sensory adaptation. Adaptation occurs in most sense receptors. It is useful because it prevents the nervous system from being bombarded with information about insignificant matters like the touch and pressure of your clothing. (Note: For more advanced students, you could explain that pressure receptors located in the skin are each connected to a sensory neuron. When pressure is first applied to the receptor, a volley of impulses is initiated in the sensory neuron. However, with continuous pressure, the frequency of action potentials decreases quickly and soon stops. This is the process known as sensory adaptation.)

5. When viewing a complicated scene such as an "optical illusion," the brain *parallels* or splits up this input to various areas of the brain—a form of neural multi-tasking. Sometimes the input information does not get reintegrated precisely, and what we sense is not necessarily what we perceive.

12.2 Photoreception

Student Textbook pages 410-418

Section Outcomes

Students will:

- describe the principal structures of the human eye and their functions
- observe the principal features of the mammalian eye and perform experiments that demonstrate the functions of the human eye
- describe several eye disorders and treatments

Key Terms

sclera
cornea
choroid
iris
pupil
adaptation
retina
rods
cones
optic nerve
aqueous humour
glaucoma
vitreous humour
lens
accommodation
cataracts
astigmatism
myopia
hyperopia
fovea centralis
colour blindness
blind spot

Biology Background

- The structures directly involved in vision are the eye, the optic nerves, and the visual areas of the cerebral cortex.
- The eye has three layers. The outer layer, or sclera, can be seen as the white of the eye; it also becomes the transparent bulge in the front of the eye called the cornea. The middle pigmented layer, called the choroid, absorbs stray light rays that enter the eye. The rod cells (photoreceptors for dim light) and the cone cells (photoreceptors for bright light and colour) are located in the retina, the inner layer of the eyeball. The cornea, humours, and especially the lens focus the light rays on the retina. In focussing on a close object, accommodation occurs as the lens becomes round. In focussing on a distant object, accommodation occurs as the lens becomes flat.
- When light rays strike rhodopsin, the light-sensitive protein within the membranous discs of rod cells, rhodopsin splits into opsin and retinal. A cascade of reactions leads to the closing of ion channels in a rod cell's plasma membrane. Inhibitory transmitter molecules are no longer released, and nerve impulses are carried in the optic nerve to the brain.
- Integration of the information occurs in the retina, which is composed of three layers of cells: the rod and cone layer, the bipolar cell layer, and the ganglion cell layer. Integration also occurs in the brain. The occipital lobe receives and processes visual information from the retina and relates this information to the other relevant lobes, such as the parietal lobe and motor cortex of the frontal lobe. One of the things the brain must do is interpret the upside-down images that are projected onto the retina by the lens of the eye.

Teaching Strategies

- As an introduction to vision, show students images of predator species (such as cats) and prey species (such as birds) and discuss the significance of the location of the animals' eyes. Binocular vision—made possible when the eyes are at the front of the head—is often associated with predator species, which must accurately judge distances to capture prey. (Primates also require binocular vision for climbing and leaping in trees.)
- Consider starting this section with Investigation 12.A: Dissection of an Eye. This activity can be done as an actual dissection or your students could conduct a virtual dissection. Web links for virtual dissections can be found at **www.albertabiology.ca**. The links can be accessed through the Student Edition or by logging in to the Instructor Edition at the Online Learning Centre and following the links to Chapter 12.
- Download a Snellen visual acuity chart from the Internet. Have several students check the visual acuity in both eyes. Compare the vision of students with and without their glasses.
- Invite an ophthalmologist in your area to come into your class and talk about eyes, vision, and eye health, and about the latest technologies in eye care and surgery.
- Consider contacting a person who has suffered loss of vision and asking him or her to talk to your students about the strategies he or she uses to compensate for the loss of this sense. Ask your students to prepare a series of questions that they would like to ask this person during the session.
- The overhead masters and reinforcement tools that have been prepared for this section are listed below. You will find them with the Chapter 12 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging in to the Instructor Edition at the Online Learning Centre.

Number (Type)
12.2.1 (HAND) The Human Eye
12.2.1A (ANS) The Human Eye Answer Key
12.2.2 (HAND) Focussing
12.2.3 (HAND) Out of Focus

12.2.4 (OH) Rods and Cones
12.2.5 (HAND) The Retina
12.2.5A (ANS/OH) The Retina Answer Key
12.2.6 (OH) The Neural Pathway of the Optic Nerve

SUPPORTING DIVERSE STUDENT NEEDS

- A significant number of new terms is introduced in this section. Students can make their own study aids by drawing a picture in colour that will cue their memory for each term. Then ask them to come up with a story to go with the term and to include the term to be memorized written in colour somewhere near the picture and story.
- Provide a dictionary of biology terms for ESL students.
- Web links to a variety of interactive web pages and animations related to the eye and vision can be found at **wwwalbertabiology.ca**. Select Student Edition and follow the links to Chapter 12. The advantage of these web sites is that students can view them over and over again during their spare time in class, at home, or at the local library.

Figure 12.6

Student Textbook page 410

It is unlikely students will be able to answer this question at this time. It would require knowledge of concepts such as photoreceptors (cones and rods), binocular vision, and perception of vision in the brain.

Biology File: Web Link

Student Textbook page 410

Biometrics technology uses a person's unique physiological characteristics to confirm identity.

Biometrics technology can measure and record:

- fingerprints
- hand measurements
- iris of the eye
- retinal veins in the eye
- voice recognition

Canada uses biometrics in its CANPASS program for frequent travellers. CANPASS, used by Canada Customs, uses finger scans to keep goods flowing between the U.S. and Canada. For example, truck drivers have their fingerprints registered in order to pass through borders smoothly

Advantages: the characteristics used in biometrics are hard to duplicate and could eliminate identity theft or use of fake ID; finger scans are quick and efficient.

Disadvantages: the data collected is easy to duplicate and/or transfer for uses other than what was intended (e.g., simplifying border crossing). It could be incorporated into passports, driver's licences, or ID cards and stored along with other personal data. It could also be linked to general digital video surveillance systems.

Answers to Questions for Comprehension

Student Textbook page 412

Q7. Student drawings should be similar to Figure 12.7 and Table 12.2 on page 411. Consider using BLM 12.2.1: The Human Eye as an alternative way to address this question.

Q8. The process that allows the eye to adjust to various intensities of light 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.

Q9. Clear liquid called aqueous humour circulates inside the front portion of the eye. To maintain a healthy level of pressure within the eye, a small amount of this fluid is produced constantly while an equal amount flows out of the eye through a microscopic drainage system. (Note: This liquid is not part of the tears on the outer surface of the eye.) Because the eye is a closed structure, if the drainage area for the aqueous humour—called the drainage angle—is blocked, the excess fluid cannot flow out of the eye. Fluid pressure within the eye increases, causing damage to the blood vessels. Without proper blood circulation, the oxygen and nutrients available to the cells in the eye are limited, and the cells deteriorate.

Figure 12.9

Student Textbook page 412

Light rays reflecting off each point on an object are bent by the cornea and the lens in such a way that an inverted and reversed image of the object forms on the retina. The image produced is much smaller than the object because light rays are bent (refracted) when they are brought into focus. The light rays cross after they pass through the lens of the eye, creating an image that is upside-down and reversed from right to left on the retina at the back of the eyeball. After some chemical operations carried out by retinal rods and cones, this vision becomes an electrical impulse. This impulse is then sent through the nervous system to the occipital lobe of the brain. We do not perceive objects as upside-down, reversed, and smaller because the brain converts this flow into a meaningful, 3-dimensional vision.

Figure 12.10

Student Textbook page 412

Light rays from each point on an object are bent by the cornea and the lens in such a way that an inverted and reversed image of the object forms on the retina. When focussing on a distant object, the lens is flat because the ciliary muscle is relaxed and the suspensory ligament is taut. When focussing on a near object, the lens accommodates; it becomes rounded because the ciliary muscle contracts, causing the suspensory ligament to relax.

Figure 12.12

Student Textbook page 413

A. Nearsighted people can see close objects better than they can see distant objects. In this image, the flower is in focus and the building is blurry.

B. The eyeball of people with myopia is elongated, so that focussed light falls in front of the retina instead of on the photoreceptors.

C. Farsighted people can see distant objects better than they can see close objects. In this image, the building is in focus and the flower is blurry.

D. The eyeball of people with hyperopia is shortened, so that focussed light falls behind the retina instead of on the photoreceptors.

Answers to Questions for Comprehension

Student Textbook page 414

Q10. The cornea bends light rays. The lens bends light rays and focusses them on the retina.

Q11. Astigmatism is caused when the cornea is uneven so light rays cannot be evenly focussed on the retina. The result is a fuzzy image. In people with myopia, the eyeball is elongated and the focussed light falls *in front* of the retina instead of on the photoreceptors.

In people with hyperopia, the eyeball is too short. The light rays do not meet before they reach the retina, and so the image is focussed *behind* the retina.

Q12. The ability of the lens to change shape to focus images clearly on the retina is called accommodation. If an object is near, the ciliary muscles contract and the suspensory ligaments relax, causing the lens to become more rounded. If an object is far away, the ciliary muscles relax and the suspensory ligaments become taut, causing the lens to flatten.

The iris allows light to enter the inner eye through the pupil. The iris can adjust the size of the pupil depending on the light conditions, a process called 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.

Figure 12.14

Student Textbook page 414

Some students may in fact be colour blind. Colour-blind individuals are actually colour *deficient*, as they lack or are deficient in particular cones, typically red or green. Thus a red-green colour-blind person may find it difficult or impossible to distinguish between these colours.

Answers to Questions for Comprehension

Student Textbook page 416

Q13. The two photoreceptors, rod cells and cone cells, are located at the back of the eye, within the retinal layer nearest the choroid. The rods permit vision in dim light and at night, and the cones permit vision in the bright light needed for colour vision.

Q14. Colour blindness is an inherited condition that occurs more frequently in males than in females. There are three types of cones, each of which absorbs a different wavelength of light. The combination of cones that can detect red, blue, or green wavelengths of light allows us to see a range of colours. Colour-blind individuals are actually colour *deficient*, as they lack or are deficient in particular cones, typically red or green. Thus a red-green colour-blind person may find it difficult or impossible to distinguish between these colours.

Q15. Light rays must pass through several layers of cells before reaching the photoreceptors (rods and cones). When not activated, the photoreceptors release an inhibitory neurotransmitter that inhibits nearby nerve cells. When they absorb light, however, the rhodopsin in the cells splits into retinal and opsin. This triggers a chain reaction that *stops* the release of the inhibitory neurotransmitter, thus *allowing* transmission of a neural impulse. This impulse passes through the bipolar cells to the ganglion cells, which form the optic nerve. Optic nerve fibres that emerge from the back of the eye transmit visual images through the thalamus to the cerebral cortex of the brain (specifically, the occipital lobe) for interpretation.

Q16. The blind spot is the area of the retina that does not have any rods or cones. This is the area where the optic nerve exits the eye. Without photoreceptors (rods or cones), no vision is possible.

Q17. The various aspects of an object, such as movement, colour, depth, and shape, appear to be integrated in the occipital lobe so that we can "see" it.

Investigation 12.A: Dissection of an Eye

Student Textbook page 417

Purpose

Students will examine the exterior and interior structures of the eye.

Outcomes

- 30-A1.4k
- 30-A1.2s
- 30-A1.4s

Advance Preparation

Please note that the information below is for the actual dissection of the mammalian eyeball.

When to Begin	What to Do
3 to 4 weeks before	■ Check supply of safety equipment (protective gloves, aprons, goggles) and replace if needed. ■ Check that proper biohazardous disposal procedures are in place. ■ Check supply of mammalian eyeballs and order as required.
2 days before	■ Photocopy **BLM 12.2.7 Investigation 12.A** ■ Organize dissecting tools and equipment.

Materials

- dissecting instruments
- aprons (1 per student)
- eye goggles (1 per student)
- dissecting pan
- dissecting microscope (optional)
- disposable protective gloves (1 pair per student)
- paper towels
- soap and water
- cow eye (1 per group)

Time Required

1 hour

Helpful Tips

- Photocopy and distribute **BLM 12.2.7: Investigation 12.A**. This resource will guide students through this investigation and will protect textbooks from exposure to the liquids used to preserve the eye. It also includes room for students to draw their sketches. Modify as necessary.
- Compared to sheep eyes, cow eyes are larger and easier to work with. These should be soaked in tap water 24 hours prior to use to dilute any storage solution which may contain formaldehyde or formalin.
- Mammalian eyeballs can be purchased from most scientific supply companies. The cost of the specimens and/or the objections of some students to doing dissections may require you to complete this activity as a demonstration or to use illustrations provided on the web. Virtual images of a mammalian eyeball dissection can be found at **www.albertabiology.ca**. Log on to the Instructor Edition and follow the links to Chapter 12.
- Before students start the dissection, remind them of all safety precautions.
- Remind students that dissection involves the careful and systematic examination of the structures of an organism.
- For information on all safety precautions for this investigation, refer to Alberta Education's ***Safety in the Science Classroom***. The web link can be found at **www.albertabiology.ca**. Log on to the Instructor Edition.
- Group your students in teams of 4 to reduce the number of specimens required. You could do this investigation as a combination of a class demonstration with digital support from the web site, identified in the second bullet under Helpful Tip, or you could set up the investigation in stations that correspond to the instructions in the student textbook.
- Have students make "flags" out of straight pins and masking tape. They can write on the masking tape the names of the different parts of the eye and then insert the pin in the appropriate structure. This will ensure that they have taken the time to actually find each region of the eye. It could also be used as a formative evaluation tool for this activity.

Safety Precautions

- Follow Alberta Education guidelines for the proper disposal of all biohazardous materials. (See reference to Alberta Education's publication ***Safety in the Science Classroom*** under Helpful Tips.)
- If you are planning to use a fresh mammalian eye, make sure that it has been properly inspected for infectious agents and that it is refrigerated. For more information, refer to Alberta Education's ***Safety in the Science Classroom***. (See Helpful Tips.)


Extreme care must be taken when students are using dissecting instruments, particularly scalpels. Make sure that students make cuts away from their bodies.




Students must wear disposable protective gloves, goggles, and aprons at all times and work in a well-ventilated area if using preserved specimens.

- Use tongs and wear protective gloves when removing specimens from shipping containers.
- Provide time for students to thoroughly wash their hands at the end of the activity.

- Some students may object to touching animal organs or may have cultural or ethical concerns about doing a dissection. Provide these students with the opportunity to do the virtual dissection in a supervised area of the school.

- Students with visual or motor disabilities should be teamed with students who can complete the investigation safely.

Answers to Analysis Questions

1. Student sketches should be similar to Figure 12.7 on page 411 of the student textbook. If you are using **BLM 12.2.7: Investigation 12.A**, students will be asked to draw and label the external as well as the internal structures of the eye.
2. Students' 2-column chart should be similar to Table 12.2 on page 411 of the student textbook.

Eye Structure	Eye Function
Optic nerve	receives impulses from the photoreceptors (rods and cones) and transmits sensory information from the eye to the brain
Posterior (rear) chamber	contains vitreous humour
Vitreous humour	maintains the shape of the eyeball and supports the surrounding cells
Sclera	protects and supports the eyeball
Choroid	absorbs stray light rays that are not detected by the photoreceptors and contains blood vessels that nourish the eye
Retina	contains the photoreceptors for sight
Blind spot	has no actual function; is the area where the ganglion cells merge to form the optic nerve; contains no photoreceptors so is incapable of detecting light
Fovea centralis	provides for acute vision because it contains a high density of cones
Anterior (front) chamber	contains aqueous humour
Lens	bends and focusses light rays onto the fovea centralis
Ciliary muscles	changes the shape of the lens in order to focus
Suspensory ligaments	attach the lens to the ciliary muscles
Aqueous humour	maintains the shape of the cornea and provides oxygen and nutrients for the surrounding cells
Iris	regulates amount of light entering the eye
Pupil	provides opening for light to enter the inner eye
Cornea	transparent part of the sclera that bends light rays into the eye

3. On their diagram, students should label rods and cones in the retinal layer at the back of the eye. Rods and cones are the receptors for sight. The rods permit vision in dim light and at night, and the cones permit vision in bright light needed for colour vision.

Answer to Conclusion Question

4. The cornea, lens, and humours bend the light rays from each point on an object to direct the rays toward the retina. The fovea centralis is an area in the retina at the back of the eye containing densely packed cones. The cones require relatively intense light to stimulate them. Thus, the structures of the eye (cornea, lens, and humours) must focus light directly onto the fovea centralis to produce a sharp image. In daylight, you can see best (your eyes produce the sharpest image) if you look directly at an object.

Assessment Options

- Collect and assess **BLM 12.2.7: Investigation 12.A.**
- Collect and assess answers to the Analysis, Conclusion, and Application questions.
- One of the Helpful Tips provided for this investigation was to mark structures using flags made out of straight pins and masking tape. Test each group's knowledge of the structures and the functions of the eye while the other students are working on the Section 12.2 Review questions.

Section 12.2: Review Answers

Student Textbook page 414

1. The eye's external layer is a white, tough and fibrous protective layer called the sclera. Light enters the eye through the cornea, the transparent part of the sclera at the front of the eye.

   The intermediate layer of the eye is the choroid, which absorbs stray light rays not detected by photoreceptors. The choroid also contains blood vessels that nourish the eye. Toward the front, the choroid forms the doughnut-shaped, coloured iris, which contains a central dark pupil.

The retina, the internal layer of the eye, is a thin layer of tissue containing the photoreceptors—the rods and cones. It also contains a bipolar cell layer and a ganglion cell layer, whose axons form the optic nerve that exits the eye at the blind spot. The fovea centralis is the area on the retina where the cornea and lens focus light for vision.

2. As the person approaches and the viewer's eye tries to keep him/her in focus, the lens changes shape. The changing shape of the lens of the eye to focus images clearly on the retina is a reflex called accommodation. As the person gets closer, the ciliary muscles contract and the suspensory ligaments relax, causing the lens to become more rounded.
3. Light rays from each point on an object enter the eye and are bent (refracted) by the cornea, lens, and humours to focus on the retina.

   In people with myopia, the eyeball is elongated and 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.

   In people with hyperopia, the eyeball is too short. The light rays do not meet before they reach the retina, and so the image is focussed *behind* the retina. Convex lenses can correct this problem by bending the light rays at a sharper angle.
4. A person can be blind even with a functioning optic nerve. This person may have had a stroke or other injury that damaged the vision perception centres in the brain. This damage would prevent the interpretation of the nerve impulses coming in from the eyes and the person would therefore be blind.
5. As people age, the lens of their eyes is thought to become less elastic. This results in the loss of the accommodation reflex and the inability to focus at different distances. For example, older people begin to hold the newspaper farther away to read because fine objects close to them look blurred. However, objects far away may also be blurred. Bifocals are the most common type of multifocal lens and are usually prescribed for people with declining accommodation. The lens is split in two sections; the upper part is concave for distance vision and the lower part is convex for near vision.
6. Students may need to do some research on the Internet to complete the chart.

Eye Condition	Description of the problem	Method of correction
glaucoma	A small amount of aqueous humour is continually produced every day and normally leaves the anterior compartment by way of tiny ducts. These drainage ducts are blocked in a person with glaucoma, and aqueous humour builds up. If not treated, the pressure builds up and restricts the blood flow to the retina. The nerve fibres begin to die due to a lack of nutrients, and the person becomes blind.	Treatment is to lower the pressure in the eye, either through eye drops or surgery.
cataract	Cataracts affect the lens. As the protein structure degenerates, the lens becomes opaque and does not allow light rays to pass through. Grey-white spots can be seen on the lens.	Surgery to replace the cataract with an artificial lens is a common surgical procedure.
astigmatism	When the cornea or lens has an uneven curvature, a fuzzy image is produced because light rays cannot be evenly focussed on the retina.	Astigmatism can be corrected by an unevenly ground artificial lens to compensate for the uneven cornea or lens.
nearsightedness (myopia)	Nearsightedness is caused by an elongated eyeball; rays focus in front of the retina when a person is viewing distant objects.	A concave lens allows the subject to see distant objects.
farsightedness (hyperopia)	Farsightedness is caused by a short eyeball; rays focus behind the retina when a person is viewing close objects.	A convex lens allows the subject to see close objects.

7. Humans are adapted to perceive their surroundings mostly using the sense of sight. The more we rely on a sense, the larger the area of the brain that is devoted to interpreting the nerve impulses arriving from those sensory receptors.

Some students may also relate their answer to the previous chapter. These students may indicate that the occipital lobes are located at the back of the brain, directly above the cerebellum. These lobes process visual stimuli—stimuli that are sent to the brain from the eyes. (Advanced students may be interested in the following additional information: A visual stimulus enters and goes directly to structures deep within the brain, where it is scanned and relayed to the occipital lobes for processing. Within the occipital lobes are groups of specialized neurons—neurons that "handle" specific colours, motions, straight lines, objects, depth, etc. These neurons then communicate with other neurons within the visual association area to compare what they have perceived with what may have been stored previously. Visual stimuli do not become meaningful until the sensory perceptions are matched to previously stored cognitive associations.)

12.3 Mechanoreception and Chemoreception

Student Textbook pages 419-429

Section Outcomes

Students will:

- describe how the structures of the human ear support the functions of hearing and balance
- explain how humans sense their environment through taste, smell, and touch
- design and plan experiments that demonstrate the structures and sensory functions of the human ear, nose, tongue, and skin
- explain how small doses of neurotoxins can be used as painkillers

Key Terms

sound waves
outer ear
pinna
auditory canal
middle ear
tympanum
ossicles
oval window
Eustachian tube
inner ear
cochlea
organ of Corti
basilar membrane
hair cells
tectorial membrane
semicircular canals
rotational equilibrium
gravitational equilibrium
utricle
saccule
otoliths
proprioceptors
taste buds
olfactory cells
olfactory bulb

Biology Background

- The structures directly involved in hearing are the ear, the cochlear nerve, and the auditory areas of the cerebral cortex.
- The ear is divided into three parts: outer, middle, and inner. The outer ear consists of the pinna and auditory canal, which direct sound waves to the middle ear. The middle ear begins with the tympanic membrane and contains the ossicles (malleus, incus, and stapes). The malleus is attached to the tympanic membrane, and the stapes is attached to the oval window, which is covered by a membrane. The inner ear contains the cochlea and the semicircular canals, plus the utricle and saccule.
- Hearing begins when the outer ear receives and the middle ear amplifies the sound waves that then strike the oval window membrane. Its vibrations set up pressure waves across the cochlear canal, which contains the organ of Corti (spiral organ), consisting of hair cells whose stereocilia are embedded within the tectorial membrane. When the basilar membrane vibrates, the sterocilia of the hair cells bend and initiate nerve impulses in the tectorial membrane. Nerve impulses travel along the auditory nerve of the cochlea and are carried to the brain.
- The ear also contains mechanoreceptors for our sense of equilibrium. Rotational equilibrium is dependent on the stimulation of hair cells within the ampullae of the semicircular canals. Gravitational equilibrium relies on stimulation of hair cells within the utricle and the saccule.
- Taste and smell are due to chemoreceptors that are stimulated by molecules in the environment. The taste buds contain taste cells that communicate with sensory fibres, while the chemoreceptors for smell are neurons.
- After molecules bind to plasma membrane receptor proteins on the microvilli of taste cells and the cilia of olfactory cells, nerve impulses eventually reach the cerebral cortex, which determines the taste and odour according to the pattern of stimulation.
- Proprioceptors are a type of mechanoreceptor involved in coordination. These receptors in muscles, tendons, and joints throughout the body send information about body position to the brain.
- The skin contains sensory receptors (mechanoreceptors) for touch, pressure, pain, and temperature.

Teaching Strategies

- Ask students if they can explain why their ears hurt after going to a loud concert or if they have noticed a reduction in their hearing (as if they have cotton in their ears). Find out if they have made the connection between loud noise and damage to the mechanoreceptors in the ears that respond to sound waves. Have your students research hearing loss by musicians and what they can do to protect their hearing at concerts.
- Consider asking an audiologist to talk to your students about hearing and protecting their hearing. If possible, have him/her bring in testing equipment and explain how testing is conducted for hearing and hearing loss. As well, ask the audiologist to discuss the latest technological developments designed to assist those people who are suffering from loss of hearing.
- Consider inviting a person who uses American Sign Language (ASL) as a first language, as well as an individual who can interpret ASL to share experiences with your class.
- Do the activity described in the Biology File: Web Link on page 420. Couple this activity with a multimedia applet that demonstrates how sound waves travel. A variety of interactive web pages and animations related to the ear and hearing can be found at **www.albertabiology.ca**. Log on to the Instructor Edition at the Online Learning Centre and follow the links to Chapter 12.
- The overhead masters and reinforcement tools that have been prepared for this section are listed below. You will find them with the Chapter 12 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging on to the Instructor Edition at the Online Learning Centre.

Number (Type)
12.3.1 (HAND) The Human Ear
12.3.1A (ANS/OH) The Human Ear Answer Key
12.3.2 (HAND) The Inner Ear and Cochlea
12.3.2A (ANS/OH) The Inner Ear and Cochlea Answer Key
12.3.4 (HAND) Balancing Act
12.3.4A (ANS/OH) Balancing Act Answer Key
12.3.5 (HAND) Taste Test
12.3.5A (ANS/OH) Taste Test Answer Key
12.3.6 (HAND) Identifying a Smell
12.3.6A (ANS/OH) Identifying a Smell Answer Key
12.3.8 (OH) The Sensory Neurons

- A significant number of new terms is introduced in this section. Students can make their own study aids by drawing a picture in colour that will cue their memory for that term. Then ask them to come up with a story to go with the term and to include the term to be memorized written in colour somewhere near the picture and story.
- Provide a dictionary of biology terms for ESL students.
- A variety of interactive web pages and animations related to the ear and hearing can be found at **www.albertabiology.ca**. Select Student Edition and follow the links to Chapter 12. The advantage of these web sites is that students can view them over and over again during their spare time in class, at home, or at the local library.

Biology File: Web Link

Student Textbook page 420

The basilar membrane in the organ of Corti bounces up and down in response to the sound waves produced by the piano, which have now been converted to pressure waves. As this membrane moves, the fine stereocilia bend against the tectorial membrane. The movement of the stereocilia signals the hair cell to transmit a neural impulse along the auditory nerve to the cerebral cortex. Different areas of the organ of Corti are sensitive to different frequencies. Piano notes played at high frequencies most strongly stimulate the hair cells closest to the oval window, and notes played at low frequencies most strongly stimulate the hair cells farthest from the oval window.

Figure 12.20

Student Textbook page 420

The sound waves are amplified by the ossicles of the inner ear. The ossicles can be thought of as a compound lever that multiplies the force of the sound waves that have reached the eardrum: each bone acts as a lever for the next, so that a small movement in one results in a larger movement in the next. The middle ear can significantly amplify and concentrate vibrations because the tympanum is 15 to 30 times larger than the oval window.

Answers to Questions for Comprehension

Student Textbook page 421

Q18. Sound waves encounter the following structures:
pinna → auditory canal → tympanum → ossicles (malleus, incus, stapes) → oval window → cochlea → organ of Corti

Q19. When sound waves push the tympanum, its vibrations are passed on and amplified by the neighbouring ossicles: three tiny, interconnected bones of the middle ear. The ossicles are the smallest three bones in the body. Each bone vibrates more than the next so that the vibrations are amplified as they pass from the malleus (hammer), to the incus (anvil), and finally to the stapes (stirrup). The stapes concentrates vibrations onto the bony wall of the inner ear, called the oval window. Because the inner ear is fluid-filled, vibrations in the oval window are converted to pressure waves in the fluid of the inner ear.

Q20. The middle ear is connected to the throat by the thin Eustachian tube. This tube allows air pressure to equalize

when there is a difference in air pressure within and without the otherwise-contained middle ear.

Figure 12.22

Student Textbook page 421

When the stapes strikes the oval window, this vibrates the window and creates pressure waves in the fluid of the cochlea that make the basilar membrane move up and down. This, in turn, causes the stereocilia of the hair cells to bend against the tectorial membrane.

Investigation 12.B: Distinguishing Sights and Sounds

Student Textbook pages 422–423

Purpose

Students will perform experiments measuring the ability to discriminate objects visually and to hear a range of sounds.

Outcomes

- 30-A1.2s
- 30-A1.4s

Part 1: Distinguishing Shades of Colour

Advance Preparation

When to Begin	What to Do
3 or 4 weeks before	■ Make sure that you have food colouring available for Part 1 of this activity.
1–2 days before	■ Photocopy **BLM 12.3.3: Investigation 12.B**

Materials
■ 5 beakers (100 mL) (or 5 clear containers of equal size) ■ liquid food colouring ■ water

Time Required

20 minutes

Helpful Tips

- Use **BLM 12.3.3: Investigation 12.B** to support this activity. Modify as necessary.
- Some students may have difficulty writing an hypothesis for this activity. You could suggest that they write their hypothesis as an "If—Then" statement. For example, "*If* there is less food colouring *then* I will have more difficulty distinguishing different shades of colour."
- Make up the solutions with the food colouring ahead of time and have them ready in the small glass containers or beakers. Set up a number of stations in your room or science lab to reduce traffic congestion. Set up one station per group of 3 or 4 students.
- Remind students that they have to observe the beakers of food colouring from the same distance and the same angle for each part of this activity.

Safety Precautions

Food colouring will stain skin and clothing. Students should be wearing disposable protective gloves and lab aprons as they perform this part of the investigation.

Answers to Analysis Questions

1. The results of this investigation should support the hypothesis that they can distinguish different shades of colour better in brighter light. Colour vision is mediated by specialized nerve cells in the retina called cones, which function only in bright light. When light becomes dim, rods take over, and these provide neither colour vision nor high acuity (ability to detect fine detail, such as that needed for reading).

Peripheral vision is provided primarily by the rods. The cones are used for colour vision and are found mainly in the centre of the field of view. Therefore, students should notice that they cannot distinguish colours as easily when looking at the beakers out of the corners of their eyes.

2. Students should find that other students obtained similar results. If not, discuss as a group the possible reasons or sources of error.

Answer to Conclusion Question

3. The rods and cones are responsible for vision. The cones are primarily responsible for colour discrimination.

In Step 5, when students look straight at the beakers, the light energy is striking the central portion of the retina. This region contains more cones. Therefore, students are able to distinguish different shades of colour—especially in bright light. In a dark room and with moderate lighting, students will be relying more on information from rods.

In Step 6, when students look out of the corners of their eyes, the light energy is striking the outside edge of the retina. This region contains more rods than cones. Therefore, you cannot easily distinguish different shades of colour even in bright light when most of the light energy is striking this region of the retina. Students will be relying more on information from rods.

In Step 7, when students move farther from the coloured water, less light energy is striking the cones. The cones require more light intensity to be stimulated. The farther

the distance, the more students will be relying on information from rods.

Part 2: Distinguishing Sound Frequencies

Advance Preparation

When to Begin	What to Do
2 to 3 weeks before	■ Locate a device that produces a wide range of sound frequencies. ■ Book a computer lab if you are going to use web resources to generate different frequencies of sound.

Materials

- a device that produces a wide range of sound frequencies such as
  - a set of tuning forks
  - a frequency signal generator
  - a Vernier or Pasco computer program that aids in analyzing different sound frequencies
  - an Internet site that provides different tone frequencies
- frequency sensor (optional)

Time Required

30 minutes

Helpful Tips

- Arrange for a quiet room with minimum background noise.
- If possible, arrange for students to wear headphones that are connected to the device being used to generate sound frequencies.
- Internet sites that provide freeware or shareware that produces different frequencies of sounds would be the most economical way to approach this activity. Using the computer would also allow some students to use their own headphones. Web links related to Investigation 12.B: Distinguishing Sights and Sounds can be found at **www.albertabiology.ca**. Log on to the Instructor Edition and follow the links to Chapter 12.

Safety Precautions

- Remind students that they must not fool around with any devices that involve the sense of hearing. For example, banging a tuning fork and inserting it in the ear canal could cause permanent hearing loss!

Answers to Analysis Questions

1. The specific structures of the inner ear that allow us to distinguish different frequencies are the oval window, organ of Corti, basilar membrane, hair cells, and stereocilia. Different areas of the organ of Corti are sensitive to different wave frequencies. High frequencies, such as the sound of a whistle, most strongly stimulate the hair cells closest to the oval window. Low frequencies, however, such as a low note played by a tuba, most strongly stimulate the hair cells farthest from the oval window.
2. The frequencies students will be able to detect will depend on a number of factors including the amount of background noise in the room, their perception of sound, and any damage they may have suffered already to the ear or organ of Corti. Predictions may or may not have been correct.
3. Hearing varies from person to person, with countless factors influencing the range of frequencies that any one of us can detect. Age and genetic makeup play a part, as do many other variables, such as the use of loud machines without wearing proper hearing protection, attendance at a noisy concert the night before, or the amount of wax in the students' ears.

Answers to Conclusion Questions

4. Hearing loss generally results from nerve damage (damage to the hair cells) or damage to the sound-conducting system of the outer or middle ear. Birth defects, ear infections, and noise are common causes of hearing loss.
5. The pinnae face forward, so humans can hear sounds in front better than they can hear sounds behind or to the side.

Answer to Extension Question

6. This activity would give students a better understanding of hearing loss. This project was suggested in the Teaching Strategies for this section.

Assessment Options

- Collect and assess students' answers to the Analysis and Conclusion questions for Part 1 and 2.

Answers to Questions for Comprehension

Student Textbook page 424

Q21. (a) In someone with nerve deafness, hair cells (and therefore their connections to the nerves) have been damaged.

(b) In someone with conduction deafness, damage has occurred to the sound-conduction system of the outer or middle ear.

Q22. Sensory neurons in the ear send information through the auditory nerve to the brain stem, thalamus, and ultimately the temporal lobes of the cerebrum for processing. Depending on which sensory neurons are stimulated, the brain can distinguish the frequency and amplitude of the sound. Recent research also suggests that the specific neurons stimulated in the temporal lobe depend on the sound's original source in the environment. Therefore the brain can also perceive the direction and location of the sound.

Biology File: Web Link

Student Textbook page 424

Hearing aids are made up of a microphone, tone hook, volume control, on/off switch, and battery compartment. The microphone picks up sounds from the environment and sends them to a processor that makes the signal louder. The hearing aid will amplify some pitches of the incoming sound more than others, but a technician can use the hearing aid's tone controls to adjust the amplified sound. After the sound is amplified, it is routed through the hearing aid tone hook to an earmold. The tone hook is a small plastic piece that hooks over and behind the outer ear (pinna). The earmold holds the hearing aid in the ear and directs sound from the hearing aid into the ear canal.

A cochlear implant is a device surgically implanted into the cochlea to activate the hearing nerve directly. The system consists of a directional microphone, cable and transmitter that fit behind the ear; a 3-4 oz. speech processor that can be worn in a pocket or on a belt; and the internal portion of the device (the magnet and receiver/stimulator) that is implanted in the mastoid process (behind the pinna). Once implanted, the device is programmed for the individual.

A hearing aid amplifies and directs the sound; the user must have some functional hearing for it to work. Cochlear implants bypass damaged portions of the ear and directly stimulate the auditory nerve. Signals generated by the implant are sent through the auditory nerve to the brain, which recognizes the signals as sound. Hearing through a cochlear implant is different from normal hearing and takes time to learn or relearn. Users should be able to recognize warning signals, understand other sounds in the environment, and enjoy a conversation in person or by telephone.

Answers to Questions for Comprehension

Student Textbook page 425

Q23. The semicircular canals contain mechanoreceptors that detect head and body rotation (rotational equilibrium). The semicircular canals are three fluid-filled loops arranged in three different planes—one for each dimension of space. The base of each canal has a jelly-like covering called a cupula. The stereocilia of hair cells in the canals stick into the cupula. When the body rotates, the fluid inside the semicircular canals moves and bends the stereocilia. Hair cells receive that rotational information and send it to the brain.

Q24. The balance required while moving the head forward and backward is called gravitational equilibrium. This equilibrium depends on the two structures called the utricle and saccule, which together make up the fluid-filled vestibule of the inner ear. Both structures 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, which send a neural impulse to the brain communicating the head's position.

Q25. A person who is lying down is in a static position. The movement or lack of movement of fluid in the inner ear tells the brain whether a person is standing, lying down, hanging upside-down, etc. When an individual is moving around, calcium carbonate crystals in the vestibule shift position. This movement results in nerve impulses being transmitted to the brain, indicating that the individual is changing positions. When the person is in an established position, the crystals stop rolling around. The vestibule doesn't send any impulses to the brain, thereby indicating that the individual is still holding that static position. Proprioceptors are another type of mechanoreceptor involved in coordination. These receptors are in muscles, tendons, and joints throughout the body and send information about body position to the brain.

Student Textbook page 426

Q26. When we eat, saliva dissolves some of our food. Specific molecules dissolved in the saliva are detected by the taste buds, the sensory receptors in the bumps (papillae) on the tongue. The taste buds depolarize in response to particular tastes, and generate an action potential that sends a neural impulse to the brain.

Student Textbook page 427

Q27. Odours are produced from particles that fit much like a lock and key into specific chemoreceptors called olfactory cells that line the upper nasal cavity. When the particles bind to the olfactory cilia of the olfactory cells, ion channels in the cell membrane open. This generates an action potential in the olfactory cells, which travels down the nerve fibres directly linked to the olfactory bulb of the brain.

Q28. The olfactory impulses are sent from the olfactory bulb of the brain to the emotional centres of the brain and the frontal lobe where the perception of odour occurs. This is why particular odours can instantly conjure up scenes and emotions from the past.

Q29. The types of touch detected by sensory receptors in the skin include light touch, pressure, and pain.

Q30. The mechanoreceptors associated with the sense of touch occur all over the body. The skin contains more than four million sensory receptors, but they are not evenly distributed. Many of the touch receptors are concentrated in the genitals, fingers, tongue, and lips.

Biology File: Try This

Student Textbook page 427

Students should notice that they can detect the prongs as separate on their palm but not their shoulder. The receptors in skin are not distributed in a uniform way around our bodies. Some places, such as fingers and lips, have more touch receptors than do other parts of the body, such as the shoulder. This is one reason why the fingers and face are more sensitive to touch than the shoulder. The chart below shows data from a 2-point discrimination threshold experiment (published in *The Skin Senses*, edited by D. R. Kenshalo, Springfield, IL, 1968):

Site	Threshold Distance
Fingers	2–3 mm
Upper lip	5 mm
Cheek	6 mm
Nose	7 mm
Palm	10 mm
Forehead	15 mm
Foot	20 mm
Belly	30 mm
Forearm	35 mm
Upper arm	39 mm
Back	39 mm
Shoulder	41 mm
Thigh	42 mm
Calf	45 mm

For more information, a web link can be found at **www.albertabiology.ca**. Log on to the Instructor Edition and follow the links to Chapter 12.

Investigation 12.C: Feel, Taste, or Smell: Design Your Own Investigation

Student Textbook page 428

Purpose

Students will design an experiment to investigate various sensory receptors and analyze data to show interrelationships between the different senses.

Outcomes

- 30-A1.1s
- 30-A1.2s
- 30-A1.3s
- 30-A1.4s

Advance Preparation

When to Begin	What to Do
1 week before	■ Make sure that you have the suggested materials for each topic.
2 days before	■ Photocopy **BLM 12.3.7: Investigation 12.C** ■ Photocopy Assessment Checklist 1: Designing an Experiment from Appendix A, if required. ■ Photocopy Assessment Checklist 2: Laboratory Report from Appendix A, if required.

Materials

- 500 mL beaker of hot water
- 500 mL beaker of ice water
- non-permanent pen for marking gridlines on different areas of the body
- alcohol thermometer
- finishing nails
- garbage bin
- blindfold
- salty water
- sugary water or sweet candy
- lemon juice
- onion juice or tonic water
- clean toothpicks or cotton swabs
- ginger
- lemon

Materials

- menthol
- perfume
- peppermint
- pine needles
- vanilla
- vinegar

Helpful Tips

- Use **BLM 12.3.7: Investigation 12.C** to support this activity. Modify it as ncessary.
- Photocopy Assessment Checklist 1: Designing an Experiment from Appendix A and/or Assessment Checklist 2: Laboratory Report from Appendix A if you plan to use either of these checklists as part of your assessment strategy for this investigation.
- Consider splitting your class into teams of 3 or 4. Assign to each team the design of an experiment to investigate one of the topics described in this activity. This will reduce the amount of time that this activity takes as well as the amount of materials that you will need to complete the investigation.
- Give students 30 minutes to design their investigation. Assessment Checklist 1: Designing an Experiment from Appendix A can be used as a guideline for this process.
- Give students 30 minutes to carry out their investigation and complete the analysis of the data they have collected.
- Give students 30 minutes to compare and/or share their data and to complete the Analysis questions.
- Remind students of the proper technique for detecting odours in a science laboratory.

Safety Precautions

- Do not bring food meant for consumption into the laboratory and do not eat or drink anything in the laboratory.
- Before starting this investigation, refer to Alberta Education's publication ***Safety in the Science Classroom***. The web link can be found at **www.albertabiology.ca**. Log on to the Instructor Edition. You can search this document to identify all safety precautions mandated by Alberta Education for this type of activity; the document describes proper disposal of the cotton swabs used in Topic 2.

Answers to Analysis Questions

1. Students may hypothesize that results would have been more difficult to analyze if the experiment had tested a combination of senses, because all senses may not be at the same level of acuity. For example, some students will have had the personal experience of losing their sense of taste when they have had a bad head cold.
2. Look for answers that include ways of controlling more of the variables in the experimental design.

Answer to Conclusion Question

3. Sensory receptors are specialized cells or neuron endings that detect specific stimuli. Human sensory receptors can be classified into four categories: photoreceptors, chemoreceptors, mechanoreceptors, and thermoreceptors. Each type of receptor is able to transduce, or convert, one form of energy from a specific type of stimuli into electrochemical energy, which can be processed by the central nervous system. We can therefore distinguish the *type* of stimulus based on the receptor that is affected. Distinguishing the *strength* of touch, taste, and smell is another matter. The strength of a stimulus here is the minimum strength of a stimulus required to generate an action potential. However, students may remember from Chapter 11 that an action potential has only one strength or magnitude (the all-or-none response). We cannot distinguish the strength of a stimulus affecting one receptor, but if a number of receptors are affected by the stimuli, we perceive the stimulus as being stronger. In an area of the body designed to be sensitive to certain stimuli, receptors are located close together so we can receive more information about strength.

   In all sensory receptors, the common result of all transduction is to produce a change in conductance of a membrane channel.

Assessment Options

- Use Assessment Checklist 1: Designing an Experiment from Appendix A to assess the experimental design of each investigation.
- Use Assessment Checklist 2: Laboratory Report from Appendix A if you are asking each individual to produce a formal laboratory report for this investigation.

Section 12.3: Review Answers

Student Textbook page 429

1. The middle ear is an air-filled space bordered on one side by the tympanum—a round, elastic structure that vibrates in response to sound waves. When sound waves travel through the auditory canal of the outer ear and push the tympanum, its vibrations are passed on and amplified by the neighbouring ossicles: three tiny, interconnected bones of the middle ear. Each bone vibrates more than the next so that the vibrations are amplified as they pass from the malleus (hammer), to the incus (anvil), and finally to the stapes (stirrup). 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 because the tympanum is 15–30 times larger than the oval window.
2. Different areas of the organ of Corti are sensitive to different wave frequencies. High frequencies, such as the shriek of a sea gull, most strongly stimulate the hair cells

closest to the oval window. Low frequencies, however, such as a low sound made by a drum, most strongly stimulate the hair cells farthest from the oval window.

Sensory neurons in the ear send information through the auditory nerve to the brain stem, thalamus, and ultimately the temporal lobes of the cerebrum for processing. Depending on which sensory neurons are stimulated, the brain can distinguish the frequency and amplitude of the sound.

3. Some people may suffer from motion sickness as they ride in an elevator. The balance required while moving the head forward and backward is called gravitational equilibrium. This equilibrium depends on the two structures called the utricle and saccule, which together make up the fluid-filled vestibule of the inner ear. Both structures 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, which send a neural impulse to the brain indicating the head's position. In an elevator, the inner ear may detect the motion of the elevator, as though the head is changing orientation, while the eyes do not. Motion sickness occurs when the utricle and saccule send information to the brain that conflicts with signals that the eyes send to the brain.
4. The tympanum (eardrum) separates the auditory canal from the middle ear. If air pressure in the auditory canal from outside air and air pressure in the middle ear are unequal, a feeling of pressure, pain, and even eardrum damage can result. Normally the Eustachian tube, which connects the middle ear and the throat, helps maintain equal pressure on both sides of the tympanum by allowing outside air (through the mouth) to enter the middle ear. If a person is swimming or diving, the pressure in the middle ear may become lower than the water pressure outside of the ear. The resulting stress causes a painful inward bulge of the eardrum. Plugging the nose and exhaling gently allows air to move through the Eustachian tube to equalize the pressure in the middle ear.
5. Noise is measured in decibels, and any noise over 80 decibels can damage hearing. The aunt should be wearing ear plugs or other technologies or she will likely suffer from permanent hearing loss. The amplitude of a sound wave is experienced as the intensity or volume of a sound. The louder the noise, the more the fluid within the cochlea puts pressure on the hair cells of the basilar membrane. The stereocilia of the hair cells are very delicate. Repeated or sustained exposure to loud noise destroys the stereocilia, and the resulting damage is permanent.

Connections: Nature of Science

Pain Relievers or Deadly Neurotoxins

Student Textbook page 430

Teaching Tips

- Have students read the information on page 426 of the student textbook and make a 3-column chart in their notebooks. List the animals that produce the neurotoxins in the first column, the neurotoxin that they produce in the second column, and the effects of the neurotoxin in the third column.
- Have students relate the information gathered to the sense organs as well as to the topics that they investigated in Chapter 11.

Answers to Questions

1. Over the course of time, these species may have developed these neurotoxins to ward off predators.
2. *Clostridium botulinum* produces seven distinct types of neurotoxins. One of these toxins inhibits the release of acetylcholine from the neural membrane, which results in paralysis. Small amounts of this toxin could paralyze the smooth muscles surrounding the arteries and arterioles, resulting in the vasodilation of these vessels. If a migraine headache is caused by vasoconstriction, then a chemical that resulted in vasodilation could be an effective drug for controlling this problem.
3. Targeted painkillers can be delivered directly to the area of the body where the pain is being experienced, in smaller doses; these painkillers should work more effectively with fewer side effects than the higher-dose, general painkillers that affect more nerves in the body.

Chapter 12: Review Answers

Student Textbook pages 432–433

Answers to Understanding Concepts Questions

1. The neural pathway from the organ of smell to the brain can be summarized by the following flowchart:

   odour particles → bind to specific chemoreceptors called olfactory cells lining upper nasal cavity → ion channels in the cell membrane open → generates an action potential in the olfactory cells → directly linked to the olfactory bulb of the brain → the impulse is sent to emotional centres of the brain and the frontal lobe where the perception of odour occurs

2. Students' answers may contain the following:

	What they detect	Example of human sense organ containing the receptor
Photoreceptors	visible light	eye (rods and cones)
Mechanoreceptors	sound waves	ear (hair cells in the organ of Corti)
	movement	ear (hair cells in the semicircular canals)
	touch/pressure/ pain	skin (various sensory receptors)
Chemoreceptors	food molecules in saliva	tongue (taste buds)
	odours	nose (olfactory cells)
Thermoreceptors	heat and cold	skin (free nerve endings)

3. **BLM 12.2.1A** can be used as the reference for this question.

Label	Structure	Function
A	sclera	protects and supports the eyeball
B	choroid	absorbs stray light rays that are not detected by the photoreceptors and contains blood vessels that nourish the eye
C	iris	regulates amount of light entering the eye
D	pupil	provides opening for light to enter the inner eye
E	lens	bends and focusses light rays onto the fovea centralis
F	cornea	transparent part of the sclera that bends light rays into the eye
G	aqueous humour	maintains the shape of the cornea and provides oxygen and nutrients for the surrounding cells
H	ciliary muscle	changes the shape of the lens in order to focus
I	vitreous humour	maintains the shape of the eyeball and supports the surrounding cells
J	retina	contains the photoreceptors for sight
K	fovea centralis	provides for acute vision because it contains a high density of cones
L	optic nerve	receives impulses from the photoreceptors (rods and cones) and transmits sensory information from the eye to the brain

Rods and cones are located within the retina. Their function is to act as photoreceptors for light energy: the rods for black and white vision in dim light; and the cones for colour vision in bright light.

4. Touch receptors in the skin transduce energy in the following manner:

light touch or pressure stimulates a mechanoreceptor → receptor depolarizes, converting energy of stimulus to electrochemical energy of nerve impulse → nerve impulse proceeds to spinal cord → impulse continues to the primary somatosensory cortex in the brain.

5. The nerve endings in the body are connected to the brain through the spinal cord. Sensory information from each part of the body (e.g., hand, arm, face, etc.) is directed to specific areas of the brain stem, thalamus, and cerebral cortex. When the area of the brain assigned to the lost limb no longer receives sensory input from the area, it begins to react to sensory input arriving at adjoining areas in the brain. In other words, the idle area overhears nearby impulses that are being processed and acts upon them in error.

6. Most humans can hear frequencies only between 20 and 20 000 Hz. The hair cells of the organ of Corti are able to distinguish both the frequency (pitch) and amplitude (volume) of sound waves. Different areas of the organ of Corti are sensitive to different wave frequencies. High frequencies, such as the sound of a whistle, most strongly stimulate the hair cells closest to the oval window. Low frequencies, such as a low note played by a tuba, most strongly stimulate the hair cells farthest from the oval window. The amplitude of a sound wave is experienced as the intensity or volume of a sound. The louder the noise, the more the fluid within the cochlea puts pressure on the hair cells of the basilar membrane.

Sensory neurons in the ear send information through the auditory nerve to the brain stem, thalamus, and ultimately the temporal lobes of the cerebrum for processing. The brain can distinguish the frequency and amplitude of the sound.

7. This process is called sensory adaptation. Sensory adaptation is a decrease in sensitivity to a given stimulus which occurs as a result of prolonged exposure to that stimulus. A massive amount of sensory information coming from many neural pathways bombards the brain every second. The benefit of sensory adaptation is that, in some cases, the brain can filter out redundant, insignificant information.
8. The reflex is called light adaptation in the eye. 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.
9. The retinas of the swift fox are dominated by photoreceptor cells called rods. While rods cannot detect colour or produce images as sharp as those of the cone cells that dominate human eyes, they are much more sensitive to and function better in low light.
10. The blind spot is the area of the retina that does not contain any photoreceptors (rods or cones). It is the location where the optic nerve and blood vessels enter and leave the eye. It is not usually noticeable because the adjacent photoreceptors, the visual information from the other eye, and the cerebral cortex fill in the hole in the field of vision.
11. photon of light energy from the moon at night → absorbed by rods → rhodopsin splits into retinal and opsin → stops release of inhibitory neurotransmitter → permits transmission of neural impulse to optic nerve → travels through the optic nerve fibres out of the back of the eye → travels to the cerebral cortex of the brain → creates a visual image
12. The primary visual cortex is located in the occipital lobe of the brain. This is the first area to receive nerve impulses that have passed along the optic nerve. Signals conveying colour information then go on to several nearby visual areas for further processing. For perception and recognition, signals are then sent to so-called "higher centres," where they interact with stored memories and input from other sensory and motor centres.
13. Even standing still is an exercise in dynamic equilibrium. Balance is maintained as a result of the interaction of three systems: the visual, the inner ear, and the proprioceptor systems.

    Vision plays a significant role in balance. Vision gives the person posing for a picture a sense of where they are in relation to other things around them. Even if a person is trying to stand perfectly still, he/she sways very slightly all the time to all four sides.

    The structures of the inner ear help us stand upright. The semicircular canals contain mechanoreceptors that detect head and body rotation (rotational equilibrium). The semicircular canals are three fluid-filled loops arranged in three different planes—one for each dimension of space. The base of each canal has a jelly-like covering called a cupula. The stereocilia of hair cells in the canals stick into the cupula, and when the body rotates, the fluid inside the semicircular canals moves and bends the stereocilia. These hair cells send rotational information to the brain.

    The balance required while moving the head forward and backward is called gravitational equilibrium. This equilibrium depends on the two structures called the utricle and saccule, which together make up the fluid-filled vestibule of the inner ear. Both structures 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, which send a neural impulse to the brain, indicating the head's position.

    Proprioceptors are found in muscles, tendons, and joints throughout the body and send information about body position to the brain. Balance is maintained by alternate contraction and relaxation of the leg muscles.
14. Students' diagrams should be similar to Figure 12.10 on page 412 of the student textbook. Accommodation occurs because the lens can change shape to focus images clearly on the retina. A change in shape allows for finer focus when viewing near and far objects. If an object is near, the ciliary muscles contract and the suspensory ligaments relax, causing the lens to become more rounded. If an object is far away, the ciliary muscles relax and the suspensory ligaments become taut, causing the lens to flatten.
15. Rotational equilibrium refers to head and body rotation. The semicircular canals contain mechanoreceptors that detect head and body rotation. The semicircular canals are three fluid-filled loops arranged in three different planes. The base of each canal has a jelly-like covering called a cupula covering the stereocilia of hair cells. When the body rotates, the fluid inside the semicircular canals moves and bends the stereocilia. The hair cells then send rotational information to the brain. A figure skater doing a spin would depend on these processes to maintain balance during a performance. The balance required while moving the head forward and backward is called gravitational equilibrium. This equilibrium depends on the two structures called the utricle and saccule, which together make up the fluid-filled vestibule of the inner ear. Both structures 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, which send a neural impulse to the brain, indicating the head's position. When someone nods, he/she uses gravitational equilibrium to maintain balance.
16. Rod cells are very efficient in low light and are the receptors primarily involved in night vision. Peripheral or side vision is what you see on the outermost edges of your field of view while you look straight ahead. The rods are the predominant photoreceptor involved in peripheral vision. Therefore, any disorder that affects the peripheral

vision is affecting the rods and therefore night vision, which would make driving at this time very dangerous.

17. The temporal lobe is dedicated to hearing, auditory perception, and the storage of memories. Students will likely state that an injury to this area of the brain will cause hearing and/or memory loss.

18. The pathway of sound can be illustrated by the following flowchart:

sound wave → (outer ear) pinna → auditory canal → (middle ear) tympanum → ossicles (malleus, incus, stapes) → oval window → pressure wave in fluid environment → (inner ear) cochlea → organ of Corti → basilar membrane → stereocilia → tectorial membrane → mechanoreceptors (hair cells) → nerve impulse → auditory nerve → temporal lobe of the brain for perception of sound.

The following chart summarizes the principal structures involved in hearing and their functions.

Structure	Function
Outer Ear	
pinna	collects sound waves
auditory canal	filters air
Middle Ear	
tympanic membrane and ossicles	amplify sound waves
oval window	receives vibrations from the ossicles and passes them into the cochlea
Inner Ear	
organ of Corti	hair cells of the organ of Corti are able to distinguish both the frequency (pitch) and amplitude (intensity) of sound waves
basilar membrane	receives pressure waves and moves stereocilia
stereocilia	triggers hair cells to depolarize
tectorial membrane	receives movement of stereocilia
mechanoreceptors (hair cells)	detect movement of stereocilia and react by initiating nerve impulse
auditory nerve	transmits nerve impulse to brain
temporal lobe of brain	processes nerve impulses from ear to allow perception of sound

19. Most humans can hear frequencies only between 20 and 20 000 Hz. Hair cells in different areas of the organ of Corti are sensitive to different wave frequencies. Repeated or sustained exposure to loud noise at certain frequencies will destroy the stereocilia that respond to that frequency of sound. The result is that the machine operator can no longer "hear" sounds within that frequency range.

Answers to Applying Concepts Questions

20. Possible effects of sensory deprivation include extreme anxiety, hallucinations, bizarre thoughts, depression, and antisocial behaviour. We use our senses to determine where we are, what our bodies are doing, and what is happening around us, as well as to keep our bodies in a balanced state (homeostasis). Deprivation of stimuli from one or more of the senses can be disorienting because we are deprived of that information, and it can eventually lead to the more serious side effects mentioned.

21. Student designs should indicate that they are protecting the occipital lobe at the base of the skull.

22. Colour-blind individuals are actually colour *deficient*, as they lack or are deficient in particular cones, typically red or green. Thus a red-green colour-blind person may find it difficult or impossible to distinguish between these colours. Answers should reflect the knowledge that cones respond to different wavelengths of light and an understanding that technologies are designed to repair or replace the red or green cones.

23. Technologies such as eyeglasses and hearing aids can help compensate for loss of hearing or vision, but the user must always carry the artificial device. A successful implant to replace the damaged structure that could receive sound waves or light rays and transduce them into nerve impulses would be a more effective treatment.

24. The lens normally changes shape to focus images clearly on the retina in a process called accommodation**.** As people age, the aging of the cells in the lens causes the lens to become less flexible, which is one of the causes of lost accommodation. Glasses are one way to compensate for this lost reflex.

25. Olfaction, the act or process of smelling, is a dog's primary sense. A dog's sense of smell is said to be 1000 times more sensitive than that of humans. Some structural adaptations in a dog that give it a keener sense of smell than humans might include the following: more olfactory receptors in its nose than humans; structures to keep inhaled air (and odours) in the nasal cavity until odour molecules can interact with the olfactory cells; a more well-developed olfactory lobe; a lower level of stimulus required to create an action potential.

26. When students stare at the green bird for 1 min and then at the cage, they should see a pale red bird in the cage. When students stare at the red bird for 1 min and then at the cage, they should see a pale green bird. As the students stare at each bird, the photoreceptors (cones) for

that colour become desensitized (or fatigued). Then, when the students look at a white or neutral background (the cage), their eyes "subtract" the colour that was fatigued, and they see its complementary colour.

27. Dogs are most likely to see blue-violet and yellow. They are likely unable to distinguish among green, orange, and red.

Answers to Making Connections Questions

28. Sensory stimuli cause a depolarization of sensory receptor cell membranes**.** If the sensory stimulus is strong enough to depolarize the membrane to the threshold potential, an action potential is produced by the sensory receptor and is conducted to the CNS. If a sensory stimulus is strong enough to affect a number of receptors, more action potentials will be generated. The pain receptors in some individuals may require a higher level of stimulus before they generate an action potential. Students may also recognize that the sensory cortex of the brain is responsible for perceiving pain (intensity, location, and type of pain).

29. Students may suggest that the scent of vanilla reduces apnea in infants because odours are associated with the emotional centres of the brain and frontal lobe. A pleasant odour may therefore cause relaxation, which might improve the breathing rates of these infants.

30. One neurotoxin from rattlesnake venom blocks receptors on postsynaptic neurons. Venom from the female black widow spider stimulates exocytosis of synaptic vesicles from neurons. If a neurotoxin blocks receptors on postsynaptic neurons (as in the rattlesnake venom), it could prevent the binding of the neurotransmitter acetylcholine, thereby blocking the transmission of a nerve impulse to the muscle and causing muscle paralysis. If the impulse is a result of a negative stimulus, such as pain, blocking it could be effective in medical treatment. If a neurotoxin increases the release of neurotransmitters (as in the spider venom), it could also result in nerve and muscle fatigue and be useful in preventing transmission of pain impulses.

31. Students' answers will depend on a number of factors, including their personal values. Accept answers that are well thought-out, with reasoning that is justified.

32. Literally thousands of drugs prescribed by doctors are derived from plants and animals. If natural habitats are destroyed, we will not be able to use those plants nor discover new ones.

`34. There isn't a right or a wrong answer to the question of patenting and selling traditional knowledge of medications. Students will have a variety of opinions on this topic.

CHAPTER 13 HORMONAL REGULATION OF HOMEOSTASIS

Curriculum Correlation

General Outcome 2: Students will explain how the endocrine system contributes to homeostasis.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
30–A2.1k identify the principal endocrine glands of the human organism, i.e., the hypothalamus/pituitary complex, thyroid and adrenal glands, islet cells of the pancreas	Throughout Section 13.1, pp. 436–442 Throughout Section 13.2, pp. 444–450 Throughout Section 13.3, pp. 451–455 Section 13.4: The Hormones of the Pancreas, p. 456 Career Focus: Ask an Endocrinologist, p. 466	Questions for Comprehension: 4–5, p. 439 7–9, p. 441 12, p. 442 15–17, p. 449 19, p. 453 25, p. 457 Section 13.1 Review: 3, p. 442 Section 13.2 Review: 3, p. 450 Chapter 13 Review: 2, 4, 5, 8, 16–18, 25 (a, c), pp. 464–465 Chapter 13 Test Career Focus, 2, p.467 Unit 5 Review: 21, 25, 30, p. 469
30–A2.2k describe the hormones of the principal endocrine glands, i.e., thyroid-stimulating hormone (TSH)/thyroxine, adrenocorticotropic hormone (ACTH)/cortisol, glucagon/insulin, human growth hormone (hGH), antidiuretic hormone (ADH), epinephrine, norepinephrine, aldosterone	Throughout Section 13.1, pp. 436–442 Throughout Section 13.2, pp. 444–450 Throughout Section 13.3, pp. 451–455 Section 13.4: The Hormones of the Pancreas, p. 456	Questions for Comprehension: 2, p. 437 6, p. 439 7–9, p. 441 10–12, p. 442 13, 14, p. 446 16, p. 449 19, p. 453 21, 22, p. 454 23, p. 455 25, 26, p. 457 Section 13.1 Review: 3, 5, p. 442 Section 13.2 Review: 1, 3, 6, 7, p. 450 Section 13.3 Review: 5, 6, p. 455 Section 13.4 Review: 1–5, p. 462 Chapter 13 Review: 2–7, 9, 10, 12–14, 17–22, 24, 25 (b, d, f), 27, 30, pp. 464–465 Chapter 13 Test Unit 5 Review: 21, 22, 27, 29, 30, p. 469

	Student Textbook	Assessment Options
30–A2.3k explain the metabolic roles hormones may play in homeostasis, i.e., thyroxine in metabolism, insulin, glucagon, and cortisol in blood sugar regulation, hGH in growth, ADH in water regulation, aldosterone in sodium ion regulation	Throughout Section 13.1, pp. 436–442 Throughout Section 13.2, pp. 444–450 Throughout Section 13.3, pp. 451–455 Section 13.4: The Effects of Glucose Imbalance, p. 457 Summary, p. 462	Questions for Comprehension: 10, 12, p. 442 13, p. 446 15, 16, p. 449 19, p. 453 21, 22, p. 454 23, p. 455 26, p. 457 Section 13.1 Review: 1–4, p. 442 Section 13.2 Review: 1, 3, p. 450 Section 13.4 Review: 1, 2, 5, p. 462 Chapter 13 Review: 1–3, 5–7, 9, 10, 14, 24, 25 (e, f), 30, pp. 464–465 Chapter 13 Test Unit 5 Review: 18, 28, 30, 31, 41, pp. 469–470
30–A2.4k explain how the endocrine system allows human organisms to sense their internal environment and respond appropriately, e.g., *calcium metabolism, osmotic pressure of blood*	Section 13.3: Coritsol, p. 454 The Adrenal Medulla: Regulating the Short-Term Stress Response, p. 452 Aldosterone, p. 454 Summary, p. 455	Questions for Comprehension: 18, 19, p. 453 22, p. 454 23, p. 455 Chapter 13 Test
30–A2.5k compare the endocrine and nervous control systems and explain how they act together, i.e., stress and the adrenal gland	Throughout Section 13.1, pp. 436–442 Section 13.3: The Adrenal Medulla: Regulating the Short-Term Stress Response, p. 452 Summary, p. 455	Questions for Comprehension: 1, 3, p. 437 18–20, p. 453 Section 13.1 Review: 2, p. 442 Section 13.3 Review: 1, 4, 6, 7, p. 455 Chapter 13 Review: 1, 12–14, 18–19, p. 464 Chapter 13 Test Unit 5 Review: 15, 17, 23, 31, pp. 468–469

	Student Textbook	Assessment Options
30–A2.6k describe, using an example, the physiological consequences of hormone imbalances, i.e., diabetes mellitus, and e.g., gigantism, goiter, cretinism, Graves' disease, diabetes insipidus.	Section 13.2: Human Growth Hormone, p. 444 The Thyroid Gland: A Metabolic Thermostat, p. 446 Summary, p. 449 Connections: Social and Environmental Contexts: Light up Your Life! p. 443 Section 13.3: Cortisol, p. 454 Aldosterone, p. 454 Summary, p. 455 Section 13.4: The Hormones of the Pancreas, p. 456 The Effects of Glucose Imbalance, p. 457 Causes of Diabetes, p. 458 Career Focus: Ask an Endocrinologist, p. 466	Questions for Comprehension: 15–17, p. 449 20, p. 453 22, p. 454 23, 24, p. 455 27–29, p. 458 30, 31, p. 455 Connections: Social and Environmental Contexts: questions 1, 2, p. 443 Section 13.2 Review: 2, 4, 6, 7, p. 450 Section 13.3 Review: 3, p. 455 Section 13.4 Review: 3, 4, 5, 6 (d), p. 462 Chapter 13 Review: 11, 15, 17–19, 20–22, 24, 29, pp. 464–465 Chapter 13 Test Career Focus, 3, p. 467 Unit 5 Review: 20, 24, 26, 31, 32, 50, 51, pp. 469–471
Outcomes for Science, Technology, and Society (Emphasis on societal and environmental concerns)		
30–A2.1sts explain that science and technology are developed to meet societal needs and expand human capability by ■ *comparing the function of technological control systems with electrochemical control systems in organisms, e.g., computer control systems for car emissions*	e.g., Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone, p. 447	e.g., Investigation 13.A: Opinions and Recommendations, p. 447 e.g., Chapter 13 Review: 22, 23, p. 465
■ *assessing the impact of research into biochemical control systems on human performance*	Section 13.1: From Hypothesis to Evidence, p. 438 Human Growth Hormone, p. 444 Connections: Social and Environmental Contexts: Light up Your Life! p. 443 Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone, p. 447 Section 13.4: Towards a Cure for Diabetes, p. 459 Investigation 13.B Analyzing Endocrine Disorders, pp. 460–461	Questions for Comprehension: 4–6, p. 439 14, p. 446 32, 33, p. 462 Connections: Social and Environmental Contexts: 1, 2, p. 443 Investigation 13.A: Opinions and Recommendations, 3, 4, p. 447 Section 13.2 Review: 6, 7, p. 450 Section 13.3 Review: 5, p. 455 Investigation 13.B, Application: 6, p. 461 Section 13.4 Review: 3, 4, p. 462 Chapter 13 Review: 4, 16, 27, pp. 464–465 Unit 5 Review: 47, 49, p. 471

	Student Textbook	Assessment Options
■ *describing the current treatment technology for type 1 diabetes*	Section 13.4: Towards a Cure for Diabetes, p. 459 Thought Lab 13.1: Blood Glucose Regulation and Homeostasis, p. 458 Career Focus: Ask an Endocrinologist, p. 466	Questions for Comprehension: 32, 33, p. 462 Thought Lab 13.1: Analysis, p. 458 Section 13.4 Review: 4, p. 462 Career Focus, 2, 3, p, 467 Chapter 13 Review: 24, p. 465 Unit 5 Review: 24, p. 469
30–A2.2sts explain that science and technology have both intended and unintended consequences for humans and the environment by ■ *explaining the relationship among ultraviolet light, ozone depletion and pigment deposition within skin cells*	e.g., Throughout Section 13.1, pp. 436–442 e.g., Section 13.3: Cortisol, p. 454 e.g., Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone, p. 447 e.g., Connections: Social and Environmental Contexts: Light up Your Life! p. 443	e.g., Questions for Comprehension: 6, p. 439 14, p. 446 32, 33, p. 462 e.g., Investigation 13.A: Opinions and Recommendations, p. 447 e.g., Connections: Social and Environmental Contexts, 1, 2, p. 443 e.g., Section 13.2 Review: 5, 6, 7, p. 450 e.g., Section 13.3 Review: 5, p. 455 e.g., Section 13.4 Review: 4, p. 462 e.g., Chapter 13 Review: 27, 28, p. 465 e.g., Unit 5 Review: 45, 47, 49, p. 471
■ *evaluating the use of biotechnology to solve practical problems, e.g., hormone synthesis for diabetes, dwarfism, milk yield in cows*	Section 13.1: From Hypothesis to Evidence, p. 438 Connections: Social and Environmental Contexts: Light up Your Life! p. 443 Section 13.3: Coritsol, p. 454, Aldosterone, p. 454 Summary, p. 455 Career Focus: Ask an Endocrinologist, p. 466	Connections: Social and Environmental Contexts, 2, p. 443 Section 13.2 Review: 6, p. 449 Section 13.3 Review: 5, p. 455 Career Focus, 2, p. 467 Chapter 13 Review: 28, p. 467
■ *evaluating the use of hormone therapy in the treatment of humans, e.g., growth hormone and aging, steroids and human performance.*	Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone, p. 447 Career Focus: Ask an Endocrinologist, p. 466	Questions for Comprehension: 14, p. 449 Investigation 13.A: Opinions and Recommendations, p. 447 Career Focus, 3, p. 467

	Student Textbook	Assessment Options
Skill Outcomes (Focus on decision making)		
Initiating and Planning		
30–A2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by formulating a hypothesis, from published data, on an environmental factor that can be detected and responded to by humans, e.g., *ultraviolet light and pigment deposition, diet and thyroid function*	Launch Lab: Modern Stress! p. 435 Throughout Section 13.1, pp. 434–442 Connections: Social and Environmental Contexts: Light up Your Life! p. 443 Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone, p. 447 Investigation 13.B: Analyzing Endocrine Disorders, pp. 460–461	Launch Lab: Analysis, Extension, p. 435 Connections: Social and Environmental Contexts, 1, 2, p. 443 Investigation 13.A: Opinions and Recommendations, p. 447 Investigation 13.B: Analysis, Application, pp. 460–461
Performing and Recording		
30–A2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by ■ *researching Seasonal Affective Disorder (SAD) or General Adaptation Syndrome and identifying the main hormonal and nervous components*	Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone, p. 447 Investigation 13.B: Analyzing Endocrine Disorders, pp. 460–461 Thought Lab 13.1: Blood Glucose Regulation and Homeostasis, p. 458 Connections: Social and Environmental Contexts: Light up Your Life! p. 443	Investigation 13.A: Opinions and Recommendations, p. 447 Investigation 13.B: Analysis, Application, p. 461 Thought Lab 13.1: Analysis, p. 458 Connections: Social and Environmental Contexts, 1, 2, p. 443
Analyzing and Interpreting		
30–A2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ inferring the role of ADH and aldosterone in the maintenance of water and ions using the analysis and interpretation of data on blood and urine composition	Section 13.1: Regulating the Regulators, p. 441 Investigation 13.B: Analyzing Endocrine Disorders, pp. 460–461	Investigation 13.B: Analysis, Application, p. 461
■ inferring the role of insulin in the regulation of blood sugar by performing an experiment to investigate the presence of reducing sugars in simulated urine and comparing the results with normal urinalysis data; and/or investigating the role of insulin in the regulation of blood sugar using a computer simulation	Thought Lab 13.1: Blood Glucose Regulation and Homeostasis, p. 458 Investigation 13.B: Analyzing Endocrine Disorders, pp. 460–461	Thought Lab 13.1: Analysis, p. 458 Investigation 13.B: Analysis, Application, p. 461 Section 13.4 Review: 5, p. 462 Chapter 13 Review: 30, p. 465 Unit 5 Review: 42, 43, pp. 470–471

	Student Textbook	Assessment Options
Communication and Teamwork		
30–A2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *evaluating individual and group processes used in planning and carrying out group investigations of hormone therapy or use of biotechnology to solve practical problems*	Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone, p. 447 Investigation 13.B: Analyzing Endocrine Disorders, pp. 460–461	Investigation 13.A: Opinions and Recommendations, p. 447 Investigation 13.B: Analysis, Application, p. 461

Chapter 13

Hormonal Regulation of Homeostasis

Student Textbook pages 434–465

Chapter Concepts

13.1 The Glands and Hormones of the Endocrine System

- The endocrine system functions with the nervous system to regulate other body systems and maintain homeostasis.
- The endocrine glands secrete hormones directly into the bloodstream.
- Hormone secretion is regulated by the nervous system, other hormones, or negative feedback mechanisms.

13.2 Hormonal Regulation of Growth, Development, and Metabolism

- The hypothalamus regulates the pituitary gland, which secretes tropic hormones that affect various endocrine glands.
- Human growth hormone mainly affects bone and muscle growth. The thyroid hormones stimulate metabolism.

13.3 Hormonal Regulation of the Stress Response

- The hormones of the adrenal glands regulate the short-term and long-term stress responses.

13.4 Hormonal Regulation of Blood Sugar

- The hormones of the pancreas act antagonistically to maintain blood glucose levels within a narrow range. Diabetes results from improper regulation of blood glucose.

Common Misconceptions

- Some students may confuse diabetes insipidus with diabetes mellitus. Diabetes insipidus is a disorder of the posterior pituitary resulting from a lack of antidiuretic hormone (ADH). Diabetes mellitus is a disease associated with the pancreas and the body's inability to produce insulin.
- Some students may confuse the exocrine glands associated with the digestive system with the endocrine (ductless) glands associated with the hormonal system.
- Another area that may be difficult for some students to visualize is that hormones travel to their target cells through the blood—there isn't a direct connection between the endocrine gland and its target cell. As well, hormones are found in extremely small concentrations at any one time.
- Students might think that, when a hormone hits its target cell, a reaction takes place instantly. However, if students research the action of hormones such as insulin, they will find that hormonal action is a very complex biochemical pathway.

Helpful Resources

Books and Journal Articles

- Dajer, Tony. "Fuel for Thought." *Discover* 23, no. 8 (August 2002): 29.
- Dajer, Tony. "Why Does Her Belly Ache?" *Discover* 25, no. 2 (February 2004): 28.
- Leutwyler, Kristin. "Treating Eating Disorders: The Discovery of Two New Hormones Gives Researchers Food for Thought." *Scientific American.com* (March 1998): 1–2.
- Mader, Sylvia. *Understanding Human Anatomy and Physiology 5/e*. Whitby: McGraw-Hill Ryerson, 2005.

Web Sites

Web links related to hormonal regulation of homeostasis can be found at **www.albertabiology.ca**. Log on to the Instructor Edition and follow the links to Chapter 13.

List of BLMs

Blackline masters (BLMs) have been prepared to support the material in this chapter. The BLMs are either for assessment (AST); use as overheads (OH); use as handouts (HAND), in particular to support activities; or to supply answers (ANS) for assessment or handouts. The BLMs are in digital form, stored on the CD that accompanies this Teacher's Resource or on the web site at **www.albertabiology.ca**, after logging on for the Instructor Edition.

Number (Type)

13.0.1 (HAND) Launch Lab: Modern Stress!
13.0.1 (ANS) Launch Lab: Modern Stress! Answer Key

13.1.1 (HAND) Endocrine System Review
13.1.2 (OH) Glands and Their Secretions
13.1.3 (OH) Secretion of ADH
13.1.4 (OH) Regulatory Pathway of Tropic Hormones

13.2.1 (OH) hGH Targets
13.2.2 (HAND) Hormones of the Pituitary Gland
13.2.2A (ANS/OH) Hormones of the Pituitary Gland Answer Key
13.2.3 (HAND) Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone
13.2.3A (ANS) Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone Answer Key
13.2.4 (HAND) Thyroid Gland
13.2.4A (ANS/OH) Thyroid Gland Answer Key
13.2.5 (HAND) Parathyroid Glands

13.3.1 (HAND) The Adrenal Glands
13.3.1A (ANS) The Adrenal Glands Answer Key
13.3.2 (OH) Hormonal and Nervous System Interaction in the Stress Response
13.3.3 (HAND) Short- and Long-term Stress Responses

13.3.3A (ANS) Short- and Long-term Stress Responses Answer Key

13.4.1 (HAND) The Pancreas
13.4.1A (ANS) The Pancreas Answer Key
13.4.2 (HAND) Regulating Blood Glucose
13.4.2A (ANS/OH) Regulating Blood Glucose Answer Key
13.4.3 (HAND) Thought Lab 13.1: Blood Glucose Regulation and Homeostasis
13.4.3A (ANS) Thought Lab 13.1: Blood Glucose Regulation and Homeostasis Answer Key
13.4.4 (HAND) Investigation 13.B: Analyzing Endocrine Disorders
13.4.4A (ANS) Investigation 13.B: Analyzing Endocrine Disorders Answer Key

13.5.1 (AST) Chapter 13 Test
13.5.1A (ANS) Chapter 13 Test Answer Key

Using the Chapter 13 Opener

Student Textbook pages 434-435

- Stress is not only not always life-threatening, according to Dr. Hans Selye, it is essential for normal function.

Teaching Strategies

- Ask students how they feel when they finish an activity where there is a lot of sensory stimuli, e.g., a concert, a dance, or a sporting event. They will likely feel energized—excited, jumpy—not at all like the person shown at the beginning of Chapter 12 (page 404). Can they relate their physical state to the sensory stimuli they experienced?
- Use the Launch Lab: Modern Stress! to show the relationship between the nervous system and the endocrine system. Using this activity will help you link the response of the sympathetic nervous system to a stressful situation to the response of the endocrine system to stress.
- Use large paper strips to create another concept map. Ask students to tell you everything that they know about hormones and the endocrine system. Some students will remember the hormones that were introduced in Biology 20 or in junior-high health classes. Write down key words on the strips of paper—1 key point per strip of paper. When students have exhausted their ideas, have 2 or 3 students come up to the front and, as a large group, try to organize the information into categories and staple the strips to the bulletin board when finished. Refer to this "concept map" throughout this chapter. (Students may be more familiar with the hormones that are linked directly to the reproductive system. Although introduced in this chapter, the hormones directly associated with the male and female reproductive system will be dealt with in Unit 6.)

Launch Lab: Modern Stress!

Student Textbook page 435

Purpose

Students will monitor one of the changes that occur in the body in response to a stressful situation.

Outcomes

- 30-A2.2sts
- 30-A2.1s

Advance Preparation

When to Begin	What to Do
2 or 3 days before	■ Prepare and photocopy a series of higher-level questions that most students would find difficult to answer. ■ Photocopy **BLM 13.0.1: Launch Lab**

Materials
■ stopwatch ■ 20-question test

Time Required

20 min

Helpful Tips

- Use **BLM 13.0.1: Launch Lab** to support this activity. Modify it as necessary.
- Throughout the test period, the tester should badger the subject by calling out "hurry up!" or "you're running out of time!"
- Remind students how to take a pulse. They can do this over 15 sec and multiply by 4 to calculate the number of heartbeats per min.
- Students could use a stethoscope or a digital pulse monitor to more accurately record the pulse rate of the test subjects.
- You could do this activity as a demonstration by connecting one student to a heart rate probe connected to a computer. This technology would give students an opportunity to graph the changes in heart rate during the stressful situation.

Safety Precautions

- Reinforce the safety precaution in the activity. Students with low blood pressure could faint in a stressful situation.

Answers to Analysis Questions

1. Students' pulse rates should increase during the stressful situation.
2. Students should recognize that the response to this situation produces the same type of physiological effects as when the sympathetic nervous system is stimulated during the fight-or-flight response. Responses to stress that might be observed in this activity include increase in heart rate and blood pressure, increase in breathing rate, and dilation of pupils.
3. In a life-threatening situation, the body's so-called fight-or-flight response will be initiated. Increased breathing rate and heart rate provide muscles with additional supplies of glucose and oxygen. Glucose and oxygen provide muscles with the energy that they need to run or fight. As well, the increased heart rate helps to remove the waste products produced by the muscles during stressful situations.
4. Students' answers could include money concerns, family illness or death, personal relationship problems, overcrowded or unsuitable living conditions, increased crime, poverty, overwork, stressful jobs, and inadequate exercise. Accept any 10 reasonable answers.

   Students may recognize that crime is directly dangerous, but any of the other long-term stressful situations may lead indirectly to health problems such as ulcers, heart attacks, or strokes.

   Students may recognize that short-term responses to stress can help prepare athletes for competition, or help people escape potentially dangerous situations.

Assessment Options

- Collect and assess students' answers to the Analysis questions.
- You may wish to use this activity simply as an introduction to the chapter. In this case, you may decide not to formally assess this activity.

13.1 The Glands and Hormones of the Endocrine System

Student Textbook pages 436-442

Section Outcomes

Students will:

- explain how the endocrine system contributes to homeostasis
- compare the nervous system with the endocrine system
- identify the principal endocrine glands in the human body and the hormones they secrete
- explain how the endocrine system allows the body to sense and respond to the internal environment
- explain the relationship between negative feedback and hormonal regulation in the body
- explain how the endocrine system is involved in seasonal affective disorder (SAD) and the sleep-wake cycle

Key Terms

endocrine glands
hormones
endocrine system
negative feedback mechanisms
antidiuretic hormone (ADH)
tropic hormones

Biology Background

- The endocrine system consists of glands and tissues that secrete hormones.
- Hormones are chemical signals that affect the activity of other cells, glands or tissues. They influence the metabolism of the cells either indirectly, by regulating the production of a particular protein (steroid hormone), or directly, by activating a cascade of reactions within the cell (amino-acid based hormone).
- Hormones influence the metabolism of cells, the growth and development of body parts, and homeostasis.
- Endocrine glands are ductless; they secrete their hormones directly into the bloodstream for distribution throughout the body. In contrast, exocrine glands secrete their products outwardly through ducts. The pancreas, for example, functions as both an exocrine gland (secreting digestive enzymes into the small intestine through a duct) and an endocrine gland (secreting its hormones, insulin and glucagon, directly into the bloodstream).
- The major endocrine glands are shown in Figure 13.7 in the student textbook on page 439, and Table 13.1 on page 440 summarizes the principal endocrine glands and some of their hormones. Note: Although the term *gonadotropin* is not used in the student textbook, you may want to be aware that the term refers to both follicle-stimulating hormone (FSH) and luteinizing hormone (LH).
- Many hormones released from the anterior pituitary gland are called tropic hormones. Tropic hormones stimulate endocrine glands to release other hormones.

Teaching Strategies

- Have your students start a vocabulary list for this chapter. Their list should include the name of a structure, its function, and an illustration. Students can add terms to their list as well as modifying and refining existing terms as they work through the chapter.
- Take a few minutes to review the structure and the function of the kidney (Section 9.1, pages 307-308) and regulating reabsorption of water (Section 9.3, page 316) before discussing antidiuretic hormone (ADH).
- Homeostasis and negative feedback loops were introduced in Section 6.1, and they are an important concept in this chapter. You might want to refer students to this information as an introduction to this chapter (Figure P4.2

on page 203). The use of a pan-balance or even a metre stick balanced on a fulcrum-like object may help students visualize what happens when hormone levels get too high or too low. Homeostasis would be represented when the balance or metre stick is level (horizontal). Raising one end of the balance would indicate that levels of the hormone are higher than normal during that part of the feedback loop (see Figure 13.25 on page 457 of the student textbook), while lowering one end would indicate that levels are below normal. Other instances of negative feedback loops in this chapter include Figure 13.9 on page 441, which illustrates the negative feedback loop controlling the secretion of ADH; Figure 13.18 on page 449 in the next section shows the negative feedback loop that regulates calcium in the blood; and Figure 13.25 on page 457 of Section 13.4 shows the negative feedback loop that regulates blood sugar.

- The following overhead masters and reinforcement tools have been prepared for this section. Many are adapted from illustrations in the student text and can be used to practise or test recall. You will find them with the Chapter 13 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging on to the Instructor Edition at the Online Learning Centre.

Number (Type)
13.1.1 (HAND) Endocrine System Review
13.1.2 (OH) Glands and Their Secretions
13.1.3 (OH) Secretion of ADH
13.1.4 (OH) Regulatory Pathway of Tropic Hormones

SUPPORTING DIVERSE STUDENT NEEDS

- Many of the concepts about endocrine physiology discussed in Chapter 13 can be related to the concepts of homeostasis that were introduced in Biology 20. ESL students can develop graphic organizers to assist in and reinforce learning about the feedback loops associated with the regulation of each type of hormone discussed in this section.
- Create a 2- or 3-page study guide of ideas in the section. This guide can be of great assistance to students who struggle with print materials, lectures, or even organization of information. The guide could be in paragraph form, point form, a graphic organizer, or a combination. It might also spotlight key vocabulary and provide essential questions the section is designed to address.
- Advanced students could be encouraged to make a digital version of this guide using presentation software.

Figure 13.2

Student Textbook page 436

The two systems are linked by the hypothalamic region of the brain. The main function of the hypothalamus is homeostasis, or maintaining the body's status quo. Factors such as blood pressure, body temperature, fluid and electrolyte balance, and body weight are held to a precise value called the set-point. Although this set-point can migrate over time, from day to day it is remarkably fixed. To achieve this task, the hypothalamus must receive information about the state of the body and must be able to initiate compensatory changes if anything drifts out of balance.

Once the hypothalamus is aware of a problem, it sends signals to the autonomic nervous system and/or specific glands of the endocrine system.

The autonomic nervous system includes the parasympathetic nervous system and a group of cells that descend to the sympathetic system in the spinal cord. With access to these systems, the hypothalamus can control heart rate, vasoconstriction, digestion, sweating, etc.

As students will discover, the hypothalamus regulates the activity of both the anterior and posterior pituitary glands. Ultimately, the hypothalamus can control every endocrine gland in the body, and alter blood pressure, body temperature, metabolism (through TSH), and adrenaline levels (through ACTH).

Answers to Questions for Comprehension

Student Textbook page 437

Q1. The axons of motor neurons, for example, lie in close proximity to specific muscles or glands (effectors). An appropriate stimulus will elicit an immediate response from the effector in milliseconds. A hormone, on the other hand, may be released at a great distance from its target organ. The target organ is waiting for the arrival of a hormone. Hormones must travel through the blood to their target cells and bind to the cell membranes in order to change the activity of the cell. This process can take from several seconds to several days to occur, and the responses tend to be more prolonged.

Q2. A hormone is a chemical that is produced by an endocrine (ductless) gland. When the endocrine gland receives a signal from the nervous system or from another hormone, it releases its hormone into the bloodstream. The hormone travels to its target cells, binds to the cell membranes, and then changes the activity of the cell. For example, the pancreas (endocrine gland) produces the hormone insulin. Insulin is released into the bloodstream and affects its target cells by making them more permeable to glucose.

Q3. Four reasons why the distinction between the nervous and endocrine systems is sometimes blurred are:

- Sometimes nervous system tissues secrete hormones.
- Several chemicals function as both neurotransmitters and hormones, depending on their location in the body.
- The endocrine and nervous systems both include responses that are regulated by negative feedback loops.
- The regulation of several physiological processes involves both the nervous and endocrine systems acting in conjunction with each other.

Figure 13.3

Student Textbook page 437

The differences between the nervous and endocrine systems include:

- Nervous system responses are faster and the response usually takes place in a fraction of a second. Endocrine system responses are slower but the response tends to be prolonged over longer periods of time.
- The axons of neurons lie in close proximity to the effector (muscle, gland, or another neuron). Endocrine glands produce hormones that are released into the bloodstream at a distance from the target cells.
- The endocrine system affects a broader range of cell types.

Figure 13.5

Student Textbook page 438

Capons do not crow, fight with other roosters, or try to mate. Capons do not grow as large as the roosters or develop the typical male plumage.

Answers to Questions for Comprehension

Student Textbook page 439

Q4. Berthold's experiments showed that, because the replaced organs were not connected to any nerves, the testes must have released something into the rooster's bloodstream that caused developmental changes in the male birds.

Q5. Challenges to researchers include the following:

- It is difficult to get useful information because different hormones often work together and one hormone can, in some cases, compensate for another that is missing.
- Some glands produce more than one hormone.
- The concentration of most hormones is extremely low.
- Hormones are not released on a continual basis. Their release can be triggered by environmental factors, or may follow a pattern that repeats over hours, weeks, or years.

Q6. Two technologies used to study the endocrine system:

- Nuclear scanning devices such as PET and high-powered microscopes have allowed scientists to visualize glands, hormones, and target-cell membranes.
- Fluorescent stains are used to colour the different hormones in a tissue sample.
- To view endocrine glands in the living body, doctors can have patients ingest capsules containing a small amount of radioactive material—effectively the same amount of radiation someone would receive from a standard X ray. This radioactive dye accumulates in a specific gland, which makes the gland easier to distinguish in PET scans or by other nuclear scanning techniques.

Student Textbook page 441

Q7. The two groups of hormones are lipid-soluble (composed of lipids) and water-soluble (composed of amino acids). Lipid-soluble hormones can easily diffuse through the lipid bilayer of the cell membranes and bind to their receptor proteins inside the target cell.

Water-soluble hormones cannot diffuse across the cell membrane. Typically, a water-soluble hormone will bind to a receptor protein on the surface of a target cell.

Q8. Each target cell contains receptor proteins. Circulating hormones bind to their specific receptor proteins, like a key into a lock. When the hormone binds to its receptor, this triggers other reactions in the target cell. In other words, the target cell receives and responds to the chemical message sent by the hormone.

Q9. Thyroxine is secreted by the thyroid gland; human growth hormone is secreted by the anterior pituitary; cortisol is secreted by the adrenal cortex; antidiuretic hormone is secreted by the posterior pituitary; insulin is secreted by the pancreas; glucagon is secreted by the pancreas.

Student Textbook page 442

Q10. When the blood plasma becomes too concentrated (if a person is dehydrated), receptors in the hypothalamus detect this and send a neural signal to the posterior pituitary gland to release ADH. ADH targets the nephrons of the kidneys, causing them to become more permeable to water. As a result, the body excretes less (but more concentrated) urine, and blood pressure increases. The hypothalamus detects this and sends a signal to the posterior pituitary to stop secreting ADH.

Q11. A tropic hormone is a hormone that stimulates other endocrine glands to release their hormones.

Q12. Typically, the hypothalamus secretes a releasing hormone into the anterior pituitary gland. This causes the anterior pituitary to release a tropic hormone into the bloodstream. The tropic hormone then stimulates the target gland to release a third hormone into the blood. The third hormone travels to another target tissue and produces an effect. This system is controlled by a negative feedback loop in which the third hormone also prevents further release of the first two hormones in the pathway.

Figure 13.10

Student Textbook page 441

Many of the hormones released from the anterior pituitary and hypothalamus are called tropic hormones, which means that their targets are other endocrine glands. Tropic hormones stimulate endocrine glands to release other hormones. The action of the hypothalamus and anterior pituitary is regulated by negative feedback loops in which a third hormone prevents further release of either the stimulating or releasing hormones in the pathway.

Section 13.1: Review Answers

Student Textbook page 442

1. Homeostasis is the relative constancy of the internal environment of the body. The endocrine system is self-regulating and helps to regulate other body systems, thereby maintaining homeostasis.
2. Students' answers may contain one of the following:
   - Some nervous system tissues secrete hormones; for example, cells in the hypothalamus produce antidiuretic hormone that is stored in the posterior pituitary.
   - Several chemicals function as both neurotransmitters and hormones, depending on their location in the body. For example, epinephrine acts as a neurotransmitter between certain neurons in the nervous system, as well as a hormone released by the adrenal glands in the fight-or-flight response.
   - The regulation of several physiological processes involves both the nervous and endocrine systems acting in conjunction with each other. When a mother breast-feeds her baby, the baby's suckling initiates sensory messages in the mother's neurons that travel to the hypothalamus, which in turn triggers the pituitary to release a hormone called oxytocin. Oxytocin travels in the bloodstream to the mammary glands of the breast, causing the secretion of milk.
3. The chart below summarizes the answer to this question.

Gland	Hormone	Major Effect
Posterior Pituitary	A. antidiuretic hormone (ADH)	promotes the retention of water by the kidneys
	B. oxytocin	stimulates the release of milk by the mammary glands
	C. oxytocin	stimulates uterine muscle contractions during childbirth
Anterior Pituitary	D. human growth hormone	stimulates cell division, bone and muscle growth, and metabolic functions
	E. adrenocorticotropic hormone (ACTH)	stimulates the adrenal cortex to secrete glucocorticoids
	F. thyroid-stimulating hormone	stimulates the thyroid gland
	G. follicle-stimulating hormone (FSH) and luteinizing hormone (LH)	FSH stimulates production of ova in the ovaries; LH stimulates sex hormone production from the ovaries and triggers ovulation
	H. FSH and LH	FSH stimulates the production of sperm in the testes; LH stimulates sex hormone production in the testes
	I. prolactin	stimulates milk production from the mammary glands

4. An example of a negative feedback loop for a mechanical system is a thermostat:

   room temperature cools below 20 °C → thermostat detects low temperature → electronic signal to furnace → temperature increases → temperature gets above 20 °C → thermostat senses warmer temperature → electronic signal to furnace → furnace stops.

   In humans, this system would look similar to this:

   skin senses body temperature above 37 °C → brain compares temperature to normal set point → effectors respond (sweat glands release water, capillaries in skin dilate, kidneys conserve water) → body temperature drops → brain compares temperature to normal set point → effectors respond (sweat glands stop, capillary beds in skin constrict, kidneys no longer conserve water)
5. Since tropic hormones stimulate another gland to produce a hormone, the above-average amount of this new hormone could be what is stimulating the pancreas to produce high levels of insulin.

Connections: Light up Your Life!

Social and Environmental Contexts

Student Textbook page 443

Teaching Strategies

- Use the text to spark a class discussion about personal circadian rhythms—ask each student to note when they feel most energized or when they feel most tired. You may want to put an informal survey up on the chalkboard to sort the "night owls" from the "day people" and discuss how that affects their lives.
- Students may want to discuss practices such as using beverages with high caffeine content to shift or extend their times of peak alertness. While they may be successful in tinkering with their circadian rhythms in the short term,

students may want to investigate the long-term effects of this practice. It is outside the subject of SAD, however it may be an additional areas students want to investigate.

Answers to Questions

1. The combination of Earth's rotation around the Sun plus the fact that Earth tilts on its axis reduces the amount of sunlight reaching northern latitudes in winter.
2. Students' answers should reflect that innovative technologies provide benefits such as improving quality of life, increasing food and fresh water supplies, and improving health-care systems. Students should note, however, that some negative aspects are associated with most technological developments.

13.2 Hormonal Regulation of Growth, Development, and Metabolism

Student Textbook pages 444-450

Section Outcomes

Students will:

- describe the structure of the anterior and posterior pituitary and explain how they are regulated
- explain how human growth hormone (hGH) contributes to healthy growth and development
- evaluate the use of hormone therapy
- describe the structure and regulation of the thyroid gland, and its role in homeostasis
- describe the physiological effects of hormonal imbalances
- formulate a hypothesis about an environmental factor to which the endocrine system responds

Key Terms

pituitary gland
posterior pituitary
anterior pituitary
human growth hormone (hGH)
thyroid gland
thyroxine (T_4)
hypothyroidism
hyperthyroidism
thyroid-stimulating hormone (TSH)
goitre

Biology Background

- Neurosecretory cells in the hypothalamus produce antidiuretic hormone (ADH) and oxytocin, which are stored in axon endings in the posterior pituitary gland until they are released.
- The hypothalamus produces releasing and inhibiting hormones, which pass to the anterior pituitary by way of a portal system. The anterior pituitary produces at least six types of hormones, some of which are tropic hormones (those that stimulate other hormonal glands to secrete hormones).
- The thyroid gland requires iodine to produce thyroxine, which increases the metabolic rate. If iodine is only available in limited quantities, a goitre develops. Hypothyroidism and hyperthyroidism are two examples of other disorders of the thyroid gland.
- Human growth hormone (hGH) is produced by the anterior pituitary. The quantity is greatest during childhood and adolescence, when most body growth is occurring. If too little hGH is produced during childhood, the individual has pituitary dwarfism, characterized by perfect proportions but a small stature. If too much hGH is secreted, a person can become a giant. Excess secretion of hGH through adulthood causes a hormonal disorder called acromegaly, in which the hands and feet in particular continue to grow.

Teaching Strategies

- Many students, especially those involved in athletics, may have heard of athletes taking human growth hormone (hGH) in an attempt to improve their performance. If time permits, have your students do a quick search of Internet sites devoted to this issue. Please note, however, that their results will include web sites promoting the use of hGH. Use this experience not only to introduce hGH, but also to teach students the importance of determining the reliability and validity of information on the Internet.
- Provide students with an opportunity to learn more about the Chernobyl nuclear reactor explosion and how radioactive iodine released in this explosion has led to a dramatic increase in the cases of thyroid cancer in people living in the surrounding area.
- The overhead masters listed below are in addition to the BLMs created to support activities in the section. You will find them with the Chapter 13 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging in to the Instructor Edition at the Online Learning Centre.

Number (Type)
13.2.1 (OH) hGH Targets
13.2.2 (HAND) Hormones of the Pituitary Gland
13.2.2A (ANS/OH) Hormones of the Pituitary Gland Answer Key
13.2.4 (HAND) Thyroid Gland
13.2.4A (ANS/OH) Thyroid Gland Answer Key
13.2.5 (HAND) Parathyroid Glands

SUPPORTING DIVERSE STUDENT NEEDS

- This section introduces students to a number of new terms such as thyroid-stimulating hormone (TSH). Continue working on the "root meaning exercise" started in Section 13.1. For example, have students write down part of this term "thyroid" and its root

word "thyro," which means coming from the thyroid gland. Then have them write "stimulating," which implies it is going to cause the thyroid to increase secretions. When they put the root meanings of these terms together, they should link TSH to a hormone that stimulates the production of hormones by the thyroid gland.

- Create a 2- or 3-page study guide of ideas in the section. This guide can be of great assistance to students who struggle with print materials, lectures, or even organization of information. The guide could be in paragraph form, point form, a graphic organizer, or a combination. It might also spotlight key vocabulary and provide essential questions the section is designed to address.
- Advanced students could be encouraged to make a digital version of this guide using presentation software.

Figure 13.11

Student Textbook page 444

Tropic hormones are hormones that stimulate endocrine glands to release other hormones. Human growth hormone is considered a tropic hormone because it is released by the anterior pituitary into the blood where it travels to the liver and stimulates the liver to secrete hormones called growth factors.

Answers to Questions for Comprehension

Student Textbook page 446

Q13. hGH increases protein synthesis, increases metabolic breakdown and release of fats stored in adipose (fat) tissue, increases cell division and growth, especially the growth of cartilage, bone, and muscle (specifically, hGH stimulates the growth of muscles, connective tissues, and the growth plates at the end of the long bones, which causes elongation of these bones).

Q14. Two benefits of synthetic hGH are that larger quantities can be produced and that it is safer than the hGH obtained from human cadavers.

Investigation 13.A: Evaluating Potential Uses for Human Growth Hormone

Student Textbook page 447

Purpose

Students will evaluate the use of hormone therapy in the treatment of humans.

Outcomes

- 30-A2.1sts
- 30-A2.2sts
- 30-A2.1s
- 30-A2.2s
- 30-A2.4s

Advance Preparation

When to Begin	What to Do
3 to 4 weeks before	■ Book computer lab and/or library. ■ Obtain permission, if required, to upload a file of bookmarks (favourites) to the school or district server.
2 days before	■ Photocopy **BLM 13.2.3: Investigation 13.A** ■ Photocopy Assessment Checklist 4: Performance Task Group Assessment from Appendix A.

Materials
■ access to print and electronic resources

Time Required

1 to 2 classes depending on how much time you allow for research

Helpful Tips

- Use **BLM 13.2.3: Investigation 13.A** to support this activity. Modify it as necessary.
- Arrange students in teams of 3 or 4 and assign each group one of the issues to investigate.
- Design a marking rubric that you will use to evaluate student presentations. Make this available to students before they start this activity.
- A common format for individual or group collection of information will greatly facilitate the compiling, synthesizing, and displaying of information.
- Uploading to the school's server a file of bookmarked URLs that deal with this topic will cut down on the "searching time" required to complete this activity. Web links related to the issue of human growth hormone can be found at **www.albertabiology.ca**. Log on to Instructor Edition and follow the links to Chapter 13.

Safety Precautions

This activity does not require any special safety precautions.

Answers to Opinions and Recommendations

3. (a) Some possible questions include:

- What is human growth hormone?
- What does human growth hormone normally do?

- Why is human growth hormone replacement therapy normally used?
- What are the dangers of excess human growth hormone?
- What other health risks are associated with human growth hormone?
- What is the cost of human growth hormone therapy?

(b) Parents might want synthetic hGH for their children to increase their growth or to reduce obesity. Parents should be aware that it is very expensive ($25 000 or more per year) and is associated with several negative health effects.

(c) Some possible questions students should consider in deciding whether athletes should be allowed to use synthetic hGH include:

- Is it fair for an athlete to use a substance that enhances his/her athletic ability?
- How close are officials to determining ways of detecting the use of human growth hormone in athletes?
- What are the dangers of excess growth hormone?
- What other health risks are associated with human growth hormone?
- Can athletes easily obtain safe hGH pills over the Internet?
- Where can I find more information?

(d) Some possible questions students might research in preparing an answer for whether health insurance should cover hGH therapy include:

- What are the costs associated with hGH therapy?
- Does hGH therapy really work?
- For which health conditions would using hGH therapy improve the quality of life?
- What are the health risks involved in not using hGH therapy for those that need it?
- What is the current state of gene therapy?
- What factors might limit the effectiveness of gene therapy?
- What other health risks are associated with human growth hormone?
- Where can I find more information?

4. Students' tables could resemble the one shown below.

Issue	Benefits	Risks
1. Should people have the option to take synthetic hGH just to increase their genetically predetermined height?		
2. Should hGH be approved as a diet treatment for obesity?		
3. Should athletes be allowed legal access to hGH?		

Assessment Options

- Use Assessment Checklist 4: Performance Task Group Assessment from Appendix A.
- Use the rubric that you developed to assess student presentations or Checklist 8: Oral Presentations.

Answers to Questions for Comprehension

Student Textbook page 449

Q15. The thyroid gland is like a metabolic thermostat because, in the same way that a thermostat responds to the level of heat in a building, the thyroid gland responds to the level of thyroxine in the body, shutting off production and secretion when levels are high and stimulating production and secretion when levels are low.

Q16. The primary effect of thyroxine is to increase the rate at which the body metabolizes fats, proteins, and carbohydrates for energy. Thyroxine does not have one specific target organ but especially stimulates the cells of the heart, skeletal muscles, liver, and kidneys to increase the rate of cellular respiration. Thyroxine also plays an important role in the growth and development of children by influencing the organization of various cells into tissues and organs.

Q17. Hypothyroidism occurs when the thyroid produces extremely low quantities of thyroxine. If there is insufficient thyroxine in the blood, there will be no signal to stop the secretion of TSH by the anterior pituitary. The relentless stimulation of the thyroid gland by TSH causes a goitre (an enlargement of the thyroid gland).

Section 13.2: Review Answers

Student Textbook page 450

1. Tropic hormones are hormones that stimulate endocrine glands to release other hormones. Human growth hormone is considered a tropic hormone because it is released by the anterior pituitary into the blood, where it travels to the liver and stimulates the liver to secrete hormones called growth factors.

2. The overproduction of human growth hormone causes gigantism and acromegaly. Gigantism is the result of the overproduction of human growth hormone during

childhood. Acromegaly is the result of the overproduction of human growth hormone after the individual reaches adulthood.

3. Note: Some students may be aware that the releasing hormone in this situation is also known as TRH (thyrotropin-releasing hormone).

Label	Description	Effects
A	more releasing hormone is secreted	stimulates the anterior pituitary gland to secrete TSH
B	more thyroid-stimulating hormone (TSH) is secreted	the anterior pituitary responds to increased levels of releasing hormone by releasing more TSH into the blood
C	more thyroxine is secreted	in response to increasing TSH, the thyroid gland secretes more thyroxine
D	less releasing hormone is secreted	increased levels of thyroxine in the blood exert negative feedback on the hypothalamus, resulting in lower levels of releasing hormone
E	less TSH is secreted	lowers levels of releasing hormone reduce the levels of TSH produced by the anterior pituitary
F	less thyroxine is secreted	lower levels of TSH result in lower production of thyroxine by the thyroid gland

4. An overactive thyroid produces an excess of thyroxine, resulting in hyperthyroidism. Since thyroxine stimulates metabolism, which releases stored energy as ATP, the symptoms of hyperthyroidism include anxiety, insomnia, heat intolerance, an irregular heartbeat, and weight loss. (Note: Weight loss and constant hunger are the result of the "burning off" of calories that occurs with high levels of thyroxine.)
5. One of the by-products of a nuclear power plant explosion is the release of radioactive iodine. In the human body, iodine is quickly swept up by the thyroid, so that the total intake of radioactive iodine becomes concentrated there. The thyroid has a maximum uptake of iodine, however, so some protection against radioactive iodine releases can be afforded by taking iodine (potassium iodide) tablets to load up the thyroid to capacity so that radioactive iodine would be more likely to be excreted.
6. The hGH treatment might help her because hGH stimulates the growth of muscles, connective tissue, and growth plates at the end of the long bones, which causes the elongation of these bones.
7. Students' answers should include a listing of the advantages and disadvantages. They may also differentiate between the treatment of age-related health problems and anti-aging treatments that are done more for cosmetic than health improvement reasons. Their answer should reflect an opinion on using hGH to counteract the effects of aging.

13.3 Hormonal Regulation of the Stress Response

Student Textbook pages 451-455

Section Outcomes

Students will:

- explain how the nervous and endocrine systems act together to regulate the stress responses
- identify and describe the actions of epinephrine and norepinephrine in the human body
- describe the effects of cortisol and aldosterone on the human body during the long-term stress response
- describe the physiological effects of chronic stress or an imbalance in the stress hormones

Key Terms

adrenal glands
adrenal medulla
epinephrine
norepinephrine
short-term stress response
fight-or-flight response
adrenal cortex
long-term stress response
cortisol
adrenocorticotropic hormone (ACTH)
aldosterone

Biology Background

- The adrenal glands respond to stress; in the short term, the adrenal medulla secretes epinephrine and norepinephrine, which bring about the responses we associate with emergency situations.
- If stress occurs long term, the adrenal cortex produces glucocorticoids (e.g., cortisol) and mineralocorticoids (e.g., aldosterone).
- Cortisol stimulates the hydrolysis of proteins to amino acids that are converted to glucose, as well as the breakdown of fat cells to release glucose; in these ways, it raises the blood glucose level.

- Aldosterone causes the kidneys to reabsorb sodium (Na^+) ions and to excrete potassium (K^+) ions.
- Addison's disease develops when the adrenal cortex is underactive, and Cushing's syndrome develops when the adrenal cortex is overactive.

Teaching Strategies

- This section introduces students to a number of new terms, such as adrenocorticotropic hormone (ACTH). Many of these terms are long, and students may be intimidated. They may find exercises to break the words down to root meanings helpful. For example, have students write down part of this term "adreno" and its root meaning (adrenal gland); then have them write "cortico" and its root meaning (cortex); finally, have students write down the suffix "tropic" and its root meaning (a hormone that targets other hormones). When they put the root meanings of these terms together, they should discover that ACTH stimulates the adrenal cortex to secrete hormones (glucocorticoids).
- Struggling learners may grasp an idea better by looking at diagrams or pictures. Use the various blackline masters provided in this resource to help these students.
- Create a 2- or 3-page study guide of ideas in the section. This guide can be of great assistance to students who struggle with print materials, lectures, or even organization of information. The guide could be in paragraph form, point form, a graphic organizer, or a combination. It might also spotlight key vocabulary and provide essential questions the section is designed to address.
- Advanced students could be encouraged to make a digital version of this guide using presentation software.
- The following overhead masters and reinforcement tools have been prepared for this section. You will find them with the Chapter 13 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging on to the Instructor Edition at the Online Learning Centre.

Number (Type)
13.3.1 (HAND) The Adrenal Glands
13.3.1A (ANS) The Adrenal Glands Answer Key
13.3.2 (OH) Hormonal and Nervous System Interaction in the Stress Response
13.3.3 (HAND) Short- and Long-term Stress Responses
13.3.3A (ANS) Short- and Long-term Stress Responses Answer Key

SUPPORTING DIVERSE STUDENT NEEDS

- A significant number of new terms is introduced in this section. Students can make their own study aids by drawing a picture in colour that will cue their memory for that term. Then ask them to come up with a story to go with the term and to include the term to be memorized written in colour somewhere near the picture and story.
- Refer ESL students to the glossary at the back of their text.

Figure 13.18

Student Textbook page 451

Students should be able to link the picture of the individuals on the roller coaster to the fight-or-flight response from their studies of the nervous system. Most will have experienced some type of adrenaline (epinephrine) rush and may be able to make the connection between adrenaline and the endocrine system.

Answers to Questions for Comprehension

Student Textbook page 453

Q18. The short-term response to stress is commonly referred to as the fight-or-flight response. Like the nerve impulses of the sympathetic nervous system, the hormones of the adrenal medulla prepare the body for fight-or-flight by increasing metabolism.

Q19. The hypothalamus stimulates the sympathetic division of the autonomic nervous system and the adrenal medulla glands during the short-term, fight-or-flight response. Both the sympathetic neurons and the adrenal glands release epinephrine and norepinephrine, which help prepare the body for fight-or-flight by increasing metabolism.

Q20. The following chart summarizes the major physiological changes that occur in the short-term and long-term stress response.

Short-term stress response	Long-term stress response
■ heart rate and blood pressure increase ■ blood flow to the heart and muscles increases ■ breathing rate increases ■ rate of metabolism increases ■ blood glucose rises	■ sodium ions and water are absorbed by the kidney ■ blood volume and pressure increase ■ protein and fat metabolism is stimulated, which releases glucose ■ inflammation is reduced and immune cells are suppressed

Biology File: Web Link

Student Textbook page 454

The third stage of GAS is called exhaustion. In this stage, the body has run out of its reserve of body energy and has a reduced immune system response—the body's ability to resist disease may be almost totally eliminated. Patients who experience long-term stress may succumb to heart attacks or severe infection due to their reduced immunity.

Recent findings have helped explain the general neurochemistry of the general adaptation syndrome, although

much remains to be discovered about how the endocrine system interacts with other systems.

Answers to Questions for Comprehension

Student Textbook page 454

Q21. Cortisol raises blood sugar levels by promoting the breakdown of muscle protein into amino acids. The amino acids are taken out of the blood by the liver, where they are used to make glucose, which is released back into the blood.

Q22. One of the ways the body fights disease is by inflammation, in which cells of the immune system attack foreign material, such as invading bacteria. Cortisol is a natural anti-inflammatory in the body, which is probably why sustained high levels of cortisol make people more susceptible to infection.

Student Textbook page 455

Q23. 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 in more water from the nephrons, raising blood pressure.

Q24. Addison's disease is caused by damage to the adrenal cortex. However, the symptoms of the disease would result from the loss of the glucocorticoids, mineralocorticoids, and gonadocorticoids. The symptoms of Addison's disease include hypoglycemia (low blood sugar), sodium and potassium imbalances, rapid weight loss, and general weakness. Low aldosterone results in a loss of sodium and water from the blood due to increased urine output. As a result, blood pressure drops. A person with this condition needs to be treated within days, or the severe electrolyte imbalance will be fatal.

Section 13.3: Review Answers

Student Textbook page 455

1. See chart.

	Short-term response	Long-term response
Part of adrenal gland	adrenal medulla	adrenal cortex
System responsible for stimulating & hormones involved	sympathetic nervous system: neurons	hypothalamus–anterior pituitary complex: adrenocorticotropic hormone (ACTH)
Substances secreted	epinephrine and norepinephrine (also called adrenaline and noradrenaline)	glucocorticoids (cortisol) and mineralocorticoids (aldosterone)
Effects on the body	■ heart rate and blood pressure increase ■ blood flow to the heart and muscles increases ■ breathing rate increases ■ rate of metabolism increases ■ blood glucose rises	■ blood volume and pressure increase ■ protein and fat metabolism is stimulated, which releases glucose ■ inflammation is reduced, and immune cells are suppressed

2. (a) It would be beneficial for the soccer player because the fight-or-flight response increases heart rate and blood pressure, increases breathing rate, and increases blood flow to the heart and skeletal muscles. All of these would help the soccer player compete.

(b) The student writing the final exam would need to remain calm, so the fight-or-flight response would likely be detrimental.

(c) The fight-or-flight response would be beneficial if you are late for your bus because it increases heart rate and blood pressure, increases breathing rate, and increases blood flow to the heart and skeletal muscles. All of these would help you run to catch your bus.

(d) The fight-or-flight response might be beneficial if you need to get "psyched up" before going on stage, but it might be detrimental if you get too excited before going on stage.

3. A long-term stress situation could involve a high-pressure job or having to deal with a family member or friend who is gravely ill. This can be detrimental to your health because in response to long-term stress situations, the cells of the adrenal cortex secrete cortisol into the blood for long periods of time. Cortisol is a natural anti-inflammatory in the body, which is probably why sustained high levels of cortisol make people more susceptible to infections.

4. The body responds to stress by increasing blood glucose levels and increasing metabolism. The result is a depletion of "sugar" in the body which could trigger a craving for sweets.

5. Cortisol is an anti-inflammatory that is used to reduce inflammation associated with joint injuries. Long term use of cortisol, however, is harmful because it inhibits the regeneration of connective tissue.

6. Norepinephrine is both a hormone released by the adrenal medulla and a neurotransmitter released by neurons associated with the sympathetic nervous system.

7. An adrenaline rush is associated with the fight-or-flight response. Adrenaline (epinephrine) is released by both the sympathetic nervous system and the adrenal glands.

The body's response to the adrenaline rush is:

- heart rate and blood pressure increase
- blood flow to the heart and muscles increases
- breathing rate increases
- rate of metabolism increases
- blood glucose rises

13.4 Hormonal Regulation of Blood Sugar

Student Textbook pages 456-462

Section Outcomes

Students will:

- describe the structure of the pancreas and its role in homeostasis
- explain how insulin and glucagon regulate levels of blood glucose
- describe the physiological effects of diabetes and how the condition occurs
- analyze data and infer the role of various hormones based on observations
- explain how science and technology are developed to meet societal needs and expand human capability

Key Terms

pancreas
islets of Langerhans
beta cells
alpha cells
insulin
glucagon
diabetes mellitus
hyperglycemia
type 1 diabetes
type 2 diabetes

Biology Background

- The hormones of the pancreas act antagonistically to maintain blood glucose levels within a narrow range. The cells of the islets of Langerhans in the pancreas secrete insulin, which lowers the blood glucose levels, and glucagon, which has the opposite effect.
- The most common illness caused by hormonal imbalance is diabetes mellitus, which is due to the failure of the pancreas to produce insulin or the failure of the cells to use insulin to make them permeable to glucose. Type 1 diabetes, in which the immune system has destroyed the beta cells of the pancreas, is usually diagnosed in childhood and those suffering from it must inject insulin daily. Type 2 diabetes usually develops later in life and has been linked with certain lifestyle choices. Those with Type 2 usually have a wider range of treatment options available.

Teaching Strategies

- Diabetes is a disorder that affects many Canadians. Contact local branches of the Canadian Diabetes Association to see if a representative of this association might be available to talk to your students about this disease, or contact a regional health unit to see if they can provide a guest speaker for your class.
- Contact your local media resource centre to see if it offers any videos that trace the history of diabetes research in Canada.
- The overhead masters and reinforcement tools listed below are in addition to the BLMs developed to support activities. You will find them with the Chapter 13 BLMs on the CD that accompanies this Teacher's Resource or at **www.albertabiology.ca**, after logging on to the Instructor Edition at the Online Learning Centre.

Number (Type)
13.4.1 (HAND) The Pancreas
13.4.1A (ANS) The Pancreas Answer Key
13.4.2 (HAND) Regulating Blood Glucose
13.4.2A (ANS/OH) Regulating Blood Glucose Answer Key

- Continue working on the "root meaning" exercise. Have students write down the prefix "hyper" (excessive); then have them write "glycemia," which is related to "glyco" (sugar) and "emia" (condition of the blood). When they put the root meanings of these terms together, they should link hyperglycemia to higher than normal blood sugar levels. If students are having trouble distinguishing the prefix "hyper" from "hypo," remind them that a *hypo*dermic needle goes "under (or below) the skin."
- Create a 2- or 3-page study guide of ideas in the section. This guide can be of great assistance to students who struggle with print materials, lectures, or even organization of information. The guide could be in paragraph form, point form, a graphic organizer, or a combination. It might also spotlight key vocabulary and provide essential questions the section is designed to address.
- Advanced students could be encouraged to make a digital version of this guide using presentation software.

Answers to Questions for Comprehension

Student Textbook page 457

Q25. The two types of cells in the pancreas are the alpha cells and the beta cells. The beta cells of the pancreas secrete insulin, which decreases blood glucose levels. The alpha

cells of the pancreas secrete glucagon, which increases blood glucose levels.

Q26. To maintain homeostasis, insulin is released from the pancreas into the blood when blood glucose levels go above the normal range. Insulin decreases blood sugar levels. If blood glucose levels go below normal, the pancreas releases glucagon which raises the blood glucose levels.

Figure 13.25

Student Textbook page 457

To maintain homeostasis, insulin is released from the pancreas into the blood when blood glucose levels rise above the normal range. Insulin decreases blood sugar levels. If blood glucose levels drop below normal, the pancreas releases glucagon, which raises the blood glucose levels.

Answers to Questions for Comprehension

Student Textbook page 458

Q27. The symptoms of diabetes mellitus are fatigue, an acetone odour to the breath, glucose in urine, and high urine output and thirst. The following explains these symptoms:

- Fatigue: Insulin circulates throughout the body and acts on specific receptors to make the target cells more permeable to glucose. Diabetes mellitus results when the body does not produce enough insulin, or does not respond properly to insulin. As a result, levels of blood glucose tend to rise sharply after meals, and remain at significantly high levels. Without insulin, cells remain relatively impermeable to glucose and cannot obtain enough from the blood. The individual experiences fatigue as the cells become starved for glucose.
- Acetone breath: If glucose can't get into the cells, the body compensates by switching to protein and fat metabolism for energy. Fat metabolism releases ketones (such as acetone) as a toxic by-product, which can be smelled on the breath.
- Glucose in urine: The kidneys are incapable of reabsorbing all of the glucose that is filtered through them from blood, and so glucose is excreted in the urine.
- High urine output and thirst: Glucose being excreted in urine changes the osmotic gradient across the nephrons of the kidneys. Large volumes of water therefore follow the glucose by osmosis into the kidney tubules and it gets excreted. The loss of excess quantities of water in the urine triggers the thirst response.

Q28. Hyperglycemia is high blood glucose levels.

Q29. The effects of long-term high levels of blood glucose can lead to blindness, kidney failure, nerve damage, and gangrene in the limbs. Diabetes can also be fatal if not properly treated.

Thought Lab 13.2: Blood Glucose Regulation and Homeostasis

Student Textbook page 458

Purpose

Students will analyze and interpret collected data on blood glucose levels, identify healthy patterns of blood glucose levels, and infer the effects of diabetes mellitus on blood glucose levels.

Outcomes

- 30-A2.1sts
- 30-A2.2s
- 30-A2.3s

Advance Preparation

When to Begin	What to Do
2 to 3 days before	■ Check supply of graph paper or book computer lab if students are going to use spreadsheet or graphing software to plot graph. ■ Photocopy **BLM 13.4.3: Thought Lab 13.2**

Materials
■ graph paper or access to computer with spreadsheet or graphing software

Time Required

30 to 45 min

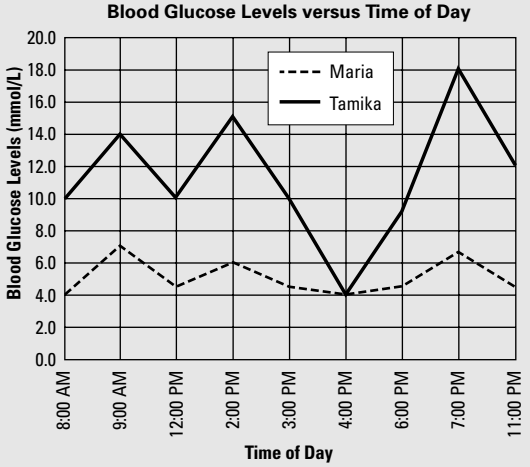
Helpful Tips

- Use **BLM 13.4.3: Thought Lab 13.2** to support this activity. Modify as necessary.
- Use this opportunity to teach students how to use graphing software or the chart capabilities found in most spreadsheet software.

Answers to Analysis Questions

1. Students' graphs should look similar to the one shown below. Note: The scale for "Time" on the *x*-axis has been

compressed to save space. This scale on students' graphs should be equally spaced.



2. Based on the graph, Tamika likely is diabetic. Her blood glucose levels were at 15.0 mmol/L 2 hours after lunch (12:00 PM) and 18.0 1 hour after supper (6:00 PM). These levels are much higher than the healthy range for blood glucose of 4.5–5.0 mmol/L. Tamika's blood glucose levels decreased sharply after these measurements because she would have taken an insulin shot when the level reached above 13–15 mmol/L. Insulin circulates throughout the body and acts on specific receptors to make the target cells more permeable to glucose. Diabetes mellitus results when the body does not produce enough insulin, or does not respond properly to insulin. As a result, levels of blood glucose tend to rise sharply after meals, and remain at significantly high levels.
3. Students should note that release of insulin happens shortly after a meal. Insulin lowers blood glucose levels. Maria's blood glucose levels rise in the hour or two after a meal, then decrease because of insulin by the beginning of the next meal.
4. Students should indicate that glucagon levels will be higher between meals or after the person has been active. Glucagon raises blood glucose levels.
5. The woman with diabetes could take insulin to help her blood glucose levels return to healthy levels after a meal. By injecting insulin directly into the bloodstream, the insulin makes the cells more permeable to glucose, thereby lowering blood glucose levels.
6. Tamika could drink fresh fruit juice or a prepared sports drink, or eat something that contains sugar. Students may suggest other answers as well.

Assessment Options

- Collect and assess students' answers to the Analysis questions.

Answers to Questions for Comprehension

Student Textbook page 459

Q30. In type 1 diabetes (also called juvenile diabetes), the immune system produces antibodies that attack and destroy the beta cells of the pancreas. As a result, the beta cells degenerate and are unable to produce insulin.

Q31. The risk factors associated with type 2 diabetes are unhealthy diet and weight gain.

Investigation 13.B: Analyzing Endocrine Disorders

Student Textbook pages 460–461

Purpose

Students will analyze and compare data collected from simulated blood and urine samples, integrate data, and identify hormonal imbalances suggested by the data.

Outcomes

- 30-A2.1sts
- 30-A2.1s
- 30-A2.2s
- 30-A2.3s
- 30-A2.4s

Advance Preparation

When to Begin	What to Do
2 to 3 days before	■ Make up simulated urine and blood samples (see Helpful Tips for directions). ■ Photocopy **BLM 13.4.4: Investigation 13.B** ■ Photocopy Assessment Checklist 2: Laboratory Report from Appendix A if you are going to use this as part of your formal assessment strategy for this investigation.

Materials

- digital blood glucose monitor (if available)
- medicine dropper
- 10 mL test tubes (10)
- test-tube rack
- 10 mL graduated cylinder
- 400 mL beaker
- hot plate
- test-tube clamp
- beaker tongs

Materials
■ Bunsen burner or small propane torch ■ simulated samples of blood (5) ■ simulated samples of urine (5) ■ Benedict's solution (if not using a monitor) ■ cotton swabs ■ blood and urine test strips (if using a monitor)

Time Required

1 hour

Helpful Tips

- Use **BLM 13.4.4: Investigation 13.B** to support this activity. Modify it as necessary.
- The original intent of this lab was to use a glucose monitor to provide students with an understanding of the actual usage of this technology. Using a glucose monitor would also simplify Part A of this investigation, reduce the time required to complete the activity, and provide students with more accurate results.
- However, it is possible to tell the samples apart using the Benedict's reagent. The colour change for patients with diabetes mellitus should be from blue to a dark olive-green. The colour change for normal individuals should be from blue to light green. The rest should all still turn green, just slightly lighter shades.
- If you are doing the Benedict's test, invest sufficient time to go over the lab and demonstrate the procedures required to complete this investigation.
- To save time and the cost of materials, consider dividing students into teams of 3. Give each team one set of simulated urine samples and one set of simulated blood samples. Make sure that each student is assigned a role in the activity!
- Review the procedures and safety precautions for Benedict's test, if required.
- To make the "normal" simulated urine, add 2 drops of yellow food colouring to 500 mL of distilled water. Dip a toothpick into red food colouring and stir the red colouring into the distilled water. Repeat until the fluorescent yellow tinge has disappeared and a realistic urine colour is reached. Use this "normal" urine solution to make the following urine samples for each patient.

Patient	Disorder	Simulated Urine
A	normal (control)	■ use the normal urine solution as is
B	diabetes mellitus	■ add 1 g of glucose (dextrose) to 100 mL of the normal urine sample
C	diabetes insipidus	■ dilute the normal urine sample at a ratio of 1:7 to give it a pale yellow colour ■ also provide students with a larger volume of simulated urine as the increased volume is one of the diagnostic tools used to identify this disease
D	Addison's disease	■ add approximately 1 tsp of table salt to 100 mL of normal urine
E	pituitary gland disorder	■ use normal urine as is

- To make the simulated blood, add 2 or 3 drops of red food colouring to the water. Use a toothpick to slowly add blue food colouring to make the simulated blood look more realistic.
- Use the chart below to make the simulated human blood samples:

Patient	Disorder	Simulated Human Blood
A	normal (control)	■ dissolve 0.90 g of glucose (dextrose) in 1 L of water
B	diabetes mellitus	■ dissolve 5.4 g of glucose (dextrose) in 1 L of water
C	diabetes insipidus	■ dissolve 0.80 g of glucose (dextrose) in 1 L of water
D	Addison's disease	■ dissolve 0.72 g of glucose (dextrose) in 1 L of water
E	pituitary gland disorder	■ dissolve 0.60 g of glucose (dextrose) in 1 L of water

- If glucose is present in the urine, it does not have to be tested for specific concentrations. The presence of glucose in urine would indicate diabetes mellitus. This would also be consistent with high concentrations of glucose in the blood.
- The sodium concentrations do not have to be tested specifically. Sodium is in everyone's blood. However, a flame test that produces a bright orange-red flame would indicate high levels of sodium in the urine, which is a symptom of Addison's disease.
- Diabetes insipidus can be identified in this activity only by looking at the urine. The pale yellow colour and the large volume of urine produced are symptoms of this disease.
- The patient with the pituitary gland and endocrine gland disorder is indicated by low glucose levels in the blood. It

might be difficult to distinguish a person with the pituitary/adrenal disorder from a normal person using only the Benedict's test. You will have to refer students to the additional information in the lab to help them identify this individual.

- Part B should be conducted as a teacher demonstration for safety and health reasons.
- Have materials organized in such a way that students in each team can quickly gather what they need.
- Make sure that you have advised your students of the procedure for cleaning up at the end of the investigation.
- *Expected Results:* See Answer to Conclusion question 3 below.

Safety Precautions


Do not drink any of the solutions used in the laboratory.



Wear gloves, and wash up any spills and your hands after each trial.



Benedict's solution is toxic and an irritant. Let students know that if they get it on their skin or in their eyes, they should immediately inform the teacher and flush their skin or eyes with clean water.


Be extremely careful around open flames, and when handling hot glassware.

- Consider conducting the flame test demonstration in a well-ventilated area or in a fume hood.
- For information on all safety precautions for this investigation, refer to Alberta Education's publication ***Safety in the Science Classroom***. The web link can be found at **www.albertabiology.ca**. Log on to the Instructor Edition and follow the links to Chapter 13.

Answers to Analysis Questions

1. Patient A acted as the control.

2. Real human body fluids (blood and urine) may contain pathogenic bacteria and viruses. Simulated human body fluids are used to prevent the spread of diseases such as hepatitis.

Answer to Conclusion Question

3.

Patient	Blood glucose concentration (mmol/L)	Glucose present or absent in urine	Sodium present or absent in the urine	Additional symptoms	Disorder
A	5.0	absent	absent	no additional symptoms	normal (healthy)
B	30	present	absent	very thirsty and urinates frequently	diabetes mellitus
C	4.5	absent	absent	large volume of dilute, pale urine	diabetes insipidus
D	4.0	absent	present	urine output is high; sodium in the urine	Addison's disease
E	3.5	absent	absent	older person whose glucagon-producing cells have deteriorated	pituitary gland and adrenal gland disorder (low blood glucose levels)

Answers to Application Questions

4. Patient A—all hormones appear to be normal.

Patient B—has diabetes mellitus. The hormonal imbalance could be a result of type 1 diabetes (inability to produce insulin) or type 2 diabetes (insulin levels are normal but the insulin receptors on the body's cells stop responding to insulin). The result is high blood glucose levels.

Patient C—has diabetes insipidus. The hormonal imbalance is the result of low levels of antidiuretic hormone (ADH). Deficient production of ADH or lack of effective action of ADH causes a large amount of urine output, increased thirst, dehydration, and low blood pressure in advanced cases. ADH does not affect blood glucose levels.

Patient D—has Addison's disease. The hormonal imbalance is the result of low levels of aldosterone. The symptoms of Addison's disease include low blood levels of glucose and large quantities of sodium in the urine.

Patient E—has a pituitary gland and an adrenal gland disorder that manifests itself through lower than normal blood glucose levels. The hormonal imbalance that causes the lower blood glucose levels is the result of a decrease in hGH, epinephrine, and cortisol secretions. These three hormones all increase blood glucose levels. Another clue provided on the chart is the statement, "this is an older person whose glucagon-producing cells have deteriorated." To compensate for the lower than normal blood sugar levels, the glucagon-producing alpha cells of the pancreas would be overworked and therefore slowly deteriorate while trying to maintain homeostasis.

5. The lack of hGH, epinephrine, and cortisol could be the result of an underactive pituitary gland (hypopituitarism) and a disorder of the adrenal cortex. The anterior pituitary gland produces human growth hormone and adrenocorticotropic hormone (ACTH). The low level of ACTH would result in low levels of cortisol. hGH also stimulates other hormones that cause the release of glycogen from the liver. Epinephrine released by the adrenal cortex also stimulates the conversion of glycogen to glucose in the liver. Lower levels of these hormones would result in lower than normal blood glucose levels.

The pancreas would secrete glucagon to help compensate for the low blood sugar levels. Glucagon stimulates the liver to convert glycogen back into glucose, which is released into the blood.

6. Patient A—normal; no treatment required

Patient B—diabetes mellitus; insulin injections and islet cell transplants are two possible treatments

Patient C—diabetes insipidus; ADH tablets

Patient D—Addison's disease; aldosterone replacement therapy

Patient E—pituitary gland and adrenal gland disorders; hormone supplements

Assessment Options

- Collect and assess students' answers to the Analysis, Conclusion, and Application questions.
- Use Assessment Checklist 2: Laboratory Report from Appendix A.

Answers to Questions for Comprehension

Student Textbook page 462

Q32. By tying off a dog's pancreatic duct with some string, Banting and his research team were able to remove some islets of Langerhans from the dog's pancreas, and then isolate insulin from the islets. They then found a way to isolate insulin from the pancreas of embryonic calves. They worked with a biochemist from the U of A to purify the extracted insulin and used it to successfully treat a boy with diabetes.

Q33. To check blood glucose levels, insert a test strip with a drop of blood into a blood glucose monitor.

Section 13.4: Review Answers

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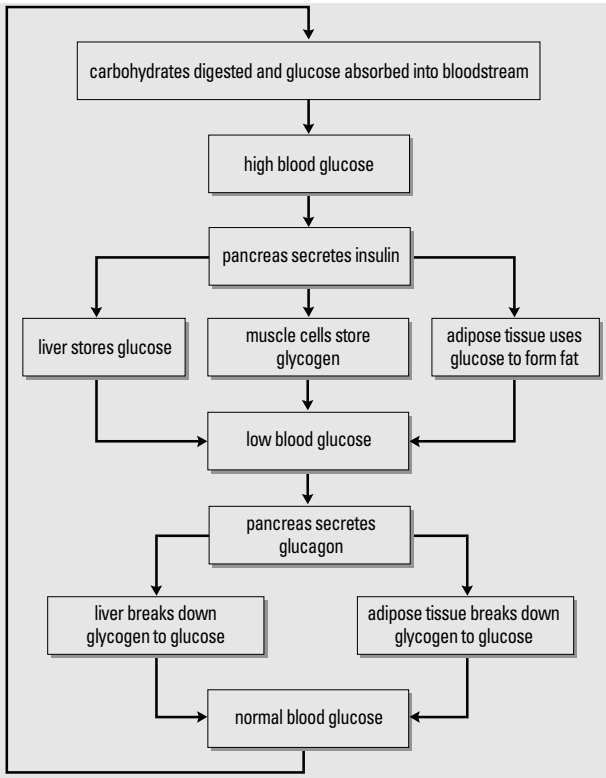
1. A negative feedback mechanism for regulation of blood glucose levels is shown below:



2. Skipping breakfast lowers blood sugar levels. To maintain homeostasis, the pancreas secretes the hormone glucagon into the blood. Glucagon causes adipose tissue to break down fat to glucose and the liver to break down glycogen to glucose. Both of these raise blood glucose levels.

3. Type 2 diabetes can occur if the insulin receptors on the body's cell membranes stop responding to insulin. In this case, insulin injections are not effective because the problem is not a lack of insulin, but the fact that the specific receptors on the target cells do not allow an increase in the permeability of these cells to glucose. Hyperglycemia is the result. Other treatments include diet, exercise, and oral medications.

4. Advantages of synthetic insulin might include the following: the cost of manufacturing it is lower, it is pure human insulin and not insulin from another animal, and the supply would be uninterrupted. The disadvantages of any medication are the negative side effects that can occur in some people.

5. (a) The individual's insulin levels drop after he/she starts to exercise. Rigorous exercise (or skipped meals) can cause blood glucose levels to drop. As a result, insulin production will drop to keep blood glucose levels higher to meet the metabolic requirements of the body during exercise. A drop in insulin production means that the liver will stop storing glucose, the muscle cells will stop storing glycogen, and the adipose tissues will stop using glucose to form fat.

(b) The individual's glucagon levels rise after he/she starts exercising. Low blood sugar caused by exercise

stimulates the pancreas to release glucagon. Glucagon stimulates the liver to convert glycogen back into glucose and the adipose tissue to break down glycogen to glucose. The glucose is then released into the blood.

(c) Having a large meal at 4 hours would raise blood glucose levels which, in turn, would increase the amount of insulin released by the pancreas and decrease the amount of glucagon.

(d) If a person had type 1 diabetes mellitus, you would expect extremely low levels of insulin (the line would be quite close to the *x*-axis). If the alpha cells of the pancreas are still intact, glucagon levels would rise over the 4 hours as the glucose levels go from extremely high at the beginning of the period to dangerously low at the end of 4 hours of exercise. If the alpha cells have also been destroyed, no glucagon will be produced.

Chapter 13: Review Answers

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Answers to Understanding Concepts Questions

1. The human nervous system is equipped to sense and respond to continuous change within the body and in its external environment. It regulates body structures and processes to maintain homeostasis despite fluctuations in the internal and external environment. The hormones of the endocrine glands regulate the organs and systems of the body to maintain homeostasis.

2. (a) The pituitary gland is often referred to as the "master gland" because it releases tropic hormones that control hormonal secretions from the thyroid, liver, adrenal cortex, and the gonads.

(b) The anterior pituitary is regulated by the hypothalamus, which secretes hormones that either stimulate or inhibit the release of other hormones from the anterior pituitary.

The posterior pituitary is considered part of the nervous system. The posterior pituitary does not produce any hormones; instead, it stores and releases the hormones ADH and oxytocin, which are produced in the hypothalamus and transferred to the posterior pituitary by neuronal axons.

3. ACTH is an example of a tropic hormone because it is released by the anterior pituitary and travels through the blood to the adrenal cortex, which it stimulates to release glucocorticoid hormones (e.g., cortisol).

4. Technology such as the scanning electron microscope, fluorescence microscope, and nuclear imaging scans have allowed scientists to visualize glands, hormones, and target cell membranes in greater detail.

5. This statement is incorrect. The correct statement would be that the beta cells of the pancreas secrete *insulin*, and the alpha cells secrete a hormone (glucagon) that *raises* blood glucose levels.

6. The following chart summarizes how each hormone affects blood glucose levels.

Hormone	Effects on blood glucose levels
cortisol	raises levels (longer acting than epinephrine)
epinephrine	raises levels
insulin	lowers levels
glucagon	raises levels

7. Increasing levels of TSH would stimulate the thyroid gland to produce more thyroxine. Increasing levels of thyroxine would have a negative effect (negative feedback) on the release of TSH from the anterior pituitary.

8. The adrenal medulla (middle region of the adrenal gland) produces two closely related hormones: epinephrine and norepinephrine (also called adrenaline and noradrenaline). These hormones regulate the short-term response to stress commonly referred to as the fight-or-flight response.

The adrenal cortex (outer region of the adrenal gland) responds to long-term stressful situations by releasing glucocorticoid and mineralocorticoid hormones. It also releases gonadocorticoid hormones.

9. The levels of hGH are high in children who are actively growing. However, as the person reaches adulthood and the skeleton is completed, the levels of hGH decrease. hGH and other growth factors increase protein synthesis; cell division and growth, especially the growth of cartilage, bone, and muscle; and the metabolic breakdown and release of fats stored in adipose tissue.

10. Glucagon and insulin are antagonists because they have opposite effects on blood glucose levels. Glucagon increases blood glucose levels while insulin lowers blood glucose levels.

11. (a) Without iodine, the thyroid gland cannot synthesize thyroxine (T_4). Lower levels of thyroxine would decrease the rate at which the body metabolizes fats, proteins, and carbohydrates for energy.

(b) A condition called a goitre results from insufficient iodine in the diet. If thryoxine cannot be made, there is no signal to stop the secretion of TSH by the anterior pituitary. The relentless stimulation of the thyroid gland by TSH causes a goitre (enlargement of the thyroid gland). In Canada it is uncommon for anyone to develop a goitre because salt refiners add iodine to salt.

12. When you are startled, the adrenal medulla is stimulated by neurons from the sympathetic nervous system to

release the hormone epinephrine. This hormone 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.

When the brain detects danger, it directs the hypothalamus to secrete a releasing hormone. The releasing hormone stimulates the anterior pituitary gland to secrete ACTH. ACTH stimulates the adrenal cortex to release cortisol. Cortisol often works in conjunction with epinephrine, but is longer lasting. Cortisol promotes the breakdown of muscle protein into amino acids. The amino acids are taken out of the blood by the liver, where they are used to make glucose, which is then released back into the blood.

Cortisol also prompts the breakdown of fat cells, which also releases glucose.

13. (Note: Students should review the discussion of norepinephrine in Chapter 11 as well as in this chapter.) Norepinephrine is released by neurons of the sympathetic nervous system and by the cells of the adrenal medulla. The sympathetic neurons release norepinephrine as a neurotransmitter, which has an excitatory effect on its target muscles. In response to a stressor, neurons of 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 norepinephrine (as well as epinephrine). This hormone 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. The main difference is that the response to danger by the nervous system is much faster than that of the endocrine system. However, the effects of norepinephrine released by the adrenal medulla last much longer.

14. Aldosterone targets the kidney, where it promotes the renal absorption of sodium ions into the bloodstream. This increase in the solute concentration of the blood draws more water from the nephrons in the kidney, resulting in higher blood pressure. Higher blood pressure would be an advantage as a stress response because more oxygen would be available to the tissues in less time. This response takes place over a much longer period of time than the short-term fight-or-flight response. Note: Students may recognize that high blood pressure, if it continues for a long time, can be harmful to the body.

15. If hypothyroidism develops during childhood, a condition known as cretinism can result. Individuals with cretinism are stocky and shorter than average; without hormonal injections, they will have mental developmental delays. Adults with hypothyroidism tend to feel tired much of the time, have a slow pulse rate and puffy skin, and experience hair loss and weight gain.

Answers to Applying Concepts Questions

16. The anterior pituitary produces six different hormones, so the effects of the lack of all those hormones will be confusing to interpret. The hypothalamus also produces hormones which are stored in the posterior pituitary gland. Without the pituitary, hormones such as ADH and oxytocin would not show up in the tests.

17.

Letter on diagram	Name of hormonal imbalance	Endocrine gland or glands involved	Hormones involved	Symptoms of the condition
A	diabetes insipidus	posterior pituitary	ADH	excessive urination and extreme thirst
	acromegaly	anterior pituitary	hGH	bones and soft tissues widen, face widens, ribs thicken, feet and hands enlarge
B	hyperthyroidism	thyroid gland	thyroxine	anxiety, insomnia, heat intolerance, irregular heartbeat
B	hypothyroidism	thyroid gland	thyroxine	slow pulse, puffy skin, hair loss, feel tired, weight gain
	goitre			enlarged thyroid gland
C	Addison's disease	adrenal cortex	aldosterone	hypoglycemia, sodium and potassium imbalances, rapid weight loss, general weakness

Letter on diagram	Name of hormonal imbalance	Endocrine gland or glands involved	Hormones involved	Symptoms of the condition
D	diabetes mellitus	pancreas	insulin	high blood sugar, thirst, glucose in urine, low energy, large volumes of urine

18. Hormones affected by a damaged anterior pituitary gland and the effects on the body include:

- hGH: lack of stimulation for the growth of muscles, connective tissue, and the growth plates at the end of the long bones
- follicle-stimulating hormone and luteinizing hormone: reduced production of egg and sperm cells
- prolactin: for a female, lack of production of milk after childbirth
- ACTH: lack of production of cortisol and aldosterone during a stress response
- thyroid-stimulating hormone: lack of stimulation of thyroid to produce thyroxine; therefore metabolism is lowered

19. The problem lies with the thyroid gland. TSH is produced by the anterior pituitary in response to low levels of thryoxine in the blood. This problem could result in the development of a goitre (enlarged thyroid gland).

20. If the tumour is affecting the adrenal cortex, there could be an overproduction of female or male sex hormones, an overproduction of cortisol, and an overproduction of aldosterone. If the tumour is affecting the adrenal medulla, there could be an overproduction of epinephrine and norepinephrine.

21. The symptoms described are those of hypothyroidism. The thyroid is the endocrine gland associated with these symptoms.

22. The man is likely suffering from diabetes insipidus or diabetes mellitus. The doctor could do a urinalysis test. If there were high levels of glucose in the urine, the doctor would suspect diabetes mellitus.

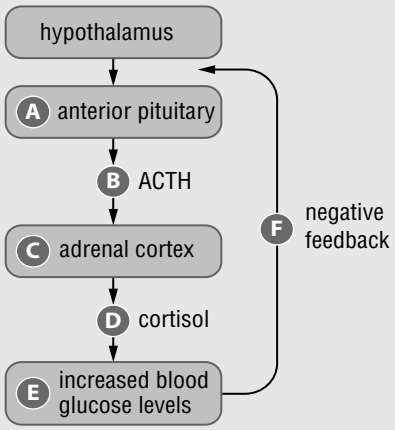
23. (a) Students could hypothesize that overcrowding would produce a similar stress response in humans.

(b) Students might suggest comparing subjects living in a crowded city with those living in a more rural setting. One possible suggestion could be doing blood tests and comparing the levels of hormones associated with long-term stress such ACTH or cortisol. Other possibilities would be to study the rates of stress-related illnesses in the two subject groups. For example, they could compare the incidence of heart attacks and strokes between the two groups.

(c) No, it would be unlikely that you could conclusively link this observation to overcrowding. There are many other factors such as age, gender, race, diet, and exposure to toxic chemicals that could influence the results of this investigation.

24. Following exercise, the person with diabetes mellitus would require more sugar. Even though a person with diabetes mellitus has higher than normal blood glucose levels, exercise can lower blood glucose levels to below normal levels. Taking insulin would further lower blood glucose levels (hypoglycemia) which could cause health problems for the individual. (Note: Some students might use the term diabetic coma even though it isn't mentioned in the student textbook).

25. Regulation of ACTH (Note: This is one possible answer; students may also choose aldosterone.)



Answers to Making Connections Questions

26. Steroid hormones, such as testosterone, estrogen, and cortisol, are lipid-based. Therefore, it is important to include lipids in the diet to provide the building blocks necessary for the synthesis of these hormones.

27. Students' answers will depend on personal point of view. High-performance athletes in the school may think it would be a good idea if it helped improve their chances of securing a scholarship. Others may think that taking any performance-enhancing drug is unethical (cheating). Other students will bring up the issue of health risks associated with taking hGH when the individual is still growing.

28. This question will likely stimulate fierce debate within the class. Some students will feel that the use of animals to study endocrine functions is beneficial and has helped millions of people. This group could bring up the work of Banting and Best and how they used dogs to isolate insulin. Other students in the class will believe that it is cruel and/or unethical to use animals for medical research. These students could include a discussion of computer modelling as an alternative method of research.

29. Some contributing factors to increased incidence of type 2 diabetes include:

- Decreased activity (Canadians are more sedentary than ever before)
- Increased consumption of fast foods that are very high in fat and carbohydrates
- Increased consumption of pre-packaged foods that are high in fat and high in salt

Any one of these factors could be addressed through conducting educational campaigns, changing eating habits, and increasing the amount of physical activity.

30. (a) At time 0, both people likely ate a meal.

(b) Person A likely has diabetes mellitus because his/her blood sugar levels increased dramatically and took much longer to return to normal.

(c) Person A would likely have taken insulin to get his/her blood glucose levels under control.

(d) The pancreas in Person B released insulin, which made the target cell membranes more permeable to glucose. As a result, blood glucose levels decreased.

(e) In both cases, blood glucose levels would decrease. In both cases, glucagon would be released by the pancreas into the blood to help increase blood glucose levels.

(f) The hormone released after 5 hours would be glucagon. Glucagon would stimulate the release of glucose stored in the liver, muscles, and fat tissue.

(g) After exercise, the person with diabetes would have to eat something or drink a pre-sweetened drink to raise his/her blood glucose level. However, this individual would have to closely monitor his/her blood glucose level to make sure that it didn't get too high.

Career Focus: Ask an Endocrinologist

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Teaching Tips

- Diabetes is a disorder that affects many Canadians. Contact local branches of the Canadian Diabetes Association to see if a representative of this association might come in to talk to your students about this disease, or contact a regional health unit to see if it can provide a guest speaker for your class. This organization might help your students organize a diabetes awareness day for the school.
- Have your students prepare a pamphlet or poster advising their peers about diabetes and what individuals can do to avoid developing type 2 diabetes. This could also be part of a diabetes awareness day in the school.
- Check to see if a student or member of the teaching staff has diabetes. If so, ask if they are willing to talk to your class about living with diabetes.
- If time permits, have your students research the latest technological and medical developments in diabetes. Have your students prepare a short multimedia presentation on their research.

Answers to Go Further Questions

1. Hypoglycemia is an abnormally low level of blood sugar (blood glucose). Because the brain depends on blood sugar as its primary source of energy, hypoglycemia interferes with the brain's ability to function properly. This can cause dizziness, headaches, blurred vision, difficulty concentrating, and unconsciousness.

2. Students might suggest that embryonic or cord stem cells could provide a source of islet cells for transplantation. Other sources of islets that have been considered include animal sources and surrogate cells engineered to mimic a beta cell's function.

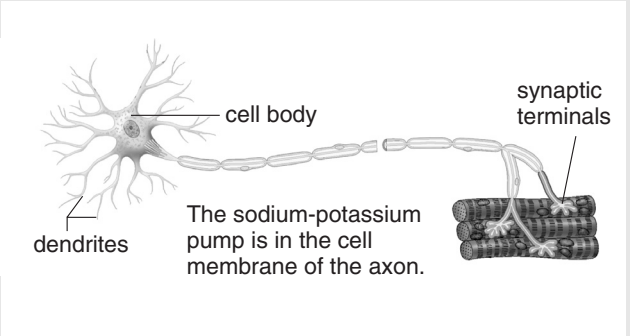
3. Students' research will likely lead to more questions than answers to this question. For example, some of the challenges associated with the Edmonton Protocol include the fact that donor pancreases necessary for islet cell transplantation are hard to come by. Also, successful extraction of islet cells is difficult, and it is challenging for researchers to determine which islet cells are likely to survive transplantation. Finally, researchers need to find a way to overcome "alloimmunity," the body's normal defences against foreign tissues that turn on whenever any kind of transplant takes place. Researchers at the clinical centre hope to accomplish this by testing safer and more effective immunosuppressive drugs. Students can find more information at **www.expressnews.ualberta.ca/article.cfm?id=1372**.

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).

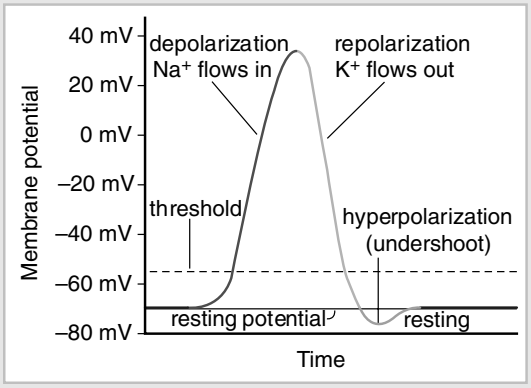
(d) Number 4 is the thalamus, and it is the primary relay centre for incoming sensory impulses.

(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.

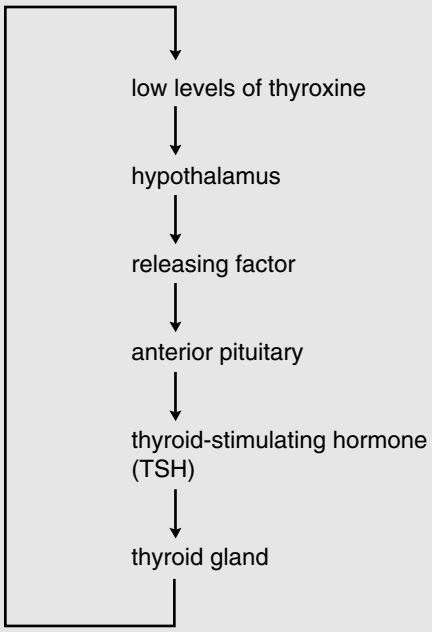
Being active on a hot day can result in your body's becoming dehydrated, which increases the concentration of the blood. When blood plasma becomes too concentrated, osmoreceptors in the hypothalamus respond by sending nerve impulses to the posterior pituitary gland. The posterior pituitary releases antidiuretic 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.

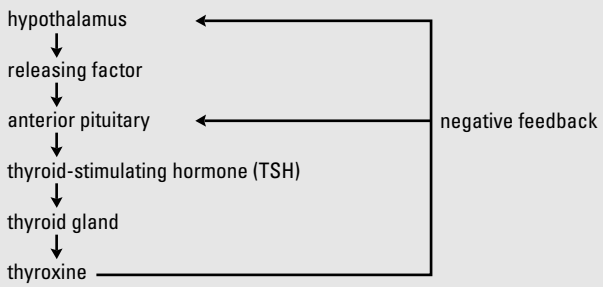
Students' answers could either support or reject the "master gland" label assigned to the pituitary gland. Some students might argue that the hypothalamus is part of the brain and not a separate endocrine gland. In this case, the name "master gland" given to the pituitary gland is suitable. Other students 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	adrenocorti-cotropic 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 norepine-phrine	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.