Table of Contents

UNIT 1

Energy and Matter Exchange in the Biosphere

Teaching Unit 1: Energy and Matter Exchange in the Biosphere

Student Textbook pages 2-71
(20% of the course time; approximately 25 hours.)

Curriculum Fit

(see the Curriculum Correlation for full listing)
Background: This unit builds on concepts from *Science 7,* Interactions and Ecosystems; *Science 9,* Biological Diversity; and *Science 10,* Energy Flow in Global Ecosystems. It provides students with a basis for the study of energy transformations in Unit 3, Photosynthesis and Cell Respiration, as well as the flow of energy through organisms in Unit 4, Human Systems.

General Outcomes

Students will

- explain the constant transfer of energy through the biosphere and its ecosystems
- explain the cycling of matter through the biosphere
- describe energy and matter exchange in the biosphere as an open system and explain how this maintains equilibrium

Contents

Chapter 1: Energy Transfer in the Biosphere
Chapter 2: Cycles of Matter

Content Summary

The four themes featured in Biology 20 are energy, equilibrium, matter, and systems. All four are introduced in Unit 1.

There is a constant flow of energy into, through, and out of ecosystems. Energy enters the ecosystem as solar or light energy. It is converted into chemical or food energy through the process of photosynthesis and is transferred through the ecosystem in this form. Energy leaves the ecosystem as unusable heat energy, generated from the production and use of ATP.

Transfer of chemical energy through ecosystems can be organized into and depicted as food chains, food webs, and food pyramids. Organisms are placed in feeding (trophic) levels based on how they obtain their food. Three general categories of trophic levels are producers, consumers, and decomposers.

Unlike energy, matter can be cycled within an ecosystem. Matter cycles through biogeochemical cycles that have both living and non-living components. Water cycles through the hydrologic cycle. Human activities, such as excessive combustion of fossil fuels, can disrupt the equilibrium of these cycles.

In Chapter 1, students trace the flow of matter and energy through ecosystems, and explore some of the complexities of these transfers. In the first section, students will explore the Sun's role as the main source of energy for life (chemosynthesis is also considered), use food chains and webs to analyze the transfer of this energy, and learn how organisms can be grouped according to how they obtain energy (trophic structure). Students further explore how producers, such as plants, store solar energy, and how that energy is transferred through the food chain. After a brief overview of the laws of thermodynamics, students will explore attempts to quantify this energy and show how it moves through ecosystems. Finally, students will examine the dynamic nature of energy and matter in systems, and the ways in which scientists study large-scale changes in systems.

In Chapter 2, students follow the movement of matter through the biosphere. This movement is organized into the study of biogeochemical cycles, which trace the movement of biologically important molecules from living organisms into the abiotic environment and back into other life forms. In the process, molecules are broken up, their components are re-formed into other molecules, and then broken up again by a series of chemical and physical processes. Students begin with the familiar hydrologic cycle and review the properties of water that make it both unique and essential to life. Next, the carbon, oxygen, nitrogen, sulfur, and phosphorus biogeochemical cycles are traced through the biosphere. To close, students examine the relationship between energy, matter, and productivity within ecosystems, review changes in the past composition of Earth's atmosphere, and examine the impacts current human activity has upon a delicately balanced biosphere.

Activities and Target Skills

Activity	Target Skills
Chapter 1: Energy Transfer in the Biosphere	
Launch Lab: Considering Connections, p. 7	■ Considering the links among all organisms on Earth and their impact on each other
Investigation 1.A: Storing Solar Energy in Plants, pp. 10-11	■ Performing an experiment to investigate variables related to the storage of solar energy in plants. ■ Ensuring the safe and responsible handling of equipment and materials, both personally and with regard to the welfare of others in the class.
Investigation 1.B: Weave Your Own Food Web, pp. 22–23	■ Relating personal energy consumption to feeding relationships and energy transfer through an ecosystem ■ Creating and analyzing a food web based on a human diet ■ Calculating the percentage of solar energy assimilated by a human diet
Investigation 1.C: Ecology of an Endangered Prairie Ecosystem, p. 26	■ Working co-operatively to research, synthesize, and analyze information about the ecology and trophic levels of a threatened species and an endangered ecosystem ■ Drawing a food web to depict feeding relationships between the threatened species and other species ■ Analyzing information to assess how ecological variables may affect the threatened species and its ecosystem ■ Presenting the result of an investigation to a group
Thought Lab 1.1: Analyzing Energy Transfers, p. 20	■ Analyzing data on energy transfer from producers to consumers
Thought Lab 1.2: Energy Fluctuation in an Ecosystem, p. 25	■ Analyzing food source data from an aquatic community to understand variables that may be causing a change in population size of a certain species
Chapter 2: Cycles of Matter	
Launch Lab: Whose Planet?, p. 33	■ Considering ethical and possible legal implications of recognizing the connectedness of all forms of matter
Investigation 2.A: Societal Uses of Water, p. 41	■ Analyzing data to determine water use by different sectors of society ■ Presenting the results of this analysis to fellow students ■ Stating conclusions based on this analysis
Investigation 2.B: Carbon Dioxide Production in Plants and Animals, pp. 44-45	■ Designing an investigation to compare carbon dioxide production by a plant and an animal ■ Gathering data to measure the rate of carbon dioxide production by a plant ■ Stating a conclusion based on the analysis of collected and provided data
Investigation 2.C: What's in the Water?, p. 51	■ Measuring and recording data on pH and water quality parameters in local water samples ■ Comparing data from different sources to determine the impact of human activities on water quality ■ Stating a conclusion

Activity	Target Skills
Investigation 2.D: Biosphere in a Bottle, p.57	■ Designing an investigation to evaluate carbon dioxide, water, and oxygen exchange in a closed biological system ■ Gathering and recording data on ecosystem variables to observe and learn how ecosystems function.
Thought Lab 2.1: Water Gains and Losses, p. 38	■ Analyzing data on water consumption and loss in a human and a small animal ■ Stating conclusions based on the analysis of data
Thought Lab 2.2: Carbon, Sulfur, and Iron, p. 48	■ Explaining how coal mining can damage to the environment and disrupt biogeochemical cycles
Thought Lab 2.3: Too Much of a Good Thing, p. 54	■ Analyzing information to investigate the impact of increasing ultraviolet radiation on organisms ■ Stating conclusions based on the analysis of information
Thought Lab 2.4: Evaluating Water Treatments, p. 58	■ Analyzing data on water quality to evaluate the effectiveness of using grasses to treat agricultural run-off
Thought Lab 2.5: Design a Self-Sustaining Mars Colony, p. 60	■ Evaluating the technological requirements for a self-sustaining, Earth-like system ■ Evaluating the potential benefits to humanity and the possible environmental consequences of implementing such technology

Conceptual Challenges

- Students may be confused to learn that Earth is both an open (with regards to energy) and closed (with regards to matter) system. Review with students how energy enters the biosphere as sunlight and leaves as heat that is radiated back in to space, making Earth an open system with regards to energy. Conversely, no matter ever enters or leaves Earth, other than the occasional meteor and satellite, making Earth a closed system with respect to matter.
- Producers (green plants, algae, and some bacteria) are able to harvest 1-2% of available solar energy. Some students find it difficult to conceptualize that these autotrophs use the energy in sunlight, along with inorganic carbon dioxide and water, to create organic molecules that store chemical energy within their bonds. This energy can then be passed further along the food chain. Reassure students who may be struggling with this concept that they will learn about photosynthesis in greater depth in Unit 3. Encourage curious students to read ahead to answer their own questions.
- The rule of 10 can be challenging to some students. As food energy is passed through trophic levels in an ecosystem, only about 10% of that energy is incorporated into the tissues at each trophic level and is available to the next trophic level. As a result, food chains are relatively short, usually consisting of 3 or 4 trophic levels. Use **BLM 1.2.6 (OH) Grizzly Bear: Energy Transfer** to help students determine the fate of 200 kJ of energy from a fish as it is assimilated by a grizzly bear. What is the fate of the 100 kJ of energy that passes out through the bear's feces? (Answer: They go to decomposers) How are the 94 kJ of energy labelled "cellular respiration and heat" used by the bear? (Answer: They provide the bear with the energy it requires to hunt, maintain its body heat, digest its meal, reproduce, and so forth.) How much energy from the meal is passed to the next trophic level—a hunter and his or her family? (Answer: 6 kJ or 3%) Remind students who point out that this is 3%, not 10%, that the rule of 10 is an approximation.
- The first and second laws of thermodynamics can sometimes be tricky for students to grasp. Some students may have trouble with the concept that energy that is "lost" isn't really lost, it is only unavailable to the next trophic level. Using **BLM 1.1.8 (OH) Energy Transfer in the Biosphere,** follow the path of energy with students as it moves through the biosphere. With the help of guiding questions, students should be able to determine that Earth or the atmosphere reabsorbs energy that is "lost," or it is radiated into space.
- Chemosynthesis can also be a challenging concept for students. Using **BLM 1.1.6 (OH) The Chemical Reactions for Chemosynthesis and Photosynthesis,** review the basic chemical reactions carried out in both processes with students who find chemosynthesis difficult to grasp. Compare the chemosynthetic reaction to the photosynthetic one, asking students to identify the differences (photosynthesis uses sunlight as a source of energy while chemosynthesis uses the energy stored in the

chemical bonds of H_2S; photosynthesis produces oxygen while chemosynthesis produces sulfuric acid) and commonalities (both reactions use carbon dioxide and water as reactants; both create organic molecules) between the two equations.

- Even though students will realize that ice floats on water, they may find it counterintuitive that water is most dense at 4 °C. A simple demonstration of melting a coloured ice cube in room temperature water (the coloured water will initially sink as it warms) may help bring this concept home. Use **BLM 2.1.4 (OH) Crystalline Structures of Solid and Liquid Water** to illustrate the different structures water molecules adopt in solid and liquid states as a result of their polarity.

Using the Unit 1 Opener and the Unit 1 Preparation Feature

The Unit Opener has been designed to establish a social, technical, and environmental context for the science in the unit. Use the Unit Opener to introduce the general unit topics within that context, and ask the Focussing Questions to guide students' thinking.

- Have the students read the Unit Opener and then write a short paragraph explaining how the International Space Station is like the planet Earth and how it is different. When the students have finished, discuss their ideas with the class as a whole.
- Suggest several examples of systems and discuss with students whether they think these systems are open or closed. Examples could include an aquarium (open to matter and energy), Biosphere 2 (open to energy, closed to matter), the solar system, (open to matter and energy), and the universe (debatable). Challenge students to try to identify a system that is closed with respect to both matter and energy.

The Unit Preparation feature has been included in order to ensure that students are familiar with the science from previous courses that relates specifically to the material they are about to study. Encourage students to take the Unit Prequiz (found at **www.albertabiology.ca**, Online Learning Centre, Student Edition) to gauge their recall, noting that if they are familiar with the background science, their experience with this unit will be much easier. The Unit 1 Preparation feature is a brief review of ecology and the biosphere.

UNIT 1: COURSE MATERIALS

Chapter, Section	Item Description	Suggested Quantity	Text Activity
Chapters 1, 2	safety goggles	40 pairs	Investigations: 1.A, 2.B (depending upon experimental design), 2.C
Chapters 1, 2	nonlatex disposable gloves	40 pairs x 3 investigations	Investigations; 1.A, 2.B (depending upon experimental design), 2.C
Chapters 1, 2	aprons	40	Investigations: 1.A, 2.B (depending upon experimental design), 2.C
Chapter 1, Section 1.1	small test tube hot plate stopper or stirring rod tweezers (or forceps) water 4 Petri dishes 5 g of cornstarch tongs or oven mitts 400 mL beaker of boiling water 150 mL beaker with 50 mL of hot ethanol in a hot water bath Lugol's iodine solution (in a dropper or spray bottle) plants with solid green leaves such as geranium (*Pelargonium*) or ivy (*Hedera*)—one plant grown for 4 days exposed to sunlight or under grow lights, and one plant placed in the dark for 4 days plants with variegated leaves such as *Coleus*, variegated geranium (*Pelargonium*), or spider plant (*Chlorophytum*)—one plant grown for 4 days exposed to sunlight or under grow lights, and one plant placed in the dark for 4 days	1 per student 1 per student 1 per student 1 per student per student per student 1 pair per student per student per student few drops per student 4 of each plant per classroom 4 of each plant per classroom	Investigation 1.A: Storing Solar Energy in Plants, pp. 10–11
Chapter 2, Section 2.2	as per students' experimental design		Investigation 2.B: Carbon Dioxide Production in Plants and Animals, p. 45
Chapter 2, Section 2.2	Probeware or colourimetric assay kit for sulfate (or iron), nitrate, phosphate, and pH test tubes (10 mL) pipette bulb sample jars and lids pipettes (2 mL) metal scoopula water sample from each area	1 complete kit per group 8–10 per group 1 per group 2 per group 2 per group 1 per group 1 per group	Investigation 2.C: What's in the Water, p. 51
Chapter 2, Section 2.3	2 L (or larger) clear bottle with lid Parafilm™ or sealing wax thermometer (alcohol or digital) 10 mL test tube bottom sediment pond or river water small aquatic plants (such as floating duckweed and various submerged plants) small aquatic invertebrates (such as snails, flatworms, shrimps, and insects)	1 per group 1 per group 1 per group 250 mL per group (approx.) 1.5 L per group (approx.) 4 per group (max.)	Investigation 2.D: Biosphere in a Bottle, p. 57

CHAPTER 1 ENERGY TRANSFER IN THE BIOSPHERE

Curriculum Correlation

General Outcome 1: Students will explain the constant flow of energy through the biosphere and ecosystems.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
20–A1.1k explain, in general terms, the one-way flow of energy through the biosphere and how stored biological energy in the biosphere, as a system, is eventually "lost" as heat, e.g., **photosynthesis/chemosynthesis* **cellular respiration (muscle-heat generation, decomposition* **energy transfer by conduction, radiation and convection*	Section 1.1: How Energy Enters the Biosphere, pp. 8-14	Q questions 1-4, p. 9 Q questions 5, 6, p. 12; 11, p. 14 Section 1.1 Review: 1-4, 6, 8, p. 15 Chapter 1 Review: 3, 10, 13, p. 30 Unit 1 Review: 1, p. 68 Chapter 1 Test
20–A1.2k explain how biological energy in the biosphere can be perceived as a balance between both photosynthetic and chemosynthetic, and cellular respiratory activities, i.e., *energy flow in photosynthetic environments *energy flow in deep sea vent (chemosynthetic) ecosystems and other extreme environments	Section 1.1: Energy for Life in the Deep Ocean, pp. 12-13 A Closer Look at Consumers, p. 13	Q questions 8-10, p. 13 Section 1.1 Review: 5, p. 15 Section 1.2 Review: 4, 9, p. 27 Chapter 1 Review: 2, 8, p. 30; 21, p. 31 Unit 1 Review: 3, 7(a), p. 68; 32, p. 70 Chapter 1 Test
20–A1.3k explain the structure of ecosystem trophic levels, using models such as food chains and food webs	Trophic Levels Describe Feeding Relationships in Ecosystems, p. 16 Food Chains and Food Webs, pp. 16-18 Investigation 1.B: Weave Your Own Food Web, pp. 22-23 Thought Lab 1.2: Energy Fluctuation in an Ecosystem, p. 25 Investigation 1.C: Ecology of an Endangered Prairie Ecosystem, p. 26	Q questions 12-14, p. 16; 15, 16, p. 18 Try This: Comparing Food Webs, p. 19 Investigation 1.B: Procedure 4, 7; Analysis 4, pp. 22-23 Thought Lab 1.2: Analysis 4, p. 25 Investigation 1.C: Analysis 2, p. 26 Section 1.2 Review: 1, 2, 8, p. 27 Chapter 1 Review: 9, 10, p. 30; 20, p. 31 Unit 1 Review: 2, 7(b), p. 68 Chapter 1 Test
20–A1.4k explain, quantitatively, the energy and matter exchange in aquatic and terrestrial ecosystems, using models such as pyramids of energy, biomass and numbers.	Modelling Feeding Relationships through Ecological Pyramids, pp. 18-24 Thought Lab 1.1: Analyzing Energy Transfers, p. 20	Q question 17, p. 19 Thought Lab 1.1, Analysis 1, p. 20 Section 1.2 Review: 6, 7, p. 27 Chapter 1 Review: 4, 6, 7, 11, 14, 15, p. 30; 16, 17, 19, p. 31 Unit 1 Review: 7(c), 8, p. 68; 21, p. 69; 25,p. 70 Chapter 1 Test
Outcomes for Science, Technology and Society (Emphasis on the nature of science)		
20–A1.1sts explain that the process of scientific investigation includes analyzing evidence and providing explanations based upon scientific theories and concepts by **(NS5e)**	Connections: Biomagnification: A Fish Story, p. 28	Section 1.2 Review: 5, p. 27 Connections: 5, p. 28 Chapter 1 Review: 16, 18, p. 31
■ *evaluating the evidence for the influence of ice and snow on the trapping of solar energy (albedo effect), and hypothesize on the consequences of fluctuations for biological systems*	Figure 1.4, p. 11	Unit 1 Review: 16, 18, p. 69; 34, 37, p. 71 Q questions 5, 6, p. 12 Section 1.1 Review: 7, p. 15
■ *explaining how metabolic heat release from harvested grain can be reduced by drying processes prior to grain storage, and explain the scientific principles involved in this technology*		
■ *explaining, in terms of energy flow, the advantage of vegetarianism in densely populated countries*	Thought Lab 1.1: Analyzing Energy Transfers, p. 20 Investigation 1.B: Weave Your Own Food Web, pp. 22-23	Thought Lab 1.1: Analysis 2-4, p. 20 Investigation 1.B: Ext. 5, p. 23 Chapter 1 Review: 20, p. 31

	Student Textbook	Assessment Options
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
20–A1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by ■ *proposing a relationship between producers and available biological energy of a system* **(IP–STS1)** ■ predicting a relationship between solar energy storage by plants and varying light conditions **(IP–NS3) [ICT C6–4.1]**	Launch Lab: Considering Connections, p. 7 A Closer Look at Producers, pp. 9-12 The Fate of Energy in the Biosphere, p. 14 Investigation 1.A: Storing Solar Energy in Plants, pp. 10-11	Launch Lab: Analysis 1-3, p. 7 Chapter 1 Review: 12, p. 30 Unit 1 Review: 6, p. 68 Investigation 1.A: Ext. 8, 9, p. 11
Performing and Recording		
20–A1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by		
■ performing an experiment to demonstrate solar energy storage by plants **(PR–NS1, 2, 3, 4, 5)** ■ *drawing annotated diagrams, by hand or using technology, of food chains, food webs and ecological pyramids* **(PR–NS4) [ICT P3–4.1, C6–4.2, P4–4.3]**	Investigation 1.A: Storing Solar Energy in Plants, pp. 10-11 Investigation 1.B: Weave Your Own Food Web, pp. 22-23 Investigation 1.C: Ecology of an Endangered Prairie Ecosystem, p. 26	Investigation 1.A: Procedure 1-6, p. 10 Investigation 1.B, Procedure 7, p. 23 Investigation 1.C, Procedure 3, p. 26 Section 1.2 Review: 3, 4, p. 27 Connections: 1, p. 28 Unit 1 Review: 4, 7(b), 8, p. 68; 25, p. 70
Analyzing and Interpreting		
20–A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by ■ analyzing data on the diversity of plants, animals and decomposers of an endangered ecosystem and predict a future outcome, e.g., wetlands, short grass prairie **(AI–STS1, 2, 3, 4) [ICT C6–4.1, 4.4]** ■ describing alternative ways of presenting energy flow data for ecosystems: pyramids of energy, biomass or numbers **(AI–STS1) (AI–NS4, 5, 6) [ICT C6–4.2, 4.3]** ■ *analyzing data on the solar energy storage by plants* **(AI–NS2, 3, 4, 5, 6)**	Investigation 1.B: Weave Your Own Food Web, pp. 22-23 Thought Lab 1.2: Energy Fluctuation in an Ecosystem, p. 25 Investigation 1.C: Ecology of an Endangered Prairie Ecosystem, p. 26 Connections: Biomagnification: A Fish Story, p. 28 Modelling Feeding Relationships through Ecological Pyramids, pp. 18-24 Investigation 1.A: Storing Solar Energy in Plants, pp. 10-11	Section 1.1 Review: 7, 8, p. 15 Investigation 1.B: Analysis 1-4, p. 23 Thought Lab 1.2: Analysis 1-4, p. 25 Section 1.2 Review: 10, p. 27 Investigation 1.C: Procedure 1, Analysis 1-4, Ext. 5, p. 26 Connections: 2-5, p. 28 Unit 1 Review: 9, 21, p. 69 Q question 18, p. 24 Chapter 1 Review: 7, p. 30; 17(b), 19, 21, p. 31 Investigation 1.A: Analysis 1-5; Conclusions 6-7, p. 11
Communication and Teamwork		
20–A1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *using appropriate International System of Units (SI) notation, fundamental and derived units and significant digits in the data presented in a food pyramid* **(CT–ST2)**	Investigation 1.B: Weave Your Own Food Web, pp. 22-23	Investigation 1.B, Analysis 3, p. 23
■ *working cooperatively as a team to investigate, synthesize and present information collected on the effect of organism diversity on an ecosystem* **(CT–STS1, 2, 3, 4) [ICT P6–4.1]**	Investigation 1.C: Ecology of an Endangered Prairie Ecosystem, p. 26	Investigation 1.C: Procedure 1-2, p. 26

Chapter 1

Energy Transfer in the Biosphere

Student Textbook pages 6–31

Chapter Concepts

1.1 How Energy Enters the Biosphere

- Producers (autotrophs) capture energy and store it by photosynthesis or chemosynthesis.
- Consumers (heterotrophs) and decomposers consume autotrophs and other heterotrophs.
- Matter is cycled in the biosphere, but energy follows a one-way path.

1.2 How Energy Is Transferred in the Biosphere

- Food chains and food webs are models that describe feeding relationships and energy transfer between organisms in trophic levels.
- Ecological pyramids are models that describe relationships between trophic levels quantitatively.
- Because all organisms are connected, changes that affect one trophic level affect other trophic levels.

Common Misconceptions

- Most food chains are very short. This is particularly true in Canada, where short growing seasons limit plant growth. Complex food webs that illustrate the feeding relationships among members of a community can give students the impression that each food chain is longer than it really is.
- Students often focus on photosynthesis as the main reaction carried out by photosynthetic organisms and may often not realize that photosynthesis is chiefly a form of energy conversion and storage. In order to utilize this energy, autotrophs must carry out cellular respiration just like heterotrophs. As such, plants and other photosynthetic organisms not only take in carbon dioxide during photosynthesis, but they also produce it during cellular respiration, albeit in a much smaller amount.
- Photosynthesis and cellular respiration are complex chemical reactions that involve a series of intermediate reactions and numerous metabolic pathways. These reactions are usually simplified to form the simple two reactants/two products reactions that illustrate the reversible nature of the reactions. As a result, however, students may believe that photosynthesis is a much simpler process than it really is. Similarly, because glucose is shown as an end product of photosynthesis and as a reactant in cellular respiration, students can be left with the impression that plants can make only glucose and that glucose is the only molecule that can be used to produce energy in cells.
- Elemental mercury is the form of mercury that is released as a pollutant to the environment. Micro-organisms in aquatic systems then convert elemental mercury into methylmercury, which then accumulates in organisms. Students may easily confuse these two compounds and think that humans pollute the environment with methylmercury directly.

Helpful Resources

Books and Journal Articles

- Molles, Manuel. *Ecology*. Toronto: McGraw-Hill Higher Education, 2005. ISBN 0072951710
- Eldredge, Niles. *Life in the Balance: Humanity and the Biodiversity Crisis.* Princeton: Princeton University Press, 2000. ISBN 0691050090
- Wilson, Edward O. *In Search of Nature*. Washington, DC: Island Press/Shearwater Books, 1997. ISBN: 155963216X

Web Sites

Web links to information about energy transfer in the biopshere 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 1.

List of BLMs

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

Number (Type)
BLM 1.0.1 (HAND) Launch Lab: Considering Connections
BLM 1.0.1A (ANS) Launch Lab: Considering Connections Answer Key

BLM 1.1.1 (OH) Photosynthesis
BLM 1.1.2 (OH) The Chemical Reactions for Photosynthesis and Cellular Respiration
BLM 1.1.3 (HAND) Investigation 1.A: Storing Solar Energy in Plants
BLM 1.1.3A (ANS) Investigation 1.A: Storing Solar Energy in Plants Answer Key
BLM 1.1.4 (OH) Path of Incoming Solar Radiation
BLM 1.1.5 (OH) Table: Albedo Values
BLM 1.1.6 (OH) The Chemical Reactions for Chemosynthesis and Photosynthesis
BLM 1.1.7 (OH) The Deep Vent Community
BLM 1.1.8 (OH) Energy Transfer in the Biosphere

BLM 1.2.1 (HAND) Terrestrial and Aquatic Food Chains
BLM 1.2.1A (ANS/OH) Terrestrial and Aquatic Food Chains Answer Key

BLM 1.2.2 (OH) Comparing Food Webs in Different Ecosystems: Woodland-Lake and Arctic
BLM 1.2.3 (HAND) Food Web Question and Answer Exercise
BLM 1.2.3A (ANS) Food Web Question and Answer Exercise Answer Key
BLM 1.2.4 (HAND) Create a Food Web Exercise
BLM 1.2.5 (OH) The Rule of 10
BLM 1.2.6 (OH) Grizzly Bear: Energy Transfer
BLM 1.2.7 (OH) Pyramid of Numbers
BLM 1.2.8 (OH) Pyramid of Biomass
BLM 1.2.9 (OH) Pyramid of Energy
BLM 1.2.10 (HAND) Ecological Pyramids Question and Answer Exercise
BLM 1.2.10A (ANS) Ecological Pyramids Question and Answer Exercise Answer Key
BLM 1.2.11 (HAND) Thought Lab 1.1: Analyzing Energy Transfers
BLM 1.2.11A (ANS) Thought Lab 1.1: Analyzing Energy Transfers Answer Key
BLM 1.2.12 (HAND) Investigation 1.B: Weave Your Own Food Web
BLM 1.2.12A (ANS) Investigation 1.B: Weave Your Own Food Web Answer Key
BLM 1.2.13 (HAND) Thought Lab 1.2: Energy Fluctuation in an Ecosystem
BLM 1.2.13A (ANS) Thought Lab 1.2: Energy Fluctuation in an Ecosystem Answer Key
BLM 1.2.14 (OH) Stellar Sea Lion Range
BLM 1.2.15 (HAND) Investigation 1.C: Ecology of an Endangered Prairie Ecosystem
BLM 1.2.15A (ANS) Investigation 1.C: Ecology of an Endangered Prairie Ecosystem Answer Key
BLM 1.2.16 (OH) Table: Concentration of Methylmercury in Aquatic Organisms
BLM 1.2.17 (HAND) Biomagnification Activity: DDT in the Ecosystem
BLM 1.2.17A (ANS) Biomagnification Activity: DDT in the Ecosystem Answer Key

BLM 1.3.1 (HAND) Chapter 1 Test
BLM 1.3.1A (ANS) Chapter 1 Test Answer Key

Using the Chapter 1 Opener

Student Textbook pages 6-7

Teaching Strategies

- Use the Launch Lab: Considering Connections.
- Discuss with students the pros and cons of using traditional knowledge for evaluating scientific problems.
- Consider inviting an Aboriginal elder to your class to discuss changes his or her people have observed in the environment.

Launch Lab: Considering Connections

Student Textbook page 7

Purpose

Students will consider how Aboriginal perspectives and observations can provide a different form of evidence for scientists considering the effects human actions have on the planet's atmosphere.

Outcomes

- Attitude Outcome: Mutual respect.

Time Required

30 minutes (15 minutes for students to read material and answer questions and 15 minutes for discussion).

Helpful Tips

- Use **BLM 1.0.1 (HAND) Launch Lab: Considering Connections** 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 1.0.1A (ANS) Launch Lab: Considering Connections Answer Key**.
- You may want to discuss Analysis question 2 as a class. Ask students to consider a day in the life of an average student. Discuss how the average student is connected with the world over the course of the day. For example, consuming food; using energy to heat the home, drive, and cook food; the lumber used to build the home the student lives in, the manufacture of natural or man-made materials to create the clothes he or she wears—these are all examples of how the student is connected to the world in the course of a day. Ask students to identify personal daily activities and interactions that link them to other citizens of the world. This is a good time to introduce the term "global village" to students.

Answers to Analysis Questions

1. Global warming brought on by the burning of fossil fuels could result in the depletion and unpredictable nature of Arctic sea-ice as increased greenhouse gases cause Arctic temperatures to rise. Activities associated with increases in greenhouse gases include burning gasoline in a car to go to work, burning oil in a factory to produce goods, or burning natural gas to heat a home. People living south of the Arctic frequently carry out these activities.
2. Accept any reasonable answer.
3. Accept any reasonable answer. You may want to point out that some events can have worldwide implications while others are more localized in their effects. This line becomes blurred very easily. For example, the tsunami in the Indian Ocean in 2004, which caused massive damage in one part of the world, resulted in people around the world providing aid for those who were directly affected.

Assessment Options

- Collect student answers to Analysis questions for marking or discuss in class.

1.1: How Energy Enters the Biosphere

Student Textbook pages 8-15

Section Outcomes

Students will:

- explain how energy enters the biosphere through the processes of photosynthesis and chemosynthesis
- describe how energy is transferred in the biosphere through the activity of producers (autotrophs) and consumers (heterotrophs)
- perform an investigation to demonstrate the storage of light energy in the form of the chemical energy of starch in green plants

Key Terms

cellular respiration
photosynthesis
producers
consumers
albedo
chemosynthesis
primary consumers
secondary consumers
tertiary consumers
decomposers

Biology Background

- In Alberta, photosynthesis is often limited by the availability of water. In addition, temperature is influenced by elevation and latitude. This further limits photosynthesis at higher elevations in the mountains and the northern regions of the province, as cooler temperatures slow chemical reactions.
- Deep-sea vents were unknown until 1977 and, although scientists believe they number in the thousands, only a few have been found. Three of these vents are at the floor of the Pacific Ocean, about 250 km off the coast of British Columbia and the state of Washington.
- Chemosynthetic bacteria form the base for the food chains of deep-sea vents. These bacteria are able to use the chemical energy in hydrogen sulfide from the vents, along with carbon dioxide and water, to form carbohydrates in the following reaction:
  $6CO_2 + 6H_2O + 3H_2S \rightarrow C_6H_{12}O_6 + 3H_2SO_4$
  As in photosynthesis, carbon dioxide and water are reactants in the equation and glucose is one of the products. The reaction differs from photosynthesis in the source of energy used (sunlight versus the chemical energy in H_2S) and in the end product of sulfuric acid, which is responsible for the high acidity of the water surrounding deep-sea vents.

Teaching Strategies

- **BLM 1.1.1 (OH) Photosynthesis** Start your discussion with a review of photosynthesis from *Science 10.*
- **BLM 1.1.2 (OH) The Chemical Reactions for Photosynthesis and Cellular Respiration** Have students write out the chemical formulas for photosynthesis and cellular respiration. After discussing the products and reactants of photosynthesis, review cellular respiration. The chemical formula for cellular respiration is the reverse of the one for photosynthesis in terms of products and reactants. Ask students if they can identify the path energy follows through each reaction. In photosynthesis, solar energy is converted into chemical energy, which is stored in the bonds of organic molecules (sugar and starch) produced in the reaction. In cellular respiration, the energy in the organic molecules is transferred to the bonds of ATP, a form of energy that can be directly used by organisms to fuel metabolic reactions. You may also want to compare the locations where these reactions occur. Photosynthesis is carried out in chloroplasts of photosynthetic organisms, while cellular respiration occurs in the mitochondria of all aerobic organisms, including photosynthetic ones.
- Use B**LM 1.1.4 (OH) Path of Incoming Solar Radiation** and **BLM 1.1.5 (OH) Table: Albedo Values** to illustrate the fate of the 98-99% of incoming solar radiation that is not captured by photosynthetic producers. You may want to black out certain albedo values in the table and get students to try to guess these values.
- An introduction to chemosynthesis can begin with video clips of the life around deep-sea vents. National Geographic and Nova have video footage available on their web sites. Web links can be found at **www.albertabiology.ca**, Online Learning Centre, Instructor Edition. Use **BLM 1.1.6 (OH) The Chemical Reactions for Chemosynthesis and Photosynthesis** to discuss the chemical reaction involved in chemosynthesis, drawing attention to the fact that carbon dioxide and water are both used as reactant in the photosynthesis and chemosynthesis reactions, as this may not be intuitive to all students. Further, **BLM 1.1.7 (OH) The Deep Vent Community** can be used to introduce the organisms living in this unique community. Students will be interested in learning that these organisms must overcome some harsh environmental conditions to survive. The water surrounding deep-sea vents is typically very acidic, due to the production of sulfuric acid by the chemosynthetic bacteria. Water temperatures can reach up to 350 °C. Light does not penetrate here, and the extreme pressure from the water above makes for organisms that require very special adaptations. You might also want to point out that, due to these hostile conditions, scientists know more about the surface of the moon than they do about life at the bottom of the oceans. If your class is particularly interested in

deep-sea vents, you may want to encourage students' interest by having them complete the Web Link on page 13 concerning Canada's role in deep-sea research. This research can be completed either as an individual and group assignment.

- Ask students what the maximum temperature of liquid water is. Most students should answer 100 °C, the boiling point. Then ask how the water around a deep-sea vent can reach 350 °C. (The answer is that the increased water pressure prevents water from changing to a gas.) You can also point out that the same explanation (in reverse) accounts for the fact that water boils in Calgary and other high elevation parts of Alberta at approximately 98 °C (because of lower air pressure).
- **BLM 1.1.8 (OH) Energy Transfer in the Biosphere** can be used to link the path energy follows through the biosphere to the first and second laws of thermodynamics. Ask students if they can identify where the energy arrows indicate the conversion of energy from one form of energy to another (sunlight to producers, all organisms to heat) or the transfer of energy from one organism to another (producers to consumers, producers and consumers to detritivores, consumers to other consumers [not shown]). Discuss how energy that is dispersed or "lost" as heat is not really lost, but is simply unavailable to other organisms. Earth or its atmosphere either absorbs such energy, or it is radiated into space.
- Investigation 1.A: Storing Solar Energy in Plants provides a hands-on way to bring home to students the concept that while glucose is the product of photosynthesis reactions in plants, these molecules are also converted into other carbon-rich organic molecules such as proteins, fats, and the focus of this investigation, starches. Starch is a main form of chemical energy storage in the photosynthetic tissues of plants, as students will learn in this investigation.

Answers to Questions for Comprehension

Student Textbook page 9

Q1. Cellular respiration is a process that releases the energy stored in carbohydrates and other energy-rich organic molecules. The chemical reactions involved in cellular respiration occur in most species, including species of plants and animals.

Q2. Photosynthesis is the process that producers, such as plants, algae, and some bacteria, use to chemically convert carbon from carbon dioxide into carbohydrates using light energy from the Sun.

Q3. Through photosynthesis, producers use the Sun's light energy to make energy-rich organic molecules. Through cellular respiration, producers, decomposers, and consumers release the energy stored in energy-rich organic molecules. The energy released by cellular respiration supports organisms' activities.

Q4. Producers and consumers are linked though the processes of photosynthesis and cellular respiration: The products of cellular respiration are reactants in photosynthesis, and the products of photosynthesis are the reactants of cellular respiration. Specifically, producers, such as plants, algae, and some bacteria, use carbon dioxide, energy from the Sun, and water to make energy-rich organic molecules (glucose). This process also releases oxygen. Consumers eat producers or other consumers to gain the fuel required to carry out their life processes. Both producers and consumers use oxygen to release the energy in glucose via cellular respiration, and in the process release carbon dioxide and water.

Investigation 1.A: Storing Solar Energy in Plants

Student Textbook pages 10-11

Purpose

Students will perform an experiment to determine the relationship between light exposure and starch formation in plants.

Outcomes

- IP-STS 3
- IP-NS3
- ICT C6-4.1
- 20-A1.1s

Advance Preparation

When to Begin	What to Do
Several weeks before	■ Find a source of solid green and variegated plants.
4 days before	■ For each pair of students, place one variegated and one green plant in dark conditions and one variegated and one green plant in light conditions for four days.
1 day before	■ Ask students to read the investigation at home the evening before. ■ Photocopy **BLM 1.1.3 (HAND) Investigation 1.A: Storing Solar Energy in Plants**

Materials

- small test tube
- hot plate
- stopper or stirring rod
- tweezers (or forceps)
- water
- 4 Petri dishes
- tongs or oven mitts
- 5 g of cornstarch
- 400 mL beaker of boiling water
- 150 mL beaker with 50 mL of hot ethanol in a hot water bath
- Lugol's iodine solution (in a dropper bottle or spray bottle)
- plants with solid green leaves such as geranium (*Pelargonium*) or ivy (*Hedera*)—one plant grown for 4 days exposed to sunlight or under grow lights, and one plant placed in the dark for 4 days
- plants with variegated leaves such as Coleus, variegated geranium (*Pelargonium*), or spider plant (*Chlorophytum*)—one plant grown for 4 days exposed to sunlight or under grow lights, and one plant placed in the dark for 4 days

Time Required

- 1/2 period to introduce the objectives of the investigation and explain/demonstrate how to set up the investigation
- 1 period for students to set up the investigation, gather data, and clean up

Helpful Tips

- Use **BLM 1.1.3 (HAND) Investigation 1.A: Storing Solar Energy in Plants** 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 1.1.3A (ANS) Investigation 1.A: Storing Solar Energy in Plants Answer Key.**
- ***Expected Results:*** After the chlorophyll has been removed and the leave are treated with iodine,
  (a) the solid, green leaf that had been in the light for the full four days will show a positive test for starch. The entire leaf will turn brownish-purple.
  (b) the solid, green leaf that had been in the dark for the full days will show a negative result when tested for starch. This leaf will stay the colour of the iodine solution. The plant will have used up all of the starch in the leaves for energy production.
  (c) only the "green" areas in the variegated plant grown in the light will turn brownish-purple; the white areas in this plant will remain the same colour as the iodine solution.

Safety Precautions

Ethanol ignites easily and iodine stains skin and clothing. Handle all chemicals with great care.

Answers to Analysis Questions

1. The green pigmentation of all leaves exposed to sunlight tested positive for starch (turned purple).

2. Diagrams should shade all green leaves exposed to sunlight to indicate starch detection. For variegated leaves exposed to sunlight, the green pigmentation only should be shaded. Leaves not exposed to sunlight did not turn purple.

3. Starch was present in the green areas only.

4. and **5.** Encourage students to explain why their predictions and hypotheses were (or were not) accurate.

Answers to Conclusion Questions

6. Light exposure is required for starch formation in green leaves.

7. Students may suggest factors such as the following: The plants placed in the sunlight may experience warmer conditions than the plants placed in darkness. Indirectly, these plants may also experience more water loss as a result of this temperature difference. These effects could be minimized by measuring the temperature variation in the light conditions and setting up equivalent temperature variations in the dark conditions.

Answers to Extension Questions

8. A typical hypothesis might be: If plants need sunlight to perform photosynthesis and make starch, then the leaves that are exposed to sunlight should show the presence of starch and the leaves that have been covered with foil should not. A typical prediction might be: I predict that the uncovered leaves will show a positive response for starch and the covered leaves will show a negative response for starch.

9. Students will observe an image on the leaf, formed as a result of light being blocked by the dark areas of the negative and light passing through the lighter areas.

Assessment Options

- Have the students write up a formal lab report with answers to Analysis, Conclusions, and Extension questions to be handed in for marking.
- Use Assessment Checklist 2 Laboratory Report. (See Appendix A.)

Answers to Questions for Comprehension

Student Textbook page 12

Q5. Earth's land and ocean surfaces absorb 51% of the incoming radiant energy from the Sun.

Q6. The amount of energy from the Sun that reaches producers is a tiny fraction of the energy from the Sun that reaches Earth's atmosphere.

Student Textbook page 13

Q7. Chemosynthesis and photosynthesis are both carried out by autotrophs. Chemosynthetic micro-organisms use energy stored in inorganic hydrogen sulfide molecules to make energy-rich organic molecules. These chemosynthetic micro-organisms obtain the building blocks for these organic molecules from carbon dioxide and water. Similarly, photosynthetic autotrophs use carbon dioxide and water to build organic molecules, but the energy they use to make these molecules is solar energy. Further, while oxygen is a product of photosynthesis, chemosynthesis produces sulphuric acid.

Q8. Herbivores are classified as primary consumers because they are the first (primary) eaters of plants and other producers.

Q9. Secondary consumers eat primary consumers. Secondary consumers include carnivores that eat mainly herbivores. Tertiary consumers eat secondary consumers. Tertiary consumers include carnivores that eat mainly other carnivores.

Q10. Decomposers do not directly capture energy from the Sun or from inorganic molecules; therefore, decomposers are not producers. Because decomposers consume organic matter and obtain energy from the energy-rich molecules within, they are heterotrophic organisms.

Biology File: Web Link

Student Textbook page 13

Canadian deep-sea research is multidisciplinary, including areas of interest from biology (e.g., biodiversity), ecology (ecodiversity), geology (plate tectonics), meteorology (e.g., the role of the ocean in climate change), and oceanography (which includes aspects of physical, chemical, and biological studies). Canada is also a world leader in the design and manufacturing of ocean-exploration technologies, such as remote submersibles (e.g., ROPOS) and "wearable" submersibles (the Newt Suit). More recently, partnered with the U.S. National Science Foundation, Canada is involved in the Neptune project—an ambitious plan to study the sea-floor from underwater laboratories in real time.

Answer to Question for Comprehension

Student Textbook page 14

Q11. The first law of thermodynamics states that energy cannot be created or destroyed. Since organisms cannot create the energy they need, they must obtain energy from other sources: sunlight, inorganic chemicals, other organisms, and organic waste. The second law of thermodynamics states that with every energy conversion, there is less energy available to do useful work. Cellular respiration, for example, is not 100% efficient: Some of the energy stored in glucose is converted into heat that disperses into the environment.

As a result, producers are essential to all life on Earth, as they contribute useable energy to the biosphere via photosynthesis.

Section 1.1 Review Answers

Student Textbook page 15

1. Light energy and the products of cellular respiration (carbon dioxide and water) are the inputs of photosynthesis.

photosynthesis: $6CO_2(g) + 6H_2O(l) + \text{light energy} \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$

carbon dioxide + water + light energy → carbohydrates + oxygen

The inputs of cellular respiration (carbohydrates and oxygen) are the products of photosynthesis.

cellular respiration: $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) + \text{energy}$

carbohydrates + oxygen → carbon dioxide + water + energy

2. Photosynthesis and chemosynthesis are both processes that producers (autotrophs) use to capture and store energy. Through photosynthesis, plants, algae, or some bacteria use energy from the Sun to build energy-rich organic molecules from carbon dioxide and water. Through chemosynthesis, thermal vent micro-organisms use energy from hydrogen sulfide to build energy-rich organic molecules from carbon dioxide and water. In addition to organic molecules, photosythesis also produces oxygen, while chemosynthesis produces sulfuric acid.

3. Like herbivores, plants use cellular respiration to access the energy stored in glucose.

4. Most of the radiant energy from the Sun that reaches the biosphere never reaches producers: Clouds, dust particles in the atmosphere, and water and land at Earth's surface reflect 30% of incoming radiant energy; the atmosphere and clouds absorb 19%; and Earth's surface absorbs 51%. Even leaves reflect some sunlight.

5. Producers use photosynthesis or chemosynthesis to capture energy, and cellular respiration to release stored energy so that it can be used. Primary consumers obtain energy by eating producers; secondary consumers, by eating primary consumers; and tertiary consumers, by eating secondary consumers. Consumers also use cellular respiration to release stored energy.

6. The first law of thermodynamics states that energy cannot be created or destroyed, but it can be transformed from one form to another, or passed from one object to another. The second law of thermodynamics states that with each energy conversion, there is less energy to do useful work, because some energy is converted into a form that organisms cannot use, such as heat.

7. The albedo of fresh snow is 80-90%, while the albedo of water is 25% or less (see page 11 of student text). Forest and grass have even lower albedo values (7–18% and 18–25%, respectively). With the loss of snow and ice cover, which has a high albedo, more of Earth's surface will have a low albedo. As the albedo of Earth's surface decreases, less incoming radiant energy from the Sun is reflected by Earth's surface, and more is absorbed, further warming the planet and reducing snow and ice cover even more.

8. As the skunk cabbage carries out cellular respiration and other reactions, it transfers energy to the environment as dissipated heat, which melts the snow.

1.2 How Energy is Transferred in the Biosphere

Student Textbook pages 16-27

Section Outcomes

Students will:

- explain the structure of trophic levels in ecosystems
- explain what happens to energy as it is transferred from one trophic level to another through the biosphere
- describe and illustrate the transfer of energy using models such as food chains and food webs
- gather and analyze data and information to assess the effect of organism diversity on an endangered ecosystem

Key Terms

trophic level
food chain
food web
pyramid of numbers
biomass
pyramid of biomass
pyramid of energy

Biology Background

- It requires seven times more land to sustain a meat-based diet than a plant-based diet. The world's cattle eat the same amount of food that would feed 8.7 billion people if humans consumed it directly. Similarly, it is estimated to take about 43 000 L of water to produce about half a kilogram of ground beef.
- Not all aquatic ecosystems exhibit an inversion when depicted by a pyramid of biomass. Such an inversion typically occurs when zooplankton consume phytoplankton as quickly as they can reproduce, so that their biomass remains low. If a pyramid of biomass is inverted, a pyramid of numbers will also be inverted (if scientists engage in the onerous task of counting the phytoplankton); however, a pyramid of energy for that ecosystem will be upright.

Teaching Strategies

- **BLM 1.2.1 (HAND) Terrestrial and Aquatic Food Chains** and **BLM 1.2.1A (ANS/OH) Terrestrial and Aquatic Food Chains Answer Key** show the feeding relationships between the different organisms in a terrestrial and aquatic food chain, as well as the different terms that are used to indicate feeding relationships between the organisms. For example, "first trophic level," "producer," and "autotroph" are all terms that refer to the same organisms. These handouts can be used in two ways depending on your needs. Using **BLM 1.2.1 (HAND) Terrestrial and Aquatic Food Chains**, ask students to fill in the missing terms after reading the text. Answers are provided on **BLM 1.2.1A (ANS/OH) Terrestrial and Aquatic Food Chains Answer Key**, which can also be used as an overhead teaching tool to teach the terms directly.
- Ask the students to name common herbivores, carnivores, omnivores (bears, pigs, rats, and people), and decomposers, and then provide other feeding relationship terms that can also be used for each organism (for example, herbivores could also be described as heterotrophs feeding at the second trophic level) to help them become more familiar with feeding relationship terms. This will also help students understand that some organisms such as omnivores and decomposers may feed at more than one trophic level and will therefore be difficult to categorize.
- **BLM 1.2.2 (OH) Comparing Food Webs in Different Ecosystems: Woodland-Lake and Arctic** provides an overhead of Figure 1.10 in the text (page 18-19) that can be used to work through the Try This (page 19) with students as a class. The Try This asks students to compare the woodland-lake and Arctic food webs illustrated in the figure through a series of guiding questions.
- **BLM 1.2.3 (HAND) Food Web Question and Answer Exercise, BLM 1.2.3A (ANS) Food Web Question and Answer Exercise Answer Key,** and **BLM 1.2.4 (HAND) Create a Food Web Exercise** can all be used to provide students with extra practice in working with and understanding food webs. **BLM 1.2.3 (HAND) Food Web Question and Answer Exercise** specifically focusses on helping students become familiar with trophic levels in food webs, while **BLM 1.2.4 (HAND) Create a Food Web Exercise** provides a hands-on activity that asks students to create a food web from various provided organisms. As an adjunct to this exercise, you may want to ask students as a class to try to create the longest food web they can with organisms they are familiar with.
- Use the second law of thermodynamics, introduced in Section 1.1, to explain the rule of 10, which students encounter in the context of how much energy is transferred from one trophic level to the next. The law expresses the energy losses that govern food chains, illustrating why energy is lost at each step of the chain. To help get across this idea, you may want to provide students with the analogy of a car relay in which each car races a lap and then passes its remaining fuel to the next car in the relay. A

car that burns 30% of its fuel during the trip and loses another 60% through a leak in the gas tank only has 10% of its fuel left at the end of the trip to pass on to the next car. The bucket pass analogy provided in the text (water is lost from the bucket with each pass) is also a useful teaching analogy. You may even want to take your class outside and get them to carry out this analogy. Following these analogies, **BLM 1.2.5 (OH) The Rule of 10** can be used to show students how the rule of ten affects energy transfer in a short prairie food chain. Remind students that the rule of 10 is an oversimplification of the amount of energy lost in the transfer of energy between members of a food chain.

- **BLM 1.2.6 (OH) Grizzly Bear: Energy Transfer** can be used to further illustrate the rule of 10. This BLM follows the passage of 200 kJ of energy from a meal as it is assimilated by a bear, producing feces, heat as a result of cellular respiration, and body tissue. In this example, only 3% of the original energy is incorporated into body tissues, providing a good example of how the rule of 10 is an approximation. Typically, energy transfer to the next trophic level is between 5 and 20%.
- **BLM 1.2.7 (OH) Pyramid of Numbers, BLM 1.2.8 (OH) Pyramid of Biomass,** and **BLM 1.2.9 (OH) Pyramid of Energy** provide examples of the three basic types of food pyramids (quantitative representations of food chains) and include their units of measurement: pyramids of numbers (number of organisms), biomass (kg), and energy (J or kJ). Examples of inverted pyramids of numbers and biomass are also provided in these overheads. A pyramid of energy can never be inverted. Although it should be clear to students how the values for a pyramid of numbers and biomass are measured, you may want to point out that to determine the values for each level of a pyramid of energy, scientists place samples of each group of organisms in a calorimeter to determine the number of calories or Joules (energy) in each step of the chain.
- **BLM 1.2.10 (HAND) Ecological Pyramids Question and Answer Exercise** and **BLM 1.2.10A (ANS) Ecological Pyramids Question and Answer Exercise Answer Key** can be used to provide students with extra practice in understanding the three types of ecological pyramids.

Answers to Questions for Comprehension

Student Textbook page 16

Q12. Organisms can be identified by how they obtain their food and what they eat: i.e., as producers, herbivores, carnivores, and decomposers. Organisms can also be identified as types of food-makers or food-consumers: i.e., as producers, primary consumers, secondary consumers, and tertiary consumers. Finally, organisms can be identified by their trophic level (feeding level) in an ecosystem. Organisms at higher trophic levels eat organisms at lower trophic levels.

Q13. A trophic level is a feeding level through which energy and matter are transferred in an ecosystem.

Q14. The first trophic level consists of producers. All other trophic levels consist of consumers. The second trophic level consists of primary consumers, the third trophic level consists of secondary consumers, and the fourth trophic level consists of tertiary consumers. Decomposers feed at all trophic levels.

Student Textbook page 18

Q15. When an organism consumes a meal, only 5-20% of the chemical energy available in that meal is incorporated into the organism’s body tissues. The rest is lost to the environment as heat produced during cellular respiration or passes out through waste products. The energy in waste and heat is not available to the next trophic level, thus only a small percentage of the original energy is transferred.

Q16. Since only about 5-20% of the energy available at one trophic level is transferred to the next trophic level, eventually there is not enough usable energy to pass on.

Student Textbook page 19

Q17. A pyramid of numbers is upright when the organisms at higher trophic levels are fewer in number than the organisms at lower trophic levels. A pyramid of numbers is inverted when the organisms at higher trophic levels are greater in number than the organisms at lower trophic levels. For example, an inverted pyramid of numbers would be used to depict an ecosystem in which thousands of plant-eating insects live off one or two trees.

Biology File: Try This

Student Textbook page 19

The woodland-lake food chains are longer than the Arctic food chains. The woodland-lake food web is more complex than the Arctic food web. The overall complexity of food webs in a tropical rainforest ecosystem would typically be greater as the level of productivity is higher due to greater availability of moisture, nutrients, sunlight, and/or heat.

Thought Lab 1.1: Analyzing Energy Transfers

Student Textbook page 20

Purpose

Students will use the rule of 10 and the food chains provided to determine the percentage of the Sun’s energy available to humans at the end of each food chain.

Outcomes

- 20-A1.1k
- 20-A1.1sts

Time Required

30 minutes

Helpful Tips

- Use **BLM 1.2.11 (HAND) Thought Lab 1.1: Analyzing Energy Transfers** 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 1.2.11A (ANS) Thought Lab 1.1: Analyzing Energy Transfers Answer Key.**

Answers to Analysis Questions

1. First chain = 0.2%; second chain = 0.02%; third chain = 0.00002%
2. Arable land that is used for grazing could feed many more people if it is used to grow grain.
3. Earth could support a much larger population if most people ate a grain-based diet.
4. Sample answer based on a hypothetical school with a population of 5.00×10^2 students:

   energy for rice field = $5200 \dfrac{\frac{\text{kJ}}{\text{m}^2}}{\text{yr}}$

   energy for chicken farm = $800 \dfrac{\frac{\text{kJ}}{\text{m}^2}}{\text{yr}}$

   minimum daily human energy consumption = 2400 kJ

   energy required per student population per year =
   $(5.00 \times 10^2)(2400 \frac{\text{kJ}}{\text{d}})(365 \frac{\text{d}}{\text{yr}}) = 4.38 \times 10^8 \frac{\text{kJ}}{\text{yr}}$

   land needed to support population on rice diet =

   $$\frac{4.38 \times 10^8 \frac{\text{kJ}}{\text{yr}}}{5200 \dfrac{\frac{\text{kJ}}{\text{m}^2}}{\text{yr}}} = 84\,230.77 \text{ m}^2$$

   land needed to support population on chicken diet =

   $$\frac{4.38 \times 10^8 \frac{\text{kJ}}{\text{yr}}}{800 \dfrac{\frac{\text{kJ}}{\text{m}^2}}{\text{yr}}} = 547\,500 \text{ m}^2$$

   84 230.77 m^2 of land is required to support a population of 500 students on a grain diet for one year (8.4×10^4 m^2 to correct significant digits), while 547 500 m^2 is required to support the same number of students on a chicken diet (5×10^5 m^2 to correct significant digits).

Assessment Option

- Collect student answers for marking or mark in class and hand in for recording.

Investigation 1.B: Weave Your Own Food Web

Student Textbook page 22-23

Purpose

Students will draw a food web based on a record of their own food consumption and calculate the percentage of the Sun's energy that is available to them through their diet, based on the food choices they make.

Outcomes

- 20-A1.1k
- 20-A1.3k

Advance Preparation

When to Begin	What to Do
1 week before	■ Book computer and library resources for student research.
1 day before	■ Ask students to read the investigation at home the evening before. ■ Remind students to bring calculators to class. ■ Photocopy **BLM 1.2.12 (HAND) Investigation 1.B: Weave Your Own Food Web**

Time Required

- 3 days for students to complete food journal
- 1-2 periods to complete research
- 1-2 periods to complete the investigation

Helpful Tips

- Use **BLM 1.2.12 (HAND) Investigation 1.B: Weave Your Own Food Web** 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 1.2.12A (ANS) Investigation 1.B: Weave Your Own Food Web Answer Key.**
- Remind students that the "calories" referred to in most nutritional information are kilocalories (sometimes written as Cal). Students must use the conversion 1 kcal = 4.2 kJ to successfully complete the investigation.

Answers to Analysis Questions

1. Student answers should add up to 100% to be correct.
2. Student answers should reflect the following equations:

   % of Sun's energy from 1st trophic level = (% of energy from producers in kJ)(0.02)(0.10) = A

   % of Sun's energy from 2nd trophic level = (% of energy from primary consumers) (0.02)(0.10)(0.10) = B

   % of Sun's energy from 3rd trophic level = (% of energy from secondary consumers) (0.02)(0.10)(0.10)(0.10) = C

   % of Sun's energy from 4th trophic level = (% of energy from tertiary consumers) (0.02)(0.10)(0.10)(0.10)(0.10) = D

   Total % of Sun's energy = A + B + C + D

   Final answers should be given as a percentage.

   (Note: Some student answers may also include decomposers in their food chains)
3. Students who assimilated the largest percentage of the Sun's energy will have consumed most of their food from the first trophic level. Students who assimilated the lowest percentage of the Sun's energy will have consumed most of their food from higher trophic levels.
4. The longest food chains will probably have four or five trophic levels. Students would assimilate more of the Sun's energy if their food chains were shorter, not longer.

Answer to Extension Question

5. A vegetarian-diet would allow more people to be fed while using less land and water resources.

Assessment Options

- Collect student Procedure calculations and food web drawings for marking.
- Collect student answers to Analysis and Extension questions for marking.

Biology File: Web Link

Student Textbook page 24

Research for the Northern River Basins Study was shared by eight component areas, one of which was traditional knowledge. Additional information may be found in the transcript from the third national science meeting of The Ecological Monitoring and Assessment Network: Traditional Knowledge Research; Uses, Effects, Applications and Choices found at http://www.eman-rese.ca/eman/reports/publications/nm97_abstracts/part-6.htm

Answer to Question for Comprehension

Student Textbook page 24

Q18. A pyramid of energy depicts the total amount of energy that is transferred through each trophic level. This differs from a pyramid of numbers, which depicts the total number of organisms found in each trophic level. Similarly, it differs from a pyramid of biomass, which depicts the relative dry mass, in grams per square metre, of organisms in each trophic level. Unlike a pyramid of numbers or a pyramid of biomass, a pyramid of energy is always upright, because there can never be more energy in a higher trophic level than in a lower trophic level.

Thought Lab 1.2: Energy Fluctuation in an Ecosystem

Student Textbook page 25

Purpose

Students will analyze the food sources of an Arctic species to figure out what factors might be causing its population to decline.

Outcomes

- 20-A1.3s

Advance Preparation

When to Begin	What to Do
1 day before	■ Photocopy **BLM 1.2.14 (OH) Stellar Sea Lion Range** if using as a handout instead of an overhead. ■ Photocopy **BLM 1.2.13 (HAND) Thought Lab 1.2: Energy Fluctuation in an Ecosystem**

Time Required

1 period

Helpful Tips

- Use **BLM 1.2.13 (HAND) Thought Lab 1.2: Energy Fluctuation in an Ecosystem** 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 1.2.13A (ANS) Thought Lab 1.2: Energy Fluctuation in an Ecosystem Answer Key.**
- Use **BLM 1.2.14 (OH) Stellar Sea Lion Range** to show students the where stellar sea lions are typically found in the world's oceans.

Answers to Analysis Questions

1. The higher the energy content of the food, the more likely that the sea lion will increase in body size.
2. Small, unhealthy sea lions are less likely to produce healthy offspring, may be less likely to mate, and may be

more likely to be consumed by predators or succumb to disease.

3. The sea lion population size is decreasing and fewer pups are being born; pups are not receiving the nourishment they require and are not surviving after birth; malnourishment of female sea lions is decreasing the number of healthy pups brought to term. Students may also suggest other factors such as climate change, increased predation, getting caught in fishnets, etc. Accept any two reasonable answers.
4. Students' food webs should consist of a main food chain that shows kelp at the first trophic level, sea urchins at the second trophic level, otters at the third trophic level, and orcas at the fourth trophic level. The food webs should also have a branch that includes sea lions in the third trophic level, and may include fish, zooplankton, and phytoplankton in the lower trophic levels (optional). All trophic levels or producer/consumer levels should be labelled. Answers must also explain that if orcas change their diet to consume fewer sea lions and more otters, the otter population would decrease, causing an increase in the sea urchin population (that the otters consume). The larger sea urchin popualation would eat more kelp, and the kelp population would decrease as a result.

Assessment Option

- Collect student answers for marking.

Investigation 1.C: Ecology of an Endangered Prairie Ecosystem

Student Textbook page 26

Purpose

Working in groups, students will research of the ecology of the prairie ecosystem and one of the endangered species found there. Students will present their findings in a presentation to the class.

Outcomes

- 20-A1.3s
- 20-A1.4s

Advance Preparation

When to Begin	What to Do
1 week before	■ Book computer and library resources for student research
1 day before	■ Check to make sure computer, screen, and projector are working properly for computer slide show presentations (if using) ■ Photocopy **BLM 1.2.15 (HAND) Investigation 1.C: Ecology of an Endangered Prairie Ecosystem**

Time Required

- 1 period for student research
- 1 period to complete food webs and analysis
- 1 period for presentations

Helpful Tips

- Use **BLM 1.2.15 (HAND) Investigation 1.C: Ecology of an Endangered Prairie Ecosystem** 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 1.2.15A (ANS) Investigation 1.C: Ecology of an Endangered Prairie Ecosystem Answer Key.**
- Introduce cost/benefit analysis to help students answer the Extension question.

Answers to Analysis Questions

1. Factors threatening the existence of the prairie ecosystem may include use of land for agriculture or urban development, pollution, and atmospheric changes and climate change. Factors threatening the existence of students' endangered species may include the above, as well as habitat fragmentation, loss of breeding grounds, hunting/predation, disease, and lack of food. Other answers may also be acceptable.
2. The loss of a species will have repercussions throughout the food web. Such extinction would likely increase the population of species in the trophic level below, as the extinct species would no longer be feeding upon these species. This effect will be greater if the extinct species in the higher trophic level had consumed the species at the lower trophic level as its main food source. Similarly, such extinction would likely decrease the population of species in the above trophic level since the species in this trophic level would have less to consume. This effect will be greater if the extinct species was the primary food source of the species at the higher trophic level. A wider menu selection means that consumers are less likely to be affected by a decrease in one of their food sources. As a further result of such extinction, the species at the higher trophic level may in turn change their diet to consume other species, altering the food web further. As a result of

these changes, energy transfer would follow a different path through the food web.

3. In general, the more diverse the pathways of energy transfer, the greater the stability of an ecosystem. This is the case because, when organisms have more diverse feeding habits, a population change or extinction of one species is less likely to lead to population change or extinction of other species that depend on it as their primary source of food. Similarly, a population change or extinction of one species is less likely to lead to a population boom in its major prey species if other species are also consuming that species as prey. Changes to the food web students hypothesized in Procedure step 2 may affect the endangered prairie ecosystem by decreasing the stability of the ecosystem as indicated above. Students should give specific examples where possible.
4. Accept any answers that make specific references to students' research findings and provide a well-reasoned explanation.

Answer to Extension Question

5. Answers should consider the pros and cons (benefits and costs), feasibility of the action plan, and how it would be carried out.

Assessment Options

- Evaluate student food webs and presentations.
- Collect student answers to Analysis and Extension questions for marking.
- To assess group performance, use Assessment Checklist 3 Performance Task Self-Assessment and/or Assessment Checklist 4 Performance Task Group Assessment. (See Appendix A.)

Section 1.2 Review Answers

Student Textbook page 27

1. Producers, specifically photosynthetic species, are the only organisms that can directly capture energy from the Sun. Students may add that chemosynthetic species are the only organisms that can directly capture energy from inorganic molecules. It is the producers that anchor a food web: there cannot be any consumers if there are no producers.
2. Fungi are decomposers. They feed at all trophic levels on waste matter, such as feces, dead bodies, and dead plant matter. In the process, fungi recycle inorganic and organic matter, making it available to all organisms to use for growth, maintenance, and to make energy-rich molecules.
3. The food chain should be linear and should include phytoplankton at the first trophic level (producer), zooplankton at the second trophic level (primary consumer), smaller fish such as sardines at the third trophic level (secondary consumer), and tuna at the fourth trophic level (tertiary consumer). Students may also include humans in the trophic level above tuna. All trophic levels or producer/consumer levels should be labelled.
4. Answers should consist of or a non-linear food web. It should include chemosynthetic bacteria at the first trophic level (producer), tubeworms and mussels at the second trophic level (primary consumer), and crabs and fish at the third trophic level (secondary consumer). All trophic levels or producer/consumer levels should be labelled.
5. Ash in the atmosphere will reflect sunlight, and therefore less radiant energy from the Sun will reach the pond. Since the photosynthetic producers in the pond will receive less energy from the Sun, they will grow less. As a result, less food will be available to the fish that feed on the producers, which may limit the size of the fish population.
6. **(a)** The pyramid of numbers will be upright and each step should be to scale. The bottom step, representing 4×10^9 phytoplankton will be very large compared to the upper levels of 11 herbivorous fish and one carnivorous fish. All population numbers should be labelled on the pyramid.
   (b) The pyramid of biomass will also be upright and each step should be to scale. Students must approximate masses of phytoplankton and fish and should label these approximations on their pyramid of biomass. For example, one phytoplankton may have a mass of 0.01 g while the fish could weigh 10 g. Accept any reasonable approximation. Note that students may be confused to learn that the pyramid of biomass is not inverted, as this is an aquatic ecosystem. Remind them that not all aquatic ecosystems show an inversion. An inversion typically occurs when zooplankton (not present in this hypothetical ecosystem) consume phytoplankton at such a fast rate that their biomass remains low.
7. The unit area in a measure of biomass provides a basis of comparison and could be considered a controlled variable. Without including the unit area, comparisons of dry weight would be meaningless.
8. **(a)** A decrease in the population size of species in a lower trophic level could limit the food supply of species found in higher trophic levels and decrease their population size. This effect will be greater if the species in the higher trophic level consumed the species at the lower trophic level as their main food source. Conversely, an increase in the population size of species found in a lower trophic level could expand the food supply of higher trophic levels, allowing the population size of species to expand at this level. If enough energy is available, the ecosystem may be able to support a larger number of trophic levels.
   (b) As the numbers of organisms in higher trophic levels increase, they will consume more food. The more

tertiary consumers there are, for example, the more secondary consumers will be consumed. If the organisms in the higher trophic level consume too many of the organisms in the lower trophic level, the population size of the species in both trophic levels may decline. This could lead to further changes (both increases and decreases) in the number of organisms found in lower trophic levels. For example, if orca (tertiary consumers) eat too many otters (secondary consumers), the number of sea urchins (primary consumers) will increase, and the kelp population (producers) would decrease. Similarly, if the number of organisms in higher tropic levels decreases (i.e., if a decreasing orca population eats fewer otter), species in the lower tropic levels could also be affected.

9. Primary consumers can reduce the amount of photosynthesis in a community when a situation occurs in which they consume a larger than normal amount of photosynthetic producers (i.e. plants or phytoplankton). For example, such a situation could occur if the number of secondary consumers declined, resulting in a subsequent increase in the number of primary consumers. Students should identify a hypothetical example; there are many possibilities.

10. (a) 1 metric tonne (t) = 1000 kg

$$\frac{300\text{ t} \times 1000\text{ kg}}{1\text{ t}} = 3 \times 10^5\text{ kg per year}$$

As one cow needs 7.7 kg of grain per day, it requires

$$(7.7\ \frac{\text{kg}}{\text{d}})(365\ \frac{\text{d}}{\text{yr}}) = 2810.5\ \frac{\text{kg}}{\text{yr}}$$

$$\frac{3 \times 10^5\ \frac{\text{kg}}{\text{yr}}}{2810.5\ \frac{\text{kg}}{\text{yr}}} = 106.74\text{ (animals)}$$

Thus the one square kilometre field can support approximately 107 animals per year (100 to correct significant digits).

(b) Correction to first printing of first edition of student text: Grain contains 14 190 $\frac{\text{kJ}}{\text{kg}}$, not 141 900 $\frac{\text{kJ}}{\text{kg}}$. Amount of energy produced by one square kilometre grain field:

$$(3 \times 10^5\text{ kg})(14\ 190\ \frac{\text{kJ}}{\text{kg}}) = 4.257 \times 10^9\text{ kJ}$$

As the average person needs a minimum of 2400 $\frac{\text{kJ}}{\text{day}}$, this person requires 876 000 $\frac{\text{kJ}}{\text{year}}$:

$$\left(\frac{2400\text{ kJ}}{\text{d}}\right)\left(\frac{365\text{ d}}{1\text{ yr}}\right) = 876\ 000\ \frac{\text{kJ}}{\text{year}}$$

$$(4.257 \times 10^9\text{ kJ})\left(\frac{1\text{ person}}{876\ 000\ \frac{\text{kJ}}{\text{year}}}\right) =$$

$$4859.6\ \frac{\text{people}}{\text{yr}}$$

Thus the field can support approximately 4860 people per year if people ate only grain (5×10^3 people per year to correct significant digits.)

(c) From part a, field can support: 106.74 animals $\times$

$$\frac{500\text{ kg}}{1\text{ animal}} = 53\ 370\text{ kg}$$

Energy in beef: $(53\ 370\text{ kg})(13\ 900\ \frac{\text{kJ}}{\text{kg}}) = 7.418 \times 10^8\text{ kJ}$

$$(7.418 \times 10^8\text{ kJ})\left(\frac{1\text{ person}}{876\ 000\text{ kJ}}\right) = 846.85\text{ people}$$

Thus, the field can support about 847 people per year if people ate only beef (8×10^2 people per year to correct significant digits).

(d) Using farmland for growing grain would support more people than using farmland for grazing cattle. One disadvantage to assuming that growing grain is the most efficient use of farmland is that it fails to take into account that some land is more suitable to grazing cattle than growing grain. Further, it fails to take into account whether there are enough water resources to grow the grain or enough people available to harvest it, and other issues such as whether farmers can afford fertilizers for the grain, or whether there is a pest issue that might affect the success of the crop.

Connections (Social and Environmental Contexts)

Biomagnification: A Fish Story

Student Textbook page 28

Teaching Strategies

- **BLM 1.2.16 (OH) Table: Concentration of Methylmercury in Aquatic Organisms** can be used to discuss the methylmercury level of fish with students as a class.
- **BLM 1.2.17 (HAND) Biomagnification Activity: DDT in the Ecosystem** and **BLM 1.2.17A (ANS) Biomagnification Activity: DDT in the Ecosystem Answer Key** provide an extra activity that enables students to further explore biomagnification as they consider the accumulation of DDT in a marine ecosystem.
- Remind students that elemental mercury is the form of mercury that is released as a pollutant to the environment. Micro-organisms in aquatic systems then convert elemental mercury into methylmercury, which then accumulates in organisms. Some students may confuse these two compounds.

Answers to Questions

1. The food web should include phytoplankton, zooplantkton, and any number of vegetarian or predatory fish as long as the methylmercury ppm values increase linearly. For example, one food web may include phytoplankton (0.0109 to 0.176 ppm), zooplankton (0.0110 to 0.376 ppm), shrimp (0.01 ppm), sardines (0.02 ppm), and tuna (0.12 ppm). Trophic levels or producer/consumer levels should be labelled.

2. **(a)** $1 \text{ ppm} = 1\,\frac{\text{mg}}{\text{kg}} \therefore 0.01\text{ppm} = 0.01\frac{\text{mg}}{\text{kg}}$

[methylmercury] in 0.2 kg shrimp = $(0.01\frac{\text{mg}}{\text{kg}})$ (0.2 kg) = 0.002 mg

(b) 0.004 mg;

(c) 0.0904 mg

3. Because methylmercury interferes with brain development of the fetus, Health Canada has set an allowable limit of 0.5 ppm of methylmercury in commercial fish. This limit does not apply to large predatory fish, such as shark, however. Since shark contains 0.99 ppm of methylmercury, Health Canada advises that pregnant women do not consume it more than once a month.

4. Fish consumption advisories could provide limits for consumption of fish that are specifically for people who eat higher amounts of fish in their diet (these limits would be lower than those meant for people who only eat fish on occasion).

5. Actions to reduce methylmercury in the environment focus on reducing the amount of mercury entering the environment. Proper disposal of wastes, such as batteries, fluorescent lamps, and hospital wastes, as well as the addition of specialized filters on coal burning facilities are several ways to lower the levels of mercury entering the environment.

Chapter 1 Review Answers

Student Textbook pages 30–31

Answers to Understanding Concepts Questions

1. Like other decomposers, mushrooms do not make organic compounds from inorganic molecules. Mushrooms use organic material from dead producers and consumers to make energy-rich organic molecules, and are thus classified as heterotrophs.

2. Producers around thermal vents use the chemical energy from hydrogen sulfide to produce necessary organic molecules by chemosynthesis.

3. Food chains are limited in length because very little energy (5–20%) is transferred from one step of a food chain to the next.

4. **(a)** Ecologists use the “rule of 10,” a rough approximation of the amount of energy that moves from one trophic level up to the next.

(b) The assumption is useful for getting an overall picture of energy transfer in an ecosystem. The rule is an oversimplification, however, because the efficiency with which energy is transferred from one trophic level to the next varies among species from 5–20%.

5. Weather patterns in the Arctic are changing; the sea ice is unusually thin in areas; the spring melt season is starting earlier in the year. Students might also suggest changing patterns of plant growth and distribution of animal populations.

6. Not all of the solar energy that reaches Earth’s atmosphere is converted to chemical energy because only some of the solar energy reaches Earth’s surface, the rest is reflected or absorbed by clouds and the atmosphere. Of the energy that reaches Earth’s surface, some is further reflected and absorbed by water, land, ice, and vegetation. Further, photosynthesis is not 100% efficient (some energy is given off as heat).

7. A food web shows the interconnectedness of trophic levels better than a food chain. Neither a food chain nor a food web, however, gives a quantitative representation of the energy transferred. A pyramid of biomass would more accurately show the transfer of energy than a pyramid of numbers, especially since some types of vegetation would be difficult to count as individuals.

8. Sea otters eat sea urchins, which feed on kelp. As sea otter numbers decline due to predation by transient orcas, the sea urchin numbers will go up because there are fewer otters to prey upon them. As the sea urchin population increases, there are more sea urchins to graze upon the kelp, and its population will decline.

9. **(a)** Many species have varied diets and therefore feed at more than one trophic level. Bears, for example, eat plants and animals. Decomposers, such as mushrooms, may consume nutrients at any trophic level.

(b) When consumers have one food source, if anything happens to their food source, the consumers may starve. The loss of these consumers will have further repercussions throughout the food web on species that consume them. A wider menu selection means that consumers are less likely to be affected by a decrease in one of their food sources.

10. Decomposers are heterotrophic and feed on all trophic levels and obtain energy and carbon from organic molecules. Producers, however, are the first step in the transfer of energy in the biosphere. Producers get energy from sunlight (or inorganic molecules, in the case of chemosynthetic organisms), and thus occupy the lowest level of a food chain.

Answers to Applying Concepts Questions

11. **(a)** Pyramids make useful models because the size of each step in the pyramid can be used to represent the number of organisms, biomass, or energy found in each trophic level. Because of the rule of 10 there tends to be smaller number of organisms, biomass, or energy in each successvie step resulting in a pyramid shape.

(b) Pyramids of numbers represent the relative numbers of organisms per trophic level; pyramids of energy represent the total amount of energy that is transferred through each trophic level; and pyramids of biomass represent the amount of dry mass of living or once living tissue in each trophic level, usually in g/m^2. Pyramids of energy, unlike pyramids of numbers or pyramids of biomass, cannot be inverted.

12. Winters in southern Alberta are generally cold and dry, which prevents prairie grasses from growing. Summer droughts can also limit the growth of prairie grasses.

13. A lynx would expend considerable energy to capture its prey, the snowshoe hare, while the snowshoe hare would not have to expend much energy to eat the grass.

14. Of the 200 J in the caterpillar's food, 100 J go to feces and 63 J are used in cellular respiration: 100 J + 63 J = 163 J, and $\frac{163 \text{ J}}{200 \text{ J}}$ = 81.5%. This energy is not available to the next trophic level.

15. The phytoplankton grows and reproduces at a rate that far exceeds that of the zooplankton. However, the phytoplankton are eaten by zooplankton as quickly as they reproduce. As a result, their biomass is lower than that of the zooplantkton and the pyramid of biomass appears inverted.

16. The pyramid of numbers for a grassland ecosystem is upright because numerous individual plants (represented by a wide base) support the primary consumers. The pyramid of numbers for a northern boreal forest is inverted because individual trees (represented by a narrow base) can support numerous consumer organisms.

17. (a) For Ecosystem A, students should create one upright pyramid of biomass, with decomposers shown to the side, and one upright pyramid of numbers. All producer/consumer levels should be labelled on each pyramid and the width of each tier should be approximately proportionate to the biomass and number of organisms, respectively. For Ecosystem B, students should create an inverted pyramid of biomass. Producers (phytoplankton) and primary consumers (zooplankton) should be labelled on the pyramid. The width of each tier should be approximately proportionate to the biomass.

(b) Using a pyramid of biomass enables biologists to overcome limitations of pyramids of numbers such as size variances (e.g., one dandelion would carry the same producer status as one tree) and difficulties representing differences in numbers of organisms at different trophic levels (e.g., a single secondary consumer compared with billions of primary consumers). A disadvantage might be the difficulty in obtaining suitable samples to estimate dry mass with sufficient accuracy. Accept all reasonable answers.

18. Relevant traditional knowledge of the taiga could include the changes in the relative abundance of game and other species over time, the ages of organisms (number of young versus aging organisms), weather patterns and vegetation through the seasons, number or presence of certain species of insects, number of trophic levels (for example, a top carnivore is no longer hunting in a certain region), and so forth.

19. (a) (mass of strawberries)(0.10) = 1 kg

mass of strawberries = 10 kg

(b) (mass of plant material)(0.10)(0.10)(0.10) = 1 kg

mass of plant material = 1000 kg

Answers to Making Connections Questions

20. (a) With each energy transfer in a food chain, some energy is converted to an unusable form, such as heat. This energy is lost to the next trophic level. Using the rule of 10, only about 10% of the energy in one trophic level is transferred to the next trophic level. When people eat a mainly grain-based diet, there is just one energy transfer between two trophic levels. When people eat a mainly meat-based diet, two or more energy transfers occur between three or more trophic levels. Energy is lost in each of these transfers. As such, cropland used to raise livestock, such as cattle, only produces 10% of the useable energy that cropland used to grow grain does. This means that it takes less cropland (about 10 times less) to feed people a grain-based diet than it does to support enough livestock to feed the same number of people a meat-based diet. Food chains supporting student answers should include a comparison of the amount of the Sun's energy available to humans eating a grain-based diet versus a meat-based diet. For a grain-based food chain, grain will be at the first trophic level and humans at the second. Grain will assimilate 2% of the Sun's energy and humans will assimilate 0.2% of the Sun's energy. For a meat-based diet, food chains will depict more trophic levels depending on the type of meat eaten (beef, fish, etc.). For a food chain in which beef is consumed, grain will occupy the first trophic level, cattle the second, and humans the third. Grain will assimilate 2% of the Sun's energy, cattle 0.2%, and humans 0.02%.

(b) First, humans are a part of various food webs. Traditionally, some people—the Inuit, for example—are hunters and fishers. If these people stopped all hunting and fishing, it is possible that the stability of the food webs they are part of would be reduced. Second, not all land is suitable for growing crops. People living in colder climates, in particular, might be challenged to grow enough crops over the short summers.

21. If less prey is available to this orca population, less energy will be available to them as top predators of the marine food chain. If less prey is available to the orca's main prey species, these species may decrease in body size or in number of organisms, indirectly leading to less energy transfer to the orca as well. While toxic chemicals, such as PCBs, would adversely affect animals at all trophic levels, some may be more susceptible to pollutants than others. If the orcas' prey is more susceptible to pollutants, they may again decrease in size or number, resulting in less energy transfer to the orca. The same holds true if the primary food source of the orcas' main prey species decreases in size or number due to pollutants. Toxic chemicals, may especially affect orcas themselves, since PCBs and similar pollutants biomagnify in the food chain, reaching their highest concentration in top carnivores. Increase in commercial and private vessels may also stress the marine ecosystem, possibly resulting in changes in energy transfer similar to those stated above.

CHAPTER 2 CYCLES OF MATTER

Curriculum Correlation

General Outcome 2 Students will explain the cycling of matter through the biosphere.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
20–A2.1k explain and summarize the biogeochemical cycling of carbon, oxygen, nitrogen, and phosphorus, and relate this to general reuse of all matter in the biosphere	Section 2.2: Biogeochemical Cycles, pp. 42-52	Q questions 6, 7, p. 43 Figure 2.11 question, p. 43 Q question 8, p. 44; 9, p. 46 Web Link: Winogradsky column, p. 47 Q questions 11, 12, p. 48; 13, 14, p. 49; 15, 16, p. 50 Section 2.2 Review: 1-8, p. 52 Section 2.3 Review: 9(a), p. 61 Chapter 2 Review: 1, 3, 6, 7, 10, 11, 12, 13, 17, p. 64 Unit 1 Review: 5, p. 68; 11, 17, p. 69; 33(b), p. 71 Chapter 2 Test
20–A2.2k explain water's primary role in the biogeochemical cycles, using its chemical and physical properties, i.e., universal solvent, hydrogen bonding	Section 2.1: The Role of Water in Cycles of Matter, pp. 34-40 Thought Lab 2.1: Water Gains and Losses, p. 38	Q question 1, p. 36; 2, p. 37 Thought Lab 2.1: Analysis 1-3, p. 38 Q questions 3-5, p. 39 Web Link: Dr. David Schindler, p. 39 Section 2.1 Review: 1-7, p. 40 Chapter 2 Review: 2, 14, 18, p. 64 Unit 1 Review: 10, 14, p. 69 Chapter 2 Test
Outcomes for Science, Technology, and Society (Emphasis on social and environmental contexts)		
20–A2.1sts explain that science and technology have both intended and unintended consequences for humans and the environment by **(STS3)**	Launch Lab: Whose Planet?, p. 33 Connections: Phytoremediation, p. 62	Launch Lab, Analysis 1-2, p. 33 Chapter 2 Test
■ *discussing the influence of human activities on the biogeochemical cycling of phosphorus, sulfur, iron, and nitrogen, e.g.,* *- feedlot operations* *- composting* *- fertilizer applications* *- waste and sewage disposal* *- vehicular and refinery emissions* *- acid deposition* *- persistent organic pollutants*	Thought Lab 2.2: Carbon, Sulfur, and Iron, p. 48	Web Link: CO_2 consumption, p. 44 Q question 10, p. 46 Thought Lab 2.2: Analysis 1-4, p. 48 Section 2.2 Review: 7(b), 8(b), p. 52 Section 2.3 Review: 8, p. 61 Chapter 2 Review: 8, 12, p. 64; 20, p. 65 Unit 1 Review: 11, p. 69; 24, 28, p. 70; 33(a), p. 71
■ *discussing the use of water by society, the impact such use has on water quality and quantity in ecosystems, and the need for water purification and conservation, e.g.,* *- manufacturing and processing* *- oil industry* *- agricultural systems* *- mining industry* *- domestic daily water consumption*	Investigation 2.A: Societal Uses of Water, p. 41 Investigation 2.C: What's in the Water?, p. 51	Section 2.1 Review: 8, 9, p. 40 Investigation 2.A: Gath. Data and Info. 1; Op. and Rec. 1-4, p. 41 Investigation 2.C: Conclusion 4-5, Ext. 6, p. 51 Chapter 2 Review: 21, 22, p. 65 Unit 1 Review: 36, p. 71
■ *analyzing the relationship between heavy metals released into the environment and matter exchange in natural food chains/webs, and the impact of this relationship on the quality of life*	Connections: Phytoremediation, p. 62	Connections: 6, p. 62 Unit 1 Review: 31, p. 70

	Student Textbook	Assessment Options
Skill Outcomes (Focus on scientific inquiry)		
Initiating and Planning		
20–A2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by		Chapter 2 Review: 19, p. 64 Thought Lab 2.2: Analysis 1-4, p. 48
■ designing an experiment to compare the carbon dioxide production of plants with that of animals **(IP–NS1, 2, 3, 4, 5) [ICT C7–4.1]**	Investigation 2.B: Carbon Dioxide Production in Plants and Animals, pp. 44-45	Investigation 2.B: Exp. Plan 1-3, p. 45
■ hypothesizing how alterations in the carbon cycle as a result of the burning of fossil fuels might interact with other cycling phenomena, e.g., sulfur, iron, water **(IP–NS3) [ICT C6–4.1]**		
■ predicting disruptions in the nitrogen and phosphorus cycles that are caused by human activities **(IP–NS3) [ICT C6–4.1]**	Thought Lab 2.2: Carbon, Sulfur, and Iron, p. 48 Investigation 2.C: What's in the Water?, p. 51	Q question 17, p. 50 Investigation 2.C: Conclusion 4-5, p. 51 Chapter 2 Review: 20, p. 65
Performing and Recording		
20–A2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by	Investigation 2.B: Carbon Dioxide Production in Plants and Animals, pp. 44-45	Investigation 2.B: Data and Obs. 4, p. 45
■ measuring and recording the pH and the amount of nitrates, phosphates, iron, or sulfites in water samples within the local area **(PR–NS2, 3, 4) (PR–STS 1) [ICT P2–4.1]**	Investigation 2.C: What's in the Water?, p. 51	Investigation 2.C: Procedure 1-4, p. 51
Analyzing and Interpreting		
20–A2.3s analyze data and apply mathematical and conceptual models to develop and address possible solutions by	Investigation 2.A: Societal Uses of Water, p. 41 Investigation 2.B: Carbon Dioxide Production in Plants and Animals, pp. 44-45	Investigation 2.B: Analysis 1-3, Conclusion 4-6, Ext. 7, p. 45 Unit 1 Review: 20, p. 69 Chapter 2 Test
■ analyzing data collected on water consumption and loss in plants and animals **(AI–NS2, 3, 4) [ICT C7–4.2]**	Thought Lab 2.1: Water Gains and Losses, p. 38	Thought Lab 2.1, Procedure 2-3, Analysis 1-5, p. 38
Communication and Teamwork		
20–A2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by ■ *working cooperatively in a group to investigate the influence of human activities on the biogeochemical cycles and, using appropriate multimedia, presenting the information to a group* **(CT–STS1, 2, 3, 4) [ICT C1–4.1, P6–4.1]**	Launch Lab: Whose Planet?, p. 33 Investigation 2.A: Societal Uses of Water, p. 41	Launch Lab: Procedure 1, p. 33 Investigation 2.A: Gath. Data and Info. 1; Org. Find. 2, p. 41

General Outcome 3: Students will explain the balance of energy and matter exchange in the biosphere, as an open system, and how this maintains equilibrium.

	Student Textbook	Assessment Options
Outcomes for Knowledge		
20–A3.1k explain the interrelationship of energy, matter and ecosystem productivity (biomass production), e.g., ■ *Antarctic ocean versus tropical seas* ■ *tropical rainforest versus desert* ■ *taiga versus tundra* ■ *intertidal zone versus deep-sea benthos* ■ *Arctic versus Antarctic*	Section 2.3: The Balance of the Matter and Energy Exchange, pp. 53-58	Web Link: Gaia Hypothesis, p. 55 Section 2.3 Review: 1-6, 9(b), p. 61 Chapter 2 Review: 15, p. 64 Unit 1 Review: 12, p. 69; 30, p. 70
20–A3.2k explain how the equilibrium between gas exchanges in photosynthesis and cellular respiration influences atmospheric composition	Section 2.2 The Carbon and Oxygen Cycles, pp. 43-44 The Slow Cycling of Carbon, pp. 44-46	Chapter 2 Review: 16, p. 64 Unit 1 Review: 19, p. 69; 27, p. 70
20–A3.3k describe the geological evidence (stromatolites) and scientific explanations for change in atmospheric composition, with respect to O_2 and CO_2, from anoxic conditions to the present and the significance to current biosphere equilibrium	Section 2.3 The Biosphere in Balance, pp. 55-57	Section 2.3 Review: 7, p. 61 Chapter 2 Review: 9, p. 64 Unit 1 Review: 13, 22, p. 69
Outcomes fro Science, Technology and Society (Emphasis on social and environmental contexts)		
20–A3.1sts explain that science and technology are developed to meet societal needs and expand human capabilities by **(STS1)**	Thought Lab 2.3: Too Much of a Good Thing, p. 54 Thought Lab 2.4: Evaluating Water Treatments, p. 58 Career Focus: Ask a Sustainability Expert, pp. 66-67	Thought Lab 2.3: Analysis 4, p. 54 Thought Lab 2.4: Analysis 1-2, p. 58 Career Focus: 1-3, p. 67
■ *evaluating the technology of a closed system in terms of energy and matter, e.g.,* *- space stations and spaceships* *- Biosphere experiments* *- manned exploration of Mars surface*	Investigation 2.D: Biosphere in a Bottle, p. 57 Thought Lab 2.5: Design a Self-Sustaining Mars Colony, p. 60	Investigation 2.D: Analysis 1-7, p. 57 Thought Lab 2.5: Procedure 1-2, Analysis 1-5, p. 60 Unit 1 Review: 23, p. 69
20–A3.2sts explain that science and technology have both intended and unintended consequences for humans and the environment by **(STS3)** ■ *describing how human activities can have a disrupting influence on the balance, in the biosphere, of photosynthetic and cellular respiratory activities, e.g.,* *- fossil fuel combustion* *- depletion of stratospheric ozone* *- forest destruction*	Thought Lab 2.3: Too Much of a Good Thing, p. 54	Thought Lab 2.3: Analysis 2-3, p. 54 Chapter 2 Review: 25, p. 65 Unit 1 Review: 35, p. 71
Skill Outcomes (Focus on decision making)		
Initiating and Planning		
20–A3.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by *predicting the effects of changes in carbon dioxide and oxygen concentration on the atmospheric equilibrium due to factors such as significant reduction of photosynthetic organisms, combustion of fossil fuels, and agricultural practices **(IP–NS3)** **[ICT C6–4.1]**	Investigation 2.D: Biosphere in a Bottle, p. 57 Thought Lab 2.5: Design a Self-Sustaining Mars Colony, p. 60	Investigation 2.D: Procedure 1, 3, Conclusion 9, p. 57 Thought Lab 2.5: Procedure 1-2, p. 60 Unit 1 Review: 6, p. 68; 16, p. 69; 35, p. 71

	Student Textbook	Assessment Options
Performing and Recording		
20–A3.2s 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 ■ *collecting evidence from various print and electronic sources on how human activities can have a disrupting influence on photosynthetic and cellular respiratory activities* **(PR–STS1, 2) [ICT C2–4.1]**	Investigation 2.D: Biosphere in a Bottle, p. 57	Investigation 2.D: Procedure 2-4, p. 57
Analyzing and Interpreting		
20–A3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by	Thought Lab 2.3: Too Much of a Good Thing, p. 54 Thought Lab 2.4: Evaluating Water Treatments, p. 58	Thought Lab 2.3: Analysis 2-4, p. 54 Thought Lab 2.4: Analysis 1-2, p. 58
■ designing and evaluating a model of a closed biological system in equilibrium with respect to carbon dioxide, water and oxygen exchange **(PR–ST2) (AI–ST1) [ICT C6–4.2]**	Investigation 2.D: Biosphere in a Bottle, p. 57 Thought Lab 2.5: Design a Self-Sustaining Mars Colony, p. 60	Investigation 2.D: Procedure 1-4; Analysis 1-7, p. 57 Thought Lab 2.5: Procedure 1-2, Analysis 1-5, p. 60
Communication and Teamwork		
20–A3.4s 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 as a group to investigate, synthesize and present information on the effects of changes to stratospheric ozone levels on society, agriculture, plants and animals* **(CT–STS1, 2, 3, 4) [ICT C2–4.1, P6–4.1]**	Investigation 2.D: Biosphere in a Bottle, p. 57 Thought Lab 2.5: Design a Self-Sustaining Mars Colony, p. 60	Investigation 2.D: Procedure 1, Analysis 7, p. 57 Thought Lab 2.5: Procedure 1-2, p. 60

Chapter 2

Cycles of Matter

Student Textbook pages 32–65

Chapter Concepts

2.1 The Role of Water in Cycles of Matter

- There is a finite amount of water, which is re-used through the hydrologic cycle.
- Water is a universal solvent of polar molecules.
- Water is essential to humans and ecosystems.
- The hydrologic cycle plays a central role in nutrient cycles (biogeochemical cycles).

2.2 Biogeochemical Cycles

- Carbon, oxygen, sulfur, and nitrogen are found in living organisms and in the land, atmosphere, and water. They are recycled through biotic and abiotic processes.
- Phosphorus is found in living organisms and in the land and water. It is recycled through biotic and abiotic processes.
- Disruptions in one biogeochemical cycle can affect another.

2.3 The Balance of the Matter and Energy Exchange

- Biotic and abiotic processes maintain the balance of matter and energy exchange in the biosphere.
- Natural processes and human activities can affect the transfer of energy and the cycling of matter through the biosphere.

Common Misconceptions

- Phosphate tends to be available in limited quantities in the environment compared to nitrogen. As a result, although an excess of either can cause an algal bloom, phosphorus is typically the limiting agent that acts as the trigger. Often students are subsequently left with the impression that phosphorus is the only nutrient that causes algal blooms.

Helpful Resources

Books and Journal Articles

- "Biogeochemical Cycles." *Science of Everyday Things: Real-life Biology.* Ed. Judson Knight and Neil Schlager. Vol. 4. Detroit: Thomson Gale, 2002. ISBN 0787656348
- Cross, Anne Fernald. "Biogeochemical Cycles." *Plant Sciences.* Ed. Richard Robinson. New York: Macmillan Reference USA, 2001.
- Brooks, Kenneth N. "Hydrologic Cycle." *Environmental Encyclopedia.* Ed. M. Bortman and P. Brimblecombe. 3rd ed. Detroit: Gale, 2003.
- "Open System." *Environmental Encyclopedia.* Ed. M. Bortman and P. Brimblecombe. 3rd ed. Detroit: Gale, 2003.

Web Sites

Web links to information about cycles of matter can be found at **www.albertabiology.ca**. Go to Online Learning Centre, and log on to the Instructor Edition. Choose Teacher Web links for the links to Chapter 2.

List of BLMs

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

Number (Type)

BLM 2.0.1 (HAND) Launch Lab: Whose Planet?
BLM 2.0.1A (ANS) Launch Lab: Whose Planet? Answer Key

BLM 2.1.1 (OH) The Hydrologic Cycle
BLM 2.1.2 (HAND) Hydrologic Cycle Activity
BLM 2.1.2A (ANS) Hydrologic Cycle Activity Answer Key
BLM 2.1.3 (OH) The Water Molecule
BLM 2.1.4 (OH) Crystalline Structures of Solid and Liquid Water
BLM 2.1.5 (HAND) Water Question and Answer Activity
BLM 2.1.5A (ANS) Water Question and Answer Activity Answer Key
BLM 2.1.6 (HAND) Thought Lab 2.1: Water Gains and Losses
BLM 2.1.6A (ANS) Thought Lab 2.1: Water Gains and Losses Answer Key
BLM 2.1.7 (HAND) Investigation 2.A: Societal Uses of Water
BLM 2.1.7A (ANS) Investigation 2.A: Societal Uses of Water Answer Key

BLM 2.2.1 (OH) Nutrient Reservoirs
BLM 2.2.2 (OH) Carbon and Oxygen Cycles
BLM 2.2.3 (HAND) Investigation 2.B: Carbon Dioxide Production in Plants and Animals
BLM 2.2.3A (ANS) Investigation 2.B: Carbon Dioxide Production in Plants and Animals Answer Key
BLM 2.2.4 (OH) Rapid and Slow Cycling of Carbon
BLM 2.2.5 (OH) The Sulfur Cycle
BLM 2.2.6 (HAND) Sulfur Cycle Activity
BLM 2.2.6A (ANS) Sulfur Cycle Activity Answer Key
BLM 2.2.7 (OH) Winogradsky Column
BLM 2.2.8 (HAND) Thought Lab 2.2: Carbon, Sulfur, and Iron
BLM 2.2.8A (ANS) Thought Lab 2.2: Carbon, Sulfur, and Iron Answer Key
BLM 2.2.9 (OH) The Nitrogen Cycle
BLM 2.2.10 (OH) Equations in the Nitrogen Cycle
BLM 2.2.11 (HAND) Nitrogen Cycle Activity
BLM 2.2.11A (ANS) Nitrogen Cycle Activity Answer Key
BLM 2.2.12 (OH) The Phosphorus Cycle

BLM 2.2.13 (HAND) Phosphorus Cycle Activity
BLM 2.2.13A (ANS) Phosphorus Cycle Activity Answer Key
BLM 2.2.14 (OH) Algal Bloom Diagram/Flow Chart
BLM 2.2.15 (HAND) Hydrologic and Biogeochemical Cycles Review Question and Answer Exercise
BLM 2.2.15A (ANS) Hydrologic and Biogeochemical Cycles Review Question and Answer Exercise Answer Key
BLM 2.2.16 (HAND) Investigation 2.C: What's in the Water?
BLM 2.2.16A (ANS) Investigation 2.C: What's in the Water? Answer Key

BLM 2.3.1 (OH) Table: Comparing Ecosystem Productivity
BLM 2.3.2 (OH) Major Biomes of the World
BLM 2.3.3 (HAND) Thought Lab 2.3: Too Much of a Good Thing
BLM 2.3.3A (ANS) Thought Lab 2.3: Too Much of a Good Thing Answer Key
BLM 2.3.4 (OH) Table: Composition of Earth's Atmosphere and Oceans
BLM 2.3.5 (OH) Concentration of Atmospheric Gases Over Time
BLM 2.3.6 (HAND) Investigation 2.D: Biosphere in a Bottle
BLM 2.3.6A (ANS) Investigation 2.D: Biosphere in a Bottle Answer Key
BLM 2.3.7 (HAND) Thought Lab 2.4: Evaluating Water Treatments
BLM 2.3.7A (ANS) Thought Lab 2.4: Evaluating Water Treatments Answer Key
BLM 2.3.8 (HAND) Thought Lab 2.5: Design a Self-Sustaining Mars Colony
BLM 2.3.8A (ANS) Thought Lab 2.5: Design a Self-Sustaining Mars Colony Answer Key

BLM 2.4.1 (HAND) Chapter 2 Test
BLM 2.4.1A (ANS) Chapter 2 Test Answer Key

Using the Chapter 2 Opener

Student Textbook pages 32-33

Teaching Strategies

- Use the Launch Lab: Whose Planet?

Launch Lab: Whose Planet?

Student Textbook page 33

Purpose

In partners or small groups, students will select a scenario and discuss their views and opinions concerning the rights of humans versus those of wildlife and/or the environment.

Outcomes

- 20–A2.1 sts
- 20–A2.4 sts

Time Required

- 15 minutes to introduce the assignment
- 30 minutes to carry it out

Helpful Tips

- Use **BLM 2.0.1 (HAND) Launch Lab: Whose Planet?** Remove sections as appropriate to meet the needs of the students in your class. The answers can be found on **BLM 2.0.1A (ANS) Launch Lab: Whose Planet? Answer Key.**
- Have the students read through the scenarios first alone to see if one has a particular appeal to them. From this point, they can discuss the issues within the group or with their partners to determine the environmental issue that they would like to explore.
- Introduce the concept of benefit/cost ratio in decision making with respect to environmental issues.
- The launch lab can also be completed as a series of debates.

Answers to Analysis Questions

1. and **2.** Accept any well-defended opinions that fully answer each question.

Assessment Options

- Collect student answers for marking or discuss in class.
- To assess group work, use Assessment Checklist 3 Performance Task Self-Assessment and/or Assessment Checklist 4 Performance Task Group Assessment. (See Appendix A.)

2.1 The Role of Water in Cycles of Matter

Student Textbook pages 34-41

Section Outcomes

Students will:

- explain water's primary role in the biogeochemical cycles as a result of its chemical and physical properties
- analyze data on water consumption and loss in plants and animals
- evaluate the use of water by society

Key Terms

biogeochemical cycles
hydrologic cycle
polar
hydrogen bond
cohesion
adhesion

Biology Background

- Water is essential to many of the homeostatic mechanisms that make human life possible. The control of body temperature, a feature of all birds' and mammals' metabolisms, is dependent on water's ability to resist temperature change (i.e., its specific heat). Cooling is aided by the body's excretion of water in the form of sweat, which removes energy from the body because water vapourizes at a high heat. Water is essential in digestion, as any food must be changed into a solution that can diffuse into the cells of the digestive tract. Transport of nutrients, oxygen, and carbon dioxide in the blood depends on water. Human cells are bathed in a close approximation of seawater called extra-cellular fluid (ECF). This is no surprise, as the biological processes that are common to all cells originated in primordial ocean waters.
- Water is not distributed evenly throughout Alberta. Northern Alberta, in general, has more of this natural resource, while the southern part of the province has less of it. Indeed, one early visitor to the province (John Palliser, 1857–1860) declared that one part of southern Alberta was so dry that it was unfit for human habitation.
- Tropical rain forests have a large diversity of tree species, unlike Alberta forests, which tend to be made up of large numbers of one or two predominant species. A large tropical forest can have up to 5000 species of trees, often 100 to 200 species per acre.

Teaching Strategies

- **BLM 2.1.1 (OH) The Hydrologic Cycle** can be used to refresh students' knowledge of the hydrologic cycle and the basics of evaporation, condensation, and precipitation. Transpiration (from *Science 10*) and the importance of ground water can be included. Alternatively, you may want to use **BLM 2.1.2 (HAND) Hydrologic Cycle Activity** and **BLM 2.1.2A (ANS) Hydrologic Cycle Activity Answer Key** to reactivate their prior learning. Have individual or groups of students draw and label the diagram of the hydrologic cycle provided, off the tops of their heads, without the use of outside resources. This should take less than half an hour. Discuss their results—the parts they included and the ones they missed.
- Use a series of demonstrations to show the effects of characteristics of water. Have students explain the meniscus of a graduated cylinder, surface tension, and the conversion of ice to steam.
- **Using BLM 2.1.3 (OH) The Water Molecule**, discuss the unequal sharing of electrons and the polar nature of the water molecule that results. This can be used as the opening of a discussion on what makes water unique and why that uniqueness is important to life. Include high specific heat, cohesion, adhesion, melting and boiling points of water, and hydrogen bonding.
- Use **BLM 2.1.4 (OH) Crystalline Structures of Solid and Liquid Water** to explain why ice floats and why water is densest at 4 °C. The changes in the structure of water and its implications for life may not be intuitive to students. As such, this may be an opportunity to point out to students the interconnections between chemistry, physics, and biology.
- **BLM 2.1.5 (HAND) Water Question and Answer Activity** and **BLM 2.1.5A (ANS) Water Question and Answer Activity Answer Key** can be given to students as a short quiz or as an in class review exercise at the end of Section 2.1.

Answers to Questions for Comprehension

Student Textbook page 36

Q1. Water has partial positive charges and partial negative charges. These partial charges attract oppositely charged ions. The partial positive charges of water's hydrogen atoms, for example, attract the negatively charged phosphate ions.

Student Textbook page 37

Q2. (a) It takes considerable energy to break the many hydrogen bonds between water molecules in a volume of water. As a result, water does not change from a liquid to a gas until about 100 °C. Similarly, water freezes at 0 °C. Over this wide temperature range, water remains a liquid and therefore able to dissolve and transport nutrients.

(b) Due to hydrogen bonding, water is most dense at 4 °C. In spring, water from melting ice on the lake surface warms to 4 °C and sinks, displacing cooler water. Similarly, as winter approaches and the warm lake water cools towards 4 °C, it becomes denser and sinks, displacing warmer water. As water sinks and rises, it cycles nutrients with it.

(c) Adhesion—hydrogen bonding between water molecules and molecules of other substances—causes water to cling to the inside surface of a plant's xylem. As water evaporates from a plant's leaves, more water is drawn up through the xylem because of cohesion—the attraction of water molecules to each other due to hydrogen bonding.

Thought Lab 2.1: Water Gains and Losses

Student Textbook page 38

Purpose

Students will get a chance to compare a typical human water budget with that of another animal—the kangaroo rat, which has a series of adaptations that allows it to live in arid conditions.

Outcomes

- 20–A2.3

Advance Preparation

When to Begin	What to Do
1 day before	■ Have the students read through the lab the night before and remind them to bring calculators to class. ■ Photocopy **BLM 2.1.6 (HAND) Thought Lab 2.1: Water Gains and Losses**

Time Required

1 period

Helpful Tips

- You can introduce this Thought Lab with a discussion of humanity's ability to survive in almost any environment on the planet. Ask students why some animals are found only in specific localities, while others exist in a wide range of climates. Ask for student suggestions of organisms that can exist in many different places. At the end of the lab, point out that adaptation to a specific locality is a double-edged sword. Adaptations that provide an advantage in one environment may actually hinder an organism in a different one.
- Use **BLM 2.1.6 (HAND) Thought Lab 2.1: Water Gains and Losses** 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 2.1.6A (ANS) Thought Lab 2.1: Water Gains and Losses Answer Key.**

Answers to Procedure Questions

2. (a) Water gain from metabolic water—human, 10%; kangaroo rat, 90%.

(b) Water gain from absorbed water—human, 90%; kangaroo rat, 10%.

3. (a) Total water loss from urine—human, 47.4% (50% using correct significant figures); kangaroo rat 22.5%.

(b) Total water loss from evaporation—human, 42.1% (40% using correct significant figures); kangaroo rat 73.2%.

Answers to Analysis Questions

1. Both organisms lose the largest percentage of water by evaporation (including breathing) and the lowest percentage through their feces. Water loss through urine is an intermediate percentage for both organisms.

2. Metabolic water makes up 90% of the kangaroo rat's water gain. Comparatively, a human only gains 10% of its water from metabolic water.

3. (a) The kangaroo rat is able to recycle water more efficiently from urine, feces, and metabolic water.

(b) Answers may include the following: the kangaroo rat sweats relatively little—it uses behavioural adaptations such as deep burrowing and nocturnal behaviour to stay cool; the kangaroo rat has a relatively long digestive tract to allow for more complete re-absorption of water from the digestive system; the kangaroo rat has very efficient kidneys that are able to reabsorb a great deal of water from the urine. Accept any reasonable answer.

4. 73.2% of the kangaroo rat's water loss occurs from evaporation, while a typical human loses 42.1%. By being active only at night when temperatures are cooler, the kangaroo rat is able to reduce water loss from evaporation. Students may note that the kangaroo rat loses a greater percentage of water through evaporation than a human does; however, a kangaroo rat lives in a much more extreme environment than the typical human.

5. (a) Carbohydrate: (620 g)(0.6) = 372 g; Fat: (20 g)(1.07) = 21.4 g; Protein: (110 g)(0.4) = 44 g

372 g + 21.4 g + 44 g + 104 g free water = 541.4 g

$$\frac{541.4\ \text{g}}{60.0\ \frac{\text{g}}{\text{d}}} = 9.02\ \text{d}$$

The cellular respiration of 1 kg of grain will release 541.4 g of water, sufficient to maintain a kangaroo rat for about 9 days.

(b) Carbohydrate: 0 g; Fat: (70 g)(1.07) = 74.9 g; Protein: (270 g)(0.4) = 108 g

74.9 g + 108 g + 656 g free water = 838.9 g

$$\frac{838.9\ \text{g}}{1900\ \frac{\text{g}}{\text{d}}} = 0.44\ \text{d}$$

The cellular respiration of 1 kg of steak will release 838.9 g of water. This should be sufficient water to maintain a human for 0.44 days.

Assessment Options

- Collect answers to Procedure and Analysis questions for marking
- Have students mark the answers in class and hand in results for recording.

Answers to Questions for Comprehension

Student Textbook page 39

Q3. Metabolic water is the water produced by cellular respiration.

Q4. Organisms gain water by eating, drinking, and absorbing water (animals through skin, plants through roots), and as a waste product of metabolism.

Q5. Organisms lose water via evaporation, including breathing and sweating in animals and transpiration in plants. Animals also lose water in feces and urine.

Biology File: Web Link

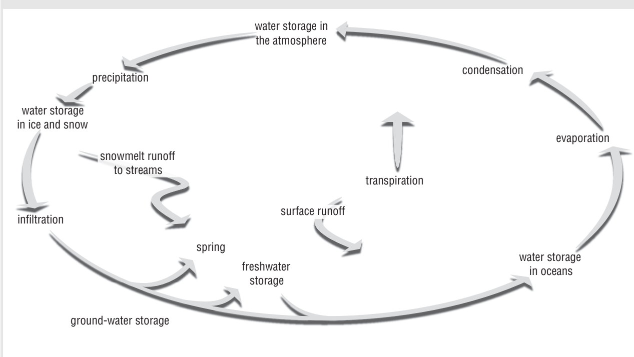
Student Textbook page 39

Dr. David Schindler has been and continues to be a serious researcher of and advocate for Earth's water resources. He is also a popular public speaker about sustainable use and management of water resources. Internationally, Dr. Schindler was acknowledged with the prestigious Tyler Award for Environmental Achievement in 2006 and is the recipient of other awards, including the Volvo International Environment Prize (1998) and the Stockholm Water Prize (1991). In Canada, Dr. Schindler's recognition includes the NSERC Award of Excellence in Research (2000), the Douglas Pimlott Award for Conservation (2001), the NSERC Gerhard Herzberg Gold Medal for Science and Engineering (2001), the Killam Prize (2003), the Order of Canada (2004), and the Alberta Centennial Medal (2005).

Section 2.1 Review Answers

Student Textbook page 40

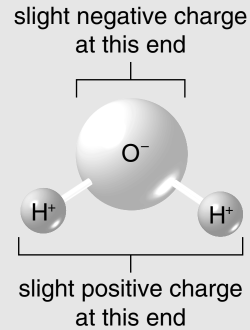
1. (a)



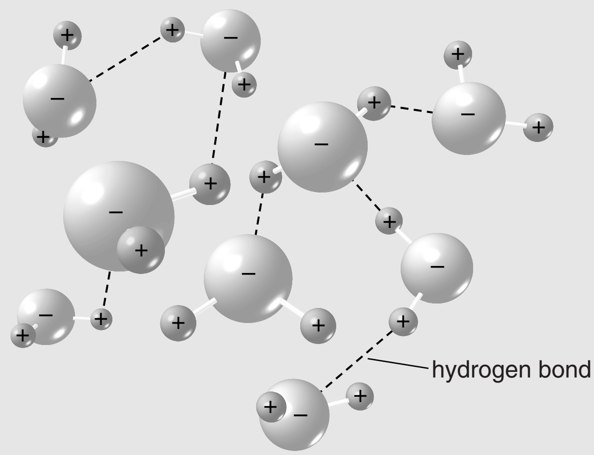
(b) The hydrologic cycle shows the pathway that water takes through the biosphere in clouds, precipitation, ice caps, rivers and streams, and lakes and oceans. It also indicates that water percolates through the ground in ground water and enters the atmosphere again via transpiration. Based on the hydrologic cycle, a biogeochemical cycle can be defined as the path a nutrient takes as it cycles through the biosphere, in different phases, through living, as well as non-living parts of the environment.

2. Water is a greenhouse gas and therefore traps heat in Earth's atmosphere, helping to maintain global temperatures within a certain range. Water also transfers heat. Water vapour distributes heat away from the equator. Ocean currents transfer warm water from hotter to cooler regions and vice versa. The ocean also moderates the temperature over nearby land. Further, photosynthesis will decrease if insufficient water is available to photosynthetic organisms. Such a reduction will decrease the amount of carbon dioxide such organisms take up, thus increasing carbon dioxide levels in the atmosphere. Because carbon dioxide is an important greenhouse gas, global temperatures may increase as a result.

3. (a)



(b)



4. Water is polar, having partial positive charges and a partial negative charge at either end, enabling the molecules to form hydrogen bonds. The charged portions of a water molecule attract oppositely charged ions and other polar molecules, enabling water to dissolve a wide variety of molecular and ionic compounds.

5. Cohesion, the attraction of water molecules to each other due to hydrogen bonding, creates surface tension. Surface tension prevents the water strider's legs from penetrating the water.

6. Water is important to life because:

- It is a reactant in photosynthesis and product of cellular respiration
- It moderates environmental temperature and body temperature
- It is a major transport material

7. Animals may obtain more water (from cellular respiration or by drinking, eating, or absorbing water through the skin). Some animals live in or near water, while others, like Ord's kangaroo rat, are physiologically and behaviourally adapted to retain water. Such organisms excrete very little water and are often nocturnal.

8. In Alberta, water is used mainly for irrigation, commercial/industrial uses, agriculture, municipal uses (drinking, washing, cooking), recreation, wildlife and fish management, habitat enhancement, and water management (lake levels).
9. Water quality is an indicator of purity (lack of pollutants).
   - (a) Maintaining water quality is important to society because we use clean water for drinking, cooking, washing, irrigating food crops, and for recreation.
   - (b) Healthy water quality is important for ecosystems because pollutants can harm organisms throughout the food chain.

Investigation 2.A: Societal Uses of Water

Student Textbook page 41

Purpose

This investigation is an analysis of data on the societal uses of Alberta's surface and ground water. Students will examine the data, picking one particular use, and make recommendations about water use.

Outcome

- 20-A2.1sts
- 20-A2.3s
- 20-A2.4s

Advance Preparation

When to Begin	What to Do
1 week before	■ Book library and/or computers for student research.
1 day before	■ Photocopy **BLM 2.1.7 (HAND) Investigation 2.A: Societal Uses of Water**

Time Required

1–3 periods (depending on number and length of presentations)

Helpful Tips

- Use **BLM 2.1.7 (HAND) Investigation 2.A: Societal Uses of Water** 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 2.1.7A (ANS) Investigation 2.A: Societal Uses of Water Answer Key**.
- Discuss the various uses of surface and ground water, focussing on major uses and uses that consume or pollute.
- Introduce the concept of benefit/cost ratio in decision-making with respect to environmental issues if you have not already done so in the launch lab.
- Be sure to limit the time for class presentations. Decide if you want computer slide show presentations, and, if using, make sure the computer and projector are functioning before the class begins.

Opinions and Recommendations

1. Accept any well-reasoned response.
2. Students answers may include using water resources more carefully; recycling water used for washing, cooking, and bathing for irrigation or industry; applying water use restrictions; and carrying out a water use education campaign. Accept any well-reasoned response that reflects students' chosen category.
3. Accept any well-defended answer.
4. (a) Students should summarize their main points if answers are being collected.
   (b) Students may include the following questions:
   Would the diversion allow for the growth of economically important crops?
   Would the diversion allow for the growth of important food crops?
   Would the diversion bring water to a heavily populated area or increase the population after diversion?
   Could the ecosystem replenish the water removed to some degree over time?
   Would the ecosystems be negatively affected?
   Are there any threatened or endangered species in the ecosystem?
   Could the diversion introduce species, such as parasites, from the water source into ecosystems in the new region?

Assessment Options

- Assess group presentations.
- Collect student answers to Opinions and Recommendations for marking or discuss in class.
- To assess group work, use Assessment Checklist 3 Performance Task Self-Assessment and/or Assessment Checklist 4 Performance Task Group Assessment. Assessment Checklist 8 Oral Presentations could also be used. (See Appendix A.)

2.2 Biogeochemical Cycles

Student Textbook pages 42-52

Section Outcomes

Students will:

- summarize the biogeochemical cycling of carbon, oxygen, nitrogen, sulfur, and phosphorus
- relate biogeochemical cycles to the reuse of all matter in the biosphere
- design an experiment to compare the production of carbon dioxide in plants and animals
- measure and record properties and chemical composition of water samples
- identify human activities that can affect cycles of matter
- predict the effect of human activities on various biogeochemical cycles

Key Terms

rapid cycling (of nutrients)
slow cycling (of nutrients)
acid deposition
nitrogen fixation
ammonification
denitrification
algal bloom

Biology Background

- How fossil fuels form is still a topic for some debate. The widely accepted theory that oil is formed from small creatures who died and settled to the bottom of the ocean floor is called the *organic theory*. It has been used to predict the location of and find oil for many years. The *inorganic theory* was first proposed by Mendeleev (who also proposed the periodic table). He believed that oil was formed deep within the Earth. The observation that oil is found in areas where there is no evidence of biological activity is one of a number of arguments suggesting that oil is formed by processes that we still do not completely understand.
- In 1970, the population of Alberta was 1.6 million; in the year 2000, the population was 3 million. In 1970, there were 617 gas wells in Alberta, 5000 in 1999. Sour gas (H_2S) is highly toxic and has the smell of rotten eggs. 30% of Alberta's natural gas wells are sour-gas wells. The concentration of sour gas in natural gas can be as high as 30%. Alberta has 200 gas-processing plants and 10 000 km of sour gas pipelines.
- Nitrogen-fixing bacteria are usually associated with the roots of legumes like peas, beans, and peanuts. These bacteria possess an enzyme that can change atmospheric nitrogen into ammonium that they share with the plants. Alders and wolf willows are plants commonly found in Alberta forests that form similar associations.
- The build-up of excess nutrients in aquatic systems is known as eutrophication. If eutrophication occurs in an ecosystem, algal overgrowth will frequently block out sunlight so that aquatic plants living below the surface can no longer carry out photosynthesis and die. When these plants die, the number of decomposers in the body of water grows quickly and oxygen levels soon become depleted. Thus, aquatic organisms, such as fish, that require oxygen die as well. An excess of either nitrogen or phosphate can cause eutrophication; however, since phosphorus is typically the limiting nutrient in aquatic ecosystems, an excess of this nutrient usually triggers the bloom.

Teaching Strategies

- Figure 2.8 (page 42) provides a striking illustration of the importance of nutrients to organisms. The plant on the left is not only healthier than the one on the right, it is nearly twice as tall. Note that the plant is pea plant, a legume, which, when grown in soil, is typically inoculated with nitrogen-fixing bacteria. You may want to use this figure as a springboard for a discussion of the costs and benefits of fertilizer use in society.
- Use **BLM 2.2.1 (OH) Nutrient Reservoirs** to link the rapid cycling of nutrients and the slow cycling of nutrients with different components of the biotic and abiotic environment. You may want to ask students if they can determine which side of the diagram shows rapid or slow cycling of nutrients, and which compartments represent biotic or abiotic components of the environment.
- **BLM 2.2.2 (OH) Carbon and Oxygen Cycles** and **BLM 2.2.4 (OH) Rapid and Slow Cycling of Carbon** can be used together to illustrate the carbon and oxygen cycles. You may also want to draw students' attention to the FYI on page 46 that discusses the intriguing phenomenon of the missing carbon sink, wherein 4.8 billion tonnes of global carbon is currently unaccounted for by scientists. Ask students to speculate where they think the missing carbon may be.
- Use **BLM 2.2.5 (OH) The Sulfur Cycle** to review the sulfur cycle with students. The role played by bacteria in this cycle can be tricky for students to grasp. As such, **BLM 2.2.6 (HAND) Sulfur Cycle Activity** and **BLM 2.2.6A (ANS) Sulfur Cycle Activity Answer Key** can be used either as an in class exercise or to provide further practice for students struggling with this cycle. **BLM 2.2.7 (OH) Winogradsky Column** can also be used to further demonstrate the role bacteria play in the sulfur cycle.
- **BLM 2.2.9 (OH) The Nitrogen Cycle** can be used to review the nitrogen cycle with students. You may want to cover one side of the overhead at a time to illustrate the terrestrial and aquatic components of this cycle separately. As in the sulfur cycle, the role played by bacteria in this cycle can be tricky for students to grasp. As such, **BLM 2.10 (OH) Equations in the Nitrogen Cycle** can be used to help illustrate the chemical conversions carried out by bacteria. Further, **BLM 2.2.11 (HAND) Nitrogen Cycle Activity** and **BLM 2.2.11A (ANS) Nitrogen Cycle Activity Answer Key** can be used either as an in class exercise or to provide further practice for students struggling with this cycle.

- Use **BLM 2.2.12 (OH) The Phosphorus Cycle** to help students understand the various steps of the phosphorus cycle. **BLM 2.2.13 (HAND) Phosphorus Cycle Activity** and **BLM 2.2.13A (ANS) Phosphorus Cycle Activity Answer Key** can provide further practice for students struggling with this cycle or you may want to use it as a quiz. **BLM 2.2.14 (OH) Algal Bloom Diagram/Flow Chart** is designed to help clarify the processes involved in the formation of algal blooms. You may want to ask students if they can outline the process on their own before using this BLM and then use the BLM to highlight points that were missed.
- After completing this section, **BLM 2.2.15 (HAND) Hydrologic and Biogeochemical Cycles Review Question and Answer Exercise** and **BLM 2.2.15A (ANS) Hydrologic and Biogeochemical Cycles Review Question and Answer Exercise Answer Key** can be used as a review aid or a quiz to assess retention of the cycles covered in this section.

SUPPORTING DIVERSE STUDENT NEEDS

Terms used in the sulfur and nitrogen cycle may be confusing, especially to ESL students. As such, you may want to suggest that students set up their own vocabulary list. Students may wish to create their own "flash cards" with the term on one side of the card and its definition or description on the other side. They may also design flowcharts of the cycles to help them remember the terms in context.

Figure 2.8

Student Textbook page 42

The pea plant on the right is lacking essential nutrients, such as sulfur, nitrogen, and phosphorus.

Answers to Questions for Comprehension

Student Textbook page 43

Q6. A nutrient reservoir is a component of the biosphere in which nutrients temporarily accumulate. Examples include soil, water, and organisms.

Q7. When organic matter accumulates, it can move out of the rapid cycling of nutrients and become part of the slow cycling of nutrients through fossilization and the formation of sediments, and as such, becomes unavailable to living organisms. Weathering, erosion, and burning fossil fuels can release accumulated substances back into the rapid cycling of nutrients.

Figure 2.11

Student Textbook page 43

Oxygen is an end product of photosynthesis and a reactant in cellular respiration. Carbon dioxide is an end product in cellular respiration and a reactant in photosynthesis.

Biology File: Web Link

Student Textbook page 44

This Web Link study on determining domestic carbon dioxide emissions should help students link the carbon cycle they have just learned about to their own behaviours and consumption habits, and those of their family.

Answers to Questions for Comprehension

Student Textbook page 44

Q8. (a) Plants take up carbon dioxide from the air and use it to create carbon compounds through photosynthesis. During forest fires or when plant matter decomposes, carbon is released to the atmosphere.

(b) Animals consume carbon-rich organisms and release carbon dioxide as an end product of cellular respiration. Decomposition of animal matter also releases carbon into the biosphere.

Investigation 2.B: Carbon Dioxide Production in Plants and Animals

Student Textbook pages 44–45

Purpose

Students will measure the amount of carbon dioxide produced by a plant and compare this data with carbon dioxide production by an animal. Students will design their own experiment, carry it out, and gather their data.

Outcomes

- 20-A2.1s
- 20-A2.2s

Advance Preparation

When to Begin	What to Do
Beginning of the term	■ Check to see what materials and testing apparatuses are available for student investigations.
1 week before	■ Book computer and library resources for student research.
1 day before	■ Ask students to read the investigation the night before. ■ Photocopy **BLM 2.2.3 (HAND) Investigation 2.B: Carbon Dioxide Production in Plants and Animals**

Materials
As per students' experimental design.

Time Required

- 1 period to discuss investigation and allow students to research and design their procedure
- 1 period to carry out procedure

Helpful Tips

- Use **BLM 2.2.3 (HAND) Investigation 2.B: Carbon Dioxide Production in Plants and Animals** 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 2.2.3A (ANS) Investigation 2.B: Carbon Dioxide Production in Plants and Animals Answer Key**.
- Assess materials available to students to complete their investigation and inform students of the material available before they design their experiments.
- Students will often learn just as much from a lab design that fails, as they will from one that succeeds. You might remind students of Edison's famous line after he had failed with thousands of prototypes for the light bulb. He was reported to have said, "I haven't failed. I now know 10 000 ways that won't work."

Safety Precaution

Inform students of any safety precautions appropriate to their experimental design.

Answers to Analysis Questions

1. (a) $(2.856 \times 10^{-6} \frac{\text{mL}}{\text{min}})(15 \text{ min}) = 4.284 \times 10^{-5}$ mL

(4.3×10^{-5} mL to correct significant digits)

(b) More. An increased amount of carbon dioxide will be produced by the larger cricket, which has more cells, all of which are actively carrying out cellular respiration and generating carbon dioxide.

(c) An active cricket would respire at a higher rate. The cells of an active cricket will carry out cellular respiration at an increased rate, requiring more oxygen and producing more carbon dioxide.

2. (a) Answers will reflect students' findings.

(b) Carbon dioxide produced by cricket per minute:

$$\frac{2.856 \times 10^{-6} \text{ mL}}{36.2 \text{ mg}} \times 1000\frac{\text{mg}}{\text{g}}$$

$$= 7.89 \times 10^{-5} \frac{\text{mL}}{\text{g}}$$

Carbon dioxide produced by plants will reflect students' findings. Answers should be in mL/g and should include a statement comparing the two values.

3. (a) Answers will reflect students' experimental design. Students may have controlled for the following variables: temperature, light, plant type, and seed type.

(b) By using controlled variables, students avoid having confounded results that can be contributed to more than one variable.

Answers to Conclusion Questions

4. Accept any answers that clearly explain how the experimental results supported or failed to support students' hypotheses.

5. Answers will reflect students' experimental design. Answers should reflect the fact that photosynthesis uses carbon dioxide as a reactant and generates oxygen as a product of the reaction, while the reverse occurs in cellular respiration.

6. (a) Accept any well-reasoned prediction. Most students will likely predict that increasing the temperature will increase the rate of cellular respiration since the rate of most reactions increase with temperature. As a result, oxygen uptake and carbon dioxide products would both increase.

(b) Accept any well-reasoned prediction. Most students will likely predict that increasing the temperature will increase the rate at which rapid cycling is carried out. As temperatures increase, cellular respiration increases, as does the rate of carbon dioxide production by organisms. Decay will also occur faster, releasing more carbon into the biosphere. Increased temperatures will increase the rate of photosynthesis as well, and plants and other photosynthetic organisms will take up carbon dioxide faster, as long as sufficient water is available.

Answer to Extension Question

7. Accept any well-reasoned hypothesis. In general, germinating and actively growing tissues and greater availability of nutrients increase the rate carbon dioxide production, as these factors increase the rate of cellular respiration. Some species of plants may respire at different rates than others. Increased light levels may also increase carbon dioxide production as more metabolic reactions occurr as the rate of increases photosynthesis.

Assessment Options

- Have the students write up a formal lab report with answers to Analysis, Conclusions, and Extension questions to be handed in for marking.
- Use Assessment Checklist 1 Designing an Experiment and Assessment Checklist 2 Laboratory Reports. (See Appendix A.)

Answers to Questions for Comprehension

Student Textbook page 46

Q9. Earth's major carbon sinks are the oceans, forests, petroleum deposits, and limestone rock.

Q10. (a) Deforestation reduces photosynthesis by reducing the number of producers, and thereby reducing the amount of carbon dioxide that is removed from the atmosphere by these organisms. Students may also mention that when biomass, such as brush and branches, is left to decompose on the ground after deforestation or is burnt after harvesting, carbon dioxide is also released into the atmosphere. If the trees that are harvested are burnt, this carbon will also be released into the atmosphere.

(b) Burning fossil fuels takes carbon out of slow cycling as it quickly releases carbon dioxide into the atmosphere.

(c) Frequently, agriculture relies on deforestation, and as a result, atmospheric carbon dioxide will increase as photosynthesis decreases (trees remove a great deal more carbon dioxide from the air than agricultural crops).

Figure 2.13

Student Textbook page 46

Seashells contain calcium carbonate ($CaCO_3$), which forms limestone rock over time. As such, they are a component of the slow cycling of carbon.

Biology File: Web Link

Student Textbook page 47

A Winogradsky column is a model of distinct microbial growth zones. The microorganisms in each of these zones depend on the release of nutrients provided by other microorganisms that have already grown in that zone. Over time, distinct layers form in which anaerobic communities exist in the bottom layers and aerobic communities exist in the upper layers.

Answers to Questions for Comprehension

Student Textbook page 48

Q11. Small amounts of acid deposition are natural, and return sulfur from the atmosphere to the oceans and soil where organisms can use it. Large amounts of acid deposition, however, damage plants, acidify lakes, kill fish and other aquatic organisms, and leach nutrients from the soil. Some students may also mention that nitrogen can play a role in acid deposition as well.

Q12. Bacteria convert sulfur from one form to another. Sulfate reducers convert sulfate to sulfide and elemental sulfur, while sulfur oxidizers convert sulfide to elemental sulfur and sulfate.

Thought Lab 2.2: Carbon, Sulfur, and Iron

Student Textbook page 48

Purpose

This short Thought Lab helps students understand how coal mining can damage the environment and disrupt biogeochemical cycles, giving students the opportunity to apply what they have just learned to a new, but important, situation.

Outcomes

- 20–A2.1s

Time Required

Approximately 30 minutes.

Helpful Tips

- Use **BLM 2.2.8 (HAND) Thought Lab 2.2: Carbon, Sulfur, and Iron** 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 2.2.8A (ANS) Thought Lab 2.2: Carbon, Sulfur, and Iron Answer Key**.
- If possible, have samples of pyrite available for students' examination.

Answers to Analysis Questions

1. Pyrite breaks down when exposed to oxygen, converting sulfide to sulfuric acid. If pyrite was exposed during the mining process, the lower pH caused by the formation of sulfuric acid may have killed the plants.

2. (a) Coal mining can expose previously buried sulfur compounds, which cause acidification of the soil and run-off, harming vegetation. Large, open pit mines can also create unstable slag heaps (waste left after coal is processed) and water and air pollution (coal dust). Aesthetic damage can also be an issue.

(b) Accept any well-defended answer.

3. (a) Depending on the amount of sulfur in the coal, the mine may have no effect on the sulfur cycle, or it may increase the amount of sulfuric acid in the cycle (rapid cycling) and decrease the amount of sulfide bound to iron in pyrite (slow cycling) as pyrite breaks down upon exposure to air.

(b) Mining removes carbon from the ground (slow cycling) and increases coal dust in the atmosphere (rapid cycling). Coal, when it is burned, releases carbon dioxide into the atmosphere as well (rapid cycling).

4. Coal mining may expose previously buried pyrite. Upon exposure to oxygen, the Fe^{2+} in the pyrite will be converted to Fe^{3+} by bacteria, increasing the overall amount of Fe^{3+} in the iron cycle.

Assessment Option

- Have students hand in the answers to the Analysis questions for marking.

Answers to Questions for Comprehension

Student Textbook page 49

Q13. Plants can use ammonium or nitrate.

Q14. $N_2(g) \rightarrow NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$
nitrogen gas → ammonium, nitrite → nitrate

Student Textbook page 50

Q15. Organisms need phosphorus to make ATP, DNA, and teeth and bones.

Q16. Phosphorus is found in organisms, soil, water, and rock (through gradual weathering). It is mainly transported through water and does not cycle through the atmosphere.

Q17. Increased amounts of phosphorous in aquatic environments can result in algal blooms. Algal overgrowth may block sunlight, resulting in the death of aquatic plants. Decomposition of the resulting organic matter reduces oxygen levels in the water, and as a result, many aquatic life forms may die.

Investigation 2.C: What's in the Water?

Student Textbook page 51

Purpose

Students will take local water samples and test them for various water quality parameters with an assay kit. They will have the opportunity to apply the material they have learned by gathering and analyzing real-world data.

Outcomes

- 20–A2.2s

Advance Preparation

When to Begin	What to Do
Beginning of the term	■ Check to see what testing apparatus is available.
3 weeks before (depending on jurisdiction)	■ Select an appropriate site. ■ Fill out the appropriate forms and arrange for transportation.
2 weeks before	■ Discuss the field trip with your students, outlining the purpose of the field trip, where you are going, and what you will be doing. ■ Hand out any appropriate forms that require a parent's signature.
1-2 days before	■ Demonstrate each test and be sure students are comfortable with what they have to do and what precautions will be necessary with the tests and the gathering of the data. ■ Photocopy **2.2.16 (HAND) Investigation 2.C: What's in the Water?**

Materials
■ water sample from each area ■ Probeware or colourmetric assay kit for sulfate (or iron), nitrate, phosphate, and pH ■ 8 to 10 test tubes (10 mL) ■ pipette bulb ■ 2 pipettes (2 mL) ■ 2 sample jars or lids ■ metal scoopula

Time Required

- Time for field trip to gather data
- 2-3 periods for investigation

Safety Precautions

- Read and follow the safety instructions that come with the assay kit.
- Be sure that students are aware of potential dangers in gathering samples in a flowing river or stream.
- Remind students to wear gloves and to wash their hands after the investigation.

Helpful Tips

- Use **BLM 2.2.16 (HAND) Investigation 2.C: What's in the Water?** 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 2.2.16A (ANS) Investigation 2.C: What's in the Water? Answer Key**.
- If one is available, consider adding a dissolved oxygen test to the data you collect. A dissolved oxygen test will help

determine the suitability of the body of water for fish and other aquatic organisms.

- Consider taking samples of benthic invertebrates, the small organisms that live in the gravel of most rivers and streams, if time and materials allow. The types and numbers of these organisms can correlate with water quality.

Answers to Analysis Questions

1. The bar graphs will usually have higher levels of sulfate, iron, nitrate, and phosphate depending on the nature of the site being tested. pH level may be higher or lower depending on the nature of the discharge into the body of water. Student graphs should include a title and labels and measurement units on both axes.
2. Any differences will be due to the nature of the discharge. For example, a freshly watered and fertilized plant will have high levels of nitrate and phosphate due to the use of fertilizers, while a plant that received water only will have significantly lower levels.
3. Comparisons with Calgary tap water will again vary depending on where samples are taken. Calgary drinking water is treated to lower some of these levels. In comparison, water downstream of Calgary has high levels of nitrate and phosphate due to storm water and sewage (treated).

Answers to Conclusions Questions

4. In general, most human activities cause phosphate and nitrate levels to go up in downstream water. Other factors vary with the discharge.
5. Moderate levels of nitrate and phosphate in water increase aquatic plant and algal growth. This subsequently increases the number of invertebrate herbivores and carnivores, which provide an abundant source of food for fish. More significant increases in nitrate and phosphate levels can also result in algal blooms. The very large number of big trout downstream of the city of Calgary provide a testament to how a problem (nutrient loading) can affect a natural environment. These fish were also well known for their oily taste many years after the local oil refineries were torn down.

Answer to Extension Question

6. The spill into Wabamun Lake was mostly Bunker C crude oil, which has a relatively high sulfur content and includes many other metals. Another component of the spill was described as pole preservative, a polycylic aromatic hydrocarbon. The immediate effects of the spill included extensive oil coverage of the lake surface; an immediate order to stop using the water for cooking, washing, showering, drinking, and swimming; oil damage to over 1000 birds, of which less than 50% survived; contamination of wildlife habitats; the shutdown of a TransAlta power plant that used the water after unacceptably high levels of aluminium, chromium, arsenic, and copper were detected; and the shutdown of the sport fishing industry on the lake. In the spring of 2006 there was another intensive clean-up effort; during that summer high temperatures brought more of the oil sunk in the lake to surface, creating oil sheens and tar balls. A fish consumption advisory from Capital Health remained in effect throughout 2006.

Assessment Options

- Have the students write up a formal lab report with answers to Analysis, Conclusions, and Extension questions to be handed in for marking.
- Use Assessment Checklist 2 Laboratory Reports. (See Appendix A.)

Section 2.2 Review Answers

Student Textbook page 52

1. **(a)** Carbon moves relatively quickly through producers, consumers, decomposers, and the atmosphere. Carbon does not accumulate for long periods in any of these components of the environment, making this part of the carbon cycle an example of the rapid cycling of matter.

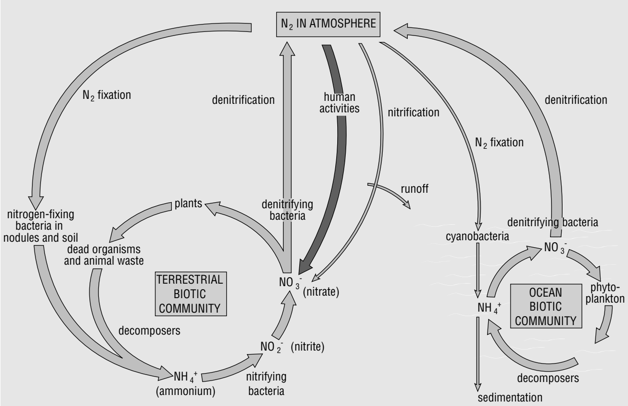
   (b) It takes many years for organic matter to accumulate and form a fossil fuel. As a fossil fuel, the carbon is not available to living organisms, and so is part of the slow cycling of matter.
2. Nitrogen and oxygen enter the atmosphere, but phosphorous and calcium do not. Instead, phosphorous and calcium move through the biosphere in water, organisms, and soil only.
3. **(a)** Bacteria convert sulfur from one form to another. Sulfate reducers convert sulfate to sulfide and elemental sulfur, while sulfur oxidizers convert sulfide to elemental sulfur and sulfate.

   (b) Through nitrogen fixation, bacteria convert nitrogen gas to ammonium. Through ammonification, bacteria break down organic matter and produce ammonium. Other bacteria further convert ammonium into nitrite and then to nitrate. Through denitrification, bacteria convert nitrate and nitrite into nitrogen gas.
4. All biogeochemical cycles move through both the abiotic and biotic environment by rapid and slow cycling, include nutrient reservoirs, and involve transport by water.
5. **(a)** Green plants need nitrogen to make DNA and proteins.

   (b) Green plants need sulfur for proteins and vitamins.

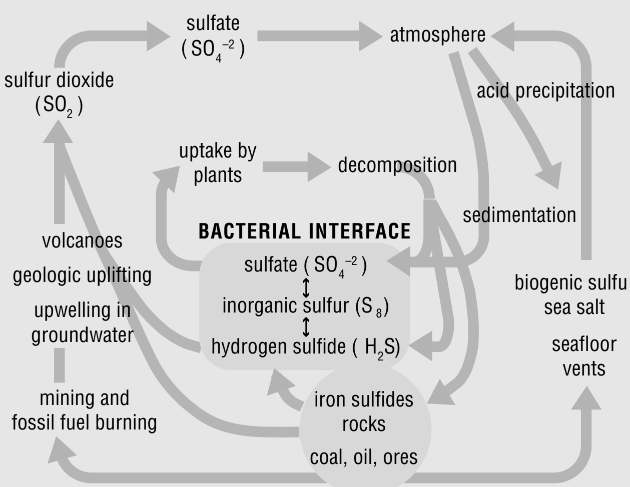
   (c) Green plants need phosphorous to make DNA and ATP.

6. (a)



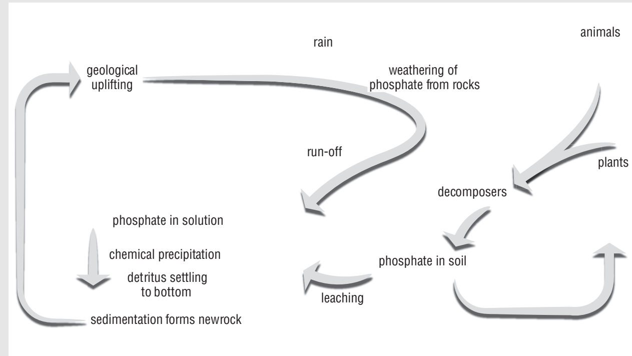
(b) Through nitrification, nitrifying bacteria convert ammonium to nitrite and then into nitrate. Plants use nitrate to make organic compounds requiring nitrogen, such as DNA and proteins. Consumers can get nitrogen by eating plants or other consumers. This is a tricky question as the conversion of ammonium to nitrite and then into nitrate is not specifically identified as nitrification in the text, but most students should be able to make the association.

7. (a)



(b) Burning fossil fuels releases sulfur to the atmosphere as sulfur dioxide. Sulfur dioxide reacts with oxygen and water vapour in the atmosphere to form sulfurous acid and sulfuric acid. These acids return to Earth's surface in acid deposition.

8. (a)



(b) Producers readily use phosphate, but the scarcity of phosphate in the environment tends to limit their growth. As a result, phosphate from detergents that enters the environment through sewage and wastewater run-off can cause algal blooms in lakes and other natural bodies of water. Algal blooms block sunlight, resulting in the death of aquatic plants, which can no longer photosynthesize. Decomposition of the resulting organic matter depletes oxygen in the water, thereby killing fish and other aquatic life.

2.3 The Balance of the Matter and Energy Exchange

Student Textbook pages 53-61

Section Outcomes

Students will:

- explain how energy, matter, and the productivity of ecosystems are interrelated
- explain the influence on atmospheric composition of the equilibrium between the exchange of oxygen and carbon dioxide in photosynthesis and cellular respiration
- describe evidence and scientific explanations for changes in the composition of Earth's atmosphere from past to present, and describe the significance of these to current states of equilibrium in the biosphere
- outline, explain, and evaluate the influence of human activities on the biosphere
- design and evaluate a model of a closed biological system

Key Terms

productivity
stromatolites

Biology Background

- Some forms of high-energy electromagnetic radiation, including ultraviolet radiation and x-ray radiation, can disrupt the DNA of cells to trigger uncontrolled growth, resulting in cancer. This radiation can physically break down genetic materials to result in a permanent mutation that is transferred to daughter cells during cell division, but is not passed on to offspring.

- Most scientists recognize five major periods of extinction. The first major extinction, affecting most of the life on Earth, probably occurred 2 billion years ago when prokaryote cells started to use photosynthesis to produce nutrients. The waste product of photosynthesis, oxygen, began accumulating in the atmosphere and was toxic to most of the anaerobic organisms on the planet, resulting in a mass extinction. Iron banding in stromatolites (fossilized bacteria) help scientists date the period in Earth's history when oxygen was first forming in the world's oceans but had not yet entered the atmosphere.
- Biosphere 2 was a privately funded research project that involved eight people living in an enclosed, 1.28-hectare structure, starting in 1991. The structure, in Arizona, was designed to determine whether space colonies could become a reality. Biosphere 2 contained 3500 species of plants and animals, and attempted to reproduce five biomes (desert, grassland, marsh, ocean, and rainforest). Biosphere 2 received only sunlight and electricity from the outside, and colonists were to grow their own food and manage their own wastes. The project came to an end in 1993. Researchers were only able to live independently in Biosphere 2 for several months, after which oxygen levels began to drop and carbon dioxide rose to unsafe levels.
- Riparian zones or planted grass filters are used to reduce erosion and nutrient run-off from nearby farms and deforested areas into these waterways. Some forestry companies now leave a buffer zone of forested land between creeks and streams and the zone of deforestation to prevent such erosion and nutrient run-off within ecosystems where they have harvested trees.
- Reduced gravity on a Mars colony (one third that of Earth's gravity) will have effects on the biological systems of most living organisms. Under such conditions, humans may experience health problems associated with weightlessness, such as space sickness (short-term nausea, vomiting, vertigo, and headaches). Long-term gravity related health problems include muscular atrophy, skeletal deterioration, balance disorders, slowing of circulation, decreased production of red blood cells, decreased immune function, sleeplessness, and weight loss. These effects are reversible when humans return to Earth. Artificial gravity has not been successfully developed yet, but likely candidates include use of rotation and magnetism.

Teaching Strategies

- Ask students which of the world's ecosystems they believe to be the most productive. Following this exercise, review **BLM 2.3.1 (OH) Table: Comparing Ecosystem Productivity** with students, explaining why some of the ecosystems they may have thought were very productive, such as the open ocean, are in fact very unproductive. You may want to use this discussion as a springboard for an explanation of productivity and the factors that affect it.
- **BLM 2.3.2 (OH) Major Biomes of the World** provides a visual overview of the world's main biomes. Have students hypothesize about the major factors that determine where specific biomes are found. This is a review of the weather unit of *Science 10*.
- The Biology File FYI on page 55 concerning the mass deforestation of tropical rainforests can provide a springboard for an interesting discussion on the effects of reduced photosynthesis on the global climate.
- **BLM 2.3.4 (OH) Table: Composition of Earth's Atmosphere and Oceans** and **BLM 2.3.5 (OH) Concentration of Atmospheric Gases Over Time** can be used in conjunction with a discussion of stromatolites to show what Earth's atmosphere was like before bacteria began to carry out photosynthesis and how the concentration of major gases changed over Earth's history.

Thought Lab 2.3: Too Much of a Good Thing

Student Textbook page 54

Purpose

Working in groups, students will analyze information on UV radiation to investigate the effect exposure may have on various organisms.

Outcomes

- 20–A3.2sts
- 20–A3.4sts

Time Required

1 class period

Helpful Tips

- Use **BLM 2.3.3 (HAND) Thought Lab 2.3: Too Much of a Good Thing** 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 2.3.3A (ANS) Thought Lab 2.3: Too Much of a Good Thing Answer Key**.
- Discuss with students the idea that what we call light is actually a wide range of wavelengths of energy that come from the Sun.
- Ask students how we have used information about the electromagnetic spectrum to produce different forms of technology (X-rays, microwaves, radios).
- Discuss with students: how some forms of electromagnetic waves are associated with cancers and the theory that these high-energy waves can disrupt the DNA of cells to trigger uncontrolled growth.
- Ask students to read through the investigation on their own before forming discussion groups.
- This lab can also be completed in partners.

Answers to Analysis Questions

1. Increasing UVR inhibits photosynthesis, and thus decreases productivity.
2. Direct effects of increasing UVR are as follows: kills fish and some amphibians, causes developmental damage in amphibians, decreases amphibians' ability to fight off disease, and causes skin deterioration and eye problems (cataracts) in humans.
3. Indirect effects of increasing UVR are as follows: changes in behaviour (fish swim to deeper, darker water; shade-seeking and nocturnal behaviour); selection for darker pigmentation; humans wear sunscreen and protective clothing; selection for efficient DNA repair processes; increased survival of fish and amphibians in water where dissolved material acts as shield.
4. A typical suggestion would be to counteract increased UVR by actively enforcing a worldwide ban on CFCs and HCFCs. To ensure that worldwide ban on CFCs and HCFCs is a wise approach, scientific studies should be completed to see how these chemicals impact the stability of the ozone layer and UVR levels. Countries could also be consulted to determine if they would be willing to enforce this ban and to determine the economic cost of this ban. Accept any reasonable answer.

Assessment Options

- Collect answers to Analysis questions for teacher marking or mark answers in class and hand in results for teacher recording.
- To assess group work, use Assessment Checklist 3 Performance Task Self-Assessment and/or Assessment Checklist 4 Performance Task Group Assessment. (See Appendix A.)

Answers to Questions for Comprehension

Student Textbook page 55

Q18. Increased amounts of sunlight allows for more photosynthesis, and thus more productivity, as long as sufficient water is available. Too much ultraviolet radiation, however, can inhibit photosynthesis and limit the growth of plants.

Q19. Other than nutrients, the two major factors that limit productivity are sunlight and water.

Biology File: Web Link

Student Textbook page 55

As might be expected from such a seemingly unscientific hypothesis, reception among the scientific community has been and remains mixed. Viewed as metaphor, the Gaia hypothesis has much in common with Aboriginal views of the interconnections of Earth and its living and non-living components, and it tends to be embraced by scientists with a more holistic approach to the study of Earth and its systems. Viewed in strictly and traditionally western scientific terms, the Gaia hypothesis has met with resistance (or rejection), especially from evolutionary biologists who tend to argue that the hypothesis lacks a coherent (or any) explanatory mechanism.

Investigation 2.D: Biosphere in a Bottle

Student Textbook pages 57

Purpose

In groups, students will design and create model ecosystems to evaluate carbon dioxide, oxygen, and water exchange, and observe ecosystem function in a closed biological system.

Outcomes

- 20–A3.2s
- 20–A3.3s

Advance Preparation

When to Begin	What to Do
3 weeks before (depending on jurisdiction)	■ Determine where and how students are going to gather materials. ■ Select an appropriate site to collect materials if doing so as a class. ■ Fill out the appropriate forms and arrange for transportation.
2 weeks before	■ Discuss the field trip with your students, outlining the purpose of the field trip, where you are going, and what you will be doing. ■ Hand out any appropriate forms that require a parent or guardian's signature.
1-2 days before	■ Decide what restrictions you want to apply to these miniature ecosystems, how long this activity should last, and whether each student should create their own ecosystem or if each group will create one ecosystem together. ■ Photocopy **BLM 2.3.6 (HAND) Investigation 2.D: Biosphere in a Bottle.**

Materials
■ 2 L (or larger) clear bottle with lid ■ thermometer (alcohol or digital) ■ 10 mL test tube ■ Parafilm™ or sealing wax ■ bottom sediment ■ pond or river water ■ small aquatic plants (such as floating duckweed and various submerged plants) ■ small aquatic invertebrates (such as snails, flatworms, shrimps, and insects)

Time Required

- Time for field trip to collect materials (if doing this as a class and you have not already done so in Investigation 2.C: What's in the Water?)
- 1 period for discussion and planning
- 1 period for creating the biosphere
- 15 minutes per period for observations and recording

Safety Precautions

Be sure that students are aware of potential dangers in gathering materials in a flowing river or stream.

Helpful Tips

- Use **BLM 2.3.6 (HAND) Investigation 2.D: Biosphere in a Bottle** 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 2.3.6A (ANS) Investigation 2.D: Biosphere in a Bottle Answer Key**.
- This activity can be combined with Investigation 2.C: What's in the Water? Students can gather their materials while testing the water.
- If students are gathering materials on their own, advise them not to include vertebrates (small fish).
- The animals in this activity will likely die due to oxygen depletion if you continue your observations over too long a period of time. Suggested time span for the investigation is 2-3 weeks.
- Be sure that the bottles are well sealed and that students do not come into contact with the water when they are disposing of the materials at the end of the activity. Warm temperatures can allow potentially harmful bacteria to reproduce rapidly.

Answers to Analysis Questions

1. Typical student answers may include the following:
   - producers: duckweed and submerged plants
   - consumers: insects and shrimp
   - decomposers: snails and flatworms
2. Biogeochemical cycles will include the water cycle and the carbon-oxygen cycle.
3. A clear bottle allows sunlight into the ecosystem. Without sunlight, no energy enters the ecosystem, and all the organisms will die.
4. Students will most likely find that their biosphere increased in temperature, as it functioned as a greenhouse.
5. Condensation on the bottle.
6. If students performed the experiment correctly, they should report that the model biosphere performed fine once it got started, until it ran out of oxygen over time. Encourage students to explain why their biospheres did or did not function properly.
7. Students may see differences in the amount of green (indicating the rate of production) in their biosphere, which they should attribute to differences in the amount of sunlight entering the biosphere. Similarly, different temperatures may be observed. The aerobic organisms in some biospheres may have died, which students should attribute to an excess of carbon dioxide and lack of oxygen in the biosphere.

Answers to Conclusion Questions

8. Decreasing the amount of sunlight available to the biosphere will decrease photosynthetic activity over time and reduce productivity. As a result, oxygen levels in the biosphere will fall and carbon dioxide levels will rise, leading to the eventual death or aerobic organisms.
9. **(a)** Decrease in atmospheric oxygen levels.
   (b) Increase in atmospheric carbon dioxide levels.

Assessment Options

- Have the students write up a formal lab report with answers to Analysis and Conclusions questions to be handed in for marking.
- Use Assessment Checklist 2 Laboratory Reports. (See Appendix A.)
- To assess group work, use Assessment Checklist 3 Performance Task Self-Assessment and/or Assessment Checklist 4 Performance Task Group Assessment. (See Appendix A.)

Thought Lab 2.4: Evaluating Water Treatments

Student Textbook page 58

Purpose

Students will analyze data on water quality to evaluate the effectiveness of using grasses improve the quality of water contaminated with agricultural run-off.

Outcomes

- 20.A2.1sts
- STS3

Time Required

15-30 minutes

Helpful Tips

- Use **BLM 2.3.7 (HAND) Thought Lab 2.4: Evaluating Water Treatments** 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 2.3.7A (ANS) Thought Lab 2.4: Evaluating Water Treatments Answer Key.**
- You may want to pair this Thought Lab up with a visit to a stream with a healthy riparian zone in your region.
- This activity can be successfully linked with the Connections feature on Phytoremediation (page 62).

Answers to Analysis Questions

1. The grass-filtered waterway had lower nitrogen and phosphorus levels than the non-filtered waterway.
2. The results could be used to convince farmers of the value of maintaining grassed slopes along their waterways.

Assessment Option

- Collect student answers for marking or discuss as a class.

Thought Lab 2.5: Design a Self-Sustaining Mars Colony

Student Textbook page 60

Purpose

In groups, students will evaluate the requirements of an Earth-like system by designing a self-sustaining Mars colony.

Outcomes

- 20-A3.1sts

Time Required

1 period

Helpful Tips

- Use **BLM 2.3.8 (HAND) Thought Lab 2.5: Design a Self-Sustaining Mars Colony** 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 2.3.8A (ANS) Thought Lab 2.5: Design a Self-Sustaining Mars Colony Answer Key.**
- Some of the analysis questions in this Thought Lab are challenging and thought provoking. These lend themselves well to gifted students.

Answers to Analysis Questions

1. Students may suggest that the water in the polar ice caps could be melted with solar panels to provide water for the Mars colony. This water could be used for drinking, washing, cooking, and other uses, and the wastewater could be recycled and used for agriculture and small-scale industrial use. Some students may also suggest that the poles be melted entirely so that the water vapour would enter the air and enhance the planet's greenhouse effect, thus helping increase temperatures on Mars.
2. Solar power is probably still a power option on Mars. Despite the distance from the Sun and the presence of atmospheric dust, solar power could still be collected and stored using large solar mirrors to concentrate solar energy. Other power options students might suggest include wind, nuclear, and geothermal energy. All energy would need to be used sparingly.
3. Reduced gravity would have effects on all living organisms. The biological systems of humans, animals, and plants may all function differently under conditions of reduced gravity. Humans may experience health problems associated with weightlessness. Students may suggest that the effects of reduced gravity could be addressed by effectively preparing the colonists for the realities of space living, using weighted suits to assist colonists in getting around (these would not influence the systemic effects of reduced gravity), and developing some means of artificial gravity.
4. Nutrients might be recycled by composting plants and food waste.
5. The atmosphere of Mars mainly consists of carbon dioxide, but it is very thin. As a result, the greenhouse effect on the planet is minimal. To engineer a runaway greenhouse effect, colonists would have to release carbon dioxide into the Mars atmosphere. A large amount of carbon dioxide is currently stored in the polar regions of the planet in a frozen state. If this carbon dioxide were vapourized into a gaseous form, the planet would warm. This would result in a feedback loop as further warming releases more solid carbon dioxide from the poles, which enters the atmosphere in a gaseous state, again increasing global temperatures. A possible consequence of creating a runaway greenhouse effect is that, true to its name, it can run away, causing more warming than desired. This is not that likely on Mars, however, as carbon dioxide is not a very effective greenhouse gas, compared with others, such as methane.
6. Accept any reasonable, well-supported opinion.

Assessment Options

- Collect colony designs and answers to Analysis questions for marking.
- To assess group work, use Assessment Checklist 3 Performance Task Self-Assessment and/or Assessment

Checklist 4 Performance Task Group Assessment. (See Appendix A.)

Section 2.3 Review Answers

Student Textbook page 61

1. The biosphere is considered an open system due to the constant input of solar energy and radiation of heat energy into space.

2. Productivity is the rate at which an ecosystem's producers capture and store energy within organic compounds over a certain length of time.

3. In summer, grasslands can have greater productivity than a forest because animals are constantly consuming the grass and new grass is constantly being grown to replace it. As a result, new biomass may accumulate at a faster rate than it does in a forest, where only limited amounts of biomass are consumed.

4. Four variables affecting terrestrial productivity are:

- Nutrient levels, which limit productivity if in short supply.
- Rainfall, which limits productivity if in short supply.
- Solar radiation and heat. Low levels limit productivity at the forest floor and in some biomes; excess ultraviolet radiation also limits productivity.
- The number of producers present in the ecosystem. Productivity increases at a greater rate if more producers are present.

5. Two variables that determine productivity in the oceans are:

- Nutrient availability, which limits productivity if in short supply. Most nutrients in oceans are found at the mouths of rivers and in coastal upwelling zones. They are also released following seasonal melting of ice.
- Solar radiation. Sufficient solar radiation allows for considerable productivity near the ocean surface, while decreased solar radiation in deeper waters tends to limit productivity.

6. The Gaia Hypothesis states that the biosphere acts like an organism in that it is self-regulating and maintains environmental conditions within certain limits.

7. Stromatolites hold clues about the composition of Earth's atmosphere and oceans from 3.8 to 2.5 billion years ago. Prior to this time, the atmosphere lacked free oxygen and bacteria and bacteria-like organisms grew, forming thick mounds in shallow seas, lagoons, and lakes. As the micro-organisms died, they formed sedimentary rocks called stromatolites over time. Some stromatolites, estimated to be 2.5 billion years old or more, suggest that, around this time, the level of oxygen in the oceans had started to increase. Scientists have identified bands of iron oxides in stromatolites from this period, which formed when iron ions combined with dissolved oxygen in the oceans. Stromatolites that are less than 1.8 billion years old do not have black bands of iron oxides, most likely due to the fact that, at this time, most of the iron ions in the oceans were already bound in iron oxides. With the ocean's store of iron ions used up, the oxygen produced by photosynthesis was free to build up as oxygen gas and eventually to escape into Earth's atmosphere. Thus scientists know that oxygen levels in the atmosphere were higher after that point in time.

8. (a) Algal blooms occur when excess phosphate or nitrate enters a body of water (phosphate is the more limiting growth factor as it is found in smaller amounts in the environment). Human activities that lead to algal blooms include deforestation, discharge of inadequately treated sewage water, raising livestock, and fertilizing lawns and agricultural fields.

(b) Seasonal turnover of nutrient rich water and warmer temperatures can promote algal blooms in the late summer and early fall. Algal blooms can block out sunlight, resulting in the death of aquatic plants. Decomposition of the dead organic matter depletes oxygen, which kills off fish and other aquatic organisms that require oxygen, resulting in a dead zone.

9. (a) An increase in annual hydrogen sulfide levels would increase the amount of sulfur being rapidly cycled in the sulfur cycle. Further bacterial metabolism would also lead to an increase in the amount of sulfate available to plants, as well as in the atmosphere. The latter would result in an increase in acid deposition. As a result, the overall rate of rapid cycling of sulfur would probably also increase.

(b) Increased amounts of acid deposition would harm the plants in a temperate deciduous forest and acidify natural bodies of water, harming vulnerable aquatic producers, thus inhibiting productivity.

Connections (Social and Environmental Contexts)

Phytoremediation

Student Textbook page 62

Helpful Tips

- This activity can be successfully linked with Thought Lab 2.4: Evaluating Water Treatments (page 58).
- If possible, arrange a visit to a site where phytoremediation is in progress.

Answers to Questions

1. Look for plants that are growing in polluted areas.

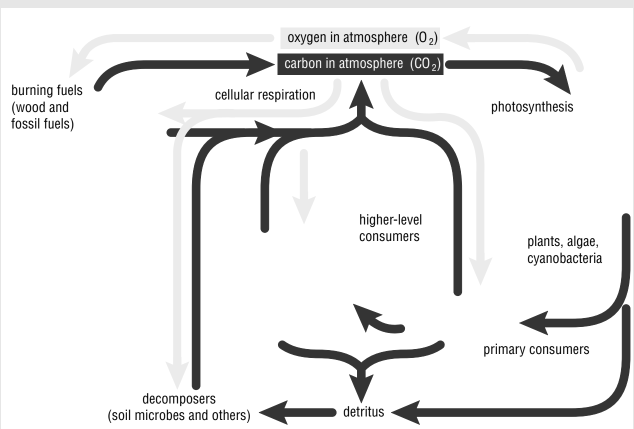
2. Accept any well-reasoned answer. In general, phytoremediation should not be abandoned, but areas undergoing the treatment should be monitored closely.
3. These plants will contain hydrocarbons that may be taken up by the animals.
4. In this case, phytoremediation would work too slowly to be effective for immediate clean up. It may be helpful for long-term remediation however.
5. Phytoremediation does not require a lot of manpower or specialized equipment. The plants used in the process are affordable.
6. Heavy metals would accumulate in the plant tissues, as the plants would not break them down. As a result, the plant material would have to be removed.

Chapter 2 Review Answers

Student Textbook pages 64-65

Answers to Understanding Concepts Questions

1.



2. Water has several properties that make it an excellent transporter of dissolved materials:
   - Water has a unique chemical structure. A molecule of water is polar and therefore able to form hydrogen bonds, which enables it to dissolve a wide variety of ionic and molecular compounds.
   - Water is less dense as a solid than as a liquid. Because of hydrogen bonding, water is less dense in its solid form than as a liquid, as the hydrogen bonds hold the water in an open crystalline structure as it freezes. Due to hydrogen bonding, water is densest at 4 °C and becomes less dense as it cools and warms below and above this value. This has key consequences for the cycling of nutrients in bodies of water, as warming and cooling exchanges nutrients between depths as water rises and sinks.
   - Water has a relatively high boiling point and melting point. As a result, it can transport compounds over a wide range of temperatures.
   - Water has special adhesive and cohesive properties. This means that water molecules are attracted to each other, as well as to other substances, making water a great transporter. For example, these qualities allow water to effectively transport nutrients up the xylem of plants.
3. **(a)** In the rapid cycling of carbon, plants remove carbon dioxide from the atmosphere and produce carbon-rich molecules in plant tissues. Plants fix much more carbon than they release through cellular respiration. Animals take up carbon by eating plant matter or other animals and release carbon dioxide through cellular respiration. Burning and decomposition of dead plant and animal matter and wastes releases carbon to the atmosphere and biosphere.

   (b) When plant and animal matter accumulate as fossil fuels, the carbon becomes part of slow cycling and is no longer available for living organisms to use in biological processes. Trees also store large amount of carbon in a form that is inaccessible to organisms and are, therefore, part of the slow cycling of carbon. Shelled aquatic organisms also store carbon in their shells for long periods, which is later incorporated into limestone
4. Animals lose water from their bodies through urine, feces, and evaporation (includes sweating and breathing). Animals replace water by drinking, eating, and through cellular respiration (metabolic water). Some organisms also absorb water through their skin.
5. **(a)** A water molecule consists of two hydrogen atoms that are covalently bonded to one oxygen atom. The hydrogen end of the molecule has a slightly positive charge and the oxygen end has a slightly negative charge, making water a polar molecule. This polarity allows a water molecule to from a weak attraction, called a hydrogen bond, between the hydrogen of one molecule and the oxygen of a nearby molecule. Hydrogen bonding explains why ice floats on water. When water freezes, it expands because hydrogen bonds hold the water molecules in an open crystal structure. As a result, ice is less dense than liquid water, in which the molecules are packed more closely together.

   (b) The hydrogen end of a water molecule has a slightly positive charge and the oxygen end has a slightly negative charge, making water a polar molecule. This polarity allows it to dissolve a wide range of ionic and molecular compounds; hence, it is called the universal solvent.

   (c) Again, the hydrogen end of a water molecule has a slightly positive charge and the oxygen end has a slightly negative charge, making water a polar molecule. This polarity allows a water molecule to form hydrogen bonds. The polarity of water molecules and resultant hydrogen bonding causes attraction between water molecules (cohesion) and attraction between water molecules and other substances (adhesion). As result, water has special adhesive and cohesive properties.

6. **(a)** Living organisms are nitrogen reservoirs because they take in nitrogen from their food (animals), the soil (plants), and directly from the air (some bacteria), which they incorporate into proteins and DNA. Nitrogen is stored in these organisms and released back into the environment when their bodies (or parts of them) are decomposed or wastes are released. Some bacteria also release nitrogen in molecules they produce in metabolic reactions.

(b) Soil is a reservoir for nitrogen because it is home to bacteria that break down organic matter to produce ammonium, nitrate, and nitrite. Ammonium and nitrate are forms of nitrogen that are usable by plants. Nitrogen remains in the soil in these usable forms until plant roots absorb it or it is changed back into nitrogen gas by denitrifying bacteria.

(c) Freshwater contains soluble nitrogen-containing compounds, such as nitrate, that have run-off from the soil, while oceans contain bacterial communities that convert nitrogen gas into forms that are usable by phytoplankton and aquatic plants (ammonium and nitrate). Most bodies of water also contain nitrogen that is released by decomposition.

(d) The atmosphere is a reservoir for nitrogen because denitrifying bacteria convert nitrite and nitrate into nitrogen gas, which enters the atmosphere. Nitrogen gas makes up 78% of the atmosphere. It is removed from this reservoir by nitrogen fixation by bacteria, the conversion of nitrogen gas into nitrate by lightning, and some human activities.

7. Carbon, sulfur, oxygen, and nitrogen cycle through Earth's atmosphere; phosphorous does not.

8. Excess phosphate can act as a fertilizer to increase algal growth. Significantly high amounts of phosphate in bodies of water can cause algal blooms. The overgrowth of algae in such blooms can block out sunlight so that aquatic plants in the water below die, as they can no longer photosynthesize. Decomposition of this excess organic matter uses up much of the oxygen in the water, resulting in the death of fish and other aquatic animals that require oxygen. This area becomes devoid of life and is known as a dead zone.

9. **(a)** Photosynthesis caused the increase in atmospheric oxygen levels.

(b) Scientists examine stromatolites to gather evidence about past levels of atmospheric oxygen. Stromatolites with black bands of iron oxides were formed when the oceans contained oxygen and free iron ions, and the atmosphere likely contained little to no free oxygen. Stromatolites without black bands were probably formed when the oceans no longer contained iron ions that were not bound up in iron oxides. As a result, oxygen produced by photosynthesis was able to escape into the atmosphere after this point in time.

10. Fertilizers contain usable forms of nitrogen, phosphorous, sulfur, and other nutrients that optimize plant growth.

11. **(a)** Plants can use ammonium and nitrate.

(b) Nitrogen-fixing bacteria transform atmospheric nitrogen into a form of nitrogen that plants can use: ammonium. Through ammonification, bacteria also decompose organic matter to produce ammonium, which is further transformed into nitrite and then into nitrate by still more bacteria.

(c) Denitrifying bacteria convert nitrite and nitrate into nitrogen gas.

12. **(a)** Acid deposition is a process by which emissions, such as those containing sulfur, undergo chemical change in the atmosphere and are deposited in the environment as dry particles and gases, or as wet acid precipitation, including rain, snow, and fog. In eastern Canada, high levels of manufacturing result in the burning a large amount of fossil fuel. This combustion releases sulfur dioxide into the atmosphere. The sulfur dioxide reacts with water vapour in the atmosphere to form sulfurous and sulfuric acid that falls with rain, snow, or sleet.

(b) The sulfur cycle and water cycle are involved in acid deposition. Some students may add that the nitrogen cycle is also involved, which is correct, although it is not clearly stated in the text.

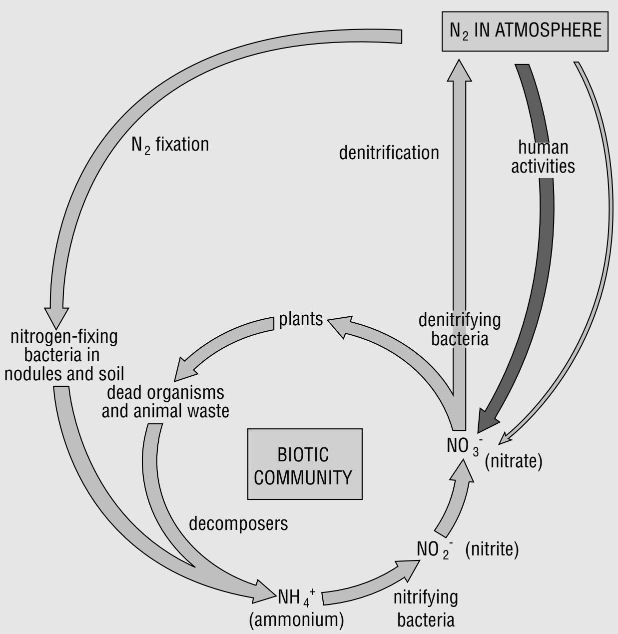
13. In the nitrogen cycle, elemental nitrogen, as well as nitrogen compounds in the lithosphere, cycle through the atmosphere in order to return once again to the soil of the lithosphere. In fact, the atmosphere is a significant nitrogen reservoir. In contrast to the nitrogen cycle, phosphorus does not cycle through the atmosphere at all. Instead, the lithosphere is a significant phosphorus reservoir. Both substances, however, are essential components of living cells, and the soil of the lithosphere is the key means by which these substances are passed (ingested or absorbed) as nutrients into living cells and released (through feces and decomposition) as nutrients to enrich the soil once again.

14. The term "ecosystem services" refers to the benefits that an ecosystem provides to its human inhabitants. These benefits include breathable air, natural filtration of water, food, pollination, erosion control, and climate stability.

15. Although nutrients may be plentiful in the deep ocean, not enough light penetrates deep waters to allow for high productivity from photosynthesis. In coastal areas, productivity is greater because coastal upwellings supply nutrient-rich water from the deep ocean, while shallow water ensures producers receive high levels of sunlight for photosynthesis.

16. Wetlands are natural filtration systems, which decontaminate water. Wetlands also provide food and shelter to numerous life forms.

17.



18. Water dissolves a wide range of ionic compounds and molecules. This means that water can transport nutrients and gases in organisms and the abiotic environment. Water vapour is a greenhouse gas, and thus traps heat in Earth's atmosphere. Because water has a high heat capacity, large bodies of water moderate temperatures over nearby land, and ocean currents carry heat from place to place. When plants lose water via transpiration or animals sweat, the evaporating water takes heat with it and cools the organism. Organisms resist environmental temperature changes somewhat because their body tissues contain large amounts of water and are, therefore, slow to heat or cool. Water also stays liquid over a wide range of temperatures and floats as ice, allowing aquatic organisms to live under the ice in winter. Because water is densest at 4 °C, cooling and warming also result in nutrient turnover, supporting life.

Answers to Applying Concepts Questions

19. The researchers could conduct a controlled experiment by setting up a series of tanks with water, the same type and amount of algae, the same type and amount of nutrients, and exposure to the same amount of UVR and visible light. The tanks should be exposed to a range of temperatures (the manipulated variable). The researchers could assess the results based on algal death or productivity, or by checking for mutations in the algal DNA.

20. (a) It appears that vegetation maintains water in an ecosystem and reduces erosion; therefore, downstream flooding may be directly caused by deforestation.

(b) Large-scale deforestation would decrease transpiration, and instead of moving through plants, water would move quickly over land into bodies of water. A lack of moisture in the air would probably change patterns of precipitation.

(c) The amount of nitrate in streams from deforested areas was high compared to the amount in streams from forested areas. The results suggest that nitrate was washed out of the soil in the deforested areas.

(d) Deforestation can result in a reduction of available nitrate that would be otherwise taken up by plants to enter the food chain. This nitrate may be more easily washed from the soil into streams and other natural bodies of water. Excess nitrate in downstream areas could result in algal blooms. In general, there will be more nitrogen in the aquatic parts of the cycle and less in the terrestrial parts.

(e) The lack of nutrients could inhibit new plant growth in a previously deforested area, as could the soil's inability to hold moisture.

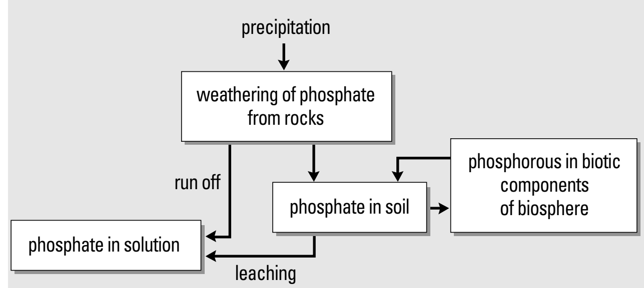
21. Precipitation could wash pesticides in a landfill into the ground water, compromising its quality.

22. (a) The heavy rains likely carried bacteria in the manure into the ground water that served as the town's water supply.

(b) Two safeguards would be more stringent water testing by qualified personnel and acting quickly on the results. Actions could include isolating a drinking water supply from the source of contamination or adding more chlorine to drinking water.

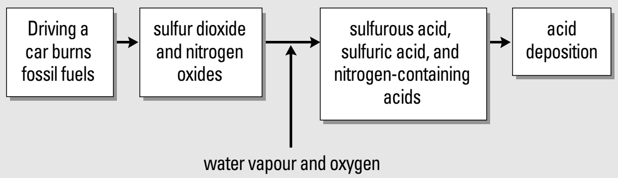
Answers to Making Connections Questions

23.



24. Garbage can be defined as waste. Students may tackle questions such as: If a grizzly bear leaves a half-eaten moose, is it garbage if the waste is eventually eaten by scavengers and decomposed? Pollution is the contamination of the environment, generally by certain chemicals or disease-causing organisms. Wild animals may release disease-causing organisms into the environment. Unless wild animals are themselves contaminated with toxic chemicals, however, they do not pollute the environment with toxic chemicals.

25. (a)



(b) Sulfur dioxide and nitrogen oxides released over Alberta may enter atmospheric circulation. The resulting acid deposition will then fall in an ecosystem elsewhere in the country.

Career Focus: Ask a Sustainability Expert

Student Textbook pages 66-67

Teaching Strategies

To supplement this Career Focus, you may want to invite a sustainability expert to talk to your class or visit a sustainable farm, industry, or building in your region.

Answers to Go Further questions

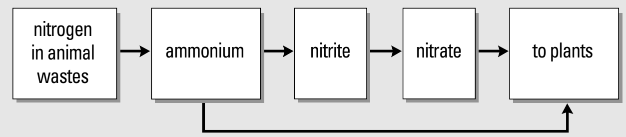
1. Students may choose to research fireplaces, use of various building materials or surface treatments, ventilation and heating systems or water or engergy use.
2. Humans have evolved to function optimally in outdoor carbon dioxide levels. In offices and other crowded indoor environments, carbon dioxide levels can increase to levels our bodies function poorly in. Thus outdoor carbon dioxide levels determine the amount of fresh air we bring into buildings.
3. Much of the food in grocery stores in Alberta comes from outside Canada. In addition, Canada ships food produced here around the world. Pollutants and contaminants produced in one part of the world may easily travel to another part of the world via air or water and pollute the food grown in this location.

Unit 1 Review Answers

Student Textbook pages 68-71

Answers to Understanding Concepts Questions

1. In a terrestrial environment, plants capture energy from the Sun and store the energy in organic molecules. Consumers obtain energy by eating plants and other consumers. Decomposers obtain energy by consuming organic matter from all trophic levels.
2. Fungi are decomposers, not producers. Unlike plants, which are autotrophic, fungi are heterotrophic and, therefore, obtain energy and carbon by consuming organic matter.
3. Thermal vent bacteria are chemosynthetic and obtain energy by splitting hydrogen sulfide. Thermal vent bacteria store energy in organic molecules, which are consumed by the giant tubeworms or clams that the bacteria live in. Energy is then transferred to crabs and fish at the next trophic level.
4.



5. Plants and animals use phosphorous in ATP and DNA, and animals use phosphorous in bones and teeth.
6. If global productivity were to decrease, the lack of photosynthesis would decrease amounts of oxygen in the atmosphere and allow carbon dioxide to build up in the atmosphere.
7. **(a)** Assuming the dolphins eat squid, the dolphin and seabird (many are scavengers) populations would likely increase if the squid population increased.

   (b) Food chains should be linear with phytoplankton at the first trophic level (producers), zooplankton at the second trophic level (primary consumers), fish at the third trophic level (secondary consumers), and seabirds at the fourth trophic level (tertiary consumers). Some students may include dolphins or squid in the food chain below seabirds, many of which are scavengers. All producer/consumer categories should be identified.

   (c) Fish that eat zooplankton are secondary consumers, and will obtain only about 10% of the energy available in the zooplankton. If the zooplankton obtains only 2500 kJ (10% of the energy available in the phytoplankton), the fish will obtain only 250 kJ from the zooplankton.
8. A pyramid of biomass for the deciduous forest will be upright with a base that is wider than any of the other steps in the pyramid. The remaining steps of the pyramid should reflect the biomass of each trophic level (will be similar to those in the pyramid of numbers in the text). Student drawings should have all producer and consumer levels labelled.
9. Since only 17% of the energy will be used for growth, this will be the amount available to the next level in the food chain: $0.17 \times 750 \text{ J} = 127.5 \text{ J}$ (130 J to correct significant figures)

10. Four properties of water that make it vital to living organisms are:
   - The density of water is greatest at 4 °C, and so ice floats. This allows aquatic organisms to survive under ice for the winter.
   - Water has a high heat capacity, and so water in body tissues is slow to cool or warm, and body temperature is regulated. Water evaporating from the surface of transpiring plants or sweating animals takes away heat, cooling the organism so it doesn't overheat.
   - Because water molecules are polar, water can dissolve many types of compounds, within living systems or in the non-living environment, transporting nutrients so they are available to organisms.
   - Cohesion (the attraction of water molecules to one another) and adhesion (the attraction of water molecules to molecules of other substances) allows water to travel up the xylem of plants by transpiration. This process is either directly or indirectly essential to many living organisms.

11. **(a)** The hydrologic cycle and sulfur cycle are involved in acid deposition. The nitrogen cycle is also important, but this is not highlighted in the text. Burning fossil fuels releases sulfur dioxide (and nitrogen oxides) into the atmosphere. These molecules react with water vapour to form acids that fall to Earth as various forms of acid deposition.

    (b) A deciduous forest ecosystem can be harmed by acid deposition, which damages the tissues of plants. Further, acid entering aquatic systems can kill fish and harm other aquatic organisms.

12. **(a)** Compared to the Arctic, the tropical rainforest has much more productivity because the climate is warm and wet, with strong sunlight year round. There is also a more rapid cycling of nutrients in a tropical rainforest.

    (b) Compared to a geologically inactive part of the sea floor (i.e., where there are no thermal vents or cold seeps), the coastal waters will have higher levels of productivity due to increased nutrient availability (this is an area of high nutrient turnover) and a greater amount of sunlight.

    (c) Compared to a geologically inactive part of the sea floor, a region near a thermal vent will have much more productivity, due to the presence of hydrogen sulfide and the chemosynthetic bacteria that live near the vent, which use this chemical as a source of energy to create organic molecules that can support an entire ecosystem.

13. Earth's atmosphere today is composed of more oxygen and less carbon dioxide than it was three billion years ago. At that time, there was little to no oxygen in the atmosphere.

14. Metabolic water is the net water produced in cellular respiration.

15. The rapid cycling of carbon moves carbon relatively quickly through biotic and abiotic components of the biosphere. Producers remove carbon dioxide from the atmosphere and store carbon in organic molecules. Consumers release carbon dioxide during cellular respiration of these molecules. Decomposition releases carbon to the biosphere from organic waste. Carbon also moves between the atmosphere and the ocean surface. In comparison, the slow cycling of carbon adds carbon to nutrient reservoirs, such as coal, oil, peat, and the deep ocean, where it is not accessible to organisms for extensive periods of time.

16. **(a)** If photosynthetic organisms could capture twice the usual amount of solar radiation, global productivity would likely increase. The resulting increase in photosynthesis would remove more carbon dioxide from the atmosphere and increase levels of oxygen. As a result, the effects of global warming would decrease. More nutrients would be tied up in plants rather than being transported through the abiotic environment. If nutrients were available, algal blooms would likely increase in frequency, but as more nutrients would be tied up in plants, this is debatable.

    (b) If photosynthetic organisms could only capture half the usual amount of solar radiation, global productivity would likely decrease. The decrease in photosynthesis would allow carbon dioxide to build up to higher levels in the atmosphere, while levels of oxygen would decrease. As a result, the effects of global warming would increase. Fewer nutrients would be tied up in plants and more would be transported through the abiotic environment.

17. **(a)** Dead zones are areas where aquatic life has been killed off due to lack of oxygen. They often result as a consequence of algal blooms.

    (b) Human activities, including deforestation, inadequately treating sewage, livestock farming, and fertilizing fields and lawns can introduce excess phosphate into natural waters. The phosphate provides nutrients for the algae, resulting in an explosion of growth, an algal bloom. During an algal bloom, an excess growth of algae blocks out sunlight and aquatic plants die. As this organic matter is decomposed, oxygen is used up and fish and other aquatic animals that require oxygen die as well, resulting in a dead zone.

18. Increased krill farming may reduce the amount of krill available to organisms that consume krill in their natural ecosystem. The population of these consumers may reduce as a result. This population reduction may affect organisms at higher trophic levels that feed on the krill-consuming species. Thus, the entire food web in the ecosystem may be altered.

19. (a) Alberta's wetlands serve as water filters and water storage sites, they help control floods, and they are home to numerous species, such as the endangered whooping crane.

(b) Wetlands are natural water filters, which remove contaminants from the water.

Answers to Applying Concepts Questions

20. (a) There are two possibilities. The bacteria may be surviving by deriving energy from the chemosynthesis of hydrogen sulfide. The resulting sulfuric acid could be used by sulfate reducing bacteria, which would produce hydrogen sulfide as a by-product of their metabolism, which would further react with iron to form black iron sulfide. The hydrogen sulfide released by volcanoes could react with iron to form black iron sulfide as well. The other possibility is that the bacteria are photosynthetic. They are producing oxygen through this process and the oxygen is binding with free iron ions in water, rather than escaping into the atmosphere. This would also explain the black precipitate, which would consist of iron oxides.

(b) It is quite likely this planet could support other forms of life. If the bacteria are carrying out chemosynthesis, they may eventually begin to carry out photosynthesis as well. Or perhaps life forms totally foreign to us will develop on this planet that base their life processes on chemosynthesis. If the bacteria are photosynthetic, life could evolve that is similar to life on Earth.

21. Since 10% of 2500 J is 250 J, the deer will obtain 250 J by eating 1.25 kg of the shrub. Since 10% of 250 J is 25 J, 25 J of energy captured by the shrub would be passed on to the cougar when it eats 1.00 kg of deer meat, assuming all the energy from the shrub has been stored in that 1.00 kg of meat. Note that only 25 J of energy from the shrub is available to the cougar no matter how much meat the cougar consumes. The rest has been lost as heat energy or waste.

22. Stromatolites that contain black bands of iron oxides must have formed when free iron ions and dissolved oxygen were found in the oceans. As oxygen produced by photosynthesis built up, it would have become bound to the oceans' store of iron ions until there were no more free ions. At this point, the black bands in stromatolites would have stopped forming, as there were no more free ions in the water. Additional oxygen gas from photosynthesis would have escaped into Earth's atmosphere. If Earth's atmosphere had always contained oxygen, presumably the black bands of iron oxides would have formed earlier as atmospheric oxygen was mixed with ocean water, forming iron oxides.

23. Student suggestions may include the following:

- A sustainable food source, such as a garden, since there is no outside access to food; possibly with drip filtration or another water-wise feature to help conserve water, and a water re-collection system to reuse run-off
- An oxygen-carbon dioxide exchange system, such as the garden
- A light source for the garden, such as sunlight or artificial full-spectrum light
- A power source, such as solar radiation, and a means of harnessing that power, such as solar panels
- A water filtration and recycling system to recycle water in urine and feces
- A waste composting system that will allow human and plant waste to be reused, providing nutrients and organic matter for the garden

24. (a) When algae or cyanobacteria reproduce in large numbers, they block out sunlight, which results in the death of aquatic plants. The decomposition of the resulting organic matter uses up all of the oxygen in the water. Other aquatic organisms in the area are starved of oxygen and die. Cyanobacterial blooms are more dangerous than algal blooms because harmful toxins may be released.

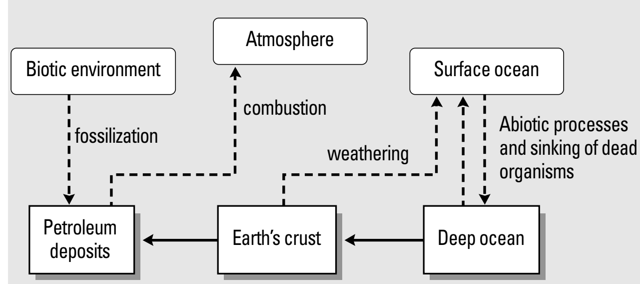
(b) Excess phosphate tends to be responsible for algal blooms.

(c) Run-off from deforested areas, inadequately treated sewage, and run-off from livestock farms, agricultural fields, and lawns may contain excess phosphate and nitrate.

25. The pyramid of biomass will be upright and should have a wide base for the producers and proportionally smaller steps for primary and secondary consumers. All biomass values [700 g/m^2 (producers), 132 g/m^2 (primary consumers), and 11 g/m^2 (secondary consumers)] and producer/consumer levels should be labelled.

26. A living organism is self-regulating and can maintain internal conditions within certain limits. Like an organism, the biosphere is self-regulating: For example, the production of carbon dioxide through cellular respiration is balanced by the uptake of carbon dioxide in photosynthesis. Similarly, all matter in the biosphere is recycled. There is a constant input of energy into the biosphere in the form of solar radiation which makes up for energy that is transformed into unusable heat.

27.

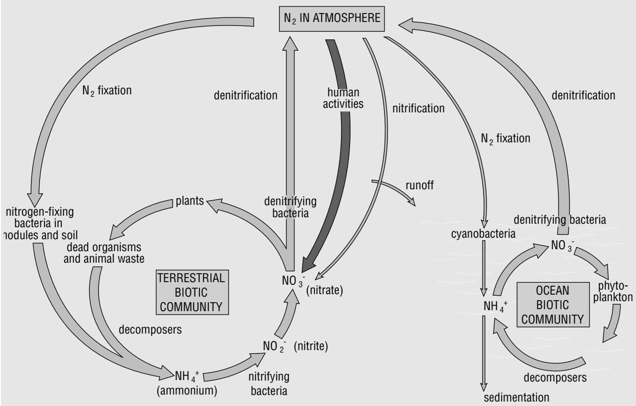


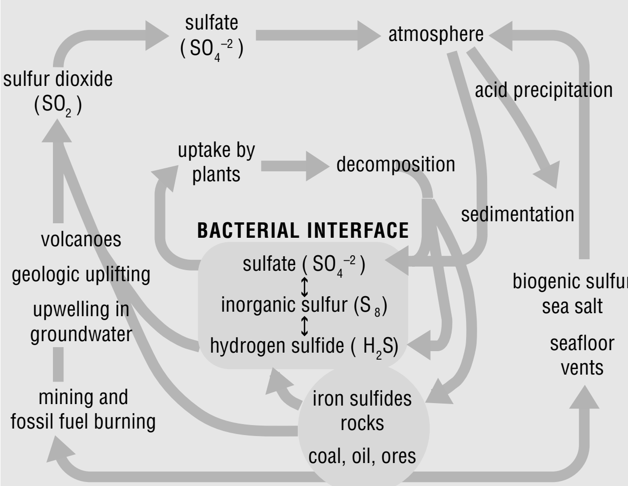
The slow cycling of carbon
Dotted arrows indicate connections to rapid cycling of carbon

28. **(a)** The carbon cycle is greatly influenced by deforestation and burning fossil fuels, which release carbon dioxide into the atmosphere. The sulfur cycle is influenced by human activities such as burning of fossil fuels, which releases sulfur dioxide into the atmosphere. Sulfur is also mined. (Students may also make a case for other biogeochemical cycles.)

(b) Bacteria play important roles in the nitrogen cycle by carrying out nitrogen fixation, ammonification, nitrification and denitrification. Bacteria play important roles in the sulfur cycle by converting sulfate to inorganic sulfur and hydrogen sulfide. Bacteria also carry out the reverse reactions.

(c) Students should illustrate the nitrogen cycle or sulfur cycle.

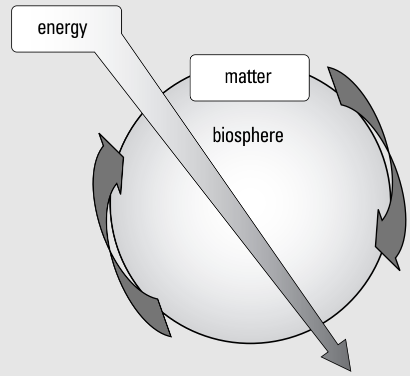




29. The batteries rust and leak their contents of heavy metals. The metals dissolve in water from precipitation, and are transported to ground water, rivers, and streams. Some metals, such as mercury, end up in the food chain where they biomagnify. (Micro-organisms can convert elemental mercury to methylmercury).

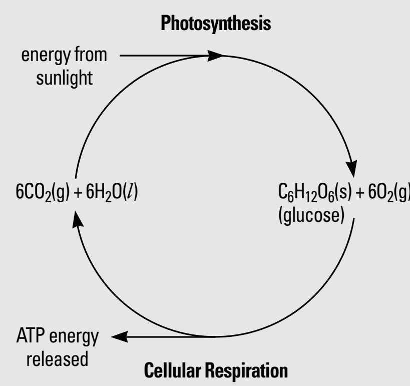
30. **(a)** Biogeochemical cycles exemplify how all matter on Earth is cycled. Matter can be broken down and put together in different ways but not removed from Earth. Energy is not cycled. It can be passed from one trophic level to another, but with each energy transformation, some energy becomes unusable.

(b)



31. Sulfur reducing bacteria such as *Desulfovibrio* produce hydrogen sulfide, which reacts with the heavy metals in solution. The heavy metal sulfide compounds would precipitate, trapping the heavy metals and keeping them out of the food chain. Sulfur oxidizers will convert excess hydrogen sulfide to sulfate, which sulfate reducers can use to produce more hydrogen sulfide. Students may also suggest using aquatic plants and then removing them after phytoremediation.

32.



Answers to Making Connections Questions

33. **(a)** Over-application of insecticides and herbicides, if they are not target-specific, could kill off soil organisms, thereby changing the soil's structure.

(b) The amount of usable nitrogen and phosphorous in soil tends to be limited, and instead of depending on the action of soil micro-organisms to make nitrogen available and abiotic natural processes to make phosphorous available, it may be simpler and more effective to add synthetic fertilizers.

34. Because the croplands farther south support large numbers of snow geese, these same numbers will be looking for food in the Arctic, where the growing season is very short and productivity is modest. The large numbers of snow geese may be over-consuming vegetation on the tundra. Therefore, culling some of the geese might help protect the tundra ecosystem.

35. Human activities that affect biogeochemical cycles can have far-reaching effects. Pollutants, such as DDT, can join the hydrologic cycle and travel long distances in the atmosphere and liquid water. Pollutants can join the carbon cycle by entering the food chain; some kinds of pollutants will become concentrated in higher-level consumers due to biomagnification.

36. (a) Floods can wash various pollutants, pathogens, and organic matter into water supplies, making the water unfit for drinking and washing. Water treatment facilities have more work to do than usual following a flood. Therefore, citizens should restrict their water-use so that water treatment facilities can keep up with demand.

(b) The heavy rains in 2005 are considered to be atypical in Alberta. Scientists do not believe that the heavy rains in one season will make up for potentially many years of drought. Alberta has experienced many droughts in the past, and if global temperatures rise, the rate of evaporation of water will likely increase, making Alberta even drier. As Alberta's human population grows, the demand for water will also increase. Many societal uses of water affect its quality, which could place usable water in short supply.

37. (a) A pond should not be considered an ecosystem, as it is not self-sustaining: it must have a constant inflow of fresh water or it will dry up due to evaporation.

(b) A fish aquarium should not be considered an ecosystem, as it is not self-sustaining: it must have a constant inflow of food, nutrients, and oxygen, or the organisms in it will die. Neither is it self-regulating: it requires a pump and regular cleaning.

(c) A wheat farm should not be considered an ecosystem, as it is not self-sustaining: it must be planted regularly, watered, and fertilized. Neither is it self-regulating: it must be harvested, pests must be removed, etc. if it is to stay healthy and productive.

(d) A city should not be considered an ecosystem, as it is not self-sustaining: it must have a constant inflow of food, power, and water to survive.

(e) Earth should not be considered an ecosystem, as it is not self-sustaining: it must have a constant inflow of energy from the sun. It is, however, self-regulating.