Table of Contents

UNIT 4

Human Systems

Teaching Unit 4: Human Systems

Student Textbook pages 200–359

(40% of the course time; approximately 50 hours)

Curriculum Fit

(See the Chapter Curriculum Correlations for full listing.)

Background: This unit builds on concepts from *Science 8*, Cells and Systems and *Science 10*, Flow of Matter in Living Systems. This unit provides background for *Biology 30*, Reproduction and Development.

General Outcomes

Students will

- explain how the human digestive and respiratory systems exchange energy and matter with the environment
- explain the role of the circulatory and defense systems in maintaining a relatively constant internal environment
- explain the role of the excretory system in maintaining a relatively constant internal environment through the exchange of energy and matter with the environment
- explain the role of the motor (muscular) system in the function of other body systems

Contents

Content Summary

All four themes—energy, equilibrium, matter, and systems—are featured in this unit.

Unit 4 deals with the human organ systems that function separately and collectively to maintain homeostasis. The Unit Preparation feature re-introduces a concept that will be drawn upon throughout this study of human anatomy and physiology—**homeostasis**, or maintaining the relative constancy of the body's internal environment. It is important for students to realize that internal conditions are not constant; they tend to fluctuate above and below a set point. Therefore, the internal state of the body is often described as one of "dynamic equilibrium." The study of homeostatic mechanisms is important in understanding the onset of illness, which usually results from changes to internal conditions that destroy homeostasis.

Chapter 6 explains the structure and function of organic molecules (macromolecules)—molecules that contain carbon (C) and hydrogen (H). Students describe the chemical nature of carbohydrates, lipids, proteins, and nucleic acids. They explain, in general terms, how carbohydrates, lipids, and proteins are synthesized and how they are broken down (hydrolyzed). Students are also introduced to enzymes and how these molecules are affected by temperature and pH. This chapter describes the structure and function of the primary and accessory organs of the digestive tract. It also explains how food is processed mechanically and chemically (including the actions of specific enzymes) to reduce macromolecules to a form that can be absorbed into the bloodstream for distribution to the liver for further processing. In the final section, students review the relationship between health and nutritional decisions. They also identify conditions that adversely affect the health of the digestive system and the technologies that are available to treat digestive system disorders. There are two major investigations in Chapter 6. The first deals with standardized tests for macromolecules, while the second is a major investigation that provides students with the opportunity to observe evidence to verify historically obtained results related to the optimum pH of two protease enzymes.

In Chapter 7, Section 7.1, the students identify the principal structures of the respiratory system, including the nasal passages, pharynx, larynx, epiglottis, trachea, bronchi, bronchioles, alveoli, diaphragm, rib muscles, and pleural membranes. In addition to the anatomy of the respiratory system, students will describe the primary function(s) of each of these structures and their connection to maintaining homeostasis. In section 7.2, students investigate the mechanics of breathing, external and internal respiration (gas and heat exchange with the external environment), and the removal of foreign material. This section contains two investigations. In Investigation 7.A, students use a spirometer to measure their own respiratory volumes. In Investigation 7.B, students investigate the effects of carbon dioxide on the rate of respiration. In the final section, students identify specific diseases associated with the respiratory system. They also identify technologies that may be used to diagnose and treat these respiratory conditions. Finally, students summarize the physiological effects of smoking and the limitation of technologies to address these effects.

Chapter 8 is a detailed look at the role of the circulatory system and defence (immune) systems in maintaining internal equilibrium. In Section 8.1, students identify the principal structures, action, and functions of the two key elements in the circulatory system—blood vessels and the heart—and describe the general circulation of blood through coronary, pulmonary, and systemic pathways. This section concludes with an overview of disorders of the circulatory system and the technologies used to treat them. In Section 8.2, students identify and describe the function(s) of the main components of human blood. They explain the homeostatic role that blood plays, including regulating body temperature and preventing blood loss. Students look at the role of the circulatory system, at the capillary level, in the exchange of matter and energy. They investigate Canada's tainted blood scandal, specific blood disorders, and the technologies used to treat these disorders. In Section 8.3, students describe and explain the general function of the lymphatic system. They

identify, list, and describe the functions of the main cellular and non-cellular components of the human immune system. Students also design a model of the functioning components of the human immune system.

Chapter 9 looks at how the human excretory system maintains homeostasis by removing metabolic wastes such as water, salt, and nitrogenous wastes while maintaining a stable concentration of other metabolites in the blood. The kidneys, which are the primary excretory organs, are major organs of homeostasis because they filter the blood, excrete nitrogenous wastes, and regulate water-salt and acid-base balances. In Section 9.1, students identify the waste products removed by the blood and the main structures and functions of the human excretory system. The role of the nephron in maintaining the composition of the blood plasma is explained. Section 9.2 details the formation of urine. Students examine the structure of the nephron and explain the function of the different regions of the nephron in maintaining the composition of blood plasma. In the final section, students describe how the kidneys contribute to homeostasis with respect to water and ions. They also explain the role of the kidney in maintaining blood pH levels. Investigation 9.B, the main investigation in Chapter 9, allows students to perform a urinalysis on simulated urine samples. This section concludes with an introduction to renal insufficiency, some of the common disorders of the excretory system, hemodialysis, and peritoneal dialysis.

Chapter 10 introduces students to the motor system and the relationship between muscle activity and the maintenance of body temperature. Although students learn about skeletal, cardiac, and smooth muscles, the bulk of Section 10.1 is devoted to the structure and function of the skeletal muscles. It provides microscopic detail of the skeletal muscle fibre, including the myofibrils that house thin and thick protein myofilaments, which are responsible for muscle contractions. This section focusses on the biochemical events of a muscle contraction and concludes with a discussion on the different sources of energy available for muscle contraction. The major investigation in this section is Investigation 10.A: Observing Muscle Tissue. Students use microscopes to compare the structure of skeletal, cardiac, and smooth muscles, as well as investigate the conditions necessary for muscle contraction, and construct a model of a muscle fibre in a Thought Lab. In Section 10.2, students learn how the skeletal muscles of the motor system support other body systems to maintain homeostasis. They look at different types of skeletal muscle and study the muscle "twitch." They identify examples of conditions that impair the healthy function of muscles and the technologies used to treat and prevent them. Students also investigate the value of exercise in maintaining the healthy structure and function of muscles.

Thus Unit 4 examines homeostasis from anatomical, physiological, biochemical, historical, medical, and social perspectives. Throughout the unit, students learn how deviations in homeostatic responses affect human health and how technology can be applied to influence homeostasis. Students are encouraged to form and express educated opinions on related medical and social issues.

Note:
Skill Outcome 20–D1.2s, bullet 1, requires the students to observe, through dissection or computer simulations, the respiratory and digestive system of a representative mammal and to identify the major structural components. The dissection of a fetal pig can be found in Appendix F of the student textbook, pp. 762-767. Part 2: The Digestive System and Part 4: The Respiratory System of this activity are designed to meet this outcome. In addition, there is a link to a virtual fetal pig dissection in the Teacher's Resource portion of the web site. Go to **www.albertabiology.ca**, Online Learning Centre. Log on to Instructor Edition. Choose Teacher Web Links for the links to Chapters 6 (digestion) and 7 (respiration).

In addition, Skill Outcome 20–D2.2s bullet 6 is an optional outcome that provides students with an opportunity to do a heart dissection. Investigation 8.A: Identifying Structures of the Circulatory System, pp. 272-273 covers this outcome. The Dissection of a Fetal Pig found in Appendix F of the Student Textbook, pp. 762-767. Part 3: The Circulatory System of this activity is also designed to meet this outcome.

Activities and Target Skills

Activity	Target Skills
Chapter 6: Digestion and Human Health	
Launch Lab: Visualizing the Human Body, p. 205	■ Sketching and recalling the organs in the digestive system
Thought Lab 6.1: How Do You Take Your Macromolecules? p. 210	■ Evaluating technologies designed to provide solutions to the problem of food preservation and long-term storage ■ Showing how food preservation technologies may solve one problem but create others

Activities and Target Skills

Activity	Target Skills
Chapter 6: Digestion and Human Health	
Investigation 6.A: Testing for Macromolecules, pp. 212-213	■ Performing qualitative tests to detect and identify the presence of carbohydrates, proteins, and lipids ■ Working cooperatively within a group and with the whole class to collect and communicate results
Thought Lab 6.2: An Accident and an Opportunity, p. 221	■ Analyzing and interpreting historical events and information ■ Assessing the validity of historical information
Investigation 6.B: Optimum pH for Two Protease Enzymes, pp. 228-229	■ Performing an experiment to investigate the influence of pH on the activity of pepsin and trypsin ■ Designing an experiment to investigate the influence of other variables on the activity of pepsin and trypsin ■ Assessing the validity of collected data and observations, as well as conclusions drawn from them
Thought Lab 6.3: Enzymes and Diet, p. 238	■ Evaluating the role of technology to solve problems that involve dietary choices ■ Identifying and evaluating enzyme-related technologies and the problems they are developed to solve
Chapter 7: The Respiratory System	
Launch Lab: Modelling Your Lungs, p. 243	■ Making a model of human lungs
Investigation 7.A: Measuring Respiratory Volumes, p. 251	■ Performing, recording, analyzing, and drawing conclusions based on data obtained by measuring respiratory volumes ■ Assessing the validity of the data
Investigation 7.B: Carbon Dioxide and the Rate of Respiration, p. 253	■ Conducting investigation into relationships between and among observable variables with respect to the rate of respiration ■ Collecting, communicating, and assessing the validity of results, using appropriate terminology
Thought Lab 7.1: Smoking and the Respiratory System, p. 260	■ Outlining and assessing the physiological effects of tobacco smoke
Thought Lab 7.2: You Diagnose It, p. 261	■ Inferring and drawing conclusions from evidence ■ Working cooperatively to collect, assess and communicate results
Chapter 8: Circulation and Immunity	
Launch Lab: Watching Blood Flow, p. 267	■ Observing blood flow
Investigation 8.A: Identifying Structures of the Circulatory System, pp. 272-273	■ Observing and identifying external and internal features of a mammalian heart through either a real or virtual dissection ■ Tracing the direction of blood flow through a mammalian heart
Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure, p. 278	■ Designing a procedure to investigate factors that affect heart rate and blood pressure ■ Measuring blood pressure ■ Determining a relationship between blood pressure and a factor selected for investigation from patterns and trends in data ■ Working cooperatively to measure and record blood pressure and another factor selected for investigation

Activities and Target Skills

Activity	Target Skills
Chapter 8: Circulation and Immunity	
Thought Lab 8.1: Cardiovascular Health, Technology, and Society, p. 280	■ Exploring solutions to problems associated with the circulatory system ■ Consulting a wide variety of sources that reflect different viewpoints on existing and proposed solutions to problems associated with the circulatory sources ■ Analyzing society's support of solutions to problems associated with the circulatory system ■ Evaluating the validity of the gathered viewpoints
Investigation 8.C: Identifying Blood Cells, p. 285	■ Determining, through microscopic inspection, the shape and abundance of the different cells in a prepared side of human blood ■ Compiling and displaying information about the cells in human blood
Thought Lab 8.2: Keeping the Blood Supply Safe, p. 289	■ Identifying and evaluating possible solutions to blood shortages ■ Investigating the roles and responsibilities of governments, medical organizations, and members of society in making decisions regarding the application of scientific and technological developments
Thought Lab 8.3: Barriers of Defence, p. 298	■ Researching main components of the human immune system ■ Designing a model or simulation to demonstrate the functioning human immune system
Chapter 9: Excretion and the Interaction of Systems	
Launch Lab: Dehydration and Urine Colour, p. 305	■ Observe samples of simulated urine and infer the hydration level of the person who provided the sample
Investigation 9.A: Identifying Structures of the Excretory System, p. 309	■ Performing a dissection of a mammalian kidney ■ Observing and identifying the main structures of a mammalian kidney
Investigation 9.B: Urinalysis, pp. 320-321	■ Collecting and interpreting data in the analysis of simulated urine, and stating a generalization based on data analysis and interpretation ■ Identifying limitations of data collected ■ Comparing collected values to theoretical values
Chapter 10: The Muscular System and Homeostasis	
Launch Lab: Working in Pairs, p. 331	■ Observing the action of the biceps and triceps
Investigation 10.A: Observing Muscle Tissue, pp. 334-335	■ Observing different types of muscle with a microscope ■ Recording observations through the use of labelled sketches ■ Obtaining and interpreting experimental evidence to account for muscle fibre contraction
Thought Lab 10.1: Designing a Muscle Fibre Model, p. 339	■ Designing a functional model of a skeletal muscle fibre ■ Working cooperatively with team members to design a muscle fibre model
Thought Lab 10.2: Injuries Related to Athletics, p. 345	■ Analyzing the effects of exercise on skeletal muscle and muscle fibre ■ Evaluating assumptions and behaviour related to athletics and physical conditioning ■ Consulting a wide variety of sources, and assessing the authority, reliability, and validity of the information gathered

Conceptual Challenges

Chapter 6

- Because their understanding of hormones is limited, students have difficulties realizing the digestive hormones are released into the blood and have their effect *after* they circulate to the digestive organ in question. Use **BLM 6.2.2 Important Secretions of the Digestive Tract** to reinforce the information.
- The sequential breakdown of macromolecules and the differentiation of parts of the digestive tract are difficult concepts for students to understand and follow. Students also find it difficult to understand that food is not all chemically digested in the stomach. A flow chart presentation of the digestion of various macromolecules, prepared by individuals or as a class will help students with the concept. Use Figure 6.21 on page 225 as a starting point for information in the flow chart.
- Students often find the biochemistry in this section difficult, particularly if they don't have any chemistry background. Even with a chemistry background, understanding what happens at a molecular level during hydrolysis (splitting by adding water) and dehydration synthesis (making by removing water) is difficult, as is differentiating between atoms and molecules. Refer students to Appendix B: A Quick Chemistry Reference for the Biology Student for help with this understanding.

Chapter 7

- The mechanics of breathing can be hard to understand. The model of the lungs made in the Launch Lab is effective for teaching the mechanics. **BLM 7.2.1: The Mechanics of Breathing** has been designed as a handout for use in reviewing the process.

Chapter 8

- Students often find it difficult to see how all the body's systems work together; the circulatory system is the one that interacts with the others. This is a reiteration of the theme of connectedness, on a smaller scale. The role of blood, discussed in Section 8.2 can be considered in relation to what students have already seen in Chapter 6 (digestion) and Chapter 7 (respiration) as a way of highlighting this concept. Blood cell activity during an immune response is another example of how the body's systems work together. **BLM 8.2.1 When Red Blood Cells Go Wrong** and **BLM 8.2.2: Blood Cell Activity** can be used to show the impact on a range of body systems.

Chapter 9

- An understanding of diffusion, osmosis, and active transport is critical to understanding the excretory process. If not reviewed as part of the unit preparation, use **BLM 9.2.1: A Review of Diffusion, Osmosis, Active Transport** as either an overhead or a handout to ensure that students are clear about the process.
- The formation of urine can be a difficult concept to understand. Students have trouble understanding that everything (except the proteins and blood cells) goes into the original filtrate and then the useful elements are reabsorbed, leaving behind a concentration of wastes that are removed as urine. **BLMs 9.2.2 Glomerular Filtration, 9.2.3 Reabsorption of Substances in the Proximal Tubule, 9.3.1 Functions of the Nephron Loop and the Distal Tubule,** and **9.3.2 Water Conservation in the Nephron** will give students a chance to explore the various steps in the process.

Chapter 10

- Use Thought Lab 10.1: Designing a Muscle Fibre Model to assist students in understanding the mechanics of muscles. **BLM 10.1.4: Contraction of Skeletal Muscle** will also help them understand muscle mechanics. Their own experience of muscle injuries should spark student interest in the workings of muscles.

Supporting Diverse Student Needs

- The terminology introduced in this unit could pose a challenge for some students, especially those whose first language is not English. Consider allowing these students to initially express their ideas in their first language and then have them translate these ideas into English.
- If a student is struggling with the terminology in this unit, consider pairing this student with one who has a good grasp of the concepts. This working pair could make graphic organizers, diagrams, or personalized "flash cards" to help keep track of the information presented in this section.
- Struggling learners may grasp a concept better by seeing it illustrated as a diagram or picture. Use the various BLMs provided in this resource to help these students.
- The rich array of materials available through the Internet makes it relatively easy to customize materials for your students. For example, ESL students might benefit from making their own crossword puzzle or word search. The interactive nature of many web sites could help others visualize the anatomy and physiology for the various human systems.
- Create two- or three-page study guide of the ideas in various sections of this unit. This guide can be of great assistance to students who struggle with print materials, lectures, or even the organization of information. The digest could be in paragraph form, point form, graphically organized, or a combination of these forms. It might also spotlight key vocabulary and provide essential questions the unit is designed to address. Advanced students could be encouraged to make a digital version of this guide using slide presentation software.

Using the Unit 4 Opener and the Unit 4 Preparation Feature

The unit opener looks at how all the human systems work together. Use the Focussing Questions to direct students' attention to the "big picture"—how human systems work together.

The Unit Preparation feature ensures that students are familiar with the various systems that make up the body. Students who completed Grade 8 Science in Alberta were briefly introduced to the human organ systems. Encourage students to take the Unit Prequiz (found at **www.albertabiology.ca,** Online Learning Centre, Student Editon) to gauge their recall, noting that if they are familiar with the background science, their experience with this unit will be much easier.

The Unit 4 Preparation feature is designed to refresh basic knowledge of the various human systems and give an overview of homeostasis and negative feedback systems. Use **BLM 6.0.1 Human Systems Overview** and **BLM 6.0.2 Homeostasis** when presenting the preparation material.

UNIT 4: COURSE MATERIALS

Chapter, Section	Item Description	Suggested Quantity	Text Activity
Chapters 6, 7, 8, 9, 10	safety goggles	40	Investigations: 6.A, 6.B, 8.A, 9.A, 9.B, 10.A; Ch9 Launch Lab
Chapters 6, 7, 8, 9, 10	nonlatex disposable gloves	40 pairs x 7 investigations	Investigations: 6.A, 6.B, 8.A, 9.A, 9.B, 10.A; Ch9 Launch Lab
Chapters 6, 7, 8, 9, 10	aprons	40	Investigations: 6.A, 6.B, 8.A, 9.A, 9.B, 10.A; Ch9 Launch Lab
Chapter 6, Section 6.2	hot plate tongs large beaker (500 mL) for hot water bath wax pencil test tubes distilled water biuret reagent albumin solution pepsin solution starch suspension iodine solution Benedict's solution glucose solution onion juice potato juice small squares of brown paper vegetable oil butter or margarine test tube racks millimetre ruler	1 per group 1 per group 1 per group 1 per group 11 per group 100 mL per group 12 mL per group 2 mL per group 2 mL per group 2 mL per group 1 small dropper bottle per group 12 mL per group 4 mL per group 1 small dropper bottle 1 small dropper bottle 3 squares of 4 cm x 4 cm per group 1 small dropper bottle 1 tsp per group 3 per group 1 per group	Investigation 6.A: Testing for Macromolecules, pp. 212–213
Chapter 6, Section 6.3	test tubes test-tube rack metric ruler 10-mL graduated cylinder test-tube holder water bath or incubator at 37 °C cubes of boiled egg white (protein samples) distilled water pepsin solution trypsin solution dilute hydrochloric acid (0.01 mol/L) dilute sodium hydroxide (0.01 mol/L) heat-resistant gloves	6 per group 1 per group 1 per group 1 per group 1 per group 1 per group or 1 incubator for class 18 cubes (5 mm X 5 mm X 5 mm) per group 10 mL per group 20 mL 2% per group 20 mL 5% per group 15 mL (0.01 mol/L) per group 15 mL (0.01 mol/L) per group 5	Investigation 6.B: Optimum pH for Two Protease Enzymes, pp. 228–229
Chapter 7, Chapter Opener	model of the human respiratory system	1 per class	Launch Lab: Modelling Your Lungs, Option 1, p. 243
Chapter 7, Chapter Opener	2L plastic pop bottles modelling clay round balloons drinking straws tape	2 per group 2 per group 2 per group	Launch Lab: Modelling Your Lungs, Option 2, p. 243

Chapter, Section	Item Description	Suggested Quantity	Text Activity
Chapter 7, Section 7.2	spirometer nose plugs (optional) disposable mouthpieces materials for recording data	1 per group 1 per group 1 per student	Investigation 7.A: Measuring Respiratory Volumes, p. 251
Chapter 7, Section 7.2	stop watch brown paper bag materials for recording data	1 per group 1 per student	Investigation 7.B: Carbon Dioxide and the Rate of Respiration, p. 253
Chapter 8, Chapter Opener	multimedia computer Internet access LCD projector, or video player and television movie or video clip showing blood flow through a capillary	1 per class 1 per class 1 per class	Launch Lab: Watching Blood Flow, p. 267
Chapter 8, Section 8.1	dissecting instruments dissecting tray/pan dissecting microscope (optional) sheep heart (or other mammalian heart) large tongs paper towels and/or newspapers plastic bag and tie (optional for storage) soap and water	1 set per group 1 per group 1 per group 1 per group 1 per group	Investigation 8.A: Identifying Structures of the Circulatory System, pp. 272–273
Chapter 8, Section 8.1	blood pressure cuffs stethoscope watch with a second hand or digital display other materials depending upon factors students decide to test	1 per group 1 per group (if you are using cuffs without digital readings) 1 per group	Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure, p. 278
Chapter 8, Section 8.2	light microscope prepared human blood slide	1 per group 1 per group	Investigation 8.C: Identifying Blood Cells, p. 285
Chapter 8, Section 8.3	toothpicks and Play-Doh™ or Plasticine™	Sufficient materials to make models	Thought Lab 8.3: Barriers of Defence, p. 298
Chapter 9, Chapter Opener	test tubes test tube holder simulated urine white paper Urine Colour Chart (from the student textbook) yellow food colouring	3 per group 1 per group 3 samples per group 1 piece per group 1 per group sufficient to prepare samples	Launch Lab: Dehydration and Urine Colour, p. 305
Chapter 9, Section 9.1	dissecting instruments dissecting tray/pan dissecting microscope (optional) mammalian kidney large tongs paper towels and/or newspapers plastic bag and tie (optional for storage) soap and water	1 set per group 1 per group 1 per group 1 per group 1 per group 1 per group	Investigation 9.A: Identifying Structures of the Excretory System, p. 309

Chapter, Section	Item Description	Suggested Quantity	Text Activity
Chapter 9, Section 9.3	test tube rack test tubes pipette or medicine dropper 10 mL graduated cylinder 100 mL beaker hot water bath chemicals for simulated urine: - distilled water -sodium chloride -urea -glucose powder -albumin powder -sweetened apple juice -yellow food colouring -2M hydrochloric acid -1M ammonia solution universal pH indicator paper with colour chart glucose test strips with colour charts	1 per group 5 per group 1 per group 1 per group 5 (for making samples) 1 per group 1 set per group 7.5 grams per sample set 17 grams per sample set 7 grams per sample set 1 gram per sample set 6 mL per sample set 1 small dropper bottle 3 or 4 drops per sample set 3 or 4 drops per sample set 5 per group 5 per group	Investigation 9.B: Urinalysis, pp. 320–321
Chapter 10, Section 10.1	light microscope dissecting microscope (optional) prepared slides of smooth muscle, cardiac muscle, and skeletal muscle sharp scissors small forceps or tweezers teasing needle dropper pipette microscope slides cover slips millimetre ruler (thin plastic) glycerinated muscle fibres in 50% glycerol (from purchased glycerinated muscle/ATP kit) dropper vial of 0.25% ATP in distilled water dropper vial of 0.05M KCl plus 0.001 $MgCl_2$ in distilled water	1 per group 1 set per group 1 per group 1 per group 1 per group 1 per group 2 per group 2 per group 1 per group 3 to 5 fibres per group 1 per group 1 per group	Investigation 10.A: Observing Muscle Tissue, pp. 334–335
Chapter 10, Section 10.1	to be determined by the students		Thought Lab 10.1: Designing a Muscle Fibre Model, p. 339

CHAPTER 6 DIGESTION AND HUMAN HEALTH

Curriculum Correlation

Human Systems, General Outcome 1: Students will explain how the human digestive and respiratory systems exchange energy and matter with the environment.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
20–D1.1k identify the principal structures of the digestive and respiratory systems, i.e., ■ mouth, esophagus, stomach, sphincters, small and large intestines, liver, pancreas, gall bladder	Launch Lab: Visualizing the Human Body, p. 205 Section 6.2: The Digestive System, pp. 217-224	Launch Lab: Procedure 1-2; Analysis 2, p. 205 Try This: Digestive tract, p. 218 Q questions 12, 13, p. 218; 16, p. 219; 21, p. 223 Try This: Surface area of small intestine, p. 223 Section 6.2 Review: 1, 2, p. 231 Chapter 6 Review: 11, p. 240 Unit 4 Review: 1, p. 356; 46, p. 358 BLM 6.4.2 Chapter 6 Test
■ nasal passages, pharynx, larynx, epiglottis, trachea, bronchi, bronchioles, alveoli, diaphragm, rib muscles, pleural membranes	See Chapter 7	See Chapter 7
20–D1.2k describe the chemical nature of carbohydrates, fats and proteins and their enzymes, i.e., carbohydrases, proteases, and lipases	Section 6.1: The Molecules of Living Systems, pp. 206-211 Section 6.2 Digestion and Absorption in the Small Intestine, pp. 224-225 Carbohydrate Digestion and Absorption, p. 226 Protein Digestion and Absorption, pp. 226-227 Fat Digestion and Absorption, pp. 227-228	Q questions 1-3, p. 207; 4, p. 208; 5, 6, p. 209; 7, 8, p. 211 Section 6.1 Review: 1-6, p. 216 Chapter 6 Review: 1-5, p. 240 Unit 4 Review: 9, p. 356 BLM 6.4.2 Chapter 6 Test
20–D1.3k explain enzyme action and factors influencing their action	Section 6.1: Vitamins and Minerals, pp. 211-214 Enzymes, pp. 214-216 Thought Lab 6.3: Enzymes and Diet, p. 238 BLM 6.2.8: Digestion of Lipids (Alternative Investigation)	Q questions 9, 10, p. 214; 11, p. 215 Section 6.1 Review: 7-10, p. 216 Section 6.2 Review: 4, p. 231 Thought Lab 6.3: Procedure 2; Analysis 1; Ext. 2, p. 238 Chapter 6 Review: 17, p. 241 BLM 6.2.8: Digestion of Lipids (Alternative Investigation) Unit 4 Review: 25, 26, p. 357 BLM 6.4.2 Chapter 6 Test
20–D1.4k describe the chemical and physical processing of matter through the digestive system into the bloodstream	Section 6.2: Digestion Begins: The Mouth and the Esophagus, pp. 218-219 Figure 6.15, p. 219 Storing, Digesting, and Pushing Food: The Stomach, p. 220 Thought Lab 6.2: An Accident and an Opportunity, p. 221 Digesting and Absorbing Nutrients: The Small Intestine, pp. 222-230 Completing Nutrient Absorption and Elimination: The Large Intestine, pp. 230-231	Q questions 14, 15, p. 219; 17-19, p. 220 Thought Lab 6.2: Analysis 1-6, p. 221 Q question 20, p. 223; 22, p. 224; 23, p. 226; 24, p. 227; 25, 26, p. 228; 27, p. 230 Section 6.2 Review: 3, 5, 6, p. 231 Chapter 6 Review: 6-10, 13-15, p. 240; 16, 24, p. 241 Unit 4 Review: 2, p. 356; 34-36, p. 357; 53, p. 358 BLM 6.4.2 Chapter 6 Test

	Student Textbook	Assessment Options
20–D1.5k explain how gases and heat are exchanged between the human organism and its environment, i.e., mechanism of breathing, gas exchange, removal of foreign material	See Chapter 7	See Chapter 7
Outcomes for Science, Technology and Society (Emphasis on science and technology)		
20–D1.1sts explain that the goal of technology is to provide solutions to practical problems by **(ST1)** ■ *discussing and evaluating the role of food additives and/or food treatment to solve the problems of food spoilage, e.g., antioxidants, irradiation technology* ■ *explaining the biological basis of nutritional deficiencies, including that of anorexia nervosa, and the technological means available to restore equilibrium of body systems* ■ *identifying specific pathologies of the digestive and respiratory systems and the technology used to treat the conditions*	Thought Lab 6.3: Enzymes and Diet, p. 238 Thought Lab 6.1: How Do You Take Your Macromolecules?, p. 210 Connections: Sorting Out Nutritional Supplements, p. 232 Psychological, Social, and Cultural Dimensions of Digestion-Related Conditions, pp. 235-237 Section 6.3: Ulcers, pp. 233-234 Inflammatory Bowel Disease, p. 234 Disorders of the Accessory Organs, p. 235	Thought Lab 6.3: Procedure 1, 2, p. 238 Thought Lab 6.1: Analysis 1-4; Ext. 5, p. 210 Web Link: Processed foods, p. 237 Web Link: Lactose intolerance, p. 226 Q question 28, p. 233; 32, p. 236; 33, p. 237 Section 6.3 Review: 4, p. 238 Chapter 6 Review: 18, 19, p. 241 Unit 4 Review: 10, p. 356 Web Link: *Helicobacter pylori*, p. 234 Q questions 29-31, p.235 Web Link: Pancreatitis, p. 235 Section 6.3: 1-3, 5, p. 238 Chapter 6 Review: 12, p. 240; 22, p. 241
20–D1.2sts explain that the products of technology are devices, systems and processes that meet given needs; however, these products cannot solve all problems by **(ST7)** ■ *assessing the physiological effects of smoking and the limitations of technologies available to deal with these conditions or diseases*	Thought Lab 6.3: Enzymes and Diet, p. 238 See Chapter 7	Web Link: Gastric bypass surgery, p. 236 Thought Lab 6.3: Ext. 2, p. 238 Chapter 6 Review: 20, 21, 23, 25, p. 241 Unit 4 Review: 61, 62, p. 359 See Chapter 7
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
20–D1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by ■ *designing an investigation to examine food energy through calorimetry* **(IP–NS1, 2, 3, 4) [ICT C7–4.1]**	Investigation 6.B: Optimum pH for Two Protease Enzymes, pp. 228-229 Connections: Sorting Out Nutritional Supplements, p. 232	Investigation 6.B: Ext. 6, p. 229 Connections: 1-4, p. 232 Unit 4 Review: 50, 61, 56, 57, p. 358
Performing and Recording		
20–D1.2s 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 ■ observing, through dissection or computer simulations, the respiratory and digestive systems of a representative mammal and identifying the major structural components **(PR–NS1, 2, 3, 4, 5) [ICT F1–4.2]** ■ performing experiments, using qualitative tests to detect the presence of carbohydrates, proteins and lipids **(PR–NS2, 3, 4, 5)** ■ *designing and performing an experiment to investigate the influence of enzyme concentration, temperature or pH on activity of enzymes, e.g., pepsin, pancreatin* ■ *designing and performing an experiment to examine the mechanics of breathing, e.g., lung volume, breathing rate*	Appendix F: The Dissection of a Fetal Pig: Part 2: The Digestive System, pp. 763-765 Investigation 6.A: Testing for Macromolecules, pp. 212-213 Investigation 6.B: Optimum pH for Two Protease Enzymes, pp. 228-229 BLM 6.2.8: Digestion of Lipids (Alternative Investigation) See Chapter 7	Appendix F: Part 2, pp. 763-765 Investigation 6.A: Procedure Parts 1-4, pp. 212-213 Section 6.1 Review: 6, p. 216 Investigation 6.B: Procedure 1-7; Ext. 6, p. 229 BLM 6.2.8: Digestion of Lipids (Alternative Investigation) See Chapter 7

	Student Textbook	Assessment Options
Analyzing and Interpreting		
20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by	Thought Lab 6.2: An Accident and an Opportunity, p. 221	Thought Lab 6.2: Analysis 1-7, p. 221 Try This: Surface area of small intestine, p. 223 Chapter 6 Review: 19, 24, 25, p. 241 Unit 4 Review: 53, p. 358
■ performing, recording, analyzing, drawing conclusions and assessing validity of data from the investigation on calorimetry, enzyme action and mechanics of breathing **(PR–NS1, 2, 3, 4, 5) (AI–NS2, 3, 4, 6) [ICT P2–4.1]**	Investigation 6.B: Optimum pH for Two Protease Enzymes, pp. 228-229 BLM 6.2.8: Digestion of Lipids (Alternative Investigation)	Investigation 6.B: Analysis 1-2; Conclusion 3-4; Ext. 5, p. 229 BLM 6.2.8: Digestion of Lipids (Alternative Investigation)
Communication and Teamwork		
20–D1.4s 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	Launch Lab: Visualizing the Human Body, p. 205	Launch Lab: Analysis 1, p. 205
■ working cooperatively to collect and communicating results using appropriate terminology, SI units and symbols **(CT–NS1, 2) [ICT P2–4.1]**	Investigation 6.A: Testing for Macromolecules, pp. 212-213 BLM 6.2.8: Digestion of Lipids (Alternative Investigation)	Investigation 6.A: Procedure Parts 1-4, pp. 212-213 BLM 6.2.8: Digestion of Lipids (Alternative Investigation)

Chapter 6

Digestion and Human Health

Student Textbook pages 204–241

Chapter Concepts

6.1 The Molecules of Living Systems

- Macromolecules such as carbohydrates, lipids, proteins, and nucleic acids are made up of smaller subunits that are chemically separated through hydrolysis.
- Enzymes are biological catalysts.

6.2 The Human Digestive System

- The digestive tract is a tube extending from the mouth to the anus through which food is broken down, nutrient molecules absorbed, and undigested material eliminated.
- Food is processed mechanically and chemically to reduce macromolecules to a form in which they may be absorbed into the bloodstream.

6.3 Health and the Digestive System

- An excess or deficiency of nutrients can lead to disorders that can be diagnosed and treated but not necessarily cured.

Common Misconceptions

- Some students may believe that gravity plays a role in moving food through the digestive tract. The action of peristalsis should be stressed.

Helpful Resources

Books and Journal Articles

- Gadsby, P. "The Inuit Paradox: How can people who gorge on fat and rarely see a vegetable be healthier than we are?" *Discover.* October, 2004.
- Mader, Sylvia. *Understanding Human Anatomy and Physiology 5/e*. McGraw-Hill Ryerson: Whitby, 2005.
- Shier, David. *Hole's Essentials of Human Anatomy and Physiology 9/e*. McGraw-Hill Ryerson: Whitby, 2006.

Web Sites

Web links to resources related to the digestive system can be found at **www.albertabiology.ca**. Go to the Online Learning Centre, and log on to the Instructor Edition. Choose Teacher Web Links for the links to Chapter 6.

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. Most handouts and all assessment tools are supported by a BLM with the answers (ANS). The BLMs are in digital form, stored on the CD that accompanies this Teacher Resource or on the web site at **www.albertabiology.ca,** Online Learning Centre, Instructor Edition, BLMs. They can be modified to suit the needs of your students.

Number (Type)

6.0.1 (OH) Human Systems Overview
6.0.2 (OH) Homeostasis

6.1.1 (HAND) Launch Lab: Visualizing the Human Body
6.1.1A (ANS) Launch Lab: Visualizing the Human Body Answer Key
6.1.2 (HAND) Macromolecules
6.1.3 (HAND) Thought Lab 6.1: How Do You Take Your Macromolecules?
6.1.3A (ANS) Thought Lab 6.1: How Do You Take Your Macromolecules? Answer Key
6.1.4 (HAND) How to Read a Nutrition Label
6.1.5 (HAND) Investigation 6.A: Testing for Macromolecules
6.1.5A (ANS) Investigation 6.A: Testing for Macromolecules Answer Key
6.1.6 (HAND) Enzyme Function
6.1.6A (ANS) Enzyme Function Answers
6.1.7 (HAND) Factors Affecting Enzyme Activity
6.1.7A (ANS) Factors Affecting Enzyme Activity Answers

6.2.1 (AST) Digestive System Quiz
6.2.1A (ANS) Digestive System Quiz Answer Key
6.2.2 (HAND) Important Secretions of the Digestive System
6.2.3 (HAND) Small Intestine
6.2.4 (HAND) Thought Lab 6.2: An Accident and an Opportunity
6.2.4A (ANS) Thought Lab 6.2: An Accident and an Opportunity Answer Key
6.2.5 (HAND) Accessory Organs
6.2.6 (AST) Chemical Digestion Quiz
6.2.6A (ANS) Chemical Digestion Quiz Answers
6.2.7 (HAND) Absorption of Nutrients in the Small Intestine
6.2.8 (HAND) Alternate Investigation: Digestion of Lipids
6.2.8A (ANS) Alternate Investigation: Digestion of Lipids Answer Key
6.2.9 (HAND) Investigation 6.B: Optimum pH for Two Protease Enzymes
6.2.9A (ANS) Investigation 6.B: Optimum pH for Two Protease Enzymes Answer Key

6.3.1 (HAND) Thought Lab 6.3: Enzymes and Diet
6.3.1A (ANS) Thought Lab 6.3: Enzymes and Diet Answer Key

6.4.1 (HAND) Digestive System Vocabulary Building
6.4.2 (AST) Chapter 6 Test
6.4.2 (ANS) Chapter 6 Test Answer Key

Using the Chapter 6 Opener

Student Textbook pages 204-205

Teaching Strategies

- Use the Launch Lab: Visualizing the Human Body on page 205 of the student textbook to reactivate prior knowledge.

Launch Lab: Visualizing the Human Body

Student Textbook page 205

Purpose

The purpose of this lab is to identify the organs of the human digestive system.

Outcome

- 20–D1.1k

dvance Preparation

When to Begin	What to Do
3 to 4 weeks in advance	■ Preview animations related to digestion at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, Teacher Web Links, or order a video on the human digestive system from your local library or media resource centre.
1–2 days before	■ Photocopy **BLM 6.1.1: Launch Lab**

Materials
none

Time Required

- 10 minutes; could be extended if using animation

Helpful Tips

- This Launch Lab is primarily designed to help students focus on the names and functions of the organs of the digestive system.
- Use **BLM 6.1.1 Launch Lab: Visualizing the Human Body** to support this activity. Remove sections as appropriate to meet the needs of the students in your class. The function descriptions requested in Analysis question can be found on 6.1.1A.
- The key digestive element in the X-ray shown with the Launch Lab is the large intestine (pink, S-curved). The green
- "Digesting Different Foods" is a colourful animation suitable for ESL students; it gives a complete overview of the digestion of the different macromolecules. The key components of the digestive system can be highlighted on the right hand side of the screen; specific foods can be selected and followed through digestion, from mouth to anus. In addition, the "Zoom In" feature gives students a look at enzyme activity for specific macromolecules along the way. Alternatively, this part of the animation could be revisited later during Section 6.1, after the macromolecules have been introduced.

Safety Precautions

None

Answers to Analysis Questions

1. Students should compare their diagrams with each other and then to illustrations in the student textbook.
2. The X-ray reveals the stomach, the small intestine, and the large intestine. The following is a summary of the functions of these organs. However, it is unlikely that all students will remember these functions.
   - The stomach has a thick, muscular wall that helps to grind up food (mechanical digestion). It also releases the gastric juice that begins the chemical digestion of protein.
   - The small intestine is the site of most chemical digestion. The wall of the small intestine has folds that bear finger-like projections called **villi**. The products of digestion are absorbed into the blood capillaries and lymph vessels in the villi.
   - The large intestine does not produce digestive enzymes; it does absorb water, salts, and some vitamins.

Assessment Option

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

6.1 The Molecules of Living Systems

Student Textbook pages 206–216

Section Outcomes

Students will:

- **describe** the chemical nature of carbohydrates, lipids, and proteins
- **explain**, in general terms, how carbohydrates, lipids, and proteins are synthesized and how they are broken down (hydrolyzed)
- **perform** standard tests to identify macromolecules

Key Terms

macromolecules
dehydration synthesis
hydrolysis
carbohydrates
lipids
proteins
peptide bond
nucleic acids
vitamins
minerals
catalyst
enzyme

Biology Background

- Carbohydrates contain atoms of carbon, hydrogen, and oxygen. Carbohydrates provide short- or long-term energy storage for living organisms. A carbohydrate molecule with three to seven carbon atoms is called a monosaccharide, or simple sugar. Glucose, fructose, and galactose are examples of monosaccharides. A disaccharide, or double sugar, is made up of two simple sugars. Sucrose, maltose, and lactose are examples of disaccharides.
- There are three polysaccharides common in plant and animal cells. Starch is a long, unbranched chain that is only partially soluble in water. Glycogen is highly branched, which makes it more soluble in water. In the human body, insulin instructs the liver to store glucose sub-units as glycogen. Cellulose consists of many long, unbranched strands that interconnect to form fibres. Some bacteria can use cellulose for energy, but this molecule is primarily a structural molecule in plants.
- Lipids are largely insoluble in water. Living organisms use lipids for many purposes: long-term energy storage, insulation, cushioning internal organs, and forming the sex hormones, which send messages around the body. Lipids are also the primary structural component of cell membranes.
- Proteins form structural components and are actively involved in almost all the chemical reactions of the living cell. Proteins are long, unbranched chains of amino acids linked by peptide bonds. In addition to their structural functions, proteins also function as enzymes that catalyze chemical reactions, help transport substances across the cell membrane, and act as chemical messengers (hormones).
- Like carbohydrates and proteins, nucleic acids are long polymers of repeating nucleotide sub-units, each consisting of a five-carbon sugar and a phosphate group. Also attached to the sugar is a base containing nitrogen. DNA and RNA are examples of nucleotides that are found in the cells.
- An enzyme is a protein molecule that functions as an organic catalyst to speed a chemical reaction. The reactants in an enzymatic reaction are called the **substrates** for that enzyme. An enzyme has an active site, where the substrates and enzyme fit together in such a way that the substrates are oriented to react. In an enzyme-mediated reaction, substrate molecules are changed and product(s) are formed. Following the reaction, the product(s) are released and the enzyme is free to act again.

Teaching Strategies

- This section discusses the structure and function of all the macromolecules introduced in the student textbook. **BLM 6.1.2 Macromolecules** highlights each macromolecule.
- **BLM 6.1.5: Investigation 6.A:1 – Testing for Macromolecules** is designed to reduce the amount of time required to complete this large investigation. This BLM provides the instructions for students as they work through the activity.
- One idea to consider is to subdivide this section into more manageable chunks. For example, discuss carbohydrates with your students, and then have them do Investigation 6.A, Part 2: Test for Starch and Part 3: Test for Sugars. Next, discuss lipids and then have your students do Investigation 6.A, Part 4: Test for Fats.
- **BLM 6.1.6: Enzyme Function** can also be photocopied for your students. This BLM is a worksheet-style activity that requires students to use their textbooks. Answers are on 6.1.6A.
- **BLM 6.1.7 Factors Affecting Enzyme Activity** is another worksheet that will help students understand enzyme activity.
- Overhead masters and quizzes have been prepared for this section. You will find them with the Chapter 6 BLMs on the CD that accompanies this Teachers' Resource or at **www.albertabiology.ca,** Online Learning Centre, Instructor Edition, BLMs.

Number (Type)
6.1.1 (HAND) Launch Lab: Visualizing the Human Body
6.1.1A (ANS) Launch Lab: Visualizing the Human Body Answer Key
6.1.2 (HAND) Macromolecules
6.1.3 (HAND) Thought Lab 6.1: How Do You Take Your Macromolecules?
6.1.3A (ANS) Thought Lab 6.1: How Do You Take Your Macromolecules? Answer Key
6.1.4 (HAND) How to Read a Nutrition Label
6.1.5 (HAND) Investigation 6.A: Testing for Macromolecules
6.1.5A (ANS) Investigation 6.A: Testing for Macromolecules Answer Key
6.1.6 (HAND) Enzyme Function
6.1.6A (ANS) Enzyme Function Answers
6.1.7 (HAND) Factors Affecting Enzyme Activity
6.1.7A (ANS) Factors Affecting Enzyme Activity Answers

Answers to Questions for Comprehension

Student Textbook page 207

Q1. The four categories of macromolecules are carbohydrates, lipids, proteins, and nucleic acids.

Q2. The process that builds macromolecules is called dehydration synthesis. To form a covalent bond between two sub-unit molecules, an –OH (hydroxyl) group is removed from one sub-unit and a hydrogen atom is removed from the other sub-unit. This chemical reaction is known as **dehydration synthesis** because removing the –OH group and H atom during the synthesis of a new biological molecule essentially removes a molecule of water (H_2O).

Q3. Cells disassemble macromolecules into their component sub-units by performing a chemical reaction that is basically the reverse of dehydration synthesis. In this reaction, called **hydrolysis**, a molecule of water is added instead of removed. During a hydrolysis reaction, a hydrogen atom from water is attached to one sub-unit and the hydroxyl group is bonded to another sub-unit, effectively breaking a covalent bond in a macromolecule.

Student Textbook page 208

Q4. Accept any two of the following: The two main types of carbohydrates are simple sugars and polysaccharides.

Simple sugars are composed of one sugar (monosaccharide) molecule or two sugar (disaccharide) molecules. Glucose is a common example of a monosaccharide and maltose is an example of a dissaccharide.

Polysaccharides are long chains (polymers) of glucose molecules bonded together.

Figure 6.5

Student Textbook page 209

The hydrolysis of a fat molecule can be summarized by the following reaction:
fat molecule + 3 H_2O molecules $\rightarrow$ 3 fatty acids + glycerol

Answers to Questions for Comprehension

Student Textbook page 209

Q5. The sub-units of a fat are 3 fatty acids and glycerol.

Q6. A saturated fatty acid does not have double covalent bonds between its carbon atoms, so it contains all the hydrogen atoms it can bond with. An unsaturated fatty acid has double bonds between some of its carbon atoms, leaving room for additional hydrogen atoms. Unsaturated fatty acids cause the resulting fat to be liquid at room temperature. Saturated fatty acids usually cause the resulting fat to be solid at room temperature.

Thought Lab 6.1: How Do You Take Your Macromolecules?

Student Textbook page 210

Purpose

The purpose of this activity is to introduce students to various methods of food preservation and to assess advantages and disadvantages of one method. They will also learn independent research skills.

Outcomes

20-D1.1sts
20-D1.2sts

Advance Preparation

When to Begin	What to Do
1 to 2 days before	■ Photocopy **BLM 6.1.4: How to Read a Nutrition Label** for your students. ■ Photocopy **BLM 6.1.3: Thought Lab 6.1: How Do You Take Your Macromolecules?**

Time Required

- 2 hours

Helpful Tips

- Use **BLM 6.1.3: Thought Lab 6.1: How Do You Take Your Macromolecules?** to support this activity. Remove sections as appropriate to meet the needs of the students in your class. The answers can be found on BLM 6.1.3A.
- Students may not be familiar with the details of a nutrition label. Use **BLM 6.1.4: How to Read a Nutrition Label** to support their efforts.
- When assigning Analysis Question 1, it will be helpful to ask students to identify the primary macromolecule (carbohydrate, protein, or fat) associated with each example they present in their chart.

Answers to Analysis Questions

1. The chart should show three examples of foods, each primarily composed of a different macromolecule.

2. Student work should show clearly how the technologies used to preserve the foods function to reduce growth of bacteria or fungi and decrease the breakdown of fats (two main reasons for food spoilage cited in the introduction of the lab.)

3. Advantages might include effectiveness in inhibiting growth of microorganisms and fat decomposition (shelf

life of the food); lack of harmful side effects to the consumer; preservation of nutrients, taste, and texture of the food.

4. Disadvantages might include long-term risks to health and physiological reactions or allergies to chemical preservatives. Some techniques are disadvantageous in that they alter the taste and texture of foods; some techniques also destroy certain nutrients.

Answer to Extension Question

5. Answers should reflect an understanding that the additives in question are indeed chemical preservatives as opposed to additives that affect texture or taste.

Assessment Options

- Collect and assess students' answers to the Analysis and Extension Questions.
- Use Assessment Checklist 7: Independent Research Skills from Appendix A.

Answers to Questions for Comprehension

Student Textbook page 211

Q7. Amino acids are the sub-units of a protein molecule.

Q8. Proteins are more structurally and functionally diverse because of the following factors.

(a) There are 20 different amino acid groups, which provide a large number of possible combinations.

(b) A strand of amino acids must undergo additional changes before it becomes a protein. Different amino acids along the strand attract and repel each other, and this causes the strand to coil and twist as the amino acids are drawn toward, or pushed away from each other. The end result is a highly complex three-dimensional structure. The final shape of a protein's three-dimensional structure determines the properties, and therefore the functions, of the protein.

Investigation 6.A: Testing for Macromolecules

Student Textbook page 212–213

Purpose

Students will use standardized tests to identify the presence of specific macromolecules.

Outcomes

- 20–D1.2s
- 20–D1.3s
- 20–D1.4s

Advance Preparation

When to Begin	What to Do
beginning of the year (or semester)	■ Check on quantity of chemical reagents required and order, if necessary.
2 or 3 days prior	■ Organize all materials and make the starch and glucose solutions. ■ Purchase consumable food products such as the onion, vegetable oil, and butter. ■ Photocopy **BLM 6.1.5: Investigation 6.A: Testing for Macromolecules** if you plan to use it. ■ Photocopy Assessment Checklist 2 Laboratory Report if you plan to use this tool to evaluate this activity.

Materials

- hot plate
- tongs
- large beaker (500 mL)
- wax pencil
- 11 test tubes
- distilled water
- Biuret reagent
- albumin solution
- pepsin solution
- starch suspension
- iodine solution
- Benedict's solution
- glucose solution
- onion juice
- potato juice
- 3 small squares of brown paper
- vegetable oil
- butter or margarine

Time Required

- 1 hour

Helpful Hints

- Use **BLM 6.1.5 Investigation 6.A: Testing for Macromolecules** to support this activity. Remove sections as appropriate to meet the needs of the students in your class. The answers can be found on **BLM 6.1.5A Investigation 6.A: Testing for Macromolecules Answer Key.**

- Have all solutions ready before the lab starts. Spread them out in different stations to reduce the number of students moving to one area.
- Predetermine student groups (4 students per group). Staggering the starting activity for each group can spread students out in the lab and reduce the potential of students standing around and waiting.
- Remind groups that they need to collect materials quickly and efficiently to complete the work in a short period of time.
- Be sure that all glassware is cleaned thoroughly after use.
- Aqueous glucose is mixed with Benedict's reagent, a solution of copper sulfate, sodium hydroxide, and tartaric acid. The mixture is heated. Carbohydrates that react with Benedict's reagent to reduce the blue copper(II) ion to form a brick red precipitate of copper(I) oxide are classified as **reducing sugars**.
- Biuret reagent is an aqueous solution of biuret (allophanamide) treated with cupric sulfate and sodium hydroxide. In the presence of protein, this blue solution will change colour to pink-purple.

Safety Precautions

- Refer to the document *Safety in Science Classroom* published by Alberta Education (see Alberta Eductation web site or Teacher Web Links at the Online Learning Centre) before starting this investigation. You can search this document to identify information including the chemical name, state, WHMIS class, hazards, and disposal information.
- There are a number of general guidelines that can be followed to increase safety when working with chemicals.
  (a) Ensure that the chemical is appropriately labelled and that the MSDS is readily available.
  (b) Minimize exposure to chemicals.
  (c) Do not handle or use chemicals unless you are WHMIS trained.
  (d) Before using any chemical, review its MSDS to determine potential hazards.
  (e) Inform students of hazards and the necessary safety precautions.
  (f) Never underestimate risks when mixing chemicals.
- Post the MSDS pages for all reagents (Benedict's, Biuret's, and iodine solutions).
- Monitor mixing of solutions in test tubes. Check that students do not put their fingers or thumbs over the openings of test tubes to shake them.

SUPPORTING DIVERSE STUDENT NEEDS

ESL Students: Using both Benedict's and Biuret's reagents may be confusing for some students. Both of these reagents contain copper sulfate but start as different colours of blue, and each one indicates the presence of completely different molecules. Suggest that students used coloured pencils to show the reagent they used and the colour changes. With a legend, this colour-coding system can be included in their lab report if required.

Answers to Analysis Questions

1. In these investigations, distilled water acted as a control so that the colour change was apparent. The control group in an investigation does not receive treatment; it functions as a comparison group to assess the effectiveness of the treatment given to the experimental group.

2. Possible answers for experimental error include contamination of samples, dirty glassware, and not following the proper procedure.

Answer to Conclusion Question

3. (a) Biuret solution is a positive test for proteins. It changes colour from blue to purple to show the presence of proteins.

(b) Iodine is a positive test for starch. It changes colour from orange to black.

(c) Benedict's solution is a positive test for reducing sugars. When heated, it forms an orange to red precipitate.

(d) Brown paper is a test for fats. Fats applied to brown paper form a translucent spot that does not dry on the paper.

Assessment Options

- Collect and assess students' responses to Assessment Checklist 2 Laboratory Report if you are using this strategy to evaluate this activity.
- Collect and assess students' answers to the Analysis and Conclusion questions.
- Use Assessment Checklist 3: Performance Task Self-Assessment. (See Appendix A.)

Answers to Questions for Comprehension

Student Textbook page 214

Q9. An **enzyme** is a protein molecule that acts as a catalyst to increase the rate of a reaction. In the cell, an enzyme brings particular molecules together and causes them to react with one another.

Q10. Each enzyme in the body has a precise three-dimensional shape that is specific to the kind of reactant molecule with which it can combine. The enzyme physically fits with a specific **substrate**—its reactant molecule. The enzyme is specific because it has a particular shape that can combine only with specific parts of its substrate molecule. When the substrate combines with its enzyme, its bonds become less stable and, thus, it is more likely to be altered and to form new bonds.

Student Textbook page 215

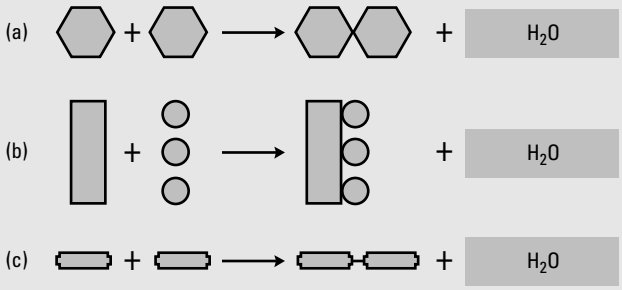
Q11. Enzyme activity is affected by any change in condition that alters the enzyme's three-dimensional shape. When the temperature becomes too low, the bonds that determine enzyme shape are not flexible enough to enable substrate molecules to fit properly. At higher temperatures, the bonds are too weak to maintain the enzyme's shape. It becomes **denatured**, meaning that its molecular shape and structure (and, thus, its properties) are permanently changed. Therefore, enzymes function best within an optimum temperature range. This range is fairly narrow for most human enzymes.

Section 6.1: Review Answers

Student Textbook page 216

1. Macromolecules are different from inorganic substances because they are organic, larger, and more complex, often being polymers made by linking together many small, similar, chemical sub-units.

2. The following is one possible way to demonstrate these processes.



- Hexagons were chosen to represent glucose since it is a 6-carbon sugar. Using a rectangle for glycerol provides space for the three fatty acids to attach. The rectangles with the points were chosen for amino acids, as they are longer molecules with R groups extending from them. Other ideas are possible.

3. Fats such as butter and lard are animal in origin; they are solid at room temperature and the fatty acids are saturated, having single bonds between the carbons. Oils are of plant origin; they are liquid at room temperature and contain unsaturated fatty acids with double or triple bonds between the carbons.

4.

Macromolecule	Structure	Example	Function
sugars	monosaccharide (simple sugar with 3 – 7 carbon atoms) or dissacharide (double sugar)	glucose maltose	short term energy storage, transport
polysaccharides	composed of many monosaccharides linked together	starch	long term energy storage
lipids	glycerol and three fatty acids; phospholipids have two fatty acids and a phosphate group	fats and oils	energy storage and cell membranes
proteins	polymers of amino acids (An amino acid contains amine and carboxyl groups. Each is unique because of its R group.)	hemoglobin, fibrin, collagen, antibodies, enzymes, actin, and myosin	transport, blood clotting, support, immunity, catalysts, and muscle action
nucleic acids	polymers of nucleotides	DNA and RNA	transfer and expression of genetic information

5. Carbohydrates: maltose and cellulose
Lipid: hydrogenated soybean oil
Inorganic: salt

6. The following table is one way for students to answer this question.

Macromolecule	Identification Test	Positive Result
Starches	Iodine	Iodine turns from a brownish colour to blue-black when mixed with starch
Sugars	Benedict's Solution	A colour change from blue to varying colours, ranging from green to orange-red, depending on the amount of sugar present
Proteins	Biuret Solution	A colour change from blue to violet
Fats	Translucence Test	Fats leave a translucent (allowing light through) spot on unglazed paper

7. Enzymes are specialized proteins that speed up the rate of chemical reactions in living things in the same way that inorganic catalysts speed up reactions elsewhere.

8. Enzymes are specific in their functions because each type has a unique three-dimensional shape. The shape of each

enzyme is complementary to the shape of its substrate. Therefore, an enzyme that is complementary to the shape of a sucrose molecule would not link up with a maltose molecule.

9. An enzyme functions when it combines with its substrate. The active site of the enzyme is complementary in its shape to the substrate, so when the two molecules fit together, a chemical reaction involving the substrate is speeded up.

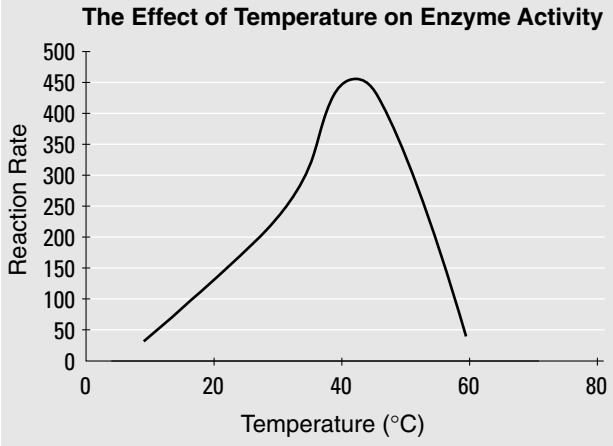
10. The following graph was produced using Microsoft Excel.

The procedure for producing such a graph is as follows:

(a) Enter sample ("made up") data that will demonstrate the effect of temperature on reaction rate in two adjacent columns in the Excel spreadsheet. Enter the data for the x-axis in the first column; y-axis data in the second column.
(b) Highlight the two columns of data, and select "INSERT", then "CHART". (The Chart Wizard, Step One will appears.)
(c) Select "XY (Scatter)" as the Chart Type and "smooth lines without markers" for the Chart sub-type.
(d) Click Next and Step Two will appear. Confirm that the correct data from the spreadsheet cells have been selected.
(e) Click Next and Step Three will appear. Enter the Chart Title and the Labels for the Values on each axis.
(f) Remove the gridlines by clicking on the "Gridlines" tab.
(g) Remove the legend by clicking on the "Legend" tab.
(h) Click Next and Step Four will appear. Place the chart in Sheet 1 in Excel.
(i) Click Finish.
(j) To rotate the label on the Y axis, right click on the label and select "Format Axis Title". Choose the "Alignment" tab and move the Orientation graphic to zero degrees.

SAMPLE DATA FOR THE GRAPH BELOW:

Temp	Rate
10	30
20	120
30	240
40	450
50	320
60	25



The optimum temperature for this enzyme-controlled reaction is about 40 °C.

When the temperature is colder than this, the bonds that determine enzyme shape are inflexible and the substrate molecules do not fit into the active site on the enzyme. At higher temperatures, the enzymes (which are proteins) become denatured. This also changes the shape of the active site.

6.2 The Digestive System

Student Textbook pages 217–231

Section Outcomes

Students will:

- **identify** the main structures and functions of the digestive system
- **describe** the physical and chemical processing of food through the digestive system and into the bloodstream
- **explain** the action of enzymes in chemical digestion
- **identify** and **describe**, in general terms, how digested molecules enter the bloodstream

Key Terms

digestive system
mouth
amylase
esophagus
peristalsis
esophageal sphincter
stomach
pyloric sphincter
pepsin
small intestine
segmentation
duodenum
villi
microvilli
pancreas
liver
gall bladder
carbohydrases
lipases
proteases
nucleases
gastrin
secretin
CCK
GIP
large intestine

Biology Background

- Digestion takes place within a tube called the digestive tract, which begins with the mouth and ends with the

anus. The functions of the digestive system are to ingest food, digest it to nutrients that can cross cell membranes, absorb the nutrients, and eliminate indigestible remains. On average, it takes about 24–33 hours for each meal to complete its passage through the digestive tract.

- Digestion involves two main processes that occur simultaneously. During mechanical digestion, large pieces of food become smaller pieces, increasing the surface area for chemical digestion. Mechanical digestion begins with the chewing of the food in the mouth and continues with the churning and mixing of food that occurs in the stomach. Parts of the digestive tract produce digestive enzymes. During chemical digestion, many different enzymes break down macromolecules to small organic molecules that can be absorbed. Each enzyme has a particular job to do.

Teaching Strategies

- A number of overhead masters and quizzes have been prepared for this section. You will find them with the Chapter 6 BLMs on the CD that accompanies this Teachers' Resource or at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs.

  Number (Type)
  6.2.1 (AST) Digestive System Quiz
  6.2.1A (ANS) Digestive System Quiz Answer Key
  6.2.2 (HAND) Important Secretions of the Digestive System
  6.2.3 (HAND) Small Intestine
  6.2.5 (HAND) Accessory Organs
  6.2.6 (AST) Chemical Digestion Quiz
  6.2.6A (ANS) Chemical Digestion Quiz Answers
  6.2.7 (HAND) Absorption of Nutrients in the Small Intestine
  6.2.8 (HAND) Alternate Investigation: Digestion of Lipids
- This investigation may be used as an alternative to Investigation 6.B: Optimum pH for Two Protease Enzymes
  6.2.8A (ANS) Alternate Investigation: Digestion fo Lipids Answer Key
- If time permits, place students in groups and have them research the anatomy of the digestive tracts of mammals other than humans—ruminants, such as cows or deer; pure carnivores, such as wolves; or rodents, such as mice or squirrels.
- The digestive system of an earthworm can be used to show the "tube within a tube" nature of the digestive system. Consider starting this section with either a real or a virtual dissection of preserved specimens.
- Use pieces of a jigsaw puzzle to demonstrate the lock and key concepts for the specificity of enzymes.
- On blank recipe cards, write the name of each specific enzyme (one enzyme per card). On another set of cards, write the names of the different substrates (macromolecules) that are digested. On a third set of cards, write the names of the end products of digestion. Students can then match the cards from all three piles.

Card Pile 1	Card Pile 2	Card Pile 3
Enzyme salivary amylase	Substrate starch	End Product maltose (disaccharide)

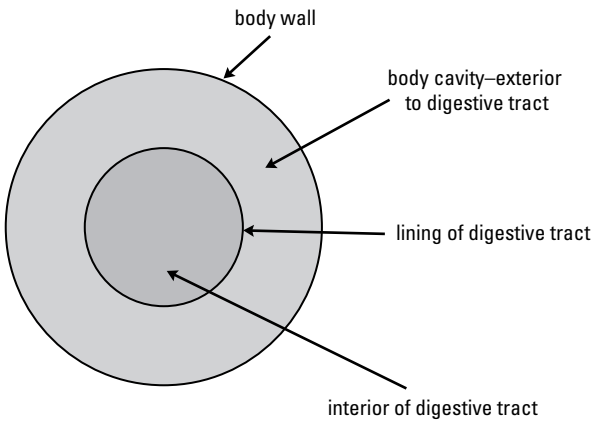
- Appendix F: Fetal Pig Dissection, Part 2: The Digestive System has been provided for use in fulfilling Skill Outcome 20-D1.2s. If you prefer to do a virtual dissection, go to **www.albertabiology.ca** and follow the links to Chapter 6 under Teacher Resources.

Biology File: Try This

Student Textbook page 218

Humans have a tube-within-a-tube body structure. The outer tube is the body wall, while the inner tube is the digestive tract. The cavity between the outer and inner tubes is called the coelom.

The following diagram can represent internal and external as they relate to the digestive tract.



Sample answer: One advantage is to increase the efficiency of digestion—the longer the food is in the digestive tract, the more nutrients can be processed and absorbed.

Answers to Questions for Comprehension

Student Textbook page 218

Q12. The organs that make up the human digestive tract are the mouth, esophagus, stomach, small intestine, large intestine, rectum, and anus.

Q13. The accessory organs are the salivary glands, liver, gall bladder, and pancreas.

Student Textbook page 219

Q14. The mechanical (physical) digestion of food begins in the mouth because you use your teeth to chew your food. Water and mucus in saliva aid the teeth as they tear and grind food into smaller pieces, increasing the surface area available for the chemical digestion of any starch that has been ingested.

Chemical digestion starts in the mouth, when an enzyme in saliva, called salivary amylase, begins to break down starch into simpler sugars (disaccharides).

Q15. The bolus moves through the esophagus partly by gravity but mainly through a wave-like series of muscular contractions and relaxations called **peristalsis**. As peristalsis continues, food is propelled through the esophagus toward the stomach, where the next stage of digestion occurs.

Q16. Entry to the stomach is controlled by a ring-like muscular structure called the **esophageal sphincter**. Relaxation of the esophageal sphincter allows the bolus to pass into the stomach. Contraction of this sphincter usually prevents the acidic contents of the stomach from backing up into the esophagus.

Student Textbook page 220

Q17. Both mechanical and chemical digestion occur in the stomach. Waves of peristalsis push food against the bottom of the stomach, churning it backward, breaking it into smaller pieces, and mixing it with gastric juice to produce a thick liquid called **chyme**.

Q18. Once active, pepsin hydrolyzes proteins to yield polypeptides—a first step in protein digestion in the digestive tract.

Q19. Very few substances are absorbed from the chyme in the stomach because most substances in the chyme have not yet been broken down sufficiently. The stomach does absorb some water and salts, however, as well as certain anti-inflammatory medications, such as Aspirin™, and alcohol.

Thought Lab 6.2: An Accident and an Opportunity

Student Textbook page 221

Purpose

Students analyze and interpret historical events and information.

Outcomes

- 20–D1.1k
- 20-D1.3s

Advance Preparation

- Photocopy **BLM 6.2.4: Thought Lab 6.2**

Time Required

- 30 minutes

Helpful Tips

- Use **BLM 6.2.4: Thought Lab 6.2: An Accident and an Opportunity** to support this activity. Remove sections as appropriate to meet the needs of the students in your class. The answer can be found on BLM 6.2.4A.
- Consider assigning students in groups of four. Provide space for each group to meet and discuss each question and each excerpt. After 20 minutes, bring the groups together for a class discussion. Discuss any discrepancies with the students and see if they can arrive at a consensus.
- You can extend this discussion to see if this type of research would be allowed today.

Answers to Analysis Questions

1. **Excerpt B:** But from the result of a great number of experiments and examinations, made with a view to asserting the truth of this opinion, in the empty and full state of the organ,…I am convinced that there is no alteration of temperature.
2. **Excerpt E:** At 2 o'clock P.M.—twenty minutes after having eaten an ordinary dinner of boiled, salted beef, bread, potatoes, and turnips, and drank a gill [about 142 mL] of water, I took from stomach, through the artificial opening, a gill of the contents….Digestion had evidently commenced, and was perceptually progressing, at the time.
3. **Excerpt C:** I think I am warranted, from the result of all the experiments, in saying, that the gastric juice, so far from being 'inert as water,' as some authors assert, is the most general solvent in nature of alimentary [food-related] matter—even the hardest bone cannot withstand its action.
4. **Excerpt D:** The gastric juice does not accumulate in the cavity of the stomach until alimentary matter is received and excites its vessels to discharge their contents for the immediate purpose of digestion.
5. One idea that students may come up with is that there is some connection between the nervous system and the digestive system.
6. Students should note that Beaumont's observations were likely accurate. **Excerpt A:** I consider myself but a humble inquirer after truths—a simple experimenter. And if I have been led to conclusions opposite to the opinions of many who have been considered luminaries of physiology, and in some instances, from all the professors of this science, I hope the claim of sincerity will be conceded to me, when I saw that such difference of opinion has been

forced upon me by the convictions of experiment, and the fair deductions of reasoning.

They could also note the digestive properties of the gastric juice **Excerpt C:** I think I am warranted, from the result of all the experiments, in saying, that the gastric juice, so far from being 'inert as water,' as some authors assert, is the most general solvent in nature of alimentary [food-related] matter—even the hardest bone cannot withstand its action.

Or, students could note that digestion starts immediately. **Excerpt E:** At 2 o'clock P.M.—twenty minutes after having eaten an ordinary dinner of boiled, salted beef, bread, potatoes, and turnips, and drank a gill [about 142 mL] of water, I took from stomach, through the artificial opening, a gill of the contents….Digestion had evidently commenced, and was perceptually progressing, at the time.

7. Students should note that as a researcher, Beaumont asked questions, conducted experiments in an attempt to answer these questions, and then communicated the inferences that he made based on his observations.

Assessment Option

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

Answers to Questions for Comprehension

Student Textbook page 223

Q20. In the small intestine, bands of circular muscle briefly contract forming closed segments. This process is called segmentation. Chyme is sloshed back and forth within the segment, causing physical digestion and mixing the nutrient macromolecules with digestive enzymes. Such movement increases contact between nutrients and the intestinal wall which enhances nutrient absorption. Peristalsis also occurs, mixing food and enzymes and pushing it on toward the large intestine.

Q21. The ridges in the inner lining of the small intestine are covered in tiny projections called villi, which, in turn, are covered in microvilli. Together, the ridges, villi, and microvilli vastly increase the absorptive surface area of the small intestine.

Figure 6.18

Student Textbook page 223

Mitochondria provide the energy (ATP) for active transport of nutrients out of the digestive tract and into the bloodstream.

Biology File: Try This

Student Textbook page 223

The surface area of the tubing would be:

Surface area $= \pi \times d \times h$

Surface area $= 3.14 \times 4\text{ cm} \times 280\text{ cm}$

Surface area $= 3519\text{ cm}^2$

If the tubing were small intestine, the surface area would become:

Surface area $= 3519\text{cm}^2 \times 30 \times 600$

Surface area $= 63\,342\,000\text{ cm}^2$ or 6334.2 m^2

The surface area of the small intestine is 18 000 times greater than the same length of tubing.

Answer to Question for Comprehension

Student Textbook page 224

Q22. The pancreas, liver, and gall bladder produce and/or store secretions necessary for digestion of macromolecules.

Pancreas: The **pancreas** delivers about 1 L of pancreatic fluid to the duodenum each day. Pancreatic fluid contains a multitude of enzymes, including:

- trypsin and chymotrypsin, which are proteases that digest proteins;
- pancreatic amylase, which is a carbohydrate that digests starch in the small intestine; and
- lipase, which digests fat.

Liver: The **liver** is the largest internal organ of the human body. The main digestion-related secretion of the liver is bile, a greenish-yellow fluid mixture that is made up of bile pigments and bile salts. Bile salts assist lipases in accessing fats because they are partly soluble in water and partly soluble in fats. Bile salts work like a detergent, dispersing large fat droplets into a fine suspension of smaller droplets in the chyme. This emulsification process produces a greater surface area of fats on which the lipases can act.

Gall Bladder: After bile is produced in the liver, it is stored in the **gall bladder**. The arrival of chyme, with a high fat concentration, in the duodenum stimulates the gall bladder to contract. This causes bile to be transported through a duct (shared by both the gall bladder and the liver) and injected into the duodenum.

Biology File: Web Link

Student Textbook page 226

The symptoms of lactose intolerance are:

- nausea
- cramps
- bloating
- gas; and/or
- wind diarrhea, which may begin anywhere from half an hour to two hours after eating or drinking foods containing lactose.

In rare cases, children are born without the ability to produce lactase. For most people, though, lactase deficiency is a condition that develops naturally over time. After about the

age of two years, the body begins to produce less lactase. However, many people may not experience symptoms until they are much older.

Between 30 and 50 million Americans are lactose intolerant. Certain ethnic and racial populations are more widely affected than others. As many as 75 percent of all African Americans and First Nation peoples and 90 percent of Asian Americans are lactose intolerant. The condition is least common among persons of northern European descent.

Answers to Questions for Comprehension

Student Textbook page 226

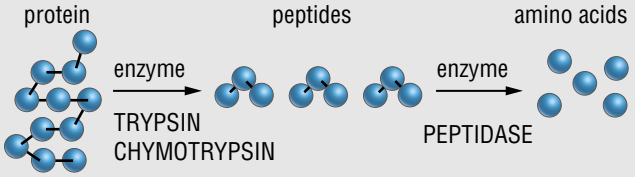
Q23. The following is one possible answer for this question.

Most of the digestion of carbohydrates does not take place until the chyme enters the small intestine, where the pH is about 8. In the small intestine, pancreatic amylase completes the digestion of starch into disaccharides. Other carbohydrases hydrolyze the disaccharides into monosaccharides, such as glucose and fructose.

Monosaccharides are absorbed by active transport into the cells of the intestinal villi. The active transport of glucose and other monosaccharides requires ATP, which is produced in the mitochondria of cells. From the cells of the intestinal lining, the monosaccharides enter the bloodstream and are transported directly to the liver.

Student Textbook page 227

Q24. A sketch showing protein digestion and absorption might appear as follows:



Student Textbook page 228

Q25. The arrival of lipids (fats) in the duodenum stimulates the secretion of bile, which emulsifies the fat droplets. The breakdown of fats by hydrolysis is carried out by lipase secreted in the duodenum. The resulting glycerol and fatty acids are absorbed into the cells of the villi by simple diffusion. Inside the cells of the intestinal lining, the fat sub-units are reassembled into triglycerides and then coated with proteins to make them soluble before they enter the lymph vessels in the villi.

Q26. In the small intestine, nucleic acids are digested by enzymes, called nucleases, to yield nucleotides. The nucleotides are hydrolyzed to their constituent bases, sugars, and phosphates. These molecules are then absorbed, like glucose and amino acids, into the bloodstream by active transport.

Investigation 6.B: Optimum pH for Two Protease Enzymes

Student Textbook pages 228–229

Purpose

Students perform an experiment to investigate the influence of pH on the activity of pepsin and trypsin.

Outcomes

- 20–D1.3k
- 20–D1.2s
- 20–D1.1s (Extension)
- 20–D1.3.s

Advance Preparation

When to Begin	What to Do
beginning of the year (or semester)	■ Check on quantity of the enzymes required and order, if necessary.
2 or 3 days prior	■ Purchase consumable food products, such as eggs. ■ Photocopy **BLM 6.2.9: Investigation 6.B: Optimum pH for Two Protease Enzymes**. ■ Photocopy Assessment Checklist 2 Laboratory Report if you are planning to use this tool to evaluate this activity.
the day of the activity	■ Organize all materials and make the enzyme solutions.

Materials

- 6 test tubes
- test-tube rack
- metric ruler
- 10-mL graduated cylinder
- test-tube holder
- water bath or incubator at 37 °C
- 18 cubes of boiled egg white (protein samples)
- 10 mL distilled water
- 20 mL 2% pepsin solution
- 20 mL 5% trypsin solution
- 15 mL dilute hydrochloric acid (0.01 mol/L)
- 15 ml dilute sodium hydroxide (0.01 mol/L)

Time Required

- 1.5 hours (1 hour on day 1 to set up lab; 30 minutes on day 2 to record observations and clean up)

Helpful Tips

- Distribute **BLM 6.2.9: Investigation 6.B: Optimum pH for Two Protease Enzymes.** This BLM will help students organize each part of this activity and keep track of their results. Answers can be found on 6.2.9A.
- Ensure students read, understand, and follow all Safety Precautions for this investigation.
- Have all solutions ready before the lab starts. Spread them out in different stations to reduce the number of students moving to one area.
- Predetermine student groups (4 students per group).
- Remind groups that they need to collect materials quickly and efficiently to complete the work in a short period of time.
- Consider spending some time doing some advance preparation with your students to make sure that they understand the procedure for this investigation.
- To prepare egg white (albumen), boil eggs for at least 5 minutes. Cool and cut the egg whites into 5 mm square cubes. One egg will make about 50 cubes.
- To prepare dilute (0.01 M) HCl, which has a pH of 2, add 50 mL of 0.1 M HCl to 300 mL of distilled water and then dilute to a final volume of 500 mL.
- To prepare dilute (0.001 M) NaOH, which has a pH of 8, add 5 mL of 0.1 M NaOH to 300 mL of distilled water and then dilute to a final volume of 500 mL.
- To prepare a 2% pepsin solution, place 4 g of dry pepsin in a flask and dilute it with 200 mL of distilled water. Use diluted HCl to adjust the pH of the solution to 2.
- To prepare a 5% trypsin solution, place 10 g of dry pancreatin (a mixture of trypsin, amylopsin, and lipase) in a flask and dilute it with 200 mL distilled water. Use diluted NaOH to adjust the pH of the solution to 8.
- ***Expected Results:*** The change in the size of the egg whites could be a bit difficult for most students to determine. However, students should see no change in the size of the egg cubes in either control test tube.

  They should see a decrease in the size of the egg cubes in P-2 (pepsin is active in an acidic pH) and T-8 (trypsin is active in a slightly alkaline pH).

Safety Precautions

- Refer to the document *Safety in Science Classroom* published by Alberta Education (see Alberta Education web site) before starting this Investigation. You can search this document to identify information, including the chemical name, state, WHMIS class, hazards, and disposal information.
- There are a number of general guidelines that can be followed to increase safety when working with chemicals.
  (a) Ensure that the chemical is appropriately labelled and that the MSDS is readily available.
  (b) Minimize exposure to chemicals.
  (c) Do not handle or use chemicals unless you are WHMIS trained.
  (d) Before using any chemical, review its MSDS to determine potential hazards.
  (e) Inform students of hazards and the necessary safety precautions.
  (f) Never underestimate risks when mixing chemicals.
- Post the MSDS pages for hydrochloric acid and sodium hydroxide.
- Monitor mixing of solutions in test tubes. Check that students do not put their fingers or thumbs over the openings of test tubes to shake them.

Answers to Analysis Questions

1. The only difference between the control test tubes and the contents of P–2/P–8 is the control tubes only contain distilled water while the other tubes have pepsin (enzyme).

2. (a) Pepsin was more active in a pH of 2.

(b) Trypsin was more active in a pH of 8.

Answers to Conclusion Questions

3. The small intestine normally has a pH of 8. Trypsin was more active in the solution with a pH of 8. Therefore, trypsin would be the enzyme that breaks down protein in the small intestine.

4. The stomach normally has a pH of 2. Pepsin was more active in the solution with a pH of 2. Therefore, pepsin would be the enzyme that breaks down protein in the stomach.

Answers to Extension Questions

5. (a) Enzymes are proteins. These molecules are very temperature-sensitive. Maintaining the temperature between 35 °C and 39 °C mimics the optimum temperature range for these enzymes.

(b) Students should point out that there was a fairly low degree of certainty in this Investigation because it was qualitative rather than quantitative. For example, they did not do any quantitative measures, such as determining the mass of the egg cubes before and after the Investigation. There were also potential sources of error. For example, the "cubes" of egg white were not exactly the same size. Another source of error could be the use of a hot water bath instead of an incubator—it would be difficult to maintain a constant temperature if the hot water bath was used.

6. Students could indicate that the temperature or the concentration of enzyme solution could be manipulated in subsequent investigations. The procedure should be similar to the one provided in the student textbook and

should include all safety precautions. If temperature is being manipulated, the procedure should indicate that the enzyme solutions have to have the same pH and be of the same concentration. They should predict that enzyme activity would be reduced at temperatures above or below the optimum temperature. If the concentration of enzyme solution was being manipulated, they would have to control the pH of each solution and provide the optimum temperature for enzyme action. They should predict that enzyme activity would be greater at higher concentrations.

Assessment Options

- Collect and assess students' answers to the Analysis, Conclusion, and Extension questions.
- Use Assessment Checklist 2: Laboratory Report, if students are completing a report.

Alternate Investigation: Digestion of Lipids Found on BLM 6.2.8: Digestion of Lipids

Purpose

To perform an experiment to investigate the influence of pH on the activity of pepsin and trypsin.

Outcomes

- 20–D1.3.k
- 20–D1.2s
- 20–D1.3.s
- 20–D1.4s

Advance Preparation

When to Begin	What to Do
■ start of year (semester)	■ Check on quantity of the enzymes required, and order if necessary
■ two or three days prior	■ Purchase consumable food products ■ Photocopy **BLM 6.2.8 Alternate Investigation: Lipase Digestion**
■ the day of the activity	■ Organize all materials and make the enzyme solution

Materials

- 3 test tubes
- test-tube holder
- plastic sandwich wrap
- 3 medicine droppers
- water bath or incubator at 37 °C
- aprons (1 per student)
- eye goggles (1 per student)
- disposable plastic gloves
- 6 mL cereal cream
- 2 mL lipase solution
- bile salts
- distilled water
- phenolphthalein solution

Time Required

- 1 hour

Helpful Hints

- Use **BLM 6.2.8: Alternate Investigation: Lipase Digestion** to support this activity. Modify it as necessary to meet the needs of your students. The answers can be found on BLM 6.2.8A.
- Ensure students read, understand, and follow all Safety Precautions for this investigation.
- Have all solutions ready before the lab starts. Spread them out in different stations to reduce the number of students moving to one area.
- Predetermine student groups (4 students per group).
- Remind groups that they need to collect materials quickly and efficiently to complete the work in a short period of time.
- Consider spending some time doing some advanced preparation with your students to make sure that they understand the procedure for this investigation.
- To prepare a 2% sodium carbonate solution, place 2 g of sodium carbonate in a flask and dilute it with 100 mL of distilled water.
- To prepare a 2% lipase solution, place 2 g of lipase powder into a flask and dilute it with 100 mL of distilled water.
- Phenolphthalein is a pH indicator. It is pink in a weak base (above pH 8.3) and turns colourless as the pH decreases. A colour change from pink to colourless (or in this case the milky appearance) would indicate the solution is turning slightly more acidic.
- You can extend this investigation by having your students design their own investigation to determine the effects of enzyme concentration on enzyme activity and/or the effects of pH on the action of lipase.

Safety Precautions

- Refer to the document *Safety in Science Classroom* published by Alberta Education (see Alberta Education web site) before starting this investigation. You can search this document to identify information including the chemical name, state, WHMIS class, hazards, and disposal information.

Answers to Analysis Questions

1. Test tube B will show the fastest colour change.
2. Phenolphthalein is a pH indicator. It is pink in a weak base (above pH 8.3) and turns colourless as the pH decreases. A colour change from pink to colourless (or in this case the milky appearance) would indicate the solution is turning slightly more acidic.
3. Bile is an emulsifier. It breaks large fat drops into tiny fat droplets increasing the surface area for the action of lipase.

Answers to Conclusion Questions

4. *Test Tube A:* Lipase will eventually digest the fat in the cream to fatty acids and glycerol. The phenolphthalein should change colour from pink to colourless but this could take some time.

   Test Tube B: Bile emulsifies the fat drops in the cream resulting in tiny droplets. The tiny fat droplets have much more surface area compared to the larger drops. As a result, lipase will digest fats to fatty acids and glycerol. As the concentration of fatty acids increase the pH of the solution will decrease and the phenolphthalein will turn from pink to colourless.

   Test Tube C: There will not be a colour change—it will stay pink. This test tube lacks the enzyme lipase so no chemical digestion of the fat in the cream can take place.
5. Test Tube B best mimics conditions in the small intestine.
   - Sodium bicarbonate is found in pancreatic secretions that enter the duodenum, changing the pH of the chyme from a pH of 2 to a pH of approximately 8.
   - The bile salts represent bile that is manufactured by the liver and stored in the gall bladder.
   - When fat enters the duodenum it triggers a hormonal regulated event which results in the gall bladder contracting and secreting bile into the duodenum.
   - Lipase enzymes are produced by the pancreas and small intestine. These enzymes catalyze the breakdown of lipids (fats and oils) into fatty acids and glycerol.

Assessment Options

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

Answer to Question for Comprehension

Student Textbook page 230

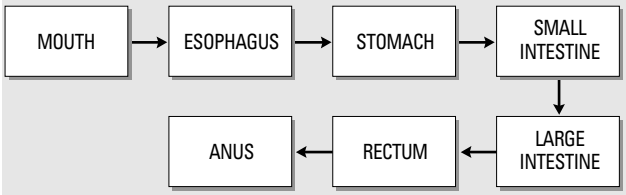
Q27 Gastrin, produced by the lower part of the stomach, enters the bloodstream and stimulates the upper part of the stomach to produce more gastric juice.

Secretin and CCK, produced by the duodenal wall, stimulate the pancreas to secrete its digestive juice and the gall bladder to release bile.

Section 6.2: Review Answers

Student Textbook page 231

1. Flow chart showing pathway of food through the digestive tract:



2. The salivary glands, liver, gall bladder, and pancreas are considered accessory organs. They add secretions involved in digestion to the digestive tract. However, food does not pass through these organs.
3. There would be significantly less surface area available for chemical digestion. This would slow down the action of enzymes (reduce the efficiency of digestive enzymes).
4. Several reasons can be given. First, most enzymes are secreted into the small intestine where the pH is about 8. These enzymes would be denatured by the acid in the stomach. Secondly, in the intestine, bile from the liver and gall bladder storage depot emulsifies fat, increasing the surface area for chemical digestion. Fat in the stomach has not been emulsified. Thirdly, since the small intestine is much longer than the stomach, there is more time for enzymatic digestion to occur as food is moved along its length.
5. The secretions from all three organs are released into the duodenum. The liver produces bile that contains bile salts that emulsify fats. The gall bladder concentrates and stores bile and releases the concentrated solution when chyme arrives from the stomach. The pancreas produces many enzymes that aid chemical digestion. The pancreas also secretes bicarbonate ions that neutralize the acidic chyme, changing the pH to about 8.
6. The presence of villi and microvilli increase the surface area of the intestinal wall. Capillaries and lymph vessels are found within each villus. These observations support the notion that it is well adapted for absorption of nutrients.

Connections (Science and Technology) Sorting Out Nutritional Supplements

Student Textbook page 232

Teaching Strategies

- Survey the class to find out how many students take supplements and what they are. Expand the inquiry to those who have family members who take supplements in order to increase participation in the discussion. List the supplements that are taken.
- Now that students have studied the process of digestion in some detail, ask them to relate the digestion process to the concept of bioavailability. Students should be able to recognize that digestion and the absorption of nutrients is a highly specialized mechanical and chemical process and that supplements need to be tested to ensure that they are in a form that can be used by the human body.

Answers to Questions

1. Some of the variables in this feature include the source of calcium, the age of the test subjects, and the gender of the test subjects.
2. Students should recognize that the age of the sample being tested is far too wide to make any concrete inferences. As well, both male and female subjects are being tested, which will make it difficult to arrive at a definite conclusion.
3. In order for this to be a fair test, only one variable should be manipulated. Investigators should use a smaller age range and/or investigate the uptake of calcium in either male or female subjects.
4. Students' answers will depend on (a) the type of supplements; (b) the availability of these supplements; (c) the cost of supplements investigated; and (d) if the supplements are supplied directly from a pharmaceutical company or if they are a generic brand.

6.3 Health and the Digestive System

Student Textbook pages 233–238

Section Outcomes

Students will:

- recognize and appreciate the relationship between health and nutritional decisions
- identify conditions that adversely affect the health of the digestive system and the technologies that are available to treat them

Key Terms

ulcer
inflammatory bowel disease
hepatitis
cirrhosis
gallstones
anorexia nervosa
obesity

Biology Background

- The actions of the digestive system help to keep us healthy and maintain homeostasis. The digestive system provides nutrients when we need them, while storing some nutrients for future use. When it is impaired, the results can range from a minor inconvenience to a major impediment to normal life.
- Our diets are closely linked to our lifestyles and life choices. Although diets differ, it is still necessary to maintain a balance of nutrients. North American society places great value on being thin and, unfortunately, this often results in many quick and unhealthy weight loss options. In some cases, individuals may become obsessed with their weight and deprive their bodies of basic nutrients in order to stay thin. Young women, in particular, are affected by this pressure and may respond by developing eating disorders.

Teaching Strategies

- This section is primarily information based. You may want to use a group research/group presentation teaching strategy for this section.
- This section includes discussion of eating disorders. It is very important to be aware of any students in your class that may in fact be dealing with anorexia, bulimia, or obesity.

SUPPORTING DIVERSE STUDENT NEEDS

- Encourage students to build their own glossaries in their science notebooks or in a database as an ICT exercise. ESL students may benefit from including pictures, flow charts, or explanations in their first language.
- Provide some key questions that are addressed by the section to assist students in creating their personal study guides.

Answer to Question for Comprehension

Student Textbook page 233

Q28. The effects of poor dietary and lifestyle habits may take weeks, months, or even years to show up. Good nutrition is the only way to provide the energy our bodies need to carry out their many activities, such as nerve transmission, muscle contraction, and cell repair and replacement. As well, good nutrition provides the essential raw materials that our bodies need as building blocks but are unable to manufacture ourselves.

Biology File: Web Link

Student Textbook page 234

Before the discovery of *Helicobacter pylori*, it was generally thought that the stomach was a sterile environment and that peptic ulcers were largely caused by lifestyle choices and/or stress. In the 1960s and 1970s, acid-suppressing drugs often managed to cure peptic ulcers without surgery. However, the ulcers often recurred and it was generally thought that it was because of the lifestyle choices that caused them in the first place.

In the early 1980s, two Australian doctors, Warren and Marshall, found a bacterium that lived in the lower half of the stomach. This bacterium was adapted for life in the stomach and could conceal itself in the stomach lining in such a way that it could not be attacked and destroyed like other bacterium that entered the stomach.

What Warren and Marshall did, in chronological order, was to:

- notice that inflammation of the stomach (gastritis) was associated with the presence of a bacterium (Warren);
- study 100 patients and discover that this bacterium was present in every patient who suffered from a duodenal ulcer (Warren and Marshall);
- grow the first culture of the bacterium, which was later named *Helicobacter pylori* (Marshall and microbiologists from Royal Perth Hospital);
- swallow a culture of this bacterium and suffer acute symptoms in order to prove the hypothesis that *H. pylori* was the cause of gastritis and peptic ulceration (Marshall);
- promote this hypothesis, despite significant scepticism from gastroenterology specialists; and
- stimulate much research and treatment trials, through persistence and publication of research papers, which eventually proved that *H. pylori* did, indeed, cause gastritis and gastric ulcers.

Answers to Questions for Comprehension

Student Textbook page 235

Q29. An ulcer forms when the thick layer of mucus that protects the lining of the stomach from the acids in the digestive juices is eroded.

Q30. Inflammatory bowel disease is the general name for diseases that cause inflammation in the intestines (bowels). Crohn's disease (also called ileitis or enteritis) is a serious inflammatory bowel disease that usually appears in the ileum of the small intestine but can affect any part of the digestive tract from the mouth to the anus. The inflammation extends deep into the lining of the affected organ, causing the intestines to empty frequently. This results in diarrhea and sometimes rectal bleeding. Thus, Crohn's disease is very painful.

Q31. The body depends on the liver to perform a number of vital functions. These functions can be divided into three basic categories:

- regulation, synthesis, and secretion of many substances important in maintaining homeostasis;
- storage of important nutrients such as glycogen (glucose), vitamins, and minerals; and
- purification, transformation, and clearance of waste products, drugs, and toxins.

A number of diseases can directly damage the liver. Damage to the liver can seriously affect the absorption of vitamins and nutrients, prevent waste products from being effectively removed from the system, and reduce the production of proteins needed to clot the blood.

If the damage is severe enough, transplantation may be necessary. A transplant provides a patient with a liver that can keep up with the demands of a full, active life.

Biology File: Web Link

Student textbook page 235

- Gallstones, which are formed when the chemical balance in the gall bladder is unbalanced, block the common bile ducts and the flow of pancreatic juices. Gallstone and long-term alcohol abuse are the leading causes of pancreatitis.
- Elevated levels of the pancreatic enzymes amylase and lipase are signs of pancreatitis.
- Nutritional strategies for avoiding pancreatitis include eating smaller meals; emphasizing fresh fruits and vegetables, whole grains, and lean protein; and avoiding fats, especially saturated fats.

Biology File: Web Link

Student Textbook page 236

In gastric bypass surgery, the stomach is made smaller by creating a small pouch at the top of the stomach, using surgical staples or a plastic band. The smaller stomach is connected directly to the middle portion of the small intestine (jejunum), bypassing the rest of the stomach, and the upper portion of the small intestine (duodenum).

Gastric bypass surgery makes the stomach smaller and allows food to bypass part of the small intestine. The person will feel full more quickly, which reduces the amount of food eaten (calories consumed). Bypassing part of the intestine also results in fewer calories being absorbed. This leads to weight loss.

Although guidelines vary, surgery is generally considered when the individual's body mass index is 40 or higher or if they have a life-threatening or disabling condition related to their weight. Some doctors will only consider doing gastric bypass surgery if the patient has not been able to lose weight with other treatments.

Most people who have gastric bypass surgery quickly begin to lose weight and continue to lose weight for up to 12 months. One study noted that people lost about one-third of their excess weight (the weight above what is considered healthy) in one to four years. One clinic claimed a long-term success rate of 99 percent since the program's inception.

Success is achieved when patients maintain a 70 percent loss of excess body weight.

Answers to Questions for Comprehension

Student Textbook page 236

Q32. Anorexia and obesity represent normal diets gone awry. Anorexic people relentlessly pursue thinness by literally starving themselves for varying periods of time. Seriously overweight people—defined medically as those who are more than 20 percent over their ideal weight—are often plagued by compulsions to eat.

Anorexia and other eating disorders are unhealthy responses to stress, painful feelings, and other problems. While the specific cause is unknown, the condition seems to stem from a combination of psychological, biological, familial, and cultural factors. New research indicates that, in 1 anorexic out of 10, a genetic abnormality may be involved.

Student Textbook page 237

Q33. You may wish to share this quotation with them:

> "Our elders teach us that although our ancestors did not have problem-free lives, our people were in excellent health before European contact. We are told that long ago people died mainly from such things as old age, complications for mothers and infants during and immediately after child-birth, and fatal injuries inflicted in battles with warring tribes. Moreover, our ancestors were very spiritual and ethical in dealing with self and others. This strength of mind contributed to the wellness of our people. So too did their healthy diet. All food was truly natural and pure. There were no such things as iodized salt, refined sugar and chemically treated food. Babies developed strong bones and immune systems as a result of being breastfed until they were three years of age. There was no trace of contemporary childhood diseases such as measles, mumps, and chicken pox. Being a migrating nation meant that everyone was physically active and generally in good condition. People walked for many miles during times of migration, hauling necessities such as water and wood by hand. Together with a strong sense of spiritual purpose, these factors contributed to the excellent physical, intellectual, emotional, and communal health of the Stoney People. Even today, our people experience a deep sense of pride in knowing that our ancestors were healthy and well-organized and that they had the ability to survive in harsh environmental conditions. Our elders also tell us that physical illness was rare before European contact, and when necessary there were medicine people to address most health needs.

Source: Long, D. A. and T. Fox. "Circle of Healing: Illness, Healing and Health Among Aboriginal People in Canada." In *Visions of the Heart: Canadian Aboriginal Issues*, edited by D.A. Long and O.P. Dickason. Harcourt: Toronto, 1996, p. 252.

Biology File: Web Link

Student Textbook page 237

A "food additive," as defined under the Canadian Food and Drug Regulations, means any substance, including any source of radiation, which becomes a part of or affects the characteristics of food. Based on this definition, the term does not refer to salt, sugar, and starch used as ingredients of food or commonly sold as food products. (Certain other substances are excluded from the definition because they fall into categories covered separately under the Food and Drug Regulations and are thus subject to other controls. These ingredients include vitamins, mineral nutrients, amino acids, spices, seasonings, and flavouring preparations, as well as agricultural chemicals, food-packaging materials, and veterinary drugs.)

The current list of approved additives includes 380 substances, classified into 14 tables based on the function of the additives.

Thought Lab 6.3: Enzymes and Diet

Student Textbook page 238

Purpose

Students evaluate the role of technology in solving problems that involve dietary choices.

Outcomes

- 20–D1.1sts
- 20–D1.2sts
- 20–D1.3s
- 20–D1.4s

Advance Preparation

When to Begin	What to Do
2 to 3 weeks before	■ Book the library and/or computer lab for student research.
2 days before	■ Photocopy **BLM 6.3.1: Thought Lab 6.3: Enzymes and Diet** ■ Photocopy Assessment Checklist 7 Independent Research Skills.

Materials
none

Time Required

- 2 hours (1 hour for research and 1 hour to complete the Analysis and Extension questions)

Helpful Tips

- Bookmarking some specific web sites will save the amount of time that students spend searching the Internet for sources of relevant information.
- Use this opportunity to review how to search the Internet. Refer students to "Safety in Your Online Activities"on page xvi of the student book.
- This activity provides students with an opportunity to investigate "fad diets." Use this opportunity to also talk about the reliability and validity of information available on the Internet.
- Use B**LM 6.3.1: Enzymes and Diet** to support this activity. Answers can be found on BLM 6.3.1A.

Answer to Analysis Question

1. Students' answers will depend on their personal beliefs and ideologies. The following is a brief overview of a raw food diet.

Those who follow this way of eating generally believe the following:

- Raw foods contain enzymes that act as catalysts to regulate the digestive process in the body.
- Heating (or freezing) food degrades or destroys enzymes in food.
- Food without enzymes is thought to lead to toxicity in the body, excess consumption of food, and, therefore, obesity.
- Living and raw foods are thought to have much higher nutrient values than foods that have been cooked.

The main idea behind raw food diets is that cooked food is supposedly toxic, because cooking destroys the enzymes contained in food.

Critics of this Diet

Raw food diets have been criticized in the mainstream medical community as being too harsh and restrictive.

- A raw food diet requires special care to include the recommended amounts of several important vitamins and nutrients, including vitamin B-12 and protein. If adopted for an extended period of time without special attention to essential nutrients, any restrictive diet can lead to nutritional deficiency.
- Much of the research advocating raw food diets has been criticized. Critics say that food enzymes cannot be fully utilized by the human body, since they are destroyed during the digestive process.
- Some nutrients are only fully released in cooking, including lycopene in tomatoes, and beta carotene in carrots.
- It is also argued that humanity has been cooking for such a long time that the human body can hardly be ill adjusted to cooked food.
- Many claims of "enhanced enzyme activity" ignore the vast and specific roles that enzymes play in physiological processes.
- Any enzyme ingested, whether raw or cooked, is rapidly digested into inactive peptides in the stomach.

Is it healthy for all people?

Proponents of this diet will support it while others reject it as being dangerous. Here is a quotation from the FAA in the United States:

> Many highly touted weight reduction diets are unhealthy or dangerous. Single food diets are nutritionally bankrupt and may cause problems with gall bladder disease. Very low calorie diets have some of the same problems. Diets that avoid single macronutrients such as fats, protein, or carbohydrates tend to be nutritionally depleted also. Long-term success with weight control is best achieved with a healthy, nutritionally balanced diet that is enjoyable and sustainable.

Is it healthy for dogs and cats?

There are many proponents that support this diet is healthy for cats and dogs. However, no scientific proof was provided supporting this claim.

Answer to Extension Question

2. Use Assessment Checklist 7 Independent Research Skills to guide students through this process.

Industrial enzymes are those catalysts used on large production-oriented scales to aid the reactions of mass quantities of chemicals. For example, specific enzymes are used in a number of applications, such as laundry detergents, paper bleaching, and food processing.

Development of medical applications for enzymes has been at least as extensive as those for industrial applications, reflecting the magnitude of the potential rewards. For example, pancreatic enzymes have been in use since the nineteenth century for the treatment of digestive disorders. The variety of enzymes and their potential therapeutic applications are considerable.

In contrast to the industrial use of enzymes, therapeutically useful enzymes are required in relatively tiny amounts, but at a very high degree of purity and (generally) specificity. A major potential therapeutic application of enzymes is in the treatment of cancer. Asparaginase has proved to be particularly promising for the treatment of acute lymphocytic leukemia.

Assessment Options

- Collect and assess answers to Analysis and Extension questions.

■ Use Assessment Checklist 7: Independent Research Skills.

Section 6.3 Review Answers

Student Textbook page 238

1. (a) Ulcers are caused by the acid-resistant bacteria *Heliobacter pylori* or by smoking, caffeine, alcohol intake, or stress.

(b) A gastric ulcer occurs when the thick layer of mucus that protects the lining of the stomach is eroded and the stomach acid eats away at the stomach wall. Technology to treat ulcers includes medications to either decrease the amount of acid or to strengthen the mucus layer. Antibiotics may also be used to reduce the growth of bacteria. Surgery can be done to block nerve signals that stimulate acid release or to remove part of the stomach. X-rays, and endoscopes are technologies used to diagnose ulcers.

2. Crohn's disease and colitis are characterized by similar symptoms. There is no cure for either, and treatment options are the same. They differ in that Crohn's affects any part of the digestive tract and the inflammation extends deep into the lining of the affected organ. Colitis occurs only in the colon and only the innermost lining is inflamed. Treatments include medications to reduce the pain, to reduce inflammation, or to reduce the immune response. Dietary modifications are useful in treating symptoms. As a last resort, surgery to remove the diseased parts of the digestive tract can be done.

3. Liver diseases pose serious health risks because the liver performs so many vital functions. In addition to producing bile salts for emulsification, the liver produces blood proteins, some needed for blood clotting. It stores glycogen, iron, vitamins, and poisons that cannot be broken down or excreted. The liver destroys alcohol and drugs and deaminates amino acids. It also excretes bile pigments that are by-products of destruction of hemoglobin from old red blood cells.

4. Since anorexia nervosa and obesity are connected to psychological problems, treatment involves psychotherapy as well as family therapy, and education in addition to physiological treatment. This increases the time and cost of treatment.

5. A person with pancreatitis would have difficulty digesting proteins, starch, and lipids in the small intestine because:

- lack of trypsin and chymotrypsin would reduce protein digestion
- lack of pancreatic amylase would reduce starch digestion
- lack of lipase would reduce fat digestion

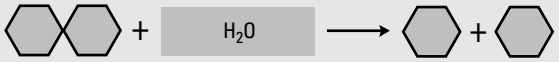
Chapter 6 Review Answers

Student Textbook pages 240-241

Answers to Understanding Concepts Questions

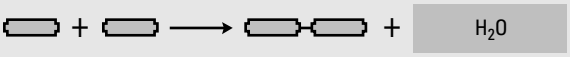
1. The following diagram can be used to represent the dehydration synthesis of maltose from two molecules of glucose.

The following diagram can be used to represent the hydrolysis of maltose to form two molecules of glucose.



A comparison of these processes shows that they represent a reversible chemical reaction. In one direction maltose is formed from 2 glucose molecules; in the opposite direction maltose is split into two glucose molecules.

2. A peptide bond is formed between two amino acids by removing a molecule of water. The following diagram represents the dehydration synthesis that forms a dipeptide molecule.



3. Essential amino acids cannot be synthesized in the body so unless they are provided in the diet, one suffers from an amino acid deficiency.

4. Monosaccharides such as glucose and fructose are simple sugars with 3 – 7 carbon atoms and with a number of hydrogen and oxygen atoms. A disaccharide such as maltose and sucrose consist of two simple sugar units bonded together. Polysaccharides like starch and glycogen are long chains of simple sugar units (usually glucose) bonded together in various ways.

5. Some proteins function as building blocks for body tissues. Some are enzymes, antibodies, hormones, neurotransmitters or transport molecules such as hemoglobin, the oxygen carrying pigment in the blood.

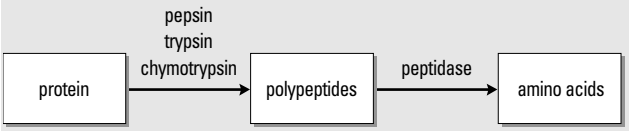
6. We know that the stomach is an organ in which both physical digestion and chemical digestion because:

- the folds of the stomach, called rugae, allow the stomach to expand as it fills with food. The muscular layers of the stomach churn the food, breaking it into smaller pieces (mechanical or physical digestion) and pushing it into the small intestine.
- the gastric glands release pepsinogen and hydrochloric acid that activates pepsin for chemical digestion of protein

7. Flow Charts Summarizing Chemical Digestion:

(a) The digestion of starch

(b) The digestion of protein

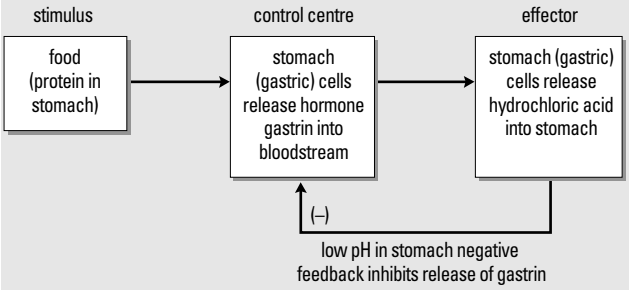


(c) The digestion of fat

8. The role of the liver in the physical digestion of fats is the production of bile that emulsifies fats in the small intestine (duodenum). Bile salts break large globules of fat into tiny droplets thereby increasing the surface area on which lipase chemically digests the fat.

9. The stomach has a pH of approximately 2 (very acidic). Pepsin in the stomach is inactive until mixed with hydrochloric acid. This activation is essential for chemical digestion of proteins in the stomach

10.



11.

Label	Structure	Digestive Processes that occur in the Structure
A	mouth	physical and chemical digestion
B	liver	none; an accessory organ that produces bile for physical digestion of fats
C	gall bladder	none; accessory organ that stores bile for physical digestion of fats
D	large intestine	absorption
E	rectum	none; elimination of feces
F	esophagus	none; carries food from the mouth to the stomach
G	stomach	physical and chemical digestion
H	pancreas	none; accessory organ that produces digestive enzymes
I	small intestine	chemical and physical digestion absorption

12. **(a)** inflammatory bowel disease—is the general name for diseases that cause inflammation in the intestines

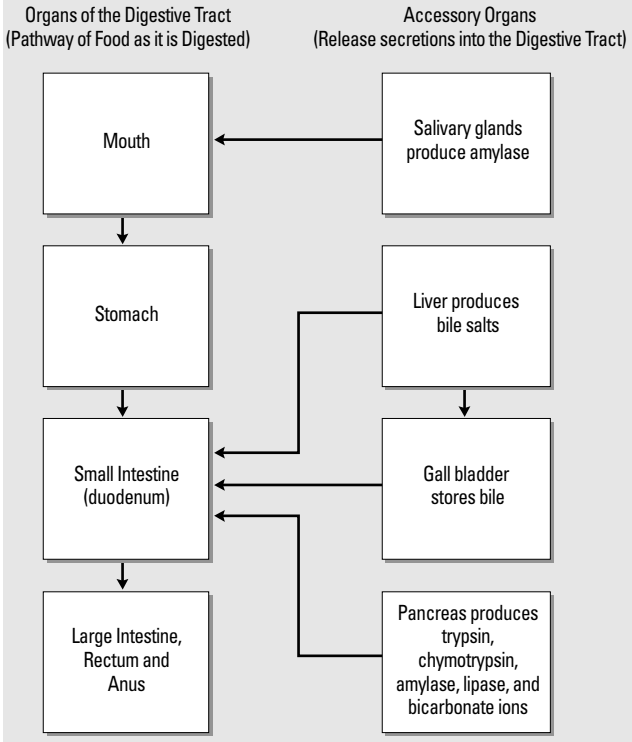
(b) cirrhosis—is a chronic disease of the liver that occurs when scar tissue replaces healthy liver tissue and prevents the liver from functioning properly

(c) ulcer—forms when the thick layer of mucus that protects the lining of the stomach from the acids in the digestive juices is eroded (acid eats away at the stomach wall after acid-resistant bacteria—*H. pylori*—attaches itself to the lining).

Answers to Applying Concepts Questions

13. The very acidic pH in the stomach kills many bacteria that are ingested. The immune system protects the child from potentially toxic bacteria that are not killed in the stomach.

14.



15.

Label	Structure	Secretion(s)	Function of each Secretion
A	salivary glands	■ salivary amylase ■ saliva	■ enzyme that contributes to the digestion of starch ■ lubricates the inside of the mouth to assist in swallowing
B	esophagus	■ mucus	■ lubricates the passage of food to the stomach
C	stomach	■ hydrochloric acid ■ proteases (pepsin)	■ its low pH activates precursor of pepsin ■ digests protein (large polypeptides) into smaller peptide chains
D	liver	■ bile	■ emulsifies fats
F	pancreas	■ trypsin and chymotrypsin ■ amylase ■ lipase ■ bicarbonate ions	■ digestion of protein into smaller peptide chains ■ digestion of starch ■ digestion of fats ■ neutralizes chyme to a pH of 8
G	small intestine	■ carbohydrases ■ proteases ■ peptidases ■ lipases ■ nucleases	■ digestion of carbohydrates ■ digestion of polypeptides ■ digestion of dipeptides ■ digestion of fats ■ digestion of nucleotides

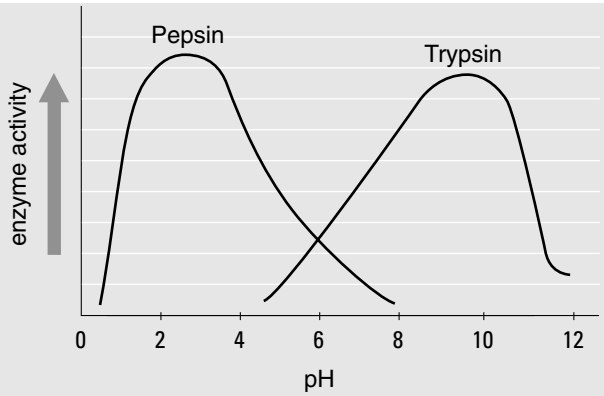
16. The following substances are identified by the following letters:

(i) Represents monosaccharides (from carbohydrate digestion) and amino acids (from protein digestion); these are absorbed directly into the bloodstream

(j) Represents protein-coated triglycerides (from fat digestion); these are absorbed into the lymphatic vessels

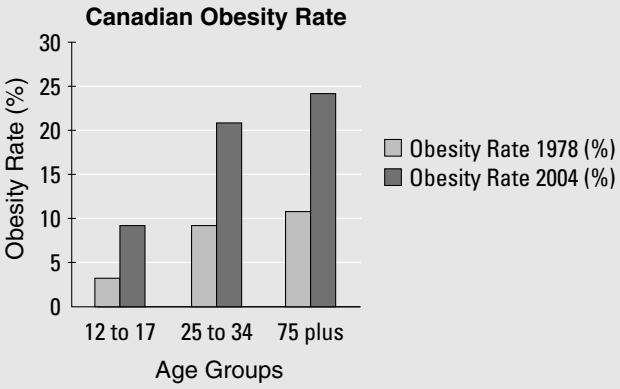
(k) Represents water, minerals (salts), and vitamins produced by bacteria; these are absorbed from the large intestine into the bloodstream.

17. The following graph represents the optimal environmental pH for the digestive enzymes pepsin and trypsin.



You could infer that pepsin is active in the stomach where the pH is approximately 2. Trypsin is active in the small intestine where the pH is close to 8.

18. The following graph shows the data on Canadian Obesity Rate.



19. (a) The obesity rate is increasing for all three age groups.

(b) Possible inferences including eating more fast food (higher fat in diet) or getting less exercise. Accept any reasonable answer.

Answers to Making Connections Questions

20. Ethical concerns include

- using scarce resources (liver for transplant) in a surgery that is likely to fail due to the presence of an underlying disease (alcoholism)
- "playing God" by asking healthcare professionals to decide who gets organs and who does not
- the "slippery slope" theory that once society begins refusing treatment because of lifestyle choices, the practice will expand to other areas (e.g., obesity treatment) because it is unethical to deny anyone in need of a new liver, even if underlying conditions jeopardize the chances of success.

21. The textbox points out that many people believe that alcoholics should be ineligible for a liver transplant. Some students will support that point of view while others will suggest that alcoholics should receive liver transplants. Others may suggest that the transplant be conditional on

receiving intensive therapy to combat alcoholism (e.g., Alcoholics Anonymous).

22. The gall bladder stores bile produced by the liver. Chyme, which has a high fat content, is a strong stimulus for the secretion of the hormone CCK. CCK travels through the bloodstream to the gall bladder. The hormone stimulates contractions of the gall bladder that inject more bile into the duodenum. The extra bile enhances the emulsification and subsequent digestion of fats.

23. After having a cholecystectomy, an individual might have to limit the amount of fat in their diet. This is necessary because the extra bile normally stored in the gall bladder is not available to emulsify fats.

24. Meal X (simple carbohydrates) would cause a more rapid increase in blood glucose levels than Meal Y (complex carbohydrates). Simple carbohydrates are digested into absorbable glucose more rapidly than complex carbohydrates.

25. (a) Given that the stomach acts as a reservoir for food during ingestion, restrictive surgery would limit the amount of food that a person could ingest during a meal. With less food entering the digestive tract, caloric intake would be reduced resulting in weight loss.

(b) Malabsorptive surgery removes sections of the small intestine. This would reduce the surface area through which nutrients are absorbed. The reduction of length might also reduce the time available for chemical digestion as the food moves toward the absorptive region (ileum) of the intestine. With fewer nutrients absorbed into the blood and lymph, caloric intake would be reduced resulting in weight loss.

CHAPTER 7 THE RESPIRATORY SYSTEM

Curriculum Correlation

Human Systems, General Outcome 1: Students will explain how the human digestive and respiratory systems exchange energy and matter with the environment.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
20–D1.1k identify the principal structures of the digestive and respiratory systems, i.e., ■ mouth, esophagus, stomach, sphincters, small and large intestines, liver, pancreas, gall bladder ■ nasal passages, pharynx, larynx, epiglottis, trachea, bronchi, bronchioles, alveoli, diaphragm, rib muscles, pleural membranes'	See Chapter 6 Section 7.1: The Respiratory Tract, pp. 245-247	See Chapter 6 Try This: Find your larynx and trachea, p. 245 Q questions 3, 4, p. 246; 5, p. 247 Section 7.1 Review: 4, 5, 8-13, p. 248 Section 7.2 Review: 1, 2, p. 254 Section 7.3 Review: 1, p. 262 Chapter 7 Review: 1, p. 264 BLM 7.4.1 Chapter 7 Test Unit Review: 3, 4, p. 356
20–D1.2k describe the chemical nature of carbohydrates, fats and proteins and their enzymes, i.e., carbohydrases, proteases, and lipases	See Chapter 6	See Chapter 6
20–D1.3k explain enzyme action and factors influencing their action	See Chapter 6	See Chapter 6
20–D1.4k describe the chemical and physical processing of matter through the digestive system into the bloodstream	See Chapter 6	See Chapter 6
20–D1.5k explain how gases and heat are exchanged between the human organism and its environment, i.e., mechanism of breathing, gas exchange, removal of foreign material	Launch Lab: Modelling Your Lungs, p. 243 Section 7.1: Stages in Respiration, pp. 244-245 Section 7.2: Breathing and Respiration, pp. 249-254	Launch Lab: Analysis 1-3, p. 243 Try This: Cellular respiration vs. respiration, p. 244 Q questions 1, 2, p. 245 Web Link: Laws of physical science, p. 246 Section 7.1 Review: 1-3, 7, 14, p. 248 Q question 6, p. 250; 7, 8, p. 252 Section 7.2 Review: 1, 3, 5-8, 10, 11, p. 254 Section 7.3 Review: 10, 12, p. 262 Chapter 7 Review: 2-4, 7, 9, 12, 14, p. 264; 16, 20, p. 265 Unit 4 Review: 11, 12, p. 356 BLM 7.4.1 Chapter 7 Test

	Student Textbook	Assessment Options
Outcomes for Science, Technology and Society (Emphasis on science and technology)		
20–D1.1sts explain that the goal of technology is to provide solutions to practical problems by **(ST1)**		Section 7.1 Review: 6, p. 248
■ *discussing and evaluating the role of food additives and/or food treatment to solve the problems of food spoilage, e.g., antioxidants, irradiation technology*	See Chapter 6	See Chapter 6
■ *explaining the biological basis of nutritional deficiencies, including that of anorexia nervosa, and the technological means available to restore equilibrium of body systems*	See Chapter 6	See Chapter 6
■ *identifying specific pathologies of the digestive and respiratory systems and the technology used to treat the conditions*	Investigation 7.A: Measuring Respiratory Volumes, p. 251 Section 7.3: Respiratory Health, pp. 256-262 Thought Lab 7.2: You Diagnose It, p. 261	Try This: Pneumothorax, p. 250 Investigation 7.A: Application 6, p. 251 Section 7.2 Review: 9, p. 254 Web Link: Respiratory infections, p. 256 Q question 9, p. 256; 10, 11, p. 258 Web Link: Asthma, p. 258 Web Link: Cancer, p. 259 Q question 12, p. 259 Thought Lab 7.2: Procedure 2, p. 261 Section 7.3 Review: 1-5, 7, 10, 12, p. 262 Chapter 7 Review: 5, 6, p. 264; 17, 18, 21, p. 265
20–D1.2sts explain that the products of technology are devices, systems and processes that meet given needs; however, these products cannot solve all problems by **(ST7)**		
■ *assessing the physiological effects of smoking and the limitations of technologies available to deal with these conditions or diseases*	Investigation 7.A: Measuring Respiratory Volumes, p. 251 Connections: Traditional Healing in Modern Times, p. 255 Thought Lab 7.1: Smoking and the Respiratory System, p. 260 Thought Lab 7.2: You Diagnose It, p. 261	Investigation 7.A: Application 7, p. 251 Connections: 1-3, p. 255 Thought Lab 7.1: Procedure questions; Analysis 1-3, p. 260 Thought Lab 7.2: Analysis 3, p. 261 Section 7.3 Review: 6, 8, 9, 11, p. 262 Chapter 7 Review: 8, p. 264; 20, p. 265
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
20–D1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by	Launch Lab: Modelling Your Lungs, p. 243 Investigation 7.A: Measuring Respiratory Volumes, p. 251 Investigation 7.B: Carbon Dioxide and the Rate of Respiration, p. 253 Thought Lab 7.2: You Diagnose It, p. 261	Launch Lab: Procedure 1, p. 243 Investigation 7.A: Ext. 5, p. 251 Investigation 7.B: Ext. 3, p. 253 Thought Lab 7.2: Analysis 2, p. 261 Chapter 7 Review: 11, 15, p. 264; 18, 19, p. 265
■ *designing an investigation to examine food energy through calorimetry* **(IP–NS1, 2, 3, 4) [ICT C7–4.1]**		

	Student Textbook	Assessment Options
Performing and Recording		
20–D1.2s 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		Chapter 7 Review: 10, p. 264
■ observing, through dissection or computer simulations, the respiratory and digestive systems of a representative mammal and identifying the major structural components **(PR–NS1, 2, 3, 4, 5) [ICT F1–4.2]**	Appendix F: The Dissection of a Fetal Pig: Part 4: The Respiratory System, pp. 766-767	Appendix F: Part 4, pp. 766-767 Unit 4 Review: 4, p. 356
■ performing experiments, using qualitative tests to detect the presence of carbohydrates, proteins and lipids **(PR–NS2, 3, 4, 5)**	See Chapter 6	See Chapter 6
■ *designing and performing an experiment to investigate the influence of enzyme concentration, temperature or pH on activity of enzymes, e.g., pepsin, pancreatin*	See Chapter 6	See Chapter 6
■ *designing and performing an experiment to examine the mechanics of breathing, e.g., lung volume, breathing rate*	Investigation 7.A: Measuring Respiratory Volumes, p. 251 Investigation 7.B: Carbon Dioxide and the Rate of Respiration, p. 253	Investigation 7.A: Procedure 1-7; Ext. 5, p. 251 Investigation 7.B: Procedure 1-6; Ext. 3, p. 253 Section 7.2 Review: 4, p. 254
Analyzing and Interpreting		
20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by	Thought Lab 7.2: You Diagnose It, p. 261	Thought Lab 7.2: Analysis 2, p. 261
■ *performing, recording, analyzing, drawing conclusions and assessing validity of data from the investigation on calorimetry, enzyme action and mechanics of breathing* **(PR–NS1, 2, 3, 4, 5) (AI–NS2, 3, 4, 6) [ICT P2–4.1]**	Investigation 7.A: Measuring Respiratory Volumes, p. 251 Investigation 7.B: Carbon Dioxide and the Rate of Respiration, p. 253	Investigation 7.A: Analysis 1-2; Conclusion 3-4, p. 251 Investigation 7.B: Analysis 1; Conclusion 2, p. 253 Unit Review: 56, p. 358
Communication and Teamwork		
20–D1.4s 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	Launch Lab: Modelling Your Lungs, p. 243	Launch Lab: Procedure 1, p. 243
■ *working cooperatively to collect and communicating results using appropriate terminology, SI units and symbols* **(CT–NS1, 2) [ICT P2–4.1]**	Investigation 7.A: Measuring Respiratory Volumes, p. 251 Investigation 7.B: Carbon Dioxide and the Rate of Respiration, p. 253 Thought Lab 7.1: Smoking and the Respiratory System, p. 260 Thought Lab 7.2: You Diagnose It, p. 261	Investigation 7.A: Extension 4, p. 251 Investigation 7.B: Extension 3, p. 253 Thought Lab 7.1: Procedure, p. 260 Thought Lab 7.2: Procedure 2, p. 261

Chapter 7

The Respiratory System

Student Textbook pages 242–265

Chapter Concepts

7.1 Structures of the Respiratory System

- The upper respiratory tract filters, warms, and moistens oxygen-containing air, and channels it into the lungs.
- The lower respiratory tract is made up of specialized structures that exchange oxygen for carbon dioxide in the bloodstream.

7.2 Breathing and Respiration

- Humans ventilate their lungs by the mechanism of breathing, which involves inspiration and expiration.
- The volume of air that is taken into the lungs can increase if the need for oxygen increases, such as during exercise.
- External respiration takes place in the lungs, between the air in the alveoli and the blood in the capillaries.
- Internal respiration takes place between the blood in the capillaries and tissue cells.
- Gas exchange occurs through the processes of simple diffusion and facilitated diffusion.

7.3 Respiratory Health

- Some disorders are specific to the respiratory system. Technologies are available to treat respiratory disorders, but they may not be able to restore the respiratory system to optimal health.
- Smoking causes respiratory diseases. Technologies can help some symptoms of smoking, but many symptoms are untreatable.

Common Misconceptions

- Students may not realize that breathing and respiration are, in fact, two separate mechanisms. Breathing is classified as the mechanism of gas exchange, while respiration involves the diffusion of gases across a semi-permeable membrane.
- Students may also confuse cellular respiration with the process of gas exchange. It is important to stress the difference between the exchange of gases and the use of oxygen to produce ATP.
- Students may think that the lungs are involved in the mechanics of breathing (inhaling and exhaling). Although the elastic tissue in the lungs does participate, the main work of breathing is the result of the contraction and relaxation of the diaphragm and rib (intercostal) muscles found in the rib cage.
- Most students believe that the need for more oxygen stimulates an increased breathing rate during strenuous exercise. In fact, accumulating carbon dioxide from cellular respiration creates the stimulus in the breathing centre that increases ventilation rate.

Helpful Resources

Books and Journal Articles

- Mader, Sylvia, *Understanding Human Anatomy and Physiology 5/e*. McGraw-Hill Ryerson, Whitby, 2005.
- Shier, David, *Hole's Essentials of Human Anatomy and Physiology 9/e*. McGraw-Hill Ryerson, Whitby, 2006.

Web Sites

Web links to resources related to the respiratory system can be found at **www.albertabiology.ca.** Go to the Online Learning Centre, and log on to the Instructor Edition. Choose Teacher Web Links for the links to Chapter 7.

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. Most handouts and all assessment tools are supported by a BLM with the answers (ANS). The BLMs are in digital form, stored on the CD that accompanies this Teacher Resource or on the web site at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs. They can be modified to suit the needs of your students.

Number (Type)

7.0.1 (HAND) Launch Lab: Modelling Your Lungs
7.0.1A (ANS) Launch Lab: Modelling Your Lungs Answer Key

7.1.1 (OH) Anatomy of the Respiratory Tract
7.1.2 (HAND) The Human Respiratory System
7.1.2A (ANS) The Human Respiratory System Answer Key
7.1.3 (OH) Brochiole and Alveoli

7.2.1 (HAND) The Mechanics of Breathing
7.2.1A (ANS) The Mechanics of Breathing Answer Key
7.2.2 (HAND) Interpreting a Spirograph
7.2.2A (ANS) Interpreting a Spirograph Answer Key
7.2.3 (HAND) Investigation 7.A: Measuring Respiratory Volumes
7.2.3A (ANS) Investigation 7.A: Measuring Respiratory Volumes Answer Key
7.2.4 (HAND) Investigation 7.B: Carbon Dioxide and the Rate of Respiration
7.2.4A (ANS) Investigation 7.B: Carbon Dioxide and the Rate of Respiration Answer Key

7.3.1 (OH) Lower Respiratory Tract Disorders
7.3.2 (AST) Respiratory Disorders Quiz
7.3.2A (ANS) Respiratory Disorders Answer Key
7.3.3 (HAND) Thought Lab 7.1: Smoking and the Respiratory System
7.3.3A (ANS) Thought Lab 7.1: Smoking and the Respiratory System Answer Key
7.3.4 (HAND) Spirograph and Respiratory Disorders
7.3.5 (HAND) Thought Lab 7.2: You Diagnose It
7.3.5A (ANS) Thought Lab 7.2: You Diagnose It Answer Key

7.4.1 (AST) Chapter 7 Test
7.4.1A (ANS) Chapter 7 Test Answer Key

Using the Chapter 7 Opener

Student Textbook pages 242-243

Teaching Strategies

- Use the Launch Lab: Modelling Your Lungs and the opening photo to focus discussion on the lungs. Students who have hiked in the mountains may be able to share their experiences as they tried to breathe at high altitudes.
- Students who completed Grade 8 Science in Alberta were introduced to the human respiratory system. Put **BLM 7.1.1: Anatomy of the Human Respiratory System** on an overhead transparency or use an LCD projector to display it to your class for review.
- Students who completed *Science 10* in Alberta were expected to explain the process of diffusion. This process was reviewed in the Unit 3 Preparation, pages 156-158. Ask students to define or describe the diffusion of molecules across a semi-permeable membrane. Those who have difficulty may want to revisit the Unit 3 Preparation.
- Divide the class into two groups. Have one group exercise for a short period of time and have the other group sit and rest. Compare the breathing rates of each group, and have students hypothesize why the breathing rates of those exercising are higher than the breathing rates of those who didn't exercise.
- If there are any football or rugby players in the class, have them describe what it is like to try to breathe when they are at the bottom of the "dog-pile." Inhaling is difficult when you are in this position because your rib cage cannot expand.

Launch Lab: Modelling Your Lungs

Student Textbook page 243

Purpose

The purpose of this Launch Lab is to examine and / or build a functioning model of the human respiratory system and to review the mechanics of breathing.

Outcomes

- 20–D1.1k
- 20–D1.1s
- 20–D1.3s
- 20–D1.4s

Please Note: There are two options for students. Option 1: Students observe a pre-made model of the human respiratory system. Option 2: Students make their own model out of 2L pop bottles, straws, and balloons.

Instructions for Option 1: Pre-made Model

Advance Preparation

When to Begin	What to Do
2 to 3 days before	■ Get the human respiratory system model from your science storage area. ■ Check that the rubber membrane (diaphragm) is in one piece and that the balloons are intact.

Materials
■ model of the human respiratory system

Time Required

- 15 minutes

Helpful Tips

- The balloons will not inflate or deflate if air can enter the plastic chamber. Make sure that the rubber stopper is inserted properly and the rubber diaphragm at the bottom is secured properly.
- You could use a three-step method for this demonstration. Show the students the model and ask them to **predict** what will happen when you pull down on the rubber membrane. Ask them to **record their observations** as you do the demonstration for them. Finally, have them try to **explain** their observations.
- Students may expect the balloons to completely fill the chamber. This model does not create a large pressure gradient. The balloons will open and close but will not inflate properly.
- This model only represents the action of the diaphragm. The movements of the rib (intercostal) muscles play a major role in changing the volume of the thoracic cavity.

Safety Precautions

None

Instructions for Option 2: Making the Model

Advance Preparation

When to Begin	What to Do
2 to 3 days before	■ Have each group collect a full set of materials, listed below. ■ Photocopy **BLM 7.0.1: Launch Lab: Modelling Your Lungs**

Materials

- 2L plastic pop bottles (per group)
- modelling clay
- 2 round balloons (per group)
- 2 drinking straws (per group)
- tape

Time Required

- 30 minutes (10 minutes to brainstorm ideas for the model, 10 minutes to create and test the model, and 10 minutes to answer the Analysis questions and clean up)

Helpful Tips

- Use **BLM 7.0.1: Launch Lab: Modelling Your Lungs** to support this activity. Modify it as appropriate to meet the needs of your class.
- If students wonder why they are performing such a simple activity, remind them that the purpose of the Launch Lab is to reactivate prior knowledge from junior-high science. As well, scientists use both simple and very complex models to help explain scientific concepts.
- Students should work in teams of two or three. This will save time and the cost of replacing consumable materials.
- The balloons will not inflate if there are poor seals around the drinking straws. The straws should be the only way that air can get into or out of the pop bottles. However, if the modelling clay is stuffed in too tight, it might pinch off the drinking straws, preventing the movement of air into and out of the balloons.
- To make sure that the balloons are inflated, and that pressure changes inside the pop bottles will cause air to move into and out of the balloons, have students blow a small amount of air into their balloons just before sealing the openings of their pop bottles.

Safety Precautions

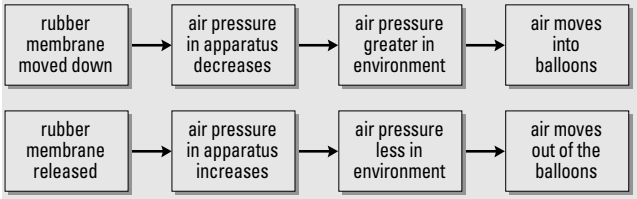
Wash hands thoroughly after completing this activity.

SUPPORTING DIVERSE STUDENT NEEDS

- Students with a disruption of motor skills may have trouble sealing the opening in the pop bottle with the modelling clay. Have these students work in a group with students who have an easier time manipulating the materials.
- You can challenge students by cutting the pop bottle in half and giving them the top half of the bottle (the portion with the narrow neck). Provide these students with a piece of plastic wrap and some tape to see if they can model what happens when the diaphragm contracts. When it contracts, the diaphragm pulls down, increasing the volume of the thoracic cavity. This lowers the air pressure in the chest cavity. When air pressure in the environment is greater than the air pressure in the chest cavity, air moves into the lungs.

Answers to Analysis Questions

1. As you pull down on the rubber membrane, the volume of the plastic container increases. This cavity is airtight, so an increase in its volume means that the same amount of air is now contained in a larger space. The result is lower pressure in the container. Since air will move from an area of higher pressure to an area of lower pressure, air rushes into the lungs from the external environment. The opposite occurs when you release the rubber membrane.
2. No. If the system were not airtight, the air pressure inside the container would always be equal to the air pressure outside the container, and the balloons would not change their shapes.
3.



Assessment Options

- Collect and assess students' answers to the Analysis questions.
- Use Assessment Checklist 3 Performance Task Self-Assessment.

7.1 Structures of the Respiratory System

Student Textbook pages 244–248

Section Outcomes:

Students will:

- identify the principal structures of the respiratory system
- identify the principal functions of the respiratory system
- observe and identify the major respiratory structures

Key Terms

respiratory system
nasal passages
pharynx
epiglottis
glottis
larynx
trachea
bronchi
bronchioles
alveoli
pleural membrane

Biology Background

- The respiratory tract extends from the nose to the lungs. It consists of the nose (nasal cavities), the pharynx (nasopharynx), the larynx (which contains the vocal cords), the trachea, the bronchi, the bronchioles, and the lungs. The bronchi, along with the pulmonary arteries and veins, enter the lungs, which consist of alveoli (air sacs surrounded by a capillary network).

Teaching Strategies

- Students' ability to understand and use the directing words is one key to their success on the *Biology 30* Diploma Exam. You can find the definitions for these terms in Appendix E page 761 of the student textbook. Focus attention on these terms when students are answering questions in the Investigations, the Section Reviews, and the Chapter Review questions.
- Assign **BLM 7.1.2: The Human Respiratory System**. This BLM can be used for review and as a formative assessment tool.
- **BLM 7.1.3: Bronchiole and Alveoli** is a representation of Figure 7.4 on page 247 of the student textbook. This illustration shows the alveoli in detail and provides an overview of external respiration. Use this BLM as an overhead transparency.
- Appendix F Fetal Pig Dissection, Part 4 The Respiratory System, pp. 762-767, has been provided for use in fulfilling Skill Outcome 20-D1.2s. For an online alternative to a physical dissection go to **www.albertabiology.ca,** Online Learning Centre, Instructor Edition, Teacher Web Links.

Certain ESL students may be challenged by the similarities in terminology in this section. BLM 7.1.1 and BLM 7.1.2 can help students describe the relationship between the structure and function of each structure in the human respiratory system. Photocopy these for your students.

Biology File: Try This

Student Textbook page 244

Respiration involves the diffusion of gases across a semi-permeable membrane. Cellular respiration involves the production of ATP at the cellular level. Single-celled organisms and some aquatic multi-cellular organisms (e.g., sponges, anemones) do not have a respiratory system.

Answers to Questions for Comprehension

Student Textbook page 245

Q1. The main function of the human respiratory system is to ensure that oxygen is brought to each cell in the body and that carbon dioxide can leave each cell and be removed from the body.

Q2. External respiration is the process by which oxygen and carbon dioxide are exchanged between the air and the blood, while internal respiration is gas exchange that occurs between the body's tissue cells and the blood.

Biology File: Try This

Student Textbook page 245

Cartilaginous rings in the trachea feel somewhat like the rings in a vacuum cleaner hose and they have the same function. They prevent the windpipe from collapsing when the action of the breathing muscles creates less pressure in the airways than in the atmosphere. Cartilage provides support in other parts of the body as well—the external ear, and the tip of the nose, for example. It also cushions the vertebrae in the backbone.

Answers to Questions for Comprehension

Student Textbook page 246

Q3. The structures of the upper respiratory tract are: paired nostrils → nasal cavity (turbinate bones) → pharynx → larynx → trachea. Students may also include the epiglottis and the glottis.

Q4. Mucus moistens the air before it enters the respiratory tract and helps to clean the air by trapping foreign particles, such as dust or bacteria. Ciliated cells move the debris back up into the nose and throat. The foreign material can then be expelled by coughing or sneezing.

Biology File: Web Link

Student Textbook page 246

The following are possible areas for web-based research.

- Boyle's Law: One of the principal gas laws states that for a given quantity of gas, the pressure is inversely proportional to its volume. The volume changes produced by the rib muscles and the diaphragm create pressure changes resulting in the movement of air according to Boyle's Law.
- Charles's Law: One of the principal gas laws states that at constant pressure, the volume of a fixed quantity of ideal gas varies directly with temperature. In other words, increasing the temperature of the gas increases the volume.
- The technological applications include hyperbaric chamber, ventilator, scuba tank, and iron-lung respirator.

Answer to Question for Comprehension

Student Textbook page 247

Q5. This is a suitable metaphor because each bronchus branches into 2 bronchioles, which then branch into 4 bronchioles, and then 8 bronchioles, and so on.

Section 7.1 Review Answers

Student Textbook page 248

1. Respiration is the overall process that provides oxygen to the cells in the body and removes carbon dioxide from the body. The respiratory system must have a large enough surface area for the efficient exchange of gases to meet the body's needs.

2. There are a number of requirements for respiration:

(a) A large surface area across which oxygen and carbon dioxide diffuse rapidly enough to meet the body's needs is required.

(b) Because the porous membrane across which gas exchange occurs consists of living cells, it must be moist. The oxygen and carbon dioxide gases are dissolved in water. (Dead dry membranes like the outer skin are not permeable to these gases.)

(c) There must be a large diffusion gradient between the concentrations of the gases on either side of the respiratory surface to maintain diffusion rates high enough to meet the body's needs.

3. (a) breathing—involves inspiration during which air moves from the surrounding environment into the spaces inside the lungs. During expiration, air moves from the lung spaces back into the surrounding environment.

(b) external respiration—the exchange of oxygen and carbon dioxide between the air and the blood across the membranes in the lungs

(c) internal respiration—the exchange of oxygen and carbon dioxide between the blood and the internal tissues across capillary and cell membranes.

(d) cellular respiration—the series of energy-releasing chemical reactions that take place inside the cells. It provides ATP for all cellular activities.

4. Structures of the upper respiratory tract:

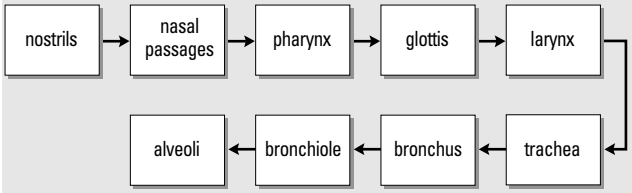
Structures	Functions
nasal passages	■ warm and moisten the air ■ mucus and ciliated cells trap dust and bacteria, moving them back up into the nose and throat
turbinate bones	■ create turbulence in the air as it passes, increasing its contact with the mucus membranes that moisten and cleanse the air
blood vessels	■ carry blood which loses heat and warms the air in the nasal passages

5. The epiglottis is a flap of cartilage that lies behind the tongue and in front of the larynx. The epiglottis closes over the glottis when a person swallows and prevents food or drink from entering the trachea. If the epiglottis did not function properly, food or liquids could enter the trachea, causing choking.

6. When you have a cold, more mucus is secreted in the cells lining the respiratory system. Coughing is a way to expel the excess mucus from the body. Cough medicine may reduce the amount you cough, which could allow for a build-up of mucus in the respiratory tract. Many cough medications may also make you sleepy.

7. Breathing through the mouth allows air to bypass the nasal cavity, so air would not be warmed and moistened as it would be when passing through the nose. The warming and moistening of the air is important for protection of the delicate structures found in the lower respiratory tract.

8. The path of air from the nose to the alveoli is:



9. The larynx contains the vocal cords. Sound is created as the vocal cords are drawn together and air passing through the narrowed space between them causes them to vibrate. A tube inserted into the trachea would pass through the larynx preventing the vocal cords from coming together. Also, exhaled air would pass through the inserted tube rather than past the vocal cords, so no sound could be made.

10. The thin pleural membranes cover the surface of each lung and the inside of the chest wall. Fluid in the space between the membranes causes them to adhere to each other in the same way that a film of tears causes a contact lens to stick to the cornea of the eye. In this way, each lung adheres to the wall of the thoracic cavity and thereby expands and contracts with the movement of the chest.

11. The walls of the trachea and bronchi are strengthened by semicircular, cartilaginous arches that prevent them from collapsing during inhalation.

12. The structures are:

A – nasal passages	F – trachea
B – nostrils	G – bronchus
C – pharynx	H – lung
D – epiglottis	I – bronchioles
E – larynx	J – diaphragm K – thoracic cavity

13. A – bronchiole B – alveoli C – capillary network

Gas exchange takes place between the blood in the capillaries and the air in the alveoli. Oxygen molecules in the air become dissolved in the film of water (moisture) on the alveolar wall and then diffuse into the blood. Carbon dioxide diffuses from the blood in the opposite direction.

14. Several characteristics of alveoli facilitate gas exchange. Their arrangement in clusters (like bunches of hollow grapes) provides a very large surface area across which external respiration occurs. The alveolar walls are covered in a film of water, providing a moist environment for diffusion of gases. Each alveolar wall is only one cell layer thick, creating the minimum distance possible across which diffusion occurs.

Alveoli are significant for gas exchange in that they are specialized tissues for that function. (The outer skin might also function in gas exchange as in amphibians, except that human skin consists of dry, dead cells several layers thick and its total surface area is much less than that of the alveoli.)

7.2 Breathing and Respiration

Student Textbook pages 249–255

Section Outcomes

Students will:

- explain the mechanics of breathing
- explain how gases are exchanged between the human respiratory system and the external environment
- perform an experiment to determine their respiratory volume
- perform an experiment to examine factors that affect the rate of respiration

Key Terms

diaphragm
rib muscles
inhalation
exhalation
spirograph
tidal volume
inspiratory reserve volume
expiratory reserve volume
vital capacity
residual volume
external respiration
internal respiration

Biology Background

- The movement of air in and out of the lungs depends on the changing air pressure inside the chest (thoracic) cavity. **Inspiration** begins when the respiratory centre in the medulla oblongata sends excitatory nerve impulses to the diaphragm, the muscles, and the rib cage. As the muscles between the ribs contract, the diaphragm lowers, and the ribs move upward and outward. The lungs then expand, creating a partial vacuum. Air pressure is greater outside of the thoracic cavity than it is inside, and this results in air moving into the lungs (inspiration). The respiratory centre now stops sending impulses to the diaphragm and muscles of the rib cage. As the diaphragm relaxes, it resumes its dome shape, and the ribs retract. This increases the air pressure inside the thoracic cavity. When the air pressure inside the chest cavity is greater than the air pressure outside, air moves out of the lungs.
- Under normal conditions, the concentration of oxygen in inhaled air is greater than the concentration of oxygen in the blood of the capillaries entering the lung area. In contrast, the carbon dioxide concentration is greater in the blood than in inhaled air. Thus oxygen diffuses across the capillary wall into the bloodstream, and carbon dioxide moves from the capillaries across the alveoli in the lungs.

Teaching Strategies

- Have students begin this section by taking a few moments to focus on and record what happens when they breathe. In particular, have them focus on the movement of the rib cage when they inhale and exhale. They may also look at what occurs when they breathe more deeply and exhale more forcefully to learn about the muscles involved in respiration.
- Refer students to the model that they made in the Launch Lab on page 243 of the student textbook. This model illustrates how changes in thoracic volumes are responsible for the processes of inhalation and exhalation. Use **BLM 7.2.1: Mechanics of Breathing** to reinforce how the actions of the muscles of the rib cage and the diaphragm cause air to move into and out of the lungs. Remind students that the lungs themselves do little as far as the mechanics of breathing is concerned.
- Convert **BLM 7.2.2: Interpreting a Spirograph** into an overhead transparency or a digital image that can be projected on the screen from your computer and consider making a photocopy for each student for their notebook. Use the BLM to support a discussion on respiratory volumes.
- **BLM 7.2.3: Investigation 7.A: Measuring Respiratory Volumes** can be used when students have access to a spirometer
- Use **BLM 7.2.4: Investigation 7.B: Carbon Dioxide and the Rate of Respiratio**n to support the investigation found on pages 248–249 in the student textbook.

SUPPORTING DIVERSE STUDENT NEEDS

- Some students will have problems with the extensive vocabulary used in this section. Use graphic organizers and other visual aids

to help students see how the terms are related to the structure or function of the respiratory system.

- Gifted Students: Discuss the importance of residual volume within the lungs. Sometimes when babies are born, they do not have a residual volume because they lack a substance in their lungs (lipoprotein). Have students find out what this substance is and how it works to prevent our lungs from collapsing.
- Gifted Students: Have students derive the equation showing the relationship between volume and pressure and then have them estimate the change in pressure that occurs inside the lungs when 0.5L of air is inhaled and 1.0L of air is exhaled.

Biology File: Try This

Student Textbook page 250

A **pneumothorax** is the collection of air in the pleural space between the lung and chest wall. The goal of treatment is the removal of air from the pleural space, allowing the lung to re-expand. Inserting a chest tube between the ribs and into the pleural space allows for the evacuation of air. Even with the chest tube in place, it may take the lung several days to return to its normal size.

Answer to Question for Comprehension

Student Textbook page 250

Q6. The following are the essential concepts that should be included:

- Inhalation: The rib (intercostal) muscles contract, lifting the rib cage up and out. At the same time, the diaphragm contracts and pulls downward. As the air pressure inside the thoracic cavity decreases, air will move into the lungs from the environment.
- Exhalation: The intercostal muscles relax, allowing the rib cage to return to its normal position. The diaphragm also relaxes and resumes its domed shape. As pressure in the thoracic cavity increases, air moves from the lungs into the environment.

Investigation 7.A: Measuring Respiratory Volumes

Student Textbook page 251

Purpose

The purpose of this investigation is to give students an opportunity to use a technological device to measure and calculate basic respiratory volumes. Students will use a spirometer to determine their tidal volume, inspiratory reserve volume, and expiratory reserve volume. They will use the results of this investigation to compute their vital capacity and tidal volume.

Outcomes

- 20–D1.5k
- 20–D1.2s
- 20–D1.3s
- 20–D1.4s

Advance Preparation

When to Begin	What to Do
3 to 4 weeks before	■ Make sure you have a separate mouthpiece for every student. ■ Check that the spirometer is functioning properly.
1 day before	■ Photocopy **BLM 7.2.3: Investigation 7.A: Measuring Respiratory Volumes**

Materials
■ spirometer ■ nose plugs (optional) ■ disposable mouthpieces (one per student)

Time Required

- 30 minutes (5 to 10 minutes per student to use the spirometer to gather data and 20 to 25 minutes to complete the Analysis and Conclusion questions. The activity may take 2 or 3 additional classes if you have your students do the Extension and Application questions.)

Helpful Tips

- If you only have one spirometer, have something else planned for the students to do while they are waiting for their turn to use it.
- Treat the used mouthpieces as biohazardous materials. For more information refer to Alberta Education's *Safety in the Science Classroom Guidelines for Safe Practices* document. This document is in the Science Curriculum area of the Alberta Education web site, or at the Online Learning Centre, Instructor Edition, Teacher Web Links.
- Photocopy **BLM 7.2.3: Investigation 7.A: Measuring Respiratory Volumes**. This BLM will guide students through the activity.
- If your school is not equipped with a spirometer, lung volume bags may be used instead.

Safety Precautions

Check to see if any students have asthma or other respiratory problems before attempting this Investigation. These students can participate as observers or recorders.

The following precautions should be followed when using a spirometer:

- Ensure that any components placed in the mouth are used only once, then sterilized, placed in a secured, double-strength plastic bag, and discarded in the regular garbage.
- Check that students do not have bleeding gums or open wounds in the mouth, which increases risks greatly.
- Ensure that students wash their hands thoroughly before and after each activity.

- Students with asthma or other respiratory disorders should not participate in this activity. These students can act as observers and recorders.
- Visually impaired students will have difficulty reading the scale on the spirometer.
- There is a great deal of reading and high-level vocabulary used in this activity. ESL students may have problems following the procedure or recording the values in the proper areas of their data chart. Consider having students work in pairs.

Students Who Need Extra Help:

- Certain mathematical calculations involved in this investigation may be difficult for some students to grasp. Consider dividing students into small groups, according to personal strengths. Each group should appoint a recorder and a calculator. It is the responsibility of students to use their respective strengths to work with their peers within the group.

Answers to Analysis Questions

1. The difference in the calculated vital capacity and the recorded vital capacity can be accounted for by experimental error. The experimental error is due to differences in breathing that occur when breathing into the spirometer. For instance, you may exhale more forcefully into the spirometer than you would in a normal exhalation.

2. The inspiratory reserve volume is larger than the expiratory reserve volume. This larger inspiratory reserve volume allows us to make take in more air when exercising or participating in a strenuous activity.

Answers to Conclusions Questions

3. No, the spirometer cannot be used to measure the total lung capacity because it cannot measure the residual volume that always remains in our lungs to prevent them from collapsing.

4. An athlete may use vital capacity to assess their training program. Measuring their vital capacity could indicate whether or not they are increasing their respiratory fitness through training. Generally, a larger respiratory volume indicates more surface area for gas exchange, resulting in improved athletic performance.

Answer to Extension Question

5. The respiratory volumes will differ based on student size, gender, physical fitness, smoking, and, in theory, the presence of any respiratory disorders such as asthma or bronchitis. To assess the effects of these factors on respiratory volumes, the class may take the respiratory volumes of various students, representing the variables above, and compare the differences. For instance, they may take two large males, a smoker and a non-smoker, and evaluate the effects of smoking on lung capacity. Another test may compare the lung volumes of two females of the same size, one of whom is very athletic.

Answers to Application Questions

6. Some respiratory disorders that may be investigated are: emphysema, in which alveoli collapse and lung volumes decrease; farmer's, or miner's, lung, which is caused by the build-up of dust and particles in the lung; or asthma, which results in a constricted respiratory tract.

7. A ventilator should not be adjusted to maximize the volume of air inhaled and exhaled because the individual does not require large amounts of oxygen. They are not engaging in any physical activity, so the body cells do not need large amounts of oxygen. Likewise, very little carbon dioxide is produced. To increase the ventilator setting would be a waste because the individual does not need to exchange this volume of air.

Assessment Options

- Collect and assess students' answers to the Analysis and Conclusion questions. Assign the Extension and Application questions as a challenge to your more advanced students.
- Use Assessment Checklist 7 Independent Research Skills if you are going to assign the research project suggested in Application question 6. (See Appendix A.)

Answers to Questions for Comprehension

Student Textbook page 252

Q7. External respiration takes place in the lungs. During external respiration, gases are exchanged between the alveoli and the blood in the capillaries that surround each alveolus.

Q8. Each alveolus lies directly alongside a capillary. As the blood moves away from the body tissues, it is oxygen-poor. As it moves through the capillary, oxygen from the air in the alveolus diffuses into the capillary. Carbon dioxide in the capillary diffuses into the alveolus and is expelled from the body when you exhale.

Investigation 7.B: Carbon Dioxide and the Rate of Respiration

Student Textbook page 253

Purpose

Students will investigate the role that carbon dioxide plays in controlling the rate of respiration.

Outcomes

- 20–D1.5k
- 20–D1.1s
- 20–D1.2s
- 20–D1.4s

Advance Preparation

When to Begin	What to Do
1 to 2 days before	■ Purchase brown paper lunch bags for each student. ■ Photocopy **BLM 7.2.4: Investigation 7.B: Carbon Dioxide and the Rate of Respiration.** ■ Locate enough stopwatches for your class, or arrange for a large wall-mounted clock that indicates seconds.

Materials
■ stopwatch ■ brown paper bags (1 per student)

Time Required

- 60 minutes

Helpful Tips

- Review the Safety Precautions for this Investigation with your students.
- Provide each student with a photocopy of **BLM 7.2.4: Investigation 7.B: Carbon Dioxide and the Rate of Respiration**. This BLM includes the procedure, as well as the Analysis, Conclusion, and Extension questions.
- Group students in teams of three, with the following roles: subject, observer, and recorder. This will speed things up and reduce the number of stopwatches required.
- Students cannot accurately take their own respiratory rate; their breathing rate will change as soon as they start thinking about it.
- Optional: Introduce the nervous control of breathing rate, which is covered in *Biology 30*. The respiratory centre is found in the medulla oblongata of the brain. Carbon dioxide is the primary stimulus that directly changes the activity of this centre. This centre is not directly affected by low oxygen levels. Chemoreceptors in the carotid arteries and the aorta are sensitive to levels of oxygen in the blood. When the concentration of oxygen decreases, these bodies communicate with the respiratory centre, and the rate and depth of breathing increases.

Safety Precautions

- Students with respiratory disorders should not be subjects in this experiment.
- Students should not hold their breath or hyperventilate long enough to cause faintness. Students should stop at the first sign of faintness or dizziness.

SUPPORTING DIVERSE STUDENT NEEDS

Some ESL students may have difficulties reading the procedure or interpreting the data that they collect. Consider dividing students into groups according to their personal strengths.

Answer to Analysis Question

1.

Test	Level of Oxygen	Level of Carbon Dioxide
holding breath	decreases the concentration of oxygen in the blood	increases the concentration of carbon dioxide in the blood
hyperventilating	increases the concentration of oxygen in the blood	decreases the concentration of carbon dioxide in the blood
breathing into a paper bag	decreases the concentration of oxygen in the blood	increases the concentration of carbon dioxide in the blood

Answer to Conclusion Question

2. As levels of carbon dioxide increase in the blood, the rate and depth of breathing increases.

Answer to Extension Question

3. Provide board space or an overhead transparency for students to record a class set of data. Use guided discussion to help students identify any similarities and differences in the data that they collect. Explanations could include differences in gender, age, size, race, athletic training, or smoking. Students should design an investigation, ensuring that they control as many variables as possible. For example, if they want to

investigate the difference in the rate of respiration between smokers and non-smokers, they should use subjects that are of the same gender, approximately the same size, and with the same degree of physical activity.

Assessment Option

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

Section 7.2: Review Answers

Student Textbook page 254

1. The two basic requirements, as summarized in Section 7.1, are (a) a large enough surface area for the quick and efficient exchange of gases and (b) a moist environment for external respiration to take place. Alveoli are thin-walled structures that are surrounded by capillaries. There are about 300 million alveoli in each lung, providing a large surface area for gas exchange. The alveoli of human lungs are lined with a thin film of water, provided by the water vapour that is added to air as it passes through the respiratory tract.

2. The role of the diaphragm is to change the size of the thoracic cavity. This alters air pressure within the lungs and causes air to enter and exit the lungs.

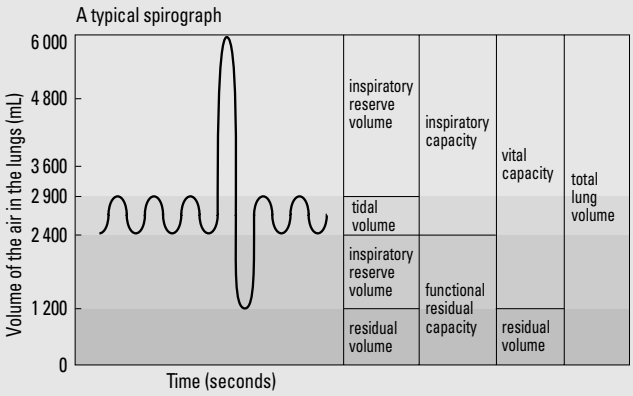
Inhaling: The diaphragm contracts and moves down, an action that increases the volume of the thoracic cavity. This reduces the pressure in the cavity. Air moves into the lungs when the pressure inside the cavity is lower than air pressure outside (air moves from a region of higher pressure to a region of lower pressure).

Exhaling: The diaphragm relaxes and resumes its normal, domed shape. This decreases the volume in the thoracic cavity which, in turn, increases air pressure in the area. Air moves out of the lungs when the pressure inside the thoracic cavity is higher than air pressure outside.

3. The model shown represents the thoracic cavity, the lungs and the diaphragm. In Diagram B (inhalation), the pulling down of the elastic membrane (diaphragm) increases the volume and reduces the pressure of the cavity. Air moves into the balloons because the air pressure outside is higher than in the cavity and the balloons. In Diagram A (exhalation), the elastic membrane returns to its normal, flat shape, which decreases the volume and increases the pressure in the cavity. Air moves out of the balloons because the pressure inside the cavity and the balloons is higher than air pressure outside.

4. (a) A spirograph shows the volume of air moving in and out of the lungs with each breath.

(b)



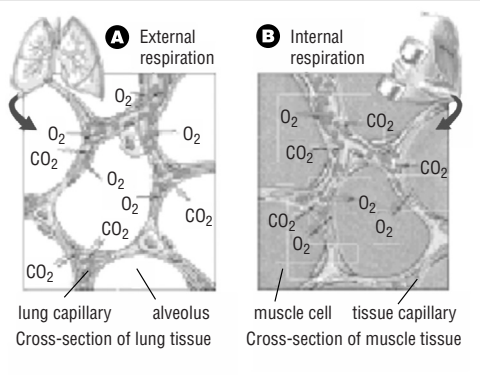
(c) The respiratory volumes represented on this graph are:

- Tidal volume represents air inhaled and exhaled during a normal breath when at rest.
- Inspiratory reserve volume represents additional air taken in beyond a normal inhalation.
- Expiratory reserve volume represents additional air that can be forced out of the lungs beyond a normal exhalation.
- Vital capacity is the total volume of gas that can be moved in or out of the lungs. Vital capacity = tidal volume + inspiratory reserve volume + expiratory reserve volume. (Note: total lung volume = vital capacity + residual volume)
- Residual volume is the amount of gas that remains in the lungs and the passageways of the respiratory system after a full exhalation.

5. (a) The three volumes of air that make up the vital capacity are the tidal volume, the inspiratory reserve volume, and the expiratory reserve volume.

(b) The residual volume is the amount of gas that remains in the lungs and passageways of the respiratory system even after a full exhalation. The lungs contain air after a full exhalation due to the presence of cartilaginous rings that keep the airways open, even if the lungs are dissected from the thoracic cavity. Lung tissue is like a sponge that contains air due to its physical structure.

6.



External respiration occurs between the alveoli and the capillaries next to them. As oxygen-poor blood moves through the lung capillaries, oxygen from the air in the alveoli diffuses into the capillaries and carbon dioxide diffuses out of the blood. Internal respiration occurs between the capillaries and the body tissues. Oxygen diffuses from the oxygen-rich blood into the tissues while carbon dioxide diffuses from the tissues into the blood.

7. Hemoglobin has three major functions. It carries about 99% of the O_2 in the blood.

(The remaining 1% is dissolved in the plasma.) Hemoglobin also buffers the pH of the blood by combining with H^+ from the carbonic acid that forms when carbon dioxide combines with water. Its third function is to carry about 23% of the CO_2 in the blood.

Bicarbonate ions form from the dissociation of carbonic acid that results from CO_2 reacting with water in the blood. About 70% of the CO_2 carried in the blood travels as bicarbonate ions (HCO_3^-).

8. The diaphragm is a muscle that contracts to begin inspiration, increasing the volume and decreasing the pressure in the thoracic cavity. If this muscle is damaged, inspiration and normal breathing would be very difficult. The patient would probably rely more heavily on intercostal muscles to carry on the breathing cycle if they were undamaged. If the injury allowed air to move between the pleural membranes, a collapsed lung might occur. (See Answer #9, below.)

9. A pneumothorax allows air into the thoracic cavity so that the pleural membranes no longer adhere to each other. (See the answer to Section 7.1 Review Questions, question 10.) The collapsed lung would fail to expand and contract with the movement of the chest wall and diaphragm. Gas exchange would no longer occur in the collapsed lung. If one lung were to collapse, the total surface area for gas exchange would be reduced by about half.

10. Removing the air from the thoracic cavity would allow a film of water to reattach the pleural membranes. In this way, the lungs would once again expand and contract with the movement of the chest wall and diaphragm.

11. The levels of carbon dioxide in the toddler's blood would increase to the point where the breathing centre in the brain would over-ride the toddler's desire to stop breathing. Normal breathing would resume.

Connections (Social and Environmental Contexts) Traditional Healing in Modern Times

Student Textbook page 255

Teaching Strategies

- Build on the discussions about supplements from the previous chapter by asking students how many of them use or have family members who use what are considered to be "alternative therapies."
- Use excerpts from a plant identification book or samples of leaves from plants to emphasize the depth of specialized knowledge that is required to practice traditional medicine. The consequences of misidentifying a plant can be quite serious.
- Contact the Aboriginal Services Branch to invite an Aboriginal healer to come to talk to the class.
- Students need to understand that "natural remedies" can be as powerful as commercial drugs and will interact with other medications and foods ingested, just as commercial drugs do. Students who are interested in traditional and natural remedies may wish to visit the web site of Health Canada's Natural Health Products Directorate. The directorate was created to ensure that "natural health products are safe, effective and of high quality, while respecting freedom of choice and philosophical and cultural diversity" and is a good place to find news of ongoing research. The link can be found at the Online Learning Centre, Instructor Edition, Teacher Web Links.

Answers to Questions

1. Students should recognize that traditional remedies are no safer than manufactured drugs because they can be just as powerful, they can have as many side effects or interfere with foods or conventional drugs, and, because they come from a different tradition, distribution should be done by a very experienced practitioner in close consultation with the user.

2. The scientific testing and regulation of conventional, manufactured drugs makes it possible to mass distribute them "over the counter" or with some limited supervision. Despite the pitfalls of this system, it is likely necessary to subject traditional remedies to the same kind of testing and regulation if they are to be mass distributed. Regulation would enable the collection of data relating to the effectiveness and any side effects of a traditional remedy, as well as ensuring common standards of quality and dose.

3. Ownership would restrict access and use, which would be detrimental to the health of local populations that rely on such remedies and have been using them for centuries. On the other hand, as Dr. King notes, there is little research money available to do the necessary testing and research because the results cannot be patented. Encourage students to see both sides of the debate and look for a workable solution.

7.3 Respiratory Health

Student Textbook pages 256–262

Section Outcomes

Students will:

- identify specific diseases that are associated with the respiratory system
- identify technologies that may be used to treat these respiratory diseases
- summarize the physiological effects of smoking and the limitation of technologies to address these effects

Key Terms

tonsillitis
laryngitis
bronchitis
pneumonia
pleurisy
emphysema
cystic fibrosis
asthma
lung cancer
carcinoma
carcinogen

Biology Background

- A number of illnesses are associated with the respiratory tract. These disorders can be divided into those that affect the upper respiratory tract and those that affect the lower respiratory tract. Infections of the nasal cavities, sinuses, throat, tonsils, and larynx are all well known. In addition, infections can also spread from the pharynx (nasopharynx) to the ears.
- The lower respiratory tract is subject to infections such as bronchitis and pneumonia. In obstructive pulmonary disorders such as bronchitis and asthma, either the bronchi and bronchioles do not effectively conduct air to and from the lungs, or the alveoli are damaged. Emphysema is an obstructive pulmonary disorder in which the destruction of the alveoli reduces the surface area for gas exchange. Smoking, which is associated with chronic bronchitis and emphysema, can eventually lead to lung cancer.

Teaching Strategies

- Provide students with a photocopy of **BLM 7.3.1: Lower Respiratory Tract Disorders**. You may wish to make an overhead transparency or a digital representation of this illustration as a visual tool during direct instruction.
- This section provides students with an overview of a number of disorders of the respiratory system. Provide students with a copy of **BLM 7.3.2: Respiratory System Disorders Quiz**. This quiz provides students with a tool to summarize each disorder presented in the student textbook.
- **BLM 7.3.3: Thought Lab 7.1: Smoking and the Respiratory System** guides your students in making an information pamphlet or a multimedia presentation describing the dangers of smoking for a junior-high audience.
- **BLM 7.3.4: Thought Lab 7.2: You Diagnose It** can be used to help students work through the activity on page 261 of the student textbook.
- If time permits, you may consider assigning a small research project on one of the diseases or disorders presented in this section. Have your students create a multimedia presentation showing the causes, symptoms, and treatments of the disorder.

Because this section is primarily information based, there are very few activities or investigations to engage students. Therefore, students can assume some control over their learning by deciding what they think is the best way to learn the material. You could encourage those students who learn best by summarizing and writing information on a chart to do so. Students can produce an electronic slide show presentation that summarizes the different disorders. Alternatively, students can use their artistic, musical, or dramatic talents to present information on the dangers of smoking.

Biology File: Web Link

Student Textbook page 256

Students can list the most common causes of a sore throat and find out the subtle distinctions between conditions that are not serious and conditions that are and need medical attention. Many respiratory infections can be treated with home remedies and practical advice.

Answers to Questions for Comprehension

Student Textbook page 256

Q9. Viruses are more likely to cause tonsillitis and laryngitis than bacteria are.

Student Textbook page 258

Q10. Bronchitis is a disorder that causes the bronchi to become inflamed and filled with mucus, which is expelled by coughing. It makes breathing difficult

because the respiratory tract is partially blocked by mucus, reducing the amount of air that can enter the lungs. The inflammation of the bronchi will also result in pain during inhaling and exhaling.

Q11. Pneumonia is a disease that occurs when the alveoli in the lungs inflame and fill with liquids. This interferes with gas exchange, and the body becomes oxygen-starved.

Biology File: Web Links

Student Textbook page 258

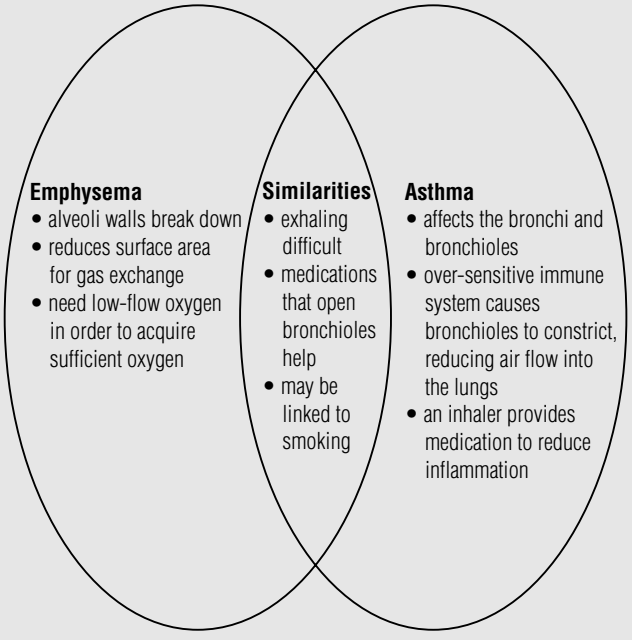
The following is a list of possible factors that may be responsible for the dramatic increase in the diagnosis of asthma during the last 20 years:

- changes in housing with greater exposure to indoor aeroallergens, such as cat hair, dust mites, cockroaches, and moulds;
- environmental factors, such as poor indoor air quality due to changes in ventilation, building practices, and outdoor air pollution;
- changes in diet;
- the impact of early childhood infections and their treatment; and
- a greater awareness of the illness, which may have led more people to be tested and diagnosed.

Answer to Question for Comprehension

Student Textbook page 259

Q12. Student answer may vary but should include the following:



Biology File: Web Link

Student Textbook page 259

Students' answers should include the following points:

- Oncogenes are abnormal forms of the genes that regulate cell growth. Instead of being inactive, they cause cells to divide.
- The dividing cells can form tumours (lumps) that can become malignant, which means they invade the surrounding tissues and spread to other parts of the body. (Benign tumour cells stay in one place and are not usually life-threatening.)
- Metastasis refers to cancerous cells that have spread to other parts of the body.

Thought Lab 7.1: Smoking and the Respiratory System

Student Textbook page 260

Purpose

The purpose of this investigation is to conduct independent research to learn the effects of smoking on the respiratory and other systems in the body.

Outcomes

- 20-D1.2sts

Advance Preparation

When to Begin	What to Do
1 to 2 days before	■ Photocopy **BLM 7.3.3: Thought Lab 7.1: Smoking and the Respiratory System** ■ Reserve computer lab time for research or ask students to do independent research to gather in the information required to answer the questions

Time Required

- 2 hours

Helpful Tips

- Use **BLM 7.3.3: Thought Lab 7.1: Smoking and the Respiratory System** to support this activity. Remove sections as appropriate to meet the needs of the students in your class.
- Links to web sites that can assist in answering the questions posed in the procedure for this lab can be found at the Online Learning Centre, Instructor Edition, Teacher Web Links.

Answers to Analysis Questions

1. Three harmful effects of smoking on the respiratory system are chronic bronchitis, emphysema, and lung cancer.

Smoking also affects other body systems, three examples of which are given here.

(a) *Reproductive System* When a pregnant woman smokes a cigarette, chemicals enter the blood of the fetus and paralyze its breathing muscles for several minutes. "Practice" contractions are crucial to proper development of the fetal breathing muscles. Carbon monoxide from cigarette smoke also reduces the amount of oxygen that maternal blood delivers to the fetus. The lack of oxygen reduces the rate of growth of the fetus. Thus, the average birth weight of babies born to smoking mothers is lowered and they often experience breathing problems because of poor development of the diaphragm and intercostal muscles.

(b) *Circulatory System* Carbon monoxide from smoke increases "bad" blood cholesterol and reduces "good" cholesterol levels. The increased mucus in the lungs caused by irritants in smoke reduces lung capacity by blocking the airways, causing less oxygenation of blood in the lungs. As a result, heart rate increases as it compensates for lower oxygen levels in the blood. Nicotine in smoke causes irregular heart beats. Other effects of smoke are vasoconstriction and hardening of the arteries, both of which cause high blood pressure. All of these factors lead to increased risk of heart attack and stroke.

(c) *Excretory System* Cigarette smoking is linked to increased risk of cancer in the bladder and kidneys.

2. There are number of reasons that people smoke. Some teens smoke because they learn the habit from family members. Peer pressure and the desire for acceptance by friends who smoke is a very powerful factor. Advertising and movies promote desirable images of smokers as fun-loving and cool. Some girls believe that smoking will prevent weight gain. Nicotine is a highly addictive drug, and once people begin to smoke heavily, quitting is very difficult.

3. Some technologies are nicotine replacement therapy; counseling and peer support groups; and lifestyle changes such as increased exercise and avoidance of public places such as bars and casinos where other people smoke.

Assessment Options

- Collect and assess students' answers to the Analysis questions.
- Use Assessment Checklist 7: Independent Research Skills (See Appendix A.)

Thought Lab 7.2: You Diagnose It

Student Textbook page 261

Purpose

The purpose of this activity is to provide students with the opportunity to apply what they have learned in Section 7.3 in a real-world situation.

Outcomes

- 20–D1.1sts
- 20–D1.2sts
- 20–D1.3s
- 20–D1.4s

Advance Preparation

When to Begin	What to Do
1 to 2 days before	■ Photocopy **BLM 7.3.1: Lower Respiratory Tract Disorders** for students to use as a reference. (optional) ■ Photocopy **BLM 7.3.4: Thought Lab 7.2 – You Diagnose It** for your students.

Materials
■ none

Time Required

- 40 minutes

Helpful Tips

- You may wish to give students to **BLM 7.3.1: Lower Respiratory Tract Disorders.** This BLM contains the information students need to answer Analysis question 1.
- **BLM 7.3.4: Thought Lab: You Diagnose It** provides students with a template to record their observations, list the possible respiratory disorders, and identify and explain the disorders for both patients.
- You might want to invite a local physician or community health nurse to make a presentation on respiratory health. You will want to talk to this individual to ensure that their material is grade-appropriate and includes different ways for students to get involved. The last thing you want is for the students to feel like this is "just another smoking lecture."

Answers to Analysis Questions

1. Patient A likely has asthma. Asthma is a chronic obstructive lung disease that affects the bronchi and bronchioles. Individuals with asthma are extremely sensitive to some triggers, which can cause the muscles around the bronchioles to react and constrict, making breathing difficult or impossible because of reduced air flow. It is also seasonal, which eliminates a number of other disorders.

Patient B likely has emphysema. Emphysema is an obstructive respiratory disorder, where the walls of the alveoli break down and lose their elasticity. This reduces the surface area for gas exchange, and causes oxygen shortages in the tissues. Exhaling becomes difficult because of the loss of elasticity in the tissues, so breathing is laboured. People with emphysema will also be tired because of the lack of oxygen.

2. Both patients would have to undergo a series of tests such as respiratory volume tests, blood tests, and chest X-rays. These tests would confirm or reject the doctor's initial diagnosis.

3. Patient A:

- The triggers of asthma are varied but include pollen, dust, cigarette smoke, air pollution, and many other irritants. Avoiding these triggers may help to reduce the chances of an asthma attack.
- Asthma can be managed but not cured. Most individuals with asthma use an inhaler, which is a hand-held device that delivers medication deep into the lungs.
- Medications work to reduce the inflammation in the airways and relax the bronchiole muscles, both of which open up the airways.

Patient B:

- Stopping smoking earlier might have prevented the onset of emphysema because almost all cases of emphysema are caused by smoking. The disease is permanent and incurable.
- Medications that open up the bronchioles can help to improve breathing.
- Emphysema patients often need low-flow oxygen tanks in order to breathe and acquire sufficient oxygen. A low-flow oxygen tank provides concentrations of oxygen that vary with the individual's rate of breathing.
- Lung volume reduction surgery (LVRS) is an experimental surgery for the treatment of emphysema.

Assessment Options

- Assess students' answers to the Analysis questions.
- You can also use a more formative evaluation strategy; have each group present their findings and discuss the similarities and differences between group responses.

Section 7.3: Review Answers

Student Textbook page 262

1. The structures illustrated in the diagram are the tonsils. They help to prevent bacteria and other pathogens from entering the body. Tonsillitis is an infection of the tonsils, usually caused by a viral infection.

2. The following chart can be used to compare bronchitis to pneumonia.

	Bronchitis	Pneumonia
Causes	bacterial infection; long term exposure to irritants and foreign bodies (cigarette smoke)	bacterial or viral infections
Symptoms	coughing that expels mucus (because cilia are destroyed)	coughing, shortness of breath
Breathing problems	inflamed mucus-filled bronchi make breathing painful; infections are likely	alveoli become inflamed and filled with liquids; this interferes with gas exchange, and the body becomes starved for oxygen

3. Emphysema is an obstructive respiratory disease caused by smoking. The lungs lose elasticity and breathing becomes difficult. The destruction of alveolar walls reduces the surface area for gas exchange. A low-flow oxygen system increases the concentration of oxygen in the air entering the lungs, thereby increasing the oxygen diffusion gradient. This compensates for the lack of surface area for oxygen diffusion.

4. A person with cystic fibrosis produces thick, sticky mucus that coats the inside of the lungs. The mucus in the lungs normally traps pathogens and then is expelled from the body by coughing. In people who have cystic fibrosis, the mucus is so thick that pathogens are trapped but cannot be expelled. As a result, the lungs get repeated infections that reduce lung function, and the individual has trouble breathing.

5. Asthma is a chronic obstructive lung disease that affects the bronchi and bronchioles, making breathing difficult or impossible because of reduced air flow. The airways of asthmatics are constantly inflamed and are sensitive to some triggers, such as pollen, dust, cigarette smoke, and other air pollutants. During an asthma attack, the bronchi and bronchioles swell, the bronchial muscles tighten, and mucus production increases. These changes obstruct the airways and make breathing difficult or impossible.

6. During an asthma attack, the bronchi and bronchioles swell, the bronchial muscles tighten, and mucus

production increases. These changes obstruct the airways and make breathing difficult or impossible. A bronchial dilator helps to reduce the inflammation and relax the bronchial muscles. This helps to reduce the obstruction of the airways making breathing easier.

7. Lung cancer is the uncontrolled and invasive growth of abnormal cells in the lungs. The abnormal cells multiply and form malignant tumours, or carcinomas. The carcinoma continues to grow and invade surrounding tissues, including the lymphatic and blood vessels in the lungs. The lymphatic and blood vessels circulate through the body and carry the cancerous cells to new locations where they can grow and invade new tissues. The spread of a tumour throughout the body is called metastasis, and the cancerous cells that spread are called metastatic cells.

8. Most cases of lung cancer are caused by smoking, making this type of cancer wholly preventable. Not smoking, or quitting if you already smoke, is one way to prevent lung cancer. Another cause of lung cancer is exposure to radon, a heavy gaseous radioactive element that is colourless and odourless. Radon is found in many homes, and testing is the only way to tell if your home has dangerously high levels of this gas.

9. (a) CT scans locate abnormalities in the lungs. A new type of scan, called a helical low-dose CT scan, is able to detect lung cancer when the tumours are still very small.

(b) Liposomes are artificial microscopic vesicles that consist of a liquid centre surrounded by phospholipids layers. They are manufactured in a lab, filled with cancer-fighting drugs, and released into the bloodstream. Their tiny size allows them to follow the spread of the cancerous cells and attack the cells before the cells start their uncontrolled growth at a new location.

10. The following chart could be used to show the four symptoms of asbestosis and the causes of each symptom:

Symptom of asbestosis	Causes
shortness of breath following exercise or other physical activity	scarred lung tissue does not expand and contract normally and cannot perform gas exchange.
dry cough	inflammation of lung tissues would result in a cough
recurrent respiratory infections	the scarring of the lung tissue would likely result in the build-up of mucus that would trap pathogens in the lungs; the inability to remove the mucus would result in multiple lung infections
respiratory failure develop as the disease progresses	as the disease progressed, the lungs would not be able to perform gas exchange and the person would experience respiratory failure

11. Reasons the friend might give for starting smoking might include reference to group acceptance/peer pressure, independence/rebellion (smoking because it's against the wishes of a parent or authority figure), looking/feeling cool, and acting like a favourite person (performer, mentor, parent). Information that could be given to convince the friend to stop includes personal health, affects on the health (physical or even emotional) of others, and cost. Greater significance should be given to the health examples cited and explained.

12. The following chart could be used to summarize the causes of each symptom of lung cancer:

Symptom	Possible causes
chronic cough	inflammation of lung tissue results in over-production of mucus, which is expelled by coughing
hoarseness	if the larynx becomes inflamed, the vocal cords are not able to vibrate normally, reducing the ability to speak in a normal voice or even speak at all
coughing up blood	damage to the alveoli would result in blood entering the lungs; this blood would be expelled when the person coughs
shortness of breath	anything that interferes with gas exchange will result in shortness of breath (the body becomes starved for oxygen)
repeated bouts of bronchitis or pneumonia	in some individuals, lung cancer will result in the lungs becoming inflamed and filled with fluids; this interferes with gas exchange, and the body becomes starved for oxygen

Chapter 7: Review Answers

Student Textbook pages 264–265

Answers to Understanding Concepts Questions

1. nasal cavity, pharynx, larynx, glottis, bronchiole, alveoli

2. (a) False: Respiration can be divided into internal and external respiration.

(b) True

(c) False: Air enters the lungs when air pressure inside the lungs is less than the air pressure in the external environment.

(d) False: The tidal volume is the amount of air inhaled and exhaled during one normal breath.

3. Stages in the process of respiration:

- Breathing involves two basic processes: inspiration (breathing in) and expiration (breathing out, or exhaling).
- External respiration is the process by which oxygen and carbon dioxide are exchanged between the air and the blood.
- Internal respiration is the process by which oxygen and carbon dioxide are exchanged between the body's tissue cells and the blood.
- Cellular respiration is the series of energy-releasing chemical reactions that take place inside the cells. Cellular respiration is the final stage in respiration. It is the sole means for providing energy for all cellular activities.

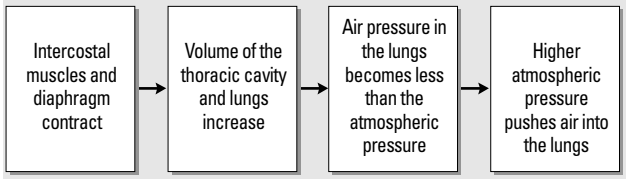
4. The two basic requirements of a gas exchange system are (a) a large enough surface area for the quick and efficient exchange of gases; and (b) for internal respiration to take place a moist environment. Alveoli are thin-walled structures that are surrounded by capillaries. There are about 300 million alveoli in each lung, providing a large surface area for gas exchange. The alveoli of human lungs are lined with a thin film of water provided by the water vapour added to air as it passes through the respiratory tract.

5. Lower respiratory system diseases include:

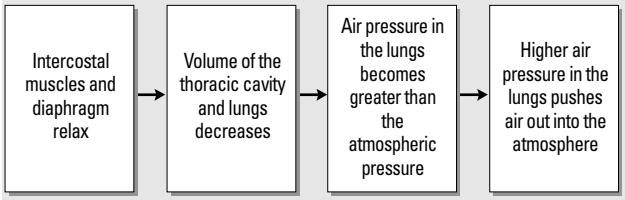
- Pneumonia: Alveoli fill with thick fluid, making gas exchange difficult.
- Bronchitis: Airways are inflamed due to infection or an irritant. Air flow into and out of the thoracic cavity is impaired.
- Asthma: Airways are inflamed due to irritation, and bronchioles constrict due to muscle spasms. Obstruction of the airway makes breathing difficult.
- Emphysema: Alveoli burst and fuse into enlarged spaces. Surface area is greatly reduced, making gas exchange difficult.

6. Lung cancer is the uncontrolled and invasive growth of abnormal cells in the lungs. The abnormal cells multiply and form a malignant tumour, or carcinoma. The carcinoma continues to grow and invade surrounding tissues, including lymphatic tissue and blood vessels. These vessels carry the cancerous cells to new locations.

7. Inspiration: The intercostal muscles contract, lifting the rib cage up and out. At the same time, the diaphragm contracts and pulls downward. As the air pressure inside the thoracic cavity decreases, air will move into the lungs from the environment.



Expiration: The intercostal muscles relax, allowing the rib cage to return to its normal position. The diaphragm also relaxes and resumes its domed shape. As pressure in the thoracic cavity increases, air moves from the lungs into the environment.



8. Look for any **two** of the following:

Benefits of quitting smoking:

- reduced chances of developing lung cancer and / or emphysema
- improved breathing
- chest infections and colds become less frequent
- reduction in chronic bronchitis (smokers' cough)
- the smell of stale tobacco on clothes, hair, breath, and face is gone
- food tastes and smells much better

Aids to help with quitting:

- nicotine replacement therapies (nicotine gum, nicotine patches, nicotine inhalers)
- non-nicotine based prescription medication

9. (a) Dissolving is the process of going into a solution. Carbon dioxide, for example, dissolves in the water (blood) and is transported from the cells of the body to the lungs.

(b) Diffusion is the movement of particles from a region of higher concentration to a region of lower concentration. Oxygen gas, for example, diffuses into the plasma and then into the red blood cells in the capillaries surrounding the alveoli in the lungs.

Answers to Applying Concepts Questions

10. (a) Answers should indicate that they are using volumes associated with a normal breath. Tidal Volume = 4000 mL – 3400 mL = 600 mL

(b) In most cases there are approximately 3 breaths every 12 seconds or 15 breaths per minute. The following is a calculation that students might use to arrive at an answer:

$$\frac{3\ breaths}{12\ s} = \frac{x}{60\ s}$$

$$12\ x = 3 \times 60$$

$$\frac{12\ x}{12} = \frac{180}{12}$$

$$x = 15\ \text{breaths}$$

(c) The total lung capacity of a smoker will be significantly less than the vital capacity of a non-smoker.

11. This breathing pattern would force a maximum amount of carbon dioxide out of the lungs after a deep exhalation. This would lower the concentration of carbon dioxide in the alveolar air and facilitate the diffusion of carbon dioxide out of the blood. The deep inhalation would also have a similar effect, bringing more oxygen into the lungs and increasing the concentration gradient, thus allowing more oxygen into the blood and to the body cells.

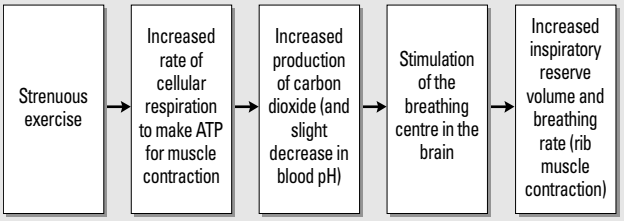
12. The key points that should be included in the answer include:

- External respiration is the process by which oxygen and carbon dioxide are exchanged between the air and the blood.
- Diagram should show oxygen diffusing from the alveoli into the capillaries that surround each alveolus.
- Diagram should show carbon dioxide diffusing from the capillaries into the alveoli.

13. Here is one example of an acceptable answer: You cannot smell many pollutants in the air that may affect your respiratory system. One example of this is carbon monoxide, which is a colourless, odourless gas that can kill you. It binds to hemoglobin in the red blood cells, which prevents the exchange of gases during external respiration.

14.

How Increased Waste Product from Cellular Respiration (Not Oxygen Concentration) during Strenous Exercise Increases Inspiratory Reserve Volume and Rate of Breathing



Note: Low oxygen concentration in the blood is not the stimulus that increases breathing rate during strenuous exercise.

15. Swimmers and divers hyperventilate to remove as much carbon dioxide gas from their body as possible. They can stay underwater longer because it takes longer for the carbon dioxide levels to build up to the point where breathing is triggered.

16. (a) The Heimlich manoeuver puts upward pressure on the diaphragm, and this decreases the volume of the thoracic cavity. This would help to force air out of the lungs, and the air may push the food out of the person's trachea.

(b) Giving water to a choking individual would not be a good idea because drinking water would not open the airway. Water will compound the choking problem, as the digestive system and respiratory system share a common opening called the pharynx. You would now have to clear the airway of the food and the water!

(c) Normal air is 21% oxygen and 0.04% carbon dioxide; respirator air is 95% oxygen and 5% carbon dioxide. Oxygen is given to treat patients with insufficient oxygen in the blood. Patients should initially be given a high concentration to restore the concentration of oxygen in the blood. The 5% carbon dioxide medical gas mixture is to stimulate respiration after a period of reduced airflow into the lungs.

17. (a) The smoker's cough is caused by the paralysis of the cilia lining the trachea and bronchial tubes. This allows the build-up of tar and mucus in the lungs. When cilia are covered with pollutants, they do not remove the mucus and contents of the cigarette smoke effectively from the airway. This build-up irritates the lungs, and the smoker has to cough in an attempt to clear the tar and mucus out of the lungs and airways.

(b) You would expect a smoker to cough up mucus as well as the tar and other chemicals found in cigarette smoke.

(c) Students could identify emphysema or lung cancer as possible diseases caused by smoking. Emphysema is an obstructive respiratory disorder in which the walls of the alveoli break down and lose their elasticity. This reduces the surface area for gas exchange and causes oxygen shortages in the tissues. Exhaling becomes difficult because of the loss of elasticity, so breathing is laboured.

Lung cancer is the uncontrolled and invasive growth of abnormal cells in the lungs. The abnormal cells multiply and form malignant tumours or carcinomas. The tumours reduce the surface area available for gas exchange and may stop air from entering the bronchioles. Growing tumours may damage tissue or produce toxins that are harmful to lung cells.

Answers to Making Connections Questions

18. Respiratory disorders that are linked to the environment include emphysema, lung cancer, chronic bronchitis, and asthma. Students should link the disorder to a suspected environmental cause or trigger. Smoking, air pollution, and allergens are three examples that students may include in their answer.

19. Taking frequent, shallow breaths would be better than taking deep breaths because this reduces the respiratory efficiency of the lungs. As a result, less polluted air will diffuse across the alveolar membrane and into the blood.

20. (a) When air enters directly into the trachea through the tracheotomy, the warming, moisturizing, and cleaning effects of the nose and turbinate bones is lost.

(b) The tracheal cover may be fitted with a small filter to clean the air, moisture (water vapour) may be added to the air, and / or the air may be warmed.

21. (a) The parts of the respiratory system affected by pharyngitis are the pharynx, nasal passages, and trachea.

(b) The symptoms of this disease are a sore throat, a runny nose, and a cough.

- sore throat—the pharynx is the common opening of the respiratory and digestive system. An infection will result in swelling and irritation of the membranes lining the pharynx.
- runny nose—inflammation and the production of extra mucus occur in the mucus membranes lining the nasal passages
- cough—a cough is a protective mechanism that helps clear the extra mucus and other irritants from the airway.

CHAPTER 8 CIRCULATION AND IMMUNITY

Curriculum Correlation

Human Systems General Outcome 2: Students will explain the role of the circulatory and defense systems in maintaining an internal equilibrium.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
20–D2.1k identify the principal structures of the heart and associated blood vessels, i.e., atria, ventricles, septa, valves, aorta, vena cavae, pulmonary arteries and veins, sinoatrial node	Section 8.1: Major Components of the Circulatory System, pp. 268-269 The Structure of the Heart, pp. 269-270 Investigation 8.A: Identifying Structures of the Circulatory System, pp. 272-273	Q questions 1, 2, p. 269; 3, 4, p. 270 Investigation 8.A: Procedure 2-6, p. 273 Section 8.1 Review: 1, 6, p. 281 Chapter 8 Review: 2, p. 302 BLM 8.4.1 Chapter 8 Test Unit 4 Review: 5, 13, 14, p. 356
20–D2.2k describe the action of the heart and the general circulation of the blood through coronary, pulmonary and systemic pathways	Section 8.1: The Beating Heart, pp. 272-274 Blood Pressure, p. 274 Cardiac Output and Stroke Volume, pp. 275-276 Pathways of the Circulatory System, pp. 276-277	Q questions 9, 10, p. 274; 11, p. 275; 12, 13, p. 277 Section 8.1 Review: 4, 5, p. 281 Chapter 8 Review: 3, p. 302 BLM 8.4.1 Chapter 8 Test Unit 4 Review: 14, p. 356
20–D2.3k describe the structure and function of blood vessels; i.e., arteries, veins, and capillaries	Launch Lab: Watching Blood Flow, p. 268 Section 8.1: The Structure of Blood Vessels, pp. 270-271 Investigation 8.A: Identifying Structures of the Circulatory System, pp. 272-273	Launch Lab: Analysis 1-3, p. 268 Q questions 5-8, p. 272 Investigation 8.A: Procedure 2-6; Analysis 1, p. 273 Section 8.1 Review: 2, 3, p. 281 Chapter 8 Review: 1, 17, p. 302 BLM 8.4.1 Chapter 8 Test Unit 4 Review: 15-17, p. 356
20–D2.4k describe the main components of blood and their role in transport and in resisting the influence of pathogens; i.e., erythrocytes, leucocytes, platelets, plasma	Section 8.2: The Formed Portion of Blood, pp. 282-284 Plasma, p. 284 The Functions of Blood, pp. 284-287 Investigation 8.C: Identifying Blood Cells, p. 285	Q questions 14-16, p. 284 Investigation 8.C: Procedure 1-7, p. 285 Section 8.2 Review: 1, 2, p. 291 Chapter 8 Review: 6, p. 302 BLM 8.4.1 Chapter 8 Test Unit 4 Review: 19, p. 356
20–D2.5k explain the role of the circulatory system at the capillary level in aiding the digestive, excretory, respiratory and motor systems' exchange of energy and matter with the environment	Section 8.2: The Functions of Blood, pp. 284-287 Circulation and the Action of Capillaries, pp. 287-288	Q questions 17, 18, p. 287; 19, 20, p. 288 Section 8.2 Review: 3, 4, 5(b), p. 291 BLM 8.4.1 Chapter 8 Test Unit 4 Review: 28, 32, p. 357; 47, p. 358
20–D2.6k explain the role of blood in regulating body temperature	Section 8.2: Homeostatic Regulation, p. 286	Q question 18, p. 287; 20, p. 288 BLM 8.4.1 Chapter 8 Test Unit 4 Review: 32, p. 357
20–D2.7k describe and explain, in general terms, the function of the lymphatic system	Section 8.3: The Lymphatic System and Immunity, pp. 292-293	Q questions 21, 22, p. 293 Section 8.3 Review: 1-3, p. 300 Chapter 8 Review: 9, p. 302 BLM 8.4.1 Chapter 8 Test Unit 4 Review: 38-42, p. 357

	Student Textbook	Assessment Options
20–D2.8k list the main cellular and non-cellular components of the human defense system and describe their role, i.e., skin, macrophage, helper T cell, B cell, killer T cell, suppressor T cell, memory T cell	Section 8.3: The Defence System, pp. 293-295 Thought Lab 8.3: Barriers of Defence, p. 298	Q questions 23-25, p. 295 Thought Lab 8.3: Procedure 1, p. 298 Section 8.3 Review: 4-6, 9, p. 300 Chapter 8 Review: 8, 10, 11, 18-20, p. 302; 27, p. 303 BLM 8.4.1 Chapter 8 Test Unit 4 Review: 43-45, p. 357
Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)		
20–D2.1sts explain how Canadian society supports scientific research and technological development that helps achieve a sustainable society, economy and environment by **(STS4a)**		
■ *evaluating the effects that the needs, interests and financial support of society have on preventing the spread of disease-causing organisms, e.g.,* Staphylococcus, *smallpox virus, E. coli and the human immunodeficiency virus (HIV)*	Thought Lab 8.2: Keeping the Blood Supply Safe, p. 289	Thought Lab 8.2: Analysis 2; Extension 6, p. 289
■ *identifying specific pathologies of the circulatory and defense systems, the technology used to treat the conditions and the reasons society supports the development of such technologies*	Cardiovascular Disorders and Treatments, pp. 277-280 Thought Lab 8.1: Cardiovascular Health, Technology, and Society, p. 280 Blood Disorders, pp. 288-291 Blood Types, pp. 296-297 Immune System Disorders, pp. 298-299	Web Link: Artificial pacemaker, p. 275 Thought Lab 8.1: Procedure 1, 2; Analysis 1, p. 280 Section 8.1 Review: 7, p. 281 Web Link: Leukemia, p. 291 Section 8.2 Review: 5(a), p. 291 Q question 27, p. 297 Web Link: Hemolytic disease, p. 297 Web Link: Peanut allergies, p. 299 Section 8.3 Review: 8, 10, 11, p. 300 Chapter 8 Review: 5, 22, p. 302; 30, p. 303 Unit 4 Review: 62, p. 359
■ *assessing the physiological effect of drugs such as alcohol and nicotine on the circulatory system and why habitual use of these drugs is a societal concern*	Homeostatic Regulation, pp. 286-287	Thought Lab 8.1: Procedure 3; Analysis 1-3; Extension 4, p. 280
20–D2.2sts explain that decisions regarding the application of scientific and technological developments involve a variety of perspectives, including social, cultural, environmental, ethical and economic considerations by **(STS4b)**	Thought Lab 8.2: Keeping the Blood Supply Safe, p. 289 Connections: The Tomorrow Project, p. 290 Thought Lab 8.1: Cardiovascular Health, Technology, and Society, p. 280	Web Link: High altitude training, p. 286 Thought Lab 8.2: Procedure 2; Analysis 3, 5, p. 289 Connections: 1, p. 290 Thought Lab 8.1: Procedure 2, Analysis 1; Extension 4, p. 280
■ *evaluating the ethical implications of organ transplants in terms of the needs, interests and financial support of society on scientific and technological research in this field, e.g., societal and scientific definitions of death*		
■ *analyzing the considerations associated with technological advances that assist in the maintenance of internal equilibrium with respect to* *- pathogens, e.g., vaccinations/inoculations* *- defective hearts, e.g., artificial valves, artificial hearts, xenotransplantation, stem cell culture* *-delivery of prescription drugs to sites of action*		Web Link: Leukemia, p. 291 Chapter 8 Review: 16, p. 302
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
20–D2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by		Chapter 8 Review: 14, 15, 22, p. 302; 23, p. 303
■ *designing procedures to investigate factors affecting heart rate and blood pressure, e.g., physical activity, emotion, gender and chemicals such as caffeine* **(IP–NS4)** **[ICT C7–4.1]**	Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure, p. 278 Investigation 8.B: Exp. Plan 1-6, p. 278	Chapter 8 Review: 12, p. 302 Unit 4 Review: 59, p. 359

	Student Textbook	Assessment Options
Performing and Recording		
20–D2.2s 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		
■ measuring blood pressure and observing blood flow in capillaries in a living organism or through demonstration in a virtual lab, e.g., *human, goldfish* **(PR–NS2, 3)**	Launch Lab: Watching Blood Flow, p. 268 Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure, p. 278	Launch Lab: Procedure 1; Analysis 3, p. 268 Investigation 8.B: Data and Obs. 7, Ext, 7; p. 278 Chapter 8 Review: 24, p. 303 Unit 4 Review: 18, p. 356
■ determining the morphology and abundance of cellular components in a prepared human blood slide **(PR–NS2, 3)**	Investigation 8.C: Identifying Blood Cells, p. 285	Investigation 8.C: Procedure 1-7; Analysis 2; Conclusion 3, 4, p. 285
■ selecting and integrating information from various sources to observe the principal features of a mammalian circulatory system and the direction of blood flow and identifying structures from drawings, e.g., *valves, chambers* **(PR–NS1) [ICT C1–4.1]**	Launch Lab: Watching Blood Flow, p. 268 Appendix F: The Dissection of a Fetal Pig, Part 3: The Circulatory System, pp. 765-766 Pathways of the Circulatory System, pp. 276-277	Launch Lab: Procedure 1; Analysis 6, p. 268 Appendix F: Procedure Part 3: A, B; Analysis 1, 2, p. 766
■ researching and designing a simulation or model of the functioning of the main components of the human immune system **(PR–NS1) (PR–ST2) [ICT C6–4.2]**	Thought Lab 8.3: Barriers of Defence, p. 298	Thought Lab 8.3: Procedure 2, 3; Analysis 2, 3, p. 298 Chapter 8 Review: 19, p. 302
■ *compiling and displaying information on blood pressure, heart rate and blood composition and researching statistical data* **(PR–NS1, 4) [ICT P4–4.3]**	Blood Pressure, p. 274 Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure, p. 278	Q question 11, p. 275 Try This: Heart rate, p. 277 Investigation 8.B: Extension 6, p. 278 Chapter 8 Review: 21, p. 302
■ *carrying out a heart dissection to identify the major parts and to determine the directional flow of blood through the organ* **(IP–NS4)**	Investigation 8.A: Identifying Structures of the Circulatory System, pp. 272-273 Appendix F: The Dissection of a Fetal Pig, Part 3: The Circulatory System, B: Examining the Organs of the Circulatory System, p. 766	Investigation 8.A: Procedure 1-6; Analysis 2, p. 273 Appendix F: Procedure Part 3, B 5-7; Analysis 1, p. 766
Analyzing and Interpreting		
20–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by		Section 8.3 Review: 9, p. 300 Unit 4 Review: 47, 49, p. 358 Chapter 8 Review, 13, p. 302 Try This: Heart rate, p. 277
■ *determining the relationship between blood pressure and exercise from patterns and trends in data* **(AI–NS2) [ICT C6–4.3]**	Cardiovascular Fitness, pp. 275-276	
■ *investigating lifestyle behaviour, physical fitness and heart rate recovery using statistical theoretical data and account for discrepancies* **(AI–NS2, 3)**	Cardiovascular Disorders and Treatments, pp. 277-280 Thought Lab 8.1: Cardiovascular Health, Technology, and Society, p. 280	Thought Lab 8.1: Procedure 3; Analysis 2, 3; Extension 4, p. 280
■ *identifying the limitations and evaluate the dependability of devices used to measure blood pressure* **(AI–NS4)**	Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure, p. 278	Investigation 8.B: Extension 7, p. 278
■ *analyzing the heart-lung machine* **(AI–ST2) [ICT C7–4.1, 4.2]**	Thought Lab 8.1: Cardiovascular Health, Technology, and Society, p. 280	Thought Lab 8.1: Procedure 2, p. 280
■ *exploring solutions to practical problems associated with the circulatory system, e.g., heart transplant, artificial blood, blood doping to enhance athletic performance* **(AI–ST2) [ICT C1–4.1, 4.2]**	Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure, p. 278 Thought Lab 8.2: Keeping the Blood Supply Safe, p. 289	Investigation 8.B: Extension 6, p. 278 Thought Lab 8.2: Procedure 2; Analysis 5, p. 289 Chapter 8 Review: 16, p. 302; 28, 30, p. 303

	Student Textbook	Assessment Options
Communication and Teamwork		
20–D2.4s 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 team members to measure and record blood pressure, heart rate or any other factor relating to the circulatory system* **(CT–NS1, 2) [ICT P4–4.3]**	Connections: The Tomorrow Project, p. 290 Thought Lab 8.3: Barriers of Defence, p. 298 Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure, p. 278	Connections: 1, p. 290 Thought Lab 8.3: Procedure 2-4; Analysis 1, p. 298 Investigation 8.B: Exp. Plan 1-6; Data and Obs. 7; Conclusion 4; Extension 7, p. 278

Chapter 8

Circulation and Immunity

Student Textbook pages 266–303

Chapter Concepts

8.1 Structures of the Circulatory System

- The heart and blood vessels are collectively called the cardiovascular system.
- The mammalian heart is a muscular organ that contains four chambers and acts as a double pump.
- There are three circulatory pathways through the body: the pulmonary pathway, the systemic pathway, and the coronary pathway.

8.2 Blood and Circulation

- Blood is a tissue made up of plasma, red blood cells, white blood cells, and platelets.
- Blood transports materials throughout the body and regulates temperature to maintain homeostasis.

8.3 The Lymphatic System and Immunity

- The lymphatic circulatory system is closely associated with the blood vessels of the cardiovascular circulatory system.
- The lymphatic system helps to maintain the balance of fluids within the body and is a key component of the immune system.
- The body's defence system is made up of non-specific defences and specific defences (immunity).
- The specific immune system contains a variety of cells that are specialized to recognize foreign substances and neutralize or destroy them.

Common Misconceptions

- A widely held misconception is that deoxygenated human blood, the blood returning in veins to the heart, is blue. When you look at larger blood vessels, such as the ones you can see in your arms and hands, the light is refracted by the skin and blood vessel walls. This refraction of light causes these blood vessels to take on a bluish color.
- Many students may infer that "deoxygenated" blood has lost all of its oxygen. This is a misconception because the hemoglobin in red blood cells leaving the lungs is typically 98% saturated at a PO_2 of about 100 mm. It is about 70% saturated at resting PO_2 in the tissues. This means that 70% of the hemoglobin returns to the lungs is still carrying its oxygen.
- A few students may believe that all arteries carry oxygen-rich blood and all veins carry oxygen-poor (deoxygenated) blood. The pulmonary artery and pulmonary veins are exceptions. The pulmonary arteries carry oxygen-poor (deoxygenated) blood to the lungs while the pulmonary veins carry oxygen-rich blood back to the left side of the heart.
- There are many misconceptions about HIV and AIDS. One misconception is that HIV and AIDS are the same thing. AIDS is a deficiency of the body's immune system to fight a variety of infections and cancers. AIDS is the final (and fatal) stage that results from the infection of the Human Immunodeficiency Virus (HIV).
- There are many myths concerning vaccinations. One of these myths is that vaccines may cause harmful side effects. According to many medical authorities, vaccines are actually very safe, despite the implications in many anti-vaccine publications. Most vaccine-adverse events are minor and temporary, such as a sore arm or mild fever.

Helpful Resources

Books and Journal Articles

- Shier, David. *Hole's Essentials of Human Anatomy and Physiology 9/e*. McGraw-Hill Ryerson: Whitby, 2006.
- Mader, Sylvia. *Understanding Human Anatomy and Physiology 5/e*. McGraw-Hill Ryerson: Whitby, 2005.

Web Sites

Web links related to the cardiovascular and immune systems can be found at **www.albertabiology.ca.** Go to the Online Centre, and log on to the Instructor Edition. Choose Teacher Web Links for the links to Chapter 8.

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. Most handouts and all assessment tools are supported by a BLM with the answers (ANS). The BLMs are in digital form, stored on the CD that accompanies this Teacher Resource or on the web site at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs. They can be modified to suit the needs of your students.

Number (Type)

8.0.1 (HAND) Launch Lab: Watching Blood Flow
8.0.1A (ANS) Launch Lab: Watching Blood Flow Answer Key
8.1.1 (AST) Heart Anatomy
8.1.1A (ANS) Heart Anatomy Answers
8.1.2 (HAND) Flow of Blood through the Heart
8.1.2A (ANS) Flow of Blood through the Heart Answers
8.1.3 (HAND) Blood Vessels
8.1.3A (ANS) Blood Vessels Answers
8.1.4 (HAND) Investigation 8.A: Identifying Structures of the Circulatory System
8.1.4A (ANS) Investigation 8.A: Identifying Structures of the Circulatory System Answer Key
8.1.5 (HAND) Electrical System of the Heart
8.1.5A (ANS) Electrical System of the Heart Answer Key
8.1.6 (HAND) Blood Velocity and Blood Pressure
8.1.6A (ANS) Blood Velocity and Blood Pressure Answer Key

8.1.7 (HAND) Pathways of the Circulatory System
8.1.7A (ANS) Pathways of the Circulatory System Answer Key
8.1.8 (HAND) Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure
8.1.8A (ANS) Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure Answer Key
8.1.9 (HAND) Thought Lab 8.1: Cardiovascular Health, Technology, and Society
8.1.9A (ANS) Thought Lab 8.1: Cardiovascular Health, Technology, and Society Answer Key
8.1.10 (HAND) How Much Blood Does Your Heart Pump?
8.1.10A (ANS) How Much Blood Does Your Heart Pump? Answer Key

8.2.1 (OH) The Cellular Components of Blood
8.2.2 (HAND) Blood Cell Activity
8.2.2A (ANS) Blood Cell Activity Answers
8.2.3 (HAND) When Red Blood Cells Go Wrong
8.2.3A (ANS) When Red Blood Cells Go Wrong Answer Key
8.2.4 (HAND) Investigation 8.C: Identifying Blood Cells
8.2.4A (ANS) Investigation 8.C: Identifying Blood Cells Answer Key
8.2.5 (HAND) Circulatory System Disorders
8.2.5A (ANS) Circulatory System Disorders Answers
8.2.6 (HAND) Thought Lab 8.2: Keeping the Blood Supply Safe
8.2.6A (ANS) Thought Lab 8.2: Keeping the Blood Supply Safe Answer Key
8.2.7 (HAND) Blood Type
8.2.7A (ANS) Blood Type Answers

8.3.1 (OH) The Human Lymphatic System
8.3.1A (ANS) Human Lymphatic System Answers
8.3.2 (OH) Immune Response
8.3.3 (HAND) Immune Response Nonspecific
8.3.3A (ANS) Immune Response Nonspecific Answers
8.3.4 (HAND) Immune Response Specific
8.3.4A (ANS) Immune Response Specific Answers
8.3.5 (HAND) Blood Cell Activity
8.3.5A (ANS) Blood Cell Activity Answers
8.3.6 (HAND) Thought Lab 8.3: Barriers of Defence
8.3.6A (ANS) Thought Lab 8.3: Barriers of Defence Answer Key

8.4.1 (AST) Chapter 8 Test
8.4.1A (ANS) Chapter 8 Test Answer Key

Using the Chapter 8 Opener

Student Textbook pages 266–267

Teaching Strategies

- Students who attended an Alberta junior high school were introduced to human systems, including the cardiovascular system, in Grade 8 Science. Use a series of questions to determine how much students remember about the heart and blood.
- Check with your students to see if any have taken First Aid and/or cardiopulmonary resuscitation (CPR) courses. Ask these students to relate what they learned in their course to the cardiovascular system. Consider inviting a paramedic or First Aid/CPR trainer into the class to talk to your students about the importance of these courses.
- Students will be using the microscope in Investigation 8.C: Identifying Blood Cells on page 285 of the student textbook. They will need to know how to use this technology in order to successfully complete this investigation. Appendix C: Microscopy Review, pages 756–758, is a review.
- Ask your students how their body responds to a viral infection (cold or influenza) and how this response helps them to fight this infection.
- A diagnosis of a heart attack tells you that the victim's heart has stopped working, but not why. Challenge your students to make a concept map or other graphic organizer showing how a heart attack might affect different elements of the body's internal well-being, such as water balance, blood pressure, oxygen and nutrient transport, and removal of waste products. This could be done as an individual assignment or as a full class discussion.

Launch Lab: Watching Blood Flow

Student Textbook page 267

Purpose

To observe the flow of blood in capillaries.

Outcomes

- 20–D2.3k
- 20–D2.2s

Advance Preparation

When to Begin	What to Do
2 to 3 weeks before	■ Arrange for use of a multimedia computer, Internet access, and an LCD projector. or ■ Order video on blood flow from local media resource centre.
1 day before	■ Photocopy **BLM 8.0.1: Launch Lab: Watching Blood Flow**

Materials

- multimedia computer
- Internet access
- LCD projector

or

- video player and television

Time Required

- 10 minutes

Helpful Tips

- If you are using a video, locate the section that deals with blood flow through a capillary. Have this section of the video cued up before class starts.
- This procedure has been done with a live goldfish in the past. It is not recommended because the fish rarely survives the ordeal.
- Replay the clip several times before discussing the Analysis questions.
- Consider using the Analysis questions as a starting point for a class discussion rather than using the questions for evaluation purposes.

Answers to Analysis Questions

1. Many students will remember that blood carries oxygen from the lungs to the cells; picks up nutrients from the digestive system and transports them to the tissues; picks up carbon dioxide from the cells and transports it to the lungs for removal; and transports wastes from the cells to kidneys for excretion.
2. Capillaries (vessels being observed) are an important part of the circulatory system because an exchange of substances takes place across their thin walls. Although each capillary is small, they form vast networks, increasing the surface area for exchange of nutrients and wastes.

   One large vessel does not provide enough surface area for exchange of nutrients and wastes.
3. Students should make the connection between increasing or decreasing heart rate and increasing or decreasing the speed of blood flow.
4. Observing the movement of blood cells (most likely red blood cells) and plasma in a capillary.
5. Students will be able to identify the heart as being responsible for the movement of blood. They may be able to identify other animals that have hearts or heart-like structures that pump fluids (blood) throughout the animal's body. Single-celled organisms and many simple multicellular animals, such as sponges, jellyfishes, sea anemones, flatworms, and roundworms, do not have a circulatory system. All of their cells are able to absorb nutrients, exchange gases, and expel wastes through direct contact with either the outside or with a central cavity that serves as a digestive tract.

   Some plants have a series of tubes (xylem/phloem) to transport water and nutrients from their roots to their leaves and bring food made in the leaves down the roots.
6. Blood flows in one direction. However, the blood flow in a capillary may appear to change direction, as red blood cells have to line up in order to pass through these tiny blood vessels.

Assessment Options

- Collect students' answers to the Analysis questions to evaluate this activity.

8.1 Structures of the Circulatory System

Student Textbook pages 268–281

Section Outcomes

Students will:

- **identify** the major structures of the circulatory system
- **describe** the structure and function of blood vessels
- **describe** the action of the heart and the circulation of blood through the body
- **dissect** and **observe** the structures of a mammalian heart
- **design** an investigation to examine heart rate and blood pressure
- **identify** disorders of the circulatory system and technologies used to treat them
- **investigate** the relationship between blood pressure, heart rate, and exercise

Key Terms

circulatory system
atria
ventricles
septum
vena cavae
pulmonary arteries
pulmonary veins
aorta
valves
arteries
veins
capillaries
sinoatrial (SA) node
atrioventricular (AV) node
blood pressure
systolic pressure
diastolic pressure
pulmonary pathway
systemic pathway
coronary pathway

Biology Background

- The three functions of the circulatory system are to transport gases, nutrients, and waste materials to and from the cells; to regulate internal body temperature and transport hormones; and to protect against blood loss and against disease-causing microbes or toxic substances that enter the body.
- Arteries and arterioles carry blood away from the heart toward the capillaries; capillaries join arterioles to venules; veins and venules return blood from the capillaries to the heart.
- The heart is a cone-shaped, muscular organ about the size of a fist. It is located between the lungs and directly behind the sternum.
- Humans have a four-chambered heart (two atria and two ventricles). A septum separates the right side from the left side. A series of valves in the heart keep the blood flowing in one direction. The right side of the heart pumps blood to the lungs, and the left side of the heart pumps blood throughout the body.
- The intrinsic conduction system of the heart consists of the SA node, the AV node, the atrioventricular bundle, and the Purkinje fibres.
- The pulmonary arteries take oxygen-poor blood to the lungs, and the pulmonary veins return blood that is oxygen-rich to the left side of the heart. The systemic circuit takes blood from the left ventricle of the heart, through the body proper, and back to the right atrium of the heart. The coronary circuit takes blood from the left ventricle to the heart muscle itself.
- Blood pressure accounts for the flow of blood in the arteries and the arterioles. Skeletal muscle contraction, valves in the veins, and respiratory movements account for the flow of blood in the venules and veins.
- Cardiovascular disease is the leading cause of untimely death in Western countries. Modern research efforts have resulted in improved diagnosis, treatment, and prevention.

Teaching Strategies

- If possible, obtain a stethoscope to allow students to listen to their own heartbeats and record the number of beats per minute and the sounds that reflect the different parts of the heart cycle.
- Convert **BLM 8.1.1: Heart Anatomy, BLM 8.1.2: Flow of Blood through the Heart,** and **BLM 8.1.3: Blood Vessels** into overhead transparencies or digital images; make photocopies of these for your students. Use these illustrations to support discussions on the anatomy of the heart, as reinforcement, or as formative assessment tools. Use different coloured markers to denote oxygenated and deoxygenated blood.
- Review the links dealing with the heart and circulatory system found at the Online Learning Centre, Instructor Edition, Teacher Web Links.
- **BLM 8.1.4: Investigation 8.A: Identifying Structures of the Circulatory System** will help students complete the dissection of the heart. This worksheet supports an actual dissection as well as a virtual dissection of the mammalian heart.
- **BLM 8.1.5: Electrical System of the Heart** gives students an opportunity to trace the electrical stimuli that make the heart contract.
- **BLM 8.1.6: Blood Velocity and Blood Pressure in Various Parts of the Circulatory System** can be used as an overhead and could serve as an introduction to "Design Your Own" Investigation 8.B: Factors that Affect Heart Rate and Blood Pressure on page 278 of the student textbook. Once again, heart rate and blood pressure sensors may be available to help bring these concepts to life for your students.
- **BLM 8.1.7: Pathways of the Circulatory System** Convert this BLM into an overhead transparency or digital image to support direct instruction or individual student work related to comparing the structure and function of the 3 pathways of the circulatory system.
- Have students complete **BLM 8.1.10: How Much Blood Does Your Heart Pump?** as an optional exercise.

SUPPORTING DIVERSE STUDENT NEEDS

- The terminology introduced in this section could pose a challenge for some students, especially ESL students. Consider allowing these students to initially express their ideas in their first language and have them translate these ideas into English.
- Struggling learners may grasp an idea better by looking at diagrams or pictures. Use the various BLMs provided in this resource to help these students. Or the interactive nature of many web sites could help others visualize the anatomy and physiology of the circulatory system.
- ESL students might benefit from making their own crossword puzzle based on the internal views of the heart.
- Create a two- or three-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 thereof. 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 slideshow presentation software.

Answers to Questions for Comprehension

Student Textbook page 269

Q1. The three main functions of the circulatory system are:

(a) The circulatory system transports gases (from the respiratory system), nutrient molecules (from the digestive system), and waste materials (from the excretory system).

(b) The circulatory system regulates internal temperature and transports hormones.

(c) The circulatory system protects against blood loss from injury and against disease-causing microbes or toxic substances introduced into the body.

Q2. The three components of the human circulatory system are:

(a) heart

(b) blood vessels

(c) blood

Student Textbook page 270

Q3. The four chambers of the mammalian heart are:

(a) right atrium

(b) left atrium

(c) right ventricle

(d) left ventricle

Q4. The function of the heart valves is to ensure that blood flows in the correct direction. There are four valves.

Student Textbook page 272

Q5. Arteries carry blood away from the heart.

Q6. Veins carry blood toward the heart.

Q7. Capillaries link arteries and veins.

Q8. (a) Arteries: An artery has highly elastic walls. This elasticity allows the artery to first expand as a wave of blood surges through it during the contraction of the ventricles, and then snap back again during the relaxation of the ventricles. This movement keeps the blood flowing in the right direction and provides an additional pumping motion to help force the blood through the blood vessels.

(b) Veins: The veins are not as elastic, and cannot contract to help the blood move back to the heart, so the contraction of muscles keeps the blood flowing toward the heart. Veins also have one-way valves that prevent the blood from flowing backwards.

(c) Capillaries: Capillaries are the smallest blood vessels. The capillary wall is a single layer of cells. Gas and nutrient exchange takes place at the capillary level.

Investigation 8.A: Identifying Structures of the Circulatory System

Student Textbook page 272–273

Purpose

The purpose of this activity is to observe, through dissection or computer simulation, the anatomy of a sheep heart and identify the major structural components.

Outcomes

- 20–D2.1k
- 20–D2.3k
- 20–D2.2s

Advance Preparation

Note: The information provided below deals only with the actual dissection of the sheep heart.

Advance Preparation

When to Begin	What to Do
4 weeks prior to the investigation	■ Order the sheep hearts from a scientific supply company. ■ Check supply of safety equipment (gloves, aprons, goggles) and replace if needed. ■ Check that proper disposal procedures are in place if you are planning to do the actual dissection.
1 day before	Photocopy **BLM 8.1.4: Investigation 8.A: Identifying Structures of the Circulatory System**

Materials

- dissecting instruments
- aprons (1 per student)
- eye goggles (1 per student)
- dissecting pan
- dissecting microscope (optional)
- sheep heart (1 per group)
- disposable plastic gloves
- paper towels
- plastic bag and tie (optional)
- soap and water

Time Required

- 1 hour

Helpful Tips

- Sheep hearts can be purchased from most scientific supply companies. The cost of the specimens may require you to complete this activity as a demonstration or use the illustrations provided on the web. For an online alternative to a physical dissection, go to **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, Teacher Web Links for the links to Chapter 8.

- You may wish to use combination of virtual and real dissections. For example, you may wish to start the lesson by using the virtual images to walk students through the dissection. Then provide students with the opportunity to do the actual heart dissection.
- Before starting the dissection, remind students of all safety precautions.
- Remind students that dissection involves the **careful** and **systematic** examination of the structures of an organism.
- Photocopy and distribute **BLM 8.1.4: Investigation 8.A: Identifying Structures of the Circulatory System**. This resource will guide students through this investigation and will protect textbooks from exposure to the liquids involved in the handling the preservation of the specimen, or with blood if using a fresh sheep heart.
- If you are planning on using a fresh sheep heart, 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 Guidelines for Safe Practices* document. This document is available in .pdf format in the Science Curriculum area of the Alberta Education web site, or use the link at the Online Learning Centre, Instructor Edition, Teacher Web Links.
- Group your students in teams of 4 to reduce the number of specimens that you have to purchase. Or, you could set this up in stations that correspond to the instructions in the student textbook. Small groups of students can rotate through the stations in five-minute intervals while others are working on the Section 8.1 Review questions.

Safety Precautions

- Extreme care must be taken when using dissecting instruments, particularly scalpels. As much as possible, make sure 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. For more information refer to Alberta Education's *Safety in the Science Classroom Guidelines for Safe Practices* document.

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 Analysis Questions

1. (a) Right atrium—upper right-hand chamber; have wrinkled, protruding appendages (auricles); slightly larger than a 2 dollar coin; in preserved specimens, they may have a slightly darker appearance; walls are relatively thin (only a few millimetres thick).

(b) Left atrium—upper left-hand chamber; have wrinkled, protruding appendages (auricles); slightly larger than a 2 dollar coin; in preserved specimens, they may have a slightly darker appearance; walls are relatively thin (only a few millimetres thick).

(c) Right ventricle—lower right-hand chamber; smooth with "fat" visible on surface; the coronary arteries and veins are visible; the wall of the right ventricle is thinner than that of the left; the right ventricle is triangular in form; it extends from the right atrium to near the apex of the heart.

(d) Arteries, including the aorta—the aorta is the largest artery in the human body; arteries have thick and elastic walls; they stay open even without blood flowing through them.

(e) Left ventricle—lower left-hand chamber; smooth with fat visible on the surface; the coronary arteries and veins are visible; the walls of the left ventricle are much thicker than those of the right ventricle; the left ventricle is longer and more conical in shape than the right ventricle.

(f) Veins—they have thinner, less muscular walls (they collapse when not filled with blood); veins have valves that allow blood to flow in one direction.

(g) Heart valves—thin flaps of tissues; supported by strong, fibrous strings called chordae tendineae; the chordae, which are attached to the muscular projections on the ventricular walls, support the valves and prevent them from inverting when the heart contracts.

2. Student drawings should include all of the structures identified below. The path of blood through the heart:

superior and inferior vena cava → right atrium → right atrioventricular valve → right ventricle → pulmonary semilunar valve → pulmonary artery → lungs → pulmonary veins → left atrium → left atrioventricular valve → left ventricle → aortic semilunar valve → aorta → body

Answers to Conclusion Questions

3. (a) Some mention should be made that the dissection gives you a true sense of what the organ is like—size, texture, coloration, and dimensions.

(b) Some mention should be made that the virtual dissection gives you a sense of the structure and function of the heart. Students may also discuss personal or cultural objections to dissection.

4. Each student will have different experiences and limitations with respect to the structure and function of the heart.

Assessment Options

- Evaluate this activity by marking answers to the Analysis questions.
- You may wish to use **Assessment Checklist 4 Performance Task Group Assessment** (see Appendix A).

Answers to Questions for Comprehension

Student Textbook page 274

Q9. The **sinoatrial node**, or the SA node, is often referred to as the pacemaker because it is the place from which these stimuli originate during normal heart functions. This node generates an electrical signal that spreads over the two atria and makes them contract simultaneously. As the atria contract, the signal reaches another node called the **atrioventricular node**, or AV node. This node transmits the electrical signal through specialized cardiac muscle cells over the walls of the ventricles to start their contraction.

Q10. The change in voltage produced by these electrical signals can be measured using a device called an electrocardiogram (ECG). In a normal ECG reading, as shown here, the small voltage increase marked as P shows the electrical activity immediately prior to atrial contraction. The large spike at QRS shows the electrical activity immediately prior to ventricular contraction. As the ventricles recover from the contraction, the small spike at T shows the electrical activity as the ventricles recover, before the next stimulation by the S-A node.

Student Textbook page 275

Q11. The "120" is the systolic pressure. Systolic pressure is the maximum pressure during ventricular contraction. The ventricles then relax and the pressure in the pulmonary arteries and the aorta drops.
The "80" is the diastolic pressure. Diastolic pressure is the lowest pressure before the ventricles contract again.

Biology File: Web Link

Student Textbook page 275

Having to amputate a man's frostbitten fingers led Dr. Wilfred G. Bigelow to make two major medical discoveries: the use of hypothermia to allow the first open-heart surgery and the development of the pacemaker to enable people to live normal lives despite life-threatening heart deficiencies.

In 1949, Dr. Bigelow was performing open-heart surgery on a dog that was artificially cooled. During this experimental operation, the dog's heart suddenly stopped. Dr. Bigelow gave the left ventricle a good poke with a probe. All four chambers of the heart responded. Further pokes clearly indicated that the heart was beating normally with good blood pressure. This led him to discover that an electric pacemaking device could enhance their hypothermia experiments.

Reducing the size, using computer chips, increasing reliability, and the development of long-life batteries are only a few of the improvements made to this technology.

Answers to Questions for Comprehension

Student Textbook page 277

Q12. The pulmonary pathway transports oxygen-poor blood to the lungs. When the blood reaches the lungs, oxygen and carbon dioxide are exchanged by diffusion between blood in the capillaries and air in the alveoli of the lungs through the actions of the respiratory system. Oxygen-rich blood returns to the left side of the heart by way of the pulmonary veins.
The systemic pathway moves oxygen-rich blood from the left ventricle of the heart to the body tissues. Oxygen and nutrients move into the tissue cells and waste products move out of the tissue cells into the blood.

Q13. The coronary pathway is dedicated to providing blood to the muscle tissue of the heart itself. The coronary arteries and cardiac veins spread throughout the muscle tissue of the heart. The coronary arteries bring oxygen and nutrients to heart cells, which do not receive any benefit from the blood moving through the interior of the heart.

Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure

Student Textbook page 278

Purpose

The purpose of the investigation is to design an experiment to determine how heart rate and blood pressure are affected by a specific factor.

Outcomes

- 20–D2.1s
- 20–D2.2s
- 20–D2.3s
- 20–D2.4s

Advance Preparation

When to Begin	What to Do
3 or 4 weeks before	■ Check availability of blood pressure cuffs and stethoscopes (if you are using a manual sphygmomanometer). ■ Check that the blood pressure cuff is functioning properly—you may have to replace batteries if using a digital sphygmomanometer.
2 days before	■ Photocopy either Assessment Checklist 1 Designing an Experiment OR Assessment Checklist 2 Laboratory Report if you are planning to use either of these checklists to evaluate your students. ■ Photocopy **BLM 8.1.8: Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure**

Materials

- blood pressure cuffs (1 per group)
- stethoscope (1 per group) if you are using a manual blood pressure cuff
- watch with a second hand or digital display
- materials will depend on the factor(s) that the students decide to test

Time Required

- 1 hour (the time will depend on the number of blood pressure cuffs available)

Helpful Tips

- Use **BLM 8.1.8: Investigation 8.B: Factors Affecting Heart Rate and Blood Pressure** to support this activity. Modify if necessary to meet the needs of your students.
- Use **BLM 8.1.6: Blood Pressure and Blood Velocity at Various Points of the Circulatory System** to begin the discussion.
- Group students in teams of 3. One student is the subject who will be tested; the second is the observer; the third records the data. Limit the number of subjects tested if time and equipment are limited.
- Before students conduct the experiment, ensure that they have a hypothesis and have established how they will test the hypothesis. Data tables should be prepared ahead of time.
- Hand out copies of Assessment Checklist 1 Designing an Experiment OR Assessment Checklist 2 Laboratory Report if you are going to use either of these checklists to evaluate this investigation.
- Make sure students are following school policies in terms of the variables that they are going to test. For example, some may want to test the affects of cigarette smoking on heart rate and blood pressure. However, smoking may contravene school policies and should be discouraged.
- Reiterate the importance of not over-inflating the blood pressure cuff.
- Here are the steps to your students need to follow if they are using a manual sphygmomanometer:
  - A rubber cuff is wrapped around your upper arm and inflated. This compresses a large artery in the arm, momentarily stopping the blood flow.
  - Air is then blown into the cuff and increasing pressure and tightening is felt on the upper arm.
  - Next, air in the cuff is released, and the person measuring the blood pressure listens with a stethoscope placed just below the blood pressure cuff. When the blood starts to pulse through the artery, it makes a sound. Sounds continue to be heard until pressure in the artery exceeds the pressure in the cuff.
  - While the person listens and watches the sphygmomanometer gauge, he or she records two measurements. Systolic pressure is the pressure of the blood flow when the heart beats (the pressure when the first sound is heard). Diastolic pressure is the pressure between heartbeats (the pressure when the last sound is heard). Blood pressure is measured in millimetres of mercury, which is abbreviated mmHg.
- Students should have graph paper, pencils, and rulers to construct graphs or have access to graphing software on a computer in the classroom.
- If you only have one blood pressure cuff, consider setting up a series of stations or have a sponge activity available to keep all students on task while they wait to use the apparatus.
- Digital blood pressure cuffs are usually easier for students to use than the manual sphygmomanometers, which include mercury and aneroid devices. If you are going to purchase a new one, consider getting one that measures both blood pressure and heart rate. This will save time and make it easier for students to gather accurate data.
- Some companies can supply digital blood pressure sensors/probeware. This technology makes collecting and graphically displaying data very efficient.

Safety Precautions

- Over-inflating the blood pressure cuff can damage underlying cells and tissues.
- Students with health problems should not be the test subjects in the investigation. They can still be involved as observers and recorders.

Answers to Analysis Questions

1. The resting blood pressure will vary but should be approximately 120 mmHg/80 mmHg.
2. Blood pressure should increase when the human body is placed under stress. Blood pressure should decrease when the stress is removed.
3. Students' answers will be directly related to the factor that they are investigating. As well, each individual will respond differently to the factor being studied. For example, if students are investigating the effects of exercise, the results will depend on the level of physical fitness of the test subjects. A fit student's heart will return to the resting rate more quickly than an unfit student's. The more vigorous the exercise is, the greater the difference in heart rate, and the longer it may take to return to resting heart rates.

Answers to Conclusion Questions

4. The differences within the class could be due to any number of factors. It will also depend on the variable that was tested (i.e., exercise might have a more dramatic affect on heart rate and blood pressure than drinking a cup of coffee would have).
5. The adaptive advantage to an increase in blood pressure is that this would increase the blood flow to the body tissues. For example, when the body's demand for oxygen increases, as it does during exercise, more blood must be delivered through the capillaries to meet the tissue's needs. Higher blood pressure is needed to ensure an increased flow to all parts of the body that require additional oxygen and nutrients.

Answers to Extension Questions

6. All effective remedies must decrease the blood pressure by relaxing the patient and decreasing the effects of stress on the body. Reducing blood pressure can happen through medical treatments that reduce the chemical responses or through methods in which an individual could naturally control the chemical responses to stress.
7. Special training and practice are required in order to accurately use a manual sphygmomanometer. It is usually difficult for students to match the sound they hear in the stethoscope with the movement of the needle in the pressure gauge. Digital sphygmomanometers may not be as accurate but are much easier to use.

Assessment Options

- Use Assessment Checklist 1 Designing an Experiment to evaluate this investigation.
- Alternatively, you could use Assessment Checklist 2 Laboratory Report to evaluate this investigation.
- Assess student responses to the Analysis and Conclusion questions.

Thought Lab 8.1: Cardiovascular Health, Technology, and Society

Student Textbook pages 280

Purpose

To identify and analyze technological solutions associated with cardiovascular disease.

Outcomes

- 20–D2.1sts
- 20–D2.2sts
- 20–D2.3s

Advance Preparation

When to Begin	What to Do
2 to 3 weeks before	■ Book the library and/or computer room for student research.
2 days before	■ Photocopy Assessment Checklist 7 Independent Research Skills if you are planning on using this checklist to evaluate your students. ■ Photocopy **BLM 8.1.9: Lab 8.1 Cardiovascular Health, Technology, and Society**

Materials
■ computer with Internet access

Time Required

- 1 to 2 hours

Helpful Tips

- Use **BLM 8.1.9: Thought Lab 8.1: Cardiovascular Health, Technology, and Society** to support this activity. Modify it as necessary to meet the needs of your students.
- Review your local Computer/Internet Acceptable Use Agreement with your students, and Online Safety on page xvi.
- Remind your students how to conduct an effective Internet search. Limit the amount of time students have for searching for information and remid them to document all sources.
- Distribute Assessment Checklist 7 Independent Research Skills at the start of the project if you are going to use this checklist to evaluate your students.

SUPPORTING DIVERSE STUDENT NEEDS

- Some students may struggle trying to locate appropriate information on the Internet. Consider providing these students with a bookmarked list of web sites to help them focus their attention on the content.
- Some students may lack the required computer skills for this project. Consider pairing these students with students who have stronger computer skills.
- Enrichment: Invite a retired heart specialist from your area to come in and talk to your students about the advances in cardiovascular diagnosis and treatment during their career.

Answers to Analysis Questions

1. The data and information students obtain will depend on the technologies they investigate; bodies and agencies such as Statistics Canada, the Canadian Heart and Stroke Foundation, the Canadian Cancer Foundation, and the Faculty of Medicine at the University of Alberta are suitable starting points for students' research.
2. Most cardiovascular problems are directly related to lifestyle choices including smoking, obesity, high cholesterol levels, high blood pressure, and inactivity.
3. A personal commitment to healthy living can be a key factor in preventing heart disease and stroke.
   - Eat healthy foods and maintain a healthy weight.
   - Increase your physical activity.
   - Do not smoke.
   - Monitor and treat high blood pressure, high cholesterol and diabetes.

Answers to Extension Question

4. It is likely students will have differing opinions on this issue. Look for arguments that are based on fact and logic, rather than on emotions.

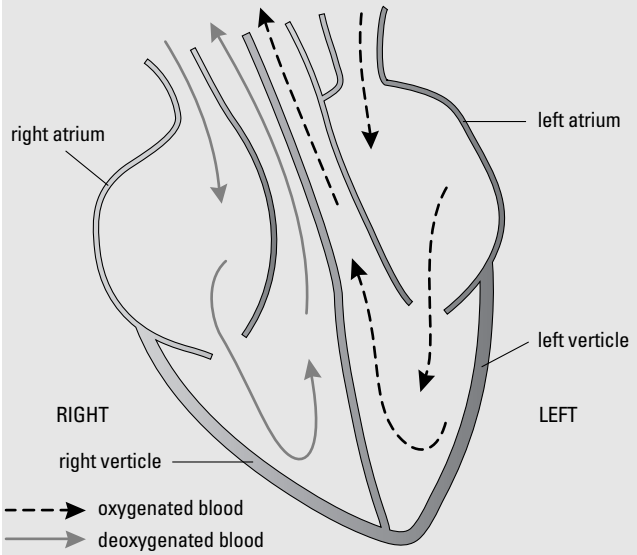
Assessment Options

- Use **Assessment Checklist 7 Independent Research Skills** to evaluate your students.
- Collect and evaluate student answers to the Analysis, Conclusion, and Extension questions found at the end of this investigation.

Section 8.1: Review Answers

Student Textbook page 281

1. Students' diagrams should resemble Figure 8.2 (B) Internal View of the heart found on page 269. Labels should include the right and left atria and the right and left ventricles. The diagram should show deoxygenated blood (blue) flowing into the right atrium through the venae cavae and flowing out of the right ventricle through the right and left pulmonary arteries. Oxygenated blood (red) should be shown flowing into the left atrium through the pulmonary veins and flowing out the left ventricle through the aorta.

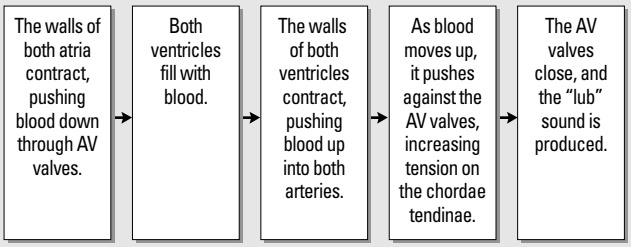


2. An artery has highly elastic walls. This elasticity allows the artery to first expand as a wave of blood surges through it during the contraction of the ventricles, and then snap back again during the relaxation of the ventricles. This movement keeps the blood flowing in the right direction and provides an additional pumping motion to help force the blood through the blood vessels.

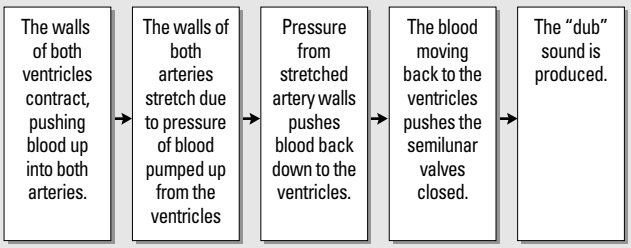
   The veins are not as elastic, and cannot contract to help the blood move back to the heart, so the contraction of skeletal muscles keeps the blood flowing toward the heart. Veins also have one-way valves that prevent the blood from flowing backwards.
3. No, not all arteries carry oxygen-rich blood, and not all veins carry oxygen-poor blood. The pulmonary artery carries oxygen-poor blood from the right side of the heart to the lungs.

   The pulmonary vein carries oxygen-rich blood from the lungs to the left side of the heart.
4. pulmonary artery → pulmonary vein → left atrium → left ventricle → aorta → superior vena cava → right atrium → right ventricle

5. The first heart sound, known as "lub," is created as follows:



The second heart sound, known as "dub," is created as follows:



6. The labels are as follows: 1. SA node; 2. AV node; 3. branches of the atrioventricular bundle; 4. Purkinje fibres.

7. There are multiple factors that can lead to high blood pressure, including those that the individual can control. Students should identify any two of these factors and include how the approach they might take to lower high blood pressure:

- Overweight (obesity): Obesity is defined as being 30% or more over your healthy body weight. It is very closely related to high blood pressure. Medical professionals strongly recommend that all obese people with high blood pressure lose weight until they are within 15% of their healthy body weight. Your health-care provider can help you calculate your healthy range of body weight.
- Sodium (salt) sensitivity: Some people have high sensitivity to sodium (salt), and their blood pressure goes up if they use salt. Reducing sodium intake tends to lower their blood pressure. North Americans consume 10–15 times more sodium than they need. Fast foods and processed foods contain particularly high amounts of sodium. Many over-the-counter medicines, such as painkillers, also contain large amounts of sodium. Read labels to find out how much sodium is contained in food items. Avoid those with high sodium levels.
- Alcohol use: Drinking more than 1–2 drinks of alcohol per day tends to raise blood pressure in those who are sensitive to alcohol.
- Birth control pills (oral contraceptive use): Some women who take birth control pills develop high blood pressure.
- Lack of exercise (physical inactivity): A sedentary lifestyle contributes to the development of obesity and high blood pressure.
- Drugs: Certain drugs, such as amphetamines (stimulants), diet pills, and some pills used for cold and allergy symptoms, tend to raise blood pressure.

8.2 Blood and Circulation

Student Textbook pages 282–291

Section Outcomes

Students will:

- describe the main components of blood
- perform a microscopic analysis of blood
- explain the role of blood in regulating body temperature
- explain the role of the circulatory system, at the capillary level, in the exchange of matter and energy
- identify certain blood disorders and the technologies used to treat them

Key Terms

plasma
formed portion
red blood cells
erythrocytes
hemoglobin
white blood cells
leucocytes
platelets
vasodilation
vasoconstriction
interstitial fluid
hemophilia
leukemia

Biology Background

- Blood is the only liquid tissue in the body. If blood is transferred from a person's veins to a test tube and is prevented from clotting, it separates into formed elements (cells and cell fragments) and a liquid (plasma). The formed elements are red blood cells, white blood cells, and platelets.
- Red blood cells, which are more numerous and smaller than white blood cells, contain hemoglobin and carry oxygen. White blood cells, which are translucent when not stained, all fight infection but are varied as to their specific characteristics and functions. Platelets are cell fragments that initiate the blood clotting when a blood vessel is damaged.
- The blood plays an important role in maintaining homeostasis. This role is in relation to temperature regulation. When the body temperature falls below normal, the regulatory centre in the brain directs the blood vessels

of the skin to constrict. This conserves heat. When the body temperature is higher than normal, the regulatory centre directs the blood vessels of the skin to dilate. This allows more blood to flow near the surface of the body, where heat can be lost to the environment.

- Oxygen and nutrient substances exit; carbon dioxide and waste molecules enter midway along a capillary in the body tissues. The direction of diffusion is determined by a material's concentration gradient.
- Anemia and leukemia are two disorders associated with the red and white blood cells, respectively.

Teaching Strategies

- **BLM 8.2.1: The Cellular Components of Blood** is an overhead transparency to support the teaching of this information.
- **BLM 8.2.2: Blood Cell Activity** and **BLM 2.2.3 When Red Blood Cells Go Wrong** gives students a chance to infer conditions based on blood test results.
- **BLM 8.2.4: Investigation 8.C: Identifying Blood Cells** is designed to support the investigation in the student textbook. Modify it as necessary to meet the needs of your students.
- Use **BLM 8.2.5: Circulatory System Disorders** to help students track this information.
- **BLM 8.2.6: Thought Lab 8.2: Keeping Canada's Blood Safe** has been created to support the activity. Modify it as necessary to meet the needs of your students.
- **BLM 8.2.7: Blood Groups** is an enrichment BLM. Blood typing is not an outcome in the *Biology 20* program of studies, however, you may wish to provide students with this information.

- Enrichment: Invite a representative of the Canadian Blood Services to talk to your students about donating blood and the safety of our blood supply. Warn this individual that your students will have some knowledge of the tainted blood scandal and the Krever Commission. (See Thought Lab 8.2: Keeping Canada's Blood Supply Safe)
- Enrichment: The program of studies for this topic does not include the detailed chemical reactions involved in blood clotting. (See pages 283–284 for treatment of blood clotting.) Challenge your students to use a different resource to list the steps in blood clotting and link these to hemophilia.
- Create a two- or three-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 thereof. 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 slideshow presentation software.

Answers to Questions for Comprehension

Student Textbook page 284

Q14. Blood is the only liquid tissue in the body. It is a mixture—if blood is transferred from a person's vein to a test tube and is prevented from clotting, it separates into two layers. The lower layer is formed elements (cells) and the upper layer is plasma. Mixtures can usually be separated into their component parts.

Q15. There are 4 to 6 million red blood cells per cubic millilitre of blood. Normal, mature red blood cells do not have a nucleus.

The same volume of blood contains 4000 to 11 000 white blood cells. All white blood cells have a nucleus.

Q16. Platelets are cell fragments. These formed elements initiate the process of blood clotting or coagulation.

Investigation 8.C: Identifying Blood Cells

Student Textbook page 285

Purpose

To determine, through microscopic inspection, the shape and abundance of cellular components in a prepared slide of human blood.

Outcomes

- 20–D2.4k
- 20–D2.2s

Advance Preparation

When to Begin	What to Do
3 to 4 weeks before	■ Check supply of prepared human blood slides. ■ Book microscopes and biology lab, if necessary.
2 days before	■ Photocopy **BLM 8.2.4: Investigation 8.C: Identifying Blood Cells.** ■ Photocopy **BLM 8.2.1: Cellular Components of Blood**, for reference.

Materials
■ light microscope (1 per group) ■ prepared human blood slide (1 per group)

Time Required

- 1 hour (time will depend on number of microscopes and the skill level of students)

Helpful Tips

- Prior to starting this investigation, review the components of human blood. This can be accomplished with BLM 8.2.1, the illustrations on page 285 of the student textbook, and/or by showing digital images of each component.
- Remind students that the cells that they are going to see, even under high power magnification, are going to be relatively small when compared to illustrations found in textbooks or on the Internet.
- If you have the proper adapter, connect one of your microscopes to a digital camera to show students exactly what they are going to see when they as they work through this investigation.
- Before starting this investigation, review the steps for proper microscope use and calculating the field of view. These skills can be found in Appendix C, on page 756 of the student textbook.
- Students may have problems actually counting the red blood cells in a complete field of view. Suggest that they use the sampling technique discussed in chapter 4, mentally dividing the field of view in half, counting the red blood cells in this area, and then multiplying by two.
- Have students work in pairs. One student can count the cells in the field of view while the other uses a tally chart record the number of each type of cell. Once they have finished, switch roles and average the tallies.
- Use **BLM 8.2.4: Investigation 8.C: Identifying Blood Cells** to support this activity. Modify it as necessary to support students' needs.

Safety Precautions

- For those that are new to the profession, a reminder that use of human body fluids is **not** permitted in Alberta. You must only use prepared slides of human blood.
- Remind students to handle the microscopes and slides carefully.

Answers to Analysis Questions

1. Red blood cells do not have a nucleus because they must be pliable and able to fold so that they can enter the tiny blood vessels and capillaries that extend to the far reaches of the body. Also, they have to fit through the tiny slits in the spleen which helps to filter the blood.

or

The presence of a nucleus would change the biconcave shape of the red blood cell. The biconcave shape increases their flexibility for moving through capillary beds and increases their surface area for the diffusion of gases.

2. It is unlikely that students will see platelets using a medium-power objective lens. These cell fragments are only 2 to 4 μm in diameter.

Answers to Conclusion Questions

3. It is likely they will indicate that white blood cells are stained purple, you can see their nucleus, and they are larger than red blood cells.

4. (a) There should be hundreds of red blood cells and only 1 to 4 white blood cells in their field of view.

(b) Students should indicate that there are many more red blood cells. However, they do not know the volume of blood in their field of view, which makes it impossible to come up with the answer of 4 million to 6 million red blood cells per mm^3 blood.

Teacher note: Blood cell counts can be performed using the hemacytometer. This is a precision instrument that possesses a platform with microscopic grid scoring, above which a specified quantity of fluid is held. By diluting blood properly, counting all cells in specified squares, and multiplying by the proper conversion factor, the number of cells per cubic millimetre can be determined.

Assessment Options

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

Biology File: Web Link

Student Textbook page 286

Students may find more than one theory as they conduct their research into this topic.

- One theory is that moderate- to high-altitude living increases red blood cell concentrations, allowing more oxygen to reach the muscles during exercise. High altitude training also hikes the levels of an important chemical called 2.3-DPG, which helps release oxygen from red blood cells to the muscles during intense exercise.
- Other studies have found that living at high altitude and training at low altitude (live high/train low) leads to increased performance, increased red blood cell mass, and increased VO_2 max.

Technological Methods include:

- **Blood doping**: The term "blood doping" refers to the blood transfusion in athletes who have normal levels of red blood cells, in an attempt to increase their maximal aerobic power and thereby improve their performance.
- **EPO**: Erythropoietin, or EPO, is an artificial hormone that allows the blood to carry more oxygen, thus boosting endurance. It is favoured by endurance athletes and has saturated such sports as professional cycling and cross-country skiing.

- **Darepoetin:** Like EPO, darepoetin stimulates the body's production of oxygen-carrying red blood cells. Its performance-enhancing effect for endurance athletes is significant.

Why are they illegal?

- Sample from the American Medical Association: "Athletes or their trainers who request blood transfusions to improve their performance are seeking to gain an unfair competitive advantage. A physician who would acquiesce to such a request is thereby assisting in an unfair practice to the detriment of competitive sports."

Answers to Questions for Comprehension

Student Textbook page 287

Q17. Blood, a vital tissue fluid, carries oxygen from the lungs and nutrients from the small intestines to the cells. It also takes carbon dioxide to the lungs and waste to the kidneys. Other functions of the blood include helping to fight infection, regulate body temperature, and transport hormones from endocrine glands to target organs.

Q18. A number of factors trigger vasomotor actions. Vasodilation in the skin occurs in response to an increase in blood (core) temperature, such as occurs during strenuous exercise. This response dissipates heat from the skin, which cools the internal temperature.

Localized vasoconstriction in the extremities occurs in response to a decrease in blood temperature. For example, the hands and fingers lose blood flow in the cold, due to vasoconstriction which limits heat loss, thereby maintaining core body temperature.

Other factors which cause vasomotor actions are changes in blood pressure. As blood pressure increases, vasodilation of arteries throughout the body tends to decrease it. As blood pressure decreases, vasoconstriction increases it. Certain drugs, such as nicotine and alcohol are vasodilators. Blushing from embarrassment is caused by rapid vasodilation of the blood vessels in the face in response to nervous stimulation.

Student Textbook page 288

Q19. The cells of the body are constantly bathed in liquid, called interstitial fluid. Any material that is exchanged between the capillaries and the cells must pass through the interstitial fluid.

Q20. Capillaries are very important in maintaining homeostasis because an exchange of substances takes place across their thin walls. Oxygen and nutrients, such as glucose, diffuse out of a capillary into the tissue fluid that surrounds cells. Wastes, such as carbon dioxide, diffuse into the capillary. The relative constancy of tissue fluid is dependent upon capillary exchange. As well, opening and closing capillary beds near the surface of the body is an important homeostatic mechanism responsible for maintaining a relatively constant internal body temperature.

Thought Lab 8.2: Keeping the Blood Supply Safe

Student Textbook page 289

Purpose

To identify and evaluate possible solutions to blood shortages.

Outcomes

- 20–D2.3s
- 20–D2.2sts

Advance Preparation

When to Begin	What to Do
2 to 3 weeks before	■ Book the library and/or the computer lab.
2 days before	■ Photocopy **BLM 8.2.6: Thought Lab 8.2: Keeping the Blood Supply Safe** ■ Photocopy Assessment Checklist 7 Independent Research Skills if you plan to use the checklist to evaluate your students.

Materials
■ none

Time Required

- 1 hour

Helpful Tips

- Use **BLM 8.2.6: Thought Lab 8.2: Keeping the Blood Supply Safe** to support this activity. Modify it as necessary to meet your students needs.
- Provide an alternative assignment for students who oppose blood transfusions for cultural or religious reasons.
- Consider inviting a representative from Canadian Blood Services in to talk to your students about donating blood. Review related links at the Online Learning Centre, Instructor Edition, Teacher Web Links if planning to provide links to students.

Answers to Analysis Questions

1. Look for some of the following points:

Giving blood saves lives. Whole blood donations are processed into a variety of blood components. Each donation can save the life of as many as four people—

people with leukemia, cancer, anemia, and those undergoing surgery for illness or injury.

No, some individuals, for cultural or religious reasons, do not share this view.

2. According to the Canadian Blood Services, the following people are eligible to donate blood:

- **Age**: Between 17th and 71st birthday (regular donor), or between 17th and 61st birthday (first-time donor).
- **Weight**: At least 50 kg (110 lb).
- **Frequency of Donation:** Minimum interval between blood donations is 56 days.
- **Health:** In general good health and feeling well. You should have had something to eat and adequate sleep. You must also meet hemoglobin (iron) requirements (the test is done at the clinic).

The following are some of the reasons why people may not be able to donate blood: (from the Canadian Blood Services web site)

- **Minor Illness:** Some may not feel like donating blood when they are not feeling good.
- **Drugs/Medications:** Some medications, or the underlying cause for taking the medication, may require a temporary deferral.
- **Dental Work:** For a cleaning or a filling, donors must wait until the day after treatment before donating blood. For an extraction, root canal or dental surgery, donors must wait 72 hours before donating blood—provided that the donor has recovered fully.
- **Low Hemoglobin Counts:** CBS temporarily defers blood donors whose hemoglobin copper sulfate test falls below the standard of 12.5 g/dL.
- **Tattoos/Body Piercing:** Donors must wait one year after having a tattoo or body piercing before donating blood or bone marrow. The reason for this temporary deferral is the increased risk of Hepatitis C and other infections associated with tattoos and piercing. Other similar procedures that may fall under this category include acupuncture and electrolysis.
- **Diabetes:** If you have diabetes that is treated by diet or oral hypoglycemics, you ***may*** be eligible to donate blood. It is important to note that each donor is different, and the use of certain medications or other underlying conditions may be cause for deferral.
- **Pregnancy:** If you have had a pregnancy in the last six months you will be temporarily deferred from giving blood and/or bone marrow.
- **HIV High Risk Activities:** Being the sexual partner of someone who has participated in high-risk sexual activities will result in a temporary deferral.
- **Exposure to Disease/Geographical Deferrals:** Exposure to diseases, such as malaria or hepatitis, may result in a temporary deferral.
- **Recent Major Surgery:** If you have had surgery recently, please speak to your local blood centre regarding your eligibility.
- **Recent Vaccinations:** Recent vaccinations may result in a temporary deferral. For example, there is a two-day deferral period after receiving a shot for influenza (the flu).

3. Up to 4 blood components may be made from 1 unit of donated whole blood:

- Red blood cells: The red blood cells carry oxygen. A concentrate contains twice the amount of red blood cells in the same volume of liquid. Most recipients of donated blood are given red cell concentrates to boost the oxygen-carrying abilities of their own blood.
- Platelets: Platelets are needed for blood clotting. People who need extra platelets include those with certain diseases, such as leukemia, or those recovering from severe blood hemorrhage.
- Plasma: Plasma is the liquid component of blood. A donation of plasma helps to boost blood volume.
- Cryoprecipitate: This substance is found in plasma and contains clotting factors. Cryoprecipitate can be isolated from plasma and is commonly used to treat severe hemorrhage.

4. Here is an example of five misconceptions that people have about donating blood:

Misconception 1: I become weak and anemic after donating blood.

- Donating blood is unlikely to make a person weak or anemic. If the person is already anemic, then the person will not be allowed to donate blood.

Misconception 2: I won't get the blood I lost back.

- Blood usually is replenished within 48 hours after blood donation. Usually not more than 350 mL of blood is collected in one donation. This is roughly <7% of the total blood volume in an average healthy person, who has approximately 5 litres of blood.

Misconception 3: I will get a disease when I donate.

- Reputable donation centres and blood banks use sterile single use bags and needles and have trained staff to handle the process. There is no risk of catching any disease in the process of donating blood.

Misconception 4: My BP will go down after donating blood.

- Some people are anxious during blood donation and their anxiety shows up as a slightly elevated pulse rate. Usually this settles down after in a few minutes. Blood donation does not usually affect blood pressure.

Misconception 5: I will feel giddy after donation.

- Unlikely! The feeling of giddiness is more psychological than physiological. There is no need to be anxious about blood donation. It is safe, easy, and painless.

5. One possible answer is through the development of artificial blood.

Answers to Extension Questions

6. The Canadian Blood Services web site identifies blood screening as the first line of defense in ensuring the safety of the Canadian blood supply. Donated blood is tested for pathogens causing syphilis, Hepatitis B and C, and West Nile Virus. The blood is also tested for HIV and Human T-Cell Lymphotropic Virus, which is associated with T-cell leukemia.

The second line of defense is screening of donors through a series of tests and questions. Potential donors from certain parts of Africa are deferred because of possible exposure to a new strain of HIV. Persons who spent time in the United Kingdom between 1980 and 1996 are also deferred due to possible exposure to vCJD—the pathogen causing "mad-cow" disease. Persons who have history of intravenous drug use or of high-risk sexual activity are not permitted to donate blood. Other reasons for deferral are also given.

Student opinions about whether they think that these and other procedures described on the web site are adequate, but must be supported by evidence.

7. Student positions about government vs. privatized management of the blood supply should be supported by evidence related to the relative costs, blood safety, blood availability, and other factors affecting the quality and timeliness of care given to those in need of blood.

Connections (Social and Environmental Contexts)

The Tomorrow Project

Student Textbook pages 286

Teaching Strategies

- Discussion points relating to the Tomorrow Project could include:
  - How much of the students' current behaviour is influenced by the release of scientific findings?
  - Would the findings of this study make the students change lifestyle habits? Why or why not?
  - If the findings of the study indicated that major changes had to be made, for example less polluting technology had to be used or certain chemicals or materials had to be discontinued, that would lower the standard of living, would students support making those changes? Why or why not?

Answers to Questions

1. The URL for the Tomorrow Project is **http://www.cancerboard.ab.ca/tomorrow/index.htm**. Mailing address is: The Tomorrow Project, Alberta Cancer Board, Division of Population Health & Information, 1331–29 Street NW, Calgary, AB, T2N 4N2.

2. Lung cancer remains the leading cause of death due to cancer for both men and women in Canada. Eating a healthy diet and avoiding tobacco are the modifiable risk factors associated with lung cancer.

Biology File: Web Link

Student Textbook page 291

Transplantation with blood-forming stem cells is an accepted treatment to restore the body's ability to make white blood cells. Cancer treatment involving very high-dose chemotherapy or radiation therapy may result in severe injury to blood-forming cells in marrow, the spongy material inside the bones. Selected patients with leukemia may benefit from high-dose chemotherapy or radiation therapy, followed by stem cell transplantation. Blood-forming stem cells are immature cells that can develop into any of the three types of blood cells (red cells, white cells, or platelets).

As a stem cell source, umbilical cord blood is not controversial and readily available; in fact, the cord blood is normally discarded after a baby's birth.

Section 8.2: Review Answers

Student Textbook page 291

1. Summary of cellular components of blood.

Point of Comparison	Red blood cells	Leucocytes	Lymphocytes	Platelets
Origin	red bone marrow	red bone marrow	thymus, red bone marrow	red bone marrow, lungs
Cells present per mm^3 of blood	5 500 000 (male) 4 500 000 (female)	6000	2000	250 000
Relative size	small	largest	large	smallest
Function	to carry oxygen and carbon dioxide to and from cells	to engulf foreign particles and pathogens	to play a role in the formation of antibodies	to play a role in the clotting of blood
Life span	120 days	a few hours to a few days	unknown	2 to 8 days

Point of Comparison	Red blood cells	Leucocytes	Lymphocytes	Platelets
Appearance	biconcave disc; no nucleus	granular; large nucleus visible	not granular; large nucleus	small cell fragments

2. Plasma contains water, blood proteins (fibrinogen, serum albumin, serum globulin), organic substances (urea, glucose, amino acids, lipids), inorganic ions (calcium, chloride, magnesium, potassium, sodium, bicarbonates, carbonates, phosphates), some dissolved oxygen and carbonic acid.

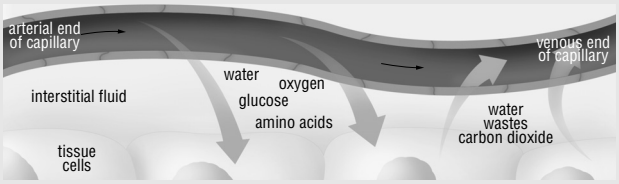
3. (a) The circulatory system and digestive system: nutrients such as glucose and amino acids diffuse directly into capillaries in the villi of the small intestine; blood transports these nutrients to the liver and other organs/cells of body. The blood also absorbs water, salts (minerals) and vitamins B and K from the large intestine.

(b) The circulatory system and endocrine system: hormones secreted by endocrine glands are taken up in the blood and transported throughout the body, thereby communicating with their specific target organs.

(c) The circulatory system and respiratory system: red blood cells pick up and transport oxygen from the lungs to the cells. Carbon dioxide dissolves in blood plasma and enters the red blood cells in the capillary networks throughout the body and is then transported to the lungs.

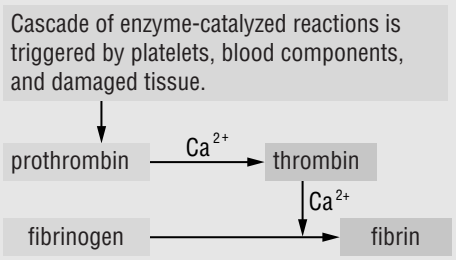
(d) Circulatory system and excretory system: blood transports nitrogenous wastes (urea and uric acid) from the cells to the kidneys where these toxic substances are removed from the blood. The kidneys also control the osmotic pressure and the pH of the blood.

4. The following diagram shows the materials exchanged between blood in the capillaries and the surrounding cells. The arrows show the direction in which the force of diffusion acts in this exchange.



5. (a) One disorder that causes a low hematocrit is leukemia. This disease is characterized by anemia, fatigue, increased susceptibility to infectious diseases and increased blood clotting time due to a low platelet count.

(b) The following flow chart summarizes some of the steps in the blood clotting process:



8.3 The Lymphatic System and Immunity

Student Textbook pages 292–300

Section Outcomes

Students will:

- describe and explain the function of the lymphatic system
- identify and list the main cellular and non-cellular components of the human defence system
- describe the role of the cellular and non-cellular components of the human defence system

Key Terms

lymphatic circulatory system
lymph
non-specific defences
cell-mediated immunity
phagocytosis
macrophages
immunity
specific defences
antibody-mediated immunity
antibodies
lymphocytes
B cells
T cells
antigens
helper T cells
killer T cells
suppressor T cells
memory T cells
ABO system
Rh factor

Biology Background

- The lymphatic system consists of lymphatic vessels and the lymphoid organs. This system, which is closely associated with the cardiovascular system, has three main functions that contribute to homeostasis: (1) lymphatic capillaries

take up excess tissue fluid and return it to the bloodstream; (2) lacteals in the villi of the small intestine absorb fats and lipids from the digestive system and transport them to the bloodstream; and (3) the lymphatic system works with the immune system to help defend the body against disease.

- The immune system includes the cells and tissues that are responsible for immunity. Immunity is the body's ability to defend itself against infectious agents, foreign cells, and even abnormal body cells, such as cancer cells. Thereby, the internal environment has a better chance of remaining stable.
- Immunity includes non-specific and specific defences. The four types of defences are barriers to entry, the inflammatory reaction, natural killer cells, and the production of protective proteins (antibodies).
- Defence by B cells is called antibody-mediated immunity because the various types of B cells produce antibodies. T lymphocytes, also called T cells, do not produce antibodies. Instead, certain T cells directly attack cells that bear non-self proteins. Other T cells regulate the immune response.

Teaching Strategies

- Use **BLM 8.3.1: Human Lymphatic System** as an overhead to support discussions on the structure and function of the lymphatic system.
- Figure 8.27 on page 294 has been converted into **BLM 8.3.2: Immune Response** to support classroom teaching and discussions.
- **BLMS 8.3.3: Immune Response Specific** and **8.3.4: Immune Response Nonspecific** can be used either as handouts or quizzes to support the material in this section.

- The Human Immune System web site (**http://www.schoolscience.co.uk/content/4/biology/abpi/immune/ index.html**) provides a basic introduction to the topic. It is somewhat interactive and includes information on topics, such as immunization, that are not covered in the Alberta Program of Studies.
- The Biology Mad – Immunology web site (**http://www.biologymad.com/**) is mainly aimed at students studying AQA (spec. A) Biology in the UK. This web site could be useful as an enrichment tool for higher-level students.
- ESL students could prepare a series of flash cards with a drawing of a particular cell or other part of the immune system on one side and an appropriate description on the back. Students could quiz each other about the items on each card (perhaps in a "game-show" format, in which students earn points, etc.).

Answers to Questions for Comprehension

Student Textbook page 293

Q21. The lymphatic circulatory system is a network of vessels, with associated glands or nodes, which extends throughout the body. The lymphatic vessels collect a fluid, called lymph, which is made up of interstitial fluid. Lymph vessels are closely associated with the capillaries of the cardiovascular system. Fluid that escapes from the cardiovascular capillaries forms part of the interstitial fluid. Some of this fluid is collected in the lymphatic capillaries and is eventually returned to the blood.

Q22. The lymphatic system also works with the white blood cells to protect the body against infection. White blood cells called lymphocytes mature in the lymph nodes, the glands that are found throughout the lymphatic system. The lymph nodes also contain macrophages, which trap and destroy bacteria that are circulating within the body.

Student Textbook page 295

Q23. The three lines of defence are:

- the skin – preventing the entry of pathogens (physical barriers)
- non-specific defences – cell-mediated immunity
- specific defences – antibody-mediated immunity

Q24. The specific immune system is primarily a function of the lymphocytes in the circulatory system. The lymphocytes are divided into two specialized groups, depending on where they mature. B lymphocytes, or **B cells**, mature in the bone marrow. T lymphocytes, or **T cells**, mature in the thymus gland, which is located near the heart.

Q25. Characteristics of B Cells:

- B cells mature in the bone marrow
- B cells give rise to plasma cells, which produce antibodies (antibodies combine with and neutralize a specific antigen)
- antibodies are secreted into blood, lymph, and other body fluids

Characteristics of T Cells:

- T cells are produced in bone marrow and mature in thymus
- these cells do not produce antibodies
- killer T cells directly attack cells that bear non-self antigens
- other T cells regulate the immune response

Student Textbook page 297

Q26. The blood groups are named for the presence of A or B antigens on the surface of the red blood cells. Type A blood has A antigen, Type B has B antigen, Type AB has both and Type O has neither. Antibodies to these antigens are found in the plasma of persons who lack the corresponding antigens. The plasma of Type O blood contains both anti-A and anti-B antibodies. Type AB plasma contains neither antibody. Type A plasma contains anti-B antibodies and Type B plasma contains anti-A antibodies.

Q27. The Rh factor is an antigen found on the surface of red blood cells in many people, who are said to be Rh+.

Individuals without the Rh factor are said to be Rh- and will produce anti-Rh antibodies if they are exposed to the Rh factor on foreign red blood cells. This can happen if an Rh- woman is pregnant with an Rh+ child. If fetal red blood cells cross the placenta and enter the maternal blood (this will most certainly occur during birth), the woman will produce anti-Rh antibodies within a few hours. The presence of these antibodies will cause hemolytic disease in the children of subsequent pregnancies.

Biology File: Web Link

Student Textbook page 297

- Anemia: A condition in which the number of red blood cells in reduced, thus reducing the amount of oxygen that can be transported in the blood.
- Hyperbilirubemia: A condition in which bilirubin, a breakdown product of hemoglobin, builds up in the blood and other tissues and fluids, causing jaundice (a yellow colouring of skin and body tissues).
- Hydrops fetalis: A condition in which, due to anemia, heart failure develops and large amounts of fluid build up in the tissues and organs of the fetus's body.

  Treatments during pregnancy include intrauterine blood transfusions and induced labour. Treatments after birth include blood transfusions, intravenous fluids, and respiratory assistance such as a mechanical ventilator.

Thought Lab 8.3: Barriers of Defence

Student Textbook page 298

Purpose

To design a model or simulation to demonstrate the functioning human immune system.

Outcomes

- 20–D2.8k
- 20–D2.2s
- 20–D2.4s

Advance Preparation

When to Begin	What to Do
2 to 3 weeks before	■ Book library and/or computer room for Internet research.

Advance Preparation

When to Begin	What to Do
1 week before	■ Assign students into groups. ■ Outline the activity for the students. ■ Have them brainstorm materials that they will need to construct their model and who will be responsible for collecting these materials.
2 days before	■ Photocopy **BLM 8.3.5: Thought Lab 8.3: Barriers of Defence** ■ Photocopy Assessment Checklist 4: Performance Task Group Assessment if you are planning on using it to evaluate your students.

Materials
■ students are to determine the materials that they will use to make their model or create their simulation ■ you may wish to supply toothpicks and coloured modelling paste

Time Required

- 30 minutes to discuss the assignment and brainstorm required materials
- 1 hour to do the library or Internet research
- 1 hour to build the model or create the simulation

Helpful Tips

- Use **BLM 8.3.5: Thought Lab 8.3: Barriers of Defence** to support this activity. Modify it as necessary.
- If you are going to use it, go over Assessment Checklist 4 Performance Task Group Assessment with your students prior to starting this activity. This tool may help get all members of the group involved in the project.
- Some students will have a tendency to waste time on this type of activity. Make sure that you established timelines in terms of research time, gathering materials, and constructing the models.
- Producing an edible model is motivating for some students.

Safety Precautions

- Check for food allergies if students are planning to build their models out of candies or other food products.

Answers to Analysis Questions

1. Students should look for similarities and differences when comparing their models. Use any discrepancies as a teaching opportunity to point out different components of the immune system.
2. Remind students that a model in science is a tool that helps to better understand a scientific concept. Scientists use models to help them communicate their ideas to other scientists and/or to students.
3. Use Assessment Checklist 4 Performance Task Group Assessment to focus attention on group dynamics.

Assessment Options

- Use Assessment Checklist 4 Performance Task Group Assessment to evaluate group work.
- Use a simple rubric such as the one below to evaluate the model of the immune system.

Scientific Model Marking Rubric

- **3 points:** Students followed directions accurately, completed their model completely and accurately, identified each part of the model, and actively participated in the class discussion about the human immune system.
- **2 points:** Students followed most of the directions accurately; completed their model but had a couple of errors; identified most parts of the model; and participated somewhat in the class discussion.
- **1 point:** Students followed some of the directions accurately but were not able to complete their model; identified some parts of the model; and participated a little bit in the class discussion.

Biology File: Web Link

Student Textbook page 299

In anaphylaxis, cells of the immune system release massive amounts of chemicals—particularly histamine. As a result, blood vessels dilate and begin to leak fluid into surrounding tissues, producing swelling. Anaphylaxis is a sudden, potentially severe allergic reaction that can involve various systems in the body (such as the skin, respiratory tract, gastrointestinal tract, and cardiovascular system). This can cause a person's blood pressure to drop, airways to narrow, and tongue to swell. The result is serious breathing difficulty, loss of consciousness, and, in some cases, even death.

Research is underway to produce a long-lasting vaccine that will protect people with peanut allergies. Other research projects are looking for new drugs to desensitize individuals. Experimental drugs, such as Xolair®, may prevent or reduce the severity of reactions for people who suffer from peanut allergies.

Biology File: Web Link

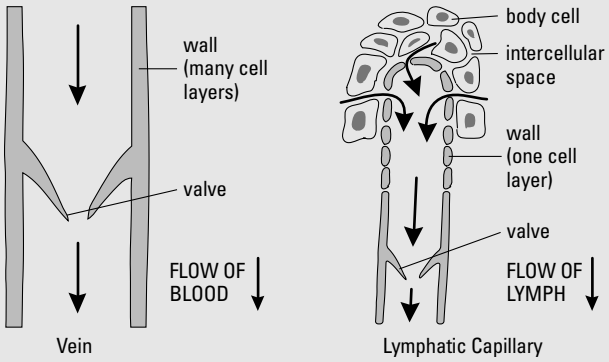
Student Textbook page 300

Using the same software techniques traditionally used to analyze databases and track spam, medical researchers can find hidden patterns in millions of HIV strains and create improved vaccine designs. The genetic patterns are necessary to train a patient's immune system to fight the deadly virus.

Section 8.3: Review Answers

Student Textbook page 300

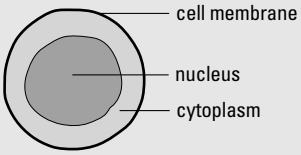
1. Lymph vessels are closely associated with the capillaries of the cardiovascular system. Fluid that escapes from the cardiovascular capillaries forms part of the interstitial fluid. Some of this fluid is collected in the lymphatic capillaries and eventually returned to the blood.
2. The lymphatic system works to maintain the steady flow of water and other substances between the blood, the interstitial fluid, and the lymphatic system. The lymphatic system also works with the white blood cells to protect the body against infection.
3. Lymph enters the lymphatic system from tissue spaces throughout the body through lymphatic capillaries. A sketch of a lymphatic capillary should show that its walls consist of one cell layer with pores between the cells through which lymph enters from intercellular spaces. The lymphatic capillary is a closed-ended tube where it originates in the tissues. Valves positioned along the length of the capillary prevent back-flow of lymph. A sketch of a vein should show that its walls are many cell layers thick, it is open-ended and that it contains valves that prevent back-flow of blood.



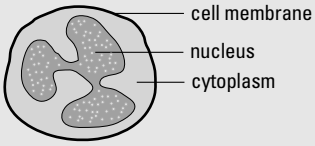
4. Antibodies are proteins that recognize foreign substances (antigens) and act to neutralize or destroy them.

   Antigens are foreign molecules that are found on the surface of the cells and on pathogens. Antigens stimulate the immune system to react to it.
5. A limphacyte should be drawn as a small spherical cell with a large nucleus. A neutrophil should be drawn to show a somewhat spherical cell with a large nucleus

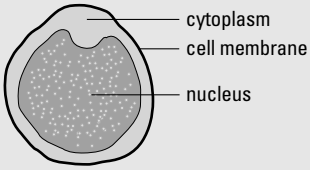
consisting of three large lobes connected by thin strands. A monocyte should be drawn to show a somewhat spherical cell with a very large nucleus which occupies most of the space inside the cell. A monocyte contains very little cytoplasm relative to the volume of the nucleus.



Lymphocyte



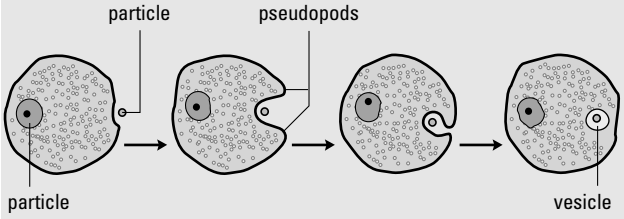
Neutrophil



Monocyte

The function of macrophages and neutrophils is the destruction of invading bacteria through phagocytosis, in which the pathogens are engulfed by the membrane of the white blood cell, forming a vesicle inside the cytoplasm, which contains the pathogen. The bacteria inside the vesicles are then destroyed when the vesicles fuse with lysosomes in the macrophage that contain destructive enzymes. The function of monocytes is that they enlarge and transform themselves into macrophages at the site of an infection.

6. The diagram should show the process of phagocytosis in which a macrophage produces pseudpods that grow around the harmful cell, creating a vesicle inside macrophage.



7. The letters ABO are derived from the four blood groups in one system of classifying blood. The letter A represents A antigen found on the red blood cell membranes of Type A blood. B represents B antigen on red blood cells in Type B blood. (AB blood has both antigens on the red cell surface.) The letter O represents the condition in Type O blood where neither antigen is present on the red cell surface.

8. Individuals who are Rh- do not produce anti-Rh antibodies unless the immune system is exposed to Rh antigens (unlike those with blood type O who produce anti-A and anti-B antigens within the first few months of life without exposure to the specific antigens.) An Rh- mother pregnant with an Rh+ child is usually not exposed to the Rh antigens until the birth of the baby, when the placenta breaks and releases fetal red blood cells into the maternal blood. Her immune system then produces anti-Rh antibodies that will cause problems with subsequent pregnancies.

9. Region A on the graph illustrates the immune response to the first exposure to an antigen associated with a pathogen. After this first exposure, plasma cells gradually produce increasing amounts of antibody molecules, reaching maximum production in about six weeks.

Region B on the graph illustrates the response to exposure to the same antigen some weeks later. This subsequent response is more rapid (maximum production in about three weeks) and generates much higher levels of antibodies.

10. The immune system identifies "self" versus "non-self" cells very early in development. An autoimmune disorder develops if this system of identification fails and T cells attack the body's own cells (the "self" cells) as if they had foreign antigens. The cause of autoimmune disorders is unknown. It is understood that the disorders tend to be hereditary and that recovery from an infection can bring on the condition.

11.

Immune System Disorder	Causes	Symptoms	Treatments
rheumatoid arthritis	T cells or antibodies attacking the linings of the joints, cartilage, bones, tendons, and ligaments	pain, stiffness, fever, fatigue, decreased appetite	anti-inflammatory drugs, steroids; antirheumatic drugs slow down immune response
food allergies	over-sensitivity of the immune system to various foods and food additives	runny nose, vomiting, diarrhea, asthmatic attack, skin problems, aches, pains	antihistamines, avoidance of the offending food or additive in the diet, epinephrine for severe attacks

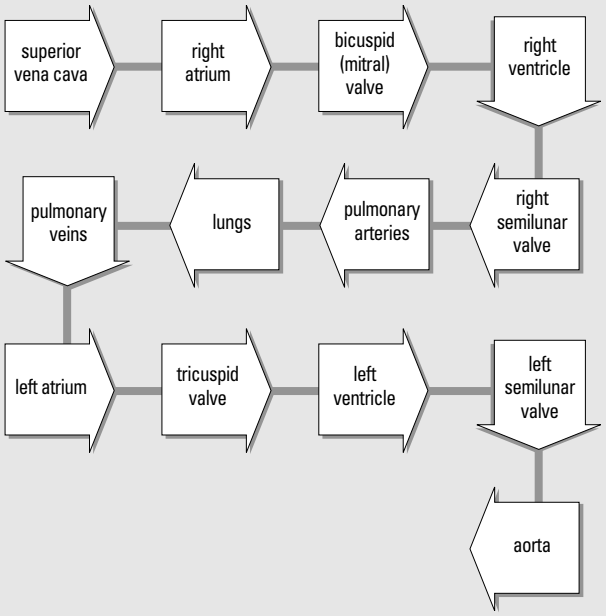
Immune System Disorder	Causes	Symptoms	Treatments
asthma	inhaled allergens, fatigue or cold air cause an immediate, massive release of histamines	spasms of the bronchioles, watery eyes, runny nose, coughing, wheezing, difficulty breathing	anti-inflammatory drugs, antihistamines

Chapter 8: Review Answers

Student Textbook pages 302–303

Answers to Understanding Concepts Questions

1. Three factors that assist blood flow through the veins are: Above the heart, gravity pulls blood back down to the heart; below the heart, muscle contractions push on the veins and force blood back towards the heart; one-way valves also prevent the backflow of blood.
2. Through observations of a mammalian heart, it can be seen that the left ventricle is the largest and strongest chamber. This adaptation is important because the left ventricle pumps blood into the systemic and coronary systems, which together contain the most extensive system of capillary networks in the body.
3. The following flow chart shows the flow of blood through the heart and the lungs:



4. Student flow charts should show the following information:

   Electrical signal from the SA node (located in the wall of the right atrium) → the two atria contract simultaneously → signal reaches AV node → AV node transmits signal through the bundle of His → Purkinje fibres initiate simultaneous contraction of the right and left ventricles (starting at the apex) forcing blood towards pulmonary artery and aorta
5. A heart attack is caused when a blood clot or other object obstructs a coronary artery. This cuts off the supply of oxygen and nutrients to the heart muscle.

   A stroke occurs when there is blockage or a rupture of an artery in the brain. This disrupts the flow of oxygen and nutrients to the part of the brain behind the damaged artery.
6. Students can select any three of the following functions of the blood:
   - transport of oxygen from lungs to cells – red blood cells
   - transport of carbon dioxide from cells to lungs – primarily plasma; some in the red blood cells
   - fight infection (part of immune system) – white blood cells
   - initiate blood clotting (maintaining homeostasis) – platelets
   - regulating body temperature (maintaining homeostasis) – plasma (countercurrent heat exchange)
7. The three primary pathways are:
   (a) coronary pathway, which is the route taken by blood to the heart muscle itself
   (b) pulmonary circulation, which is the route taken by the blood between the heart and the lungs
   (c) systemic circulation, which is the route taken by the blood from the heart to the rest of the body
8. Macrophages are phagocytic cells found in the liver, spleen, brain, and lungs; they also circulate in the bloodstream and interstitial fluid. These cells ingest and kill bacteria. Other white cells target body cells that have become cancerous or infected by viruses.
9. Lymph is circulated through a series of glands and vessels that extends throughout the body.

   Similarities to blood circulatory system:
   - lymph travels in a closed system
   - lymphatic vessels have valves to prevent the backflow of lymph (similar to veins)
   - depends on the contraction of skeletal muscles outside of the circulatory system (similar to veins)

   Differences:
   - unlike the circulatory system, the lymphatic system does not have a pump
10. In cellular immunity, a T cell that has a receptor for the particular antigen attaches to the macrophage and then goes through a process of rapid cell division. This produces a number of types of T cells. Helper T cells give off chemicals that stimulate other macrophages, B cells, and other T cells. Cytotoxic (killer) T cells bind to other cells that have been infected and destroy them. Suppressor T cells slow and stop the process of cellular immunity,

while memory T cells remain in the bloodstream to promote faster response if the same antigen appears again.

11. Pathogens can enter the body through the air you breathe, the water you drink, the food you eat, or through breaks in the skin.

Answers to Applying Concepts Questions

12. Students could describe microscopic analysis (counting) of red blood cells similar to the Investigation 8.C on page 285 of the student textbook. Students could also describe a test that involves centrifuging blood until it forms layers and visually analyzing the thickness of the red blood cell layer.

13. During vigorous physical activity, the heart pumps blood more forcefully to meet the higher energy requirements. The systolic blood pressure increases proportionally with exercise effort and energy production.

Nearly opposite of the systolic blood pressure, the diastolic blood pressure typically does not change much during dynamic exercise. The slight decrease in diastolic blood pressure is due primarily to the vasodilation of the arteries from the exercise.

14. When the body's internal environment becomes too warm, the body must be able to rid itself of heat in order to maintain a constant internal temperature. Blood transports heat from where it is formed by cellular respiration and muscular activity, or sitting in a hot tub, to the blood vessels in the skin. Under the control of the nervous system, these vessels dilate to increase the amount of blood flowing and, therefore, to increase the amount of heat that can be lost from the skin. This process is called vasodilation.

15. Students' experiments should include a hypothesis and a logical method of testing the hypothesis. Look for experiments that involve the removal of platelets from the blood, removing calcium ions, or removing one or more of the intermediary proteins required in this process.

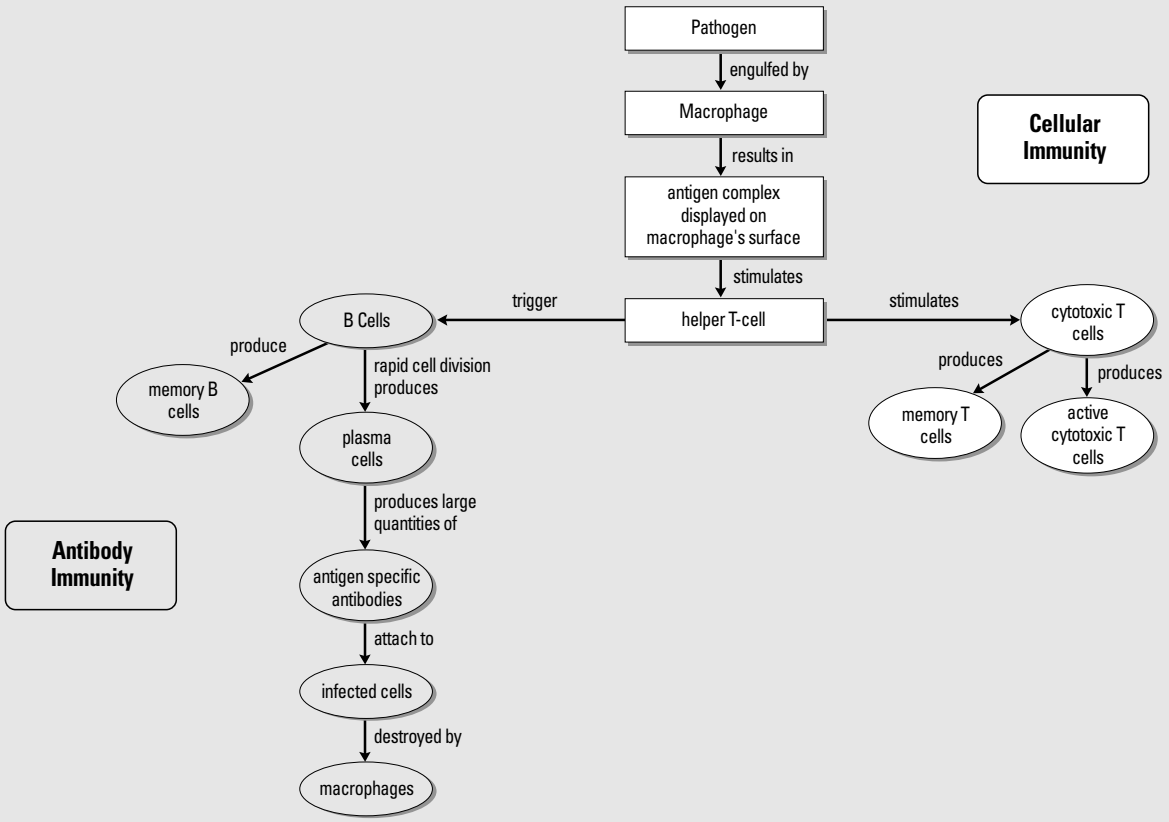
Students might also design an experiment to test the effect of temperature on the time it takes for blood to clot, since temperatures lower than body temperature prolong clotting time.

16. If the artificial blood could not carry carbon dioxide, there would be a build-up of carbon dioxide within the body tissues. The carbon dioxide would only be able to travel dissolved in the plasma. This would not be sufficient to satisfy the needs of the patient to transport carbon dioxide.

17. Students' diagrams should resemble Figure 8.4 on page 271 of the student textbook.

	Artery	Vein	Capillary	Lymph Vessels
Number of layers	3	3	1	lymph capillaries 1 cell thick
Elasticity	very	not very	no	no
Valves	no	yes	no	yes (larger vessels)
Function	transport blood away from the heart	transport blood towards the heart	gas and nutrient exchange	drain excess fluid from tissues and return to cardiovascular system

18. The concept map below is one example of a map that illustrates the relationship among different immune system cells.



19. Transplanted tissue from another individual contains antigens that stimulate an immune response from the host's T lymphocytes. The T lymphocytes would go through rapid cell division, producing helper T cells and cytotoxic T cells that attack the "invading" cells.

20. The following is an example of a possible answer.

Non-specific Immunity	Specific Immunity
Advantage: Always available, ready for immediate response against wide range of antigens—not just to specific antigens or those that were previously encountered by the immune system; thus non-specific immune defences especially important in first exposure to a particular type of foreign organism or substance.	Advantage: With the aid of memory cells, responses to subsequent exposure are faster, targeted, and more powerful than non-specific components of non-specific immune response; specific immune response capable of targeting and attacking cells in a malignant tumour.
Disadvantage: Specific immune response is potentially more effective than non-specific immune response; response to a particular antigen is always the same regardless of the number of times in contact with that antigen.	Disadvantage: Response is slower than non-specific immune response; more time required to reach maximal response to first exposure to a particular type of antigen.

21. (a) If the blood in the container is indeed blood type B as labelled, then the following results will occur when it is mixed with blood types A, AB, and O. If the patient has blood type B as shown on her chart, then the same results would occur when mixing her blood with the three samples.

Blood Type Samples	Results after mixing Blood Type B with Samples
A (anti-B antibodies)	agglutination
AB (no anti-A or anti-B antibodies)	no agglutination
O (anti-A and anti-B antibodies)	agglutination

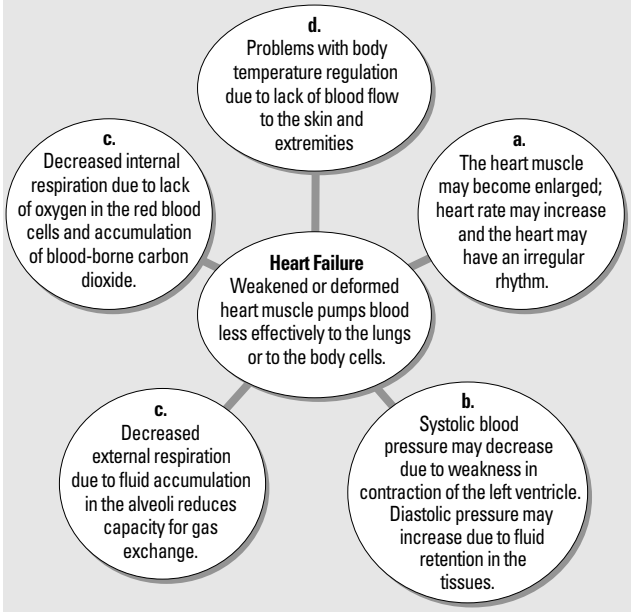
(b) If the patient has blood type B, then blood type O could be used for the transfusion, provided that the Rh factor is also compatible.

22. (a) Damage to the left atrioventricular valve would result in a "whoosh" sound after the lub sound, signifying backflow of blood into the left atrium.

(b) Damage to the aortic semilunar valve would result in a "whoosh" sound after the dub sound, signifying backflow of blood to the left ventricle.

(c) Damage to the AV node may result in an irregular contraction of the ventricles.

23. Student graphic organizers should include the following points:



24.(a) Blood pressure decreases with distance from the left ventricle because there are more arterioles than arteries, which increases the total cross-sectional area of the blood vessels. Blood pressure is highest in the aorta and lowest in the vena cavae.

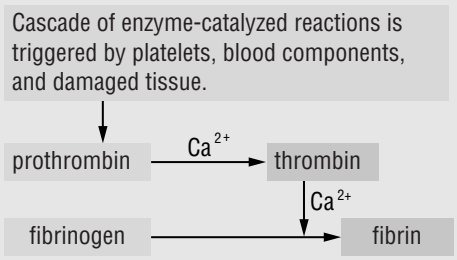
(b) The decrease in blood pressure as blood moves from arteries to capillaries causes the blood velocity to gradually decrease as it flows towards the capillaries.

Because there are more capillaries than arteries, blood moves even more slowly through the capillaries.

Blood velocity increases slightly in the venous vessels.

(c) The increase in the velocity of the blood in the veins is due to a progressive reduction in the cross-sectional area as small venules join to form larger veins.

25. (a) A student flow chart might appear as follows:



The process of blood clotting is complex and involves many steps that are not described in this flow chart. Hemophilia is caused by abnormalities in factors not shown. In classical hemophilia, Factor VIII is not produced. In a less common form of the disease called hemophilia B or Christmas disease (named after the family in which was discovered), Factor IX is not produced.

(b) Joints and other internal areas normally suffer minor injuries through activities such as sports and exercise. We are frequently unaware of small traumas that break internal blood vessels because the blood-clotting mechanism stops this internal bleeding within a few minutes. Bruises may or may not become visible. In hemophiliacs, this internal blood clotting does not occur and bleeding, especially into the joints, is a real danger because it cannot be stopped by applying bandages or pressure. With regular transfusions of the missing clotting factors, much internal bleeding in hemophiliacs can be controlled.

Answers to Making Connections Questions

26. Babies and younger children have not likely been exposed to as many pathogens as adolescents. As a result, their immune system is not prepared to prevent the disease. Some students may include information on vaccinations.

27. Allergies are hypersensitivities to substances, such as pollen or animal hair, which ordinarily would do no harm to the body. Environmental allergens stimulate various immune system responses, such as the production and activation of mast cells. Mast cells release excessive amounts of histamine, causing the cold-like symptoms typically associated with allergies.

28. These include trying to avoid direct contact with people with contagious infections, since contagious diseases, such as cold and flu, are spread by direct contact (shaking hands, handling paper from an infected person) and inhaling droplets in the air (which may contain viruses) that are released into the air when the person sneezes.

A very effective way to limit the spread of pathogens is regular and thorough hand-washing, since many pathogens enter our mouths from our fingers and from food eaten with unwashed hands.

29. Students might suggest a proportional link between body size and heart rate: the larger the body (and, therefore, the larger the heart), the slower the heart rate, and vice versa. Generally speaking, biologists believe this to be the case. Some students might also suggest a relationship between body size and metabolism, whereby smaller animals would tend to have faster metabolic rates and, therefore, faster heart rates. There is less agreement among scientists on this idea, due to the numerous factors that can affect metabolism, but many scientists do support it. Accept all reasoned and reasonable answers.

30. Angioplasty is a procedure in which a surgeon inserts a tube into a clogged artery in the heart. When the tube reaches the site of the clog, a tiny balloon is inflated to force the artery open. Frequently a stent, a tiny mesh tube, is then inserted. The stent is designed to keep the area open after the procedure.

CHAPTER 9 EXCRETION AND THE INTERACTION OF SYSTEMS

Curriculum Correlation

Human Systems, General Outcome 3: Students will explain the role of the excretory system in maintaining an internal equilibrium in humans through the exchange of energy and matter with the environment.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
20–D3.1k identify the principal structures of the excretory system, i.e., kidneys, ureters, urinary bladder, urethra	Section 9.1: The Organs of the Excretory System, pp. 306-307 Investigation 9.A: Identifying Structures of the Excretory System, p. 309	Q questions 4-5, p. 307 Figure 9.1 question, p. 307 Investigation 9.A: Analysis 1-2, p. 309 Section 9.1 Review: 1, 2, 4, p. 310 Chapter 9 Review: 1, p. 328 BLM 9.4.1 Chapter 9 Test Unit 4 Review: 6, p. 356
20–D3.2k explain the structure and function of the nephron in maintaining normal body fluid composition, i.e., water, pH, ions	Section 9.1: The Kidneys: The Body's Blood Cleansers, pp. 307-310 An Overview of the Nephron and its Three Functional Regions, p. 308 Section 9.2: Urine Formation in the Nephron, pp. 311-315	Q questions 6, 7, p. 310 Section 9.1 Review: 4, 5, 6, p. 310 Q questions 8, 9, p. 312; 10, p. 313; 11, p. 314 Section 9.2 Review: 1, 2, 4, p. 315 Section 9.3 Review: 1, 4(a) Chapter 9 Review: 3-7, 11, p. 328; 13, 15, 18, p. 329 BLM 9.4.1 Chapter 9 Test Unit 4 Review: 20-22, p. 356; 23, 30, 31, p. 357
20–D3.3k describe the function of the kidney in excreting metabolic wastes and expelling them into the environment	Section 9.1: The Problem of Wastes, p. 306 The Solution to Wastes: Excretion, p. 306	Q questions 1-3, p. 306 Section 9.1 Review: 3, 7, p. 310 Section 9.2 Review: 4, p. 315 Chapter 9 Review: 2, 12, p. 328 BLM 9.4.1 Chapter 9 Test Unit 4 Review: 22(b), p. 357
Outcomes for Science, Technology and Society (Emphasis on the nature of science)		
20–D3.1sts explain that the goal of science is knowledge about the natural world by **(NS1)**		
■ *examining how lifestyle factors contribute to hypertension and affect kidney function, e.g.,* ■ *drugs such as alcohol and nicotine* ■ *sedentary lifestyle* ■ *dietary excesses or deficiencies* ■ *stress*	The Kidney-Coronary Connection, pp. 323-325	Section 9.3 Review: 2(b), p. 326 Chapter 9 Review: 14, p. 329
■ *explaining how our understanding of nephron function is applied to renal and peritoneal dialysis*	Hemodialyis and Peritoneal Dialysis, pp. 319-321	Chapter 9 Review: 17, 20, p. 329
■ *identifying specific pathologies of the excretory system and the scientific knowledge connected with the treatment* ■ *identifying the physiological complexities and challenges of organ transplant*	Disorders of the Excretory System, pp. 318-319 Problems with Kidney Function, pp. 319-321 Kidneys Transplants, pp. 321-323 Connections: Metabonomics, p. 324	Q questions 16, 17, p. 321 Connections: 2, p. 324 Section 9.3 Review: 3, 10, 11, p. 326 Q questions 18, 19, p. 323 Chapter 9 Review: 8, p. 328; 16, 21, p. 329 Unit 4 Review: 62, p. 359

	Student Textbook	Assessment Options
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
20–D3.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by ■ predicting how blood pressure affects urine formation, composition and volume **(IP–NS1) [ICT C6–4.1]**	The Kidney-Coronary Connection, pp. 323-325	Section 9.3 Review: 5, 9, p. 326 Chapter 9 Review: 19, p. 329 Unit 4 Review: 60, p. 359 Section 9.3 Review: 8, p. 326
Performing and Recording		
20–D3.2s 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 ■ r*esearching and creating a flow chart to describe how humans maintain homeostasis with respect to water and ions, e.g.,* **(PR–NS1) [ICT C7–4.1, 4.2]** ■ *water uptake is high, e.g., tea, carbonated soft drink* ■ *action of diuretic compounds, e.g., caffeine, ethanol* ■ *sodium intake is excessive, e.g., anchovy pizza* ■ *performing a kidney dissection to identify major parts of the organ* **(IP–NS4)**	Section 9.3: Regulating Reabsorption of Water, p. 316 Reabsorption of Salts, p. 317 Maintaining Blood pH, p. 317 Investigation 9.A: Identifying Structures of the Excretory System, p. 309	Section 9.2 Review: 5, p. 315 Q questions 12, 13, p. 316 Try This: Aldosterone, p. 317 Q questions 14, 15, p. 318 Section 9.3 Review: 2, 4(b), 7, 9, p. 326 Chapter 9 Review: 9, 10, p. 328; 14, p. 329 Investigation 9.A: Procedure 1-5; Analysis 1-2, p. 309
Analyzing and Interpreting		
20–D3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ observing the principal features of a mammalian excretory system and identifying structures from drawings obtained from various print and electronic sources **(AI–NS1) [ICT C1–4.1]** ■ collecting and interpreting data in analysis of simulated urine, identifying limitations of data, comparing to theoretical values, and producing a generalization **(PR–NS1, 2, 3, 4, 5) (AI–NS2, 4, 6) [ICT C6–4.4]** ■ making analogies between kidney function and renal dialysis, and contrasting hemodialysis with peritoneal dialysis **(AI–ST2);** and, e.g. by ■ *assessing technological solutions to kidney failure, e.g., peritoneal dialysis, hemodialysis and kidney transplant and identifying the potential strengths and weaknesses of each* **(AI–ST2) [ICT C2–4.1, 4.2]**	Investigation 9.A: Identifying Structures of the Excretory System, p. 309 Launch Lab: Dehydration and Urine Colour, p. 305 Upsetting the Balance of the Excretory System, p. 318 Investigation 9.B: Urinalysis, pp. 320-321 Connections: Metabonomics, p. 324 Hemodialyis and Peritoneal Dialysis, pp. 319-321 Figure 9.10, p. 322 Kidney Transplants, pp. 321-323	Investigation 9.A: Identifying Structures of the Excretory System, p. 309 Investigation 9.A: Analysis 1-2, p. 309 Chapter 9 Review: 1, 12, p. 328 Launch Lab: Procedure 1-4; Analysis 1-2, p. 305 Investigation 9.B: Analysis 1-2; Conc. 3-5; Ext. 6-7, p. 321 Connections: 1, p. 324 Section 9.3 Review: 6, 10, p. 326 Chapter 9 Review: 15, p. 329 Unit 4 Review: 48, p. 358 Chapter 9 Review: 17, 20, p. 329 Unit 4 Review: 63, p. 359
Communication and Teamwork		
20–D3.4s 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 team members to assess and record simulated urine composition* **(CT–NS1, 2) [ICT C6–4.3, C7–4.2]**	Investigation 9.B: Urinalysis, pp. 320-321	Investigation 9.B: Procedure 1-3 (Tests 1-4), pp. 320-321

Chapter 9

Excretion and the Interaction of Systems

Student Textbook pages 304–329

Chapter Concepts

9.1 The Structures and Function of the Excretory System

- Each kidney receives blood that is processed to form urine, which drains through a ureter and into the urinary bladder for excretion.
- Each kidney contains over one million nephrons that process blood to form urine.

9.2 Urine Formation in the Nephron

- The functional unit of the kidney is the nephron.
- Each nephron filters blood, reabsorbs substances such as sodium and glucose for reuse in the body, and secretes excess or toxic substances such as urea to produce urine.

9.3 Excretory System Health

- Antidiuretic hormone (ADH) regulates the amount of water reabsorbed in the distal tubule.
- Aldosterone regulates the amount of salt that is reabsorbed or secreted.
- The acid-base balance of the blood is adjusted by the secretion of hydrogen ions and reabsorption of bicarbonate ions.
- Various technologies are used to solve problems involving dysfunctions and disorders of the excretory system.

Common Misconceptions

- Most students may be surprised to learn that urine isn't some "other" material produced by the body, but is, rather, blood that has been "doctored" through filtering and selective absorption and secretion.
- A misconception for many is that the excretory system is reducible to either the kidneys or urine. This is an incredibly complicated system that plays many different roles in maintaining homeostasis.
- Some students may assume that since we have two kidneys, we need two kidneys. In fact, a person can survive with less than one complete kidney. There is some redundancy built into the human body.
- People sometimes confuse the terms excretion and defecation, but they do not refer to the same process. Defecation refers to the elimination of feces from the body and is a function of the digestive system. Excretion, on the other hand, refers to the elimination of metabolic wastes, which are the products of metabolism. For example, the undigested food and bacteria that make up feces have never been part of the functioning body, while the substances excreted in urine were once metabolites in the body.

Helpful Resources

Books and Journal Articles

- Shier, David. *Hole's Essentials of Human Anatomy and Physiology 9/e*. McGraw-Hill Ryerson, Whitby, 2006.
- Mader, Sylvia. *Understanding Human Anatomy and Physiology 5/e*. McGraw-Hill Ryerson, Whitby, 2005.

Web Sites

Web links related to the human excretory system can be found at **http://www.albertabiology.ca**. Go to the Online Learning Centre, and log on to the Instructor Edition. Choose Teacher Web Links for the links to Chapter 9.

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. Most handouts and all assessment tools are supported by a BLM with the answers (ANS). The BLMs are in digital form, stored on the CD that accompanies this Teacher Resource or on the web site at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs. They can be modified to suit the needs of your students.

Number (Type)

9.0.1 (HAND) Launch Lab: Dehydration and the Colour of Urine
9.0.1A (ANS) Launch Lab: Dehydration and the Colour of Urine Answer Key

9.1.1 (HAND) The Urinary System
9.1.1A (ANS) The Urinary System Answer Key
9.1.2 (HAND) Anatomy of the Kidney
9.1.2A (ANS) Anatomy of the Kidney Answer Key
9.1.3 (OH) Anatomy of the Nephron
9.1.4 (HAND) Functions of the Nephron
9.1.4A (ANS) Functions of the Nephron
9.1.5 (HAND) Investigation 9.A: Identifying Structures of the Excretory System
9.1.5A (ANS) Investigation 9.A: Identifying Structures of the Excretory System Answer Key
9.1.6 (OH)/(HAND) A Review of Diffusion, Osmosis, Active Transport

9.2.1 (HAND) Glomerular Filtration
9.2.1A (ANS) Glomerular Filtration Answer Key
9.2.2 (HAND) Reabsorption of Substances in the Proximal Tubule
9.2.2A (ANS) Reabsorption of Substances in the Proximal Tubule Answer Key
9.2.3 (HAND) Functions of the Nephron Loop and the Distal Tubule
9.2.3A (ANS) Functions of the Nephron Loop and the Distal Tubule Answer Key
9.2.4 (HAND) Water Conservation in the Nephron

9.3.1 (HAND) Investigation 9.B: Urinalysis

9.3.1A (ANS) Investigation 9.B: Urinalysis Answer Key
9.3.2 (HAND) Composition of Urine
9.3.2A (ANS) Composition of Urine Answer Key
9.3.3 (HAND) Regulation of Osmotic Pressure of Body Fluids
9.3.3A (ANS) Regulation of Osmotic Pressure of Body Fluids Answer Key
9.3.4 (HAND) Regulation of Body Fluid Volume
9.3.4A (ANS) Regulation of Body Fluid Volume Answer Key
9.3.5 (HAND) Hemodialysis and Peritoneal Dialysis
9.3.5A (ANS) Hemodialysis and Peritoneal Dialysis Answer Key
9.3.6 (HAND) Kidney Transplants
9.3.6A (ANS) Kidney Transplant Rubric
9.4.1 (AST) Chapter 9 Test
9.4.1A (ANS) Chapter 9 Test Answer Key

Using the Chapter 9 Opener

Student Textbook page 304–305

Teaching Strategies

- Have students make a list of the different systems that are associated with the excretion of metabolic wastes. Many will include the elimination of feces from the digestive system. Discuss this misconception with them and remind students that the excretory system is responsible for removing metabolic wastes.
- Check with your media resource centre to see if you can borrow an introductory video on the excretory system. A video of this nature will provide students with the "big picture."
- Clearly establish a mindset that deals with the importance of learning the terminology associated with this chapter.

Launch Lab: Dehydration and Urine Colour

Student Textbook page 305

Purpose

Students will investigate the relationship between the colour of (simulated) urine and the level of hydration.

Outcomes

- 20–D3.2k
- 20–D3.3s

Advance Preparation

When to Begin	What to Do
1 day before	■ Prepare a class set of 3 simulated urine samples. ■ Photocopy **BLM 9.0.1: Launch Lab: Dehydration and the Colour of Urine**

Materials
■ 3 test tubes (per group) ■ test tube holders ■ protective goggles, aprons, and gloves ■ 3 samples of simulated urine (per group) ■ white paper ■ Urine Colour Chart (from the student textbook) ■ yellow food colouring

Time Required

- 15 minutes

Helpful Tips

- Use **BLM 9.0.1: Launch Lab: Dehydration and the Colour of Urine** to support this activity. Modify it as necessary.
- Make three stock solutions of simulated urine that match the colour chart provided on page 305 of the student textbook. The solutions can be made with distilled water and yellow food colouring. Ensure that one sample matches #1 on the Urine Colour Chart, another sample matches #4 on the chart, and the last one matches #7.
- To save time, pour approximately 10 mL of each solution into three test tubes for your students and have them ready for distribution at the start of class. You will require 1 set of test tubes per group of students.
- The sample should be held up in front of a white background, in good light, and the colour compared to the chart. The lower the number on the Urine Colour Chart, the better the level of hydration. For example, a urine colour rating of 1, 2, or 3 is considered to be well hydrated (Armstrong, 2000).
- If time permits, challenge your students to compare dehydration and **exertional hyponatremia**, which can be just as harmful. "Exertional hyponatremia" means low blood sodium levels and is caused by drinking too much water or drinking fluids that do not contain sodium.

Safety Precautions

- Yellow food colouring will stain skin and clothing. Make sure students wear protective goggles, gloves, and lab aprons during this Investigation.

Answers to Analysis Questions

1. Students' answers will depend on the colour of the simulated urine solutions that you prepare for them. The darker the colour, the more concentrated the urine and the more the body is trying to conserve water by reabsorbing it from the urine before it leaves the body.
2. Dehydration can lead to serious illness or fatality.

Assessment Option

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

9.1 Overview of the Excretory System

Student Textbook pages 306–310

Section Outcomes

Students will:

- identify the main structures and functions of the human excretory system
- explain the function of the nephron
- dissect a mammalian kidney and observe its structure

Key Terms

excretory system
excretion
kidneys
ureters
urinary bladder
urethra
nephrons
renal arteries
glomerulus
Bowman's capsule
filtrate
collecting duct
renal veins

Biology Background

- The human excretory system regulates the composition of blood by removing wastes and excess substances from the blood plasma. The kidneys, each of which drain into a **ureter**, produce urine. Ureters drain urine into the urinary bladder for storage. Urine then leaves the body through the **urethra**.
- Macroscopically, a kidney has three regions: the renal cortex, the renal medulla, and the renal pelvis, which is continuous with the ureter. Microscopically, a kidney contains over one million nephrons.
- The functional unit of the kidney is the nephron. The three general processes that take place in the nephron are as follows:
  - Glomerular filtration: water, salts, and nutrient and waste molecules move from the glomerulus to the inside of the glomerular capsule. These small molecules are called **glomerular filtrate**.
  - Tubular reabsorption: nutrient and salt molecules are actively reabsorbed from the proximal tubule into the capillary network that surrounds each nephron. Water passively follows these molecules and is reabsorbed at the descending limb and the collecting duct.
  - Tubular secretion: certain molecules are actively secreted from the capillary network into the distal tubule.

Teaching Strategies

- Students are introduced to many new terms in this section. It is very important that students learn the terms as they work through this section. A lack of understanding early in this chapter will lead to mass confusion as students look, in detail, at the formation of urine in the next section.
- **BLM 9.1.1: The Urinary System**, **BLM 9.1.2: Anatomy of the Kidney**, **BLM 9.1.3: Anatomy of the Nephron,** and **BLM 9.1.4 Functions of the Nephron** can be photocopied and distributed to students as tools to summarize the main concepts presented in this section. These BLMs can also be used as formative assessment tools.
- **BLM 9.1.5: Identifying Structures of the Excretory System** supports Investigation 9.A on page 309 of the student textbook. This BLM can be used in either a real or virtual dissection of the mammalian kidney.
- Review web and multimedia resources on the excretory system that can be used to help students visualize the structure and function of the kidney, and more specifically, the nephron. An Internet-enabled computer connected to an LCD projector could provide an opportunity to bring these resources into your classroom without having to take your students to the computer lab. Links can be found at the Online Learning Centre, Instructor Edition, Teacher Web Links.

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 initially express their ideas in their first language and then have them translate these ideas into English.
- Struggling learners may grasp an idea better by looking at diagrams or pictures. Use the various BLMs provided in this resource to help these students.
- Order a class set of multi-coloured pipe cleaners available at most stores that sell educational materials. Provide students with four or five of these pipe cleaners and have them build a simple model of the nephron. This will help tactile learners visualize the relationship between the circulatory system and the tubular structure of the nephron.
- Have students create a two- or three-page study guide of the ideas presented in this 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 paragraph form, point form, graphically organized, or a combination of these elements. It might also be useful to spotlight key vocabulary and provide the essential questions that the section addresses. Advanced students could be encouraged to make a digital version of this guide using slide presentation software.

Answers to Questions for Comprehension

Student Textbook page 306

Q1. The basic function of the excretory system is to regulate the volume and composition of body fluids by removing wastes and returning needed substances to the body for reuse.

Q2. Four examples of metabolic wastes produced in the human body include carbon dioxide, water, nitrogenous wastes (ammonia, urea, uric acid), and salts (Na^+, Cl^-, H^+).

Q3. Any waste can pose a threat to health if it is allowed to accumulate in the body. By excreting nitrogenous wastes, the excretory system rids the body of toxic substances.

Figure 9.1

Student Textbook page 307

The word "renal" appears with the renal artery and renal vein. The renal artery transports blood to the kidney for filtration. The filtered blood returns to the circulatory system through the renal veins, which connect to the inferior vena cava.

Answers to Questions for Comprehension

Student Textbook page 307

Q4. The structures of the human excretory system are the kidneys, ureters, urinary bladder, and urethra. The renal artery transports blood to the kidney for filtration. The filtered blood returns to the circulatory system through the renal veins, which connect to the inferior vena cava.

Q5. Urine leaves the body through these structures: kidneys → ureters → urinary bladder → urethra

Investigation 9.A: Identifying Structures of the Excretory System

Student Textbook page 309

Purpose

Students learn to identify the main features of the mammalian kidney.

Outcomes

- 20–D3.1k
- 20–D3.2s
- 20–D3.3s

Advance Preparation

Note: The information provided deals only with the actual dissection of the mammalian kidney.

When to Begin	What to Do
4 weeks prior to the investigation	■ Order the mammalian kidney (pig or sheep) from a scientific supply company. ■ Check supply of safety equipment (gloves, aprons, goggles) and replace, if needed. ■ Check that proper disposal procedures are in place.
2 days before	■ Photocopy **BLM 9.1.5: Identifying Structures of the Excretory System.**

Materials
■ dissecting instruments ■ aprons (1 per student) ■ eye goggles (1 per student) ■ dissecting pan ■ dissecting microscope (optional) ■ mammalian kidney (1 per group) ■ disposable plastic gloves ■ paper towels ■ soap and water

Time Required

- 1 hour

Helpful Hints

- Use **BLM 9.1.5: Investigation 9.A: Identifying Structures of the Excretory System** to support this activity. Modify as necessary. This resource will guide students through this investigation and will protect textbooks from exposure to the liquids involved in the handling the preservation of the specimen, or with blood if using a fresh kidney.
- Mammalian kidneys can be purchased from most scientific supply companies. The cost of the kidneys may require you to complete this activity as a demonstration or to use the illustrations provided on the web. For an alternative toa physical dissection of the mammalian kidney, go to **www.albertabiology.ca,** Online Learning Centre, Instructor Edition, Teacher Web Links, for the links to Chapter 9.
- Before starting the dissection, remind students of all safety precautions.
- Remind students that dissection involves the **careful** and **systematic** examination of the structures of an organism.
- If you are planning on using a fresh mammalian kidney, 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*

Guidelines for Safe Practices document. This document is available in the Science Curriculum area of the Alberta Education web site.

- Group your students in teams of four to reduce the number of specimens that you have to purchase. You could do this investigation as a combination of a class demonstration with digital support from the web site identified previously, or you could set this up in stations that correspond to the instructions in the student textbook. Small groups of students can rotate through the stations in five-minute intervals while others are working on Section 9.1: Review Questions.

Safety Precautions

- Extreme care must be taken when using dissecting instruments, particularly scalpels. To the extent possible, make sure 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. For more information refer to Alberta Education's *Safety in the Science Classroom Guidelines for Safe Practices* document. This document is available in the Science Curriculum area of the Alberta Education web site or via the link at the Online Learning Centre, Instructor Edition, Teacher Web Links.

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 Analysis Questions

1. The diagram should resemble Figure 9.2 on page 307 of the student textbook. Students will not be able to see the nephrons.

2. See Figure 9.3 on page 308 of the student textbook. Students should identify that the glomerulus, glomerular capsule, proximal tubule, distal tubule, and top of the collecting duct are found in the renal cortex and that the nephron loop and collecting duct are found in the renal medulla.

Assessment Options

- Collect and evaluate answers to Analysis questions.
- Use Assessment Checklist 2: Laboratory Report or Checklist 4: Performance Task Group Assessment. (See Appendix A.)

Answers to Questions for Comprehension

Student Textbook page 310

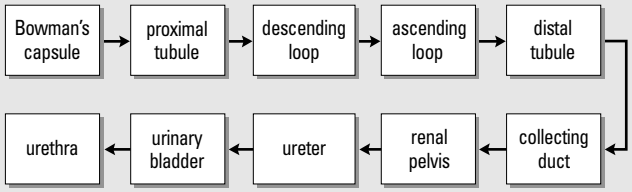
Q6. The three regions of the kidney are the renal cortex, the renal medulla, and the renal pelvis.

Q7. Blood flow through the nephron renal artery → glomerulus → arteriole → capillary network → venule → renal vein

Section 9.1: Review Answers

Student Textbook page 310

1. Urine (nephric filtrate) first forms in Bowman's capsule, so the pathway shown in the following flow chart begins there.



2. The main structures of the human excretory system and their functions are shown in the table below.

Structure	Function
kidney	■ primary organs of the urinary system ■ removes metabolic wastes from the blood and produces urine
ureters	■ peristalsis pushes urine from the kidneys into the urinary bladder
urinary bladder	■ temporarily stores urine until it can be expelled from the body
urethra	■ extends from the urinary bladder to an external opening
renal artery	■ transports unfiltered blood to the kidney
renal vein	■ returns filtered blood to the circulatory system

3. The basic function of the excretory system is to regulate the volume and composition of body fluids by removing metabolic wastes and returning needed substances to the body for reuse.

4. (a) The sketch should resemble Figure 9.2 on page 307. It should show labels for the renal cortex, the renal medulla, and renal pelvis.

(b) The glomerulus, proximal tubule and distal tubule, and the "top" parts of the loop of Henle are found in the renal cortex. Most of the descending and ascending loops of Henle and the collecting ducts are found in the renal medulla. The collecting ducts empty into the renal pelvis.

5. Student answers' should resemble the Figure 9.3 on page 308. Labels on the student sketch should show (a) blood entering the kidney via the renal artery, (b) filtrate being formed in the glomerulus and Bowman's capsule, and (c) urine being excreted via the collecting duct.

6.

Term	Explanation
a filter	The filtration structure at the top of each nephron is a cap-like formation called the glomerular capsule. The renal artery enters the kidney and splits into a fine network of capillaries called a glomerulus. The walls of the glomerulus act as a filtration device. They are impermeable to proteins, other large molecules, and red blood cells, so these remain within the blood. Water, small molecules, ions, and urea (waste) pass through the walls and proceed further into the nephron. The filtered fluid that proceeds from the glomerulus into the glomerular capsule is referred to as filtrate.
a tubule	The glomerular capsule is connected to a small, long, narrow tubule that is twisted back on itself to form a loop. This long, hairpin loop is a reabsorption device. The tubule has three sections: the proximal tubule, the loop of the nephron, and the distal tubule. This tubule absorbs substances that are useful to the body, such as glucose and ions, from the filtrate passing through it. The tubule also secretes substances into the tissues surrounding it.
a duct	The tubule empties into a larger pipe-like channel called a collecting duct. The collecting duct functions as a water-conservation device, reclaiming water from the filtrate passing through it so little water is lost from the body. The filtrate that remains in the collecting duct is a suspension of water and various solutes and particles (urine)

7. The following is a sample answer.

All of the systems mentioned are part of the excretory system. The respiratory system excretes carbon dioxide and small amounts of other gases, including water vapour. The skin excretes water, salts, and some urea in perspiration. The digestive system excretes water, salts, lipids, and a variety of pigments and other cellular chemicals. (Note that the elimination of food residue—feces—is not considered to be a process of excretion.) Most metabolic wastes, however, are dissolved or suspended in solution and are excreted by the excretory (urinary) system. The circulatory system (blood) transports metabolic wastes to the kidneys for excretion.

9.2 Urine Formation in the Nephron

Student Textbook pages 311–315

Section Outcomes

Students will:

- explain the function of the nephron in maintaining the composition of blood plasma
- describe the function of the kidney in excreting metabolic wastes and expelling them into the environment

Key Terms

glomerular filtration
tubular reabsorption
tubular secretion
water reabsorption
proximal tubule
loop of Henle
distal tubule

Biology Background

- In the glomerulus, filtration moves water and solutes (with the exception of proteins) from blood plasma into the nephron. The composition of the filtrate begins to change in the proximal tubule. The filtrate moves into the nephron loop that dips into, and then out of, the medulla tissue of the kidney. The loop helps to concentrate urine through the reabsorption of water in the descending limb. Sodium is reabsorbed in the ascending limb.
- In the distal tubule, more reabsorption and secretion occur. The filtrate then moves to the collecting duct, where additional reabsorption and/or secretion occurs. The liquid then leaves the collecting duct as urine.

Teaching Strategies

- If they have not done so already, have students work through **BLM 9.1.6: A Review of Osmosis, Diffusion, and Active Transport** as a reminder of these processes. Students must understand these processes in order to understand the function of the nephron in the kidney.

- The formation of urine is a very complex process. The following BLMs are designed to break down this process into more manageable chunks for the students. Students can fill in the names of each structure and summarize its function(s).

  Number (Type)
  - **BLM 9.2.1: Glomerular Filtration**
  - **BLM 9.2.2: Reabsorption of Substances in the Proximal Tubule**
  - **BLM 9.2.3: Functions of the Nephron Loop and the Distal Tubule**
  - **BLM 9.2.4: Water Conservation in the Nephron**
- There are a number of web and multimedia resources on the excretory system that can be used to help students visualize the structure and function of the kidney and, more specifically, the nephron. An Internet-enabled computer connected to an LCD projector could provide an opportunity to bring these resources into your classroom without having to take your students to the computer lab.

SUPPORTING DIVERSE STUDENT NEEDS

Have students (in small groups) create a concept map that summarizes the essential processes in each part of the nephron in order to reinforce learning of the vocabulary and concepts associated with nephron structure and function. Students can explain their concept map designs to other members of their group.

Answers to Questions for Comprehension

Student Textbook page 312

Q8. The two factors that contribute to glomerular filtration are the size of the pores of the capillaries that form each glomeruli and blood pressure.

Q9. The glomerular filtrate contains small dissolved molecules in approximately the same concentration as plasma. The large molecules (proteins) are too large to pass through the capillary into the filtrate.

Student Textbook page 313

Q10. The cells of the proximal tubule are richly endowed with mitochondria, which use the energy-releasing power of ATP to drive the active transport of sodium ions and other solutes back into the blood.

Student Textbook page 314

Q11. As the filtrate moves up the ascending limb of the loop of Henle, it becomes more dilute (i.e., less concentrated) as sodium ions are actively transported and other ions are passively transported out of the filtrate.

Section 9.2: Review Answers

Student Textbook page 315

1. Parts of the nephron and their function

Part of the Nephron	Function
glomerulus	Filtration ■ Glomerular blood pressure forces some of the water and dissolved substances from the blood plasma through the pores of the glomerular walls
Bowman's capsule	Receives filtrate from the glomerulus
proximal tubule	Reabsorption ■ Active reabsorption of all nutrients, including glucose and amino acids ■ Active reabsorption of positively charged ions such as sodium, potassium, calcium ■ Passive reabsorption of water by osmosis ■ Passive reabsorption of negatively charged ions such as chloride and bicarbonate by electrical attraction to positively charged ions Secretion ■ Active secretion of hydrogen ions
Descending nephron loop	Reabsorption ■ Passive reabsorption of water by osmosis
Ascending nephron loop	Reabsorption ■ Active reabsorption of sodium ions ■ Passive reabsorption of chloride and potassium ions
Distal tubule	Reabsorption ■ Active reabsorption of sodium ions ■ Passive reabsorption of negatively charged ions such as chloride and bicarbonate ■ Passive reabsorption of water by osmosis Tubular Secretion ■ Active secretion of hydrogen ions form the blood into the tubule ■ Passive secretion of potassium ions by electrical attraction to chloride ions
Collecting duct	Reabsorption ■ Passive reabsorption of water by osmosis

2. The sketch of the simplified nephron should show the incoming arteriole, the Bowman's capsule, the outgoing arteriole, the proximal tubule, the loop of Henle, the distal tubule, the surrounding capillaries, and the collecting duct.

(a) The movement of sodium ions from the nephron to the surrounding capillaries takes place in the ascending limb of the nephron loop.

(b) The movement of water from the nephron to the surrounding capillaries takes place in the descending loop of the nephron and from the collecting duct as it passes through the renal medulla.

(c) The movement of glucose out of the nephron takes place in the proximal tubule. This is a selective process because only the molecules recognized by a specific carrier molecule are actively reabsorbed.

(d) Potassium ions are actively secreted into the distal tubule from the blood. Penicillin and other drugs are also secreted into the distal tubule.

3. Students may answer this question using a variety of formats (for example, paragraph, point form, tabular, Venn diagram). The substance of students' answers likely will focus on comparing and contrasting the composition of blood and of urine, although some students might also refer to where in the body the two fluids are found, as well as the fact that some substances enter and leave blood and urine through the same mechanisms (i.e., diffusion, active transport). In terms of composition, which is the principal context for answering the question, suitable points of comparison could include the presence of protein and glucose in blood, as opposed to urine, and the relatively higher concentration of sodium in urine compared to blood. Water should be noted as a primary constituent of both fluids.

4. Reabsorption refers to both the passive and active transport of molecules and ions from the filtrate (nephron) back into the capillary network (blood).

Certain molecules (potassium ions and some drugs for example) are actively secreted from the capillary network into the distal tubule for excretion.

5. Most students should realize that the body will try to conserve water by reducing the amount of urine it produces. The volume of the urine would decrease, which would increase the concentration of the molecules and ions being expelled (deeper yellow colour).

9.3 Maintaining the Excretory System

Student Textbook pages 316–326

Section Outcomes

Students will:

- describe how the kidneys contribute to homeostasis with respect to water and ions
- perform a urinalysis using simulated urine samples
- relate the design of dialysis technologies to the design of the kidney

Key Terms

antidiuretic hormone
aldosterone
renal insufficiency
dialysis
hemodialysis
peritoneal dialysis

Biology Background

- The kidneys are key organs of homeostasis. The kidneys excrete more concentrated urine when the body needs to conserve water and more dilute urine when the body has excess water. Antidiuretic hormone (ADH) stimulates the reabsorption of water in the collecting duct and, thus, the excretion of concentrated urine. Aldosterone promotes the reabsorption of sodium ions in the distal convoluted tubule and collecting duct, as well as the secretion of potassium ions. The kidneys also maintain blood pH within narrow limits by excreting excess hydrogen ions and reabsorbing bicarbonate ions.
- Dialysis treatment works to remove wastes from the blood using the principle of diffusion. **Hemodialysis** filters blood through an artificial membrane outside of the body, while **peritoneal dialysis** uses the membrane of the peritoneum in the abdominal cavity to filter blood.
- The health of the excretory system is linked to the health of other body systems. Proper care of, and respect for, the kidneys and excretory system are factors that contribute to maintaining a healthy blood pressure, which is particularly helpful in maintaining overall health.

Teaching Strategies

- In order to properly explain the function of the nephron in maintaining normal body fluid composition, i.e., water and pH, ions, the student textbook introduces antidiuretic hormone (ADH) and aldosterone. Although these hormones are introduced at this level, detailed information on these hormones will not be covered until *Biology 30*.
- **BLM 9.3.1: Urinalysis** supports Investigation 9.B: Urinalysis on pages 320-321 of the student textbook.
- **BLM 9.3.2: Composition of Urine, BLM 9.3.3: Regulation of Osmotic Pressure of Body Fluids**, and **BLM 9.3.4: Regulation of Body Fluid Volume** can be used to reinforce these complicated processes.
- **BLM 9.3.6: Kidney Transplants** introduces issues such as living organ donation and **xenotransplants**.
- You may wish to demonstrate dialysis by filling a 20 cm dialysis tube with starch solution, sealing both ends, and placing it in a beaker of distilled water. Adding iodine solution to the distilled water will demonstrate that small molecules (iodine) can pass through the pores in the membrane but the large molecules (starch) do not pass through the pores. The starch inside the dialysis tubing will turn bluish black indicating that the iodine has passed through the membrane. Amylose in starch is responsible

for the formation of a deep blue colour in the presence of iodine. The iodine molecule slips inside the amylose coil.

SUPPORTING DIVERSE STUDENT NEEDS

- Enrichment: Arrange a visit to a dialysis clinic to observe patients undergoing dialysis and have students present a report about their visit to the class.
- Have students prepare a multimedia presentation about kidney function. This activity could also benefit students in need of concept and / or vocabulary reinforcement.

Answers to Questions for Comprehension

Student Textbook page 316

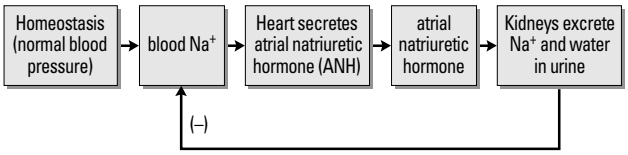
Q12. Osmoreceptors are cells that are sensitive to osmotic pressure. The osmoreceptors send impulses that cause the release of antidiuretic hormone (ADH).

Q13. If the blood becomes concentrated, osmoreceptors signal the release of ADH, which increases the permeability of the distal tubule and collecting duct, allowing more water to be reabsorbed into the blood. If the blood becomes too dilute, osmoreceptors stop, or prevent, the release of ADH. As a result, the distal tubule and the collecting duct become less permeable to water, which allows more water to become excreted in the urine.

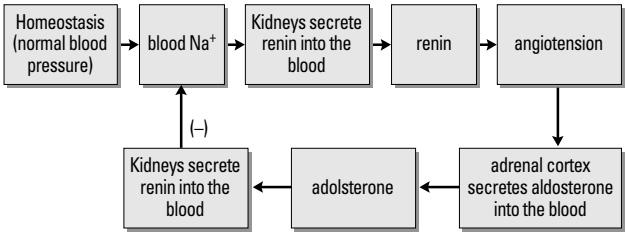
Biology File: Try This

Student Textbook page 317

Sample answers are provided below.
Sample A:



Sample B:



Answers to Questions for Comprehension

Student Textbook page 318

Q14. The kidneys regulate salt balance in the blood by controlling the excretion and reabsorption of various ions. The reabsorption of salt increases blood volume and pressure because more water is reabsorbed. A drop in blood Na^+ results in release of the hormone aldosterone. Aldosterone stimulates the distal tubule and collecting ducts to reabsorb Na^+ ions. Aldosterone also stimulates the secretion of K^+ ions into the distal tubules and collecting ducts.

Q15. The kidneys keep blood pH within normal limits. They reabsorb HCO_3^- ions and excrete H^+ ions as needed to maintain the pH at about 7.4. The chemical reactions that act to maintain a constant pH are linked to the respiratory system because H_2CO_3 reacts in solution to form carbon dioxide and water. Therefore, levels of H_2CO_3 are linked to levels of CO_2, which are regulated by breathing.

Investigation 9.B: Urinalysis

Student Textbook pages 320–321

Purpose

Students collect and interpret data in the analysis of simulated urine.

Outcomes

- 20–D3.3s
- 20–D3.4s

Advance Preparation

When to Begin	What to Do
4 weeks before	■ Check the supply of chemicals, including urea. Order new chemicals if required.
1 day before	■ Photocopy **BLM 9.3.1: Urinalysis** if you are planning to provide this worksheet for your students. ■ Prepare samples of simulated urine (see Helpful Tips, below). ■ Photocopy Assessment Checklist 4 Performance Task Group Assessment if you are planning to evaluate teamwork and cooperation.

Materials

■ 1 test tube rack per group
■ 5 test tubes per group
■ 1 pipette or medicine dropper
■ hot water bath
■ chemicals to make simulated urine:
  ■ apple juice
  ■ sodium chloride (NaCl)
  ■ urea
  ■ glucose powder
  ■ albumin powder
  ■ yellow food colouring
  ■ 20 mol/L hydrochloric acid
  ■ 1M ammonia solution
■ universal pH indicator paper with colour chart
■ glucose test strips with colour charts

Time Required

- 1 hour

Helpful Tips

- Use **BLM 9.3.1: Investigation 9.B: Urinalysis** to support this activity. Modify as necessary.
- The following are the recipes to make the simulated urine samples. Use varying amounts of food colouring in each sample for effect.

Sample	Recipe
Control Sample	1.5 g sodium chloride, 2.5 g urea, 0.5 g glucose powder, 1 drop 2.0 mol/L HCl (hydrochloric acid,) and 0.5 g albumin powder (raw egg whites can be used as well) dissolved in 500 mL of distilled water. Use a pH meter to make sure that the pH is between 5 and 7.
Suspect 1	1.5 g NaCl, 2.5 g urea, 3 or 4 drops of HCl dissolved in 500 mL of distilled water.
Suspect 2	1.5 g NaCl, 2.5 g urea, 3 or 4 drops of ammonia dissolved in 500 mL of distilled water.
Suspect 3	1.5 g NaCl, 2.5 g urea, and 0.5 g albumin powder dissolved in 500 mL of distilled water.
Suspect 4	1.5 g NaCl, 5 g urea, 3 mL sweetened apple juice (should smell "fruity"), 1 g glucose, dissolved in 500 mL of distilled water.
Crime Scene Sample	1.5 g NaCl, 5 g urea, 3 mL sweetened apple juice (should smell "fruity"), 1 g glucose, dissolved in 500 mL of distilled water.

Refer to "Preparing Solutions" is the front matter of this Teacher's Resource.

- Have all groups run the four tests with the Control Sample. This will let them have some practice with the tests prior to testing the suspects' urine.
- Split the class into five teams. To save time, assign each team to test only one additional sample of urine. Provide a place on the board or on an overhead transparency to record class results.
- Discuss the Analysis questions with your class. Use this as an opportunity to review the formation of urine from Section 9.2.
- Alternative tests:

Test	Description
Test 2: Protein	■ Biuret solution can be used to test for the presence of proteins. Proteins (amino acids) contain an amino group (NH_2). When Biuret solution interacts with this amino group, its colour changes from blue to purple.
Test 4: Glucose	■ Benedict's reagent is used as a simple test for reducing sugars such as glucose. The Benedict's test for sugar involves adding Benedict's solution to the solution to be tested and heating gently (often in a boiling water bath). A positive Benedict's sugar test will produce an orange to brick-red colour. If you are going to do the Benedict's test, you must use a reducing sugar when you make the simulated urine. Table sugar (sucrose) will not react with Benedict's reagent.

- ***Expected Results:*** Students' results should be similar to those shown below.

Test	Control Tests	Crime Scene	Suspect 1	Suspect 2	Suspect 3	Suspect 4
Colour / odour/ clarity	cloudy. normal odour yellow	fruity smell, clear, yellow	clear, yellow, has an odour	clear, yellow, no odour	cloudy, yellow, has an odour	clear, yellow, fruity smell
Protein	positive	negative	negative	negative	positive	negative
pH	between pH 5 and pH 7	between 5 and 7	below pH 5	above pH 7	between pH 5 and pH 7	between pH 5 and pH 7
Glucose	positive (high amount)	positive (high amount)	negative	negative	negative	positive (high amount)

Safety Precautions

- For those new to the teaching profession in Alberta, you are reminded that, as of September 1987, all activities involving the extraction and analysis of samples of human fluid or tissue are prohibited in Alberta Schools. This prohibition applies to all activities involving the extraction of human tissue and fluid samples, including cheek cells, blood, saliva, and urine. (Alberta Education 2004, *Safety in the Science Classroom*, p. 54.
- Remind students of the procedure for smelling a chemical safely.
- Food colouring will stain skin and clothing. Remind students to be careful when handling the simulated urine.
- Remind students to wear eye goggles and lab aprons for the duration of the activity.
- To dispose of the simulated urine, dilute with a large quantity of water and flush into an approved waste water treatment system.

Answers to Analysis Questions

1. Suspect number 4 committed the crime.

2. The urine sample collected at the crime scene matches the urine sample from suspect number 4 (odour: fruit/apple; positive test for glucose; negative test for protein).

Answers to Conclusion Questions

3. Suspect number 4 may have diabetes mellitus. Urine normally doesn't contain any glucose. Glucose is reabsorbed from the glomerular filtrate in the proximal tubule of the nephron. Diabetes mellitus is characterized by high blood sugar (glucose) levels, which result from defects in insulin secretion, or action, or both. Diabetes mellitus, commonly referred to as diabetes, means "sweet urine." Elevated levels of blood glucose (hyperglycemia) lead to a spillage of glucose into the urine, hence the term "sweet urine."

4. Students' answers may include the following:
- There are usually no red blood cells in urine.
- Hemoglobin is not normally found in the urine.
- Bilirubin is normally not detected in the urine.
- There may be a trace of urobilinogen in the urine.
- Nitrites and white blood cells (leukocytes) are not normally present in the urine.

5. Possible answers could include the fact that
- the tests were not quantitative,
- the tests were not performed using medical laboratory protocols (cleanliness), or
- sophisticated technology was not used to analyze the urine.

To get a more comprehensive picture, more tests have to be performed in this investigation. These include bilirubin, hemoglobin, microscopic analysis, specific gravity, and ketones, to name a few.

Answers to Extension Questions

6. Glucose passes from the glomerulus and is found in the filtrate. Specific carrier molecules in the proximal tubule ensure that all of the glucose is reabsorbed into the circulatory system.

Protein molecules are normally too large to pass through the pores in the glomeruli. They do not enter the filtrate in a healthy individual.

7. Some performance-enhancing drugs may be secreted into the filtrate as it passes through the distal tubule. These molecules will not be absorbed in the collecting duct and will be found in the urine.

Assessment Options

- Collect and assess students' answers to Analysis, Conclusion, and Extension questions.
- Use Assessment Checklist 4 Performance Task Group Assessment if you are evaluating group work.

Answers to Questions for Comprehension

Student Textbook pages 321

Q16. Renal insufficiency is a general term used to describe the state in which the kidneys cannot maintain homeostasis due to damage to their nephrons.

Q17. Hemodialysis uses an artificial membrane in an external device—in essence, an artificial kidney—that is connected to an artery and a vein in a person's arm.

Peritoneal dialysis uses the lining of the intestines, called the peritoneum, as the dialysis membrane. Dialysate is introduced to the abdominal cavity, where the large surface area and rich supply of capillaries of the peritoneum slowly filter the blood.

Student Textbook page 323

Q18. Dialysis enables people with kidney disease to live their lives in a relatively unchanged way. However, dialysis is not a cure and it is not intended to be a long-term solution to the problem of kidney disease. Individuals with kidney functions of ten percent or less will eventually have to replace their kidneys.

Q19. The short-term success would depend on the availability of organs for transplantation, surviving surgery, and contracting an infection. Long-term success depends on the success of anti-rejection drugs and solving the problem that caused the original kidney disease.

Biology File: Try This

Student Textbook page 323

- It is important to stress during any discussions on the subject of organ donation that there is no right or wrong answer.
- Students could be asked to consider the government proposal to assume that unless people state that they do not wish to be an organ donor, their organs may be harvested after death. Under the current (2007) system, only those who specify that they do wish to be organ donors contribute to the program.

Connections (Nature of Science) Metabonomics

Student Textbook page 324

Teaching Strategies

- Interested students may wish to find out how the nuclear magnetic resonance spectroscopy works.

Answers to Questions

1. Urinalysis can disclose evidence of diseases, even ones that have not shown significant signs or symptoms.

2. Almost everything that happens in your body produces metabolites. Changes in the levels of metabolites can be measured in body fluids such as blood or urine, and these changes provide clues that can help diagnose diseases, identify genetic mutations, or measure the body's reactions to pharmaceutical drugs or other chemicals.

Section 9.3: Review Answers

Student Textbook page 326

1. The amount of water reabsorbed from the filtrate influences two important characteristics of blood: its volume and the concentration of plasma solutes (its osmotic pressure).

2. Both sides of this diagram are identical, so either side could be used to represent the mechanism by which osmotic pressure of body fluids is increased or decreased. However, if students use the diagram on page 317 as their reference, then they will complete captions for the labels as follows:

(a) A: Body fluids too dilute (osmotic pressure too low)

B: Osmoreceptors in the hypothalamus send signal to decrease the release of ADH.

C: Decreased reabsorption of water in kidney tubules and collecting ducts; increased water in urine

D: Osmotic pressure of body fluids increases.

E: Body fluids too concentrated (osmotic pressure too high).

F: Osmoreceptors in hypothalamus sense increased osmotic pressure, and send signals to the pituitary gland to release ADH into the bloodstream.

G. Increased reabsorption of water in kidney tubules and collecting ducts; decreased water in urine.

H: Osmotic pressure of body fluids decreases.

(b) Alcohol is a diuretic because it partially decreases ADH release, which decreases the permeability of the tubules and collecting ducts to water. Less water is reabsorbed from the nephron, increasing the water content of the urine.

3. A person with diabetes insipidus produces very little ADH. The distal tubule and the collecting duct remain impermeable to water. This allows more water to be excreted in the urine, causing excessive urination. The excess water loss triggers the thirst sensation because the osmotic pressure of body fluids is too high. Water continues to be lost very rapidly and thirst persists, unless the individual is given medication containing ADH.

4. (a) The distal tubule and collecting duct are involved in water absorption.

(b) If a person drinks very little water, the blood plasma becomes too concentrated. In response, osmoreceptors send impulses that cause the release of ADH. ADH increases the permeability of the distal

tubule and collecting duct, allowing more water to be reabsorbed into the blood.

5. Aldosterone has the net effect of retaining both salt and water. Aldosterone also stimulates the secretion of K^+ ions into the distal tubule and collecting duct if the K^+ ion concentration in the blood is too high. Without aldosterone, the body would not be able to maintain Na^+ and K^+ ion balances.

6. Creatine is excreted because the concentration is higher in the urine than it is in the plasma.

   Uric acid is excreted because the concentration is higher in the urine than it is in the plasma.

   Bicarbonate ion is absorbed because the concentration is higher in the blood plasma than it is in the urine.

7. The kidneys regulate the acid-base balance of the blood (pH of blood around 7.4). The kidneys monitor and control blood pH levels, mainly by excreting hydrogen ions (H^+) and reabsorbing bicarbonate ions (HCO_3^-).

8. Low blood pressure can result in acute kidney failure. The cause of acute kidney failure is often a drastic drop in blood pressure that prevents an adequate amount of blood from reaching your kidneys. The kidneys would not be able to remove waste products from the blood.

9. Humans can't drink salt water because the kidneys can only make urine that is less salty than salt water. Therefore, to get rid of all the excess salt taken in by drinking salt water, you have to urinate more water than you drank, so you would die of dehydration.

10. **(a)** Protein in the urine—one symptom of increased permeability of the glomerulus and Bowman's capsule caused by infection or injury; sometimes occurs with no known cause in adolescents—usually disappears in adulthood.

    (b) Blood in the urine—one symptom of serious damage to the glomeruli and Bowman's capsules by infection (such as *Streptococcus* bacteria) or physical trauma that has created large pores that allow red blood cells into the filtrate.

    (c) Glucose in urine—one sign of diabetes mellitus; frequently occurs naturally after a meal rich in sugary foods. (If diabetes mellitus is suspected, patients must fast several hours before giving a urine sample for a glucose test.)

    (d) White blood cells in urine—a sign of a kidney or bladder infection.

11.

Disorder	Causes	Symptoms	Treatment
kidney stones	development of crystalline formations due to excess calcium in urine	abdominal and/or back pain	many stones pass through the urinary tract on their own; medications may break down the crystalline formations; ultrasound shock waves can be used to disintegrate the crystalline structures; surgery to remove larger stones
renal insufficiency	kidney infection, high blood pressure, diabetes mellitus, trauma, poisoning, atherosclerosis, blockage of tubules	kidneys cannot maintain homeostasis due to damage to their nephrons	kidney transplant; dialysis
urinary tract infections	bacteria or virus	painful burning sensation during urination, a need to urinate more frequently, bloody or brown urine	antibiotics, surgery in severe cases

Chapter 9: Review Answers

Student Textbook page 328–329

Answers to Understanding Concepts Questions

1.

Label	Structure	Function
A	Renal artery	carries blood from the aorta into the kidney for filtration
B	Renal vein	carries filtered blood from the kidney to the inferior vena cava

Label	Structure	Function
C	Aorta	brings oxygen-rich blood from left side of heart to organs of lower body, including the kidneys via the renal arteries
D	Kidney	filters blood; reabsorbs nutrients, water and other useful molecules; removes metabolic waste products; helps regulate blood volume; helps maintain pH of blood
E	Ureter	carries urine from kidney to the urinary bladder
F	Urinary Bladder	temporarily stores urine
G	Urethra	carries urine to the external environment

2. The active transport of Na^+ ions out of the ascending limb of the loop of the nephron and into the renal medulla controls the volume of urine produced. Na^+ pumping in the ascending loop of the nephron establishes an osmotic gradient that is used to regulate volume of water. This water is then returned to the cardiovascular system.

3. Antidiuretic hormone (ADH) plays a role in water absorption. When ADH is present, more water is reabsorbed (blood volume and pressure rise), and a decreased amount of urine results.

One example of ADH release occurs on a warm day. The hypothalamus will be stimulated to release ADH if an individual does not drink much water. The release of ADH causes more water to be reabsorbed and less urine is formed.

4. Proteins and blood cells are not normally found in the urine because these molecules are too large to pass through the capillary walls of the glomerulus. Because they do not enter the glomerular filtrate, they cannot become part of the urine.

5. If blood pH is too acidic, H^+ ions are actively transported from the blood into the urine. This process takes place in the distal tubule.

The kidneys also help regulate the levels of bicarbonate ions in the blood. Bicarbonate ions pass freely through the capillary walls in the glomerulus and enter the glomerular filtrate. The concentration of bicarbonate in the glomerular fluid is equivalent to that of plasma. If bicarbonate ions are not reabsorbed, the buffering capacity of the blood will be rapidly depleted. The process of reabsorption of the bicarbonate ions primarily occurs in the proximal tubule, although some can be reabsorbed from the distal tubule.

6. The following is a partial list.

- Blood leaving the kidney has a much lower concentration of urea (nitrogenous waste).
- Blood leaving the kidney has a much lower concentration of uric acid (nitrogenous waste).
- Blood leaving the kidney has a lower concentration of potassium ions (under hormonal control).
- Blood leaving the kidney will have a lower concentration of metabolites (drugs, products of metabolic reactions in the body) (tubular secretion).
- Blood leaving the kidney has the same concentration of glucose (glucose actively reabsorbed).
- Blood leaving the kidney has the same concentration of amino acids (amino acids actively reabsorbed).
- Blood leaving the kidney has less ammonia (tubular excretion).

7. Four types of dissolved substances found in the filtrate include nitrogenous wastes (urea, uric acid), glucose, amino acids, and salts (Na^+, Cl^-, K^+, HCO_3^-). Accept any four of the answers.

8. If the bladder has a bacterial or viral infection, the disorder is called cystitis; if only the urethra is involved, the condition is called urethritis. Urinary tract infections are more common in women than in men, primarily because of the differences in anatomy. In females, the urethral and anal openings are closer together, making it easier for bacteria from the bowels to enter the urinary tract and start an infection.

Symptoms of a urinary tract infection include a painful burning sensation during urination; a need to urinate frequently, even if no urine is present; and bloody or brown-coloured urine. The upper abdomen or lower back may be tender, and other symptoms may include chills, fever, nausea, or vomiting.

9. The following flow chart is one way to show how the kidneys control water levels in this situation.

blood plasma dilute → osmoreceptors signal to stop releasing ADH → distal tubule and collecting duct less permeable to water → more water excreted in the urine

10. Filtration occurs when whole blood enters the glomerulus. Due to blood pressure in the glomerulus, water and small molecules move from the glomerulus to the inside of the glomerular capsule. This is a filtration process because large molecules and formed elements in the blood are unable to pass through the capillary wall.

Tubular Reabsorption occurs as molecules and ions are both passively and actively reabsorbed from the nephron into the blood of the capillary network that surrounds the nephron. When sodium ions are actively reabsorbed, chloride ions follow passively. The reabsorption of salt (NaCl) increases the concentration of solutes in the blood, and water will move from the tubule into the blood by osmosis.

Tubular secretion of salt along the thick portion of the ascending limb produces an osmotic gradient. Because of the osmotic gradient within the renal medulla, water leaves the collecting duct and moves into the capillary bed surrounding the nephron.

Osmosis is the diffusion of water across a semi-permeable membrane. Tubular secretion and reabsorption establishes osmotic gradients in the kidney, which, in turn, regulates the balance of water in the body.

11. Serious dehydration would have the following effects.

(a) Glomerular filtration would be less (dehydration would reduce blood pressure). Angiotension released by the adrenal glands is a vasoconstrictor that increases blood pressure.

(b) Tubular reabsorption would create increased levels of ADH, resulting in increased reabsorption of water in the collecting duct. Aldosterone stimulates the distal tubule and collecting ducts to reabsorb sodium ions, which allows more water to reabsorb.

(c) ADH secretion would increase the permeability of the distal tubule and collecting duct, resulting in more water being removed from the urine (increased concentration of urine).

12. (a) A: renal cortex

B: renal medulla

C: renal artery

D: renal vein

E: ureter

(b) The functions of sections of the human kidney are as follows.

(i) Cortex: the processes of filtration (glomerulus). Tubular reabsorption (proximal tubule) of materials required by the body are removed from the filtrate and returned to the bloodstream. Tubular secretion (distal tubule) involves the active transport of materials out of the blood and into the distal tubule.

(ii) Medulla: cells of the medulla have an increased concentration of Na^+ ions. The high levels of Na^+ are the result of active transport of sodium ions out of the ascending limb of the nephron. Reabsorption of water (osmosis) occurs in the collecting ducts as they pass through this region.

(iii) Collecting duct: reabsorption of water by osmosis as urine moves through. Collecting ducts pass through renal medulla.

(iv) Renal pelvis: a central space that is continuous with the ureter. The collecting ducts deliver urine to the renal pelvis.

13. The following chart identifies the structures in the diagram shown.

Label	Structure
A	Bowman's capsule
B	renal artery
C	renal vein
D	loop of the nephron
E	capillary network
F	proximal tubule
G	glomerulus
H	distal tubule
I	renal cortex
J	renal medulla
K	collecting duct

(b) The following chart summarizes the function of the different parts of the nephron.

Label	Part of the Nephron	Function
i	glomerulus	Filtration ■ Glomerular blood pressure forces some of the water and dissolved substances from the blood plasma through the pores of the glomerular walls
ii	Bowman's capsule	Receives filtrate from the glomerulus
iii	proximal tubule	Reabsorption ■ Active reabsorption of all nutrients, including glucose and amino acids ■ Active reabsorption of positively charged ions such as sodium, potassium, calcium ■ Passive reabsorption of water by osmosis ■ Passive reabsorption of negatively charged ions such as chloride and bicarbonate by electrical attraction to positively charged ions Secretion ■ Active secretion of hydrogen ions
iv	Descending loop of Henle	Reabsorption ■ Passive reabsorption of water by osmosis

Label	Part of the Nephron	Function
v	Ascending loop of Henle	Reabsorption ■ Active reabsorption of sodium ions ■ Passive reabsorption of chloride and potassium ions
vi	Distal tubule	Reabsorption ■ Active reabsorption of sodium ions ■ Passive reabsorption of negatively charged ions such as chloride and bicarbonate ■ Passive reabsorption of water by osmosis Tubular Secretion ■ Active secretion of hydrogen ions ■ Passive secretion of potassium ions by electrical attraction to chloride ions
vii	Collecting duct	Reabsorption ■ Passive reabsorption of water by osmosis

Answers to Applying Concepts Questions

14. Alcohol stimulates urine production partly by decreasing ADH release, which decreases the permeability of the distal tubule and collecting ducts to water. More dilute urine (lighter colour) is expelled from the body.

15. (a) water—180 L of water are filtered into the capsules each day; only 1.8 L of urine are produced; 99% of the water that is filtered is reabsorbed into the bloodstream from the proximal tubules, the descending loop of Henle, the distal tubule, and the collecting ducts.

(b) sodium—630 g of sodium enter the filtrate; 3.2 g of sodium are excreted in the urine; 99.5% of the sodium entering the filtrate is reabsorbed into the bloodstream from the proximal tubule, the loop of Henle, and the distal tubule

(c) glucose—180 g of glucose enter the filtrate; theoretically 0.0 g of glucose is excreted in the urine; all of the glucose is reabsorbed into the bloodstream in the proximal and distal tubules.

(d) urea—54 g of urea enter the filtrate; 30.0 g of urea are excreted in the urine; only 44% of the urea is reabsorbed through all regions of the nephron.(56% of the urea in the blood is excreted).

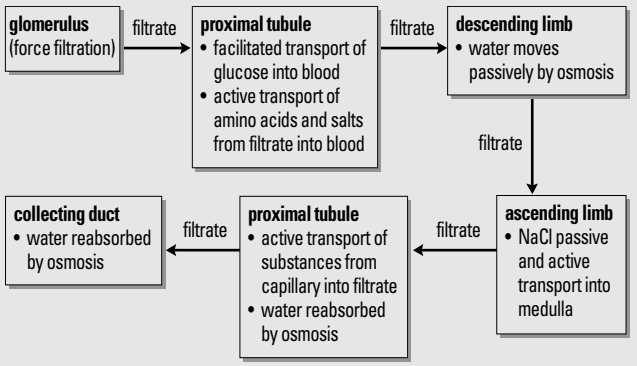
16. The following are potential answers:

- A kidney transplant using a living donor generally has a higher success rate because the kidney is usually a better genetic match and therefore is not as likely to be rejected.
- The time between the donor and recipient surgeries is usually minimal, which may improve long-term graft survival. The recipient does not have to wait for a cadaveric organ, which can take as long as 2–5 years.

17.

Function	Human Kidney	Dialysis Machine
Filtration of Blood	Glomerulus (force filtration).	Blood passes through dialysis tubing; small molecules pass through this membrane by diffusion.
Tubular Reabsorption	Glucose and amino acids are actively reabsorbed from the filtrate in the proximal tubule.	Substances can be added to the blood by increasing their concentration in the diasylate; these molecules will diffuse from the diasylate into the blood.
Tubular Secretion	Certain molecules are actively secreted from the capillary network into the distal tubule.	This process cannot be duplicated in a dialysis machine.

18.



Answers to Making Connections Questions

19. (a) As blood filtering becomes impaired, urine output decreases, water and waste products accumulate in the blood, and blood then appears in the urine.

(b) Students need to associate the inability of the glomerulus to filter blood properly, due to nephritis, with the resulting presence of blood cells in the filtrate. Thus, students might suggest that the presence of red blood cells causes a change in urine colour. (This response is partly correct, but incomplete. As unfiltered red blood cells break down, hemoglobin—the red pigment in such cells—is released, leading to the colour change.)

20. Students should indicate that artificial kidney dialysis uses the same chemical principles as the kidneys do to

maintain the chemical composition of the blood. The processes of diffusion across semi-permeable membranes, polarity, and concentration gradients are central to the dialysis process for both natural and artificial kidneys. Dialysis machines, however, cannot excrete unwanted substances such as medication or excess H^+ ions. Therefore, one would expect to find higher concentrations of metabolites in healthy urine than you would find in dialysis filtrate.

21. (a) Student answers will depend on their point of view. Accept answers that are well thought out and address the issue of cost of transplants vs. the cost of dialysis. (In Alberta, the cost of ongoing dialysis over a few years is considerably higher than the cost of transplant surgery and follow-up medical care.)

(b) Students may want to know the long-term implications of being on dialysis, the impact on daily routines, the inability to travel, the inability to do a regular job due to continued ill health etc.

CHAPTER 10 THE MUSCULAR SYSTEM AND HOMEOSTASIS

Curriculum Correlation

Human Systems: General Outcome 4: Students will explain the role of the motor system in the function of other body systems.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
20–D4.1k explain how the motor system supports body functions, i.e., circulatory, respiratory, digestive, excretory and locomotory	Section 10.1: Movement and Muscle Tissue, pp. 332-333 The Cooperation of Skeletal Muscles, p. 333 Section 10.2: Homeostasis, Muscles, and Other Body Systems, pp. 348-249	Q questions 1, 2, p. 333; 3, p. 336 Try This: The Diaphragm, p. 336 Section 10.1 Review: 1-3, 8-10, p. 342 Section 10.2 Review: 10, 12, p. 350 Chapter 10 Review: 2, 9, 10, p. 352; 25, p. 353 BLM 10.3.1 Chapter 10 Test Unit 4 Review: 7, 8, p. 356; 37, p. 357
20–D4.2k describe, in general, the action of actin and myosin in muscle contraction and heat	Section 10.1: Skeletal Muscle Consists of Bundles and Fibres, pp. 335-336 The Mechanism of Muscle Fibre Contractions, pp. 336-339 Energy for Muscle Contraction, p. 339	Q question 4, p. 336; 5, 6, p. 338; 7, p. 339; 8-10, p. 341 Section 10.1 Review: 4, 5, 7, p. 342 Section 10.2 Review: 4, 5, p. 350 Chapter 10 Review: 4-6, 11, 13, 14, 16, p. 352; 24, p. 353 BLM 10.3.1 Chapter 10 Test Unit 4 Review: 24, 27, p. 357; 52, 54, p. 358
Outcomes for Science, Technology and Society (Emphasis on the nature of science)		
20–D4.1sts explain that concepts, models and theories are often used in interpreting and explaining observations, and in predicting future observations by (NS6a) ■ *analyzing the effects of exercise on the muscle fiber* ■ *describing the relationship between fitness and efficiency of muscle action* ■ *assessing the physiological effects on the motor system of drugs such as steroids, creatine phosphate, energy-enhancing drugs*	Career Focus: Ask an Athletic Therapist, pp. 354-355 Exercise and Muscle Contraction, p. 344 Thought Lab 10.2: Injuries Related to Athletics, p. 345 The Value of Exercise, pp. 347-348 Connections: How Much Does It Cost to Be The Best?, p. 343	Try This: *Rigor mortis*, p. 340 Career Focus: 1, p. 355 Thought Lab 10.2: Analysis 1-2, p. 345 Q question 14, p. 346; 15, p. 347; 16, 17, p. 348 Unit 4 Review: 55, p. 358; 58, p. 359 Section 10.2: 6, 9, p. 350 Chapter 10 Review: 8, p. 352; 22, 23, p. 353 Web Link: Diet supplements, p. 342 Connections: 1, 2, p. 343
20–D4.2sts explain that the goal of technology is to provide solutions to practical problems by (ST1) ■ *identifying specific pathologies of the motor system and the technology used to treat the conditions*	Career Focus: Ask an Athletic Therapist, pp. 354-355 Complications of the Muscular System, p. 344	Chapter 10 Review: 19, p. 352 Career Focus: 2, 3, p. 355 Q question 12, p. 344; 13, p. 346 Section 10.2 Review: 1, 2, 13, p. 350 Chapter 10 Review: 21, p. 353 Unit 4 Review: 62, p. 359
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
20–D4.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by ■ designing an investigation to determine the relationship between muscle activity and energy **(IP–NS1, 2, 3, 4) [ICT C7–4.1]**	The Mechanism of Muscle Fibre Contractions, pp. 336-339 Energy for Muscle Contraction, pp. 339-342	Try This: Heat generation, p. 341 Chapter 10 Review: 18, p. 352 Section 10.1 Review: 9, p. 342 Chapter 10 Review: 5, 12, p. 352

	Student Textbook	Assessment Options
Performing and Recording		
20–D4.2s 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 ■ observing types of muscle under magnification **(PR–NS3)** ■ *designing and constructing a model of a muscle fiber* **(PR–ST2) [ICT C7–4.1]**	Launch Lab: Working in Pairs, p. 331 Thought Lab 10.2: Injuries Related to Athletics, p. 345 Investigation 10.A: Observing Muscle Tissue, pp. 334-335 Thought Lab 10.1: Designing a Muscle Fibre Model, p. 339	Launch Lab: Procedure 1-2; Analysis 1-2, p. 331 Thought Lab 10.2: Procedure 2, p. 345 Chapter 10 Review: 22, p. 353 Investigation 10.A: Procedure Parts 1, 2, p. 335 Chapter 10 Review: 1, p. 352 Thought Lab 10.1: Procedure 1-4, p. 339 Section 10.1 Review: 7, p. 342 Chapter 10 Review: 3, 17, p. 352
Analyzing and Interpreting		
20–D4.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by	Investigation 10.A: Observing Muscle Tissue, pp. 334-335 Thought Lab 10.2: Injuries Related to Athletics, p. 345	Investigation 10.A: Analysis 1-4; Conc. 5-7, p. 335 Thought Lab 10.2: Analysis 2, p. 345 Section 10.2 Review: 8, p. 350 Chapter 10 Review: 13, 14, p. 352; 20, p. 353 Unit 4 Review: 52, p. 358
■ *obtaining and interpreting data to demonstrate a direct correlation between energy use by muscle cells and heat production* **(PR–NS1, 2, 3, 4) (AI–NS2)**	Launch Lab: Working in Pairs, p. 331	Try This: Heat generation, p. 341 Launch Lab: Analysis 3, p. 331
■ *evaluating dependability of technologies used for temperature measurement, assessment or analysis and identifying limitations of such measurements* **(AI–NS3, 4)**	Launch Lab: Working in Pairs, p. 331	Try This: Heat generation, p. 341 Launch Lab: Analysis 3, p. 331
Communication and Teamwork		
20–D4.4s 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	Thought Lab 10.1: Designing a Muscle Fibre Model, p. 339 Thought Lab 10.2: Injuries Related to Athletics, p. 345	Thought Lab 10.1: Procedure 1-3; Analysis 1, p. 339 Thought Lab 10.2: Analysis 1, p. 345
■ *working cooperatively with team members to measure body temperature* **(CT–NS1)**	Launch Lab: Working in Pairs, p. 331	Launch Lab: Procedure 1-2, Analysis 3, p. 331
■ *using appropriate SI notation, fundamental and derived units* **(CT–NS2)**	Investigation 10.A: Observing Muscle Tissue, pp. 334-335	Investigation 10.A: Procedure Part 2: 2, 4-7, pp. 334-335

Chapter 10

The Muscular System and Homeostasis

Student Textbook pages 330–353

Chapter Concepts

10.1 Movement and Muscle Tissue

- There are three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle.
- Skeletal muscle produces body movement, maintains body temperature, and provides support for the body.
- Muscle fibres are filled with myofibrils that house thin (actin) and thick (myosin) contractile protein myofilaments.
- Actin and myosin slide past each other during a muscle contraction.
- Creatine phosphate, fermentation, and aerobic cellular respiration provide energy for muscle contractions.

10.2 Muscles, Health, and Homeostasis

- Three types of skeletal muscle—slow-twitch, fast-twitch, and an intermediate type—are found in different parts of the body.
- Muscles atrophy with inadequate stimulation and can hypertrophy with appropriate repeated stimulation.
- The muscular system works with other body systems to maintain homeostasis.

Common Misconceptions

- Students have difficulties understanding that muscles only do work when they are contracting, which explains why muscles are usually found in antagonistic pairs.
- Students will have difficulty with the terminology, especially terms such as myofibril and myofilament. Myofibrils are cylindrical in shape and run the length of the muscle fibre. These fibres have light and dark bands called striations. The striations are formed by the placement of myofilaments (actin and myosin) within contractile units of myofibrils called sarcomeres. The myofilaments have a fixed length. When the muscle fibre contracts, the sarcomeres within the myofibrils shorten. When a sarcomere shortens, the actin (thin) filaments slide past the myosin (thick) filaments and approach one another. During the sliding process, the sarcomere shortens; however, the myofilaments (actin and myosin) themselves remain the same length.

Helpful Resources

Books and Journal Articles

- Mader, Sylvia. *Understanding Human Anatomy and Physiology 5/e.* McGraw-Hill Ryerson: Whitby, 2005.
- Shier, David. *Hole's Essentials of Human Anatomy and Physiology 9/e.* McGraw-Hill Ryerson: Whitby, 2006.
- Albom, Mitch. *Tuesdays With Morrie: An Old Man, a Young Man, and Life's Greatest Lesson.* Broadway Books: New York, 2002.

Web Sites

Web links related to the muscular system and homeostasis can be found at **www.albertabiology.ca.** Go to the Online Learning Centre, and log on to the Instructor Edition. Choose Teacher Web Links for the links to Chapter 10.

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. Most handouts and all assessment tools are supported by a BLM with the answers (ANS). The BLMs are in digital form, stored on the CD that accompanies this Teacher Resource or on the web site at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition, BLMs. They can be modified to suit the needs of your students.

Number (Type)

10.0.1 (HAND) Launch Lab: Working in Pairs
10.0.1A (ANS) Launch Lab: Working in Pairs Answer Key
10.1.1 (HAND) Types of Muscle Tissue
10.1.1A (ANS) Types of Muscle Tissue Answer Key
10.1.2 (HAND) Investigation 10.A: Observing Muscle Tissue
10.1.2A (ANS) Investigation 10.A: Observing Muscle Tissue Answer Key
10.1.3 (OH) Structure of Skeletal Muscle
10.1.4 (HAND)/(AST) Contraction of Skeletal Muscle
10.1.4A (ANS) Contraction of Skeletal Muscle Answer Key
10.1.5 (HAND)/(AST) Sliding Filament Model of Muscle Contraction
10.1.5A (ANS) Sliding Filament Model of Muscle Contraction Answer Key
10.1.6 (HAND)/(AST) Role of Calcium Ions
10.1.6A (ANS) Role of Calcium Ions Answer Key
10.1.7 (HAND) Thought Lab 10.1: Designing a Muscle Fibre Model
10.1.7A (ANS) Thought Lab 10.1: Designing a Muscle Fibre Model Answer Key
10.1.8 (OH) Energy Sources for Muscle Contraction
10.1.9 (HAND)/(AST) The Role of Creatine Phosphate in Muscle Contractions
10.1.9A (ANS) The Role of Creatine Phosphate in Muscle Contractions Answer Key

10.1.10 (HAND)(AST) ATP from Aerobic Cellular Respiration and Fermentation
10.1.10A (ANS) ATP from Aerobic Cellular Respiration and Fermentation Answer Key
10.1.11 (HAND)/(AST) Oxygen Debt
10.1.11A (ANS) Oxygen Debt Answer Key

10.2.1 (HAND) Thought Lab 10.2: Injuries Related to Athletics
10.2.1A (ANS) Thought Lab 10.2: Injuries Related to Athletics Answer Key
10.2.2 (HAND)/(AST) Experiments with Isolated Skeletal Muscles
10.2.2A (ANS) Experiments with Isolated Skeletal Muscles Answer Key
10.2.3 (HAND)(AST) Types of Muscle Fibres
10.2.3A (ANS) Types of Muscle Fibres Answer Key
10.2.4 (OH) Common Disorders and Ailments of Skeletal Muscle

10.3.1 (AST) Chapter 10 Test
10.3.1A (ANS) Chapter 10 Test Answer Key

Using the Chapter 10 Opener

Student Textbook pages 331–332

Teaching Strategies

- Review the structure and the function of the mitochondria.
- Review aerobic and anaerobic cellular respiration and the generation of ATP from previous science courses.
- You can demonstrate the organization of skeletal muscle and bone by using a skinned chicken wing. Point out that skeletal muscles attach to bones and are arranged in pairs. Remind students that muscles can only do work when they contract. Have them predict the direction of movement generated by the contraction of a specific muscle in the chicken wing.

Launch Lab: Working in Pairs

Student Textbook page 331

Purpose

Students demonstrate that skeletal muscles work in pairs.

Outcomes

- 20–D4.2s

Advance Preparation

When to Begin	What to Do
2 days before	■ Photocopy **BLM 10.0.1: Launch Lab: Working in Pairs**

Time Required

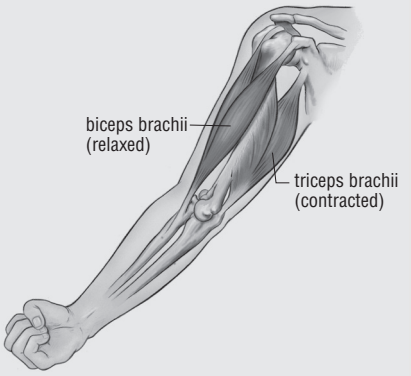
- 15 minutes

Helpful Tips

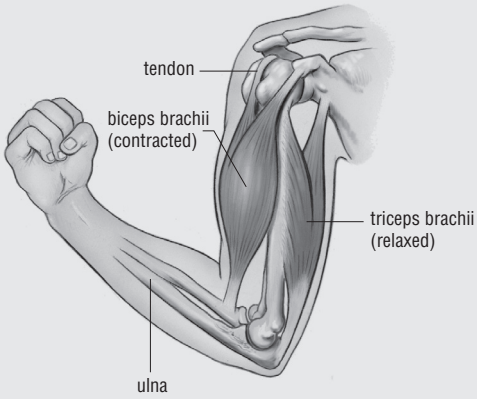
- Use **BLM 10.0.1: Launch Lab: Working in Pairs** to support this activity. Modify it as necessary.
- This activity could be combined with the chicken wing activity previously discussed.
- Borrow some very light free weights from the physical education department. Have one or two students demonstrate muscle action as they are doing arm curls. The weights should be fairly light to prevent any muscle or joint injuries.

Answers to Analysis Questions

1. The following diagram can be used as a marking guide.



2. The following diagram can be used as a marking guide.



3. It is unlikely that students would notice an increase in muscle temperature through their sense of touch. They would not be able to determine if the temperature increase was the result of muscle activity or of heat radiating from blood vessels in the skin. A temperature probe inserted directly into the muscle would be a direct way to measure temperature increase as a result of muscle contraction.

Assessment Options

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

10.1 Movement and Muscle Tissue

Student Textbook pages 332–342

Section Outcomes

Students will:

- **observe** and **compare** the three types of muscle tissue
- **describe,** in general, the action of actin and myosin in muscle contraction and heat production
- **identify** the sources of energy for muscle contraction

Key Terms

smooth muscle
cardiac muscle
skeletal muscle
muscle fibres
myofibrils
myofilaments
actin myofilament
myosin myofilament
sliding filament model

Biology Background

- Muscle (contractile) tissue is composed of cells called **muscle fibres**. Muscle fibres contain actin and mysoin filaments, whose interaction account for movement.
- Skeletal muscles, smooth muscles, and cardiac muscles are found in the human body. Skeletal muscle, also called voluntary muscle, is attached by tendons to the bones of the skeleton; when the muscle contracts, body parts move. Contraction of the skeletal muscle is under voluntary control and occurs faster than in the other muscle types. Skeletal muscles are multinucleated and have a striated appearance. Smooth (visceral) muscle is so named because the cells lack striations. The spindle-shaped cells form layers in which the thick middle portion of one cell is opposite the thin ends of the adjacent cells. Smooth muscle is not under voluntary control. Found in the walls of the digestive tract and blood vessels, smooth muscle contracts more slowly than skeletal muscle, but it can remain contracted for longer periods of time. Cardiac muscle is found only in the walls of the heart. Its contractions pump blood and account for the heartbeat. Cardiac muscle combines features of both smooth and skeletal muscle. Like skeletal muscle, it has striations, but the contraction of the heart is mostly involuntary. Cardiac muscle cells have a single nucleus and are branched. The heart appears to be composed of one large, interconnecting mass of muscle cells; in fact, cardiac muscle cells are separate and individual. They are bound end to end at **intercalated disks**, areas where folded plasma membranes between cells contain adhesion and gap junctions.
- Skeletal muscles work in pairs; when they contract, some act as prime movers, others are synergists, and still others are antagonists.
- A series of events leads to muscle fibre contraction. Nerve impulses from the spinal cord travel down a motor neuron to a muscle. Each motor neuron branch terminates at the neuromuscular junction of a muscle fibre. Impulses travel down the T system of the muscle fibre to the sarcoplasmic reticulum, where calcium (Ca^{2+}) is stored. Calcium is released, and myosin myofilaments pull actin myofilaments to the centre of the sarcomere, causing the sarcomeres to shorten. ATP supplies the energy for muscle contraction.
- Calcium plays a vital role in muscle contraction. Calcium ions bind to troponin, exposing myosin-binding sites. After breaking ATP down, myosin heads bind to an actin filament, forming cross-bridges that pull the actin filament to the centre of a sarcomere.
- Working muscles require a supply of ATP, which anaerobic creatine phosphate breakdown and fermentation can quickly generate. Cellular respiration in mitochondria is best for sustained exercise.

Teaching Strategies

- This section will be very confusing for many students: a significant number of new terms are introduced, and a number of biochemical events must be kept track of in order to understand the concepts presented. Dividing this section into small, manageable parts is one way to help all students learn this material.
- You may wish to begin teaching this section with a discussion on weight lifting, body-building, or the use of steroids. Use the Connections feature "How Much Does It Cost to be the Best?" on page 343 to begin the class discussion.
- Use **BLM 10.1.1: Types of Muscle Tissue**, a handout, and **10.1.3: Structure of Skeletal Muscle**, an overhead, to help students learn the terminology associated with structure of this type of muscle.
- **BLM 10.1.2: Investigation 10.A: Observing Muscle Tissue** guides students through this investigation.
- **BLM 10.1.4: Contraction of Skeletal Muscle and BLM 10.1.5: Sliding Filament Model of Muscle Contraction** are handouts that can reinforce events associated with the contraction of a myofibril. These BLMs can also be used in conjunction with Thought Lab 10.1: Designing a Muscle Fibre Model. Use **BLM 10.1.7: Thought Lab 10.1: Designing a Muscle Fibre Model** to support the activity.
- One way to help students visualize the mechanism of muscle contraction is to make a human model of the myofibril. Have students assume the roles of the different components to walk through the events in this complex process. You may have to arrange to use the gymnasium or stage area in order to have enough room for students to build their human model.

- **BLM 10.1.6: Role of Calcium Ions in Muscle Contraction** can be used in conjunction with discussions on the importance of this ion in the contraction of skeletal muscles.
- **BLM 10.1.8: Energy Sources for Muscle Contraction** is an overhead; **BLM 10.1.9: The Role of Creatine Phosphate in Muscle Contractions, BLM 10.1.10: ATP From Aerobic Cellular Respiration and Fermentation**, and **BLM 10.1.11: Oxygen Debt** are handouts that can be used to help students decipher how muscles are supplied with energy under different conditions.

Answers to Questions for Comprehension

Student Textbook page 333

Q1.
- Smooth muscle cells are non-striated, have a single nucleus, and are usually arranged in parallel lines, forming sheets. They are under involuntary control and found in the walls of many internal organs.
- Cardiac muscle is only found in the heart and forms the wall of this organ. Its cells are striated, and each has a single nucleus. Cardiac muscle cells are tubular and branched, forming a tough, net-like structure. Cardiac muscle contraction is involuntary.
- Skeletal muscles are tubular and striated. Skeletal muscle contraction is voluntary. These muscle cells are long, and each has a number of nuclei (multinucleated). They are usually referred to as fibres, rather than cells.

Q2. To lengthen, a muscle must relax so that an opposing force can pull the muscle back to its full length. The arrangement of opposing pairs of muscles around a joint (in effect, a fulcrum) allows them to act together to stretch each other out and provides the force to move a bone (in effect, a lever) in opposite directions.

Investigation 10.A: Observing Muscle Tissue

Student Textbook pages 334–335

Purpose

Students observe different types of muscle cells with a microscope and obtain and interpret experimental evidence to account for muscle fibre contraction.

Outcomes

- 20–D4.2s
- 20–D4.3s
- 20–D4.4s

Advance Preparation

When to Begin	What to Do
several months before	■ Check the supply of prepared muscle cells and order replacements from a scientific supply company, if necessary.
2 weeks before	■ Order a glycerinated muscle fibre kit from a scientific supply company (shelf life of chemicals is 10 days).
2 days before	■ Photocopy **BLM 10.1.2: Investigation 10.A: Observing Muscle Tissue.**
the day of the investigation	■ Prepare muscle tissue (see Helpful Tips, below, for instructions).

Materials

- light microscope
- dissecting microscope (optional)
- prepared slides of smooth muscle, cardiac muscle, and skeletal muscle (1 set of slides per group)
- sharp scissors
- small forceps or tweezers
- dropper pipette
- 2 microscope slides
- millimetre ruler (thin plastic)
- glycerinated muscle fibres in 50% glycerol
- dropper vial of 0.25% ATP in distilled water
- dropper vial 0.05M KCl plus 0.001 $MgCl_2$ in distilled water
- teasing needle (1 per group)

Time Required

- 1 hour

Helpful Tips

- Use **BLM 10.1.2: Investigation 10.A: Observing Muscle Tissue** to support this activity. Modify it as necessary.

Part 1

- Part 1 of this investigation is fairly straightforward. Group students according to the number of microscopes and muscle slide sets that are available. Students observe three types of muscle and record their observations. Students should refer to Figure 10.1: Comparing and contrasting smooth, cardiac, and skeletal muscles, found on page 332 of the student textbook.

- If microscopes or muscle slide sets are in short supply, consider setting up three microscope stations—one for each type of muscle. Establish a time for each group of students to do Part 1 of this investigation while the others are working on Part 2.

Part 2

Note: Teacher notes for this investigation are adapted from *Contraction of Glycerinated Muscle with ATP: Instruction Manual*, by Carolina Biological Supply Company. Permission pending.

The following information is based on the assumption that you have ordered a Glycerinated Muscle/ATP kit or components of a kit from one of the scientific equipment supply companies.

- Storage of muscle tissue and solutions:
  (a) Glycerinated muscle preparations can be stored in a freezer indefinitely—thaw just before use.
  (b) Store ATP and salt solutions in the refrigerator—remove just before use.
  (c) ATP solutions should be used within 10 days of receipt.
- Preparation of muscle tissue:
  (a) All glassware and dissecting tools must be cleaned thoroughly and rinsed well in distilled water before use.
  (b) The strip of muscle tissue contains hundreds of muscle fibres. Pour the glycerol into a clean petri dish.
  (c) Cut the muscle into pieces, about 2 cm in length, and keep these pieces in the glycerol. Unused muscle tissue can be returned to the freezer in 50% glycerol.
  (d) Place the petri dish containing a segment of skeletal muscle tissue on the stage of a dissecting microscope. Looking through the microscope, use a teasing needle to gently tease the segment into very thin strands. The thinnest strand you will likely create will include 4 individual muscle fibres. Strands exceeding 0.2 mm in cross-sectional diameter are too thick to be used.
  (e) Each group of students requires 2 sets of muscle fibres. To save time, prepare one watch glass of glycerol and the 2 sets of muscle fibres per group.
- Student Procedure:
  (a) Students can follow the procedure as outlined on page 334 of the student textbook.
  (b) Note for Step 2 in the procedure: Students will likely have to use a teasing needle in order to lay the muscle fibres out straight. If dissecting microscopes are available, have the students place the slide under the dissecting scope and use a thin, plastic ruler to measure the length of the muscle fibres in millimetres.
  (c) Students should wait at least 30 seconds after the application of the ATP and salt solutions before measuring the length of the muscle fibres.
  (d) Before students clean up, you might want to have them cover one of the contracted sets of muscle fibres with a cover slip and have them observe these fibres under a compound microscope. They can compare the contracted muscle fibres to the skeletal muscle fibres that they observed in Part 1 of this investigation.
- Note on student results:
  (a) The speed and extent of the muscle contractions students will observe are influenced by the amount of glycerol on the slide, the concentration of active ATP, the ions present, and the width of the dissected muscle strand.
  (b) Under favourable conditions, the myofibres can be expected to contract to almost 50% of their starting length within 10 seconds.

Safety Precautions

- Refer to the document *Safety in Science Classroom* published by Alberta Education (see Alberta Education web site) before starting this investigation. You can search this document to identify information including the chemical name, state, WHMIS class, hazards, and disposal information.
- There are a number of general guidelines that can be followed to increase safety when working with chemicals.
  (a) Ensure that the chemical is appropriately labelled and that the MSDS is readily available.
  (b) Minimize exposure to chemicals.
  (c) Do not handle or use chemicals unless you are WHMIS trained.
  (d) Before using any chemical, review its MSDS to determine potential hazards.
  (e) Inform students of hazards and the necessary safety precautions.
  (f) Never underestimate risks when mixing chemicals.
- Post the MSDS pages for all reagents (KCl and $MgCl_2$ solutions).

Answers to Analysis Questions

1.
- **Smooth muscle** cells are long and tapered at each end like a spindle. Each has a single nucleus and the cells are usually arranged in parallel lines.
- **Cardiac muscle** is unique to the heart and forms the wall of this organ. Its cells are striated (have bands of light and dark), and each has a single nucleus. Cardiac muscle cells are tubular and branched, forming a net-like structure.
- **Skeletal muscle** cells are tubular and striated. Skeletal muscle cells are very long, and each has many nuclei.

2. Involuntary contraction occurs without conscious control. Voluntary muscle contraction is consciously controlled by the nervous system. No, you couldn't distinguish this in your observations because nervous tissue was not involved in this investigation.

3. The heart needs a unique type of muscle to suit its function—to contract and relax repeatedly and endlessly for scores of years, from before birth to death.

4. Controlled variables could include the size and thickness of the myofibrils; the amount of glycerol on the slide; the

amount of ATP and salt solution added; and the length of time students waited for the muscle fibres to contract. Manipulated variables are the salt and ATP solutions.

Observations should note that the myofibrils do not contract until both ATP and salts (KCl and $MgCl_2$) are added to the slides. The myofibrils treated with ATP and the salt solutions should be approximately 50% shorter than those that have not been treated with these solutions.

Answers to Conclusions Questions

5. The following is an example of a possible answer.

Smooth muscle cells are long and tapered at each end like a spindle. Each has a single nucleus and the cells are usually arranged in parallel lines, forming sheets. Although smooth muscle is slower to contract than skeletal muscle, it can sustain prolonged contractions and does not fatigue easily.

The cells of cardiac muscle are striated (have bands of light and dark) and each has a single nucleus. Cardiac muscle cells are tubular and branched, forming a net-like structure. This structure provides the strength required to pump blood to all cells of the body.

Skeletal muscle cells are very long, and each has many nuclei—the length of the muscle cell and its needs for energy and materials are too much to be coordinated by a single nucleus. Striated muscle is often used in short, intense bursts, whereas smooth muscle sustains longer, or even near-permanent, contractions.

6. The factors that are required for muscle contraction are ATP and salt solutions (ions).

7. The intent of this question is to start them thinking about the contraction of a skeletal muscle. Students are not expected to identify the different bands or zones or to know anything about the sliding filament model.

Assessment Options

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

Biology File: Try This

Student Textbook page 336

As in other skeletal muscles, the diaphragm is composed of functional units (**motor units**), each comprised of a motor neuron and the muscle fibres innervated by the motor neuron. The diaphragm must have an impulse delivered to it before it contracts. That impulse can originate in the higher brain centres, as when you voluntarily inhale and exhale, or in the lower brain, as when low oxygen levels or high levels of acid or carbon dioxide are present in the cerebrospinal fluid or blood.

Answers to Questions for Comprehension

Student Textbook page 336

Q3. Skeletal muscle fibre consists of hundreds of thousands of cylindrical sub-units called **myofibrils**. Each of these is made of even finer **myofilaments**, which contain protein structures responsible for muscle contraction.

Q4. An **actin** (thin) **myofilament** consists of two strands of protein molecules that are wrapped around each other, somewhat like two strands of beads loosely wound together. A **myosin** (thick) **myofilament** is also composed of two strands of protein wound around each other; however, a myosin myofilament is about 10 times longer than an actin myofilament, and the myosin strands have a different shape. One end of a myosin myofilament consists of a long rod, while the other end consists of a double-headed globular region, often called the "head."

Student Textbook page 338

Q5. When a muscle fibre contracts, the heads of thousands of myosin myofilaments move first. This moves them closer to their rod-like "backbone" and a few nanometers in the direction of the flex. Because the heads are attached (chemically bound) at this time to actin myofilaments, the actin myofilaments are pulled along with the myosin heads as they flex. As a result, the actin myofilaments slide past the myosin myofilaments in the direction of the flex. As one myosin head after another flexes, the myosin, in effect, "walks" in place, step by step, along the actin. Each step requires a molecule of ATP to provide the energy that repositions the myosin head before each flex.

Q6. The **sliding filament model** of muscle contraction can be described as follows:

- Within each myofilament, the actin is anchored at one end, at a position in striated muscle tissue called the Z line. Because it is tethered like this, the movement of actin pulls its "anchor" (the Z line) along with it.
- As actin moves past myosin, it drags the Z line toward the myosin.
- The mechanism of muscle contraction depends on the structural arrangement of thousands of myosin myofilaments in relation to thousands of pairs actin myofilaments. With one actin molecule being pulled inward in one direction, and the other actin molecule being pulled inward in the opposite direction, the two pairs of actin drag the Z lines towards each other as they slide past the myosin. As the Z lines are pulled closer together, the plasma membranes to which they are attached move towards one another, and the entire muscle fibre contracts.

Thought Lab 10.1: Designing a Muscle Fibre Model

Student Textbook page 339

Purpose

Students design a functional model of a skeletal muscle fibre.

Outcomes

- 20–D4.2s
- 20–D4.4s

Advance Preparation

When to Begin	What to Do
2 or 3 days before the activity	■ Photocopy Assessment Checklist 4 Performance Task Group Assessment if you plan to use this tool to assess your students. ■ Photocopy the following BLMs if you haven't already done so: **BLM 10.1.3: Structure of Skeletal Muscle; BLM 10.1.4: Contraction of Skeletal Muscle;** and **BLM 10.1.5: Sliding Filament Model of Muscle Contraction** plus **10.1.7 Thought Lab 10.1: Designing a Muscle Fibre Model**

Materials
■ to be determined by the students

Time Required

- 90 minutes (30 minutes in the first class for brainstorming; 60 minutes in the second class to build and demonstrate models)

Helpful Tips

- Use **BLM 10.1.7: Thought Lab 10.1: Designing Muscle Fibre Model** to support this activity. Modify it as necessary.
- Providing students with an opportunity to do their brainstorming at the end of an earlier class will save time. In addition, it gives students an opportunity to gather the materials that they will need to build their models.
- Copy and distribute Checklist 9 Developing Models to your students prior to starting the activity to give students a better idea of what you are looking for in terms of the model itself, as well as the presentation.
- To save even more time, bring in bags of materials that the students can use to build their models.

Answers to Analysis Questions

1. Students' answers will depend on the materials that they selected and how they decided to put their models together. Students should notice if their model is lacking any components, based on comparison with the models of other groups.
2. Students' answers will depend on the materials that they selected and how they decided to build their model. Look for an indication that these fibres would have to be linked in some fashion.

Assessment Options

- Use Assessment Checklist 9 Developing Models to evaluate the model.
- Use Assessment Checklist 4 Performance Task Group Assessment to assess the groups' performance during this activity.

Answer to Question for Comprehension

Student Textbook page 339

Q7. No, the muscle cannot contract without calcium ions. When the calcium ion concentration in the sarcoplasm is low, tropomyosin inhibits myosin binding, and the muscle is relaxed. When the calcium ion concentration is raised, Ca^{++} binds to troponin. This causes the troponin-tropomyosin complex to be shifted away from the attachment sites for the myosin heads on the actin. When this repositioning has occurred, the myosin heads attach to actin and, using ATP energy, move the actin myofilament to shorten the myofibril.

Biology File: Try This

Student Textbook page 340

Rigor mortis is caused by partial contraction of the skeletal muscles. The muscles are unable to relax, so the joints become fixed in place. More specifically, rigor mortis sets in because the membranes of muscle cells become more permeable to calcium ions. Living muscle cells expend energy (ATP) to actively transport calcium ions to the outside of the cells. The calcium ions that flow into the muscle cells promote the cross-bridge attachment between actin and myosin myofilaments. The muscle fibres continue to ratchet, becoming shorter and shorter until they are fully contracted. Muscles need ATP in order to release from a contracted state (it is used to actively transport the calcium ions out of the cells so the myofilaments detach from one another). Without the flow of blood to the muscle cells, the ATP reserves are quickly exhausted. This means that the actin and myosin myofilaments will remain linked until the muscles themselves start to decompose. The joints are stiff for 1–3 days, but after

this time general tissue decay and the leaking of lysosomal intracellular digestive enzymes will cause the muscles to relax.

Answers to Questions for Comprehension

Student Textbook page 341

Q8. Creatine phosphate is a high-energy compound that builds up when a muscle is resting. This compound cannot participate directly in muscle contraction; instead, it can regenerate ATP. The chemical reaction occurs in the midst of sliding filaments. Therefore, it is the speediest way to make ATP available to muscles. Creatine phosphate provides enough energy for only about eight seconds of intense activity, and then it is spent.

Q9. Fermentation, such as creatine phosphate breakdown, supplies ATP without consuming oxygen. This allows the muscle to continue activity in anaerobic conditions.

Q10. Aerobic cellular respiration, completed in mitochondria, usually provides most of a muscle's ATP. Glycogen and fat are stored in muscle cells. Therefore, a muscle fibre can use glucose from glycogen and fatty acids from fats as fuel to produce ATP when oxygen is available.

Biology File: Try This

Student Textbook page 341

The temperature probe should indicate an increase in skin temperature as the student exercises. The accuracy of the results will depend on the sensitivity of the thermometers used in this activity.

Biology File: Web Link

Student Textbook page 342

Studies of creatine supplementation show increases in muscle phosphocreatine by 15 to 40%. Most studies indicate an associated improvement in muscle mass, strength, and performance, especially in high-intensity activity. Animal studies of the long-term effects of supplementation suggest possible damaging effects to the liver and kidneys, but implications of these studies for human health are not currently established.

Answer to Question for Comprehension

Student Textbook page 342

Q11. When a muscle uses fermentation to supply its energy needs, it incurs an oxygen deficit. Oxygen deficit is obvious when a person continues to breathe heavily after exercising. Replenishing an oxygen deficit requires replenishing creatine phosphate supplies and disposes of lactate. Lactate can be changed back to pyruvate and metabolized completely in mitochondria; it can also be sent to the liver to synthesize glycogen.

Section 10.1: Review Answers

Student Textbook page 342

1.

	Cardiac Muscle	Smooth Muscle	Skeletal Muscle
Shape	Tubular, branched	Long and tapered	Very long and tubular
Number of Nuclei/Fibre	One	One	Many
Presence of Striations	Yes	No	Yes
Voluntary or Involuntary	Involuntary	Involuntary	Voluntary
Location in Body	Walls of the heart	Walls of the internal organs; iris of the eye	Usually attached to bones
Function	Pump blood	Peristalsis; dilation and constriction of blood vessels; contraction of uterus; iris of the eye	Body movement; maintenance of body temperature; support; protection of internal organs; stabilizing joints

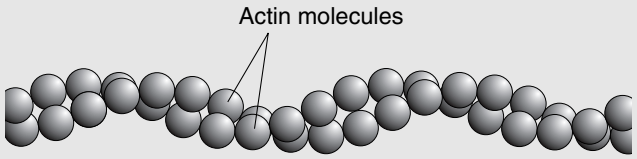
2. Muscles shorten when they contract, so they can only pull, not push.

3. A sketch should show that a skeletal muscle is made of many multinucleated muscle fibres. The muscle is attached to bone at each end with a tendon. Striations are visible.

4. Skeletal muscles have a rich supply of blood vessels to supply oxygen and nutrients to the mitochondria, which will produce energy needed for contraction. Any wastes produced, such as carbon dioxide, will be removed via capillaries and veins.

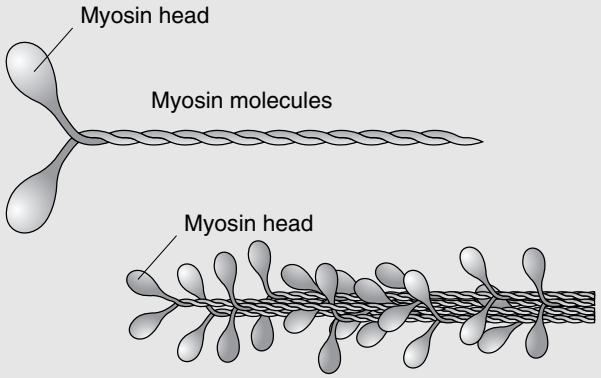
5. Actin is a thin myofilament. Two strands of protein molecules wrap around each other, making it globular. Myosin is a thick myofilament. Two strands of protein are wound around each other. It is ten times longer than an actin myofilament and has a definite shape, with one end being the "head" and the other being a long rod.

Actin:



Thin filament

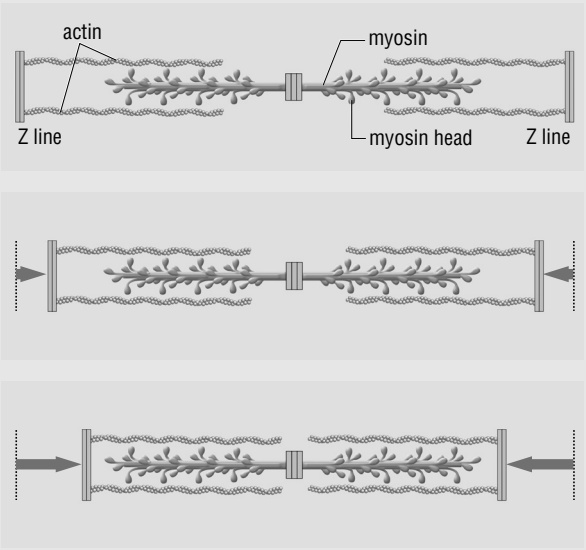
Myosin:



6. The following components of skeletal muscle tissue are given in order of decreasing size and complexity in their hierarchy of organization:

Component	Structure	Function
muscle fibres	single muscle cells grouped into muscle fibre bundles	muscle contraction
myoglobin	oxygen-binding pigment (similar to hemoglobin) inside the sarcoplasm of muscle fibres	binds to oxygen and stores it for use during aerobic cellular respiration in muscle fibres
sarcolemma	membrane surrounding a muscle fibre	regulates the movement of materials into and out of the muscle fibre
sarcoplasm	cytoplasm inside a muscle fibre	site of metabolic processes for cell activities; contains myoglobin and glycogen
sarcoplasmic reticulum	smooth endoplasmic reticulum inside a muscle fibre	stores calcium ions needed for muscle contractions
myofibrils	cylindrical bundles of myofilaments inside a muscle fibre; as long as the muscle fibre itself	contain myofilaments of proteins called actin and myosin
actin myofilaments	thin filaments inside a myofibril that are composed of the protein called actin	bind to myosin during muscle contractions (part of the functional unit of contraction)
myosin myofilaments	thick filaments inside a myofibril that are composed of the protein called myosin	bind to actin during muscle contractions (part of the functional unit of contraction)

7. Student sketches and captions should be similar to the diagrams below.



8. When calcium ions are released, they bind to troponin that causes the troponin-tryopomyosin complex to shift away from the myosin heads. This exposes the attachment sites on the actin. The myosin now binds to the actin and contraction occurs. In other words, calcium ions reposition the molecules that inhibit muscle contraction, so without calcium, actin and myosin would not come together.

9. There are three sources of ATP for muscle contraction: the breakdown of creatine phosphate, aerobic cellular respiration, and fermentation.

(a) Creatine phosphate is a high-energy compound stored in resting muscle. It breaks down and generates ATP for immediate use at the onset of muscle contraction. It provides enough energy for about eight seconds of intense activity. The release of energy from ATP is not dependent on the presence of oxygen.

(b) The process of aerobic cellular respiration takes place in the mitochondria and usually provides most of the ATP for muscle contraction, provided that oxygen is available. The fuels for this cellular respiration are glucose (from glycogen stores) and fatty acids (from fats).

(c) The release of energy from glucose through fermentation generates ATP without the use of oxygen and it creates an oxygen debt in the form of lactate. Fermentation is limited by accumulating lactate and increasing acidity in the sarcoplasm, resulting in cramping and fatigue.

10. Lactate forms in skeletal muscle tissue when oxygen is in short supply and fermentation occurs. It is removed during prolonged heavy breathing after strenuous exercise, as lactate is converted to pyruvate, which is metabolized aerobically in the mitochondria. Lactate is also transported to the liver and converted into glycogen.

Connections (Social and Environmental Contexts)
How Much Does It Cost To Be the Best?

Student Textbook page 343

Teaching Strategies

- If the discussion concerning performance-enhancing substances does not animate the class, consider including practices strictly aimed at enhancing appearance, including anti-aging products.

Answers to Questions

1. Students' answers should include a count of those who answered the question affirmatively and those who said no, plus a chart of anecdotal responses for the reasons why. Their discussion of the results should include comments on whether they expected the results they got and what they thought the reasons given meant in terms of what is important to people.

2. You may wish to use or adopt BLM 4.2.9: Debate Organizer for this activity. Appoint a judge or panel of judges to assess the debate and declare a winning side. Two students will present factual arguments in favour of allowing performance-enhancing substances and two will present factual arguments against allowing their use in competition.

Each two-person team can have assistants to help with research, organization of their points, and practice. The class can decide how the debate should be organized: how much time each team member is allotted to present their points, the order of presentations, how much time will be allowed for rebuttal, and if speakers will be allowed to speak out of turn or while someone else is presenting.

Either the class or the judging panel can set out criteria for choosing the winner, and the class as a whole can comment on the judge's decision. The goal is to give students practice at taking part in reasoned debate.

10.2 Muscles, Health, and Homeostasis

Student Textbook pages 344–350

Section Outcomes

Students will:

- explain how the skeletal muscles of the motor system support other body systems to maintain homeostasis
- identify conditions that impair the healthy functioning of muscles and technologies that are used to treat or prevent these conditions
- describe the benefits of exercise for maintaining the healthy structure and functioning of muscles

Key Terms

atrophy
hypertrophy
muscle twitch
slow-twitch fibres
fast-twitch fibres

Biology Background

- At first, a stimulus to a muscle may be too weak to cause a contraction, but as soon as the strength of the stimulus reaches a threshold level, the muscle contracts and then relaxes. This single contraction is called a **muscle twitch**. A simple muscle twitch has three periods—latent, contraction, and relaxation. When a muscle is not permitted to relax completely between stimuli, the contraction gradually increases in intensity. The then muscle becomes maximally contracted until it fatigues.
- When a muscle uses anaerobic means of supplying energy needs, it incurs an oxygen debt. Repaying the oxygen debt requires replenishing creatine phosphate supplies and disposing of lactate.
- Muscles that are not used, or that are used in only very weak contractions, decrease in size, or **atrophy**. Forceful muscular activity over a prolonged period causes muscle to increase in size as the number of myofibrils within the muscle increase. Increased muscle size is called **hypertrophy**.
- Slow-twitch fibres have a steady tug and have more endurance. These muscle fibres are most helpful in sports such as long-distance running, biking, jogging, or swimming. Because they produce most of their energy aerobically, they tire only when their fuel supply is gone. Fast-twitch fibres tend to be anaerobic and seem designed for strength because their motor units contain many fibres. These muscle fibres provide explosions of energy and are most helpful in sports such as sprinting, weight lifting, or swinging a baseball bat or golf club.

Teaching Strategies

- If your school has a football or rugby team, invite their athletic therapist to the class to talk to the students about the diagnosis, treatment, and rehabilitation of athletic injuries. You could also contact your local ambulance service to see if one of their Emergency Medical Technicians would be willing to do a mini first aid session on the treatment of common athletic injuries (sprains and strains).
- Ask students who have experienced a muscle strain or tear to describe their experiences, including treatment and rehabilitation. Or, see if any of your students has had a broken arm or leg. Have the student describe what happened to the muscles in that appendage while the bone was healing.
- The Career Focus feature: Ask an Athletic Therapist on pages 354-355 can be used as a starting point for Thought Lab 10.2: Injuries Related to Athletics.
- **BLM 10.2.4: Common Disorders and Ailments of the Skeletal Muscles** can be photocopied and distributed to students.
- **BLM 10.2.2: Experiments with Isolated Skeletal Muscles** and **BLM 10.2.3: Types of Muscle Fibres** can be used to support information about slow- and fast-twitch muscle fibres.

Answer to Question for Comprehension

Student Textbook page 344

Q12. Muscle atrophy can occur through lack of or the reduction of use of skeletal muscle.

Thought Lab 10.2: Injuries Related to Athletics

Student Textbook page 345

Purpose

Students analyze the effects of exercise on skeletal muscle and muscle fibre. They then evaluate assumptions and behaviour related to athletics and physical condition. Students should consult a wide variety of sources and assess the authority, reliability, and validity of information gathered.

Outcomes

- 20–D4.1sts
- 20–D4.3s

Advance Preparation

When to Begin	What to Do
2 to 3 weeks before	■ Book library and/or the computer lab.
2 days before	■ Contact an athletic therapist, EMT, or other specialist requesting that they come to your class to talk about the treatment of muscle-related injuries. ■ Photocopy **BLM 10.2.1: Thought Lab 10.2: Injuries Related to Athletics**

Time Required

- 2 hours (1 hour for research; 1 hour to do Analysis question 1)

Helpful Tips

- Hand out **BLM 10.2.1: Thought Lab 10.2: Injuries Related to Athletics** prior to starting this activity. This BLM will provide students with a starting point for their research.
- The time required for this activity can be reduced by having students share the results of their research electronically. They can do this via e-mail or by posting their information to a computer network, allowing them to compile the research of all students into one file.

Safety Precautions

You may wish to refer students to "Safety in Your Online Activities" on page xvi.

Answers to Analysis Questions

1. Answers will depend (a) on the injury selected and (b) the medium used to outline the cause, treatment, and prevention of this injury. **BLM 10.2.4: Common Disorders and Ailments of Skeletal Muscle** can be used as a guide to evaluate students' research.
2. "No pain, no gain" is a dangerous misconception. Moderation is important, as most athletic-related injuries result simply from the overuse of muscles. In addition, pain is one of the key ways that the body signals that something is wrong.

Assessment Options

- Collect and assess students' research.
- Use Assessment Checklist 7: Independent Research Skills from Appendix A.

Answers to Questions for Comprehension

Student Textbook page 346

Q13. Hypertrophy is an increase in the size of individual muscle fibres, whereas atrophy is a reduction in the size of individual muscle fibres.

Q14. A muscle fatigues due to the depletion of energy reserves. Fatigue is apparent when a muscle relaxes, even though stimulation continues.

Student Textbook page 347

Q15. Eye muscle is composed of fast-twitch fibres, and soleus muscle is composed of slow-twitch fibres. Hint: Have students examine the graph in Figure 10.12.

Student Textbook page 348

Q16. Aerobic capacity of endurance athletes is greater due to factors such as hypertrophy, more active enzyme activity in the muscle fibres, more numerous mitochondria in the muscle fibres, and a greater density of blood vessels surrounding muscle fibres.

Q17. Muscle enlargement is produced only by frequent periods of high-intensity exercise in which muscles work against a high resistance, as in weight lifting. As a result of resistance training, fast-twitch muscle fibres become thicker, so the muscle grows by hypertrophy—an increase in the size of the muscle fibre.

Section 10.2: Review Answers

Student Textbook page 350

1. (a) Muscle atrophy is caused by reduction in neural stimulation, frequently due to damage to the nervous system such as paralysis from a spinal cord injury. Prolonged loss of stimulation (as in permanent injuries) causes irreversible muscle atrophy. Physical therapy is of some use in providing stimulation to muscles following an injury or surgery.

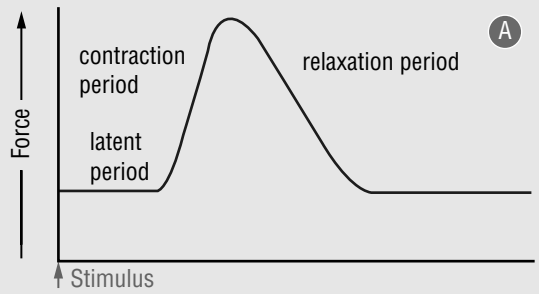
(b) As a muscle atrophies, it decreases in size and loses tone and strength because the muscle fibres become smaller. Prolonged loss of neural stimulation leads to the death of muscle fibres, creating permanent loss of muscle function.

2. Hypertrophy is an exercise-induced increase in muscle mass. It occurs due to an increase in the size of individual skeletal muscle fibres, not to an increase in their number.

Atrophy is a decrease in muscle mass due to reduced stimulation of muscles. It occurs due to a decrease in the size of individual skeletal muscle fibres, not to a decrease in their number.

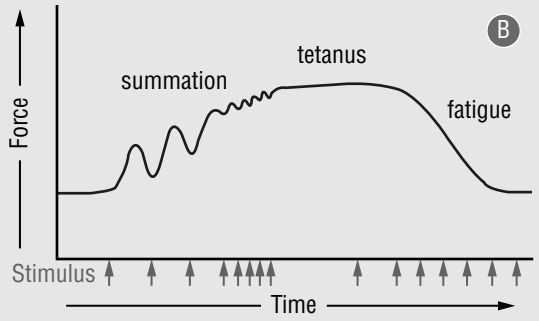
3. Any single stimulus at or above a certain threshold causes the muscle to contract and then relax a fraction of a second later. This is a muscle twitch.

4. Student diagrams should resemble the figure below.



- latent period—the time between stimulation and initiation of muscle contraction (during this time calcium ions are leaving the sarcoplasmic reticulum and are penetrating the myofibrils)
- contraction period—the time during which a muscle shortens (Z lines are pulled closer together)
- relaxation period—when the muscle returns to its normal length (actin and myosin myofilaments slide past each other to their resting position)

5. Student diagrams should resemble the figure below.



- summation—occurs when a muscle receives a rapid series of threshold stimuli and responds to each stimulus before completely relaxing from the previous one. Successive twitches blend together creating a cumulative response called summation.
- tetanus—a maximum sustained muscle contraction following summation; during tetanus, the muscle remains contracted and the graph no longer shows individual twitches. (Tetanus allows us to sustain the skeletal positions through sustained contractions, such as in the action of holding a glass of water.)
- fatigue—tetanus ends due to depletion of energy reserves; fatigue is apparent when a muscle relaxes even though stimulation continues as shown in the graph.

6. Some beneficial changes to muscle that result from regular exercise are:

- an increased blood supply, due to the growth of extra blood vessels;
- enzymes becoming more effective;

- mitochondria becoming more abundant, so muscles can withstand more exertion; and
- muscles becoming able to store more glycogen.

7. Comparison of fast-twitch and slow-twitch muscle fibres

Fast-twitch muscle fibres	Slow-twitch muscle fibres
contract rapidly, generating lots of power	contract slowly and have more endurance
anaerobic, therefore accumulation of lactate causes them to tire quickly	aerobic and resist fatigue
rich in glycogen but tire when the fuel supply is gone	have a store of glycogen and fat; the abundant mitochondria can maintain a steady, prolonged production of ATP when oxygen is available
light-coloured because they have little or no myoglobin and have fewer mitochondria and blood vessels	dark in colour due to the presence of myoglobin and contain many mitochondria surrounded by dense capillary beds to draw more blood and oxygen
used during activities like sprinting, weight lifting, swinging a hockey stick, or a racket.	used in activities such as biking, jogging, swimming, and long-distance running

8. (A) Person with a spinal injury: With a spinal cord injury, this person will likely not be participating in endurance activities, just short bursts of activity for which the intermediate and fast-twitch fibres are needed.

(B) World-class sprinter: A sprinter needs fast-twitch fibres for the generation of power but also lots of intermediate fibres that will resist fatigue. There is a low percentage of slow-twitch fibres because sprints are short events that do not require endurance.

(C) A sedentary person: This person has relatively equal numbers of each type of muscle fibre. With no training demands, there is no need to develop one type of muscle more than the others.

(D) Average active person: The average active person participates in walking, cycling, jogging, or other light activities. Because endurance is important, they have 50% slow-twitch fibres. They may occasionally participate in activities that require power, so for endurance, they have 40% intermediate fibres and only 10% fast-twitch.

(E) Middle distance runner: For middle distances, endurance is important, so these athletes have slow-twitch and intermediate twitch fibres.

(F) World-class marathon runner: This person needs good endurance and resistance to fatigue so having a majority of slow-twitch fibres is good. They may need to exert an extra short burst of speed at the end of the race, so having some intermediate fibres is necessary.

(G) Extreme endurance racer: For this athlete, endurance is most important, hence the high percentage of slow-twitch fibres with very few intermediate and no fast-twitch fibres.

9. Resistance training causes fast-twitch fibres to become thicker, so the muscle grows by hypertrophy. After a myofibril reaches a certain size, it may split into two myofibrils that are also capable of getting thicker.

10. As body temperature drops, a person experiences involuntary skeletal muscle contractions, commonly known as shivering. This action is initiated by temperature-sensitive cells in the hypothalamus of the brain. Shivering is a survival response. It tends to raise body temperature because as ATP is broken down during contraction of skeletal muscles, some of its energy is also released as heat.

11. During prolonged exposure to conditions that decrease core body temperature, death from hypothermia results. Shivering does not release enough heat to maintain body temperature indefinitely and eventually ATP sources are exhausted.

12. (a) The heart muscle pumps blood containing nutrients and oxygen to the tissues. Muscles in the blood vessels cause constriction and dilation to control body temperature and blood pressure.

(b) The diaphragm contracts and relaxes, allowing breathing to occur.

(c) Peristalsis moves food through the digestive tract.

(d) Muscle contraction moves urine in the ureters and urethra. Muscle in the bladder allows it to expand and then contract to expel urine.

13. The Rest, Ice, Compression, and Elevation method is useful because it limits the inflammatory response in injured muscles and joints.

Rest—prevents further injury and irritation of the injured tissues

Ice—causes vasoconstriction and reduces the release of histamines, thereby reducing accumulation of fluids in the injured tissue that causes swelling and pain

Compression—exerts pressure on vessels, reducing blood flow, swelling, and pain

Elevation—increases the flow of venous blood and lymph from the resting injured limb; gravity compensates for lack of skeletal muscle contractions that normally push blood and lymph through veins back to the heart.

Chapter 10: Review Answers

Student Textbook page 352–353

Answers to Understanding Concepts Questions

1. The chart below identifies the three types of muscle tissue illustrated and includes a brief description of each type.

Cell	Type	Description
A	Skeletal muscle	■ are striated and tubular ■ cells (fibres) each have many nuclei ■ contract voluntarily ■ are usually attached to bones of the skeleton
B	Smooth muscle	■ are non-striated ■ cells each have one nucleus ■ contract involuntarily ■ are found in the walls of internal organs
C	Cardiac muscle	■ are striated, tubular, and branched ■ cells each have one nucleus ■ contract involuntarily ■ are found in the walls of the heart

2. Skeletal muscle supports the body, allows movement, stabilizes joints, protects internal organs, creates body form, and helps to maintain body temperature.

3. Student illustrations should show that a muscle fibre is made of myofibrils that are in turn composed of myofilaments composed of the proteins actin and myosin. Sketches will be similar to right half of Figure 10.3 on page 335.

4. The key events in a muscle fibre from contraction to relaxation are as follows:

- The heads of myosin myofilaments move first, bending backward and inward.
- Calcium ions bind to troponin to cause the troponin-tropomyosin complex to be shifted away from the attachment sites for the myosin heads on the actin.
- The myosin attaches to the actin and pulls it along as the myosin heads flex. As each myosin flexes, the myosin "walks along" the actin. The Z lines are pulled closer together.
- One molecule of ATP provides the energy to reposition the myosin head before each flex.

5. Creatine phosphate and ATP regenerate each other through the process of contracting and relaxing muscle tissue. To start contracting, muscle tissue breaks down creatine phosphate, releasing a phosphate group that binds to ADP, producing ATP. Creatine phosphate provides enough energy (generates enough ATP) for about 8 s of intense activity, and then it must be regenerated through the transfer of phosphate groups from ATP to creatine.

6. Oxygen is supplied to skeletal muscle through a high concentration of blood vessels in the muscles.

7. When muscle cells are functioning anaerobically, as they do during glycolysis, the reduced NADH that starts to accumulate reduces pyruvate. This reaction produces lactate and oxidized NAD+. The NAD+ is regenerated, allowing the reactions of glycolysis to continue and thus continuing to generate ATP. At the same time, lactate accumulates in the muscle cells. Some lactate is removed by the bloodstream and carried to the liver. Remaining lactate requires oxygen to be in the reactions that break it down and remove it from the body. The period immediately following exertion, when the body needs oxygen to break down the lactate, is the period when the body is considered to have an oxygen deficit.

8. Muscles fatigue because of the depletion of glycogen and the build-up of lactic acid. A person's physical condition can affect tolerance to fatigue because people who are more physically fit have muscle fibres with a greater aerobic capacity. Physically fit people also tend to have a greater proportion of intermediate-twitch muscle fibres and a higher proportion of hypertrophied muscle fibres as compared with atrophied muscle fibres.

9. If body temperature drops, then skeletal muscles will contract involuntarily. This creates shivering, which produces body heat to try to raise body temperature.

10. Students may suggest examples such as the following: conservation of body heat (through constriction of blood vessels near skin); generation of body heat (through shivering); continual heart contraction and relaxation; interaction of diaphragm and rib muscles in breathing. Accept any answer that clearly shows a connection between the action of muscle tissue (skeletal, smooth, and cardiac) and homeostasis.

11. Myoglobin is an oxygen-binding pigment (similar to hemoglobin) found in skeletal muscle fibres. It provides a ready supply of oxygen in the muscle that supports aerobic cellular respiration during exercise.

12. The initial supply of ATP in skeletal muscles supports strenuous exercise for only about eight seconds. After that, new ATP is supplied by the breakdown of creatine phosphate, through aerobic cellular respiration, and by fermentation.

13. Graph A: Muscle Twitch (single stimulus)

Region 1: Latent period—the time between stimulation and initiation of muscle contraction (during this time calcium ions are leaving the sarcoplasmic reticulum and penetrating the myofibrils)

Region 2: Contraction period—the time during which a muscle shortens (Z lines are pulled closer together)

Region 3: Relaxation period—the time when the muscle returns to its normal length (actin and myosin myofilaments slide past each other to their resting position)

14. Graph B: Summation and Tetanus (multiple stimuli applied)

Region 4: Summation—occurs when a muscle receives a rapid series of threshold stimuli and responds to each stimulus before completely relaxing from the previous one. Successive twitches blend together, creating a cumulative response called summation.

Region 5: Tetanus—the muscle remains contracted in a state of tetanus that continues until neural stimulation stops or until the muscle fatigues due to depletion of energy reserves. (Tetanus allows us to maintain the skeletal positions through sustained contractions, such as in the action of holding a glass of water.)

Region 6: Fatigue—tetanus ends due to depletion of energy reserves; fatigue is apparent when a muscle relaxes even though stimulation continues as shown in this graph.

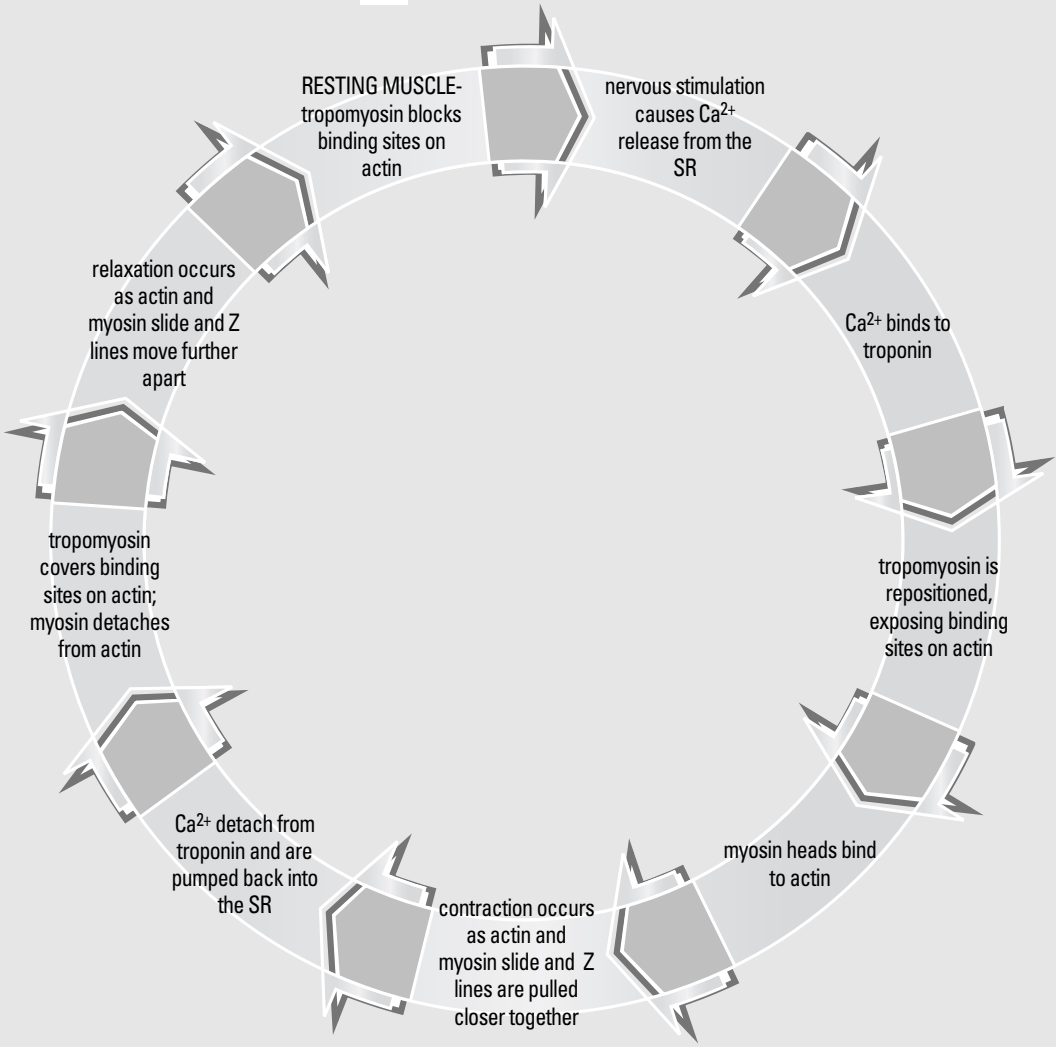
Answers to Applying Concepts Questions

15. The esophagus contains smooth muscle. This is supported by the fact that swallowing is a slow involuntary action.

The heart contains cardiac muscle that is found only in this organ. This muscle type is involuntary, resistant to fatigue and does not undergo tetanus.

16. Myofibrils are cylindrical in shape and run the length of the muscle fibre. These fibres have light and dark bands called striations. The striations are formed by the placement of myofilaments (actin and myosin) within contractile units of myofibrils called sarcomeres. The myofilaments have a fixed length. When the muscle fibre contracts, the sarcomeres within the myofibrils shorten. When a sarcomere shortens, the actin myofilaments (thin) slide past the myosin myofilaments (thick) and approach one another. During the sliding process, the sarcomere shortens; however, the myofilaments (actin and myosin) themselves remain the same length.

17. (a) The scheme below is one way to represent muscle contraction as a cyclic pathway. (Note: SR refers to the sarcoplasmic reticulum)



(b) Two factors that can modify the activity of this cycle are the amounts of ATP and calcium available.

18. Warming up stretches muscles and increases blood flow to provide oxygen and nutrients for energy production.

19. Heat would cause vasodilation and an increased blood flow to the area. This would speed up removal of lactic acid and decrease the pain.

20. A skeletal muscle can maintain a moderate level of tension for long periods of time because different fibres contract at different times.

21. **Hypertrophy:** Regular, moderate exercise strengthens the muscles and enables them to use energy more efficiently. During the first few months of training, skeletal muscles increase in size. This is called hypertrophy and is due to an increased mass of individual skeletal muscle fibres.

Physical training causes other changes to muscles as well. The enzymes within muscle fibres become more active and numerous and the mitochondria become more abundant. A trained athlete's muscles withstand far more exertion than the muscles of an untrained person before fermentation begins. An athlete's muscles also receive more blood and store more glycogen than those of an untrained person.

Atrophy: Muscles may be impaired simply from a lack of use. This condition is referred to as atrophy. Atrophy is a reduction in the size, tone, and power of a muscle. If a skeletal muscle experiences reduced stimulation, its fibres decrease in size and become weaker.

Answers to Making Connections Questions

22. This question requires students to search for, and recognize, patterns and trends in the data represented by the graphs. In the first set of data, for 0–30 min of exercise, blood glucose remains fairly constant, while the percentage of blood-free fatty acids decreases with the level of exercise. Muscle triglyceride increases from mild to moderate exercise but decreases from moderate to heavy; meanwhile, the percentage of muscle glycogen, not detected at all during mild exercise, plays a significant role in providing energy during moderate exercise and nearly doubles as the exercise level increases to heavy. Based on these trends, students might reasonably predict a similar pattern for the second set of data, representing 90–120 min of exercise. That is, their bar graph for heavy exercise could show blood glucose remaining at roughly 10% blood-free fatty acids at a decreased percentage compared to the percentage for moderate exercise (e.g., 30%) decreased muscle triglyceride (e.g., 10%), and increased muscle glycogen (perhaps 50%). Some students might suggest that the people involved in the experiment that provided these data were well-trained athletes, which is a fair assumption given the percentages for aerobic energy sources in the mild exercise column and the pronounced muscle glycogen usage in the moderate and heavy exercise columns.

23. **(a)** The muscle tissue of someone who does the 100-m dash would contain lots of fast-twitch muscle fibres for a rapid generation of power.

(b) A weight lifter would also have lots of fast-twitch fibres, again, to generate power.

(c) A 10 000-m runner would have lots of slow-twitch fibres that resist fatigue and provide more endurance.

24. When the biceps muscle contracts, it shortens and flexes (bends) the elbow joint. The elbow is not extended (straightened) by the relaxation of the biceps because no force is exerted as a muscle lengthens. Instead the contraction of an opposing muscle, the triceps, straightens the elbow joint. The biceps and the triceps are one example of an antagonistic pair of muscles. As the bicep contracts, the triceps is relaxed and vice versa. If the rugby player tears the biceps muscle, then the player would be unable to flex the elbow joint. The ability to straighten the arm at the elbow would be unaffected.

25. The person with MD might have trouble breathing if the breathing muscles (diaphragm and intercostal muscles) are affected. Upon contraction, healthy skeletal muscles increase the volume of the thoracic cavity, decreasing air pressure in the lungs so that atmospheric pressure pushes air into the alveoli. If these muscles are not contracting with sufficient force to maintain normal breathing patterns, then a respirator (a machine that forces air into the lungs) would be required.

Career Focus: Ask an Athletic Therapist

Student Textbook pages 354-355

Teaching Strategies

- Invite an athletic therapist (or other physical therapist) from a local hospital or sports clinic to come to the class to make a presentation. Suggest that the speaker include some hands-on activities for the students to do, related to the material they covered in Chapter 10.
- Arrange for a field trip to an athletic therapist's clinic in order to see one in action.

Answers to Go Further Questions

1. Students will likely recognize that if an athlete understands the workings of the human body, even at the level they have just studied throughout the unit, they should be able to perform better because the athlete will be working "with" the body instead of against it. Examples can be taken from chapters related to digestion, respiration, the heart, hydration, muscles, or immunity and the body's ability to heal itself.

2. Again, students should recognize the benefits of taking advantage of the way the body is designed to function in order to maintain their health and fitness. Examples of using their knowledge of how their bodies work include: exercising to maintain fitness, eating in accordance with

the body's need for adequate nutrition, not smoking (or ingesting other substances that can harm their bodies), wearing proper protective equipment during higher-risk activities. Arguments supporting the notion of personal responsibility to take care will likely be based on healthcare costs and access; arguments against an obligation to be responsible will likely be based on the notion of free will and independence.

3. With the possible exception of rehydration drinks, students will not be able to answer the question from the information in the text. The answer should show that they have investigated the technology, and they have related its design (or redesign) directly to an understanding of human physiology, be it how the brain is cushioned or how it reacts to certain types of blows, or how the foot is constructed and how it responds to the stresses of vigorous activity, or how the body processes fluids and deals with heat. The goal of the question is to have the students see how knowledge of human physiology is applied in real life situations.

Unit 4: Review Answers

Student Textbook pages 356–359

Answers to Understanding Concepts Questions

1. The following chart identifies the five organs of the digestive tract. It also summarizes the structural and functional characteristics of each organ.

Organ of the Digestive Tract	Structural Characteristics	Functional Characteristics
Mouth	■ teeth and tongue ■ mucus membranes ■ salivary ducts enter mouth	■ teeth and tongue for the physical digestion of food ■ mucus membranes add moisture to food ■ salivary glands (exocrine gland) secrete saliva; chemical digestion (amylase) of starch; add moisture to food
Esophagus	■ tube connecting mouth to stomach ■ circular and longitudinal muscles	■ tube transports bolus of food to stomach ■ muscles responsible for peristalsis
Stomach	■ muscular organ with numerous ridges and folded lining ■ exocrine glands secrete gastric juice	■ muscles and folds; physical digestion of food; increasing surface area ■ gastric juice includes the enzyme pepsinogen ■ gastric juice also contains HCl(aq), which activates pepsinogen; pepsin digests protein to polypeptides
Small Intestine	■ long tube ■ exocrine glands in lining ■ pancreatic and bile ducts enter upper portion (duodenum) ■ numerous villi and microvilli	■ the length of the small intestine ensures the maximum length of time for digestion and absorption ■ the exocrine glands lining the intestine plus the pancreatic enzymes digest proteins, carbohydrates, and fats ■ villi and microvilli increase the surface area for the absorption of nutrients; capillary and lymphatic vessels transport nutrients
Large Intestine	■ shorter, but wider, tube	■ absorption of water and dissolved minerals

2. The accessory organs of the digestive system are:
   - Liver: responsible for producing bile salts from cholesterol. Bile emulsifies fat droplets; all monosaccharides (except glucose) are removed from the blood and converted into glycogen, which is stored in the liver until needed.
   - Pancreas: a source of several enzymes that chemically digest carbohydrates, fats, and peptides (sub-units of proteins).
   - Gall bladder: stores bile until required; bile emulsifies fats, increasing the surface area for chemical digestion.

3. The plural membranes surround the lungs. Each pleuron is made up of two layers separated by a thin film of lubricating fluid. One layer adheres to the rib cage and the diaphragm, while the other is fused to the lungs. The surface tension of water molecules in this fluid helps to keep the lungs inflated.

4. Sketches should show the following structures that air passes through:

nose → pharynx → larynx → trachea → bronchus → bronchioles → alveolus

5. Use Figure 8.2: An internal view **(B)** of the human heart on page 269 of the student textbook as a guide for the first sketch. Figure 8.7 on page 274 is a good guide for the second sketch.

6. Urine follows the following path:

kidney → ureters → urinary bladder → urethra

7. Ureters and the urinary bladder are made up of smooth muscles. Peristalsis moves urine within the ureters, and peristaltic contractions cause the urine to enter the bladder. The bladder is also a smooth muscle because it is under involuntary, nervous control.

8. Two possible answers are as follows.

- Movement of muscles generates large amounts of heat, which helps to maintain normal body temperature. Shivering (muscle contractions) helps to produce more heat when you are cold.
- The contraction of skeletal muscles helps to move blood in the veins back to the heart.

9. (a) The three major classes of macronutrients are: carbohydrates, proteins, and lipids (fats). Three similarities that these molecules share are:

- all are classified as organic molecules (carbon, hydrogen, and oxygen atoms)
- they are made of smaller sub-units that must be digested (broken down)
- they supply the energy and the building blocks that are needed to synthesize cellular contents

(b) The enzymes that act on each major category are:

- carbohydrates are digested by carbohydrase enzymes to form simple sugars that move by diffusion into the capillary bed found in the villi
- proteins are digested by protease enzymes to form amino acids that move by diffusion into the capillary bed found in the villi
- lipids are digested by lipases to form fatty acid molecules and glycerol; these enter the cells of the villi and, within these cells, re-form as lipoprotein droplets before entering the lacteals

10. The three main nutrients are important for the following reasons:

- Carbohydrates: the quickest and most readily available source of energy for the body is glucose. Carbohydrates are digested to simple sugars that can be converted to glucose.
- Proteins: are digested to amino acids, which are transported to the tissues. Ordinarily, amino acids are not used as an energy source. Most are incorporated into structural proteins found in muscles, skin, hair, and nails. Others are used to synthesize such proteins as hemoglobin, plasma proteins, enzymes, and hormones.
- Lipids: used for long-term nutrient and energy storage, insulation, cushioning of internal organs, and to form hormones that send messages around the body. Lipids are also the structural components of cell membranes.

11. Inhalation: nervous stimulation results in the contraction of the diaphragm and the intercostal muscles. This causes the diaphragm to lower and the rib cage to move up and out. The result is lower air pressure in the lungs, and air comes rushing in from the environment.

Exhalation: due to a lack of nervous stimulus, the diaphragm relaxes and rises back to its normal, domed shape. At the same time, the intercostal muscles relax and the rib cage moves down and in. Air pressure in the lungs increases and the air moves from the higher pressure in the lungs to the lower pressure in the environment.

12. External respiration refers to the exchange of gases between air in the alveoli and blood in the pulmonary capillaries. Blood entering the pulmonary capillaries has a higher concentration of carbon dioxide than atmospheric air; therefore, most of the carbon dioxide diffuses out of the blood into the lungs. Blood entering the pulmonary capillaries has a lower concentration of oxygen than atmospheric air; therefore, oxygen gas diffuses across the alveoli into the plasma and then into the red blood cells in the lungs.

13. The right and left sides of the heart account for the name "double pump" because the right side of the heart pumps blood to the lungs and the left side of the heart pumps blood to the rest of the body.

14. (a) The following shows the movement of blood, starting from the right atrium:

right atrium → right AV valve → right ventricle → pulmonary semilunar valve → pulmonary artery → lungs → pulmonary vein → left atrium → left AV valve → left ventricle → aortic semilunar valve → aorta → coronary artery → heart muscle capillaries → coronary vein → right atrium

Coronary circulation serves the heart muscle itself.

(b) The coronary pathway differs from the others in that it carries deoxgenated blood. Its circulation supplies metabolic needs of the heart muscle, whereas the systemic circulation supplies the needs of skeletal muscles and internal organs in the rest of the body. The pulmonary circulation (which is included in the

above pathway), carries blood through capillaries in the lungs where it is oxygenated.

15. The many branching arteries in the coronary circulation system provide an efficient method of supplying the heart muscle with blood (nutrients and oxygen) and an efficient way to get rid of metabolic waste products produced by this vital organ. Another significant feature of the coronary arteries is their small size. Because they have such a small diameter, the coronary arteries may become clogged.

16.

Characteristic	Artery	Vein
Structure	■ wall has three layers ■ middle layer is thick, smooth muscle that can contract to regulate blood pressure	■ wall has three layers ■ walls are thinner, have less smooth muscle compared to an artery
Function	■ transports blood away from the heart	■ transports blood towards the heart
Oxygen Composition of Blood Carried	■ most arteries have a relatively high concentration of oxygen (oxygenated blood) ■ the exception is the pulmonary artery, which transports oxygen-poor blood (deoxygenated) to the lungs	■ most veins have a relatively high concentration of carbon dioxide and a low concentration of oxygen (deoxygenated) ■ the exception is the pulmonary vein, which transports oxygen-rich blood to the left atrium
Movement of Blood	■ blood is under pressure and moves in spurts that correspond to the contraction of the ventricles	■ blood is under less pressure ■ valves in veins keep blood flowing towards the heart ■ rely on the contraction of smooth muscles to help push blood toward the heart
Pressure Difference	■ blood is under pressure ■ pressure decreases the further away from the heart	■ blood is under lower pressure ■ rely on the contraction of smooth muscles to help push blood towards the heart

17. Capillaries (a) are only one cell thick, while arteries and veins have layers of tissue; (b) form vast networks, rather than individual hose-like tubes; and (c) are the site of gas and nutrient exchange between the blood and all the cells of the body.

18. Refer to the graph included with question 23, page 303. As blood flows from arteries into capillary networks, the diameter of the vessels decreases, but the total cross-sectional area of the vessels increases. This increases the frictional resistance between the blood cells and the walls of the vessels, thereby decreasing blood pressure and the speed at which it flows.

19. The top layer would be the liquid portion of the blood—the plasma. Plasma is mainly water. You would find plasma proteins, salts, gases, nutrients, and nitrogenous waste products in this component of the blood.

The middle layer would contain the white blood cells, while the lowest layer contains the red blood cells. White blood cells fight infection and are part of the immune system.

Red blood cells do not have a nucleus. Hemoglobin, the oxygen-carrying pigment, is found in the red blood cells. Red blood cells transport oxygen and help to transport carbon dioxide.

20. Renal artery → glomerulus → capsule (Bowman's) → proximal tubule → loop of the nephron (or Henle) → distal tubule → collecting duct → renal pelvis

21. ■ Filtration: water, salts, nutrient molecules, and waste molecules move under pressure from the glomerulus to the inside of the capsule. These small molecules are called glomerular filtrate. Large molecules normally remain in the blood.

■ Reabsorption: nutrient and salt molecules are actively reabsorbed from the proximal tubule into the capillary network surrounding the nephron. Water flows passively.

■ Secretion: certain molecules are actively secreted from the capillary network into the distal tubule.

22. (a)

Filtrate Components that are Reabsorbed at the Proximal Tubule	Filtrate Components that are not Reabsorbed at the Proximal Tubule
most water	some water
nutrients	much nitrogenous waste
necessary salts	excess salts

(b) Molecules that are not reabsorbed become part of the urine and are removed from the body.

23. (a) Water: approximately 180 L of water is filtered every day. Normally, 99% of the water is reabsorbed from the filtrate as it passes through the remainder of the tubule.

(b) Ions (salts): the kidneys regulate salt balance in blood by controlling the excretion and reabsorption of various ions. For example, sodium (Na^+) is an important ion in plasma that must be regulated. Approximately 630 g of salts are filtered each day. Only 3.2 g are excreted in the urine. Over 99% of the sodium ions are actively reabsorbed in the proximal and distal tubules.

(c) pH: the bicarbonate (HCO_3^-) buffer system and the process of breathing work together to maintain the pH of the blood. Only the kidneys, however, can rid the body of a wide range of acidic and basic substances. The kidneys are slower acting than the buffer/breathing mechanism, but they have a more powerful effect on pH. The kidneys reabsorb bicarbonate ions and excrete hydrogen ions as needed to maintain the normal pH of the blood.

24. The steps in the sliding filament model are as follows.

- neuromuscular impulses trigger the release of calcium from the sarcoplasmic reticulum
- the calcium causes the troponin protein that is blocking the actin attachment sites to bind with tropomyosin and make the actin attachment sites available to the myosin heads
- the heads of the myosin myofilament bend backward and inward and attach to the pairs of actin myofilaments enveloping it
- pairs of actin myofilaments are pulled along with the myosin heads as they flex, dragging the Z lines of the actin myofilaments in the direction of the flex, towards the myosin core
- as one after another myosin head flexes, the myosin "walks" along the pairs of actin myofilaments and the Z lines move closer together as the muscle fibre contracts

25. Enzymes are specific. Each kind can cleave (or digest) only a certain type of molecule. Enzymes do not have the right molecular shape to attack themselves. As well, many enzymes are secreted in an inactive form and are only activated when they enter a region of the digestive tract with a specific pH.

26. (a) The first curve (on the left) is the one that would take place in the human. This enzyme is active at normal body temperature (37 °C). The enzyme of the right is most active at a temperature that would be fatal to humans!

(b) Two other factors that influence enzyme activity are pH and enzyme concentration. All enzymes are only active in a very narrow range of pH values. A higher concentration of enzyme will speed up the rate of the chemical reaction.

27. (a) (Interpretation 1)

- Upon release, calcium ions bind to tropinin, exposing the myosin binding sites.
- ATP is hydolyzed (ADP + phosphate) when the myosin head is unattached.
- ADP + P are bound to myosin as the myosin head attaches to the actin myofilament.
- ADP + P release causes the myosin head to change position and the actin myofilament to move.
- Binding of another ATP causes the myosin head to return to its resting position.

(Interpretation 2)

ATP produced previous to strenuous exercise only lasts a few seconds, and then muscles acquire new ATP in three ways: creatine phosphate breakdown, fermentation, and cellular respiration.

- Creatine phosphate provides enough energy for 8 seconds of intense activity, and then it is spent. Creatine phosphate is rebuilt when a muscle is resting by transferring a phosphate group from ATP to creatine.
- Fermentation also supplies ATP without consuming oxygen. During fermentation, glucose is broken down to lactate (lactic acid). The energy released by this reaction is used to attach a phosphate group to ADP to make ATP.
- Cellular respiration occurring in the mitochondria usually provides most of the muscle's ATP. The breakdown of glucose to carbon dioxide and water releases energy to attach a phosphate group to ADP to make ATP. Students may remember that the energy in one glucose molecule is sufficient to make 36 ATP.

(b) The different sources of acquiring ATP are interrelated because:

- all are called into action during strenuous exercise that last more than just a few seconds;
- all involve the chemical breakdown of high energy compounds; and

- the energy released from these high energy compounds is used to bond a phosphate group (P) to ADP to form ATP.

28. The following are examples of one function of blood in relation to each body system listed below.

(a) Digestive system: blood in capillaries in each villus of the small intestine absorbs nutrients (glucose and amino acids) and transport these to the tissues.

(b) Respiratory system: capillaries surround the alveoli and are the site of gas exchange. Carbon dioxide diffuses from the blood into the alveoli, while oxygen diffuses from the alveoli into the blood.

(c) Excretory system: blood transports nitrogenous (metabolic) wastes to the kidneys. The kidneys filter the blood, reabsorb water/nutrients, and excrete the wastes. The kidneys also help to maintain the pH balance of the blood by actively secreting H^+ ions and absorbing HCO_3^- ions.

(d) Muscular system: blood transports oxygen (red blood cells) and glucose to the muscle cells. Glucose and oxygen combine in the mitochondria of muscle cells to produce ATP (cellular respiration). Blood is also responsible for transporting waste products [carbon dioxide, lactate (lactic acid), and metabolic wastes] away from the muscles to the excretory system.

(e) Immune system: white blood cells fight infection and play a role in the development of immunity (the ability to resist disease).

29. Some students might answer quantitatively by constructing a comparison chart such as the one below. Other students might answer qualitatively by describing how the composition of filtrate and urine differ from each other and from plasma. For example, plasma and filtrate carry equal amounts of glucose; plasma contains all of the blood proteins; all three fluids carry comparable amounts of sodium ions; and most of nitrogenous wastes to be removed from the body are in the urine, with negligible amounts in the plasma and filtrate.

Component	Plasma (g/L)	Glomerular Filtrate (g/L)	Urine (g/L)
glucose	1.0	1.0	0.0
protein	44.0	0.0	0.0
sodium ions	3.0	3.0	3.8
nitrogenous wastes	0.3	0.3	31.3

30. The concentration gradient established by the difference in solution concentration (some students might say, more precisely, osmostic pressure) between the interior of the tubule and the interstitial fluid surrounding it allows for the active transport of sodium ions and the passive transport of potassium and chloride ions, as well as the diffusion of water, between these two regions.

31. The interstitial fluid does not become diluted through water reabsorption because sodium ions are constantly being reabsorbed from the tubule and the collecting duct at the same time that water is being reabsorbed.

32. The blood's role in absorbing heat and carrying it to the skin to be dissipated helps the body maintain a constant internal temperature (homeostasis). Blood vessels near the surface of the skin can either dilate (vasodilation) to increase heat loss or constrict (vasoconstriction) to preserve body heat, but no materials are exchanged.

33. Fast-twitch fibres provide explosions of energy. Fast-twitch fibres are rich in glycogen a good source of gluese, but they have fewer mitochondria, little or no myoglobin, and fewer blood vessels than slow-twitch fibres. Fast-twitch fibres can develop maximum tension more rapidly than slow-twitch fibres, and the maximum tension is greater; however, their dependence on anaerobic energy leaves them vulnerable to an accumulation of lactate (lactic acid) that causes them to fatigue quickly.

34. The churning action of the stomach mixes the food with gastric juice and physically breaks the food down.

Physical digestion increases the surface area of the food, which increases the efficiency of the enzymes responsible for chemical digestion.

35. (a) Physical processing takes place in the mouth (teeth and tongue grinding the food), the stomach (muscle contractions squeeze food in between the folds of the stomach lining), and the small intestine (bile from the gall bladder enters the duodenum and emulsifies fat).

Chemical digestion takes place in the mouth (salivary amylase begins the digestion of starch), the stomach (pepsin begins the digestion of proteins), and in the small intestine (most chemical digestion takes place in the small intestine).

(b) Physical digestion is required to break large pieces of food into small pieces. This increases the surface area for chemical digestion. Chemical digestion involves the use of enzymes to break down (hydrolyze) macromolecules to small organic molecules that can be absorbed. Each enzyme has a particular job to do.

36. - Carbohydrates are digested by a number of enzymes that are collectively called carbohydrases. The end products of carbohydrate digestion are simple sugars (monosaccharides). Simple sugars, such as glucose, are absorbed into the cells of the intestinal villi by active transport.
- Proteins are digested by a number of enzymes that are collectively called proteases. The end products of protein digestion are amino acids. Amino acids are absorbed into the villi in the small intestine by active transport.

- Lipids (fats) are digested by a number of enzymes that are collectively called lipases. The end products of lipid digestion are fatty acids and glycerol. These end products are absorbed into the cells of the villi by simple diffusion.

37. Muscle fibre, which is responsible for muscle contractions, is made up of the following major parts:

myoglobin	stores oxygen for use during muscle contractions
sarcolemma	surrounds the muscle fibre and regulates the entry and exit of materials
sarcoplasm cytoplasm	the site of metabolic processes for normal cell activities; contains myoglobin and glycogen (which stores energy for muscle contractions)
sarcoplasmic reticulum	stores calcium ions needed for muscle contractions
Myofibrils	contain myofilaments that are responsible for muscle contractions
thick filament	binds to actin and causes muscle contractions
thin filament	binds to myosin and causes muscle contractions

38. The lymphatic system consists of a network of lymphatic vessels, associated glands (nodes), and fluid called lymph.

Similarities between the lymphatic system and the cardiovascular system include:

- both circulate fluids
- both have capillaries to absorb materials;
- lymph vessels and veins have valves in them to keep fluid moving in one direction
- lymph vessels and veins both rely on the contraction of skeletal muscles to move fluids
- both systems produce cells that are responsible for fighting off pathogens

The key difference is that blood arrives at and leaves the heart in a continuous circuit of cardiovascular vessels, while lymph forms in closed-ended tubes in capillary beds. Lymph is mixed back into the general blood circulation after it is delivered to the heart through ducts that empty into large veins near the heart.

39. Lymph forms from interstitial fluid that has been collected and absorbed by lymphatic capillaries.

40. Midway along the capillary, solutes diffuse out of the capillary and wastes diffuse into the capillary. Substances that leave a capillary contribute to interstitial fluid (also called tissue fluid, the fluid between the body's cells). Tissue fluid tends to contain all the components of plasma, except lesser amounts of protein. The lymphatic capillaries always collect excess tissue fluid, which circulate it as lymph that is eventually returned to the systemic venous blood when the major lymphatic vessels enter the veins in the shoulder region.

41. (a) Lymph capillaries are closed-ended tubes that collect interstitial fluid (that is, lymph) for eventual transport to the circulatory system, while blood capillaries are open-ended tubes that connect the arterial circulatory system with the venous circulatory system.

(b) Lymph vessels differ from veins of the circulatory system in that the walls of lymph vessels are thinner and the interior space is, therefore, more voluminous.

(c) Lymph is essential interstitial fluid that has been collected and channeled back to the circulatory system. Lymph also carries white blood cells, so, unlike interstitial fluid, it functions as part of the body's defence system.

42. The pathway of lymph, in general terms, can be summarized as follows.

- Lymph capillaries branch and interconnect freely and extend into almost all regions of the body except bone marrow, the central nervous system, and tissues such as the epidermis.
- Lymph capillaries join to form larger vessels called lymph veins.
- At certain locations, lymph veins enter lymph nodes.
- Lymphatic vessels from all over the body, except the upper right quadrant, drain into the thoracic duct. This vessel delivers the lymph into the base of the left subclavian vein in the shoulder area. In this way, lymph is continuously emptied into the blood where it mixes with the plasma.

43. T cells are lymphocytes (cells of the lymphatic system) that mature in the thymus gland (near the heart). There are several types of T cells. The key ones (and their specific functions) are:

- helper T cells, which secrete chemicals that activate macrophages, B cells, and other T cells when a foreign antigen is detected
- killer T cells, which bind with infected cells and destroy them by puncturing a hole in their cell membranes
- suppressor T cells, which slow/suppress the cellular immunity process to make sure normal tissue/healthy cells are not destroyed during a defence by the immune response
- memory T cells, which remain in the bloodstream after a successful encounter with a foreign antigen, in order to trigger a faster response the next time the same foreign antigen appears

44. Memory cells in both B cell and T cell lymphocyte defenders are created after the first successful defence of the body against foreign antigens. Memory cells remain in the bloodstream, ready to detect the foreign antigen and trigger a successful immune response the next time it invades.

45. The following is a summary of the body's immune response, triggered by the entry of pathogens at the site of an infection.

- Non-phagocytic leucocytes arrive at the site of the infection. These cells release histamine, which causes blood vessels at the site to dilate and become more permeable to fluid and leucocytes. The increased blood flow and accumulation of fluid makes the area swollen and hot.
- Phagocytic macrophages engulf and destroy invading bacteria.
- The antigens from the pathogen protrude from the cell membrane of the macrophage.
- Receptor sites on the surface of the helper T cells bind to the antigens on the surface of the macrophage. This union triggers the release of chemical messengers from both cells. The messengers cause T cells to multiply. Some of these T cells destroy infected tissue cells, breaking the reproductive cycle of the pathogen.
- The antibodies on B cells bind to the antigens, contributing to the destruction of the pathogens.
- T cells bind to the B cell antibody-antigen complex. This union of T and B cells activates the B cell, causing it to enlarge and divide, which produces plasma cells and memory cells.
- The plasma cells produce antibodies and release them into the bloodstream. Antibodies and memory B cells remain in the blood, ready to fight a new infection by the same pathogen.

Answers to Applying Concepts Questions

46. (a) The small intestine has a large surface area due to the presence of villi and microvilli in the intestinal lining.

(b) The small intestine has a large surface area to increase the rate of absorption of nutrients needed by the body.

47. Her blood potassium level will continue to be about 4 mmol/L because homeostatic mechanisms operate to absorb and maintain it at that level. The excess potassium she is ingesting will be excreted.

48. Since the identity of Substance X is not given, it is not reasonable to infer it should have been filtered (that is, removed) prior to passing from the glomerulus to the Bowman's capsule. If Substance X is something that should not pass into the nephron (e.g., glucose or red blood cells), then its presence in the urine would signal a problem. If Substance X is something that should be a component of urine (e.g., urea, sodium ions), then its presence would suggest proper nephron/kidney function (at least with respect to the excretion of these particular substances). Students' reasoning is more important for assessment here than the correctness of their answers.

49. Antony van Leeuwenhoek was observing lymph vessels containing lymph.

50. There would be a minimal effect because the pancreas also releases amylase that would digest the starch into maltose in the small intestine.

51. Without bile salts, fat digestion would be significantly reduced. Without bile, emulsification would not occur. Enzymes could only hydrolyze the lipid molecules on the outside of the fat globule.

52. Myosin can't bond to actin when a muscle is relaxed because the myosin binding sites on the actin are blocked by the troponin-tropomyosin complex. Calcium is needed to rearrange the complex so that the myosin binding sites become uncovered.

Answers to Making Connections Questions

53. Possible student inferences are outlined.

- Esophagus: since no digestion takes place in this organ, food spends very little time in it; peristalsis may delay the passage of larger boluses slightly, accounting for the 10 s figure
- Stomach: food needs time for physical digestion via churning as well as the chemical digestion of proteins
- Small intestine: the digestion of macromolecules and the absorption of nutrients requires a fair amount of time
- Large intestine: the absorption of water and salts and the anaerobic breakdown of solid matter by intestinal bacteria require a significant amount of time
- Rectum: the storage process may time a great amount of time before there is sufficient quantity of feces to stimulate the elimination process

54. Energy from aerobic respiration of skeletal muscle fibres that does not go into contraction is released to the body as heat. (Some students may also suggest that waste heat through inefficient conversion of chemical energy to kinetic energy also contributes to body heat.)

55. The breast muscle (meat) of a bird is made up of fast-twitch fibres that are used for the rapid, powerful contractions needed for flight. They probably are of intermediate type, as they can sustain long periods of repeated contractions without fatiguing.

56. The student in experiment B would have the higher respiration rate because carbon dioxide levels would have increased significantly, stimulating a higher breathing rate, while the breath was held.

57. (a) In order to answer this question, students need to understand the six steps in the contraction of a muscle. These steps are:

1. The influx of calcium ions from the sarcoplasmic reticulum triggers the exposure of binding sites on actin.
2. ATP is hydrolyzed when myosin head is unattached.
3. ADP + P are bound to myosin as myosin head attaches to actin.
4. ADP + P release causes myosin head to change position and the actin filament to move.
5. Binding of ATP causes myosin head to return to resting position.
6. Calcium ions are actively transported back into the sarcoplasmic reticulum, and the muscle relaxes.

If a muscle is in rigor mortis, the membranes of muscle cells become more permeable to calcium ions; however, the muscle will quickly run out of ATP. Muscles need ATP in order to release from a contracted state (it is used to pump the calcium out of the cells so the fibres can unlatch from each other). ATP reserves are quickly exhausted from the muscle contraction and other cellular processes; this means that the actin and myosin myofilaments will remain linked until the muscles themselves start to decompose.

So, if a muscle has a continual supply of ATP, students could predict that the calcium ions would be pumped back into the sarcoplasmic reticulum and the muscle would relax.

(b) If the sarcoplasmic reticulum (endoplasmic reticulum in muscle cells) wasn't intact, students could predict that this muscle could stay contracted longer. The reason that the muscle would stay contracted is that in a living muscle, the membranes of the sarcoplasmic reticulum contain active transport proteins that pump calcium ions back into the sarcoplasmic reticulum. If this membrane is not intact, then the calcium ions cannot be pumped out and the actin, and myosin myofilaments will remain linked until the muscles themselves start to decompose

58. As exercise intensity is increased:

- In the circulatory system, heart rate increases and blood vessels dilate to provide more oxygen and glucose to body cells and remove wastes (carbon dioxide) that are being produced. Blood vessels also dilate to increase loss of heat.
- In the respiratory system, breathing rate increases to increase the rate of gas exchange, providing more oxygen and eliminating carbon dioxide.
- The digestive system decreases activity.
- Increased blood pressure leads to increased glomerular filtration in the kidney and increased urine production. Since the body will be warm, some of the water will be lost as sweat, so increased urine production may not be as noticeable.

59. The decreased blood pressure is due to loss of fluids while vomiting. If there aren't fluids to be absorbed, blood volume and blood pressure will drop. The heart rate is elevated to try to increase blood pressure.

60. The head injury may have affected the person's ability to produce or release ADH. Without ADH, the nephrons are not reabsorbing water into the blood, and the person is thirsty.

61. The risks and benefits of Aspirin™ use are:

Risks:

- Gastrointestinal bleeding, which could lead to anemia.
- Children or teens with risk factors should not take Aspirin™, due to the risk of Reye's Syndrome.
- Some people are allergic to Aspirin™.
- Birth defects have been found in babies of women who took high doses of Aspirin™ during the last trimester of their pregnancies.
- Liver damage or stomach bleeding might occur in people who drink three or more glasses of alcohol per day.
- Since Aspirin™ thins the blood, it wouldn't be suitable for people with blood clotting disorders.

Benefits:

- It reduces headache pain and inflammation due to injury or arthritis.
- It reduces the risk of cardiovascular disease (heart attack and stroke).
- It is associated with the prevention of breast, stomach, esophageal, ovarian and prostate cancer, and leukemia.
- It reduces the risk of gastrointestinal tumours forming.

62. Students are to select two body systems from the following table for their answer.

Body System	Possible Disorders (students are to identify one per system)	Description of how Technology is used to Address the Disorder
Excretory System	Kidney Failure	Dialysis Machine: very successful. Keeps patients alive until a kidney comes available. Kidney transplant and the use of the immunosuppressant Cyclosporin–Cyclosporin has significantly increased the success of transplants.
	Kidney Stones	Ultrasound: used to break kidney stones into fragments that are eliminated with the urine.
Digestive System	Stomach Ulcers, Crohn's Disease, Colitis, Colorectal Cancer, Polyps	Endoscopes: successfully used to look at the lining of either the upper or lower digestive tract. They allow biopsies to be taken, which allows accurate diagnosis of the disorder. X-rays and CAT (CT) Scans: also successful diagnostic technologies.
Respiratory System	Emphysema, Asthma, Lung Cancer	Spirometers: used to measure lung capacities. CAT (CT) Scans and X-rays: can detect lung abnormalities.
Musculoskeletal System	Bone fractures, Ligament and Tendon Tears, Cartilage Damage	X-rays, MRIs, and CAT (CT) Scans: successfully detect the location and severity of the fracture or tear. Arthroscopic Surgery: successfully used for joint injuries.
	Severe Arthritis	Artificial Joints: can replace hips, elbows, knees and wrists, providing patients with mobility and freedom from pain Medications: can reduce the pain.
Circulatory System	Heart Arrhythmias	ECGs: successfully detect abnormalities in the heart cycle. Pacemakers can be inserted to normalize the electrical activity in the heart.
	Hypertension	Sphygmomanometers: used by physicians and can be used at home to help people monitor their blood pressure
	Heart Stoppage	Defibrillators: can sometimes shock the heart into beating again if applied at the right time in the cycle

63. (a) Nitrogenous wastes are removed from the blood by simple diffusion. The concentration of urea and uric acid is higher in the patient's blood than in the dialyzing fluid, so diffusion through the dialysis membrane into the dialyzing fluid occurs. Fresh fluid washes over the dialysis membranes continuously, removing the nitrogenous wastes as they diffuse out of the blood.

(b) In a healthy kidney, most nutrient molecules are returned to the blood in the proximal tubule, with the remainder being reabsorbed in the distal tubule. During dialysis, nutrients are not replaced since they are never removed from the blood. However, the dialyzing fluid is formulated to contain higher concentrations of certain nutrients than are found in the blood, so during dialysis, these nutrients enter the blood by simple diffusion, adding to nutrients already present.