

Biology Teacher's Edition (Being Reviewed)



Biology Teacher's Edition

Jean Brainard, Ph.D. (JBrainard)

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CHAPTER

1

TE What is Biology?

CHAPTER OUTLINE

1.1 SCIENCE AND THE NATURAL WORLD**1.2 BIOLOGY: THE STUDY OF LIFE****1.3 WORKSHEET ANSWER KEYS**



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Contents: CK-12 Biology

Unit 1: Introduction to Life Science

- Chapter 1: What is Biology?
- Chapter 2: The Chemistry of Life

Unit 2: Cells

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Unit 3: Genetics

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Unit 10: Human Biology

- Chapter 21: Introduction to the Human Body: Bones, Muscles, and Skin
- Chapter 22: The Nervous and Endocrine Systems
- Chapter 23: The Circulatory, Respiratory, Digestive, and Excretory Systems
- Chapter 24: The Immune System and Disease
- Chapter 25: Reproduction and Human Development

Biology Glossary

The Teacher's Edition (TE)

The TE includes sample answers to the Review Questions from the Student Edition (SE), and the Workbook/Worksheet answer keys, which are available upon request. Please send an email to teachers-requests@ck12.org to request sample answers.

Each unit and chapter will have a general overview. Each chapter section will also include an introduction and teaching strategies. The majority of content will be presented by individual lesson.

This Teacher's Edition will focus on eight subtopics for each lesson:

- a. Key Concept
- b. Standards

- c. Lesson Objectives
- d. Lesson Vocabulary
- e. Check Your Understanding
- f. Teaching Strategies
- g. Reinforce and Review
- h. Points to Consider

Worksheets and Assessments

- **CK-12 Biology Workbook** supplements CK-12's Biology FlexBook and contains six worksheets for each lesson. Worksheet answer keys are available in the TE by request.
- **CK-12 Biology Quizzes and Tests** contains lesson, chapter, and unit assessments. Answers to these assessments are included in CK-12 Biology Quizzes and Tests and will be provided upon request. Please send an email to teachers-requests@ck12.org to request answers.

Science Notebook

For a year's study of Biology, we recommend a **science and/or lab notebook** in which students may:

- Answer the *Check Your Understanding* questions.
- Answer/reflect on the *Points to Consider* questions.
- Write additional questions about an upcoming lesson, chapter, or unit of study.
- Draw pictures of living organisms and diagrams of life processes.
- Take notes and define academic vocabulary.
- Keep a record of pertinent web sites to access relevant information.
- Write up lab activities.
- Write up ideas for possible long-term projects.
- Keep reflections on what they have learned.

Students should date each entry and refer back to their ideas earlier in the year, reflecting on their deepening understanding.

Teaching Strategies

Throughout the TE, we will provide numerous examples of strategies that can be used to make the content accessible to students. Many strategies and activities have been included as web site links, and we recommend that these be previewed before assigning to the students. Traditional examples of general teaching strategies, differentiated instruction, enrichment, science inquiry, and reinforcement strategies will be provided. For additional examples of teaching strategies, see [Biology I #38; II Teacher's Edition](#).

Teaching Strategies: General

- a. Appreciate what's difficult for students, helping them develop scientific ways of thinking.

- b. Vary class activities, using a wide variety of resources to aid students in deepening their understanding of scientific issues.
- c. Give students opportunities to participate in scientific investigations to understand “doing science.”

- **Using Visuals**

Use illustrations in the student edition as a tool for teaching content, exploring ideas, and probing students’ misunderstandings.

- **Building Science Skills**

Have students apply higher-level thinking or other relevant skills as they relate to lesson content (e.g., predicting, forming hypotheses, drawing conclusions, interpreting data, observing, classifying, making inferences, comparing and contrasting, identifying cause and effect, analyzing). This might be achieved through a simple activity, answering questions, class discussion, and/or partner work.

- **Discussion**

Stimulate class discussion of a topic. This could include scripted questions to ask the class, with expected or sample answers. The discussion tips should be specific and focused. For example, don’t write: “Discuss Darwin’s theory of evolution.” Instead, write: “Guide students in discussing why Darwin’s theory was not widely accepted in his own lifetime.” Ask: “How did Darwin’s theory of evolution conflict with prevailing views of living things?”

- **Demonstration**

Do (and fully describe) an in-class demonstration to illustrate or explain a process, concept, etc. Keep in mind constraints on classroom time and resources. Include a concluding sentence or scripted question that relates the demonstration to the process or concept.

- **Activity**

Have students do a simple hands-on activity that will help them better understand a topic or process. Explain fully how the activity is to be done. This could be a pencil-and-paper activity or other activity that does not involve materials, although readily available classroom materials could be used. Again, conclude with a sentence or question that ties the activity with the topic or process being studied.

Teaching Strategies: Differentiated Instruction

These strategies can be used for all three types of student populations that are typically addressed by DI (i.e., ELL, LPR, SN), but a particular population has been specified each time a strategy is used. The strategy can be tailored somewhat to that population, even if it’s only by referring to the population type in the strategy (e.g., “Pair English language learners with native speakers of English”).

- **KWL**

Have students make a KWL chart, where K = Know, W = Want to Know, and L = Learned. Students should fill in the K and W columns before reading and the L column after reading a particular passage or lesson.

- **Cloze Prompts**

Give students cloze sentences (basically, fill-in-the-blank sentences) about important lesson concepts. Students are instructed to fill in the missing words as they read the lesson.

- **Gallery Walk**

Divide the class into groups and have the groups walk around the room to read and discuss posted questions or topics (each on a large sheet of paper). Each group (using a different color pen) answers the questions or writes comments about the topics. They also read and respond to answers/comments written by other groups. This is followed by discussing the answers/comments with the class, reviewing misunderstandings they reveal, or by groups summarizing what they know about one or more questions/topics.

- **Think-Pair-Share**

Assign questions or topics to individual students to think about. Pair ELL students with native speakers and LPR students with more proficient readers to work together on answering the questions or discussing the topics.

- **Fruiter Model**

Assign this vocabulary strategy, which involves students drawing a large box and dividing it into four parts labeled “Definition,” “Drawing,” “Example,” and “Non-example.” Assign students a vocabulary word and tell them to fill in each part of the box for that word.

- **Cluster Diagram**

Have individual students, pairs, groups, or the class as a whole make a cluster diagram organizing lesson concepts.

- **Concept Map**

Have individual students, pairs, groups, or the class as a whole make a concept map organizing lesson concepts.

- **Venn Diagram**

Have individual students, pairs, groups, or the class as a whole make a Venn diagram organizing lesson concepts.

- **Compare/Contrast Table**

Have individual students, pairs, groups, or the class as a whole make a compare/contrast table for specific lesson concepts, processes, etc. (e.g., photosynthesis and cellular respiration; mitosis and meiosis). You may need to provide the column and row headings for the table.

- **Cycle Diagram**

Have individual students, pairs, groups, or the class as a whole make a cycle diagram to show the steps in a cyclical process (e.g., life cycle of amphibians).

- **Flow Chart**

Have individual students, pairs, groups, or the class as a whole make a flow chart to show the steps in a process (e.g., photosynthesis).

- **Main Ideas/Details Chart**

Have students divide a sheet of paper in half, on the left side write the main ideas from a passage or lesson (skipping several lines between the main ideas). On the right side, students are instructed to fill in important details about each main idea as they read.

- **Word Wall**

Post lesson vocabulary words and their definitions, examples, etc., on a bulletin board or wall. Refer students to the word wall as they study lesson content.

Teaching Strategies: Enrichment

Although online and/or library research is always an option for enrichment, it tends to be overused. Avoid it unless it is really relevant and likely to be helpful for the other students in the class. Whatever students are assigned to do, they should be given a chance to share their work with the class through an informal oral presentation, a written report, etc. In some cases (e.g., making a board game or crossword puzzle), the product can be used by the class to reinforce or review lesson content.

- Research a Topic
- Present a Role-Play
- Teach a Topic
- Create a Video
- Create a Poster
- Debate an Issue
- Interview an Expert
- Create a Model
- Demonstrate a Process
- Take a Survey
- Write an Essay
- Make a Board Game
- Make a Crossword Puzzle
- Create a Web Site
- Make a Diagram
- Make a Diorama
- Make a Display
- Write a Research Proposal
- Make a Video
- Write a Rap (Song)
- Present a PowerPoint Show
- Lead a Discussion

Teaching Strategies: Science Inquiry

These strategies should get students involved in thinking or acting like a scientist. They should help the students learn lesson content by encouraging them to be actively engaged in scientific thinking and/or using scientific methods.

- Ask a Research Question: e.g., based on hypothetical observations.
- Formulate a Hypothesis: e.g., based on a research question. Must be specific and testable; could also ask students to describe data that would support or disprove the hypothesis.
- Develop a Research Plan: e.g., to test a specific hypothesis. Could focus on types of variables, controls, etc.
- Analyze Data: Data could be in a graph or table that is provided in the SE or TE or students could find the data online.

- **Solve a Problem:** requiring application of lesson concepts, procedures, etc.

Reinforcement Activity

In addition to online quizzes, this could be a quick teacher-directed activity or something students do alone or in pairs to make sure they understand lesson content. It should probably be aimed at the average to below-average students in the class, though reinforcement activities are important for all students. Some suggestions are listed below. The goal is to reveal to the teacher or to the students themselves what they know and what they still don't understand. The activity should include a sentence suggesting a way for students to learn what they don't know (e.g., "Find definitions in the FlexBook of any vocabulary words you did not know.").

- **Take an Online Quiz:** Have students track their own level of mastery of concepts as measured by quizzes. Additionally, you could have students take the quiz before and after teaching the material and have them track their growth.
- **Make Flashcards:** This activity could be used for boldface vocabulary words or important concepts; have students use the flashcards to quiz a partner.
- **Label a Drawing:** The drawing could be art from the SE with the labels deleted.
- **Outline the Lesson:** This could be done with a partner or as a class using an overhead projector.
- **Ask Questions:** Each student turns in a question on an index card. Then, the teacher answers or reviews material relevant to those questions that are asked most frequently.
- **List and Discuss:** Students make a list of something (e.g., reproductive isolating mechanisms), and then partners compare and discuss their lists.
- **Use Vocabulary:** Students use the lesson vocabulary words in sentences or a brief paragraph.
- **Make a Quiz:** Students write a few fill-in, matching, or true/false questions and then use them to quiz a partner.
- **Make a Drawing:** Students create a simple sketch to demonstrate comprehension of a process (e.g., cell division).
- **Complete a Chart:** Students complete missing parts of a diagram or fill in cells of a table that have missing information.

Check Your Understanding

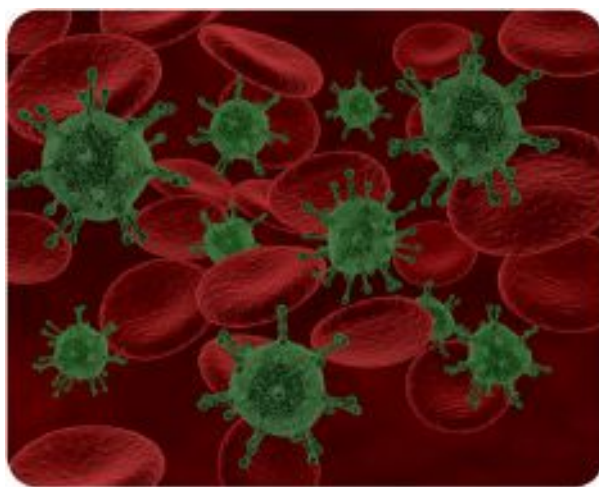
This section includes questions related to previously presented information that the authors consider important for **the student** to have access to the information in the current lesson.

Points to Consider

Questions in this section serve as a segue into the next lesson (or chapter). Ask students to read the Points to Consider at the end of the lesson in their FlexBook. They can be answered individually or as an opening to lead a class discussion. Use these questions to assess student understanding and misconceptions before beginning the next unit of study.

Contributors

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What is Biology?

Outline

Lesson 1.1: Science and the Natural World

1.1.1 Goal of Science

- Nature Can Be Understood
- Scientific Ideas Can Change
- Scientific Knowledge Can Withstand the Test of Time
- Science Cannot Answer All Questions

1.1.2 The Scientific Method

- Making Observations

- Asking a Question
- Forming a Hypothesis
- Testing the Hypothesis
- Drawing Conclusions
- Communicating Results

1.1.3 Experiments

- KQED: Medicine From the Ocean Floor
- Variables
- Sample Size and Repetition

1.1.4 Other Types of Scientific Investigations

- Natural Studies
- Modeling

1.1.5 Scientific Theories

1.1.6 KQED: Bio-Inspiration: Nature as Muse

Lesson 1.2: Biology: The Study of Life

1.2.1 Characteristics of Life

- Response to the Environment
- Growth and Development
- Reproduction
- Keeping Things Constant
- Complex Chemistry
- Cells

1.2.2 Unifying Principles of Biology

- The Cell Theory
- The Gene Theory
- Homeostasis
- Evolution

1.2.3 Interdependence of Living Things

- Symbiosis
- Competition
- Levels of Organization
- Diversity of Life

1.2.4 Evolution of Life

- Darwin and the Theory of Evolution
- Evolutionary Theory After Darwin
- Misconceptions About Evolution

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 1.1:

Lesson	Number of Class Periods
1.1 Science and the Natural World	3
1.2 Biology: The Study of Life	2
Assessment	1

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

- http://www.troy.k12.ny.us/academics/bio/labs/scimethod1_lab_school.asp
- http://www.biology4teachers.com/scientific_method.htm

The Web sites below may also be helpful for this lesson and other lessons throughout the text. They provide additional background and ideas for classroom activities.

- <http://www2.estrellamountain.edu/faculty/farabee/biobk/BioBookintro.html>
- http://serendip.brynmawr.edu/sci_edu/waldron/
- <http://teachone.tripod.com/biology/>
- <http://www.accessexcellence.org/AE>

1.1 Science and the Natural World

Key Concept

The goal of science is to understand the natural world through systematic study, using evidence and logic. A scientific investigation is a plan for asking questions and testing hypotheses. A scientific theory is a broad explanation that is widely accepted because it is supported by a great deal of evidence.

Standards

- CA.9–12.IE.1.b, c, d, f, g, j, k, n
- NSES.9–12.A.1.1, 2, 4, 6; NSES.9–12.A.2.1, 2, 5, 6; NSES.9–12.E.2.3; NSES.9–12.G.2.1, 2, 3; NSES.9–12.G.3.2, 3, 4
- AAAS.9–12.1.A.1, 2, 3; AAAS.9–12.1.B.1, 2, 3, 4, 6, 7; AAAS.9–12.1.C.4, 7; AAAS.9–12.11.B.1, 2, 3; AAAS.9–12.12.A.1, 2; AAAS.9–12.12.D.5
- McREL.9–12.11.1.1, 2, 3, 4, 5; McREL.9–12.11.2.1, 2, 3, 4, 5, 6, 7; McREL.9–12.11.3.1, 2, 3, 4, 5, 6, 7, 8; McREL.9–12.11.4.1, 2; McREL.9–12.11.5.1, 2, 3, 4, 5, 6, 7, 8; McREL.9–12.11.6.1, 2, 3, 4, 5; McREL.9–12.11.7.1, 2, 3, 4; McREL.9–12.12.1.1, 2, 3, 4; McREL.9–12.12.2.15, 17, 18, 20, 22; McREL.9–12.12.3.7, 8, 9; McREL.9–12.12.6.3; McREL.9–12.12.7.7, 8; McREL.9–12.13.3.2, 3, 4, 5

Lesson Objectives

- Identify the goal of science.
- Describe how scientists study the natural world.
- Explain how and why scientists do experiments.
- Describe types of scientific investigations.
- Explain what a scientific theory is.

Lesson Vocabulary

- **dependent variable:** variable in a scientific experiment that is affected by another variable, called the independent variable
- **evidence:** any type of data that may be used to test a hypothesis
- **experiment:** special type of scientific investigation that is performed under controlled conditions
- **hypothesis:** possible answer to a scientific question that can be proven false
- **independent variable:** variable in a scientific experiment that is manipulated by the researcher to investigate its affect on another variable, called the dependent variable
- **model:** representation of part of the real world
- **observation:** anything that is detected with the senses

- **prediction:** statement that tells what will happen under certain conditions
- **science:** distinctive way of gaining knowledge about the natural world that tries to answer questions with evidence and logic
- **scientific investigation:** plan for asking questions and testing possible answers
- **scientific law:** statement describing what always happens under certain conditions in nature
- **scientific theory:** broad explanation that is widely accepted as true because it is supported by a great deal of evidence

Teaching Strategies

Introducing the Lesson

Describe a common activity such as comparison-shopping. Guide students in identifying how it is similar to science. (Both involve posing questions, making observations, analyzing data, and drawing conclusions.)

Building Science Skills

Have students watch the video demonstrations at the links below. Ask them to predict what will happen in each demonstration. Challenge the class to brainstorm hypotheses to explain their observations.

- <http://www.youtube.com/watch?v=x5DRuPuzqKI#38;NR=1#38;feature=fvwp>
- <http://www.youtube.com/watch?v=773Rv8pZeOs>

Differentiated Instruction

Instruct students to start a word wall for biology. For each lesson, beginning with this one, select a few students to add some or all of the new vocabulary terms to the wall. They should include definitions, examples, or illustrations of the terms. **ELL, LPR**

Enrichment

Ask interested students to investigate landmark scientific discoveries in biology (e.g., Van Leeuwenhoek's discovery of microorganisms; Krebs's discovery of the Krebs cycle; Watson, Crick, and Franklin's discovery of the structure of DNA). Give students an opportunity to share what they learn with the class. Ask them to explain how the discoveries were made and how they affected the direction of science. These and other discoveries are described at the link below.

- <http://science.discovery.com/convergence/100discoveries/big100/biology.html>

Science Inquiry

Divide the class into groups, and ask each group to develop a research plan to test the same hypothesis (e.g., plants will bend in order to face the light). Their plan should include independent and dependent variables and controls. Give groups a chance to share their ideas and discuss their merits.

1.1. SCIENCE AND THE NATURAL WORLD

Overcoming Misconceptions

Read the statements below to the class. Ask students whether they think the statements are true or false. Then explain why each of the statements is a misconception. For more information, go to this link: <http://undsci.berkeley.edu/teaching/misconceptions.php>

- There is a single scientific method that all scientists follow.
- Science is based only on data and involves no creativity.
- Without an experiment, a study is not scientific.
- Scientific ideas are always changing so they can't be trusted.
- Scientific data can prove that hypotheses are true or false.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

The Points to Consider at the end of each lesson in this book will help you relate what you just learned to what is coming next. The questions will help guide you to the next lesson or chapter. Before reading the next lesson of this chapter, consider these points:

- Remember the opening photo of red blood cells and green viruses? The blood cells are cells of a living thing. Do you think that the viruses are living things? Why or why not?
 - (*Sample response:* Students may think that viruses are living things because they can multiply.)
- Lab experiments are the main method of gathering evidence in some branches of science. Why might lab experiments not be the best way to study living things, such as wild animals?
 - (*Sample response:* Wild animals might act differently in a lab than they do in their natural setting. It would be hard to know if what you learn about them in a lab also applies in nature.)

1.2 Biology: The Study of Life

Key Concept

Living things have certain characteristics, such as being composed of cells and being able to respond to the environment, grow, and reproduce. Four basic principles underlying all of biology are cell theory, gene theory, homeostasis, and evolution. The great diversity of life on Earth today is the result of 4 billion years of evolution.

Standards

- CA.9–12.LS.6.a
- NSES.9–12.C.1.1; NSES.9–12.C.3.1, 2, 3, 4; NSES.9–12.C.4.3; NSES.9–12.D.3.4; NSES.9–12.E.2.3; NSES.9–12.G.1.3; NSES.9–12.G.3.3, 4
- AAAS.9–12.1.C.1; AAAS.9–12.5.A.2; AAAS.9–12.5.B.3; AAAS.9–12.5.F.1, 3, 6, 7, 8; AAAS.9–12.10.H.3, 4, 5, 6; AAAS.9–12.12.A.1
- McREL.9–12.13.4.1

Lesson Objectives

- List the characteristics of all living things.
- State four unifying principles of biology.
- Describe how living things interact.
- Explain how life on Earth evolves.

Lesson Vocabulary

- **adaptation**: characteristic that helps living things survive and reproduce in a given environment
- **biodiversity**: number of different species in an area or in the entire biosphere
- **biology**: science of life, study of life
- **biome**: group of similar ecosystems with the same general type of physical environment
- **biosphere**: part of Earth where all life exists, including land, water, and air
- **cell**: basic unit of structure and function of living things
- **cell theory**: theory that all living things are made up of cells, all life functions occur within cells, and all cells come from already existing cells
- **community**: all of the populations of different species that live in the same area
- **competition**: relationship between living things that depend on the same resources in the same place and at the same time
- **ecosystem**: all the living things in a given area together with the physical factors of the nonliving environment

- **evolution:** change in the characteristics of living things over time, the change in species over time
- **gene theory:** theory that the characteristics of living things are controlled by genes that are passed from parents to offspring
- **homeostasis:** process of maintaining a stable environment inside a cell or an entire organism
- **natural selection:** evolutionary process in which some living things produce more offspring than others so the characteristics of organisms change over time
- **organ:** structure composed of more than one type of tissue that performs a particular function
- **organ system:** group of organs that work together to do a certain job
- **organism:** an individual living thing
- **population:** all the organisms of the same species that live in the same area
- **reproduction:** process by which living things give rise to offspring
- **symbiosis:** close relationship between organisms of different species in which at least one of the organisms benefits from the relationship
- **tissue:** group of cells of the same kind that perform a particular function in an organism

Teaching Strategies

Introducing the Lesson

Ask students to name examples of living things. Write their responses on the board. Record the names of at least 10 different organisms. Then challenge students to identify ways all of the living things are alike. Tell the class they will learn six defining characteristics of living things in this lesson.

Using Visuals

Make sure students appreciate Earth's biodiversity. Have them compare the kingdoms in FlexBook **Figure 1.16** (reproduced below). Ask volunteers to find and share additional pictures of organisms in each kingdom. With the class, brainstorm possible characteristics that were used to divide living things into these kingdoms.



Diversity of life from Archaeobacteria to Plants and Animals. (Image of Archaeobacteria courtesy of NASA and under the public domain. Image of Plant courtesy of challiyan and under the Creative Commons license CC-BY-SA 3.0.

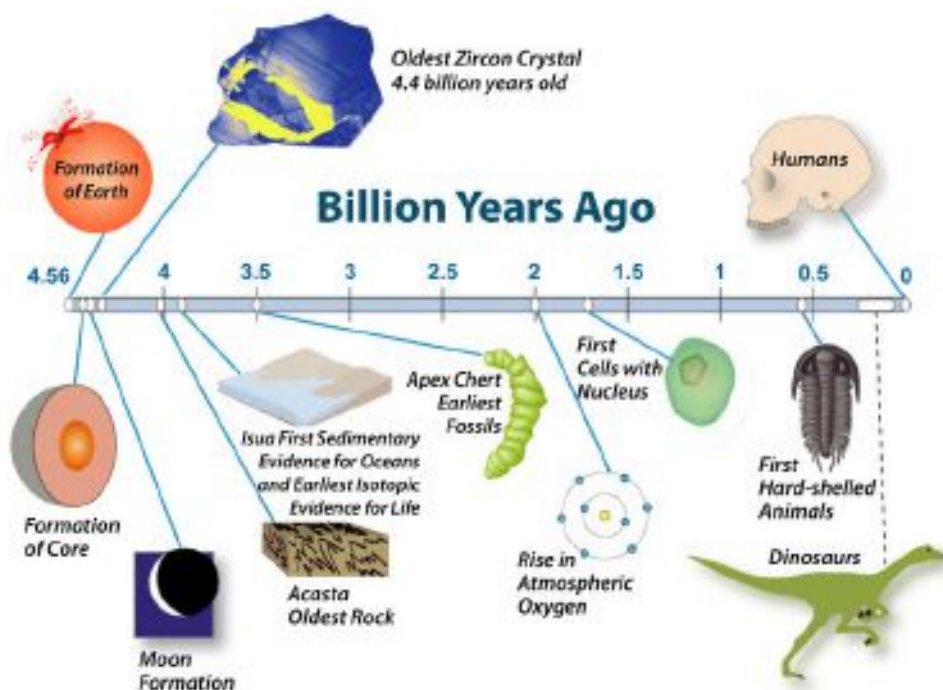
Images of Bacteria copyright 4designersart, 2010; of Protist copyright MichaelTaylor, 2010; of Fungus copyright turtleman, 2010; and of Animal copyright Alex Staroseltsey, 2010, all used under licenses from Shutterstock.com.)

Differentiated Instruction

Students should focus on the sections headed *Characteristics of Life* and *Unifying Principles of Biology*. Create cloze sentences based on these two sections by leaving out the boldfaced terms in the relevant sentences. Have students complete the sentences as they read the sections. **ELL, LPR**

Enrichment

Ask a few volunteers to create a room-sized scale model based on the diagram in FlexBook **Figure 1.17** (reproduced below). The model should use linear distances marked on the floor or a wall of the classroom to represent the time intervals between major events in the evolution of life. The model will help the class appreciate the vastness of geologic time. It will be useful for later chapters as well.



This timeline shows the history of life on Earth. In the entire span of the time, humans are a relatively new addition. (Image courtesy of Andree Valley and under the Creative Commons license CC-BY-SA 2.0.)

Science Inquiry

Have groups of students look for evidence of life by doing the investigation “Is Yeast Alive” at the link below. They will test dried baker’s yeast for metabolism and growth.

- http://serendip.brynmawr.edu/sci_edu/waldron/#yeast

Real-World Connection

Point out that the theory of evolution is widely accepted today by scientists but not by everyone else. Have students ask classmates, friends, and relatives their views about evolution. Ask volunteers to share some of the responses. The responses should remain anonymous. Discuss with the class possible reasons why some people still reject the theory of evolution.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you learned that living things have complex chemistry.

- Do you know which chemicals make up living things?
 - (Answers may vary. Students might mention familiar elements such as oxygen and carbon.)
- All living things need energy to carry out the processes of life. Where do you think this energy comes from? For example, where do you get the energy you need to get through your day?
 - (*Sample response:* Students may think they get energy from food, which comes from other living things, including plants and animals.)

1.3 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys

CHAPTER

2

TE The Chemistry of Life

CHAPTER OUTLINE

-
- 2.1 MATTER AND ORGANIC COMPOUNDS**
 - 2.2 BIOCHEMICAL REACTIONS**
 - 2.3 WATER, ACIDS, AND BASES**
 - 2.4 WORKSHEET ANSWER KEYS**
-



(Opening image courtesy of David Iberri, <http://en.wikipedia.org/wiki/File:CaMKII.png>, and under the Creative Commons license CC-BY-SA 3.0.)

The Chemistry of Life

Outline

Lesson 2.1: Matter and Organic Compounds

2.1.1 Chemical Substances

- Elements
- Compounds

2.1.2 The Significance of Carbon

- KQED: Energy From Carbon?

2.1.3 Carbohydrates

- Monosaccharides
- Polysaccharides
- KQED: Biofuels: From Sugar to Energy

2.1.4 Lipids

- Saturated Fatty Acids
- Unsaturated Fatty Acids
- Types of Lipids

2.1.5 Proteins

- Protein Structure
- Functions of Proteins

2.1.6 Nucleic Acids

- Structure of Nucleic Acids
- Roles of Nucleic Acids

Lesson 2.2: Biochemical Reactions

2.2.1 What Are Chemical Reactions?

- Chemical Equations
- Conservation of Matter

2.2.2 Chemical Reactions and Energy

- Exothermic Reactions
- Endothermic Reactions
- Activation Energy

2.2.3 Biochemical Reactions and Enzymes

- Types of Biochemical Reactions
- Enzymes

Lesson 2.3: Water, Acids, and Bases

2.3.1 Water, Water Everywhere

2.3.2 Structure and Properties of Water

- Chemical Structure of Water
- Properties of Water

2.3.3 Acids and Bases

- Acidity and pH
- Acids
- Bases

2.3.4 Acids and Bases in Organisms

2.3.5 Water and Life

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 2.1:

Lesson	Number of Class Periods
2.1 Matter and Organic Compounds	3.0
2.2 Biochemical Reactions	2.0
2.3 Water, Acids, and Bases	2.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

- <http://www.accessexcellence.org/AE/ATG/data/released/0335-HeidiHaugen/index.php>
- http://mdk12.org/instruction/curriculum/hsa/biology/enzyme_activity/teachers_guide_exploration2.htm

For a well-illustrated summary of chapter contents, see:

- <http://www.estrellamountain.edu/faculty/farabee/biobk/BioBookCHEM1.html>

Use this PowerPoint presentation to give the class an overview of biochemistry, including organic compounds and enzymes:

- http://www.biology4all.com/resources_library/source/158.ppt#

fold it is an interactive site with puzzle related to protein folding.

- <http://fold.it/portal/>

2.1 Matter and Organic Compounds

Key Concept

Living things are composed of organic compounds, which also carry out life processes. Organic compounds consist mainly of carbon. Types of organic compounds include carbohydrates, lipids, proteins, and nucleic acids.

Standards

- CA.9–12.LS.1.h; CA.9–12.LS.4.e, f; CA.9–12.LS.5.a
- NSES.9–12.B.1.1, 2; NSES.9–12.B.2.1, 2, 3, 6; NSES.9–12.C.1.3; NSES.9–12.C.2.1; NSES.9–12.C.5.2
- AAAS.9–12.4.D.7; AAAS.9–12.5.B.3; AAAS.9–12.5.C.3, 4, 8

Lesson Objectives

- Define elements and compounds.
- Explain why carbon is essential to life on Earth.
- Describe the structure and function of the four major types of organic compounds.

Lesson Vocabulary

- **amino acid**: small molecule that is a building block of proteins
- **carbohydrate**: organic compound such as sugar or starch
- **chemical bond**: force that holds molecules together
- **chemical reaction**: process that changes some chemical substances into others
- **complementary base pair**: pair of nucleotide bases that bond together—either adenine and thymine (or uracil) or cytosine and guanine
- **compound**: substance with a unique, fixed composition that consists of two or more elements
- **DNA**: deoxyribonucleic acid, double-stranded nucleic acid that makes up genes and chromosomes
- **double helix**: double spiral shape of the DNA molecule
- **element**: pure substance that cannot be broken down into other types of substances
- **lipid**: organic compound such as fat or oil
- **matter**: anything that takes up space and has mass
- **monosaccharide**: simple sugar such as glucose that is a building block of carbohydrates
- **nucleic acid**: organic compound such as DNA or RNA
- **nucleotide**: small molecule containing a sugar, phosphate group, and base that is a building block of nucleic acids
- **organic compound**: compound found in living things that contains mainly carbon

- **polynucleotide**: chain of nucleotides that alone or with another such chain makes up a nucleic acid
- **polypeptide**: chain of amino acids that alone or with other such chains makes up a protein
- **polysaccharide**: chain of monosaccharides that makes up a complex carbohydrate such as starch
- **protein**: organic compound made up of amino acids
- **RNA**: ribonucleic acid, single-stranded nucleic acid that helps make proteins
- **saturated fatty acid**: molecule in lipids in which carbon atoms are bonded to as many hydrogen atoms as possible
- **unsaturated fatty acid**: molecule in lipids in which some carbon atoms are bonded to other groups of atoms rather than to hydrogen atoms

Teaching Strategies

Check Your Understanding

Introduce lesson concepts by asking students to recall what they know about water and the water cycle. Guide them in focusing their prior knowledge.

- Ask: What type of substance is water? (chemical compound)
- What elements make up water? (hydrogen and oxygen)
- Call on volunteers to describe the water cycle and identify the states of matter that water passes through in the cycle.
- Ask: What causes water to change state? (heating or cooling)

Introducing the Lesson

Students are likely to have heard about organic compounds in advertising and popular media (e.g., low-carb or low-fat foods, high-protein diets). Call on volunteers to share with the class anything they already know about these organic compounds. Tell students they will learn more about the compounds in this lesson.

Activity

Divide the class into four groups. Have each group to create a three-dimensional model of one of the four major types of organic compounds. Display the models in the classroom. Ask students to identify which compound each model represents.

Differentiated Instruction

Define the prefixes mono- (“one”), poly- (“many”) and un- (“not”). Ask students to think about how the prefixes change the meanings of the vocabulary terms in which they appear. Pair English language learners with native speakers of English. Have pairs discuss how knowing the meaning of prefixes such as these can help them understand new terms. **ELL**

Enrichment

Hemoglobin is often used as an example of the relationship between structure and function in proteins. Ask interested students to investigate the structure of hemoglobin and how it relates to the oxygen-carrying function of the molecule. Have students explain the relationship to the class. Suggest that they create sketches to illustrate their explanation.

Science Inquiry

Have groups of students do the inquiry activity, “Who Took Jerell’s iPod,” at the URL below. In the activity, students will learn how to test for triglycerides, glucose, starch, and proteins and then use the tests to solve a mystery. The activity will reinforce students’ understanding of the biological functions and food sources of organic compounds.

- http://serendip.brynmawr.edu/sci_edu/waldron/

Real-World Connection

Have students bring labels of their favorite foods to class. Ask them to identify different types of organic compounds in the foods. Discuss how the body uses each type of organic compound.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Large organic compounds consist of many smaller units that are linked together in chains.

- How can the smaller units become linked together? What process do you think is involved?
 - (Students may or may not know that chemical reactions are involved. You may choose to introduce some of these concepts at this time.)
- What do you think holds the smaller units together in a chain?
 - (*Sample answer:* Some force causes the smaller units to be attracted to each other.)

2.2 Biochemical Reactions

Key Concept

Chemical reactions break and form chemical bonds and change some chemical substances into others. Chemical reactions may release or absorb energy, but all chemical reactions need activation energy to begin. Enzymes speed up biochemical reactions in organisms by lowering activation energy.

Standards

- CA.9–12.LS.1.b
- NSES.9–12.B.2.1, 3; NSES.9–12.B.3.1, 2, 4, 5; NSES.9–12.C.1.2; NSES.9–12.C.5.6
- AAAS.9–12.4.D.9
- McREL.9–12.13.5.1, 5, 6

Lesson Objectives

- Describe what happens in chemical reactions.
- State the role of energy in chemical reactions.
- Explain the importance of enzymes to living organisms.

Lesson Vocabulary

- **activation energy:** energy needed to start a chemical reaction
- **anabolic reaction:** endothermic reaction in organisms
- **biochemical reaction:** chemical reaction that occurs inside the cells of living things
- **catabolic reaction:** exothermic reaction in organisms
- **endothermic reaction:** chemical reaction that absorbs energy
- **enzyme:** protein that speeds up biochemical reactions
- **exothermic reaction:** chemical reaction that releases energy
- **metabolism:** sum of all the biochemical reactions in an organism
- **product:** substance that forms as the result of a chemical reaction
- **reactant:** starting material in a chemical reaction

Teaching Strategies

Introducing the Lesson

Ask the class to think about fireworks they have seen on the Fourth of July. Call on volunteers to describe the sights and sounds of the fireworks. Tell students that fireworks are caused by chemical reactions, which they will learn about in this lesson.

Demonstration

Students will get an instant appreciation for the importance of enzymes and other catalysts by watching the dramatic ending of the demonstration at the URL below. Point out that the drop of sulfuric acid is a catalyst and the reaction involves organic compounds.

- Ask: Was the reaction endothermic or exothermic? (exothermic)
- Ask: How can you tell? (It gave off a lot of energy as heat and light.)

- <http://boyles.sdsmt.edu/instfire/instfire.htm>

Differentiated Instruction

Help students understand activation energy with a simple analogy. Place a pen near the edge of a desk. Give the pen just enough of a push that it falls off the desk. Point out that the push is like activation energy. It started the pen in motion. However, once the pen started falling, it required no additional energy from you to keep moving.

Enrichment

Assign a few students to investigate the relationship between temperature and enzyme action. Have them draw or find online graphs that show this relationship for a specific enzyme. Ask them to explain why the enzyme is less effective at lower and higher temperatures. Relate the discussion to the importance of temperature homeostasis.

Science Inquiry

Present the case study, “Why Is Patrick Paralyzed?”, which can be downloaded at the URL below. The activity introduces students to a rare genetic disease caused by an enzyme deficiency. Students are challenged to explain how the enzyme deficiency causes the disease.

- http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=482#38;id=482

Overcoming Misconceptions

Students often think that enzymes are reactants that are used up in the reactions they catalyze. Use an analogy to help them understand the correct role of enzymes in chemical reactions. Tell the class that an enzyme is like a wrench. It helps get a job done, is not changed by doing the job, and can be used over and over again. Direct students to the animation below to see the enzyme-wrench analogy in detail.

- <http://www.biologyinmotion.com/minilec/wrench.html>

2.2. BIOCHEMICAL REACTIONS

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Most chemical reactions in organisms take place in an environment that is mostly water.

- What do you know about water? How would you describe it?
 - (*Sample answer:* Water is a clear liquid found all over Earth. It's also called H₂O. It has no taste or smell. It can exist as a gas called water vapor. When it freezes, it turns to ice.)
- Water behaves differently than most other substances. Do you know why?
 - (Students are unlikely to be aware that water's polarity gives it unique properties. Encourage students to elaborate on any suggestions that water's chemical structure may be responsible for its unusual behavior.)

2.3 Water, Acids, and Bases

Key Concept

Water molecules are polar, which gives water unique properties, such as a relatively high boiling point. Pure water is neutral and has a pH of 7, whereas acids have a pH lower than 7 and bases a pH higher than 7. Water is involved in most biochemical reactions, so it is essential to life.

Standards

- NSES.9–12.A.1.3; NSES.9–12.B.2.4
- AAAS.9–12.5.C.7

Lesson Objectives

- Describe the distribution of Earth's water.
- Identify water's structure and properties.
- Define acids, bases, and pH.
- Explain why water is essential for life.

Lesson Vocabulary

- **acid**: solution with a pH lower than 7
- **base**: solution with a pH higher than 7
- **hydrogen bond**: type of chemical bond that forms between molecules; found between water molecules
- **pH**: scale that is used to measure acidity
- **polarity**: difference in electrical charge between different parts of the same molecule
- **solution**: mixture that has the same composition throughout

Teaching Strategies

Introducing the Lesson

Ask students to recall experiences in which water froze and expanded out of its container (e.g., ice cubes in a freezer tray, a can of pop left in a freezer, water freezing and cracking pipes). Tell students that most other substances shrink when they freeze but water behaves differently because of its chemical structure.

Activity

As students study acids and bases, have them use litmus paper to test common acids and bases (e.g., vinegar, baking soda solution). Explain how to interpret the color changes. Relate them to the pH chart figure in the FlexBook.

Differentiated Instruction

Have students make a compare/contrast table to summarize the similarities and differences between acids and bases. Suggest that they compare them in terms of factors such as pH range, taste, effects on tissues and materials, and examples. **LPR, ELL**

Enrichment

Challenge students to learn about the capillary action of water and why water has this property (hydrogen bonding). Ask them to demonstrate and explain it to the class. In their demonstration, students might use a glass of water colored with a few drops of food coloring and a stalk of celery.

Science Inquiry

Assign the activity “What Is pH?”, which you can download at the URL below. The activity will allow students to raise and test questions about pH.

- <http://www.nslc.ucla.edu/step/gk12/lessons.htm>

Chemistry Connection

Extend the coverage of acids and bases to neutralization reactions. This will give students a better understanding of the chemistry of acids and bases. A good place to start is the PowerPoint presentation at the URL below.

- <http://www.chalkbored.com/lessons/chemistry-11/neutralization.ppt>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Most biochemical reactions take place within cells. Cells are the microscopic building blocks of organisms.

- What do you think you would see if you could look inside the cell of an organism? What structures do you think you might observe?
 - (Students might say they would observe the nucleus of the cell. They may or may not be familiar with other cell structures, such as mitochondria, ribosomes, and vacuoles.)
- What biochemical processes might be occurring?
 - (*Sample response:* The cell might be using food for energy and getting rid of wastes.)

2.4 Worksheet Answer Keys

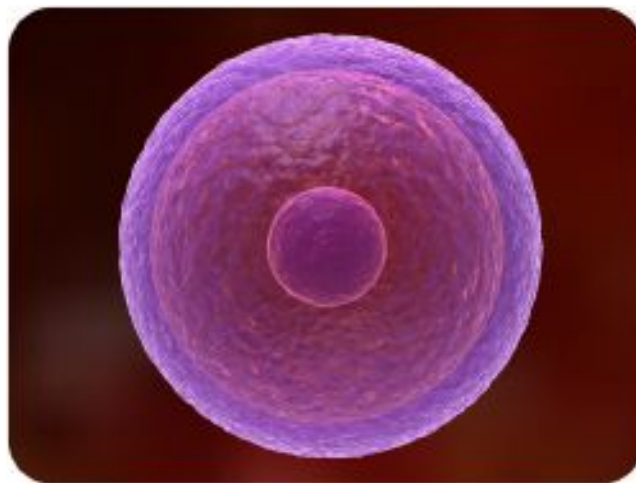
- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys

CHAPTER 3

TE Cellular Structure and Function

CHAPTER OUTLINE

- 3.1 INTRODUCTION TO CELLS**
 - 3.2 CELL STRUCTURES**
 - 3.3 CELL TRANSPORT AND HOMEOSTASIS**
 - 3.4 WORKSHEET ANSWER KEYS**
-



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Cellular Structure and Function

Outline

Lesson 3.1: Introduction to Cells

3.1.1 Discovery of Cells

- Leeuwenhoek's Discoveries
- The Cell Theory
- Microscopes
- KQED: The World's Most Powerful Microscope
- KQED: Confocal Microscopy

3.1.2 Diversity of Cells

- Cell Size

- Cell Shape

3.1.3 Parts of a Cell

3.1.4 Two Types of Cells

- Prokaryotic Cells
- Eukaryotic Cells
- Viruses: Prokaryotes or Eukaryotes?

Lesson 3.2: Cell Structures

3.2.1 Overview of Cell Structures

3.2.2 The Plasma Membrane

- The Phospholipid Bilayer
- Other Molecules in the Plasma Membrane
- Extensions of the Plasma Membrane

3.2.3 Cytoplasm and Cytoskeleton

- Functions of the Cytoplasm
- Cytoskeleton

3.2.4 The Nucleus and Other Organelles

- The Nucleus
- Mitochondria
- Endoplasmic Reticulum
- Ribosomes
- Golgi Apparatus
- Vesicles and Vacuoles
- Centrioles

3.2.5 Special Structures in Plant Cells

- Cell Wall
- Central Vacuole
- Plastids

3.2.6 Organization of Cells

- From One Cell to Many
- Levels of Organization in Multicellular Organisms

Lesson 3.3: Cell Transport and Homeostasis

3.3.1 Transport Across Membranes

3.3.2 Passive Transport

- Simple Diffusion
- Osmosis
- Facilitated Diffusion

3.3.3 Active Transport

- Sodium-Potassium Pump
- Vesicle Transport

3.3.4 Homeostasis and Cell Function

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 3.1:

Lesson	Number of Class Periods
3.1 Introduction to Cells	1.5
3.2 Cell Structures	2.0
3.3 Cell Transport and Homeostasis	1.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

In this lab, students learn how to use a light microscope and analyze evidence from a forensic mystery.

- http://www.accessexcellence.org/AE/AEC/AEF/1994/haugen_microscope.php

Students prepare wet-mount slides of the aquatic plant Elodea and view them under the light microscope. Then they investigate the effects of solutions of different concentrations on the shape and size of the plant's cells.

- <http://biology.arizona.edu/sciconn/lessons/mccandless/elodea.html>

You and your advanced students can learn more about specific topics in cell biology with the searchable college textbook at the link below.

- <http://www.ncbi.nlm.nih.gov/books/bv.fcgi?call=bv.View..ShowTOC#38;rid=cooper.TOC#38;depth=10>

3.1 Introduction to Cells

Key Concept

Discoveries about cells using microscopes led to the development of the cell theory. All cells are very small because they need to pass substances across their surface. Cells are diverse, but all cells have a plasma membrane, cytoplasm, ribosomes, and DNA. Eukaryotic cells also have a nucleus, but prokaryotic cells do not.

Standards

- CA.9–12.LS.1.a, c; CA.9–12.LS.10.d; CA.9–12.IE.1.k
- NSES.9–12.A.2.3; NSES.9–12.C.1.1, 5; NSES.9–12.C.3.4; NSES.9–12.G.3.3
- AAAS.9–12.5.C.1, 4

Lesson Objectives

- State the cell theory, and list the discoveries that led to it.
- Describe the diversity of cell shapes, and explain why cells are so small.
- Identify the parts that all cells have in common.
- Contrast prokaryotic and eukaryotic cells.

Lesson Vocabulary

- **cytoplasm:** all of the material inside the plasma membrane of a cell (excluding organelles)
- **eukaryote:** organism that has cells containing a nucleus and other organelles
- **eukaryotic cell:** cell that contains a nucleus and other organelles
- **nucleus:** (plural, nuclei) organelle inside eukaryotic cells that contains most of the cell's DNA and acts as the control center of the cell
- **organelle:** structure within the cytoplasm of a cell that is enclosed within a membrane and performs a specific job
- **plasma membrane:** thin coat of lipids (phospholipids) that surrounds and encloses a cell
- **prokaryote:** single-celled organism that lacks a nucleus
- **prokaryotic cell:** cell without a nucleus that is found in single-celled organisms
- **ribosome:** organelle inside all cells where proteins are made
- **virus:** tiny, nonliving particle that contains DNA but lacks other characteristics of living cells

Teaching Strategies

Check Your Understanding

The Dutch microscopist, Anton van Leeuwenhoek, not only made careful observations about what he saw with his light microscopes, but he wrote about what he saw in report form. Ask your students to recall a time when they not only observed an object or event, but also wrote about it. Ask them, “How did writing about what you saw enhance your understanding and/or recall of the object or event?”

Introducing the Lesson

Go around the class and ask each student in turn to state something they already know about cells until no new ideas are forthcoming.

- (*Sample answers:* Cells are the basic units of structure and function of living things; all living things are made of one or more cells; all cells come from other living cells.)

Tell students they will learn much more about cells in this chapter.

Demonstration

Show students a variety of different types of cells under a microscope. Include a diversity of prokaryotic and eukaryotic cells. You can obtain prepared slides of cells from a supplier such as Carolina Biological (www.carolina.com). Alternatively, have students view micrographs of a diversity of cells online (see the Web sites below). Challenge students to identify basic structures in the cells, such as the cell membrane and nucleus. Ask them to predict the functions of structures they can't identify.

- <http://library.thinkquest.org/3564/gallery.html>
- <http://www.cellsalive.com/gallery.htm>

Differentiated Instruction

Kinesthetic learners may have a better understanding of cells if they make a three-dimensional cell model. Suggest materials such as gelatin or modeling clay for the cytoplasm, plastic wrap or a zip-lock bag for the cell membrane, and various small objects such as marbles or pebbles for the nucleus and other organelles. Invite them to share their models with the class.

Enrichment

Have interested students explore the history of scientific thought about cells, starting with ancient Greek philosopher Democritus (see Web sites below). Ask them which discovery they think was most important and why.

- <http://teachertech.rice.edu/Participants/dawsonm/cells/timeline.htm>
- <http://science-of-aging.healthaliciousness.com/timelines/cell-history-timeline-detail.php>

3.1. INTRODUCTION TO CELLS

Science Inquiry

Discuss with students how they could decide whether a mystery cell came from a prokaryotic or eukaryotic organism.

- Ask: What cellular structures would you look for? (*Sample answers:* nucleus; organelles such as mitochondria)
- Ask: How would the presence or absence of these structures help you solve the mystery? (Eukaryotic cells have these structures; prokaryotic cells do not.)

Overcoming Misconceptions

A common misconception is that cells are static structures. Explain that cells are dynamic biochemical “factories.” Other common misconceptions can be found at the link below. Discuss why they are not true.

- <http://www.biologylessons.sdsu.edu/classes/lab7/altern.html>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Cells have many different structures that carry out the processes of life.

- Besides the cell parts described in this lesson, what other structures do you think cells might have? What life processes might these other structures carry out?
 - (*Sample response:* They might have structures for storage and energy.)
- Do you think plant and animal cells are the same? Or do they differ in some way? How might they differ?
 - (*Sample response:* Students may think plant and animal cells have most of the same structures but just plant cells have structures for photosynthesis.)

3.2 Cell Structures

Key Concept

The plasma membrane is a phospholipid bilayer that supports and protects a cell and controls what enters and leaves it. The cytoplasm consists of everything inside the plasma membrane surrounding the organelles. In eukaryotic cells, the nucleus is the largest organelle and contains most of the cell's DNA. Plant cells have special structures not found in animal cells. Organisms may consist of a single cell or many cells organized in tissues, organs, and organ systems.

Standards

- CA.9–12.LS.1.a, e, f, g, i, j
- NSES.9–12.C.1.1, 3, 5, 6; NSES.9–12.C.5.3, 4
- AAAS.9–12.5.C.1, 2; AAAS.9–12.5.F.8

Lesson Objectives

- Describe the structure and function of the plasma membrane.
- Identify the roles of the cytoplasm and exoskeleton.
- Outline the form and function of the nucleus and other organelles.
- List special structures of plant cells, and state what they do.
- Explain how cells are organized in living things.

Lesson Vocabulary

- **ATP:** (adenosine triphosphate) energy-carrying molecule that cells use to power their metabolic processes
- **cell wall:** rigid layer that surrounds the plasma membrane of a plant cell and helps support and protect the cell
- **central vacuole:** large, sac-like organelle in plant cells that stores substances such as water and helps keep plant tissues rigid
- **chloroplast:** organelle in the cells of plants and algae where photosynthesis takes place
- **cytoskeleton:** structure of filaments and tubules in the cytoplasm that provides a cell with an internal framework
- **endoplasmic reticulum (ER):** organelle in eukaryotic cells that helps make and transport proteins
- **endosymbiotic theory:** theory that eukaryotic organelles such as mitochondria evolved from ancient, free-living prokaryotes that invaded primitive eukaryotic cells
- **Golgi apparatus:** organelle in eukaryotic cells that processes proteins and prepares them for use both inside and outside the cell

- **mitochondria:** organelle in eukaryotic cells that makes energy available to the cell in the form of ATP molecules
- **phospholipid bilayer:** double layer of phospholipid molecules that makes up a plasma membrane
- **vacuole:** large, sac-like organelle that stores and transports materials inside a cell
- **vesicle:** small, sac-like organelle that stores and transports materials inside a cell

Teaching Strategies

Introducing the Lesson

Engage students in thinking about necessary structures in cells. Remind them that cells are metabolically active. Ask questions such as:

- a. How do cells let necessary materials in while keeping harmful substances out?
- b. What keeps cells from collapsing?
- c. Where do cells get the energy they need?

Using Visuals

Have students compare and contrast plant and animal cells (see **Figure 3.9** and **Figure 3.15** in FlexBook). Ask them to identify structures that are found in both cells. Then have them find structures that occur in just one of the cells and identify their functions. Discuss why plant and animal cells differ in these ways. The URLs below may be useful for this strategy.

- http://www.diffen.com/difference/Animal_Cell_vs_Plant_Cell
- <http://www.wisc-online.com/objects/ViewObject.aspx?ID=ap11604>
- <http://library.thinkquest.org/12413/structures.html>

Differentiated Instruction

Visuals learners may benefit from the activities at the URLs below. The first activity allows students to interact with animated plant and animal cell models. They can use the animation to test their knowledge of the structures in each type of cell. The second URL links with virtual jigsaw puzzles of animal and plant cells that students can assemble online.

- http://www.cellsalive.com/cells/cell_model.htm
- <http://www.cellsalive.com/puzzles/index.htm>

Enrichment

Ask a few creative students to develop an analogy for a cell and its structures. It should compare either an animal cell or a plant cell to something more familiar, such as a soccer team or a city (e.g., soccer goalie or city limits for the plasma membrane; team captain or city hall for the nucleus; and so on). Give students a chance to explain their analogy to the class.

Science Inquiry

Assign groups of students to complete one or more of the cell structure inquiry activities at the URL below. It is a resource of the National Science Teachers Association. The web site provides reproducible students worksheets for each activity.

- <http://dev.nsta.org/ssc/pdf/v4-0933s.pdf>

Health Connection

When you discuss mitochondria, ask students to predict how problems with mitochondria might affect the ability of a cell to carry out normal processes. Explain that many human diseases are caused by dysfunctional mitochondria. The diseases affect more than 50 million adults in the U.S. alone. They include some types of deafness, diabetes, and cancer. Often, the diseases are fatal. You and your students can learn more about them at the URL below.

- <http://www.mitoresearch.org/diseases.html>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Cells carry out all the functions of life, and they use nutrients and oxygen and produce wastes. These substances must cross the plasma membrane.

- How do you think substances cross the plasma membrane to enter or leave the cell? Does the membrane have tiny holes in it like a sieve?
 - (*Sample answer:* A sieve is too simple. Maybe it's something like a window that can open and close.)
- What if the substances are large? Protein molecules, for example, are very large. How do they enter or leave the cell?
 - (*Sample answer:* They might have to have a special opening, just for them.)

3.3 Cell Transport and Homeostasis

Key Concept

Substances are transported into and out of cells across the plasma membrane by passive transport, which requires no energy, or by active transport, which requires energy from the cell. Types of passive transport include diffusion and osmosis; types of active transport include ion pumps and vesicle transport. Cell transport helps maintain homeostasis by keeping conditions inside cells within normal ranges.

Standards

- CA.9–12.LS.1.a
- NSES.9–12.C.1.1, NSES.9–12.C.5.4
- AAAS.9–12.5.C.1, 7

Lesson Objectives

- Describe different types of passive transport.
- Explain how different types of active transport occur.
- Outline the role of cell transport in homeostasis.

Lesson Vocabulary

- **active transport:** movement of substances across a plasma membrane that requires energy
- **diffusion:** type of passive transport that does not require the help of transport proteins
- **endocytosis:** type of vesicle transport that moves substances into a cell
- **exocytosis:** type of vesicle transport that moves substances out of a cell
- **facilitated diffusion:** diffusion with the help of transport proteins
- **osmosis:** diffusion of water molecules across a membrane
- **passive transport:** movement of substances across a plasma membrane that does not require energy
- **sodium-potassium pump:** type of active transport in which sodium ions are pumped out of the cell and potassium ions are pumped into the cell with the help of a carrier protein and energy from ATP
- **transport protein:** protein in a plasma membrane that helps other substances cross the membrane
- **vesicle transport:** type of active transport in which substances are carried across the cell membrane by vesicles

Teaching Strategies

Introducing the Lesson

Have the class preview the figures in Lesson 3.3, including the figure captions. Explain that the figures show how different types of substances pass through the plasma membrane of cells. Ask students to predict factors that might influence how a given substance passes through the membrane (e.g., size and concentration of its molecules).

Activity

Assign the activity “Diffusion, Osmosis, and Active Transport” at the URL below. Students will explore a 3D aquapore embedded in a membrane and, using a “Molecular Rover,” fly through the aquapore and consider how it facilitated their travel from one side of the membrane to another. The Web site also provides discussion questions, common misconceptions, and extensions.

- <http://workbench.concord.org/database/activities/321.html>

Differentiated Instruction

Have students make a Venn diagram comparing and contrasting passive and active transport. **ELL, LPR**

Enrichment

Urge students to learn more about the sodium-potassium pump and its significance. For example, they might find out how many pumps are located on a typical cell membrane, how much of a cell’s energy they use, and problems that result if the pumps do not work normally. Ask them to summarize what they learn in an oral report to the class. Suggest that they start their research with the URL below.

- http://www.vivo.colostate.edu/hbooks/molecules/sodium_pump.html

Science Inquiry

Ask students to complete the active transport activity at the URL below. They will investigate the effects of amino acid concentration and ATP on amino acid transport. They will be asked to develop hypotheses to explain their observations.

- <http://www.jdenuno.com/APBiology/Labs/ActiveTransportLab.pdf>

Overcoming Misconceptions

A common misconception about osmosis is that molecules cease moving at equilibrium. Explain that molecules keep moving at equilibrium but move equally in both directions so there is no further change in concentration. You can learn more misconceptions about osmosis at the URL below:

- <http://www.lifescied.org/cgi/content/full/4/3/235>

3.3. CELL TRANSPORT AND HOMEOSTASIS

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

All cells share some of the same structures and basic functions, but cells also vary.

- Plant cells have structures that animal cells lack. What important process takes place in plant cells but not in animal cells that might explain their differences?
 - (photosynthesis)
- All cells, including both plant and animal cells, need energy for processes such as active transport. How do cells obtain the energy they need?
 - (Students might infer that the energy comes from exothermic chemical reactions. Accept all reasonable responses.)

3.4 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER

4

TE Photosynthesis and Cellular Respiration

CHAPTER OUTLINE

- 4.1 ENERGY FOR LIFE
 - 4.2 PHOTOSYNTHESIS: SUGAR AS FOOD
 - 4.3 POWERING THE CELL: CELLULAR RESPIRATION
 - 4.4 ANAEROBIC RESPIRATION
 - 4.5 WORKSHEET ANSWER KEYS
-



(Opening image copyright by Derek Ramsey, http://en.wikipedia.org/wiki/File:Monarch_Butterfly_Danaus_plexippus_Feeding_Down_3008px.jpg, and under the GNU-FDL 1.2 license.)

Photosynthesis and Cellular Respiration

Outline

Lesson 4.1: Energy for Life

- 4.1.1 Why Living Things Need Energy
- 4.1.2 How Organisms Get Energy: Autotrophs and Heterotrophs
 - Autotrophs
 - Heterotrophs
- 4.1.3 Energy Molecules: Glucose and ATP

- Glucose
- ATP
- Why Organisms Need Both Glucose and ATP

4.1.4 Making and Using Food

- Photosynthesis
- Cellular Respiration

Lesson 4.2: Photosynthesis: Sugar as Food

4.2.1 Stages of Photosynthesis

4.2.2 The Chloroplast: Theater for Photosynthesis

4.2.3 Photosynthesis Stage I: The Light Reactions

- Steps of the Light Reactions
- Summary of Stage I

4.2.4 Photosynthesis Stage II: The Calvin Cycle

- Steps of the Calvin Cycle
- Summary of Stage II

4.2.5 Chemosynthesis

Powering the Cell: Cellular Respiration

4.3.1 Stages of Cellular Respiration

4.3.2 Cellular Respiration Stage I: Glycolysis

- Splitting Glucose
- Results of Glycolysis

4.3.3 Anaerobic and Aerobic Respiration

4.3.4 Structure of the Mitochondrion: Key to Aerobic Respiration

4.3.5 Cellular Respiration Stage II: The Krebs Cycle

- Steps of the Krebs Cycle
- Results of the Krebs Cycle

4.3.6 Cellular Respiration Stage III: Electron Transport

- Transporting Electrons
- Making ATP

4.3.7 How Much ATP?

Lesson 4.4: Anaerobic Respiration

4.4.1 Fermentation

- Lactic Acid Fermentation
- Alcoholic Fermentation

4.4.2 Aerobic vs. Anaerobic Respiration: A Comparison

- Advantages of Aerobic Respiration
- Advantages of Anaerobic Respiration

Pacing the Lesson

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 4.1:

Lesson	Number of Class Periods
4.1 Energy for Life	1.0
4.2 Photosynthesis: Sugar as Food	2.0
4.3 Powering the Cell: Cellular Respiration	2.0
4.4 Anaerobic Respiration	1.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this inquiry lab, students investigate how photosynthesis and cellular respiration affect gas levels in a closed ecosystem.

- http://www.accessexcellence.com/AE/AEC/AEF/1996/linhares_lab.php

2. In this investigation, students use chromatography to separate plant pigments.

- <http://www.science-projects.com/PhotosynthPigments.htm>

3. In this lab, students test factors that affect the rate of anaerobic respiration in yeast.

- http://serendip.brynmawr.edu/sci_edu/waldron/#cellrespiration

These Web sites may also be helpful:

4. Students can find interactive animations of photosynthesis at this Web site.

- <http://www.cnr.vt.edu/DENDRO/forestbiology/photosynthesis.swf>

5. This Web site has animations of the Calvin Cycle. It keeps a running tally of ATP and NADPH.

- <http://www.science.smith.edu/departments/Biology/Bio231/calvin.html>

4.1 Energy for Life

Key Concept

Living things need energy from food to carry out all life processes. Autotrophs make food for themselves and other living things, using either light energy in the process of photosynthesis or chemical energy in the process of chemosynthesis. Living things use glucose to store and transport energy. They use ATP to power life processes inside cells.

Standards

- CA.9–12.LS.6.d, f
- NSES.9–12.C.1.5; NSES.9–12.C.4.2; NSES.9–12.C.5.1, 6
- AAAS.9–12.4.C.1; AAAS.9–12.5.E.3

Lesson Objectives

- State why living things need energy.
- Describe how autotrophs and heterotrophs obtain energy.
- Compare and contrast glucose and ATP.
- Outline how living things make and use food.

Lesson Vocabulary

- **autotroph:** organism that makes its own food
- **cellular respiration:** process in which cells break down glucose and make ATP for energy
- **consumer:** organism that consumes other organisms for food
- **energy:** ability to do work
- **food:** organic molecules such as glucose that organisms use for chemical energy
- **glucose:** simple carbohydrate with the chemical formula $C_6H_{12}O_6$ that is the nearly universal food for life
- **heterotroph:** organism that gets food by consuming other organisms
- **photosynthesis:** process of using the energy in sunlight to make food (glucose)
- **producer:** organism that produces food for itself and other organisms

Teaching Strategies

Introducing the Lesson

Ask students to recall what they learned about chloroplasts in the *Cellular Structure and Function* chapter.

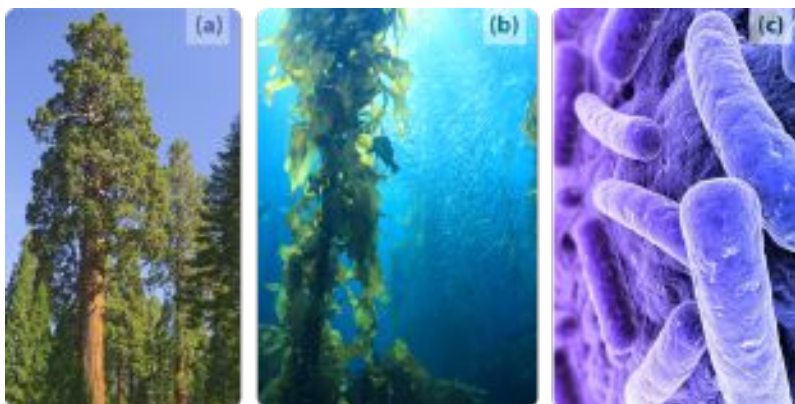
- (Sample answers: Chloroplasts are organelles in plant cells; they are green; they contain chlorophyll.)

Tell the class that chloroplasts are where photosynthesis takes place. Have the class brainstorm questions they have about photosynthesis.

- (e.g., Why do plants need light for photosynthesis? Are plants the only living things that perform photosynthesis?)

Using Visuals

Say photosynthesis and students are likely to think of plants. Call their attention to **Figure 4.1** in the FlexBook to ensure they know that other types of organisms also undergo photosynthesis.



Photosynthetic autotrophs, which make food using the energy in sunlight, include (a) plants, (b) algae, and (c) certain bacteria. (Images copyrighted by (a) Tom Grill, (b) imageZebra, and (c) Sebastian Kaulitzki, 2010. All three images used under licenses from Shutterstock.com.)

Differentiated Instruction

Most students will know something about photosynthesis from earlier science classes. Help them recall what they already know with a three-column KWL chart. Before students start reading the chapter, they should fill in the first two columns of the chart by listing what they already know (K) about photosynthesis and what they want (W) to know. After they read Lessons 1 and 2, they should complete the third column by listing what they learned (L).

ELL, LPR

Enrichment

Have interested students learn more about chemoautotrophs, including what types of organisms they are, where they live, and how they make food. Ask them to share the information in a PowerPoint presentation. Suggest they begin with the Web site below.

4.1. ENERGY FOR LIFE

- <http://www.astro.wisc.edu/townsend/static.php?ref=diploma-6>

Science Inquiry

Present this statement to the class as a hypothesis: Chlorophyll is required for photosynthesis.

- Ask: What data would support the hypothesis? (Sample answer: All known photosynthetic organisms have chlorophyll.)
- Ask: What data that would refute the hypothesis? (Sample answer: Discovery of a photosynthetic organism that does not have chlorophyll)

Overcoming Misconceptions

Students may think that glucose is the only molecule that organisms use for energy. Explain that glucose is a small, stable molecule that contains a lot of energy. Organisms use it for storing and transporting energy. Individual cells, on the other hand, use the smaller amount of energy in ATP for their chemical processes. Compare glucose to a \$100 bill (easy to carry around in your wallet) and ATP to a quarter (useful for a vending machine).

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Living things must have chemical energy from food to power life processes. Most of the chemical energy in food comes ultimately from the energy in sunlight.

- Do you know how the energy in sunlight is captured by plants and other photosynthetic autotrophs?
- How do you think light energy changes to chemical energy during the process of photosynthesis?
- Some producers live in places that do not receive sunlight. How do you think they make food?

4.2 Photosynthesis: Sugar as Food

Key Concept

Photosynthesis occurs in chloroplasts in two stages: the light reactions and the Calvin cycle. The light reactions capture energy from sunlight and store it in NADPH and ATP. The Calvin cycle forms glucose from carbon dioxide using the stored energy from the light reactions. Some bacteria use chemosynthesis rather than photosynthesis to make food.

Standards

- CA.9–12.LS.1.f, i
- NSES.9–12.C.1.5; NSES.9–12.C.5.2
- AAAS.9–12.4.C.1

Lesson Objectives

- Outline the stages of photosynthesis.
- Describe the chloroplast and its role in photosynthesis.
- List the steps of the light reactions.
- Describe the Calvin cycle.
- Define chemosynthesis.

Lesson Vocabulary

- **Calvin cycle:** second stage of photosynthesis, in which carbon atoms from carbon dioxide are combined, using the energy in ATP and NADPH, to make glucose
- **chemosynthesis:** process of using the energy in chemical compounds to make food
- **chlorophyll:** green pigment in a chloroplast that absorbs sunlight in the light reactions of photosynthesis
- **electron transport chain:** series of electron-transport molecules that pass high-energy electrons from molecule to molecule and capture their energy
- **grana:** within the chloroplast, consists of sac-like membranes, known as thylakoid membranes
- **light reactions:** first stage of photosynthesis, in which light energy from the sun is captured and changed into chemical energy that is stored in ATP and NADPH
- **photosystem:** group of molecules, including chlorophyll, in the thylakoid membrane of a chloroplast that captures light energy
- **stroma:** space outside the thylakoid membranes of a chloroplast where the Calvin cycle of photosynthesis takes place

- **thylakoid membrane:** membrane in a chloroplast where the light reactions of photosynthesis occur

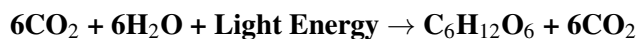
Teaching Strategies

Check Your Understanding

Many students see plants, but do not notice them. As a means of activating student interest in the topic of photosynthesis, ask your students to notice all of the plants they see the rest of that day. Students can contribute their findings the next class period. Did the students see plants outdoors? Indoors? Did all of the plants have green leaves? The latter is an interesting question to ask students in the winter in colder climates where deciduous plants dominate; it can lead to a brief discussion of how plants can live throughout the winter without leaves. (Plants can live without leaves in the winter because they have stored food molecules — made by photosynthesis — as starch.) This discussion could also foster a connection between the FlexBook material and the students' environment outside the class.

Introducing the Lesson

On the board, write the following equation from the end of Lesson 4.1:



Call on students to identify the process represented by the equation (photosynthesis) and describe it in words (carbon dioxide and water react with light energy, forming glucose and carbon dioxide). Point out that the equation is just a summary of photosynthesis and the process actually involves many chemical reactions, which they will read about in this lesson.

Discussion

Photosynthesis is arguably the single most important biological process. Remind students of the roles of photosynthesis — from feeding almost all living things to being responsible for oxygen in the atmosphere. Then ask students whether or not they agree that photosynthesis is the most important biological process. Challenge them to support their viewpoint.

Differentiated Instruction

Pair students who need additional assistance with this topic with those who are excelling, and have each pair create a flowchart of photosynthesis. It should include the light reactions and Calvin cycle. Tell students to illustrate their flow chart with simple diagrams that help them understand the processes. Encourage them to save their flow chart in their science notebook. **ELL, LPR**

Enrichment

Some students may be interested in learning more about various photosynthetic pigments and how they respond to different wavelengths of light. Ask them to organize what they learn and teach a lesson on the topic to the rest of the class. Suggest they use visuals to help convey the information.

Science Inquiry

Share with the class the famous 17th-century experiment of Jan van Helmont, which is described below. Then discuss the experiment with the class.

Jan Van Helmont tested the prevailing idea that plants grow because of matter they absorb from the soil. He grew a willow tree in a large container of soil to which he added water as needed. He measured the mass of the soil and the tree at the start of the experiment and again after five years. By the end of five years, the tree gained had gained 164 pounds but the soil still weighed the same. Van Helmont deduced that the tree's weight gain had come from the water he had given it over the five years of its growth and not from the soil.

- Ask: How did van Helmont's results disprove the prevailing idea about plant growth? (The willow tree gained a lot of mass but the soil lost none. Therefore, the gain in mass of the tree could not be due to matter absorbed from the soil.)
- Ask: How did van Helmont explain his results? (He deduced that the tree gained mass from the water he gave it.)
- Ask: What is the correct interpretation of van Helmont's results? (The tree gained mass by changing water and carbon dioxide in the air to glucose and other organic compounds needed for growth.)

Overcoming Misconceptions

Misconceptions about photosynthesis abound. The Web sites below list and correct several common misconceptions. Discuss them with your students.

- <http://www.actionbioscience.org/education/hershey.html>
- http://en.wikibooks.org/wiki/Transwiki:Photosynthesis_misconceptions

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

All living things need to break down glucose to make ATP for energy. Cellular respiration is the process in which this occurs.

- How do you think cellular respiration occurs? What steps do you think might be involved?

4.2. PHOTOSYNTHESIS: SUGAR AS FOOD

- (Students might infer that cellular respiration is the opposite of photosynthesis.)
- How many molecules of ATP do you think cells get from a single molecule of glucose?
 - (Students are likely to assume that more than one ATP molecule results.)

4.3 Powering the Cell: Cellular Respiration

Key Concept

Cellular respiration uses energy in glucose to make ATP. Aerobic respiration uses oxygen and occurs in three steps: glycolysis, the Krebs cycle, and electron transport. The latter two steps occur in mitochondria. In aerobic respiration, up to 38 molecules of ATP may be produced from a single molecule of glucose.

Standards

- CA.9–12.LS.1.g, i
- NSES.9–12.C.1.2; NSES.9–12.C.5.3

Lesson Objectives

- Name the three stages of cellular respiration.
- Give an overview of glycolysis.
- Explain why glycolysis probably evolved before the other stages of aerobic respiration.
- Describe the mitochondrion and its role in aerobic respiration.
- List the steps of the Krebs cycle, and identify its products.
- Explain how electron transport results in many molecules of ATP.
- State the possible number of ATP molecules that can result from aerobic respiration.

Lesson Vocabulary

- **aerobic respiration:** type of cellular respiration that requires oxygen
- **anaerobic respiration:** type of cellular respiration that does not require oxygen
- **glycolysis:** first stage of cellular respiration in which glucose is split, in the absence of oxygen, to form two molecules of pyruvate (pyruvic acid) and two (net) molecules of ATP
- **Krebs cycle:** second stage of aerobic respiration in which two pyruvate (pyruvic acid) molecules from the first stage react to form ATP, NADH, and FADH₂

Teaching Strategies

Check Your Understanding

Present these statistics and facts to your students as a means of generating interest in the topic of cellular respiration. Tell your students that:

- Mitochondria exist in almost all eukaryotic cells. Both heterotrophic and autotrophic eukaryotes contain mitochondria. (Review the earlier lessons for these terms.) Mitochondria are present in both plants and animals. Moreover, plants, as well as animals, carry out cellular respiration. Thus, plants use oxygen in cellular respiration and generate oxygen as a byproduct of photosynthesis.
- An average 40-year-old male consumes between 35-40 ml oxygen/kg/min, whereas, elite runners can consume double that (80 ml of oxygen/kg/min)!
- Given these values, how much oxygen do you think you consume per minute? Why do you think trained runners can consume more?
- To learn more on oxygen consumption, VO_{2max} , and its relationship to fitness level, see http://www.nismat.org/physcor/max_o2.html

Introducing the Lesson

Ask students to recall how eating a snack or a meal gave them energy. Explain that digesting food breaks it down to small molecules such as glucose.

- a. Ask: What happens to glucose? Do cells use glucose for energy? (Cells use ATP for energy.) Tell students they will learn in this lesson how cells break down glucose to form ATP.

Building Science Skills

Cellular respiration is sometimes confused with respiration, or breathing. Call on students to distinguish the two processes. Then have students to infer how the two processes are related. (Breathing brings oxygen into the body and releases carbon dioxide. It enables cellular respiration because in this process, cells use oxygen and release carbon dioxide.)

Differentiated Instruction

Have small groups of students make Venn diagrams comparing and contrasting aerobic and anaerobic respiration.
ELL, LPR, SN

Enrichment

Challenge students to write a poem or rap about aerobic respiration. Urge them to be creative while staying true to the facts. Invite students to share their writing with the class.

Science Inquiry

Have groups of students devise an experiment to test the hypothesis that a certain species of bacteria is an obligate anaerobe, meaning it is required to perform anaerobic respiration. They should identify the independent variable (presence or absence of oxygen) and the dependent variable (survival of the bacteria).

- a. Ask: What variables would you control (anything that might affect survival of the bacteria, such as temperature and pH).
- b. Ask: Based on the hypothesis, what results would you expect? (The bacteria will survive in the absence of oxygen but not in the presence of oxygen.)

Chemistry Connection

Use the Krebs cycle to reinforce basic chemistry concepts (e.g., reactant, product, chemical bond, chemical reaction, activation energy, exothermic reaction). Call on volunteers to use the concepts to explain the Krebs cycle figure in the FlexBook.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

The last two stages of aerobic respiration require oxygen. However, not all organisms live in places where there is a plentiful supply of oxygen.

- How do you think organisms get energy from glucose to make ATP if they cannot use oxygen?
 - (*Sample answer:* They might have other ways to make ATP that do not need oxygen.)
- Do they just use glycolysis, which produces only two ATP molecules? Or do you think there might be other steps involved?
 - (*Sample answer:* I think there might be other steps involved because glycolysis alone probably wouldn't provide enough ATP.)

4.4 Anaerobic Respiration

Key Concept

Anaerobic respiration occurs without oxygen by fermentation. There are two types of fermentation: lactic acid fermentation and alcoholic fermentation. Anaerobic respiration produces less ATP than aerobic respiration, but anaerobic respiration occurs more quickly.

Standards

- NSES.9–12.C.1.2

Lesson Objectives

- Define fermentation.
- Describe lactic acid fermentation and alcoholic fermentation.
- Compare the advantages of aerobic and anaerobic respiration.

Lesson Vocabulary

- **alcoholic fermentation:** type of anaerobic respiration that includes glycolysis followed by the conversion of pyruvic acid to ethanol and carbon dioxide and the formation of NAD^+
- **fermentation:** type of anaerobic respiration that includes glycolysis followed by the conversion of pyruvic acid to one or more other compounds and the formation of NAD^+
- **lactic acid fermentation:** type of anaerobic respiration that includes glycolysis followed by the conversion of pyruvic acid to lactic acid and the formation of NAD^+

Teaching Strategies

Check Your Understanding

Take a poll of your students. This poll is not meant to be scientific, but is meant to stimulate thinking about the lesson content.

- The first question for your students is: “Do you think more high school students are better at sprinting or at distance running?” Tally the opinions and write on the blackboard. Next, ask them if they are better at

sprinting or at running longer distances. (Obviously, if there are physically impaired students in your class, you will modify this poll.) Tally the results. As a class, calculate the percent of students in each category. Were the actual results the same as the predicted ones?

- After your students have completed this activity, tell them that you will be teaching them about aerobic and anaerobic respiration, and that different types of muscles fibers are specialized for one or the other. Some people have more “sprinting fibers,” which are specialized for anaerobic metabolisms and others, more “endurance” fibers, which are specialized for aerobic respiration. Specific training can alter the distribution between the two types. For example, there will be an increase in endurance fibers (also known as slow-twitch) in a person training for a marathon.

Reference: Ingalls, Christopher. 2004. Nature vs. nurture: can exercise really alter fiber type composition in human skeletal muscle? J. Appl Physiol 97: 1591-1592. <http://jap.physiology.org/cgi/content/full/97/5/1591>

Introducing the Lesson

Ask students to recall from Lesson 4.3 which stage of aerobic respiration does not require oxygen (glycolysis). State that anaerobic respiration also starts with glycolysis. Tell the class they will read about other stages of anaerobic respiration in this lesson.

Demonstration

You can demonstrate lactic acid fermentation by making yogurt in the classroom. You can find instructions at the URL below. It takes several days for the yogurt cultures to finish growing. You can also demonstrate alcoholic fermentation by letting yeast dough rise in the classroom (following package directions). This can be done in one class period. Make sure students do not taste the demonstrations. Discuss how the two processes are similar.

- <http://www.wikihow.com/Make-Yogurt>

Differentiated Instruction

Give visual and kinesthetic learners a chance to see, smell, and taste fermented foods from a variety of ethnic cuisines (e.g., sauerkraut, pickles, miso, soy sauce, cider, cheese, yogurt, pepperoni). Explain that all the foods have been broken down by anaerobic respiration in microbes.

Enrichment

Instruct a small group of students to create a board game that correctly models the process of lactic acid or alcoholic fermentation. Have them demonstrate their game to the class and explain how it models the biological process.

Science Inquiry

Ask the class to infer what signs they would look for as evidence of lactic acid fermentation and alcoholic fermentation. (Sample answers: sour taste for lactic acid fermentation; gas bubbles for alcoholic fermentation)

4.4. ANAEROBIC RESPIRATION

Real-World Connection

Tell students that sprinters have more muscle fibers specialized for lactic acid fermentation than endurance runners. This gives sprinters a burst of energy, but it doesn't last long. It also causes lactic acid to build up in their muscles, and this must be metabolized by the liver. You or your students can learn more at the URL below.

- <http://staff.jccc.net/pdecell/cellresp/fermentation.html>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Two important functions of cells are making food and using it for energy. Photosynthesis and cellular respiration are the processes that carry out these functions. Other important functions of cells are growing and dividing.

- Do you know how cells grow? What do you think controls the growth of cells?
 - (Sample answers: I think cells grow by making more organic molecules. I think growth is controlled by genes.)
- How do you think cells divide? Do all cells divide in the same way?
 - (Students might know that some cells divide by mitosis and others by meiosis. Accept all reasonable responses.)

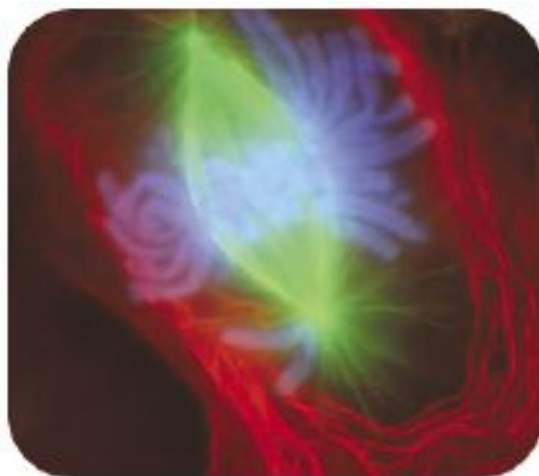
4.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 5 TE The Cell Cycle, Mitosis, and Meiosis

CHAPTER OUTLINE

- 5.1 CELL DIVISION AND THE CELL CYCLE
 - 5.2 CHROMOSOMES AND MITOSIS
 - 5.3 REPRODUCTION AND MEIOSIS
 - 5.4 WORKSHEET ANSWER KEYS
-



(Opening image courtesy of Conly Rieder and the National Institutes of Health, <http://commons.wikimedia.org/wiki/File:Mitosis-fluorescent.jpg>, and under the public domain.)

The Cell Cycle, Mitosis, and Meiosis

Outline

Lesson 5.1: Cell Division and the Cell Cycle

5.1.1 Cell Division

- Cell Division in Prokaryotes
- Cell Division in Eukaryotes

5.1.2 The Cell Cycle

- Eukaryotic Cell Cycle
- Interphase
- Control of the Cell Cycle
- Cancer and the Cell Cycle

Lesson 5.2: Chromosomes and Mitosis

5.2.1 Chromosomes

- Chromatids and the Centromere
- Chromosomes and Genes
- Human Chromosomes

5.2.2 Mitosis and Cytokinesis

- Prophase
- Metaphase
- Anaphase
- Telophase
- Cytokinesis

Lesson 5.3: Reproduction and Meiosis

5.3.1 Reproduction: Asexual vs. Sexual

- Asexual Reproduction
- Sexual Reproduction

5.3.2 Meiosis

- Phases of Meiosis
 - Meiosis I
 - Meiosis II

5.3.3 Gametogenesis

5.3.4 Sexual Reproduction and Genetic Variation

5.3.5 Sexual Reproduction and Life Cycles

- Haploid Life Cycle
- Diploid Life Cycle
- Alternation of Generations

Pacing the Lesson

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 5.1:

Lesson	Number of Class Periods
5.1 Cell Division and the Cell Cycle	1.5
5.2 Chromosomes and Mitosis	2.0
5.3 Reproduction and Meiosis	2.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web site for appropriate laboratory activities for this chapter:

- This Web site contains three lab activities in which students make models of chromosomes and use them to simulate mitosis, meiosis, and fertilization. The Web site includes student handouts and teacher preparation notes.
- <http://serendip.brynmawr.edu/exchange/waldron/mitosis>

These Web sites may also be helpful:

This NIH unit for high school students covers cell biology and cancer (Lesson 5.1). The unit has five modules that contain animations and news-alert videos.

- <http://science.education.nih.gov/Customers.nsf/HSCancer?OpenForm>

This Web site provides an animation of mitosis (Lesson 5.2).

- <http://biology.about.com/library/blmitosisanim.htm>

See these URLs for animations of meiosis (Lesson 5.3).

- [/library/blmeiosisanim.htm](http://biology.about.com/library/blmeiosisanim.htm) <http://biology.about.com/library/blmeiosisanim.htm>
- <http://biology.about.com/library/blmeiosisanim2.htm>

5.1 Cell Division and the Cell Cycle

Key Concept

Cell division is part of the life cycle of cells. The cell cycle also includes phases of growth and DNA synthesis. Regulatory proteins normally control the cell cycle at key checkpoints. Cancer is a disease that occurs when the cell cycle is no longer regulated.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.1.c
- NSES.9–12.A.1.1, 4, 6; NSES.9–12.C.1.4, 6
- AAAS.9–12.5.C.4, 5

Lesson Objectives

- Contrast cell division in prokaryotes and eukaryotes.
- Identify the phases of the eukaryotic cell cycle.
- Explain how the cell cycle is controlled.
- Define cancer, and relate it to the cell cycle.

Lesson Vocabulary

- **binary fission:** type of cell division that occurs in prokaryotic cells in which a parent cell divides into two identical daughter cells
- **cancer:** disease that occurs when the cell cycle is no longer regulated and cells divide out of control
- **cell cycle:** repeating series of events that a cell goes through during its life, including growth, DNA, synthesis, and cell division
- **cell division:** process in which a parent cell divides to form two daughter cells
- **cytokinesis:** splitting of the cytoplasm to form daughter cells when a cell divides
- **DNA replication:** process of copying of DNA prior to cell division
- **interphase:** stage of the eukaryotic cell cycle when the cell grows, synthesizes DNA, and prepares to divide
- **mitosis:** process in which the nucleus of a eukaryotic cell divides
- **tumor:** abnormal mass of cells that may be cancerous

Teaching Strategies

Introducing the Lesson

Tell students that each of them started out as a single cell smaller than the period at the end of a sentence. Now, each of them consists of trillions of cells. Ask them to explain how they developed from one cell to trillions of cells. (*Sample answer:* The single cell divided, then those two cells divided, and so on.) Tell the class they will learn how cells divide in this chapter.

Demonstration

Demonstrate cell division by binary fission. At the URL below, students can watch a video of a paramecium dividing, “rock-and-roll” style. After the video, call on students to describe what they observed and relate it to the steps of binary fission described in the lesson.

- <http://www.youtube.com/watch?v=K0ZP8VtxUZ0#38;feature=related>

Differentiated Instruction

Encourage students to make their own cycle diagram of the eukaryotic cell cycle, using *Eukaryotic Cell Cycle* from the FlexBook as a basis. Tell students to add sketches, key words, or examples to their diagram to help them understand and remember the phases of the cycle. **ELL, LPR, SN**

Enrichment

Chemistry students might be interested in knowing more about regulatory proteins and how they control the cell cycle. Direct them to the URLs below. After they develop more in-depth knowledge, ask them to teach the topic to the rest of the class.

- <http://news.ucsc.edu/2005/08/725.html>
- <http://www.medicalnewstoday.com/articles/208933.php>
- http://www.biology.arizona.edu/cell_bio/tutorials/cell_cycle/cells2.html
- <http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/C/CellCycle.html>

Science Inquiry

Have students do the online onion root tip activities at the URL below. Onion root tip cells are a model system for viewing the phases of the cell cycle. Students will observe prepared slides of root tip cells and tally the number and percent of cells in each phase of the cycle. Then they will use the data to determine the length of each phase.

- http://www.biology.arizona.edu/cell_bio/activities/cell_cycle/cell_cycle.html

Health Connection

Expand on the connection between regulation of cell division and cancer that is introduced in the lesson. Explain how mutations in proto-oncogenes and tumor-suppressor genes lead to unregulated cell growth and cancer. The diagram and first two URLs below provide background information on the topic. The third URL provides student animations and activities relating to cancer and the cell cycle. It provides a teacher’s guide as well.

- http://biology.kenyon.edu/courses/biol114/Chap07/Chapter_07.html
- <http://science.education.nih.gov/supplements/nih1/cancer/guide/understanding1.htm>
- <http://science.education.nih.gov/supplements/nih1/cancer/default.htm>



(Image courtesy of CK-12 Foundation and under the Creative Commons license CC-BY-NC-SA 3.0.)

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

When a eukaryotic cell divides, the nucleus divides first in the process of mitosis.

- What do you think happens during mitosis? Can you predict what molecules and cell structures are involved in this process?
 - (Students might already know or infer that the chromosomes divide and the nuclear membrane breaks down.)
- How do you think mitosis might differ from binary fission? What steps might be involved in mitosis?
 - (Sample answer: In mitosis, the chromosomes in the nucleus must divide first before the rest of the cell divides.)

5.2 Chromosomes and Mitosis

Key Concept

Chromosomes are coiled structures containing genes. They are the form in which DNA goes through cell division. Cell division in eukaryotic cells includes mitosis, in which the nucleus divides, and cytokinesis, in which the cytoplasm divides and daughter cells form. Mitosis has four phases: prophase, metaphase, anaphase, and telophase.

Standards

- CA.9–12.IE.1.d, CA.9–12.LS.1.c
- NSES.9–12.A.1.4; NSES.9–12.C.1.3, 4; NSES.9–12.C.2.1, 2
- AAAS.9–12.5.B.4; AAAS.9–12.5.C.4

Lesson Objectives

- Describe chromosomes and their role in mitosis.
- Outline the phases of mitosis.

Lesson Vocabulary

- **anaphase**: third phase of mitosis, during which sister chromatids separate and move to opposite poles of the cell
- **centromere**: region of sister chromatids where they are joined together
- **chromatid**: one of two identical copies of a chromosome that are joined together at a centromere before a cell divides
- **chromatin**: grainy material that DNA forms when it is not coiled into chromosomes
- **chromosome**: coiled structure made of DNA and proteins containing sister chromatids that is the form in which the genetic material of a cell goes through cell division
- **gene**: unit of DNA on a chromosome that is encoded with the instructions for a single protein
- **homologous chromosomes**: pair of chromosomes that have the same size and shape and contain the same genes
- **metaphase**: second phase of mitosis, during which chromosomes line up at the equator of the cell
- **prophase**: first phase of mitosis, during which chromatin condense into chromosomes, the nuclear envelope breaks down, centrioles separate, and a spindle begins to form
- **telophase**: last stage of mitosis, during which chromosomes uncoil to form chromatin, the spindle breaks down, and new nuclear membranes form

Teaching Strategies

Check Your Understanding

Did you know that:

- The bacterium *E. coli* has one chromosome, a human has 46 chromosomes, and a species of field horsetail (a plant) has 216 chromosomes!
- If all of the nucleotide bases in all your chromosomes were spaced about 1 mm apart, they would spread from Memphis, Tennessee to Los Angeles, California (a distance of over 1600 miles)!

http://www.ornl.gov/sci/techresources/Human_Genome/posters/chromosome/faqs.shtml



(Image under the public domain.)

Introducing the Lesson

Introduce chromosomes by showing students a colorful human karyotype (see URLs below for examples). Call on volunteers to explain what the karyotype represents (a complete set of human chromosomes). Say that two copies of each of the 23 different human chromosomes must be present in each cell.

Ask: How do all those chromosomes divide properly during cell division so that each daughter cell gets a complete set? (Answers may vary.) Tell students they will learn how when they read this lesson.

- http://www.genomenetwork.org/resources/whats_a_genome/Chp1_2_1.shtml
- <http://www.mathemagic.org/MOBBM/DynamicDNA.html>
- <http://www.nicerweb.com/bio3400/Locked/media/ch01/karyotype.html>

Activity

Have students work through the phases of mitosis with the interactive animation at the URL below.

- <http://www.cellsalive.com/mitosis.htm>

5.2. CHROMOSOMES AND MITOSIS

Differentiated Instruction

Visual learners and English language learners may benefit from the excellent video animation of mitosis at the URL below. They will be whisked inside a cell to see the colorful, dynamic interactions of chromosomes and other structures. The eerie, sci-fi music adds to the dramatic nature of the presentation. **ELL**

- <http://www.youtube.com/watch?v=VGV3fv-uZYI>

Enrichment

Ask a small group of students to create a three-dimensional model of mitosis. If they need inspiration, they can get a wide range of ideas at the URLs below. Give the group a chance to present the model to the class.

- <http://www.starsandseas.com/SAS%20Cells/SAS%20Mitosis/Mitosis.htm>
- <http://www.youtube.com/watch?v=e-2TL0qR8Ow>
- <http://www.shermanisd.net/Curriculum/Cell%20Biology/mitosis.htm>

Science Inquiry

Assign the activity “The Process of Mitosis” at the URL below. Students will actively model the mitosis in the classroom with a few readily available materials.

- <http://www.scienceteacherprogram.org/biology/savitzky06.html>

Overcoming Misconceptions

Students may hold one of the following common misconceptions about chromosomes. Make sure they are aware of the correct information.

- a. The X-shaped structures seen during mitosis are “basic” (unreplicated) chromosomes. (No; they are condensed, replicated chromosomes consisting of two identical DNA double helices.)
- b. The X-shaped structures seen during mitosis are homologous chromosome pairs. (No; they are condensed, replicated chromosomes. Pairing of homologous chromosomes does not occur during mitosis.)

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Cell division occurs not only as organisms grow. It also occurs when they reproduce.

- What role do you think cell division plays when prokaryotes such as bacteria reproduce?
 - (*Sample answer:* I think prokaryotes reproduce through simple cell division, by binary fission.)
- How do you think cell division is involved in the reproduction of eukaryotes such as humans?
 - (*Sample answer:* I think that eukaryotes reproduce with special daughter cells produced by the parents.)

5.3 Reproduction and Meiosis

Key Concept

Asexual reproduction involves one parent and produces offspring that are genetically identical to each other and to the parent. Sexual reproduction involves two parents and produces offspring that is genetically unique. The sequence of stages an organism goes through from one generation to the next is its life cycle.

Standards

- CA.9–12.IE.1.d, CA.9–12.LS.1.c; CA.9–12.LS.2.a, b, d, e
- NSES.9–12.A.1.4, 6; NSES.9–12.C.1.6; NSES.9–12.C.2.2
- AAAS.9–12.5.B.2, 3; AAAS.9–12.5.C.4, 5

Lesson Objectives

- Compare and contrast asexual and sexual reproduction.
- Give an overview of sexual reproduction, and outline the phases of meiosis.
- Explain why sexual reproduction leads to variation in offspring.
- Define life cycle, and identify different types of sexual life cycles.

Lesson Vocabulary

- **asexual reproduction:** reproduction that involves a single parent and results in offspring that are all genetically identical to the parent
- **crossing-over:** exchange of genetic material between homologous chromosomes when they are closely paired during meiosis I
- **diploid:** having two of each type of chromosome
- **egg:** female gamete
- **fertilization:** union of two gametes that produces a diploid zygote
- **gamete:** reproductive cell produced during meiosis that has the haploid number of chromosomes
- **gametogenesis:** development of haploid cells into gametes such as sperm and egg
- **haploid:** having only one chromosome of each type
- **independent assortment:** independent segregation of chromosomes to gametes during meiosis
- **life cycle:** series of stages a sexually reproducing organism goes through from one generation to the next
- **meiosis:** type of cell division in which the number of chromosomes is reduced by half and four haploid cells result

- **sexual reproduction:** type of reproduction that involves the fertilization of gametes produced by two parents and produces genetically variable offspring
- **sperm:** male gamete
- **zygote:** diploid cell that forms when two haploid gametes unite during fertilization

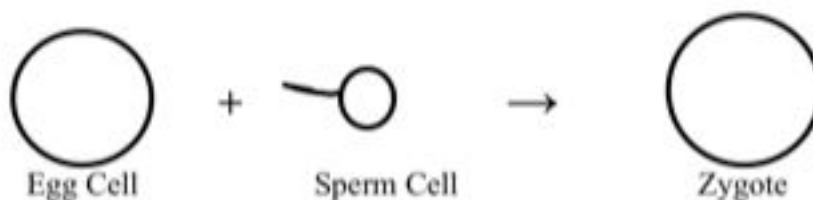
Teaching Strategies

Check Your Understanding

In the previous lesson, students were taught about mitosis. Before launching into the material in this lesson, have a classroom discussion about mitosis. Ask students to recall what they learned about mitosis, and if there are any steps of the process that are unclear to them. Discuss how mitosis and meiosis will share some similar mechanisms.

Introducing the Lesson

Sketch a simple diagram of human fertilization on the board or an overhead. A sample diagram is shown below. Point out that a zygote, like other human cells, has 23 pairs of chromosomes, or 46 chromosomes altogether. Ask students to explain how two cells (the egg and sperm) can combine and produce a cell (the zygote) with the normal number of chromosomes. (Students should infer that the egg and sperm each contain just 23 chromosomes, or one of each pair.) Tell the class they will learn in this lesson how egg and sperm cells form with half the normal number of chromosomes.



(Image courtesy of CK-12 Foundation and under the Creative Commons license CC-BY-NC-SA 3.0.)

Build Science Skills

Review the pros and cons of asexual vs. sexual reproduction. Challenge students to predict conditions under which each type of reproduction might be advantageous. Then assign Problem 5 (Asexual vs. sexual reproduction) at the URL below.

- http://www.biology.arizona.edu/cell_bio/tutorials/meiosis/05q.html

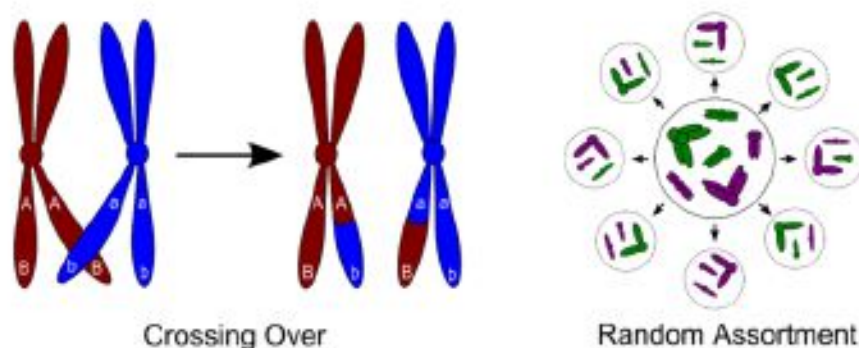
Differentiated Instruction

Pair English language learners with native English speakers. Ask pairs to make a table comparing and contrasting mitosis and meiosis. Suggest they add the table to their science notebook. **ELL**

5.3. REPRODUCTION AND MEIOSIS

Enrichment

Ask a few students to make diagrams illustrating how crossing-over and independent assortment occur and how they increase genetic variation in gametes. Students might use different colors to distinguish chromosomes and parts of chromosomes. Sample diagrams of crossing-over and independent assortment are shown below. Have students explain their diagrams to the class.



(Images courtesy of CK-12 Foundation and under the Creative Commons license CC-BY-NC-SA 3.0.)

Science Inquiry

Present the following scenario to students: During metaphase II of meiosis, one duplicated pair of chromosomes fails to attach to a spindle. Despite this error, meiosis and cytokinesis progress and two daughter cells result.

- Ask: What chromosomes will each daughter cell have? (One of the daughter cells will have an extra copy of the chromosome that failed to attach to the spindle; the other daughter cell will have no copies of that chromosome.)

Overcoming Misconceptions

Correct the following common student misconceptions about sexual and asexual reproduction. Explain why each statement is false.

- Sexual reproduction always involves mating. (False. Sexual reproduction also occurs in other ways, such as conjugation in bacteria and cross-pollination in plants.)
- Plants do not reproduce sexually. (False. Many plants reproduce sexually. In flowering plants, pollen is the male gamete and an egg is the female gamete.)
- Asexual reproduction occurs only in microorganisms. (False. Plants and fungi may also reproduce asexually.)

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In sexually reproducing organisms, parents pass a copy of each type of chromosome to their offspring by producing gametes. When gametes are fertilized and form offspring, each has a unique combination of chromosomes and genes from both parents. The inherited gene combination determines the characteristics of the offspring.

- Is it possible to predict possible gene combinations in offspring from the genes of their parents?
 - (Students might say yes if they have prior knowledge of Punnett squares.)
- Can the characteristics of offspring be predicted from the characteristics of their parents?
 - (Students might say yes based on their own experiences of familial resemblance.)

5.4 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 6

TE Gregor Mendel and Genetics

CHAPTER OUTLINE

6.1 MENDEL'S INVESTIGATIONS

6.2 MENDELIAN INHERITANCE

6.3 WORKSHEET ANSWER KEYS



(Opening image courtesy of Rasbak, http://commons.wikimedia.org/wiki/File:Blauwschokker_Kapucijner_rijserwt_bloem_Pisum_sativum.jpg, and under the license of GNU-FDL 1.2.)

Gregor Mendel and Genetics

Outline

Lesson 6.1: Mendel's Investigations

6.1.1 Mendel and His Pea Plants

- Blending Theory of Inheritance
- Why Study Pea Plants?
- Controlling Pollination

6.1.2 Mendel's First Set of Experiments

- F1 and F2 Generations
- Law of Segregation

6.1.3 Mendel's Second Set of Experiments

- F1 and F2 Generations
- Law of Independent Assortment

6.1.4 Mendel's Laws and Genetics

- Rediscovering Mendel's Work
- Genetics of Inheritance
- Genotype and Phenotype

Lesson 6.2: Mendelian Inheritance

6.2.1 Probability

6.2.2 Probability and Inheritance

- Probability and Gamete Formation
- Probability and Fertilization

6.2.3 Using a Punnett Square

- Predicting Offspring Genotypes
- Predicting Offspring Phenotypes
- Determining Missing Genotypes
- Punnett Square for Two Characteristics

6.2.4 How Mendel Worked Backward to Get Ahead

6.2.5 Non-Mendelian Inheritance

- Codominance and Incomplete Dominance
 - Codominance
 - Incomplete Dominance
- Multiple Alleles
- Polygenic Characteristics
- Effects of Environment on Phenotype

Pacing the Lesson

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 6.1:

Lesson	Number of Class Periods
6.1 Mendel's Investigations	2.5
6.2 Mendelian Inheritance	2.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities. They allow students to simulate Mendel's experiments. (Lesson 6.1)

- <http://www2.edc.org/weblabs/Mendel/MendelMenu.html>
- http://www.accessexcellence.org/AE/AEC/AEF/1996/nolin_pea.php

This Web site has links to information, activities, and videos about Mendel and genetics:

- <http://www.kumc.edu/gec/>

Students can learn about Mendelian inheritance with this fun activity:

- http://serendip.brynmawr.edu/sci_edu/waldron/#dragon1

6.1 Mendel's Investigations

Key Concept

Gregor Mendel experimented with pea plants to study heredity. Based on his research, he developed his laws of segregation and independent assortment. Mendel's laws were rediscovered in 1900 and are now understood in terms of genes and alleles.

Standards

- CA.9–12.IE.1.d, k; CA.9–12.LS.2.a, d, e; CA.9–12.LS.3.b
- NSES.9–12.A.1.6; NSES.9–12.A.2.1, 6; NSES.9–12.C.3.1; NSES.9–12.G.1.1; NSES.9–12.G.3.2, 3, 4
- AAAS.9–12.1.A.2; AAAS.9–12.1.B.3, 7; AAAS.9–12.5.B.2; AAAS.9–12.5.F.5; AAAS.9–12.10.H.5
- McREL.9–12.11.3.1, 2, 3, 4, 5; McREL.9–12.12.5.5; McREL.9–12.12.6.1, 3; McREL.9–12.12.7.3; McREL.9–12.13.2.1, 5; McREL.9–12.13.3.5

Lesson Objectives

- Explain why and how Mendel studied pea plants.
- Describe the results of Mendel's experiments.
- State Mendel's laws of segregation and independent assortment.
- Outline the genetics of inheritance.

Lesson Vocabulary

- **allele**: one of two or more different versions of the same gene
- **dominant allele**: allele that masks the presence of another allele for the same gene when they occur together in a heterozygote
- **genetics**: the science of heredity
- **genotype**: alleles an individual inherits at a particular genetic locus
- **heterozygote**: organism that inherits two different alleles for a given gene
- **homozygote**: organism that inherits two alleles of the same type for a given gene
- **hybrid**: offspring that results from a cross between two different types of parents
- **law of independent assortment**: Mendel's second law stating that factors controlling different characteristics are inherited independently of each other
- **law of segregation**: Mendel's first law stating that the two factors controlling a characteristics separate and go to different gametes
- **locus**: position of a gene on a chromosome

- **phenotype:** characteristics of an organism that depend on how the organism's genotype is expressed
- **pollen:** tiny grains that bear the male gametes of seed plants and transfer sperm to female reproductive structures
- **pollination:** fertilization in plants in which pollen is transferred to female gametes in an ovary
- **recessive allele:** allele that is masked by the presence of another allele for the same gene when they occur together in a heterozygote

Teaching Strategies

Check Your Understanding

Ask students to describe the two ways chromosomes/chromatids separate during meiosis. You may want to do a quick review of meiosis from the chapter *The Cell Cycle, Mitosis, and Meiosis*.

Introducing the Lesson

Students are likely to have learned about Gregor Mendel in earlier science classes. Call on volunteers to state anything they already know about Mendel or his work. Record their statements on the board. Tell the class to check whether the statements are correct when they read this lesson about Mendel's discoveries.

Activity

Have groups of students create simple models of at least two pairs of homologous chromosomes. (For example, students might use small strips of paper in different lengths to represent different pairs of chromosomes and paper of different colors to distinguish members of each pair.) Then have them use their models to simulate segregation and independent assortment.

Differentiated Instruction

This lesson has important vocabulary terms that students will need to understand as they go forward in biology. If you haven't already started a word wall, start with this lesson. Post the vocabulary terms and definitions on a wall. Leave plenty of space around each term. Then have students add sketches, key words, or examples that help convey the meaning of the terms. **ELL, LPR**

Enrichment

Have a few students learn more about De Vries, Correns, and Tschermak and the rediscovery of Mendel's laws. Ask them to create a Web page, PowerPoint, or other visual presentation to share what they learn.

Science Inquiry

Have students play the game *The Princess and the Wrinkled Pea* at the URL below. They will solve a genetics problem in the guise of a game by applying principles of Mendelian inheritance.

- http://biologica.concord.org/webtest1/web_labs_mendels_peas.htm

6.1. MENDEL'S INVESTIGATIONS

Real-World Connection

Relate Mendelian genetics to the profession of genetics counseling. Explain that genetics counselors advise people who are concerned about having a child with a genetic disorder. Counselors may use family histories, Mendelian genetics, and other tools to determine the probability of a child with a particular genotype. Ask interested students to investigate this important profession and report back to the class on what they learn.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

With his first set of experiments, Mendel found that characteristics appear to skip generations. With his second set of experiments, he found that different characteristics are inherited independently of one another.

- Why would this information be useful? Can you think of a practical application of Mendel's laws?
 - (Answers may vary; encourage a diversity of suggestions.)
- Could Mendel's laws be used to predict the characteristics of the offspring of a given set of parents? How do you think this might be done?
 - (Students might say you could make a chart like **Figure 6.6** and fill in the cells with possible combinations of parental traits.)

6.2 Mendelian Inheritance

Key Concept

Based on probability and knowledge of Mendelian inheritance, a Punnett square can be used to predict the proportions of different genotypes in the offspring of a given set of parents. Mendel didn't know about genes, but luckily he studied simple dominant-recessive traits, so he could work backward from phenotypes to determine the pattern of inheritance. More complex patterns of inheritance include codominance, incomplete dominance, multiple alleles, multiple genes, and environmental influences on gene expression.

Standards

- CA.9–12.IE.1.a, d, g, j; CA.9–12.LS.2.a, c, d, e, g; CA.9–12.LS.3.a, c
- NSES.9–12.A.1.6; NSES.9–12.A.2.1, 4, 6
- AAAS.9–12.5.B.2; AAAS.9–12.5.F.5; AAAS.9–12.12.B.1

Lesson Objectives

- Define probability.
- Explain how probability is related to inheritance.
- Describe how to use a Punnett square.
- Explain how Mendel interpreted the results of his experiments.
- Describe complex patterns of inheritance.

Lesson Vocabulary

- **codominance**: relationship between two alleles for the same gene in which both alleles are expressed equally in the phenotype of the heterozygote
- **incomplete dominance**: relationship between the alleles for a gene in which one allele is only partly dominant to the other allele so an intermediate phenotype results
- **polygenic characteristic**: characteristic, or trait, controlled by more than one gene, each of which may have two or more alleles
- **probability**: the likelihood, or chance, that a certain event will occur
- **Punnett square**: chart for determining the expected percentages of different genotypes in the offspring of two parents

Teaching Strategies

Introducing the Lesson

Toss a coin to see if a head or tail turns up, after first asking the class to predict the outcome of the toss. Use the coin toss as a vehicle to introduce the concept of probability. Tell students they will learn how probability is related to heredity when they read this lesson.

Activity

Assign the drag-and-drop activity at the URL below. Students will use Punnett squares to determine expected proportions of genotypes and phenotypes of offspring.

- http://www.zerobio.com/drag_gr11/mono.htm

Differentiated Instruction

Pair ELL and native English speakers, and ask partners to make a cluster diagram for the section “Non-Mendelian Inheritance.” **ELL**

Enrichment

Have students who need extra challenges solve the case study *Those Old Kentucky Blues* at the URL below. In this honors activity, they will use pedigrees and other information to determine the inheritance pattern of an interesting genetic condition.

- http://sciencecases.lib.buffalo.edu/cs/collection/detail.asp?case_id=208#38;id=208

Science Inquiry

Have students use Mendelian principles to solve the genetics problems at the URL below.

- http://www.biology.arizona.edu/mendelian_genetics/problem_sets/monohybrid_cross/monohybrid_cross.html

Overcoming Misconceptions

Students commonly think that the expected proportions of genotypes in offspring, as given in a Punnett square, are the actual proportions. Explain that they are only the most likely proportions, and other proportions may occur in any given family.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Like most of the characteristics of living things, the characteristics Mendel studied in pea plants are controlled by genes. All the cells of an organism contain the same genes, because all organisms begin as a single cell. Most of the genes code for proteins.

- How is the information encoded in a gene translated into a protein? Where does this occur, and what processes are involved?
 - (Students may or may not be familiar with the processes of protein synthesis — transcription and translation — and the role of ribosomes in the latter process.)
- If cells have the same genes, how do you think different cells arise in an organism? For example, how did you come to have different skin, bone, and blood cells if all of your cells contain the same genes?
 - (*Sample answer:* I think that different genes are translated into proteins in different cells.)

6.3 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER

7

TE Molecular Genetics: From DNA to Proteins

CHAPTER OUTLINE

7.1 DNA AND RNA**7.2 PROTEIN SYNTHESIS****7.3 MUTATION****7.4 REGULATION OF GENE EXPRESSION****7.5 WORKSHEET ANSWER KEYS**



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Molecular Genetics: From DNA to Proteins

Outline

Lesson 7.1: DNA and RNA

7.1.1 Central Dogma of Molecular Biology

7.1.2 DNA

- Griffith Searches for the Genetic Material
- Avery's Team Makes a Major Contribution
- Hershey and Chase Seal the Deal
- Chargaff Writes the Rules
- The Double Helix
- DNA Replication

7.1.3 RNA

- RNA vs. DNA
- Types of RNA

Lesson 7.2: Protein Synthesis

7.2.1 Transcription

- Steps of Transcription
- Processing mRNA

7.2.2 The Genetic Code

- Reading the Genetic Code
- Characteristics of the Genetic Code

7.2.3 Translation

Lesson 7.3: Mutation

7.3.1 Causes of Mutation

7.3.2 Types of Mutations

- Chromosomal Alterations
- Point Mutations
- Frameshift Mutations

7.3.3 Effects of Mutations

- Beneficial Mutations
- Harmful Mutations

Lesson 7.4: Regulation of Gene Expression

7.4.1 How Gene Expression Is Regulated

7.4.2 Prokaryotic Gene Regulation

- The Role of Operons
- The Lac Operon

7.4.3 Eukaryotic Gene Regulation

- The TATA Box
- Regulation During Development
- Gene Regulation and Cancer

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 7.1:

Lesson	Number of Class Periods
7.1 DNA and RNA	1.5
7.2 Protein Synthesis	2.0
7.3 Mutation	1.0
7.4 Regulation of Gene Expression	1.0

- Class periods are assumed to be 60 minutes long.

Online Resources

The following labs are suitable for this chapter and are available online:

1. Students can extract their own DNA (from cheek cells) and learn about DNA structure and replication. (Lesson 7.1)

- http://serendip.brynmawr.edu/sci_edu/waldron/#dna

2. Students will use simple paper models to simulate DNA transcription and translation. (Lesson 7.2)

- http://serendip.brynmawr.edu/sci_edu/waldron/#dna

3. Groups of students will investigate a hypothetical anthrax case by modeling DNA sequencing. They will focus on the role of mutations in the identification of DNA samples. The lab uses online videos and animations. (Lessons 7.1 and 7.3)

- http://www.pbs.org/wgbh/nova/teachers/activities/0401_02_nsn.html

4. Students will transcribe and translate a DNA sequence containing a mutation. Then they will perform a BLAST search to determine the protein that is encoded in the sequence. They will also infer which disease is caused by the protein. (Lessons 7.1, 7.2, 7.3)

- <http://teacherknowledge.wikispaces.com/Quist+-+Connecting+DNA+to+Disease+Using+BLAST>

5. In this wet lab, students will investigate how genes are regulated during development by observing differential gene expression in genetically modified plants. The Web site provides extensive pre- and post-lab materials, worksheets, links, and other resources. The lab is suitable for AP biology students. (Lesson 7.4)

- http://www.moreheadplanetarium.org/files/Same_Genes_Notebook.pdf

These Web sites may also be helpful:

1. This Web page provides many relevant links for activities, articles, online animations, quizzes, and other materials on molecular genetics.

- http://www.nclark.net/DNA_RNA

2. This Web site from the Cold Spring Harbor Laboratory provides animations, photographs, biographical sketches, problems, and links for students to learn about and explore the molecules of genetics.

- <http://www.dnafb.org/dnafb/>

7.1 DNA and RNA

Key Concept

The central dogma of molecular biology can be summed up as DNA → RNA → Protein. Starting in the early 1900s, several researchers made important discoveries about DNA and how it codes for proteins. Three types of RNA are also involved in protein synthesis: mRNA, rRNA, and tRNA.

Standards

- CA.9–12.IE.1.d, k; CA.9–12.LS.1.d; CA.9–12.LS.4.a; CA.9–12.LS.5.a
- NSES.9–12.A.1.6; NSES.9–12.A.2.1, 2, 5; NSES.9–12.C.1.1, 3; NSES.9–12.C.2.1; NSES.9–12.G.1.1; NSES.9–12.G.3.2, 3, 4
- AAAS.9–12.1.A.2; AAAS.9–12.5.B.3; AAAS.9–12.5.C.4
- McREL.9–12.11.3.1, 2, 3; McREL.9–12.11.4.1, 2; McREL.9–12.12.5.2, 3, 4; McREL.9–12.12.6.3, 4; McREL.9–12.13.2.1, 2

Lesson Objectives

- State the central dogma of molecular biology.
- Outline discoveries that led to knowledge of DNA's structure and function.
- Describe the structure of RNA, and identify the three main types of RNA.

Lesson Vocabulary

- **central dogma of molecular biology:** doctrine that genetic instructions in DNA are copied by RNA, which carries them to a ribosome where they are used to synthesize a protein (DNA → RNA → protein)
- **Chargaff's rules:** observations by Erwin Chargaff that concentrations of the four nucleotide bases differ among species; and that, within a species, the concentrations of adenine and thymine are always about the same and the concentrations of cytosine and guanine are always about the same
- **messenger RNA (mRNA):** type of RNA that copies genetic instructions from DNA in the nucleus and carries them to the cytoplasm
- **ribosomal RNA (rRNA):** type of RNA that helps form ribosomes and assemble proteins
- **transfer RNA (tRNA):** type of RNA that brings amino acids to ribosomes where they are joined together to form proteins

Teaching Strategies

Introducing the Lesson

By taking the *Tour of the Basics* at the URL below, students can review genes and chromosomes and get an introduction to the structure of DNA.

- <http://learn.genetics.utah.edu/content/begin/tour/>

Activity

Have students build an edible model of DNA. This will help them learn the structure of DNA and how DNA bases pair. The URL below provides everything you and your students need for the activity.

- http://www.nclark.net/Have_Your_DNA_and_Eat_It_Too.pdf

Differentiated Instruction

Pair less proficient readers with more proficient readers, and ask pairs to make a table comparing and contrasting the structure and function of DNA and RNA. A sample table is shown below (**Table 7.2**). **LPR**

TABLE 7.2: RNA vs. DNA

	RNA	DNA
Structure:	single stranded	double stranded
Bases:	C, G, A, U	C, G, A, T
Sugar:	ribose	deoxyribose
Size:	relatively small	very large
Location:	nucleus and cytoplasm	nucleus only

Enrichment

Ask your advanced students to do the online genetics tutorial at the URL below. It uses multimedia to present principles of molecular genetics at a more sophisticated level than the text.

- http://morgan.rutgers.edu/MorganWebFrames/How_to_use/HTU_Frameset.html

Science Inquiry

Have small groups of students do the activity *Where Do Genes Begin?* (see URL below). In the activity, students will build a simple model of DNA and use it to investigate Chargaff's rules and DNA sequencing.

- http://www.nclark.net/Watson_Crick_Model.pdf

Overcoming Misconceptions

Common student misconceptions about DNA include:

- a. DNA, genes, and chromosomes are interchangeable concepts.
- b. DNA is the only genetic material in the genome.
- c. Simple organisms such as bacteria do not have DNA.
- d. All DNA sequences code for proteins.

Work with students to restate each misconception so it is true.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

All three types of RNA are needed by cells to make proteins.

- Can you develop a model in which the three types of RNA interact to make a protein?
 - (Try to elicit a range of responses.)
- How do you think mRNA copies the genetic instructions in DNA? How are these instructions encoded in the DNA molecule?
 - (*Sample answer:* I think mRNA has a complementary sequence of bases to the DNA it copies and that the sequence of bases encodes the instructions.)

7.2 Protein Synthesis

Key Concept

Transcription is the DNA → RNA part of the central dogma. It occurs in the nucleus. A copy of mRNA is made that is complementary to a strand of DNA. The sequence of bases in DNA or RNA makes up the genetic code, which is universal, unambiguous, and redundant. Translation is the RNA → protein part of the central dogma. It occurs at a ribosome. All three types of RNA are involved in translation.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.1.d; CA.9–12.LS.4.a, b, e; CA.9–12.LS.5.a, b
- NSES.9–12.A.1.6; NSES.9–12.C.1.1, 2, 3; NSES.9–12.C.2.1
- AAAS.9–12.5.B.3; AAAS.9–12.5.C.4

Lesson Objectives

- Give an overview of transcription.
- Describe the genetic code.
- Explain how translation occurs.

Lesson Vocabulary

- **codon:** group of three nitrogen bases in nucleic acids that makes up a code “word” of the genetic code and stands for an amino acid, start, or stop
- **genetic code:** universal code of three-base codons that encodes the genetic instructions for the amino acid sequence of proteins
- **promoter:** region of a gene where a RNA polymerase binds to initiate transcription of the gene
- **protein synthesis:** process in which cells make proteins that includes transcription of DNA and translation of mRNA
- **transcription:** process in which genetic instructions in DNA are copied to form a complementary strand of mRNA
- **translation:** process in which genetic instructions in mRNA are “read” to synthesize a protein

Teaching Strategies

Introducing the Lesson

Introduce protein synthesis by discussing the common meanings of transcription (copying words) and translation (changing words from one language into another). Tell students they will read in this lesson how DNA is transcribed into RNA, which is then translated into a protein.

Activity

Divide the class into small groups and have each group do the activities *RNA Transcription* and *RNA Translation*, which can be accessed at the URL below. Students will develop a model that shows how the sequence of bases in DNA determines the order of bases in mRNA. Then they will determine the amino acid sequence encoded in the mRNA.

- http://serendip.brynmawr.edu/sci_edu/waldron/pdf/DNATeachPrep.doc

Differentiated Instruction

Pair English language learners with native English speakers, and ask pairs to create a flow chart of protein synthesis, including both transcription and translation. Tell partners to sketch simple diagrams to illustrate the steps of the flow chart. Give them a chance to share their flow charts with the class. **ELL**

Enrichment

Provide students with materials such as white yarn or string, colored markers, scissors, and clear tape. Then challenge the students to devise a way to use the materials to demonstrate RNA splicing. Set aside time for the students to present their demonstration to the class.

Science Inquiry

Assign the activity *How Does DNA Determine the Traits of an Organism?* (see URL below). Students will analyze DNA data for a fictitious organism named a snork. Then, based on the DNA base sequence, they will determine the organism's traits. This fun activity can be done as a homework assignment.

- <http://www.biologycorner.com/worksheets/snorks.html>

Overcoming Misconceptions

A persistent misconception about protein synthesis is that amino acids are products, rather than reactants, of translation. Make sure students know that amino acids come from ingestion and biosynthesis, which are separate from translation.

7.2. PROTEIN SYNTHESIS

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

When DNA is replicated or transcribed, accidents can happen, leading to a change in the base sequence.

- What do you think could cause such accidents to occur?
 - (Students might mention mutagens such as UV light.)
- How might the changes affect the reading frame? How might the encoded protein be affected?
 - (*Sample answer:* It might interrupt the reading frame. If that happened, the protein might be drastically affected.)

7.3 Mutation

Key Concept

Mutations are caused by environmental factors known as mutagens. Examples of mutagens include radiation and certain chemicals. Germline mutations occur in gametes, and somatic mutations occur in other body cells. Mutations may alter entire chromosomes or change a single nucleotide. Their effects may be neutral, beneficial, or harmful. Mutations are essential for evolution because they are the ultimate source of genetic variation in a species.

Standards

- CA.9–12.IE.4.c; CA.9–12.LS.7.c
- NSES.9–12.C.2.3; NSES.9–12.C.3.1; NSES.9–12.F.1.1
- AAAS.9–12.5.A.1; AAAS.9–12.5.B.4, 5; AAAS.9–12.5.C.6; AAAS.9–12.5.F.3, 5; AAAS.9–12.6.E.2

Lesson Objectives

- Identify causes of mutation.
- Compare and contrast types of mutations.
- Explain how mutations may affect the organisms in which they occur.

Lesson Vocabulary

- **chromosomal alteration:** mutation that changes chromosome structure
- **frameshift mutation:** deletion or insertion of one or more nucleotides that changes the reading frame of the genetic material
- **genetic disorder:** disease caused by a mutation in one or a few genes
- **germline mutation:** mutation that occur in gametes
- **mutagen:** environmental factor that causes mutations
- **mutation:** change in the sequence of bases in DNA or RNA
- **point mutation:** change in a single nucleotide base in the genetic material
- **somatic mutation:** mutation that occurs in cells of the body other than gametes

Teaching Strategies

Introducing the Lesson

Call on volunteers to describe drastic mutations they have read about or seen in science fiction stories or movies, or describe examples yourself. Explain that real mutations rarely have such drastic effects, but they are extremely important. Without them, evolution could not occur. Tell students they will learn more about mutations in this lesson.

Activity

Assign the activities at the URLs below. Students will investigate the effects of different mutations on the encoded proteins.

- http://serendip.brynmawr.edu/sci_edu/waldron/pdf/DNATeachPrep.doc
- <http://molo.concord.org/database/activities/102.html>

Differentiated Instruction

Pair less proficient readers with more proficient readers, and ask partners to make a table comparing and contrasting the following types of mutations: deletions, insertions, duplications, inversions, translocations, and point mutations.
LPR

Enrichment

Ask a group of students to create a public service announcement identifying common mutagens that may cause cancer and ways that people can reduce their exposure to them. Have students make a video of their announcement and present it to the class or, if possible, the entire school.

Science Inquiry

Have students do the online activity *Test Neurofibromin Activity in a Cell* (see URL below). After reading about the protein neurofibromin and its role in normal cell division, students will predict how mutations in the gene for this protein might affect cell division. Then they will use an interactive animation to test their prediction. They will observe the simulated effects of different mutations on cells as though seen through a microscope.

- <http://learn.genetics.utah.edu/content/begin/dna/neurofibromin/>

Overcoming Misconceptions

Misconceptions about mutations are common. Discuss the examples below and give students the correct facts as well as examples of mutations that illustrate why the misconceptions are false.

1. All mutations are harmful.

- *Fact:* Most mutations are neutral and some may even be beneficial. For several examples of beneficial mutations in yeast and bacteria, go to this link:
 - <http://www.gate.net/rwms/EvoMutations.html>.

2. All mutations change the protein products of genes.

- *Fact:* Some mutations have no effect on protein products. For example, mutations may occur in noncoding sections of DNA, or they may result in synonymous codons that code for the same amino acids.

3. All mutations have phenotypic effects.

- *Fact:* Many mutations are recessive and do not affect phenotypes. Having one copy of the normal allele is sufficient for a normal phenotype. For example, the mutations that cause PKU and cystic fibrosis are recessive. Two copies of the recessive alleles must be present for the diseases to appear in the phenotype.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Sometimes even drastic mutations do not affect the proteins produced by a particular type of cell. The reason? The genes affected by the mutations are not normally used to make proteins in that type of cell. In all cells, some genes are turned off — they are not transcribed — while other genes are turned on.

- How do cells control which genes are turned on and used to make proteins?
 - (Students might say cells have special genes that control which other genes are turned on.)
- Can you think of a mechanism that might prevent transcription of a gene?
 - (Encourage creative but reasonable responses.)

7.4 Regulation of Gene Expression

Key Concept

Gene transcription is controlled by regulatory elements on DNA that either activate or repress transcription. In prokaryotes, this typically involves an operon, such as the lac operon in *E. coli*. In eukaryotes, regulation of transcription is more complex. It generally includes regulatory elements such as the TATA box and homeobox genes that switch other regulatory genes on or off.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.4.d
- NSES.9–12.A.1.6; NSES.9–12.C.1.4, 6
- AAAS.9–12.5.B.6; AAAS.9–12.5.C.6; AAAS.9–12.6.B.1

Lesson Objectives

- Identify general mechanisms that regulate gene expression.
- Describe how gene regulation occurs in prokaryotes.
- Give an overview of gene regulation in eukaryotes.

Lesson Vocabulary

- **gene expression:** use of a gene to make a protein
- **homeobox gene:** gene that codes for regulatory proteins that control gene expression during development
- **operator:** a region of an operon where regulatory proteins bind
- **operon:** region of prokaryotic DNA that consists of a promoter, an operator, and one or more genes that encode proteins needed for a specific function
- **regulatory element:** region of DNA where a regulatory protein binds
- **regulatory protein:** protein that regulates gene expression
- **TATA box:** regulatory element that is part of the promoter of most eukaryotic genes

Teaching Strategies

Introducing the Lesson

Introduce gene regulation with an analogy. Tell students that the genes we inherit are like the hard drive of a computer, but each type of cell has its own separate “software.” The “software” turns on or off a particular set of genes through the mechanisms of gene regulation. Tell students they will learn how genes are regulated in this lesson.

Demonstration

Suggest that students watch the online animation below. It demonstrates the lac operon mechanism for gene regulation.

- <http://www.dnatube.com/video/22/Lac-operon-mechanism>

Differentiated Instruction

Pair less proficient readers with more proficient readers, and ask pairs to work together to make a main ideas/details chart for the lesson. Suggest that they try to write a main idea for each heading and subheading in the lesson and include at least one detail per main idea. **LPR**

Enrichment

This lesson focuses on transcriptional regulation of gene expression. Have interested students research translational regulation. Ask them to summarize at least one translational regulation mechanism, such as microRNA-mediated regulation, and present their summary to the class. Encourage them to make a diagram to help explain the mechanism.

Science Inquiry

Challenge groups of students to formulate a hypothesis for how the lac operon evolved. They should consider why it might be advantageous for an organism to be able to control the production of proteins that it needs only in certain situations, rather than produce the proteins all the time. Give groups a chance to share and discuss their hypotheses.

Health Connection

Elaborate on the connection between gene regulation and cancer that is presented in the lesson. Explain that tumor-suppressor genes normally act like “brakes” to inhibit cell growth and division, whereas proto-oncogenes normally act like “gas pedals” to accelerate cell growth and division. When mutations occur in these genes, it’s similar to the cells to losing their brakes and hitting the gas pedal. The cells grow and divide uncontrollably. Students can learn more by watching the video at the URL below.

- <http://www.youtube.com/watch?v=ZCy7gCPWEcM>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Scientists know more about human chromosomes and genes than they know about the genetic material of most other species. In fact, scientists have identified all of the approximately 20,000-25,000 genes in human DNA.

- What do you know about human chromosomes and genes? For example, do you know how many chromosomes humans normally have?
 - (Humans normally have 23 pairs, or 46 chromosomes in each cell.)
- Do you know how human characteristics are inherited? Can you identify characteristics that are controlled by a single gene?
 - (*Sample answers:* Human characteristics are inherited according to Mendel's laws. ABO blood type is a characteristic controlled by a single gene.)

7.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 8

TE Human Genetics and Biotechnology

CHAPTER OUTLINE

8.1 HUMAN CHROMOSOMES AND GENES

8.2 HUMAN INHERITANCE

8.3 BIOTECHNOLOGY

8.4 WORKSHEET ANSWER KEYS



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Human Genetics and Biotechnology

Outline

Lesson 8.1: Human Chromosomes and Genes

8.1.1 The Human Genome

8.1.2 Chromosomes and Genes

- Autosomes
- Sex Chromosomes
- Human Genes

8.1.3 Linkage

- Sex-Linked Genes
- Linkage Maps

Lesson 8.2: Human Inheritance

8.2.1 Mendelian Inheritance in Humans

- Autosomal Traits
- Sex-Linked Traits
- Pedigree Analysis Activity

8.2.2 Non-Mendelian Inheritance

- Multiple Allele Traits
- Polygenic Traits
- Pleiotropy
- Epistasis

8.2.3 Genetic Disorders

- Genetic Disorders Caused by Mutations
- Chromosomal Disorders
- Diagnosing Genetic Disorders
- KQED: Treating Genetic Disorders

Lesson 8.3: Biotechnology

8.3.1 Biotechnology Methods

- Gene Cloning
- Polymerase Chain Reaction

8.3.2 Applications of Biotechnology

- Applications in Medicine
- KQED: Pharmacogenomics
- KQED: Synthetic Biology
- Applications in Agriculture

8.3.3 Ethical, Legal, and Social Issues

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 8.1:

Lesson	Number of Class Periods
8.1 Human Chromosomes and Genes	1.5
8.2 Human Inheritance	2.5
8.3 Biotechnology	1.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. Students will determine their own phenotypes and genotypes for several readily observable traits and calculate the percentage of the class with each trait. (Lesson 8.2)

- <https://www.delsearegional.us/Academic/Classes/highschool/science/mnicastro/Labs%20Academic%20Biology/Human%20Inheritance%20Lab.doc>

2. This lab is similar to the lab described above but also includes a component in which students work with pedigrees. (Lesson 8.2)

- <http://www.mrulichslandofbiology.com/Labs/Lab-HumanInheritanceandPedigreeAnalysis.pdf>

3. In this lab, students will solve problems of identification based on blood type. (Lesson 8.2)

- http://serendip.brynmawr.edu/sci_edu/waldron/#blood

4. This laboratory leads students through gene cloning techniques. It offers both wet lab and virtual options. (Lesson 8.3)

- http://www.dnalc.org/labcenter/transformation/transformation_h.html

5. This virtual PCR lab comes complete with sound effects. (Lesson 8.3)

- <http://learn.genetics.utah.edu/content/labs/pcr/>

These Web sites may also be helpful:

1. This Web site links you and your students to the history, achievements, and current undertakings of the Human Genome Research Project.

- <http://www.genome.gov/>

2. This curriculum supplement covers the basics of human genetics and its relationship to disease. It includes several student activities.

- http://science-education.nih.gov/Customers.nsf/HSGenetic?OpenForm#38;CS_11=

3. This Web site provides teaching ideas and classroom activities for several human genetic disorders.

- <http://www.usoe.k12.ut.us/CURR/Science/core/bio/genetics/home%20page.htm>

4. Go to this URL for an animation of restriction enzyme digestion of plasmid DNA and subsequent ligation of the sticky ends.

- <http://www.hhmi.org/biointeractive/dna/animations.html>

5. This Web site has an animation of the polymerase chain reaction.

- <http://www.hhmi.org/biointeractive/dna/animations.html>

6. At this URL, students can see an animation showing how to make a transgenic plant.

- <http://cls.casa.colostate.edu/TransgenicCrops/how.html>

8.1 Human Chromosomes and Genes

Key Concept

The human genome consists of at least 20,000 genes on 23 pairs of chromosomes. Of these pairs, 22 are autosomes, and the other pair consists of sex chromosomes (X, Y). Linked genes are located on the same chromosome; sex-linked genes are located on a sex chromosome. The frequency of crossing-over between genes is used to construct linkage maps, which show the locations of genes on chromosomes.

Standards

- CA.9–12.IE.1.d, k; CA.9–12.LS.2.f; CA.9–12.LS.3.d
- NSES.9–12.A.1.6; NSES.9–12.A.2.2; NSES.9–12.C.2.1, 2; NSES.9–12.G.1.1; NSES.9–12.G.3.4
- McREL.9–12.11.4.2; McREL.9–12.13.2.2, 6

Lesson Objectives

- Define the human genome.
- Describe human chromosomes and genes.
- Explain linkage and linkage maps.

Lesson Vocabulary

- **autosome:** chromosomes 1–22 in humans, which contain genes for characteristics unrelated to sex
- **human genome:** all of the DNA of the human species
- **Human Genome Project:** international science project that sequenced all 3 billion base pairs of the human genome
- **linkage map:** map that shows the positions of genes on a chromosome based on the frequency of crossing-over between the genes
- **linked genes:** genes that are located on the same chromosome
- **sex chromosome:** X or Y chromosome (in humans)
- **sex-linked gene:** gene located on a sex chromosome
- **X-linked gene:** gene located on the X chromosome

Teaching Strategies

Introducing the Lesson

Help students recall what they know from popular media about DNA testing. Discuss the role that DNA testing plays in solving criminal cases.

- Ask: What does DNA testing show? (*Sample answer:* an individual's DNA sequence)
- Ask: Why does DNA evidence usually provide definitive evidence of identity? (*Sample answer:* No two people except identical twins have exactly the same DNA sequence.)

Discussion

Have students learn more about the Human Genome Project at the Web sites below. Then discuss the project with the class as an example of the role of collaboration in the advancement of scientific knowledge. Also discuss the importance of this landmark achievement.

- http://www.ornl.gov/sci/techresources/Human_Genome/home.shtml
- <http://www.genome.gov/10001772>

Differentiated Instruction

Pair less proficient with more proficient readers, and ask pairs to create a main ideas/details chart of lesson concepts. They should first skim each passage to identify main idea sentences. Then they should read the passage more closely to find important details. **LPR**

Enrichment

Have interested students learn about spectral karyotyping. The Web site below is a good place for them to start. Ask the students to share colored images of spectral karyotypes with the class and explain this method of karyotyping. They should also discuss advantages of spectral karyotyping over traditional methods.

- http://www.biology.arizona.edu/human_bio/current/new_karyotyping/new_karyotyping.html

Science Inquiry

Science often runs into ethical, social, and legal issues. Our ability to extract an individual's DNA is no exception. For example, who owns a person's DNA? How can people keep their own DNA private? Students can address these issues by doing the activity *See Your DNA* at the URL below. After extracting a sample of their own DNA, they will draft a policy statement about DNA ownership and privacy.

- http://www.pbs.org/wgbh/nova/teachers/activities/2809_genome.html

Overcoming Misconceptions

Students commonly hold the misconception that single genes are the cause of most genetic traits and inherited disorders. Be sure to spend time discussing polygenic traits, and give students several examples of human traits and disorders that are polygenic, such as adult height, skin color, and certain cancers.

8.1. HUMAN CHROMOSOMES AND GENES

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

You read in this lesson about the chromosomes and genes that control human traits. Most traits are controlled by genes on autosomes, but many are controlled by genes on the X chromosome.

- Do you think it matters whether a gene is on an autosome or the X chromosome when it comes to how it is inherited?
 - (Some students might say that it doesn't matter because Mendel's laws apply to all chromosomes.)
- How do mothers and fathers pass their sex chromosomes to their sons and daughters? Their autosomes?
 - (Mothers pass X chromosomes to both sons and daughters, just like autosomes, but fathers pass only X chromosomes to daughters and only Y chromosomes to sons.)

8.2 Human Inheritance

Key Concept

Traits have different inheritance patterns depending on whether the genes are autosomal or X-linked. Most human traits have complex modes of inheritance, such as multiple alleles or multiple genes. More complexity may be introduced by pleiotropy and epistasis. Genetic disorders may be caused by mutations in one or a few genes or by abnormal numbers of chromosomes.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.2.e, f, g; CA.9–12.LS.3.a, c; CA.9–12.LS.7.b
- NSES.9–12.A.1.6; NSES.9–12.C.2.2
- AAAS.9–12.6.E.2, 3; AAAS.9–12.8.F.3

Lesson Objectives

- Describe inheritance in humans for autosomal and X-linked traits.
- Identify complex modes of human inheritance.
- Describe genetic disorders caused by mutations or abnormal numbers of chromosomes.

Lesson Vocabulary

- **epistasis**: situation in which one gene affects the expression of another gene
- **gene therapy**: way to cure genetic disorders by inserting normal genes into cells with mutant genes
- **genetic trait**: characteristic that is encoded in DNA
- **multiple allele trait**: trait controlled by one gene with more than two alleles
- **nondisjunction**: failure of replicated chromosomes to separate during meiosis II, resulting in some gametes with a missing chromosome and some with an extra chromosome
- **pedigree**: chart showing how a trait is passed from generation to generation within a family
- **pleiotropy**: situation in which a single gene affects more than one trait
- **sex-linked trait**: traits controlled by a gene located on a sex chromosome
- **X-linked trait**: trait controlled by a gene located on the X chromosome

Teaching Strategies

Introducing the Lesson

Call on a volunteer to demonstrate tongue rolling. (Students with this trait, which is pictured below, are likely to be aware of it.) Explain that the inheritance of tongue rolling is an example of autosomal dominant inheritance. Tell students they will learn about this and other types of inheritance in humans when they read this lesson.



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Building Science Skills

Explain that a pedigree, such as the one in FlexBook **Figure 8.5**, is a type of model. It represents a particular pattern of inheritance. Divide the class into groups, and ask each group to make a hypothetical pedigree that models a different inheritance pattern (e.g., autosomal dominant, X-linked recessive, and so on). Have groups examine each other's pedigrees and try to identify the inheritance patterns they represent.

Differentiated Instruction

Pair beginning ELL students with more advanced ELL students, and have partners make a Venn diagram comparing and contrasting autosomal and sex-linked inheritance. **ELL**

Enrichment

Suggest that interested students explore the new science of epigenetics. It studies environmental influences on gene activity that are passed from one generation to the next. At the URLs below, students can find videos, articles, and interactive activities on the topic.

- <http://learn.genetics.utah.edu/content/epigenetics/>
- <http://www.time.com/time/health/article/0,8599,1951968,00.html#ixzz1Cp9ISU2C>

Science Inquiry

Challenge students with one or more activities at the URLs below. In the activities, students will apply principles of sex-linked inheritance to solve genetics problems.

- http://www.biology.arizona.edu/mendelian_genetics/problem_sets/Sex_linked_Inheritance/sex_linked_inheritance.html
- http://www.biology.arizona.edu/human_bio/problem_sets/color_blindness/color_blindness.html

Overcoming Misconceptions

Students commonly confuse genetic disorders and hereditary disorders. While many disorders have a genetic component, they are not necessarily hereditary. Explain the difference.

- a. A disorder is genetic if people with a certain genotype are more likely to develop the disorder. Whether they actually develop the disorder will depend on other genes they inherit, their environment, and other factors.
- b. A disorder is hereditary only if people who inherit a certain genotype always develop the disorder.

Use cancer as an example. Point out that many types of cancer are genetic diseases. If you inherit certain genes, you are more likely to develop these types of cancer. However, few cancers are hereditary. It is rare for a specific gene to always cause cancer when it is present.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Technology has been developed to cure some genetic disorders with gene therapy. This involves inserting normal genes into cells with mutations. Scientists use genetic technology for other purposes as well.

- What other genetic problems might scientists try to solve with genetic technology? What about problems in agriculture?
 - (*Sample answer:* Scientists might try to cure genetic diseases in other species or make them more likely to survive difficult conditions.)
- Why might scientists want to alter the genes of other organisms? How might this be done?
 - (*Sample answers:* They might want to make the organisms more useful to people, such as making a plant that produces more food or resists insect pests. This might be done by giving the organisms genes from other species.)

8.3 Biotechnology

Key Concept

Gene cloning is the process of isolating and making copies of a gene or other DNA segment. The polymerase chain reaction makes many copies of a DNA segment. Biotechnology can be used to transform bacteria so they are able to make human proteins. It can also be used to make transgenic crops that yield more food or resist insect pests. Biotechnology has raised a number of ethical, legal, and social issues.

Standards

- CA.9–12.IE.1.d, m; CA.9–12.LS.5.c, d, e
- NSES.9–12.A.1.6; NSES.9–12.A.2.3; NSES.9–12.E.2.1, 3; NSES.9–12.F.6.1, 2; NSES.9–12.G.1.3; NSES.9–12.G.3.3
- AAAS.9–12.8.A.1; AAAS.9–12.8.F.3, 7; AAAS.9–12.12.D.2
- McREL.9–12.13.4.1, 2, 3, 4

Lesson Objectives

- Describe gene cloning and the polymerase chain reaction.
- Explain how DNA technology is applied in medicine and agriculture.
- Identify some of the ethical, legal, and social issues raised by biotechnology.

Lesson Vocabulary

- **biotechnology**: use of technology to change the genetic makeup of living things in order to produce useful products
- **gene cloning**: process of isolating and making copies of a gene
- **genetic engineering**: using biotechnology to change the genetic makeup of an organism
- **pharmacogenomics**: field that is tailoring medical treatments to fit our genetic profiles
- **polymerase chain reaction (PCR)**: biotechnology process that makes many copies of a gene or other DNA segment
- **recombinant DNA**: DNA that results when DNA from two organisms is combined
- **synthetic biology**: field of biology involved in engineering new functions from living systems
- **transgenic crop**: crop that has been genetically modified with new genes that code for traits useful to humans

Teaching Strategies

Introducing the Lesson

Most students will have heard about cloning in popular media. Ask them to share what they already know. Tell them they will learn more about cloning when they read this lesson.

Activity

Assign pairs or groups of students to debate some of the ethical, legal, and social issues about biotechnology that are listed in the lesson. Students should prepare a list of facts and arguments in support of their stance on the issues. Use the debate to identify student misconceptions and to underscore the connection between science and society.

Differentiated Instruction

Have pairs of students make a Frayer model for the term biotechnology. Tell them to draw a large box and divide it into four parts, labeled “Definition,” “Drawing,” “Example,” and “Non-example.” Give partners time to work together to fill in the parts of the box. **ELL, LPR**

Enrichment

Ask a few students to make a video about one of the lesson topics. They should explore the topic in greater depth and create a video to convey what they learn. The video should include some type of visual presentation, such as an animation or a skit.

Science Inquiry

Bacteria use restriction enzymes to cleave the DNA of viruses that infect them. Ask the class to brainstorm hypotheses that explain why the restriction enzymes do not cleave a bacterium’s own DNA. (Students might hypothesize that the bacterial DNA is protected in some way.) Direct them to the URLs below to see if their hypothesis is correct.

- <http://www.nature.com/scitable/topicpage/restriction-enzymes-545>
- http://www.neb.com/nebecomm/tech_reference/restriction_enzymes/dam_dcm_cpg_methylation.asp
- http://en.wikipedia.org/wiki/Restriction_modification_system

Real-World Connection

Dolly the sheep was the first mammal cloned from an adult cell. With the module at the URL below, students can investigate this major scientific advance and its real-world implications.

- http://novaonline.nvcc.edu/eli/evans/his135/events/dolly96/Dolly_Module.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you read that bacteria can be transformed with human genes so they are able to make human proteins. This is possible because the genetic code is universal. Genetic information is encoded and read in the same way in all known species. This demonstrates that all life on Earth has a common evolutionary history, beginning with the earliest living things.

- How did the first living things on Earth arise? How and when might this have happened?
 - (Answers may vary. In fact, the first living things on Earth arose about 4 billion years ago.)
- What do you think the first living things were like?
 - (Students may or may not know that they were single-celled organisms similar to bacteria.)

8.4 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 9

TE Life: From the First Organism Onward

CHAPTER OUTLINE

- 9.1 EARTH FORMS AND LIFE BEGINS**
 - 9.2 THE EVOLUTION OF MULTICELLULAR LIFE**
 - 9.3 CLASSIFICATION**
 - 9.4 WORKSHEET ANSWER KEYS**
-



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Life: From the First Organism Onward

Outline

Lesson 9.1: Earth Forms and Life Begins

9.1.1 Earth in a Day

9.1.2 Learning about the Past

- The Fossil Record
- Molecular Clocks
- Geologic Time Scale

9.1.3 How Earth Formed: We Are Made of Stardust!

9.1.4 The First Organic Molecules

- Which Organic Molecule Came First?
- RNA World Hypothesis

9.1.5 The First Cells

- LUCA
- Photosynthesis and Cellular Respiration

9.1.6 Evolution of Eukaryotes

9.1.7 Arsenic in Place of Phosphorus - New Biochemicals for Life?

Lesson 9.2: The Evolution of Multicellular Life

9.2.1 Setting the Stage: The Late Precambrian

- Life During the Late Precambrian
- The Precambrian Extinction

9.2.2 Life During the Paleozoic

- Paleozoic Era

9.2.3 Mesozoic Era: Age of Dinosaurs

9.2.4 Cenozoic Era: Age of Mammals

- KQED: The Last Ice Age

Lesson 9.3: Classification

9.3.1 Linnaean Classification

- Binomial Nomenclature
- Revisions in Linnaean Classification

9.3.2 Phylogenetic Classification

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 9.1:

Lesson	Number of Class Periods
9.1 Earth Forms and Life Begins	2.5
9.2 The Evolution of Multicellular Life	2.0
9.3 Classification	1.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this lab, students will remove fossils from sediments, classify them, and draw conclusions about their relative ages. (Lesson 9.1)

- <http://www.accessexcellence.org/AE/AEPC/WWC/1995/shells.php>

2. This role-playing lab simulates time travel to the beginning of planet Earth. On the trip, students will “witness” the origin of life and key events in the evolution of life on Earth. (Lesson 9.1)

- <http://www.indiana.edu/~ensiweb/lessons/time.mac.html>

3. Students will observe prepared slides of prokaryotes and eukaryotes to identify organelles in the evolution of prokaryotes to eukaryotes (endosymbiotic theory). (Lesson 9.1)

- <http://www.accessexcellence.org/AE/AEPC/WWC/1995/prokfeast.php>

4. Students will compare amino acid sequences in proteins and then construct a phylogenetic tree to represent evolutionary relationships based on the sequences. (Lesson 9.3)

- http://www.accessexcellence.org/AE/AEPC/WWC/1995/simulation_amino.php

5. In this interactive computer lab, students will examine features of various groups of animals to decide where an extinct animal (Archaeopteryx) should be placed phylogenetically. (Lesson 9.3)

- <http://www.accessexcellence.org/AE/AEPC/WWC/1995/whereshould.php>

These Web sites may also be helpful:

1. For more information on particular topics, visit the Web site below. It is a multi-authored encyclopedia on the history of life on Earth.

- http://www.palaeos.org/Main_Page

2. An animation about the origin of life is available at the URL below.

- http://animation.mirage3d.nl/index.php?option=com_content#38;task=view#38;id=33#38;Itemid=52

3. You can find classroom activities, labs, and links relating to the history of life at the Web site below.

- <http://www.nclark.net/HistoryLife>

4. This online chapter is a concise and well-illustrated introduction to biological classification and provides links to several other useful Web sites.

- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookDivers_class.html

5. This excellent introduction to the principles of taxonomy includes crossword puzzles and flashcards.

- <http://anthro.palomar.edu/animal/default.htm>

6. This informative summary of plant and animal classification has numerous links to articles, activities, and quizzes pertaining to lesson content.

- <http://www.fi.edu/tfi/units/life/classify/classify.html>

9.1 Earth Forms and Life Begins

Key Concept

Fossils, molecular clocks, and the geologic time scale help us understand the history of life on Earth. Earth formed about 4.6 billion years ago, and the first organic molecules appeared about 4 billion years ago. The first cells were extremely simple. One cell (the last universal common ancestor, or LUCA) gave rise to all subsequent life on Earth. Eukaryotic cells evolved about 2 billion years ago. Their evolution is explained by endosymbiotic theory.

Standards

- CA.9–12.IE.1.i; CA.9–12.LS.7.d; CA.9–12.LS.8.e, g
- NSES.9–12.C.3.3; NSES.9–12.D.3.1, 2, 3, 4; NSES.9–12.G.3.3
- AAAS.9–12.4.C.1; AAAS.9–12.4.D.4; AAAS.9–12.5.F.1, 2, 7, 8
- McREL.9–12.13.6.1, 3, 5

Lesson Objectives

- Explain how scientists learn about the history of life on Earth.
- Describe how and when planet Earth formed.
- Outline how the first organic molecules arose.
- Describe the characteristics of the first cells.
- Explain how eukaryotes are thought to have evolved.

Lesson Vocabulary

- **absolute dating:** carbon-14 or other method of dating fossils that gives an approximate age in years
- **extinction:** situation in which a species completely dies out and no members of the species remain
- **fossil:** preserved remains or traces of organisms that lived in the past
- **geologic time scale:** timeline of Earth based on major events in geology, climate, and the evolution of life
- **Last Universal Common Ancestor (LUCA):** hypothetical early cell (or group of cells) that gave rise to all subsequent life on Earth
- **molecular clock:** using DNA (or proteins) to measure how long it has been since related species diverged from a common ancestor
- **relative dating:** method of dating fossils by their location in rock layers; determines which fossils are older or younger but not their age in years
- **RNA world hypothesis:** hypothesis that RNA was the first organic molecule to evolve and that early life was based on RNA, rather than DNA or protein

Teaching Strategies

Introducing the Lesson

Pique students' interest in Earth's vast age and history. Compare Earth's age to a 24-hour day, and ask students at what time of day they think humans evolved (humans evolved in just the last 20 seconds of the day). Tell students they will read about Earth's early history in this lesson.

Activity

When students read about fossils and dating methods, assign the interactive animations at the URLs below. The first animation is an interesting way for students to learn how fossils can be used to interpret the past. The second animation allows students to simulate the collection and analysis of radiometric data.

- <http://www.ucmp.berkeley.edu/education/explorations/tours/stories/guide/index.html>
- <http://www.indiana.edu/ensiweb/virt.age.html>

Differentiated Instruction

Pair less proficient readers and English language learners with students who are excelling in the class. Ask partners to work together to outline the lesson. Tell them to use the headings and sub-headings in the text as the basis of their outline. **LPR, ELL**

Enrichment

Suggest to advanced students that they take the online tutorial *From Soup to Cells: The Origin of Life* at the URL below. It provides AP-level coverage of the topic of life's origins.

- http://evolution.berkeley.edu/evolibrary/article/0_0_0/origsoflife_01

Science Inquiry

Provide students with copies of the table Prokaryotes, Eukaryotes, and Organelles (shown in **Table 9.2**). Challenge them to explain how the data in the table support endosymbiotic theory.

TABLE 9.2: Prokaryotes, Eukaryotes, and Organelles

	Prokaryotes	Eukaryotes	Mitochondria of Eukaryotic Cells	Chloroplasts of Eukaryotic Cells
DNA	One circular chromosome without a nucleus.	Multiple linear chromosomes within a nucleus.	One circular chromosome without a nucleus.	One circular chromosome without a nucleus.
Replication	Binary fission	Mitosis	Binary fission	Binary fission
Size	1–10 microns	50–500 microns	1–10 microns	1–10 microns
Appearance on Earth (billions of years ago)	3.5	1.8	1.8	1.8

Overcoming Misconceptions

Many people mistakenly think that evolution is a theory about the origin of life. Make sure students understand that evolution is a theory about how life changed once it began. Although evolutionary biologists are interested in how life began, it is not the main focus of evolutionary biology. Similarly, not knowing how life began does not throw into doubt the fact that evolution has occurred and is still taking place.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

TABLE 9.3: DNA Similarities

Species	DNA Similarity with Species A (%)
Species B	42
Species C	85
Species D	67
Species E	91

Points to Consider

The earliest organisms lived in the ocean. Even after eukaryotes evolved, it was more than a billion years before organisms lived on land for the first time.

- What special challenges do you think organisms faced when they moved from water to land?
 - (*Sample answers:* Their skin might dry out; they would have to breathe air; they wouldn't be able to swim.)
- How do you think they met these challenges? What adaptations might they have evolved?
 - (*Sample answers:* They might have evolved waterproof skin, lungs to breathe air, and legs for walking.)

9.2 The Evolution of Multicellular Life

Key Concept

Multicellular life evolved in the late Precambrian. The Precambrian ended with a mass extinction. It was followed by the Cambrian explosion, which began the Paleozoic Era. During the Paleozoic, major groups of organisms evolved, and plants, amphibians, and reptiles moved to the land. The Paleozoic ended with the Permian extinction. The following Mesozoic Era was the age of dinosaurs. The current Cenozoic Era is the age of mammals.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.C.3.2, 4
- AAAS.9–12.5.A.1; AAAS.9–12.5.F.8, 9

Lesson Objectives

- Describe important events of the late Precambrian.
- Give an overview of evolution during the Paleozoic Era.
- Explain why the Mesozoic Era is called the age of the dinosaurs.
- Outline the main evolutionary events of the Cenozoic Era.

Lesson Vocabulary

- **Cambrian explosion:** spectacular burst of new life that occurred at the start of the Paleozoic Era
- **Cenozoic Era:** age of mammals that lasted from 65 million years ago to the present
- **mass extinction:** extinction event in which many if not most species abruptly disappear from Earth
- **Mesozoic Era:** age of dinosaurs that lasted from 245 million years ago to 65 million years ago
- **Paleozoic Era:** age of “old life” from 544–245 million years ago that began with the Cambrian explosion and ended with the Permian extinction
- **Permian extinction:** extinction at the end of the Paleozoic Period that was the biggest mass extinction the world had ever seen until then

Teaching Strategies

Introducing the Lesson

Most students will have prior knowledge of dinosaurs, so use dinosaurs as an example to introduce the evolution of multicellular life. Call on several students to state anything they know about dinosaurs. Make a list on the board. Tell students they will read about the evolution of dinosaurs and other multicellular organisms in this lesson.

Demonstration

As you discuss the evolution of multicellular life, display online illustrations of important events and organisms that characterized the different geological periods since the beginning of the Cambrian. This will help make the information in the lesson come to life. The Web sites below are recommended for their excellent images of the history of life, including extant organisms.

- <http://www.ucmp.berkeley.edu/alllife/eukaryota.html>
- <http://tolweb.org/tree/>
- <http://www.dlib.org/dlib/october05/10featured-collection.html>
- <http://www.uoregon.edu/~bsl/astronomy/>

Differentiated Instruction

Prepare a gallery walk by posting the names of the geologic periods on large sheets of paper in different parts of the room. Divide the class into groups, being cognizant of the limitations of any special needs students. Ask groups of students to move from period to period and write on the posted papers any information they can recall about the periods. After the gallery walk, discuss the information they recorded. Point out any errors and underscore important points. SN

Enrichment

Ask a small group of students to create a diorama representing one of the geologic periods described in the lesson. The diorama should illustrate the climate and the major types of organisms that lived during the period. Display their completed diorama in the classroom. Challenge other students to identify the period it represents.

Science Inquiry

Have groups of students do the activity *Earth History: Time Flies, No Matter What the Scale* (see URL below). They will order important events in the history of life on a model of the geologic time scale. They will also relate the geologic time scale to an annual calendar. An answer key is included.

- http://www.asm.org/index.php?option=com_content#38;view=article#38;id=90592#38;Itemid=520

Overcoming Misconceptions

The idea that evolution is a conscious striving for perfection is a common misconception. Explain to the class that organisms do not try to evolve new traits; that evolution helps organisms adapt to changing environments, not become perfect; and that so-called “lower” organisms may be better adapted to their environments than so-called

“higher” organisms. Point out that some organisms, including cockroaches and sharks, have changed very little for millions of years because their ancient traits have allowed them to survive and reproduce despite environmental changes.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

The human species evolved during the Cenozoic Era. The scientific name of the human species is *Homo sapiens*.

- Do you know what this name means? Do you know why species are given scientific names?
 - (*Homo sapiens* literally means “wise human.” Species are given scientific names so they have a unique, consistently used identifier.)
- What is a species? What determines whether a group of organisms is considered a species?
 - (A species is a type of living thing, such as *Homo sapiens*. A group of organisms is considered a species if members of the group can mate and produce fertile offspring together but not with members of other such groups.)

9.3 Classification

Key Concept

The Linnaean classification system is based on similarities in obvious physical traits. It consists of a hierarchy of taxa, from the species to the kingdom, and gives each species a unique genus and species name. The recently added domain is a larger and more inclusive taxon than the kingdom. Phylogeny is the evolutionary history of group of related organisms. It is represented by a phylogenetic tree. A clade is used to classify organisms based on evolutionary relationships.

Standards

- CA.9–12.LS.8.f
- NSES.9–12.C.3.5
- AAAS.9–12.5.A.2; AAAS.9–12.5.F.2

Lesson Objectives

- Outline the Linnaean classification, and define binomial nomenclature.
- Describe phylogenetic classification, and explain how it differs from Linnaean classification.

Lesson Vocabulary

- **binomial nomenclature:** method of naming species with two names, consisting of the genus name and species name
- **clade:** group of related organisms that includes an ancestor and all of its descendants
- **domain:** taxon in the revised Linnaean system that is larger and more inclusive than the kingdom
- **genus:** taxon above the species in the Linnaean classification system; group of closely related species
- **kingdom:** largest and most inclusive taxon in the original Linnaean classification system
- **Linnaean classification system:** system of classifying organisms based on observable physical traits; consists of a hierarchy of taxa, from the kingdom to the species
- **phylogenetic tree:** diagram that shows how species are related to each other through common ancestors
- **phylogeny:** evolutionary history of a group of related organisms
- **species:** group of organisms that are similar enough to mate together and produce fertile offspring
- **taxa:** (singular, taxon) grouping of organisms in a classification system, such as the Linnaean system; for example, species or genus
- **taxonomy:** science of classifying organisms

Teaching Strategies

Introducing the Lesson

On the board, write the scientific name of a common species such as the domestic cat (*Felis catus*). Call on volunteers to explain (or explain yourself if necessary) what the two parts of the name represent (the genus and species names). Tell the class they will learn more about how organisms are named and classified in this lesson.

Activity

Students can apply principles of Linnaean and phylogenetic classification by doing the activities at the URLs below. In the first activity, they will develop a classification system for different kinds of “organisms” in the “pasta kingdom.” In the second activity, they will apply cladistics to a group of organisms represented by a collection of nails, screws, and bolts.

- <http://www.accessexcellence.org/AE/ATG/data/released/0070-JudithAllard/>
- http://www.pbs.org/wgbh/nova/teachers/activities/2905_link.html

Differentiated Instruction

Help students focus on the main ideas in the lesson. Pair less proficient readers with more proficient readers, and ask partners to complete cloze sentences, such as those below, while they read the lesson. **LPR**

- a. Taxonomy is ... (a method of organizing living things into groups.)
- b. Biologists classify organisms in order to ... (make sense of the incredible diversity of life on Earth.)
- c. Binomial nomenclature is ... (Linnaeus’ method of naming species.)
- d. The scientific name of a species consists of ... (its genus and species names.)

Enrichment

Ask a small group of students who need extra challenges to create a taxonomy board game. The object of the game should be to identify correctly an organism’s species based on a series of increasingly specific clues about the organism’s traits. Encourage other students to play the game.

Science Inquiry

Have groups of students create a cladogram for the “evolution” of a familiar technology, such as audio devices. Students can do online research to identify the sequence in which major innovations occurred in their technology. (For example, audio devices evolved through stages of record players, 8-track tape players, cassette players, Walkmans, CD players, and iPods). Discuss their completed cladograms, and relate them to cladograms in the evolution of life.

Overcoming Misconceptions

Students may have the misconception that evolutionary relationships are linear, when in fact phylogenies are branched like bushes. At the URL below, you can find an interactive cartoon series that cleverly makes this point and clarifies the misconception.

- http://www.indiana.edu/ensiweb/famtree_v_phylog.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

This chapter gives you a glimpse of 4 billion years of evolution on Earth. In the next chapter, you will read about the forces that bring about evolution. Natural selection is one of these forces. It generally results in a population or species becoming better adapted to its environment over time.

- How does natural selection work? How does it bring about evolutionary change?
 - (Fitter members of a species live longer and produce more offspring than other members of the species. Over time, their traits become more common in the species.)
- What might be the other forces of evolution?
 - (Students might mention mutation, but they may not be able to identify gene flow or genetic drift.)

9.4 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 10 TE The Theory of Evolution

CHAPTER OUTLINE

10.1 DARWIN AND THE THEORY OF EVOLUTION

10.2 EVIDENCE FOR EVOLUTION

10.3 MICROEVOLUTION AND THE GENETICS OF POPULATIONS

10.4 MACROEVOLUTION AND THE ORIGIN OF SPECIES

10.5 WORKSHEET ANSWER KEYS



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The Theory of Evolution

Outline

Lesson 10.1: Darwin and the Theory of Evolution

10.1.1 Darwin's Theory at a Glance

10.1.2 The Voyage of the Beagle

- Darwin's Observations
- The Galápagos Islands

10.1.3 Influences on Darwin

- Earlier Thinkers Who Influenced Darwin
- Artificial Selection

- Wallace's Theory

10.1.4 Darwin's Theory of Evolution by Natural Selection

- Evolution of Darwin's Theory
- Applying Darwin's Theory
- KQED: Chasing Beatles, Finding Darwin

10.1.5 KQED: The California Academy of Sciences

10.1.6 KQED: The Farallon Islands: California's Galapagos

Lesson 10.2: Evidence for Evolution

10.2.1 Fossil Evidence

10.2.2 Evidence from Living Species

- Comparative Anatomy
- Comparative Embryology
- Vestigial Structures
- Comparing DNA
- KQED: The Reverse Evolution Machine

10.2.3 Evidence from Biogeography

- Biogeography of Camels: An Example
- Island Biogeography
- Eyewitness to Evolution

Lesson 10.3: Microevolution and the Genetics of Populations

10.3.1 The Scale of Evolution

10.3.2 Genes in Populations

- Gene Pool
- Allele Frequencies

10.3.3 The Hardy-Weinberg Theorem

10.3.4 Forces of Evolution

- Mutation
- Gene Flow
- Genetic Drift
- Natural Selection

Lesson 10.4: Macroevolution and the Origin of Species

10.4.1 Origin of Species

- Allopatric Speciation
- Sympatric Speciation

10.4.2 Coevolution

10.4.3 Timing of Macroevolution

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 10.1:

Lesson	Number of Class Periods
10.1 Darwin and the Theory of Evolution	1.5
10.2 Evidence for Evolution	2.0
10.3 Microevolution and the Genetics of Populations	2.0
10.4 Macroevolution and the Origin of Species	1.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. Students will model natural selection in this lab by “capturing” food using various utensils. (Lessons 10.1, 10.2, 10.3)

- <http://www.biologycorner.com/worksheets/naturalselection.html>

2. This Web site contains a large collection of population genetics labs using simple materials such as M&M’s, crackers, and pop beads. (Lesson 10.3)

- <http://www.woodrow.org/teachers/bi/1994/hwintro.html>

3. This Web site provides two different labs that allow students to explore how genetic drift causes allele frequencies to change in small populations.

- Science <http://www.nslc.ucla.edu/step/gk12/lessons.htm#Biology/Life> Science

These Web sites may also be helpful:

1. This Web site provides a chronology of evolutionary science, from Plato to the Human Genome Project.

- http://www.accessexcellence.org/AE/AEPC/WWC/1995/cron_evol.php

2. This Web site has original articles, scientist interviews, links, and other materials for both teachers and students who want more in-depth information about many chapter topics.

- <http://www.actionbioscience.org/evolution/>

3. At the URL below, you can access a wide variety of useful activities, labs, and links relating to evolution.

- <http://www.nclark.net/Evolution>

4. At this URL, you can find a large collection of activities on evolution.

- <http://www.pbs.org/wgbh/evolution/library/10/index.html>

5. This Web site is highly recommended. It provides lesson plans, common misconceptions, and many other useful resources on evolution.

- <http://evolution.berkeley.edu/evosite/evohome.html>

10.1 Darwin and the Theory of Evolution

Key Concept

During his voyage on the *Beagle*, Charles Darwin made many observations that helped him develop his theory of evolution. He was also influenced by other early thinkers — including Lamarck, Lyell, and Malthus — as well as his own knowledge of artificial selection. Darwin's book, *On the Origin of Species*, clearly spells out his theory of evolution by natural selection and also provides a great deal of evidence to support it.

Standards

- CA.9–12.IE.1.k, n; CA.9–12.LS.7.d; CA.9–12.LS.8.b
- NSES.9–12.C.3.1, 2, 4; NSES.9–12.F.2.1, 3; NSES.9–12.G.3.3, 4
- AAAS.9–12.5.B.5; AAAS.9–12.5.F.1, 4, 7, 9; AAAS.9–12.10.D.1, 2, 3; AAAS.9–12.10.H.1, 2, 3, 4
- McREL.9–12.11.1.3, 4; McREL.9–12.11.2.3, 5; McREL.9–12.11.3.1, 2; McREL.9–12.11.4.1

Lesson Objectives

- State Darwin's theory of evolution by natural selection.
- Describe observations Darwin made on the voyage of the *Beagle*.
- Identify influences on Darwin's development of evolutionary theory.
- Explain how a species can evolve through natural selection.

Lesson Vocabulary

- **artificial selection:** process in which organisms evolve traits useful to humans because people select which individuals are allowed to reproduce and pass on their genes to successive generations
- **fitness:** relative ability of an organism to survive and produce fertile offspring
- **Galápagos Islands:** group of 16 small volcanic islands in the Pacific Ocean 966 kilometers (600 miles) off the west coast of South America, where Darwin made some of his most important observations during his voyage on the *HMS Beagle*
- **inheritance of acquired characteristics:** mistaken idea of Jean Baptiste Lamarck that evolution occurs through the inheritance of traits that an organism develops in its own lifetime

Teaching Strategies

Introducing the Lesson

Ask students to recall what they already know about Charles Darwin. (*Sample answers:* He developed the theory of evolution; he traveled to the Galápagos Islands.) Tell the class they will learn more about Darwin in this lesson.

Activity

Assign the activities *Darwin and Natural Selection* and *Evolution and Adaptation* at the URL below. The former activity involves the observations and deductions that led Darwin to form his theory. The latter activity explores how various species have evolved adaptations to their way of life.

- <http://www.arkive.org/education/resources>

Differentiated Instruction

Tell less proficient readers to make a main ideas/details chart as they read the lesson. Instruct them to divide a sheet of paper down the middle and record the main ideas on the left side and the details for each main idea on the right side. Advise them to write one main idea for each of the main headings in the lesson. **LPR**

Enrichment

Gifted students may be interested in reading Darwin's own words. Suggest that they read Chapter 3, "The Struggle for Existence," in Darwin's book, *On the Origin of Species*. (They can access the chapter online at the URL below.) The chapter provides an overview of Darwin's main ideas.

- <http://www.literature.org/authors/darwin-charles/the-origin-of-species/>

Real-World Connection

Discuss why Darwin waited so long to publish his theory of evolution as an example of how society influences science. Relate the discussion to current issues in science and society. For example, discuss social pressure to restrict stem cell research. Ask students to state their views on the issue.

Science Inquiry

Challenge groups of students to apply Darwin's theory to explain the evolution to antibiotic resistance in bacteria. They can learn more about the problem at the URL below.

- http://www.cdc.gov/narms/faq_pages/3.htm

Overcoming Misconceptions

When you discuss the theory of evolution, make sure students do not have the misconception that a scientific theory is just any explanation, which is how the term theory is used in everyday language. Explain that a scientific theory, such as the theory of evolution, is a widely accepted explanation that is supported by a great deal of evidence and

can explain many natural phenomena. You may want to show the video *Isn't Evolution Just a Theory?* (see URL below).

- <http://www.pbs.org/wgbh/evolution/educators/teachstuds/svideos.html>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Darwin's book *On the Origin of Species* is a major milestone in science. It introduced biology's most important theory. It also provided an excellent example of how to think like a scientist. A scientist uses evidence and logic to understand the natural world. In this lesson, you read about some of the evidence Darwin used. This evidence included fossils and artificial selection.

- What other evidence might be used to show that evolution occurs? What about evidence based on molecules?
 - (Similarities in DNA or proteins show organisms are related by descent from a common ancestor.)
- Do you think it's possible to see evolution occurring? How might that happen?
 - (*Sample answer:* You might see that some members of a species have more surviving offspring than other members of the species. This would mean that evolution by natural selection is occurring.)

10.2 Evidence for Evolution

Key Concept

Evidence for evolution comes from fossils and comparisons of the anatomy, embryos, and DNA of living things. Further evidence comes from biogeography, or the study of how and why organisms live where they do. Adaptive radiation occurs when one species evolves into many new species to fill available niches.

Standards

- CA.9–12.IE.1.d, I; CA.9–12.LS.8.a, e, f
- NSES.9–12.C.3.3
- AAAS.9–12.5.A.2; AAAS.9–12.F.2.9

Lesson Objectives

- Describe how fossils help us understand the past.
- Explain how evidence from living species gives clues about evolution.
- State how biogeography relates to evolutionary change.

Lesson Vocabulary

- **adaptive radiation:** process by which a single species evolves into many new species to fill available niches
- **analogous structure:** structure that is similar in unrelated organisms because it evolved to do the same job, not because it was inherited from a common ancestor
- **biogeography:** study of how and why plants and animals live where they do
- **comparative anatomy:** study of the similarities and differences in the structures of different species
- **comparative embryology:** study of the similarities and differences in the embryos of different species
- **homologous structure:** structure that is similar in related organisms because it was inherited from a common ancestor
- **paleontologist:** scientist who finds and studies fossils to learn about evolution and understand the past
- **vestigial structure:** structure such as the human tailbone or appendix that evolution has reduced in size because it is no longer used

Teaching Strategies

Introducing the Lesson

Pass a fossil, fossil reproduction, or photo of a fossil around the classroom (you can order fossils at the URL below). Ask students what they can infer about the organism from its fossil (e.g., living in water for a shell fossil). Tell students they will read in this lesson how scientists use fossils to determine what extinct organisms were like and how they evolved.

- http://www.teacherstorehouse.com/product_search.asp?order_key=#38;track=#38;submit=TRACK#38;term=fossil

Use Visuals

Have students compare and contrast the homologous and analogous structures figures (see FlexBook, **Figure 10.8** and **Figure 10.9**). Challenge students to explain how each figure provides evidence for evolution (i.e., descent from a common ancestor (homologous structures) and evolution of similar adaptations in unrelated organisms (analogous structures)).

Differentiated Instruction

Have pairs or small groups of students make Frayer models for the vocabulary words “homology” and “analogy.” To make a Frayer model, they should divide a sheet of paper into four squares labeled “Definition,” “Example,” “Drawing,” and “Non-example.” They should work together to fill in the squares. **ELL, LPR**

Enrichment

Ask a few students to find and compare amino acid sequences in the protein cytochrome c. They should try to find data for at least three different species. The URL below is a good starting point. Students should use the data to infer which species are more closely related (those with the more similar sequences). Ask students to present their work to the class and explain why cytochrome c is especially useful for reconstructing phylogenetic relationships.

- <http://chemistry.umeche.maine.edu/CHY431/Evolve2.html>

Science Inquiry

Assign the activity at the URL below. Using real data, students will develop phylogenies for related populations of lizards on the Canary Islands. They will use several different types of data, including biogeography, morphology, and DNA data.

- <http://www.indiana.edu/ensiweb/lessons/island.html>

Overcoming Misconceptions

A common misconception is that there is little or no evidence for evolution. In fact, there is a huge amount of evidence for evolution and it comes from a diversity of fields. The URL below provides a summary and many examples. You can share it with your students.

- <http://www.talkorigins.org/indexcc/CA/CA202.html>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

The Grants saw evolution occurring from one generation to the next in a population of finches.

- What factors caused the short-term evolution the Grants witnessed? How did the Grants know that evolution had occurred?
 - (A drought and lack of food caused the birds to evolve. Their average beak size increased over 2 years.)
- What other factors do you think might cause evolution to occur so quickly within a population?
 - (Accept all reasonable responses. *Sample answer:* a natural disaster)

10.3 Microevolution and the Genetics of Populations

Key Concept

The population is the unit of evolution. All the genes of its members make up its gene pool, which is characterized by the frequency of alleles. The Hardy-Weinberg theorem states that, if a population meets certain conditions, its allele frequencies will not change. From the Hardy-Weinberg theorem, the forces of evolution can be inferred. The forces are mutation, gene flow, genetic drift, and natural selection.

Standards

- CA.9–12.IE.1.1; CA.9–12.LS.6.g; CA.9–12.LS.7.a, b, c, e, f; CA.9–12.LS.8.a, c
- NSES.9–12.A.2.4; NSES.9–12.C.2.3; NSES.9–12.E.2.1
- AAAS.9–12.1.C.4; AAAS.9–12.5.A.1; AAAS.9–12.5.B.1, 5; AAAS.9–12.5.F.3, 5, 6, 7, 9; AAAS.9–12.10.H.5; AAAS.9–12.11.B.1
- McREL.9–12.13.5.6

Lesson Objectives

- Distinguish between microevolution and macroevolution.
- Define gene pool, and explain how to calculate allele frequencies.
- State the Hardy-Weinberg theorem.
- Identify the four forces of evolution.

Lesson Vocabulary

- **allele frequency**: how often an allele occurs in a gene pool relative to the other alleles for that gene
- **directional selection**: type of natural selection for a polygenic trait in which one of two extreme phenotypes is selected for, resulting in a shift of the phenotypic distribution toward that extreme
- **disruptive selection**: type of natural selection for a polygenic trait in which phenotypes in the middle of the phenotypic distribution are selected against, resulting in two overlapping phenotypes, one at each end of the distribution
- **gene flow**: change in allele frequencies that occurs when individuals move into or out of a population
- **gene pool**: all the genes of all the members of a population
- **genetic drift**: a random change in allele frequencies that occurs in a small population
- **Hardy-Weinberg theorem**: founding principle of population genetics that proves allele and genotype frequencies do not change in a population that meets the conditions of no mutation, no migration, large population

size, random mating, and no natural selection

- **macroevolution:** evolutionary change that occurs over geologic time above the level of the species
- **microevolution:** evolutionary change that occurs over a relatively short period of time within a population or species
- **population genetics:** science focusing on evolution within populations that is the area of overlap between evolutionary theory and Mendelian genetics
- **sexual dimorphism:** differences between the phenotypes of males and females of the same species
- **stabilizing selection:** type of natural selection for a polygenic trait in which phenotypes at both extremes of the phenotypic distribution are selected against, resulting in a narrowing of the range of phenotypic variation

Teaching Strategies

Introducing the Lesson

Review how probability can be used to predict the genotypes of offspring of two parents by applying Mendel's rules of inheritance. Then say that probability can also be used to predict the genotypes in the next generation of a population. Tell students they will learn how when they read this lesson.

Building Science Skills

The Hardy-Weinberg theorem is often difficult for students to understand. Solving the Hardy-Weinberg practice problems at the URL below may improve student understanding.

- <http://www.talkorigins.org/indexcc/CA/CA202.html>

Differentiated Instruction

Create a gallery walk of the four forces of evolution (mutation, gene flow, genetic drift, and natural selection). Write the name of each force on a separate sheet of paper, and post one sheet on each wall of the classroom. Have groups of students circulate around the room, adding what they know to each sheet of paper and reading the comments of the other groups.

Enrichment

Challenge students who excel in math to solve more advanced Hardy-Weinberg problems. Suitable problems can be found at the URL below.

- <http://mansfield.osu.edu/sabedon/biol1509.htm>

Science Inquiry

Students can explore natural selection with a virtual simulation at this URL.

- <http://www.biologyinmotion.com/evol/index.html>

Overcoming Misconceptions

A common misconception is that all evolution occurs by chance. Make sure students understand that only mutation and genetic drift are chance processes. Natural selection, the main driver of adaptive evolutionary change, does not occur by chance. It occurs when some individuals have more surviving offspring than others do because of beneficial traits that help them survive and reproduce in their environment.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Disruptive selection for a polygenic trait results in two overlapping phenotypes. Theoretically, disruptive selection could lead to two new species forming.

- How might this happen? Can you describe how it could occur?
 - (*Sample answer:* Individuals with the different phenotypes might become more and more different until they could no longer interbreed.)
- How else might one species diverge into two?
 - (*Sample answer:* Part of a species might get separated from the rest and evolve into a new species.)

10.4 Macroevolution and the Origin of Species

Key Concept

New species arise in the process of speciation. Allopatric speciation occurs when some members of a species become geographically separated. Sympatric speciation occurs without geographic separation. Coevolution occurs when species evolve together. Darwin thought that evolution occurs gradually. This model of evolution is called gradualism. The fossil record better supports the model of punctuated equilibrium.

Standards

- CA.9–12.IE.1.g; CA.9–12.LS.8.d
- NSES.9–12.C.3.5; NSES.9–12.C.6.3
- AAAS.9–12.1.A.3; AAAS.9–12.11.B.3; AAAS.9–12.11.C.6
- McREL.9–12.11.6.1

Lesson Objectives

- Describe two ways that new species may originate.
- Define coevolution, and give an example.
- Distinguish between gradualism and punctuated equilibrium.

Lesson Vocabulary

- **allopatric speciation:** evolution of a new species that occurs when some members of an original species become geographically separated from the rest of the species
- **coevolution:** process in which two interacting species evolve together, with each species influencing the other's evolution
- **gradualism:** model of the timing of evolution in which evolutionary change occurs at a slow and steady pace
- **punctuated equilibrium:** model of the timing of evolution in which long periods of little evolutionary change are interrupted by bursts of rapid evolutionary change
- **speciation:** process by which a new species evolves
- **sympatric speciation:** evolution of a new species that occurs when without geographic separation first occurring between members of an original species

Teaching Strategies

Introducing the Lesson

Impress students with the incredible diversity of species. Tell them that there are tens of millions of species alive on Earth today, most of which have yet to be identified, and they represent only 1 percent of all the species that ever lived on Earth.

- Ask: How did all these species evolve? (Encourage multiple responses.)
- Tell students they will learn how new species evolve when they read this lesson.

Activity

With the class, do the quick speciation activity at the URL below. It is an effective way to show students how new species could evolve through genetic drift.

- <http://www.indiana.edu/ensiweb/lessons/quick.speciation.html>

Differentiated Instruction

All your students and especially visual learners will have a better understanding of speciation if they do the tutorial at the URL below. It provides a clear, well-illustrated explanation of the species concept and ways that speciation can occur. It covers all the lesson topics.

- http://evolution.berkeley.edu/evolibrary/article/0_0_0/evo_40

Enrichment

Interested students can read about the diversity of evidence for macroevolution at the URL below. Ask them to summarize the evidence for the class.

- <http://www.talkorigins.org/faqs/comdesc/section5.html>

Science Inquiry

Assign the case study “Something Fishy in Paxton Lake” at the URL below. In the activity, students will design an experiment to test the hypothesis that speciation has occurred in stickleback fish in the lake.

- <http://ublib.buffalo.edu/libraries/projects/cases/stickleback/stickleback.html>

Overcoming Misconceptions

A widely believed misconception is that “missing links” disprove evolution. Explain why transitional forms may be less likely to form fossils according to the punctuated equilibrium model of evolution.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

You read in this chapter about adaptive radiation on the Galápagos Islands. A single finch species evolved into many new species to fill all available niches. For example, the species evolved adaptations for a variety of food sources.

- What is a species' niche? What do you think it might include besides the food a species eats?
 - (*Sample answers:* Other species such as predators; environmental factors such as temperature.)
- Niche is a term from ecology. What is ecology? How do you think knowledge of ecology might help scientists understand evolution?
 - (*Sample answers:* Ecology is the study of living things and their environment. The environment influences how living things evolve, so knowledge of ecology is important to understand evolution.)

10.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 11 THE Principles of Ecology

CHAPTER OUTLINE

11.1 THE SCIENCE OF ECOLOGY

11.2 RECYCLING MATTER

11.3 BIOMES

11.4 WORKSHEET ANSWER KEYS



(Opening image courtesy of the National Science Foundation, <http://www.nsf.gov/news/overviews/earth-environ/assets/interact06.jpg>, and under the public domain.)

The Principles of Ecology

Outline

Lesson 11.1: The Science of Ecology

11.1.1 Organisms and the Environment

11.1.2 The Ecosystem

- Niche
- Habitat
- Competitive Exclusion Principle

11.1.3 Flow of Energy

- Producers

- Consumers
- Decomposers
- KQED: Banana Slugs: The Ultimate Recyclers

11.1.4 Food Chains and Food Webs

- Food Chains
- Food Webs

11.1.5 Trophic Levels

- Trophic Levels and Energy
- Trophic Levels and Biomass

Lesson 11.2: Recycling Matter

11.2.1 Biogeochemical Cycles

11.2.2 The Water Cycle

- Evaporation, Sublimation, and Transpiration
- Condensation and Precipitation
- Groundwater and Runoff
- KQED: Tracking Raindrops

11.2.3 The Carbon Cycle

11.2.4 The Nitrogen Cycle

Lesson 11.3: Biomes

11.3.1 Terrestrial Biomes

- Terrestrial Biomes and Climate
- Climate and Plant Growth
- Climate and Biodiversity
- Climate and Adaptations
- Survey of Terrestrial Biomes

11.3.2 Aquatic Biomes

- Aquatic Biomes and Sunlight
- Aquatic Biomes and Dissolved Substances
- Aquatic Organisms
- Marine Biomes
- Freshwater Biomes
- Wetlands
- KQED: Restoring Wetlands
- KQED: San Francisco Bay: A Unique Estuary
- KQED: Studying Aquatic Animals

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 11.1:

Lesson	Number of Class Periods
11.1 The Science of Ecology	2.0
11.2 Recycling Matter	1.5
11.3 Biomes	2.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this lab, students will undertake a field study to collect data on biotic and abiotic environmental factors in two different ecosystems. (Lesson 11.1)

- <http://www.scribd.com/doc/396425/AP-Biology-Ecology-Lab>

2. This deceptively simple lab will reinforce students' understanding of the scientific method, build their observational skills, and give them hands-on experience with ecological fieldwork. No special equipment or materials are needed. (Lessons 11.1, 11.2, and 11.3)

- http://nsm1.nsm.iup.edu/rgendron/Obsn_Lab.doc

3. In this lab, students will investigate the role of sunlight and nutrients on primary productivity in an aquatic ecosystem. This is a good lab for AP students. It requires a science laboratory. (Lesson 11.3)

- <http://io.uwinnipeg.ca/simmons/ysesp/contents.htm>

These Web sites may also be helpful:

1. This Web site has clear and interesting animations to help students understand interspecific competition and the nitrogen cycle.

- <http://www.biology.ualberta.ca/facilities/multimedia/index.php?Page=280>

2. The three ecology chapters in this concise and well-illustrated text cover many of the same topics as the FlexBook ecology unit, but with enough additional material to make them worth reading. They could be assigned for enrichment.

- <http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookTOC.html>

3. This Web site has many links to additional information and activities about world biomes.

- <http://www.theteacherscorner.net/thematicunits/biomes.htm>

4. This Web site has lesson plans for each world biome and includes species and scientist profiles.

- <http://www.thewildclassroom.com/biomes/index.html>

5. These Web sites have excellent information, climographs, and illustrations for major world biomes. They provide a wealth of information and visuals. They are useful for both teachers and students.

- <http://www.cotf.edu/ete/modules/msese/earthsysflr/biomes.html>
- <http://earthobservatory.nasa.gov/Experiments/Biome/>
- <http://www.ucmp.berkeley.edu/exhibits/biomes/index.php>
- <http://www.thewildclassroom.com/biomes/index.html>

11.1 The Science of Ecology

Key Concept

Ecology is the study of how living things interact with each other and with their environment. An ecosystem consists of all the biotic and abiotic factors in an area and their interactions. Each species has a particular niche and habitat, and two different species cannot occupy the same niche in the same place for very long. Ecosystems require constant inputs of energy, but matter is recycled. Food chains and food webs show how energy and matter move through ecosystems.

Standards

- CA.9–12.IE.1.d, g; CA.9–12.LS.6.e, f
- NSES.9–12.A.1.4, 6; NSES.9–12.C.1.5; NSES.9–12.C.4.2; NSES.9–12.C.5.1, 2, 5, 6
- AAAS.9–12.5.E.2, 3; AAAS.9–12.11.A.1. 2; AAAS.9–12.1.C.4
- McREL.9–12.13.5.5, 6

Lesson Objectives

- Distinguish between abiotic and biotic factors.
- Define ecosystem and other ecological concepts.
- Describe how energy flows through ecosystems.
- Explain how food chains and webs model feeding relationships.
- Identify trophic levels in a food chain or web.

Lesson Vocabulary

- **abiotic factor**: nonliving aspect of the environment, such as sunlight and soil
- **biomass**: total mass of organisms at a trophic level
- **biotic factor**: living aspects of the environment, including organisms of the same and different species
- **carnivore**: consumer that eats animals
- **chemoautotroph**: producer that uses energy from chemical compounds to make food by chemosynthesis
- **competitive exclusion principle**: principle of ecology stating that two different species cannot occupy the same niche in the same place for very long
- **decomposer**: organism that breaks down the remains of dead organisms and other organic wastes
- **detritivore**: decomposer that consumes detritus
- **detritus**: substance composed of dead leaves, other plant remains, and animal feces that collects on the soil or at the bottom of a body of water

- **ecology:** branch of biology that is the study of how living things interact with each other and with their environment
- **food chain:** diagram that represents a single pathway through which energy and matter flow through an ecosystem
- **food web:** diagram that represents multiple intersecting pathways through which energy and matter flow through an ecosystem
- **habitat:** physical environment in which a species lives and to which it has become adapted
- **herbivore:** consumer that eats producers such as plants or algae
- **niche:** role of a species in its ecosystem that includes all the ways the species interacts with the biotic and abiotic factors of the ecosystem
- **omnivore:** consumer that eats both plants and animals
- **photoautotroph:** producer that uses energy from sunlight to make food by photosynthesis
- **saprotroph:** decomposer, such as a fungus or protozoan, that feeds on any remaining organic matter that is left after other decomposers do their work
- **scavenger:** decomposer that consumes the soft tissues of dead animals
- **trophic level:** feeding position in a food chain or food web, such as producer, primary consumer, or secondary consumer

Teaching Strategies

Introducing the Lesson

Most students are likely to have some familiarity with ecology from previous science classes. Help them recall what they already know by asking them to define, in their own words, basic ecological concepts, such as ecosystem, niche, and habitat. Tell students they will learn more about these concepts when they read this lesson.

Building Science Skills

After students read the lesson, guide them in applying what they learned. On the board, list several familiar organisms in nature (e.g., rabbit, robin, pine tree). Then call on students to describe each organism's niche, habitat, and ecological role (i.e., producer, consumer, or decomposer). Ask a few students to go to the board and sketch a food chain that includes one or more of the organisms. Ask other students to identify their trophic levels.

Differentiated Instruction

If you haven't already started a word wall, consider starting one for ecology. Pair English language learners with native English speakers, and assign each pair one or more vocabulary terms from the lesson. Make sure the most important and basic terms are covered. Ask partners to post their words, along with definitions and illustrated examples, on a wall of the classroom. Have students add more vocabulary words to the word wall as they complete each of the other ecology lessons in their FlexBook. **ELL**

Enrichment

Ask a few interested students to research the community of organisms that lives in the ecosystem around a hydrothermal vent on the ocean floor (see chapter opening page). Then have the students create an illustrated food chain showing how energy flows through the ecosystem. Set aside time for students to share their food chain with the class. Ask them to explain how the producers in the food chain make food and how the consumers get it.

Science Inquiry

Describe a classic case of competitive exclusion in which character displacement allows species with overlapping niches to coexist. Good examples include MacArthur's warblers and Darwin's finches (see URLs below). Before describing the outcome of the competition, ask students to predict what they think is likely to happen. (They are likely to predict that one species will outcompete and replace the other.) Then describe the actual outcome (the species evolved differences in the area of overlap so they no longer compete.)

- http://www.stanford.edu/group/stanfordbirds/text/essays/MacArthur's_Warblers.html
- <http://cas.bellarmine.edu/tietjen/RootWeb/CompetitionSmall.htm>

Overcoming Misconceptions

A common student misconception is that ecosystems are simply collections of organisms. Ask students if they have ever heard the expression, "the whole is greater than the sum of its parts." Explain why an ecosystem is a good example. An ecosystem is more than just the sum of its organisms. It also includes interactions among organisms and interactions between organisms and the environment.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you learned how matter is transferred through food chains and webs. Producers make food from inorganic molecules. Other organisms consume the producers. When organisms die, decomposers break down their remains and release inorganic molecules that can be used again by producers. In this way, matter is recycled by the biotic factors in ecosystems.

- Do you think that abiotic factors in ecosystems might also play a role in recycling matter? In what way?
 - (Students are likely to know that abiotic factors are involved in cycles of matter, such as the water cycle.)
- What abiotic factors might be involved in recycling matter? For example, what abiotic factors might be involved in recycling water?
 - (Abiotic factors involved in the water cycle include bodies of water, such as the ocean, sunlight, and changes in temperature.)

11.2 Recycling Matter

Key Concept

Cycles of matter include both biotic and abiotic parts of ecosystems. The water cycle takes place on, above, and below Earth's surface. In the cycle, water occurs as water vapor, liquid water, and ice. In the carbon cycle, carbon passes among sedimentary rocks, fossil fuel deposits, the ocean, the atmosphere, and living things. The nitrogen cycle moves nitrogen back and forth between the atmosphere and organisms. Bacteria play important roles in the nitrogen cycle.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.6.d
- NSES.9–12.A.1.6; NSES.9–12.C.4.1; NSES.9–12.C.5.6; NSES.9–12.D.2.1, 2
- AAAS.9–12.4.C.1

Lesson Objectives

- Define biogeochemical cycles.
- Describe the water cycle and its processes.
- Give an overview of the carbon cycle.
- Outline the steps of the nitrogen cycle.

Lesson Vocabulary

- **aquifer**: underground layer of rock that stores water
- **biogeochemical cycle**: interconnected pathways through which water or a chemical element, such as carbon, is continuously recycled through the biotic and abiotic components of the biosphere
- **carbon cycle**: interconnected pathways through which carbon is recycled through the biotic and abiotic components of the biosphere
- **condensation**: process in which water vapor changes to tiny droplets of liquid water
- **evaporation**: process in which liquid water changes to water vapor
- **exchange pool**: part of a biogeochemical cycle that holds an element or water for a short period of time
- **groundwater**: water that exists in the ground, either in the soil or in rock layers below the surface
- **nitrogen cycle**: interconnected pathways through which nitrogen is recycled through the biotic and abiotic components of the biosphere
- **nitrogen fixation**: process of changing nitrogen gas to nitrates that is carried out by nitrogen-fixing bacteria in the soil or in the roots of legumes

- **precipitation:** water that falls from clouds in the atmosphere to Earth's surface in the form of rain, snow, sleet, hail, or freezing rain
- **reservoir:** part of a biogeochemical cycle that holds an element or water for a long period of time
- **runoff:** precipitation that falls on land and flows over the surface of the ground
- **sublimation:** process in which ice and snow change directly to water vapor
- **transpiration:** process in which plants give off water vapor from photosynthesis through tiny pores, called stomata, in their leaves
- **water cycle:** interconnected pathways through which water is recycled through the biotic and abiotic components of the biosphere

Teaching Strategies

Introducing the Lesson

Tell the class that the average American uses about 100 gallons of water per day (about a quarter of it for toilet flushing). This means that each of us uses an average of 36,500 gallons of water per year.

- **Ask:** At this rate, why isn't water quickly used up? (Because it is constantly recycled.)

Tell students they will learn in this lesson how water and other kinds of matter are recycled.

Activity

Have students play the carbon cycle game at the Web site below. They will pretend they are a carbon atom moving through the carbon cycle and win points by traveling to all the places that carbon is stored.

- http://www.windows.ucar.edu/earth/climate/carbon_cycle.html

Differentiated Instruction

Group students who are visually impaired or have trouble with abstract concepts with students who can assist them. Have the group create a three-dimensional cycle diagram to show how carbon cycles through the biosphere. They should use objects such as toy trees and toy animals to represent the organisms in the cycle. They might use small objects such as dry beans or pasta to represent carbon dioxide and other carbon compounds. Give pairs a chance to demonstrate their diagram to the class by moving the carbon compounds through the cycle and explaining what is happening at each stage. **SN**

Enrichment

Ask a few students to create criss-cross or other word puzzles that incorporate at least a dozen of the lesson vocabulary terms. Distribute copies of the puzzles to the class to complete as a homework assignment. The Web site below has applications students can use to create word puzzles.

- <http://puzzlemaker.discoveryeducation.com/>

Science Inquiry

State that a greater concentration of carbon dioxide in the atmosphere is a major contributor to the greenhouse effect and global warming. Challenge the class to use their knowledge of the carbon cycle to infer ways that the concentration of carbon dioxide in the atmosphere could be reduced in order to help control global warming. (*Sample answers:* Plant more trees and decrease the destruction of forests; reduce the mining and burning of fossil fuels; find and use alternatives to cement; reduce reliance on animal products and increase reliance on plant foods, so fewer animals and more plants are raised.)

Real-World Connection

Based on their knowledge of the nitrogen cycle, ask students to think of ways they could make more nitrogen available to plants in a garden (e.g., grow legumes with nitrogen-fixing bacteria; enrich the soil with decomposing matter, such as manure or decaying leaves).

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you read how matter is recycled through ecosystems. Ecosystems vary in the amount of matter they can recycle. For example, rainforests can recycle more matter than deserts.

- Consider the abiotic and biotic factors of a rainforest and desert. How might they be different?
 - (They might have different soils, rainfall, and organisms.)
- Why do you think a rainforest can recycle more matter than a desert?
 - (It has many more living things.)

11.3 Biomes

Key Concept

Terrestrial biomes — from tundras to tropical forests — are determined mainly by climate. Climate limits plant growth and the range of other organisms. Aquatic biomes are determined mainly by sunlight and concentrations of dissolved oxygen and nutrients in the water.

Standards

- CA.9–12.IE.1.d, m
- NSES.9–12.A.1.6
- AAAS.9–12.12.D.7

Lesson Objectives

- Identify and describe terrestrial biomes
- Give an overview of aquatic biomes.

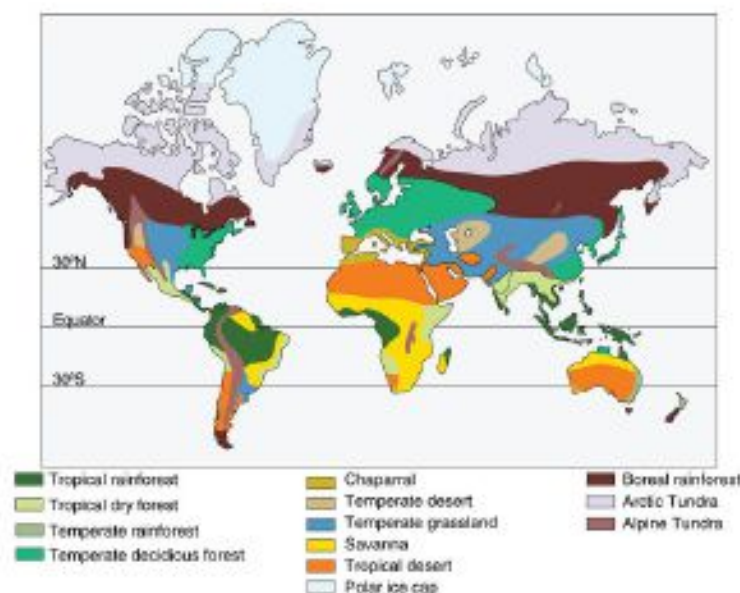
Lesson Vocabulary

- **aphotic zone:** area in aquatic biomes deeper than 200 meters
- **aquatic biome:** water-based biomes, defined by the availability of sunlight and the concentration of dissolved oxygen and nutrients in the water
- **climate:** average weather in an area over a long period of time
- **dormancy:** state in which a plant slows down cellular activity and may shed its leaves
- **freshwater biome:** aquatic biome, such as a pond, lake, stream, or river, in which the water contains little or no salt
- **growing season:** period of time each year when it is warm enough and wet enough for plants to grow
- **intertidal zone:** in marine biomes, the narrow strip along the coastline that is covered by water at high tide and exposed to air at low tide
- **marine biome:** aquatic biome in the salt water of the ocean
- **photic zone:** area in an aquatic biome that extends to a maximum depth of 200 meters
- **phytoplankton:** bacteria and algae that use sunlight to make food
- **terrestrial biome:** a biome of or pertaining to land, as in terrestrial ecosystem
- **wetland:** area that is saturated with water or covered by water for at least one season of the year
- **zooplankton:** tiny animals that feed on phytoplankton

Teaching Strategies

Introducing the Lesson

Have students find their own biome on the **Worldwide Distribution of Terrestrial Biomes** map shown in the FlexBook and below. Ask them to describe the climate and biodiversity of their biome, based on their own experiences. Tell them they will read about their own and other biomes in this lesson.



(Image created by CK-12 Foundation and is under the Creative Commons license CC-BY-NC-SA 3.0.)

Activity

Assign the activities at the URLs below. In the first activity, students will match biomes with temperature and precipitation graphs. In the second activity, they will match plant specimens with the biome in which they are found, based on growing conditions in the biomes.

- <http://earthobservatory.nasa.gov/Experiments/Biome/graphindex.php>
- http://earthobservatory.nasa.gov/Experiments/Biome/plant_it.php

Differentiated Instruction

Ask students who need help with reading to complete a Know/Want to Know/Learned (KWL) chart for one or more of the biomes shown in the **Worldwide Distribution of Terrestrial Biomes** figure shown in the FlexBook and above. They should fill in the first two columns of the chart before they read the lesson and the last column after they read the lesson. A sample chart has been started below for the tropical rainforest biome (see **Table 11.2**). Ask students to share what they learned with the class. **LPR**

TABLE 11.2: short caption

Know	Want to Know	Learned
Tropical rainforests are wet and are found near the equator.	Are all tropical areas wet and covered by rainforests?	Some tropical areas are dry and covered by grasses.

Enrichment

Set up a biome Web site, and ask each of eight students to create a page for the Web site about one of the eight major biomes in the lesson. Their Web pages should convey the nature of the biomes (e.g., abiotic factors, major species, biodiversity) and include visuals such as graphs and pictures in addition to text. Encourage all the students in class to visit the biome Web site.

Science Inquiry

Have students build a model aquatic biome. They can use one of the hands-on biome-building activities at the URL below. The activity will help them understand how biotic and abiotic factors shape an aquatic biome. Encourage students to do the extension exercises listed at the bottom of the activity.

- <http://www.thewildclassroom.com/biomes/index.html>

Overcoming Misconceptions

Listed below are several common misconceptions about biomes. Explain to students why each misconception is false.

- A biome is the same thing as an ecosystem. (A biome covers a large area that may consist of many ecosystems.)
- All deserts are hot. (Deserts are defined by low moisture, not by temperature. Some deserts are very cold.)
- Tropical rainforests must have fertile soil because they have so many plants. (Tropical rainforests have thin, relatively poor soil because heat promotes rapid decomposition and high precipitation leaches nutrients from the soil.)
- Antarctica has a tundra biome. (Antarctica has very low moisture and has a desert biome.)

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

7. Compare the data for Seattle and Denver in **Table 11.3** . Seattle is farther north than Denver. Why is Seattle warmer?

TABLE 11.3: short caption

City, State	Latitude (° N)	Altitude (ft above sea level)	Location (relative to ocean)	Average Low Temperature in January (° F)
Seattle, Washington	48	429	Coastal	33
Denver, Colorado	41	5183	Interior	15

Points to Consider

You read in this lesson that wetlands have high biodiversity.

- In general, what abiotic factors do you think contribute to high biodiversity?
 - (*Sample answer:* sunlight and water)
- Do you think Earth's biodiversity is increasing or decreasing? Why?
 - (*Sample answer:* I think it is decreasing because human actions are causing many species to go extinct.)

11.4 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 12

TE Communities and Populations

CHAPTER OUTLINE

12.1 ONLINE RESOURCES

12.2 COMMUNITY INTERACTIONS

12.3 CHARACTERISTICS OF POPULATIONS

12.4 HUMAN POPULATION GROWTH

12.5 THE BIODIVERSITY CRISIS

12.6 NATURAL RESOURCES AND CLIMATE CHANGE

12.7 THE ENCYCLOPEDIA OF LIFE: INFORMATION FOR EDUCATORS

12.8 WORKSHEET ANSWER KEYS



(Opening image courtesy of Metatron, http://en.wikipedia.org/wiki/File:Ocellaris_clownfish.JPG, and under the Creative Commons license CC-BY-SA 3.0.)

Communities and Populations

Outline

Lesson 12.1: Community Interactions

12.1.1 What Is a Community?

12.1.2 Predation

- Predation and Populations

- Keystone Species
- Adaptations to Predation

12.1.3 Competition

- Interspecific Competition and Extinction
- Interspecific Competition and Specialization

12.1.4 Symbiotic Relationships

- Mutualism
- Commensalism
- Parasitism

12.1.5 Ecological Succession

- Primary Succession
- Secondary Succession
- Climax Communities

Lesson 12.2: Characteristics of Populations

12.2.1 Population Size, Density, and Distribution

- Population Density
- Population Distribution

12.2.2 Population Structure

- Population Pyramids
- Survivorship Curves

12.2.3 Population Growth

- Population Growth Rate
- Dispersal and Migration

12.2.4 Patterns of Population Growth

- Exponential Growth
- Logistic Growth
- K-Selected and r-Selected Species

Lesson 12.3: Human Population Growth

12.3.1 Early Population Growth

12.3.2 Demographic Transition

- Death Rates Fall
- Birth Rates Fall

- Stages of the Demographic Transition

12.3.3 Recent Population Growth

12.3.4 Future Population Growth

- Census Update: What the World Will Look like in 2050

Lesson 12.4: The Biodiversity Crisis

12.4.1 What Is Biodiversity?

- Millions of Unseen Species

12.4.2 Why Is Biodiversity Important?

- Economic Benefits of Biodiversity
- Ecosystem Services of Biodiversity

12.4.3 Human Actions and the Sixth Mass Extinction

- Causes of Extinction
- KQED: Disappearing Frogs
- KQED: Nonnative Species
- How You Can Help Protect Biodiversity
- KQED: Lost Salmon

12.4.4 The Encyclopedia of Life

- Field Guides
- EOL Podcasts
- One Species at a Time

12.4.5 The Biodiversity Heritage Library

Lesson 12.5: Natural Resources and Climate Change

12.5.1 Renewable and Nonrenewable Resources

- Renewable Resources
- Nonrenewable Resources

12.5.2 Soil and Water Resources

- Soil
- Water
- KQED: Are We in Danger of Running Out of Water?
- Too Much of a Good Thing

12.5.3 The Atmosphere

- Air Pollution
- Acid Rain
- Ozone Depletion

12.5.4 Global Climate Change

- What Is the Greenhouse Effect?
- Global Warming
- Effects of Climate Change
- KQED: Climate Watch: California at the Tipping Point
- KQED: Giant Redwoods and Global Warming
- KQED: Acidic Seas
- What Can Be Done?

12.5.5 KQED: Earth Day

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 12.1:

Lesson	Number of Class Periods
12.1 Community Interactions	2.0
12.2 Characteristics of Populations	1.0
12.3 Human Population Growth	1.0
12.4 The Biodiversity Crisis	1.0
12.5 Natural Resources and Climate Change	2.0

- Class periods are assumed to be 60 minutes long.

12.1 Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this lab, students can investigate an example of mutualism in termites and protozoa. The lab is relatively advanced, but it requires few materials other than a microscope. (Lesson 12.1)

- http://www.accessexcellence.org/AE/AEC/AEF/1995/everson_endosymbiosis.php

2. This lab requires students to examine organisms in local ecosystems at different points on a continuum of ecological succession. It will help them see ecological change as a continuous process rather than as a series of discrete stages. (Lesson 12.1)

- http://www.msta-mich.org/downloads/mcfmeap/succession_lesson.pdf

3. Students will explore how scientists estimate the size of a fish population using a common visual census technique. (Lesson 12.2)

- <http://uncw.edu/aquarius/education/lessons/Aq%20FishStix.pdf>

4. At this URL, students can use a simulation application to model population dynamics. The application allows them to input starting values and see graphical outputs of population change. (Lesson 12.3)

- <http://www.cbs.umn.edu/populus>

5. In this project, students research a local ecosystem and design an environmentally friendly development project for an undeveloped or poorly developed site. The project will give students insights into the many ways that human actions may affect ecosystems. (Lessons 12.5)

- <http://www.lessonplansinc.com/science.php/biology/lessonplans/C96/>

6. Students can observe how acid affects different materials, including stone, plant, and animal materials, and then relate their observations to the effects of acid rain on the environment. (Lesson 12.5)

- <http://mypages.iit.edu/~smile/bi8811.html>

7. Students will create an experiment and run a simulator to investigate the causes and health effects of smog and ground-level ozone. The Web site includes teacher instructions, student worksheets, class discussion questions, and links to additional information. (Lesson 12.5)

- <http://www.ciese.org/curriculum/airproj/ozonesmogcity.html>

8. In this activity, students will play the roles of individuals involved in using, destroying, or protecting a threatened rainforest. The activity will help students appreciate the complexity of global environmental problems and the need for cooperative efforts to solve them. (Lesson 12.5)

- http://www.accessexcellence.org/AE/AEPC/WWC/1991/rainforest_role.php#1

9. In Part I of this lab, students will create a town and assess how various activities create greenhouse gases. In Part II, they use a model to collect temperature data and investigate the greenhouse effect. (Lesson 12.5)

- http://www.keystonecurriculum.org/highschool/2009_lessons_word_pdf_ppt/13-Too%20Cool%20for%20School.pdf

These Web sites may also be helpful:

1. This Web site provides links to many population biology articles, activities, quizzes, games, simulations, and labs.

- <http://www.nclark.net/Populations>

2. At the URL below, you will find activities for investigating models of population growth, carrying capacity, and the history of human population growth.

- <http://naturalsciences.sdsu.edu/classes/lab2.7/lab2.7.html#anchor10771668>

3. This Web site provides comprehensive information on biodiversity hotspot science and detailed information, maps, and human impacts on the most important biodiversity hotspots around the world.

- <http://www.biodiversityhotspots.org/Pages/default.aspx>

4. Visit this frequently updated Web site for articles on the importance of biodiversity, threats to biodiversity, global warming, and other environmental issues.

- <http://www.globalissues.org/issue/169/biodiversity>

5. This Web site has many articles about preserving natural resources and curbing global warming. It is a good source for current news stories relating to these issues.

- <http://www.nrdc.org/>

6. The URL below provides a diversity of conservation education materials, including articles, facts and figures, activity ideas, and lesson plans.

- <http://www.nrcs.usda.gov/feature/education/>

7. This Web site has films, photos, interviews, podcasts, posters, an ask-the-expert feature, animations, publications (including interactive e-books), and other resources, all pertaining to global environmental issues.

- <http://unep.org/>

8. At this Web site, you can find data, publications, and multimedia on global and regional environmental issues.

- <http://www.worldbank.org/>

9. This Web site has many student exercises and labs pertaining to air pollution, including its causes and effects. Each activity comes with teacher instructions, student worksheets, and links to other Web sites that provide any necessary data.

- <http://www.ciese.org/curriculum/airproj/index.html>

12.2 Community Interactions

Key Concept

A community is the biotic part of an ecosystem. It consists of all the populations of all the species that live in the same area and how they interact. Types of species interactions include predation, competition, and symbiosis, and types of symbiosis include mutualism, commensalism and parasitism. Ecological succession is the process in which a community changes through time. Change is the norm for most communities.

Standards

- CA.9–12.IE.1.d, i
- NSES.9–12.A.1.4; NSES.9–12.C.4.3
- AAAS.9–12.5.D.1, 2

Lesson Objectives

- Define community as the term is used in ecology.
- Describe predation and its effects on population size and evolution.
- Explain why interspecific competition leads to extinction or greater specialization.
- Compare and contrast mutualism, commensalism, and parasitism.
- Outline primary and secondary succession, and define climax community.

Lesson Vocabulary

- **climax community:** final stable stage of ecological succession that may be reached in an undisturbed community
- **commensalism:** symbiotic relationship in which one species benefits while the other species is not affected
- **ecological succession:** changes through time in the numbers and types of species that make up the community of an ecosystem
- **host:** species that is harmed in a parasitic relationship
- **interspecific competition:** relationship between organisms of different species that strive for the same resources in the same place
- **intraspecific competition:** relationship between organisms of the same species that strive for the same resources in the same place
- **keystone species:** species that plays an especially important role in its community, so that major changes in its numbers affect the populations of many other species in the community
- **mutualism:** type of symbiotic relationship in which both species benefit

- **parasite:** species that benefits in a parasitic relationship
- **parasitism:** symbiotic relationship in which one species benefits while the other species is harmed
- **pioneer species:** type of species that first colonizes a disturbed area
- **predation:** relationship in which members of one species consume members of another species
- **predator:** species that consumes another in a predator-prey relationship
- **prey:** species that is consumed by another in a predator-prey relationship
- **primary succession:** change in the numbers and types of species that live in a community that occurs in an area that has never before been colonized
- **secondary succession:** change in the numbers and types of species that live in a community that occurs in an area that was previously colonized but has been disturbed
- **specialization:** evolution of different adaptations in competing species, which allows them to live in the same area without competing

Teaching Strategies

Introducing the Lesson

Introduce community interactions with a visual example. Have students look at the lion and buffalo in **Figure 12.1** (see FlexBook).

- **Ask:** What type of relationship do the lion and buffalo have? (Predator-prey relationship.)
- **Ask:** What other types of relationships do species have? (Accept all reasonable responses.)

Tell students that predator-prey interactions are just one of many types of community interactions they will read about in this lesson.

Activity

Involve the class in the activity *Sight Hunting—Camouflage and Natural Selection* (see URL below). Students will simulate a hunt for camouflaged animals by predators that hunt using sight. After the activity, discuss the evolution of camouflage by natural selection.

- <http://www.hawkquest.org/TA/XL/Survival-games.pdf>

Differentiated Instruction

Pair less proficient readers with more proficient readers, and have pairs make a table comparing and contrasting the three types of symbiotic relationships: mutualism, commensalism, and parasitism. Tell them to include examples of each type of relationship in their table. **LPR**

Enrichment

Ask a group of students to create a classroom display that shows how primary ecological succession occurs. They should create a series of dioramas or illustrations that show a typical sequence of ecosystem changes through time. Encourage other students to study and discuss the display.

12.2. COMMUNITY INTERACTIONS

Science Inquiry

Have students find and photograph areas in their neighborhood that have recently been disturbed. Possible areas might include building sites, road construction sites, and new landscaping projects. Make sure students obtain permission to photograph any private property or people. Ask them to share their photographs. As a class, discuss how the areas would change if they were left undisturbed. Have students continue to observe any areas that remain undisturbed and periodically report their observations to the class.

Overcoming conceptions

Students commonly think that only species that interact directly, such as predator and prey species, influence each other's populations. Describe a keystone species as a counter example, and explain how it influences the populations of many other species in its community. A good example is the elephant in African savannas. See the URL below for more information.

- <http://www.fieldtripearth.org/article.xml?id=754>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Communities consist of populations of different species. The size and growth of populations in a community are influenced by species interactions. For example, predator-prey relationships control the growth of both predator and prey populations.

- How might populations grow without these influences? What other factors do you think might affect population growth?
 - (Sample answer: Climate change or other abiotic factors also might affect population growth.)
- What factors do you think may have affected the growth of the human population?
 - (Encourage a diversity of possible responses.)

12.3 Characteristics of Populations

Key Concept

Populations are characterized by size, density, pattern of spacing of individuals, and age-sex structure, which is represented by a population pyramid. Population growth rate is determined by rates of birth, death, immigration, and emigration. Under ideal conditions, populations can grow exponentially, but most populations do not live under ideal conditions and grow logistically instead. In logistic growth, density-dependent factors slow growth as population size nears the carrying capacity.

Standards

- CA.9–12.LS.6.c
- NSES.9–12.A.2.4; NSES.9–12.C.4.4; NSES.9–12.F.2.1, 3
- AAAS.9–12.11.C.4; AAAS.9–12.12.B.1, 2

Lesson Objectives

- Define population size, density, and dispersion.
- Relate population pyramids and survivorship curves to population structure.
- Identify factors that determine population growth rate.
- Compare and contrast exponential and logistic growth.

Lesson Vocabulary

- **age-sex structure:** number of individuals of each sex and age in a population
- **carrying capacity (K):** largest population size that can be supported in an area without harming the environment
- **dispersal:** movement of offspring away from their parents
- **emigration:** movement of individuals out of a population
- **exponential growth:** pattern of population growth in which a population starts out growing slowly but grows faster and faster as population size increases
- **immigration:** movement of individuals into a population
- **K -selected:** species in which population growth is controlled by density-dependent factors and population size is generally at or near carrying capacity
- **logistic growth:** pattern of population growth in which growth slows and population size levels off as the population approaches the carrying capacity

- **migration:** regular movement of individuals or populations each year during certain seasons, usually to find food, mates, or other resources
- **population density:** average number of individuals in a population per unit of area or volume
- **population distribution:** describes how the individuals are distributed, or spread throughout their habitat
- **population growth rate (r):** how fast a population changes in size over time
- **population pyramid:** bar graph that represents the age-structure of a population
- **r -selected:** species in which population growth is rapid but death rates are high so population size is generally below the carrying capacity
- **survivorship curve:** graph that represents the individuals still alive at each age in a population

Teaching Strategies

Introducing the Lesson

Generate student interest in populations by sharing these facts and figures:

- Bacteria populations have some of the fastest rates of growth of any species. They can multiply from one to millions in about 12 hours.
- The populations of most other species grow much more slowly. For species with very slow growth rates, it may take thousands of years for populations to increase to millions of individuals, and many never grow that large.
- It took the human population tens of thousands of years to grow to the 1 million mark, but it has grown by several billion people just during the last 100 years.

Tell students they will learn more about populations and how they grow in this lesson.

Activity

Recommend that students go to the Web site below and play a game in which they set the levels of important environmental variables (e.g., temperature, food, predators) and observe how population growth is affected. They can choose to simulate population growth of rabbits or microorganisms. Students may be amazed at how quickly both populations grow under ideal conditions. The Web site also provides teacher notes and student worksheets.

- <http://www.activescience-gsk.com/module3/home.html>

Differentiated Instruction

Help students focus their reading by having them create a KWL chart. Before they read the lesson, they should fill in the Know and Want to Know columns. You might suggest that they preview the figures in the lesson to stimulate their curiosity about populations. Students can fill in the Learned column as they read. Discuss anything they wanted to know but didn't learn when they read the lesson. **LPR**

Enrichment

Ask interested students to read Paul Ehrlich's *Population Bomb*, Garrett Hardin's *The Tragedy of the Commons*, or Thomas Malthus' *An Essay on the Principle of Population*. Have them write a short essay in which they state and justify their own view of the opinions expressed by the author.

Science Inquiry

Ask students to go to the Web site below and do the activity on the Kaibab deer population of Arizona. The activity focuses on density-dependent changes in carrying capacity. Students will analyze data and make recommendations for regulating the deer population.

- <http://www.biologycorner.com/worksheets/kaibab.html>

Overcoming Misconceptions

Students commonly confuse the terms population and community. Make sure they understand that a population consists only of members of the same species who live in the same area, whereas a community consists of members of different species that live in the same area. In other words, a community consists of more than one population.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Human populations have an interesting history that you will read about in the next lesson. You just read about population dispersion and growth. Make some predictions about dispersion and growth in human populations:

- Do you think human populations have a clumped, random, or uniform dispersion?
 - (The human population has a clumped dispersion.)
- How fast do human populations grow? What might limit their growth?
 - (Human populations can grow exponentially. Possible limits on growth include crowding, disease, and lack of food.)

12.4 Human Population Growth

Key Concept

Early humans lived in small, slowly growing populations with high birth and death rates. With industrialization, starting in the 1700s in Europe and North America, death rates fell, followed later by birth rates. This is called the demographic transition. Some other countries have gone through a similar demographic transition, but many seem stalled at early stages, with high birth rates and rapid population growth. The human population will have to stop growing eventually because the carrying capacity will be reached.

Standards

- CA.9–12.IE.1.g
- NSES.9–12.A.1.3, 6; NSES.9–12.F.2.2, 3; NSES.9–12.G.3.3
- AAAS.9–12.8.A.3; AAAS.9–12.11.C.4; AAAS.9–12.12.D.7
- McREL.9–12.11.2.5; McREL.9–12.11.6.1, 2, 5; McREL.9–12.12.4.2

Lesson Objectives

- Describe early human population growth.
- Outline the stages of the demographic transition.
- Explain trends in recent human population growth.
- Summarize the human population problem and possible solutions to the problem.

Lesson Vocabulary

- **demographic transition:** changes in population that occurred in Europe and North America beginning in the 18th century, in which death rates fell and population growth rates increased, followed by birth rates falling and population growth rates decreasing

Teaching Strategies

Introducing the Lesson

Have students go to the Web site below and observe the world population clock. They will see the number of new individuals added to the human population, second by second, as they watch. They can also compare the current

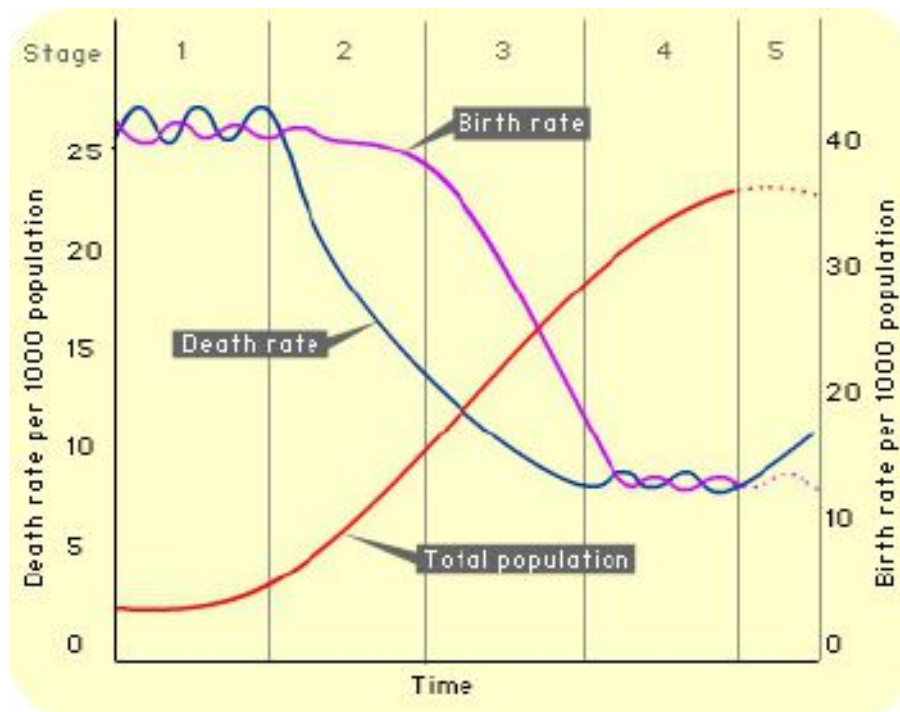
number with the size of the human population in previous years, back to 1970. They might want to see, for example, how much the human population has grown since the year they were born or even since they started the current school year. Ask students to predict how long they think it will take the human population to reach the 7 billion mark (or some other milestone) at the rate it is currently growing. Tell students they will learn in this lesson why the human population is increasing so rapidly today.

- <http://www.ibiblio.org/lunarbin/worldpop/>

Using Visuals

Use the “Stages of the Demographic Transition” figure (see FlexBook and below) to reinforce population concepts.

- **Ask:** During which stages does population size remain about the same? Why? (Stages 1 and 5, because birth and death rates are about the same during these two stages.)
- **Ask:** Why does population grow rapidly during stage 2? (Death rates have fallen but birth rates remain high.)
- **Ask:** Which model of population growth is represented by the red line in the graph? How can you tell? (The logistic model; you can tell by the slowing of growth as the population approaches the carrying capacity.)



Stages of the Demographic Transition. In the demographic transition, the death rate falls first. After a lag, the birth rate also falls. How do these changes affect the rate of population growth over time? (Image courtesy of Charmed88 and under the public domain.)

Differentiated Instruction

Ask students to think about the five questions listed below. Then, pair less proficient with more proficient readers, and ask partners to discuss how they would answer the questions. **LPR**

- How did the human population grow up until about 1800?
- How has the human population grown during the last 200 years?

12.4. HUMAN POPULATION GROWTH

- c. What is the demographic transition?
- d. What are some signs that there are too many people on Earth today?
- e. How is the human population likely to grow in the future?

Enrichment

Ask two small groups of students to debate issues related to human population growth and overpopulation. Assign one group the cornucopian view and the other group the neo-Malthusian view. Students should research their assigned point of view and try to find evidence to support it. Set aside class time for students to present their debate.

Science Inquiry

Download the international population simulator at the Web site below, and assign each student a different country to investigate. Ask them to do background research on their assigned country to provide a context for its demographic parameters. Then have them use the simulator to test how different levels of fertility and life expectancy affect population growth and the age-sex structure in their assigned country. Finally, ask students to write a summary of what they learned about human population dynamics by using the simulation program.

- <http://geosim.cs.vt.edu/Java/IntlPop/IntlPop.html>

Real-World Connection

Discuss how the age structure of a population affects society. Have the class brainstorm problems that might be faced by an aging population such as the U.S. population (e.g., large numbers of elderly people that have high health care costs) and problems that might be faced by a very youthful population such as the population of Angola (e.g., large numbers of young people that must be supported and educated).

Reinforce and Review

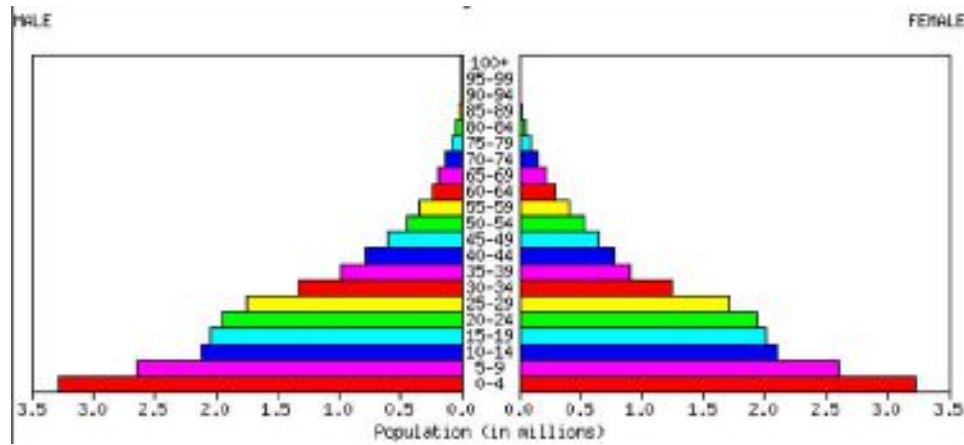
Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**



(Image courtesy of the U.S. Census Bureau and under the public domain.)

Points to Consider

The human population may already be larger than its carrying capacity.

- What evidence might show that there are too many people on Earth today?
 - (Sample answer: Some people don't have enough resources.)
- How does human overpopulation affect the environment? How does it affect the populations of other species?
 - (Sample answer: Humans are harming the environment and causing other species to go extinct.)

12.5 The Biodiversity Crisis

Key Concept

Biodiversity refers to the number of different species in an ecosystem or the biosphere as a whole. Biodiversity has direct economic benefits and also provides services to entire ecosystems. Evidence shows that a sixth mass extinction is occurring, caused mainly by habitat loss due to human actions. There are many steps people can take to help protect biodiversity, such as using less energy.

Standards

- CA.9–12.LS.6.a, b, e; CA.9–12.LS.8.b
- NSES.9–12.C.4.5; NSES.9–12.C.5.5; NSES.9–12.F.4.1; NSES.9–12.F.6.5
- AAAS.9–12.4.C.1; AAAS.9–12.5.A.1; AAAS.9–12.5.D.3;
- AAAS.9–12.8.A.3

Lesson Objectives

- Define biodiversity.
- Identify economic benefits and ecosystem services of biodiversity.
- Relate human actions to the sixth mass extinction.

Lesson Vocabulary

- **exotic species:** species that is introduced (usually by human actions) into a new habitat where it may lack local predators and out-compete native species
- **habitat loss:** destruction or disruption of Earth’s natural habitats, most often due to human actions such as agriculture, forestry, mining, and urbanization
- **sixth mass extinction:** current mass extinction caused primarily by habitat loss due to human actions

Teaching Strategies

Introducing the Lesson

Write the term “biodiversity” on the board, and ask students what it means. If they cannot provide a satisfactory definition, work with them to determine the literal meaning of the term based on the word parts “bio-“ (life, living

organisms) and “diversity” (difference, variety). Tell students they will learn in this lesson about threats to Earth’s biodiversity and why preserving biodiversity matters.

Activity

Ask students to write a letter to the editor of a local newspaper outlining how and why individuals can help protect biodiversity. They should tailor the suggestions to their local community as much as possible. For example, if curbside recycling is available, they might urge citizens to take advantage of it. If it isn’t available, they might suggest alternative ways to recycle, such as taking recyclables to a drop-box location. In either case, students should also explain how recycling helps protect biodiversity.

Differentiated Instruction

Pair English language learners with native English speakers, and ask partners to create a cluster diagram for biodiversity. **ELL**

Enrichment

Recommend to interested students that they read one of the following classics of ecology:

- *The Yosemite* (1912) by John Muir (who founded the Sierra Club and is known as the “father of the conservation movement.”)
- *Sand County Almanac* (1949) by Aldo Leopold (a collection of essays that is called the “conservationist Bible.”)
- *Silent Spring* (1962) by Rachel Carson (a book that is widely credited with helping to launch the modern environmental movement.)

Ask students to write a book report that includes a summary, the author’s main conclusions or recommendations, and their own personal reactions to the work. Collect their book reports in a binder, and make them available for the rest of the class to read.

Science Inquiry

With the class, do the simulation activity, *Biological Diversity—How It Stops Disease from Spreading* (activity 2), at the Web site below. In this simulation, students represent trees in two different forests: a second growth monoculture of Douglas firs, and an old growth forest with several different tree species. Students will observe that disease spreads throughout the monoculture forest and kills most of the trees, whereas it stops spreading after just a few trees die in the biodiverse forest.

- <http://www.accessexcellence.org/AE/ATG/data/released/0534-KathyParis/index.php>

Overcoming Misconceptions

Many people think that some species are unimportant and that they may be sacrificed for human benefit without serious consequences. Describe a real or hypothetical example to demonstrate the impact on an ecosystem of the extinction of an apparently insignificant species. For example, describe how the loss of a single pollinator might cause a flowering plant species to go extinct and how the effects of this loss might be felt all the way up the food chain.

12.5. THE BIODIVERSITY CRISIS

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

All species depend on the environment to provide them with the resources they need. As populations grow, resources may be used up. Just using the resources can create more problems.

- What resources do you depend on?
 - (Encourage a diversity of responses.)
- Does using the resources pollute the environment? Are the resources running out?
 - (*Sample answer:* Using fossil fuels pollutes the environment, and these resources are also running out.)

12.6 Natural Resources and Climate Change

Key Concept

Renewable resources, such as sunlight and wind, can be replaced by natural processes as quickly as humans use them. Nonrenewable resources, such as fossil fuels, exist in fixed amounts and are being used up. Even renewable resources such as soil and water may be ruined by careless human actions. Air pollution consists of chemical substances and particles released into the air, mainly by human actions. Air pollution, in turn, causes acid rain, ozone depletion, and global warming.

Standards

- CA.9–12.IE.1.g; CA.9–12.LS.6.b
- NSES.9–12.C.4.5; NSES.9–12.F.3.1, 2, 3; NSES.9–12.F.4.1, 2, 3; NSES.9–12.F.5.2, 3, 4; NSES.9–12.F.6.5
- AAAS.9–12.5.D.3; AAAS.9–12.5.E.1, 2; AAAS.9–12.8.C.3, 4, 5

Lesson Objectives

- Distinguish between renewable and nonrenewable resources.
- Describe threats to soil and water resources.
- Identify the causes and effects of air pollution.
- Explain global climate change.

Lesson Vocabulary

- **acid rain:** low-pH precipitation that forms when air pollution combines with water
- **air pollution:** chemical substances and particles released into the air mainly by human actions, such as burning fossil fuels
- **algal bloom:** excessive growth of algae in bodies of water because of high levels of nutrients, usually from fertilizer in runoff
- **dead zone:** area in the ocean or other body of water where low oxygen levels from excessive growth of algae have killed all aquatic organisms
- **global warming:** recent rise in Earth's average surface temperature generally attributed to an increased greenhouse effect
- **greenhouse effect:** natural feature of Earth's atmosphere that occurs when gases in the atmosphere radiate the sun's heat back down to Earth's surface, making Earth's temperature far warmer than it otherwise would be
- **natural resource:** something supplied by nature that helps support life
- **nonrenewable resource:** natural resource that exists in a fixed amount and can be used up

- **ozone hole:** hole in the ozone layer high in the atmosphere over Antarctica caused by air pollution destroying ozone
- **renewable resource:** natural resource that can be replenished by natural processes as quickly as humans use it
- **soil:** mixture of eroded rock, minerals, organic matter, and other materials that is essential for plant growth and forms the foundation of terrestrial ecosystems
- **sustainable use:** use of resources in a way that meets the needs of the present and also preserves the resources for the use of future generations

Teaching Strategies

Introducing the Lesson

Students will have learned something about natural resources in previous science classes. Encourage them to recall how renewable resources differ from nonrenewable resources by asking them to name several examples of each type of resource. (e.g., solar and wind energy and timber for renewable resources; natural gas and coal for nonrenewable resources). Tell them they will learn more about both types of natural resources in this lesson.

Activity

Do a simple activity to make the point that it becomes more and more difficult and costly to find nonrenewable resources as they are used up. Before class begins, hide 100 pennies around the classroom. Then, when students arrive for class, give them two minutes to find as many pennies as they can. Tally the number of pennies found in the two-minute interval. Repeat this process, two minutes at a time, until no more pennies are found in two minutes. Students will observe that fewer pennies can be found in each two-minute interval as the number of hidden pennies dwindles. Relate this observation to the time and expense involved in finding new sources of nonrenewable resources, such as fossil fuels, as they are used up.

Differentiated Instruction

Pair less proficient and more proficient readers, and ask partners to work together to make a main ideas/details chart of lesson content. Suggest that they write at least one main idea for each of the major headings in the text. **LPR**

Enrichment

Ask a small group of interested students to make a short video that shows how individuals and families can conserve water. Encourage them to think of creative ways to demonstrate how much water people waste in routine activities and the simple steps people can take to reduce the waste. For example, they might show how much water collects in a stoppered bathtub during a 10-minute vs. 5-minute shower. If possible, arrange for students to show their video to the entire student body.

Science Inquiry

Students will explore how land use affects water quality by doing the activity *We All Live Downstream* (see URL below). In the activity, students will assume they have been assigned a certain section of riverfront property to develop and a grant of one million dollars for the development. They are asked to describe the property, outline how

they would develop it, explain why they would develop it that way, and predict how the development is likely to affect the quality of river water.

- <http://www.accessexcellence.org/AE/ATG/data/released/0497-AlondaDroege/description.php>

Overcoming Misconceptions

Students are likely to be exposed to a great deal of misinformation about climate change and its causes. Use the following common misconceptions as a quiz to identify which misconceptions students believe. Then restate each misconception as a true statement. Provide additional information about each true statement as needed to explain why it is true.

- Global warming is not really happening.
- Global warming is not a serious problem.
- Global warming is completely natural.
- Preventing global warming is bad for the economy.
- There is nothing I can do to help stop global warming.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to requests@ck12.org to request sample answers.**

Points to Consider

Microorganisms such as bacteria are important living resources in all ecosystems. They recycle nutrients and other matter.

- What do you know about microorganisms? Besides bacteria, are there other types of microorganisms?
 - (Students might mention protozoa, such as paramecium and amoeba.)
- Are viruses microorganisms? Are they living things?
 - (Accept all responses, but ask students to support their views.)

12.7 The Encyclopedia of Life: Information for Educators

<http://www.eol.org/>

The EOL has developed web-based tools and services that provide visitors enhanced capability to use EOL content for their own purposes and to contribute to the site and become part of a growing international community interested in biodiversity. In addition to EOL podcasts and the *One Species at a Time* series, additional tools and services are listed below.

NameLink

<http://www.eol.org/content/page/namelink>

NameLink is a service provided by EOL to quickly identify information associated with taxon names and to provide common species names. Submit a webpage address and have the taxon names within the page automatically identified and link up to projects which have information about those names. The common names appear within the webpage or on-line article.

NameLink can be used to identify additional information regarding many species. For example, insert the following URLs into the *URL insertion box* on the NameLink page, and explore the information generated by this tool.

Education LifeDesk

<http://www.edulifedesks.org/>

Register at <http://www.edulifedesks.org/> to join the *CK-12 Biology* group.

A **LifeDesk** is an online environment that provides a collaborative space for creating, editing, and publishing web pages of species information. The goal of using a LifeDesk, in many cases, is to generate content to publish to the EOL, including text and images.

Try using a LifeDesk in a variety of ways. For example, individually or in a small group, research and write or upload images for different sections (e.g., Habitat, Conservation Status, Ecology, etc) of a species page. Alternatively, students can work on the same sections of different species pages and then compare their research findings about the different organisms. Because LifeDesks are on-line, students from different schools or in different locations can collaborate on projects.

When published to EOL, students or classes get credited for the contributions they make to this authentic project. However, there is no requirement to publish content, so LifeDesks can be easily used for class projects that are not visible to external audiences.

LifeDesks have a workflow system that allows groups to set assignments and alert each other when edits have been made or review of work is required. This allows students independence outside of the classroom to work on projects and communicate with their instructors.



Example of student created content published to EOL using an Education LifeDesk.

Field Guides

<http://education.eol.org/ideas/tools/fieldguide>

Field Guides pull selected content from EOL species pages into a format that is easier to view and use for particular projects. Rather than sorting through all 1.9 million species pages and all of the Table of Contents information, users will see information for just the organisms and information they select. Users are able to customize and edit the content in their field guide. Field guides can be made public and print options are available for use in a variety of contexts.

Try creating a field guide for the organisms found in your schoolyard or for the organisms discussed in another chapter of this FlexBook that you are studying. See what information is found in EOL and what is missing. Is there anything you can contribute to EOL, such as an image or some class research information?

Adding Images and Video

You can contribute images of organisms to EOL through popular media sharing sites like Flickr or Wikimedia Commons http://commons.wikimedia.org/wiki/Main_Page. The Encyclopedia of Life Images Flickr group already has over 60,000 images and short video clips, and our members are adding new ones daily.

Basic Flickr accounts are free and it's easy to tag your images for EOL use. See the group page for instructions: http://www.flickr.com/groups/encyclopedia_of_life. EOL harvests the group pool every couple of days, so your images and videos will show up quickly on EOL pages and/or field guides. Uploading images to EOL supports learning of basic technology skills, proper citing of electronic resources and familiarization with scientific and common names for organisms, all while helping to build a global resource.

BioBlitzes

<http://education.eol.org/bioblitz>

A BioBlitz is a snapshot - a limited-time, limited-space species inventory of the organisms that live in an area. BioBlitzes let people get involved in the natural environment, increasing their awareness of and understanding for the environment. BioBlitzes are conducted to learn more about an area's biodiversity (what different life forms live here?), distribution (where do they live?), and abundance (how many of them are there?).

BioBlitzes can be a source of new information that can be shared with local conservation management groups as well as the EOL.

Students can organize BioBlitzes in their school yards or neighborhood parks. Partner with scientists from local conservation groups or universities to help with identification of species or try your best and see how many different species you can find. Put your event on the BioBlitz Worldwide map <http://education.eol.org/bioblitz/worldwide>, upload your images to EOL, and make a field guide of the species you and your classmates identified.

Species Interaction Visualization

The Species Interaction Visualization tool will allow users to view the relationships among species of their choosing. Users will be able to draw upon existing information, or add their own observations and information.

NOTE: This tool is still under development. More information will be available in the near future.

Citing the Encyclopedia of Life

Properly citing reference materials and resources is an important skill to learn. When any content (i.e., images, video, text) from EOL is reused or re-purposed for a project it needs to be referenced so others know where the information originated. EOL provides guidance <http://www.eol.org/content/page/citing> on how to site its digital resources.

12.8 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER

13

TE Microorganisms: Prokaryotes and Viruses

CHAPTER OUTLINE

13.1 PROKARYOTES**13.2 VIRUSES****13.3 WORKSHEET ANSWER KEYS**



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Microorganisms: Prokaryotes and Viruses

Outline

Lesson 13.1: Prokaryotes

13.1.1 Evolution and Classification of Prokaryotes

- Prokaryote Evolution
- Domain Bacteria
- Domain Archaea

13.1.2 Prokaryote Structure

- Plasma Membrane and Cell Wall
- Cytoplasm and Cell Structures
- Extracellular Structures

- Endospores

13.1.3 Prokaryote Metabolism

13.1.4 Prokaryote Habitats

- Temperature

13.1.5 Reproduction in Prokaryotes

- Binary Fission
- Genetic Transfer

13.1.6 Bacteria and Humans

- Benefits of Bacteria
- Bacteria and Disease
- Controlling Bacteria

Lesson 13.2: Viruses

13.2.1 Characteristics of Viruses

13.2.2 Structure and Classification of Viruses

- Structure of Viruses
- Classification of Viruses

13.2.3 Discovery and Origin of Viruses

- Discovery of Viruses
- Origin of Viruses

13.2.4 Replication of Viruses

13.2.5 Viruses and Human Disease

13.2.6 Control of Viruses

13.2.7 Viruses in Research and Medicine

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 13.1:

Lesson	Number of Class Periods
13.1 Prokaryotes	2.5
13.2 Viruses	1.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In these lab activities, students will isolate and culture bacteria in food or soil. (Lesson 13.1)

- http://www.foodsafeschools.org/FSAG_CD/Resources/RI/RILessonPlans/High/hLesson1aLaboratory.htm
- <http://www.umsl.edu/microbes/pdf/bacillus.pdf>

2. This lab challenges students to simulate a virus outbreak and conduct an epidemiological study to locate “patient zero.” (Lesson 13.2)

- <http://lpsl.coe.uga.edu/mile3/resa/gpsinaction/lessonplans/Virus.pdf>

These Web sites may also be helpful:

1. Several microbe worksheets, activities, and other classroom materials are available at this URL.

- <http://www.bioedonline.org/resources/index.cfm?parentCategory=216#category224>

2. This Web site from the CDC has a diversity of materials for the classroom pertaining to microbes and epidemiology.

- <http://www.cdc.gov/excite/about.htm>

3. This Web site is suitable for advanced students. It describes engineering solutions for remote sampling of extremophiles and PCR analysis of their genomes.

- <https://str.llnl.gov/Sep09/dzenitis.html>

13.1 Prokaryotes

Key Concept

Prokaryotes are single-celled organisms with a nucleus. They are classified in the domains Bacteria and Archaea. They live virtually everywhere on Earth. Archaea even live in extreme environments. Prokaryotes may be photoautotrophs, chemoautotrophs, photoheterotrophs, or chemoheterotrophs. Some are aerobic; others are anaerobic. They reproduce asexually by binary fission, but genetic transfer increases genetic variation. Bacteria have many important relationships with humans that may be beneficial or harmful.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.1.c; CA.9–12.LS.7.d; CA.9–12.LS.10.d
- NSES.9–12.A.1.6; NSES.9–12.C.3.1; NSES.9–12.D.3.4; NSES.9–12.F.1.2; NSES.9–12.G.2.3; NSES.9–12.G.3.2, 4
- AAAS.9–12.5.A.1; AAAS.9–12.5.C.1; AAAS.9–12.5.F.3; AAAS.9–12.12.B.6, 8
- McREL.9–12.11.3.1, 2, 3

Lesson Objectives

- Outline the classification and evolution of prokaryotes.
- Describe the structure of prokaryotes.
- Identify different types of metabolism found in prokaryotes.
- Describe the range of prokaryote habitats.
- Explain how prokaryotes reproduce.
- Identify important relationships between bacteria and humans.

Lesson Vocabulary

- **antibiotic drug:** drug that kills bacteria and cures bacterial infections and diseases
- **antibiotic resistance:** ability to withstand antibiotic drugs that has evolved in some bacteria
- **Archaea:** one of two prokaryote domains that includes organisms that live in extreme environments
- **Bacteria:** domain of prokaryotes, some of which cause human diseases
- **biofilm:** colony of prokaryotes that is stuck to a surface, such as a rock or a host's tissue
- **cyanobacteria:** Gram-positive blue-green photosynthetic bacteria of the type that added oxygen to Earth's early atmosphere and evolved into chloroplasts of eukaryotic cells
- **endospore:** spores that form inside prokaryotic cells when they are under stress, enclosing the DNA and helping it survive conditions that may kill the cell

- **extremophile:** any type of Archaea that lives in an extreme environment, such as a very salty, hot, or acidic environment
- **flagella:** (singular, flagellum) long, thin protein extensions of the plasma membrane in most prokaryotic cells that help the cells move
- **genetic transfer:** method of increasing genetic variation in prokaryotes that involves cells “grabbing” stray pieces of DNA from their environment or exchanging DNA directly with other cells
- **Gram-negative bacteria:** type of bacteria that stain red with Gram stain and have a thin cell wall with an outer membrane
- **Gram-positive bacteria:** type of bacteria that stain purple with Gram stain and have a thick cell wall without an outer membrane
- **plasmid:** small, circular piece of DNA in a prokaryotic cell
- **vector:** organism, such as an insect, that spreads pathogens from host to host

Teaching Strategies

Introducing the Lesson

Introduce students to the study of prokaryotes with a fun pre-assessment activity called *What Do You Know about Microbes?* (see URL below). The activity uses Glo Germ™ powder and a black light. It will help students appreciate the ubiquity of microbes.

- http://www.bioedonline.org/resources/files/TSO_Mic_01_s.pdf

Building Science Skills

Because prokaryotes are invisible with the unaided eye, it is easy to underestimate their significance. On the board, list the following key roles filled by prokaryotes:

- a. Decomposing organic wastes.
- b. Recycling carbon and nitrogen.
- c. Producing food.
- d. Adding oxygen to the atmosphere.

Have the class brainstorm what Earth might be like if there were no prokaryotes to fill these roles.

Differentiated Instruction

Give kinesthetic learners — and any students who need extra review — copies of the worksheet “Parts of a Prokaryote” (see URL below). After reading about prokaryote structures, students will color the structures in a prokaryote diagram and answer review questions about them. **SN**

- <http://www.lessonplansinc.com/science.php/biology/lessonplans/C119/>

Enrichment

Ask a small group of advanced students to do the lab *The Action of Antiseptics and Disinfectants* (see URL below). Students will grow harmless bacteria on agar in petri dishes. Then they will observe, measure, and compare the

diameters of inhibited growth zones around blotters of different antibacterial agents to determine their relative effectiveness. Have students prepare a classroom display of their experiment and its outcome.

- Science <http://www.nslc.ucla.edu/step/gk12/lessons.htm#Biology/Life> Science

Science Inquiry

Assign the inquiry activity *Going to Extremes* at the URL below. It can be done as a whole-class or group activity. In the activity, students will explore extremophile Archaea and their significance in hydrothermal vent communities.

- <http://oceanexplorer.noaa.gov/explorations/07fire/background/edu/media/extremes>

Health Connection

Explain that a minority of bacteria is pathogenic, but they have a big impact on human health. Work with students to compile a list of pathogenic bacteria and the diseases they cause (e.g., *Mycobacterium*, tuberculosis; *Pseudomonas*, pneumonia; *Treponema*, syphilis; *Salmonella*, food poisoning; *Clostridium*, tetanus). Discuss how bacteria can be killed and their infections prevented or cured (i.e., antiseptics, disinfectants, antibiotics).

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you read that some bacteria cause human diseases. Many other human diseases are caused by viruses.

- What are viruses? Do they belong in one of the three domains of life?
 - (No; viruses are not generally considered to be living things.)
- Can you name any diseases that are caused by viruses? Do you know how viruses spread from one person to another?
 - (Diseases caused by viruses include the common cold, influenza, and AIDS. Viruses may spread through airborne water droplets, in contaminated food or water, by direct contact with infected people, or through sexual activity.)

13.2 Viruses

Key Concept

Viruses are tiny particles, smaller than prokaryotic cells. They are not cells and cannot replicate without help, but they have nucleic acids and can evolve. Multiple hypotheses for viral origins have been proposed. After infecting a host cell, a virus uses the cell's machinery and metabolism to produce new copies of itself. Viruses cause many human diseases by killing host cells or disturbing their homeostasis. Viruses are useful tools in scientific research and medicine.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.1.c; CA.9–12.LS.10.c, d
- NSES.9–12.A.1.6; NSES.9–12.A.2.3; NSES.9–12.E.2.1; NSES.9–12.F.1.2; NSES.9–12.G.3.2, 4
- AAAS.9–12.8.F.4
- McREL.9–12.11.3.4, 5; McREL.9–12.12.6.2

Lesson Objectives

- Describe the structure of viruses.
- Outline the discovery and origins of viruses.
- Explain how viruses replicate.
- Explain how viruses cause human disease.
- Describe how viruses can be controlled.
- Identify how viruses are used in research and medicine.

Lesson Vocabulary

- **capsid:** protein coat that surrounds the DNA or RNA of a virus particle
- **latency:** period of dormancy of a virus inside a living body that may last for many years
- **vaccine:** substance containing modified pathogens that does not cause disease but provokes an immune response and results in immunity to the pathogen
- **virion:** individual virus particle that consists of nucleic acid within a protein capsid

Teaching Strategies

Introducing the Lesson

Help students recall what they know about viruses from previous chapters, or suggest that they review the section on viruses in the *Cellular Structure and Function* chapter.

- **Ask:** Why are viruses not considered to be living things? (They are not cells, and they cannot reproduce on their own.)
- **Ask:** If viruses are not living things, why do you think they are studied in biology, the science of life? (*Sample answers:* They have DNA; they can evolve; they can cause diseases in living things.)

Tell students they will learn more about viruses in this lesson.

Activity

Divide the class into six groups, and assign each group one of the following viruses: poliomyelitis virus, yellow fever virus, bacteriophage, influenza virus, mumps virus, and HIV. Then have each group create a three-dimensional model of its assigned virus, following the instructions at the URL below. After groups create and share their models, discuss with the class the variety of viral shapes.

- <http://school.discoveryeducation.com/curriculumcenter/viruses/pdf/activity1.pdf>

Differentiated Instruction

Pair less proficient readers and English language learners with students who are excelling in the class. Then ask partners to work together to make a concept map of lesson content. **LPR, ELL**

Enrichment

Suggest that interested students learn more about viral vaccines and how they are developed. The Web sites below are good sources. Ask students to prepare a PowerPoint presentation to share the most important information with the class.

- <http://www.fda.gov/BiologicsBloodVaccines/Vaccines/ApprovedProducts/ucm205541.htm>
- <http://virology-online.com/general/vaccines.htm>
- <http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/V/Vaccines.html>

Science Inquiry

Have groups of students do the activity *How Do Viruses Recognize a Target Cell?* (see URL below). Students will explore how viruses recognize and bind to target cells and how specific viruses are used to deliver genes to target cells in gene therapy.

- <http://teach.genetics.utah.edu/content/tech/genetherapy/Viruses%20Recognize%20Target%20Cell.pdf>

Overcoming Misconceptions

A common misconception is that antibiotics can cure viral infections such as flu. Explain to students how antibiotics work. Tell them that antibiotics kill bacteria by inhibiting translation of bacterial mRNA or the synthesis of bacterial cell walls. Remind students that viruses don't have these mechanisms to attack. The anti-viral drugs that have been discovered don't kill viruses because viruses aren't alive, but they do help prevent viruses from multiplying and causing symptoms of illness.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this chapter, you read about two of the three domains of life: Bacteria and Archaea. The next chapter introduces the simplest, smallest members of the third domain, the Eukarya.

- Some Eukarya are single-celled organisms. What do you think they are?
 - (Students might mention organisms such as paramecium and amoeba.)
- How might single-celled eukaryotes differ from single-celled prokaryotes? How might they be the same?
 - (*Sample answer:* Single-celled eukaryotes, unlike prokaryotes, have larger cells and a nucleus; like prokaryotes, they have a cell membrane, cytoplasm, ribosomes, and other basic cell structures.)

13.3 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER

14

TE Eukaryotes: Protists and Fungi

CHAPTER OUTLINE

14.1 INTRODUCTION TO PROTISTS

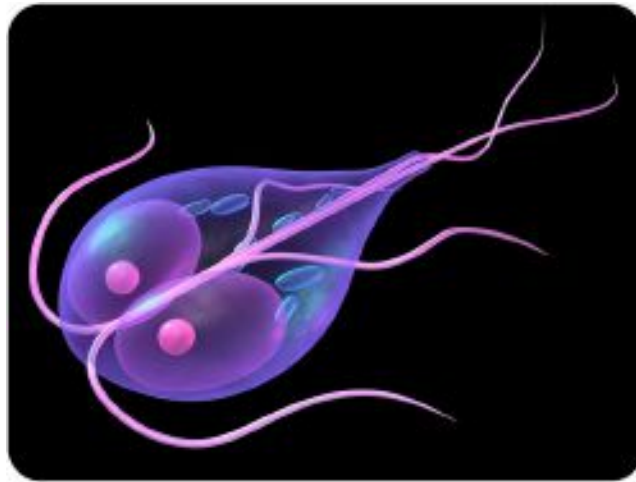
14.2 TYPES OF PROTISTS

14.3 INTRODUCTION TO FUNGI

14.4 ECOLOGY OF FUNGI

14.5 PROTISTS, FUNGI, AND HUMAN DISEASES

14.6 WORKSHEET ANSWER KEYS



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Eukaryotes: Protists and Fungi

Outline

Lesson 14.1: Introduction to Protists

14.1.1 Kingdom Protista

14.1.2 Evolution of Protists

- The First Eukaryotic Cells
- Evidence for the Endosymbiotic Theory

14.1.3 Characteristics of Protists

- Protist Habitats
- Motility of Protists
- Protist Reproduction
- Protist Nutrition

Lesson 14.2: Types of Protists

14.2.1 Animal-Like Protists: Protozoa

- Ecology of Protozoa
- Classification of Protozoa

14.2.2 Plant-Like Protists: Algae

- Ecology of Algae
- Classification of Algae
- Reproduction of Algae
- KQED: Algae Power

14.2.3 Fungus-Like Protists: Molds

- Slime Molds
- Water Molds

Lesson 14.3: Introduction to Fungi

14.3.1 What Are Fungi?

14.3.2 Habitats of Fungi

14.3.3 Structure of Fungi

14.3.4 Reproduction of Fungi

- Asexual Reproduction
- Sexual Reproduction

14.3.5 Evolution of Fungi

14.3.6 Classification of Fungi

- The Kingdom Fungi
- Fungal Phyla

Lesson 14.4: Ecology of Fungi

14.4.1 Fungi as Decomposers

14.4.2 Symbiotic Relationships of Fungi

- Fungi as Parasites
- Mutualism in Fungi

14.4.3 Human Uses of Fungi

- Fungi for Food
- Fungi for Pest Control
- Other Uses of Fungi

Lesson 14.5: Protists, Fungi, and Human Disease

14.5.1 Protists and Human Disease

- Trypanosoma Protozoa
- Giardia Protozoa
- Plasmodium Protozoa

14.5.2 Fungi and Human Disease

- Fungal Poisoning
- Fungal Parasites
- Fungal Allergies

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 14.1:

Lesson	Number of Class Periods
14.1 Introduction to Protists	1.0
14.2 Types of Protists	1.5
14.3 Introduction to Fungi	1.0
14.4 Ecology of Fungi	1.0
14.5 Protists, Fungi, and Human Disease	1.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. Students will use a microscope to observe slides of various protists and sketch their observations. (Lesson 14.2)
 - <http://www.lew-port.com/10712041113402793/lib/10712041113402793/download/Protist%20lab.pdf>
2. In this lab, students can explore mutualistic relationships between protozoans and other organisms. (Lesson 14.2)
 - <http://www.asm.org/images/MDA-PDF/mda-symbioticrelationshipsbwpdf.final.pdf>
3. For a mushroom dissection lab, see the URL below. (Lesson 14.3, Lesson 14.4)

- <http://www.namyco.org/education/k-12.html>

These Web sites may also be helpful:

1. For more information on protists, visit these URLs.

- <http://www.ucmp.berkeley.edu/alllife/eukaryotasy.html>
- <http://faculty.clintoncc.suny.edu/faculty/michael.gregory/files/bio%20102/bio%20102%20lectures/protists/protists.htm>

2. You can find many protist images at the URL below.

- <http://megasun.bch.umontreal.ca/protists/protists.html>

3. You and your students can learn more about phytoplankton at this Web site

- <http://www.noc.soton.ac.uk/soes/staff/tt/eh/>

4. This Web site offers a great deal of information about amoebae.

- <http://www.bms.ed.ac.uk/research/others/smaciver/amoebae.htm>

5. These URLs are all good sources of information and activities on fungi.

- http://botit.botany.wisc.edu/toms_fungi/teachers.html
- http://www.fungi4schools.org/WF_contents.htm
- <http://herbarium.usu.edu/fungi/FunFacts/factindx.htm>
- <http://web.mac.com/diannasmith1/FUNGIPHOTOS/Welcome.html>
- <http://www.ucmp.berkeley.edu/fungi/fungi.html>
- <http://www.lichen.com/>

14.1 Introduction to Protists

Key Concept

The diverse kingdom Protista includes all eukaryotes that are not animals, plants, or fungi. It consists of both single-celled and multicellular organisms. Protists were the first eukaryotes to evolve. Evidence supports their evolution from endosymbiotic prokaryotic cells. Most protists are motile and have complex life cycles. They get food through ingestion, absorption, or photosynthesis.

Standards

- None

Lesson Objectives

- Describe the protist kingdom.
- Outline the evolution of protists.
- Identify protist characteristics.

Lesson Vocabulary

- **cilia:** (singular, cilium) short, hairlike projections, similar to flagella, that allow some cells to move
- **motility:** the ability to move
- **protist:** kingdom in the domain Eukarya that includes all eukaryotes except plants, animals, and fungi
- **pseudopod:** temporary, foot-like extension of the cytoplasm that some cells use for movement or feeding

Teaching Strategies

Introducing the Lesson

Ask students to identify distinguishing features of plants (autotrophs that cannot move) and animals (heterotrophs capable of moving). State that single-celled organisms resembling plants or animals are called protists. Tell students they will learn about the protist kingdom in this lesson.

Building Science Skills

Before students read the lesson, discuss possible evidence for endosymbiotic theory.

- **Ask:** What evidence would support endosymbiotic theory? (Evidence that eukaryotic organelles resemble prokaryotic cells, such as having a similar plasmid membrane and the same method of reproduction.)

Students can see if they were correct when they read the lesson.

Differentiated Instruction

Work closely with any special needs students to create a cluster diagram for the protist kingdom. Include circles for the evolution, motility, reproduction, and nutrition of protists. **SN**

Enrichment

Ask a group of students to create a PowerPoint presentation or Web site on the role of photosynthetic protists in aquatic ecosystems. They might include sample aquatic food chains, photos of aquatic organisms, and facts and figures about aquatic photosynthetic protists.

Science Inquiry

Point out that many protists have both asexual and sexual reproduction. State that the two modes of reproduction are advantageous under different conditions.

- **Ask:** Why might asexual reproduction be advantageous under ideal conditions? (Asexual reproduction is quick and easy, and all the offspring are just like the parent.)
- **Ask:** Why might sexual reproduction be advantageous under stressful or changing conditions? (Sexual reproduction increases genetic variation and the chance that some organisms will survive changing conditions. The production of reproductive spores helps ensure survival during harsh conditions.)

Overcoming Misconceptions

Students commonly think that all single-celled organisms are the same, and they may lump protists together with prokaryotes. Make sure students realize that protists are eukaryotes. Review how prokaryotes and eukaryotes differ.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

14.1. INTRODUCTION TO PROTISTS

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Protists are traditionally classified as animal-like, plant-like, or fungi-like. You will read more about each of these types of protists in the next lesson.

- Based on what you already know about animals, plants, and fungi (such as mushrooms), how might the three types of protists differ?
 - *(Sample answer: They might differ in how they move and obtain food.)*
- Why do you think these protists are not classified with the organisms they resemble? For example, why aren't animal-like protists classified as animals? What sets protists apart from other eukaryotes?
 - *(Sample answer: Protists are mainly single-celled instead of multicellular.)*

14.2 Types of Protists

Key Concept

Animal-like protists are called protozoa. They are heterotrophic, and most are single-celled. Plant-like protists are called algae. They are photosynthesizers and may be single-celled or multicellular. Fungus-like protists are called molds. They are absorptive feeders found on decaying organic matter. Like fungi, they reproduce with spores.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.7.d
- NSES.9–12.C.3.5
- AAAS.9–12.5.A.1

Lesson Objectives

- Describe animal-like protists.
- Give an overview of plant-like protists.
- Identify types of fungus-like protists.

Lesson Vocabulary

- **algae:** (singular, alga) plant-like protists such as diatoms and seaweeds
- **amoeboid:** type of protozoa, such as *Amoeba*, that moves with pseudopods
- **ciliate:** type of protozoa, such as *Paramecium*, that moves with cilia
- **flagellate:** type of protozoa, such as *Giardia*, that moves with flagella
- **kelp:** multicellular seaweed that may grow as large as a tree and occurs in forests found throughout the ocean in temperate and arctic climates
- **protozoa:** (singular, protozoan) animal-like protists, such as *Amoeba* and *Paramecium*
- **slime mold:** fungus-like protist commonly found on rotting logs and other decaying organic matter
- **sporozoa:** (singular, sporozoan) type of protozoa that cannot move as adults
- **water mold:** fungus-like protist commonly found in moist soil and surface water

Teaching Strategies

Introducing the Lesson

Have the class preview visuals of the three types of protists (see **Table 14.3**, **Figure 14.6** and **Figure 14.8** in FlexBook). Ask students what similarities and differences they see among the three types. Tell students they will read about the different types of protists in this lesson.

Demonstration

Demonstrate different ways that protozoa move by showing students videos such as those listed below.

- <http://www.youtube.com/watch?v=QGAm6hMysTA>
- <http://www.youtube.com/watch?v=Nn1aSz36Ra0>
- http://www.youtube.com/watch?v=7pR7TNzJ_pA#38;feature=related

Differentiated Instruction

Have less proficient readers make a compare-contrast table of the three types of protists: animal-like, plant-like, and fungi-like protists. In their table, they should include examples of each type. **LPR**

Enrichment

Ask interested students to investigate how and why the classification of algae has changed (from plants to protists). Ask them to share what they learn in an oral report.

Science Inquiry

Assign the inquiry activity at the URL below. Students will pose a simple question about slime molds and then design and complete a controlled experiment to answer the question. The activity will give students an opportunity to develop several useful lab skills while they observe how slime molds move and obtain nutrients.

- http://www.accessexcellence.org/AE/AEC/AEF/1995/skinner_mold.php

Real-World Connection

Tell students that several companies are developing methods for making biofuels from algae. Discuss what problems this energy source would or would not solve. (It's a renewable energy source that could reduce our need for nonrenewable fossil fuels. It wouldn't solve the problem of global warming because the fuels are still burned, releasing CO₂ and other greenhouse gases.)

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you read about slime molds and water molds. These aren't the only kinds of molds. In fact, you are probably more familiar with molds that are classified as fungi. The next lesson introduces the fungi.

- How do you think fungi might be different from fungi-like protists? (*Hint: Fungi are also eukaryotes, but they belong to a different kingdom than protists.*)
 - (*Sample answer: They might be multicellular instead of single-celled.*)
- What types of molds might be fungi rather than protists?
 - (Students might mention molds on bread or other foods.)

14.3 Introduction to Fungi

Key Concept

Fungi are a kingdom in the domain Eukarya that includes molds, mushrooms, and yeasts. Most fungi are multicellular. They are unique in having cell walls made of chitin. They live in water or on dead matter or soil, where they absorb food. Many are involved in symbiotic relationships. Most fungi can reproduce both asexually and sexually. The earliest fungi may have evolved as early as 600 million years ago.

Standards

- NSES.9–12.C.3.4, 5

Lesson Objectives

- Identify what fungi are.
- Describe habitats of fungi.
- Outline the structure of fungi.
- Describe fungi reproduction.
- Summarize the evolution of fungi.
- Give an overview of fungi classification.

Lesson Vocabulary

- **budding**: type of asexual reproduction in yeasts in which an offspring cell pinches off from the parent cell
- **chitin**: tough carbohydrate that makes up the cell walls of fungi and the exoskeletons of insects and other arthropods
- **fungi**: (singular, fungus) kingdom in the domain Eukarya that includes molds, mushrooms, and yeasts
- **hyphae**: (singular, hypha) thread-like filaments that make up the body of a fungus and consist of one or more cells surrounded by a tubular cell wall
- **mycelium**: body of a fungus that consists of a mass of threadlike filaments called hyphae
- **zygospore**: diploid spore in fungi that is produced by the fusion of two haploid parent cells

Teaching Strategies

Introducing the Lesson

Purchase a variety of whole, fresh mushrooms at a supermarket. Bring them to class on the day students will start studying fungi. Give students a chance to examine the variety of mushrooms and try to identify their structures. Tell the class they will learn about mushrooms and other types of fungi in this lesson.

Activity

Distribute copies of the *World of Fungi* worksheets from the British Mycological Society (see URL below). Have students complete the worksheets individually or in pairs. Topics addressed include fungi classification, diversity, structures, growth, feeding, and habitats. Students will draw and label diagrams of fungi and their cells and compare fungi to plants. A closing matching activity assesses student comprehension.

- http://www.fungi4schools.org/Documentation/03World-of-Fungi/WF01_Welcome_to_the_World_of_Fungi.pdf

Differentiated Instruction

Pair beginning and advanced English language learners, and ask partners to make a cluster diagram for fungi. The diagram should include separate circles for habitats, structure, reproduction, evolution, and classification of fungi.
ELL

Enrichment

Ask a few creative students to do the activity at the URL below. Each student will do research to learn about different species of fungi, make a judgment about which species is their favorite or the “nastiest,” and then make a poster to show the notable features of their chosen fungus. Offer a token prize to the student who creates the best poster.

- http://www.fungi4schools.org/Documentation/03World-of-Fungi/WF03_Favourite_or_Nastiest_Fungi.pdf

Science Inquiry

Adopting the simple procedures and materials described at the URL below, students can grow molds using different substrates and preservatives to generate and test their own hypotheses about fungi. Have students present their results in a graph or table.

- http://herbarium.usu.edu/fungi/FunFacts/moist_chamber.htm

Language Arts Connection

Tell students that fungi pop up relatively often in literature, often as a metaphor for decay or in association with fairies or elves. Ask students to read two poems about mushrooms, one by Emily Dickinson and one by Sylvia Plath. Copies can be found at the URLs below. Discuss with students what the poems reveal about fungi.

- <http://www.americanpoems.com/poets/emilydickinson/11250>
- <http://www.americanpoems.com/poets/sylviaaplath/1415>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you read that fungi differ from plants in major ways. For example, unlike plants, fungi do not make their own food by photosynthesis.

- How do you think fungi obtain food? What organisms might they consume?
 - (They might consume dead trees and other dead plants.)
- What roles do you think fungi might play in food chains and webs?
 - (Fungi are decomposers.)

14.4 Ecology of Fungi

Key Concept

Most fungi are saprotrophs. They are the only decomposers that can break down wood and the cellulose in plant cell walls. Many fungi are involved in symbiotic relationships such as lichen. Humans use fungi for many purposes, including as food or in the preparation of food. Fungi are model research organisms as well.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.6.e

Lesson Objectives

- Describe the role of fungi as decomposers.
- Identify symbiotic relationships of fungi.
- List human uses of fungi.

Lesson Vocabulary

- **lichen**: mutualistic relationship between a fungus and a cyanobacterium or green alga
- **mycorrhiza**: mutualistic relationship between a plant and a fungus that grows in or on its roots

Teaching Strategies

Introducing the Lesson

The interesting video at the URL below is a good way to introduce students to the ecology of fungi. Animal Planet star Jeff Corwin provides amazing facts and figures about leaf-cutter ants and the unique fungi they depend on, a mutualistic relationship that is at least 25 million years old.

- <http://videos.howstuffworks.com/animal-planet/6601-corwins-quest-leaf-cutter-ants-fungal-secret-video.htm>

Discussion

Discuss lichens in depth as a vehicle to give students a greater understanding of symbiotic relationships. First have students read the article *Lichens: Two Lives in One*, which is available at the first URL below. Then follow up with the suggestions in the teacher's guide at the second URL. The guide provides study questions, adaptations for special needs students, assessments, extension ideas, and other useful materials relating to the article.

- http://www.dnr.state.mn.us/young_naturalists/lichens/index.html
- http://files.dnr.state.mn.us/education_safety/education/teachers/activities/volunteer_studyguides/lichens_studyguide.pdf

Differentiated Instruction

Have students who need extra help make a main ideas/details chart as they read the lesson. Before reading, they should divide a sheet of paper in half and on the left side list the main headings of the lesson, skipping several lines between each heading. Then, as they read, they should record important details about each main idea on the right side of the paper. **LPR**

Enrichment

Ask a small group of students to create a display about mycorrhiza, using orchids as the focus. The display should be amply illustrated and convey how the orchids and fungi interact and benefit from the relationship. Set aside time for the students to present their display to the class.

Science Inquiry

The URL below has two inquiry activities on fungi that allow students to explore and identify the organisms involved in this symbiosis. Assign one or both activities to pairs or groups of students.

- http://zoology.muohio.edu/labs/Hays_Inquiry.pdf

Real-World Connection

Share with students the roles of fungi in industry and human diets. The URLs below are teaching posters that you can download and use to help convey the information. They show the range of ways we depend on fungi in our day-to-day lives.

- http://www.fungi4schools.org/Documentation/04Favourite_Fungus/FF25_Supermarket_Challenge_poster.pdf
- http://www.fungi4schools.org/Documentation/04Favourite_Fungus/FF26_Thank_Fungus_poster.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

You read in this lesson that many fungi are parasites, and they make their hosts sick. An example in humans is athlete's foot.

- Do you know any other human diseases caused by fungi?
 - (Examples include yeast infections and ringworm.)
- Besides parasitism, how else might fungi make people sick?
 - (Fungi may also cause poisonings and allergies.)

14.5 Protists, Fungi, and Human Diseases

Key Concept

Most protist diseases in humans are caused by protozoa. Protozoa make humans sick when they become human parasites. Examples are the protozoa that cause giardiasis and malaria. Fungi may cause poisonings, parasitic infections, or allergies. For example, many mushrooms are poisonous, yeasts may be parasitic, and mold allergies are very common.

Standards

- NSES.9–12.G.3.1
- AAAS.9–12.1.C.2; AAAS.9–12.6.E.1
- McREL.9–12.13.1.1; McREL.9–12.13.2.1, 5

Lesson Objectives

- Explain how protists cause human disease.
- Identify three ways fungi can make humans sick.

Lesson Vocabulary

- **athlete's foot:** infection of the skin between the toes by the fungus *Trichophyton*
- **candidiasis:** infection of the mouth or of the vagina in females that is caused by the yeast *Candida*
- **giardiasis:** disease caused by *Giardia* protozoa that spreads through contaminated food or water
- **malaria:** disease caused by *Plasmodium* protozoa and transmitted by mosquitoes in tropical and subtropical regions of the world
- **ringworm:** skin infection caused by the fungus *Trichophyton* that causes a characteristic ring-shaped rash

Teaching Strategies

Introducing the Lesson

Show students an image of the *Plasmodium* protozoa that causes malaria.



(Image courtesy of Ute Frevert/Margaret Shear and under the Creative Commons license CC-BY-2.5.)

Then share the following facts and figures with the class:

- At least 3.3 billion people — half the world's population — are at risk of malaria.
- Each year, 1 million people die from malaria.
- Every 30 seconds, a child dies from malaria.

Tell students that this lesson will introduce them to malaria and other human diseases caused by protists or fungi.

Building Science Skills

Discuss the role of vectors in the transmission of protozoan diseases, such as malaria and sleeping sickness. Challenge students to infer how knowledge of vectors could be used to interrupt transmission of the diseases. You and your students can learn more at the URLs below.

- <http://www.parasitesandvectors.com/content/1/1/24>
- <http://www.aaas.org/international/africa/malaria/toure.html>

Differentiated Instruction

Create a gallery walk of human diseases caused by protists and fungi. Post several large sheets of paper around the room and write the name of a different disease on each sheet. Have small groups of students move around the room, from sheet to sheet, adding notes about each disease. They should also read and comment on the notes written by other groups. After the gallery walk, read the groups' notes and discuss the most important points they make, as well as any misconceptions they reveal.

Enrichment

Encourage interested students to learn more about the groundbreaking epidemiological research of Carlos Chagas, which is introduced in the lesson. They can start with the links below. Ask them to prepare and give a PowerPoint presentation about Chagas' work and its significance.

- <http://www.uta.edu/chagas/html/histCarl.html>
- <http://www.dbbm.fiocruz.br/tropical/chagas/chapter.html>

Science Inquiry

Involve the class in the inquiry activity *Giardia and Giardiasis—Research and Role Play*, which you can access at the URL below. Students will investigate how the Giardia parasite infects a human host, how it spreads, and how transmission can be prevented.

- http://www.bam.gov/teachers/epidemiology_giardia.html

History Connection

Protists and fungi not only cause human diseases directly. They also cause diseases in plants, including agricultural crops, and this can have a devastating impact on human populations. Share with students the case of the Irish potato famine of the 1840s. The famine was caused by a water mold that infected potato plants, which were a staple of the Irish diet. During the famine, a million people died and a million more emigrated from the country. The overall population declined by 25 percent. The famine was a watershed in Irish history, permanently changing Ireland's demographic, political, and cultural landscape.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this chapter, you learned about two kingdoms of Eukarya, the protists and fungi. In the next chapter, you'll learn about another kingdom of Eukarya, the plants.

- Plants are a very diverse kingdom. How many different kinds of plants can you think of?
 - (Encourage students to name as many different plants as they can.)
- What traits do you think might distinguish plants from other eukaryotes? What do you already know about plants that might help you answer this question?
 - (*Sample answer:* Plants contain chlorophyll and can make food.)

14.6 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER

15

TE Plant Evolution and Classification

CHAPTER OUTLINE

15.1 INTRODUCTION TO THE PLANT KINGDOM

15.2 FOUR TYPES OF MODERN PLANTS

15.3 WORKSHEET ANSWER KEYS



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Plant Evolution and Classification

Outline

Lesson 15.1: Introduction to the Plant Kingdom

15.1.1 What Are Plants?

- How Do Plants Obtain Food?
- What Do Plants Need?

15.1.2 The Importance of Plants

15.1.3 Life Cycle of Plants

15.1.4 Evolution of Plants

- The Earliest Plants
- Life on Land

- Vascular Plants Evolve
- Seed Plants Emerge
- Seed Plants Diverge

15.1.5 Classification of Plants

15.1.6 KQED: Albino Redwoods, Ghosts of the Forest

Lesson 15.2: Four Types of Modern Plants

15.2.1 Nonvascular Plants

- Characteristics of Nonvascular Plants
- Evolution of Nonvascular Plants
- Diversity of Nonvascular Plants

15.2.2 Vascular Plants

- Vascular Tissues
- Evolution of Vascular Plants
- Diversity of Seedless Vascular Plants

15.2.3 Seed Plants

- Parts of a Seed
- Classification of Seed Plants
- Evolution of Seed Plants

15.2.4 Flowering Plants

- Parts of a Flower
- Flowers and Pollinators
- Other Characteristics of Flowering Plants
- Evolution of Flowering Plants
- Classification of Flowering Plants

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 15.1:

Lesson	Number of Class Periods
15.1 Introduction to the Plant Kingdom	2.5
15.2 Four Types of Modern Plants	2.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. Students can investigate plant structures and plant diversity by doing the lab *What Parts of a Plant Do We Eat?* (Lesson 15.1).

- http://serendip.brynmawr.edu/sci_edu/waldron/

2. In this simple investigation, students will collect and analyze pollen released by wind-pollinated plants. (Lesson 15.2)

- <http://www.accessexcellence.org/MTC/96PT/Share/fiorella.php>

These Web sites may also be helpful:

1. This Web site has a wide range of information on plants, including the fossil record, life history, ecology, systematics, and morphology of plants.

- <http://www.ucmp.berkeley.edu/plants/plantae.html>

2. At these URLs, you can find more information about bryophytes.

- <http://hiddenforest.co.nz/bryophytes/index.htm>
- <http://scitec.uwichill.edu.bb/bcs/bl14apl/bryol.htm>

3. Students can interact with a virtual plant cell at this Web site.

- <http://www.life.illinois.edu/cgi-bin/plantbio/cell/cell.cgi>

4. For detailed coverage of all lesson topics, visit this URL.

- <http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TOC.html>

5. The existence of non-photosynthetic plants is often overlooked. Direct students to the URL below. It focuses on the parasitic plant *Rafflesia arnoldii*, which also produces the world's largest flower.

- <http://www.loc.gov/rr/scitech/mysteries/flower.html>

6. Go to this USDA Web site for detailed data and images of a huge number of plants.

- <http://plants.usda.gov/index.html>

15.1 Introduction to the Plant Kingdom

Key Concept

Plants are multicellular eukaryotes with chloroplasts and cell walls made of cellulose. All plants have specialized reproductive organs and a life cycle with alternation of generations, and almost all plants produce food by photosynthesis. The earliest plants are thought to have evolved in the ocean from green alga. Plants were among the first organisms to colonize land, and they evolved important adaptations to terrestrial life, including vascular tissues, seeds, and flowers. Today, plants are divided into nonvascular and vascular plants, and vascular plants are further divided into seedless and seed plants.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.2.b
- NSES.9–12.A.1.6; NSES.9–12.C.1.5; NSES.9–12.C.3.4, 5; NSES.9–12.C.5.2
- AAAS.9–12.4.C.1; AAAS.9–12.5.B.5; AAAS.9–12.5.F.1; AAAS.9–12.12.D.7

Lesson Objectives

- Identify traits of plants.
- Explain the importance of plants.
- Give an overview of the plant life cycle.
- Outline major events in plant evolution.
- Describe how plants are classified.

Lesson Vocabulary

- **alternation of generations:** change back and forth from one generation to the next between haploid gametophyte and diploid sporophyte stages in the life cycle of plants
- **angiosperm:** type of seed plant that produces seeds in the ovary of a flower
- **cone:** structure consisting of scales that bear naked seeds in the type of seed plants called gymnosperms
- **flower:** structure in angiosperms consisting of male and female reproductive structures that attracts animal pollinators
- **fruit:** structure in many flowering plants that develops from the ovary and contains seeds
- **gametophyte:** haploid generation in the life cycle of a plant that results from asexual reproduction with spores and that produces gametes for sexual reproduction
- **germination:** early growth and development of a plant embryo in a seed
- **gymnosperm:** type of seed plant that produces bare seeds in cones

- **lignin**: tough, hydrophobic carbohydrate molecule that stiffens and waterproofs vascular tissues of plants
- **ovary**: one of two female reproductive organs that produces eggs and secretes estrogen
- **plant**: multicellular eukaryote with chloroplasts, cell walls made of cellulose, and specialized reproductive organs
- **rhizoid**: hair-like structure in a nonvascular plant that absorbs water and minerals and anchors the plant to a surface
- **seed**: structure produced by a seed plant that contains an embryo and food supply enclosed within a tough coat
- **sporophyte**: diploid generation in the life cycle of a plant that results from sexual reproduction with gametes and that produces spores for asexual reproduction
- **vascular tissue**: type of tissue in plants that transports fluids through the plant; includes xylem and phloem
- **vegetative reproduction**: asexual reproduction in plants using nonreproductive tissues such as leaves, stems, or roots
- **weed**: plant that is growing where people do not want it

Teaching Strategies

Introducing the Lesson

Spur student interest in plants by having them peruse the URL below. It uses colorful images, animations, and videos to illustrate some of the world's most unusual plants. Tell students they will be introduced to the plant kingdom in this lesson.

- <http://myamazingfact.blogspot.com/2009/09/10-of-worlds-strangest-plant-species.html>

Discussion

Discuss the evolution of land plants as a series of adaptations to dryness and other challenges faced by plants that colonized the land. For each major adaptation (e.g., vascular tissues, leaves, roots, seeds, pollen, pollen tubes, flowers), call on volunteers to explain how the adaptation helps plants survive or reproduce successfully on land.

Differentiated Instruction

This lesson is relatively long and content heavy. Work with struggling students to outline the lesson. This will help them organize and focus on the most important content. **ELL, LPR, SN**

Enrichment

Assign any students who need extra challenges to learn more about carnivorous plants, including their classification, evolution, and diversity. They can start with the URLs below. Ask the students to share what they learn with a poster or PowerPoint presentation.

- <http://www.sarracenia.com/faq/faq5025.html>
- http://www.botany.org/Carnivorous_Plants/

Science Inquiry

Divide the class into groups, and ask each group to design an experiment to test the hypothesis that plants need sunlight, air, or water. Have groups present their design to the rest of the class. They should state their hypothesis or research question, identify dependent and independent variables, and explain how they would control other variables. They should also explain what results would support their hypothesis.

Real-World Connection

Help students appreciate the significance of plants in their everyday lives. Lead them in brainstorming ways they interact with plants or use plant products in a typical day—from the oxygen they breathe and the food they eat, to building materials and potentially life-saving drugs such as aspirin.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Vascular plants are now the most common plants on Earth. However, nonvascular plants should not be ignored. They were the first plants to evolve, and some still survive today.

- In what ways do you think modern nonvascular plants are different from other types of modern plants? In what ways do you think they are similar?
 - (*Sample answer:* They might be different in not having true roots or leaves. They might be similar in having chloroplasts and cell walls made of cellulose.)
- How might modern nonvascular plants differ from other eukaryotes, such as fungi?
 - (*Sample answer:* Modern nonvascular plants might be producers instead of consumers like fungi.)

15.2 Four Types of Modern Plants

Key Concept

Nonvascular plants, or bryophytes, include liverworts, hornworts, and mosses. They are low growing, reproduce with spores, and need a moist habitat. Vascular plants, or tracheophytes, have xylem and phloem tissues as well as roots, stems, and leaves. Most vascular plants are seed plants — either gymnosperms, which produce seeds in cones, or angiosperms, which produce seeds in the ovaries of flowers. Flowers attract pollinators, and the ovaries may develop into fruits, which aid in seed dispersal.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.C.3.4, 5
- AAAS.9–12.5.F.1

Lesson Objectives

- Describe modern nonvascular plants.
- Give an overview of living vascular plants.
- Outline the classification and evolution of seed plants.
- Summarize the adaptations and evolution of flowering plants.

Lesson Vocabulary

- **bryophyte**: type of plant that lacks vascular tissues, such as a liverwort, hornwort, or moss
- **endosperm**: stored food inside a plant seed
- **nectar**: sweet, sugary liquid produced by the flowers of many angiosperms to attract animal pollinators
- **petal**: outer parts of flowers that are usually brightly colored to attract animal pollinators
- **phloem**: type of vascular tissue in a plant that transports food from photosynthetic cells to other parts of the plant
- **pistil**: female reproductive structure of a flower that consists of a stigma, style, and ovary
- **seed coat**: tough covering of a seed that protects the embryo and keeps it from drying out until conditions are favorable for germination
- **sepal**: part of a flower that helps protect it while it is still in bud
- **spermatophyte**: type of plant that reproduces by producing seeds
- **stamen**: male reproductive structure of a flower that consists of a stalk-like filament and a pollen-producing anther

- **tracheophyte:** type of plant that has vascular tissues, such as a seed plant or flowering plant
- **xylem:** type of vascular tissue in a plant that transports water and dissolved nutrients from roots to stems and leaves

Teaching Strategies

Introducing the Lesson

Have students take a quick online tour of the types of modern plants at the URL below. It will give them an illustrated overview of lesson content and allow them to take side trips to investigate less familiar plants, such as bryophytes. Tell students they will read more about types of modern plants in this lesson.

- <http://www.perspective.com/nature/plantae/index.html>

Activity

Work with students to create a class terrarium that includes bryophyte species, such as mosses and liverworts. Terrarium instructions can be found online (see URL below). The activity will allow students to observe nonvascular plants in a simulated natural habitat.

- http://en.wikibooks.org/wiki/Adventist_Youth_Honors_Answer_Book/Nature/Lichens,_Liverworts_%26_Mosses

Differentiated Instruction

Pair beginning and advanced English-language learners, and have partners make a compare/contrast table of the four types of modern plants. They should include examples of each type. **ELL**

Enrichment

Challenge interested students to investigate the work of scientists who are developing a standard “DNA barcode” for all plants. Students can start with the URLs below. Ask them to report back to the class on the importance of this endeavor, which will allow botanists to identify all known plant species quickly and accurately.

- <http://news.bbc.co.uk/2/hi/science/nature/7221946.stm>
- [\http://news.bbc.co.uk/2/hi/science/nature/8172673.stm

Science Inquiry

Show the class images of a diversity of seeds that have different adaptations for dispersal (see URL below for examples). Ask students to infer how each seed is dispersed, based on the seed’s characteristics. Discuss why dispersal is adaptive and how the characteristics evolved through natural selection.

- <http://www.texaseducator.com/family/jbouyer/lessons/Science/askew/mycourses/botfruit.htm>

Overcoming Misconceptions

People commonly think that all plants are vascular plants, like the trees, garden plants, grasses, and weeds they are likely to be familiar with. Make sure students are aware that the plant kingdom includes nonvascular plants, or bryophytes. Have them view additional images of bryophytes by doing an image search online. Discuss the importance of nonvascular plants in plant evolution.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this chapter, you read about the evolution and classification of plants. In the next chapter, you can read more about the special cells, tissues, and organs of plants that make them such important and successful organisms.

- How do you think plant cells differ from the cells of other eukaryotes, such as animals? What unique structures do plant cells contain?
 - (Sample answer: chloroplasts.)
- Besides vascular tissues, what other types of tissues do you think plants might have?
 - (Sample answer: tissues for storing food or water.)

15.3 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 16

TE Plant Biology

CHAPTER OUTLINE

16.1 PLANT TISSUES AND GROWTH

16.2 PLANT ORGANS: ROOTS, STEMS, AND LEAVES

16.3 VARIATION IN PLANT LIFE CYCLES

16.4 PLANT ADAPTATIONS AND RESPONSES

16.5 WORKSHEET ANSWER KEYS



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Plant Biology

Outline

Lesson 16.1: Plant Tissues and Growth

16.1.1 Plant Cells

- Plant Cell Structures
- Types of Plant Cells

16.1.2 Plant Tissues

- Dermal Tissue
- Ground Tissue
- Vascular Tissue

16.1.3 Growth of Plants

Lesson 16.2: Plant Organs: Roots, Stems, and Leaves

16.2.1 Roots

- Root Systems
- Root Structures and Functions
- Root Growth

16.2.2 Stems

- Stem Diversity
- Stem Tissues and Functions
- Stem Growth

16.2.3 Leaves

- Leaf Variation
- Factories for Photosynthesis
- Seasonal Changes in leaves

Lesson 16.3: Variation in Plant Life Cycles

16.3.1 General Plant Life Cycle

16.3.2 Life Cycle of Nonvascular Plants

16.3.3 Life Cycle of Seedless Vascular Plants

16.3.4 Life Cycle of Gymnosperms

16.3.5 Life Cycle of Angiosperms

Lesson 16.4: Plant Adaptations and Responses

16.4.1 Plant Adaptations

- Adaptations to Water
- Adaptations to Extreme Dryness
- Adaptations to Air

16.4.2 Plant Responses

- Plant Tropisms
- Daily and Seasonal Responses
- Responses to Disease
- KQED: Plant Plague: Sudden Oak Death

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 16.1:

Lesson	Number of Class Periods
16.1 Plant Tissues and Growth	1.0
16.2 Plant Organs: Roots, Stems, and Leaves	2.0
16.3 Variation in Plant Life Cycles	2.0
16.4 Plant Adaptations and Responses	1.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this lab, students will investigate the process of transpiration and analyze the form and function of stomata. (Lesson 16.2)

- http://www.lessonplansinc.com/science.php/biology/detail/transportation_in_plants

2. This lab allows students to follow plant reproduction by planting Amaryllis bulbs and observing their development through the production of seeds. (Lesson 16.3)

- http://www.accessexcellence.org/AE/AEC/AEF/1995/chase_pollin.php

3. In this lab, students will test the effects of different variables on the percent of seed germination. (Lesson 16.3)

- <http://zoology.muohio.edu/labs/lessonplans.htm>

4. *The Roots of Desert Plants* lab at this URL reinforces chapter concepts about plant adaptation. It is a guided inquiry lab that gives students experience handling plants and drawing what they observe. Optional statistical analysis exercises are also provided. (Lesson 16.4)

- <http://scene.asu.edu/habitat/activities/roots.html>

These Web sites may also be helpful:

1. This USDA database is a rich resource you can use to learn about native and invasive plants in your geographic area.

- <http://plants.usda.gov/index.html>

16.1 Plant Tissues and Growth

Key Concept

Plants have eukaryotic cells with large central vacuoles, cell walls containing cellulose, and plastids such as chloroplasts and chromoplasts. Different types of plant cells include parenchymal, collenchymal, and sclerenchymal cells. The three types of plant cells are found in each of the major types of plant tissues: dermal, ground, and vascular tissues. Each type of tissue has a different structure and function. Most plants continue to grow as long as they live through a combination of cell growth and cell division. Undifferentiated cells in meristem allow primary and secondary growth of stems and roots.

Standards

- NSES.9–12.C.1.6; NSES.9–12.C.5.4

Lesson Objectives

- Describe plant cell structures, and list types of plant cells.
- Compare and contrast different types of plant tissues.
- Explain how plants grow.

Lesson Vocabulary

- **cuticle:** waxy, waterproof substance produced by epidermal cells of leaves, shoots, and other above-ground parts of plants to prevent damage and loss of water by evaporation
- **dermal tissue:** type of plant tissue that covers the outside of a plant in a single layer of cells called the epidermis
- **ground tissue:** type of plant tissue making up most of the interior of the roots and stems of plants that carries out basic metabolic functions and provides support and storage
- **meristem:** type of plant tissue consisting of undifferentiated cells that can continue to divide and differentiate, and from which plants grow in length or width

Teaching Strategies

Introducing the Lesson

Urge students to recall what they know about plant cells from the *Cellular Structure and Function* chapter. Ask them how plant cells differ from the cells of other multicellular eukaryotes, such as animals and fungi. Tell students they will learn more about plant cells in this lesson.

Demonstration

Bring to class examples of the three main types of plant tissues for students to examine (e.g., a raw potato for ground tissues, a celery stalk for vascular tissues, an apple's skin for dermal tissues). Alternatively, display a cross-sectional diagram of a plant stem, root, or leaf, clearly identifying the three tissues (see "Figure 2. Plant tissue types" at URL below). Call on volunteers to point out how the three types of tissues differ. Discuss with the class how the different tissues are suited for the particular roles they play in plants.

- <http://www.scq.ubc.ca/capturing-the-sun-an-exploration-into-the-world-of-plant-science/>

Differentiated Instruction

Have less proficient readers and English language learners label the plant cell diagram at the URL below. They can check their answers at the Web site. **LPR, ELL**

- <http://www.hobart.k12.in.us/jkousen/Biology/cell.htm>

Enrichment

In the activity at the URL below, advanced students can investigate hormonal control of plant tissue differentiation and relate it to gene expression.

- http://www.accessexcellence.org/AE/AEPC/WWC/1994/plant_biotechnology.php

Science Inquiry

Have students read in detail how to measure plant growth at the URL below. Then have them brainstorm research questions that could be answered with the measurement data. Discuss how they would use the data to answer the questions.

- http://www.sciencebuddies.org/science-fair-projects/project_ideas/PlantBio_measuring_growth.shtml

Overcoming Misconceptions

The URL below presents several documented student misconceptions about plant growth. Discuss the misconceptions with your students to ensure that they have the correct information.

- <http://ed-share.educ.msu.edu/PMsum02/LosSuavecitos/Suavecitos/plants/plantsgrow.htm>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Plants are complex organisms with tissues organized into organs.

16.2 Plant Organs: Roots, Stems, and Leaves

Key Concept

Roots absorb water and minerals and transport them to stems. They also anchor and support the plant and may store food. Stems hold plants upright, bear leaves and other structures, and transport fluids between roots and leaves. Leaves collect sunlight and make food by photosynthesis.

Standards

- none

Lesson Objectives

- Outline the structure, function, and growth of roots.
- Give an overview of stem diversity and how stems function and grow.
- Describe leaf variation, and explain how leaves make food and change seasonally.

Lesson Vocabulary

- **bark:** tissue that provides a rough, woody external covering on the stems of trees
- **deciduous plant:** type of plant that seasonally loses its leaves to reduce water loss during the cold or dry season each year and grows new leaves later in the year
- **evergreen plant:** type of plant that keeps its leaves and stays green year-round
- **fibrous root:** threadlike root that makes up part of the fibrous root system of some plants
- **mesophyll:** specialized tissue inside plant leaves where photosynthesis takes place
- **root hair:** tiny hairlike structure that extends from an epidermal cell of a plant root and increases the surface area for absorption
- **root system:** all the roots of a plant, including primary roots and secondary roots
- **stomata:** (singular, stoma) tiny pore in the epidermis of a plant leaf that controls transpiration and gas exchange with the air
- **taproot:** single, thick primary root that characterizes the root system of some plants

Teaching Strategies

Introducing the Lesson

Pique students' interest in plant organs by sharing the following amazing facts:

- A single rye plant can have more than 14 billion root hairs that make up a surface area about as large as a football field.
- The roots of desert plants can extend as far as 68 meters (223 feet) below the soil surface.

Tell students they will read about roots and other plant organs in this lesson.

Demonstration

Real-life, tactile examples often make a bigger impression on students than abstract examples. Bring to class a potted plant with a taproot system (e.g., dandelion) and one with a fibrous root system (e.g., grass). As students watch, carefully pull the plants from the soil without breaking off the roots. Pass the plants around the class and encourage the students to examine the roots closely. Call on volunteers to describe how the two types of root systems differ. Discuss the conditions in which each type of root system is adaptive.

Differentiated Instruction

Work with students to make a cluster diagram of plant organs, with one circle for each major organ described in the lesson (roots, stems, and leaves).

Enrichment

Ask one or more creative students to learn more about tree-ring dating and then teach the topic to the rest of the class. Tell them to use some type of visuals or props in their presentation.

Science Inquiry

Ask small groups of students to select a particular type of plant tropism and then design an experiment to demonstrate it. Have groups share their experimental designs.

Overcoming Misconceptions

A common misconception is that plants get organic compounds from the soil through their roots. Discuss this misconception with students. Point out that plants get carbon from inorganic carbon dioxide in the air, and they convert it to organic compounds (sugars) during photosynthesis. Explain that roots obtain water and mineral nutrients from the soil, both of which are also needed for photosynthesis.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you read about the diversity of roots, stems, and leaves. The life cycles of plants are also diverse.

- What do you already know about the life cycle of plants? What type of life cycle do plants have?
 - (*Sample answer:* alternation of generations between diploid sporophyte and haploid gametophyte generations)
- Predict how the life cycles of different plants might vary. For example, how might the life cycle of seed plants differ from the life cycle of seedless vascular plants?
 - (*Sample answer:* The life cycle of seed plants includes the formation and dispersion of seeds.)

16.3 Variation in Plant Life Cycles

Key Concept

All plants have a life cycle that alternates between diploid sporophyte and haploid gametophyte generations, and between sexual and asexual reproduction. In nonvascular plants, the gametophyte generation is dominant. In vascular plants, the sporophyte generation is dominant. Seedless vascular plants, such as ferns, reproduce with spores. Seed plants reproduce with pollen and eggs in cones or flowers. Pollination must occur for fertilization to take place and seeds to develop.

Standards

- CA.9–12.LS.2.b

Lesson Objectives

- Describe a general plant life cycle.
- Outline the life cycle of nonvascular plants.
- Describe the life cycle of seedless vascular plants.
- Summarize the gymnosperm life cycle.
- Describe the angiosperm life cycle.

Lesson Vocabulary

- **antheridia:** (singular, antheridium) male reproductive organs of the gametophyte generation of plants that produce motile sperm
- **archegonia:** (singular, archegonium) female reproductive organs of the gametophyte generation of plants that produce eggs
- **sporangium:** (plural, sporangia) structure on a plant of the sporophyte generation that produces spores for asexual reproduction

Teaching Strategies

Introducing the Lesson

Ask students to recall what they read about plant life cycles and reproduction in the *Plant Evolution and Classification* chapter. Call on one student after another until no new information is forthcoming. Tell students they will learn more about plant life cycles in this lesson.

Discussion

Ask students to identify the pros and cons of each type of reproduction (sexual and asexual) in plants. Discuss situations in which each type of reproduction might be advantageous.

Differentiated Instruction

Have visual and kinesthetic learners make a cycle diagram of a general plant life cycle. Tell them to illustrate their diagram with their own sketches or with drawings from the Internet. Suggest that they save their cycle diagram in their science notebook. **SN**

Enrichment

Challenge a small group of students to create a *Jeopardy*-type quiz game based on plant life cycles. Set aside time for the class to play the game as a review of lesson content.

Science Inquiry

Have students use simple materials to model flower parts and the processes of pollination and fertilization. You can find instructions at the URL below.

- http://alex.state.al.us/lesson_view.php?id=24127

Overcoming Misconceptions

A common misconception is that plant pollination is the same thing as fertilization. Make sure students understand that pollination is the transfer of pollen to the ovule (in gymnosperms) or carpel (in angiosperms), whereas fertilization is the fusion of two haploid gametes to produce a diploid nucleus. Explain that pollination can occur without fertilization also occurring. For more information, see the URL below.

- <http://www.actionbioscience.org/education/hershey.htm>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you read about many of the reproductive adaptations of plants.

- What are some other plant adaptations? For example, how have desert plants adapted to very dry conditions?
 - (*Sample answer:* Some have thick fleshy leaves or barrel stems to store water.)
- Besides deserts, what other extreme habitats do plants occupy? What special adaptations might plants require to live in these other habitats?
 - (*Sample answer:* Plants occupy extremely cold habitats, so they might need special adaptations like losing their leaves and going dormant during the winter.)

16.4 Plant Adaptations and Responses

Key Concept

Plants live just about everywhere on Earth, so they have evolved adaptations that allow them to survive and reproduce under a diversity of conditions. Various plants have evolved adaptations to live in the water, in very dry environments, or in the air as epiphytes. Like all organisms, plants detect and respond to stimuli in their environment. Their main response is to change how they grow. This is controlled by hormones.

Standards

- NSES.9–12.C.6.2
- AAAS.9–12.5.F.6

Lesson Objectives

- Explain how plants have adapted to a diversity of environments.
- Identify types of plant responses to environmental stimuli.

Lesson Vocabulary

- **epiphyte**: plant that is adapted to grow on other plants and obtain moisture from the air
- **tropism**: turning by an organism or part of an organism toward or away from an environmental stimulus
- **xerophyte**: plant that is adapted to a very dry environment

Teaching Strategies

Introducing the Lesson

Bring a cactus plant to class. Challenge students to identify ways the cactus might be adapted to an arid habitat. Tell students they will learn more about plant adaptations such as these in this lesson.

Demonstration

Have students go to the URL below to observe different types of plant motions through time-lapse photography. Discuss what triggers and controls each type of motion.

- <http://plantsinmotion.bio.indiana.edu/plantmotion/starthere.html>

Differentiated Instruction

Pair less proficient readers and English language learners with students who are excelling in the class. Ask partners to work together to create a cluster diagram of plant adaptations, with separate circles for adaptations to water, extreme dryness, and air. **LPR, ELL**

Enrichment

Have interested students explore how plants use chemicals to defend themselves from insect pests. The video and article at the URLs below are possible sources. Ask the students create a poster or PowerPoint to share what they learn with the rest of the class. Discuss with the class how natural plant defenses might be used to protect crop plants and reduce the use of chemical herbicides.

- http://www.sciencedaily.com/videos/2007/0906-plants_under_attack.htm
- <http://www.sciencedaily.com/releases/2007/05/070509161003.htm>

Science Inquiry

Assign the online activity *Plant Adaptations to the Desert*. Students will investigate the relationship between leaf surface area and water intake, as well as the function of waxy cuticle in limiting water loss.

- http://scene.asu.edu/habitat/activities/desert_plant.html

Real-World Connection

Discuss why plants have been the source of many medicinal drugs. Give examples, such as aspirin from willow trees. You can find many other examples at the URL below.

- <http://www.rain-tree.com/plantdrugs.htm>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this chapter you read about the cells, tissues, and organs that make up plants. You also read about plant life cycles. Like plants, animals are complex organisms with tissues and organs. Animals also have life cycles.

- How do the cells of animals differ from those of plants? What tissues and organs might be found in animals?
 - (*Sample answers:* Animal cells lack cell walls and chloroplasts. Animals might have nervous and muscle tissue and organs such as a brain and heart.)
- What is the general animal life cycle? How does it differ from the general life cycle of plants?
 - (The general animal life cycle includes a dominant diploid generation and sexual reproduction. It is a simpler life cycle than the general life cycle of plants.)

16.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 17 TE Introduction to Animals

CHAPTER OUTLINE

17.1 OVERVIEW OF ANIMALS

17.2 OVERVIEW OF INVERTEBRATES

17.3 WORKSHEET ANSWER KEYS



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Introduction to Animals

Outline

Lesson 17.1: Overview of Animals

17.1.1 Characteristics of Animals

- Animal Cells
- Animal Structure and Function
- Animal Life Cycle and Reproduction

17.1.2 Classification of Animals

- Major Animal Phyla
- Invertebrate vs. Invertebrate

17.1.3 Major Trends in Animal Evolution

- Animal Origins

- Evolution of Invertebrates
- Moving from Water to Land
- Evolution of Chordates
- Evolution of Vertebrates
- Evolution of Amniotes

Lesson 17.2: Overview of Invertebrates

17.2.1 Characteristics of Invertebrates

- Digestion
- Movement
- Nervous System
- Reproduction

17.2.2 Invertebrate Evolution

- Multicellularity
- Tissues
- Radial Symmetry
- Cephalization
- Bilateral Symmetry
- Mesoderm
- Complete Digestive System
- Pseudocoelom and Coelom
- Segmented Body
- Notochord

17.2.3 Classification of Invertebrates

- Major Invertebrate Phyla
- Protostomes and Deuterostomes

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 17.1:

Lesson	Number of Class Periods
17.1 Overview of Animals	2.0
17.2 Overview of Invertebrates	2.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. This is a simple lab in which students will use microscopes to observe plant and animal cells and identify their differences.

- http://www.biologycorner.com/worksheets/comparing_plant_animal.html

2. In this lab, students will make and use a taxonomic key to learn distinguishing characteristics of common invertebrate and vertebrate animals.

- <http://www.marietta.edu/biol/introlab/animaldiv1.pdf>

These Web sites may also be helpful:

1. At the URL below, you can find a wealth of information, images, and other materials documenting the diversity of the animal kingdom.

- <http://animaldiversity.ummz.umich.edu/site/index.html>

17.1 Overview of Animals

Key Concept

Animals are multicellular eukaryotes that lack cell walls. All animals are heterotrophs, and they reproduce sexually. They also have sensory organs, the ability to move, and internal digestion. Except for the chordates, all animal phyla consist only of invertebrates, or animals without a backbone. Chordates include both vertebrates and invertebrates. The earliest animals evolved from protists more than 600 million years ago. The first animals to live on land were invertebrates. Amphibians were the first vertebrates to live on land, and amniotes were the first animals that could reproduce on land.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.C.6.1
- McREL.9–12.11.2.5, 6

Lesson Objectives

- Identify characteristics that all animals share.
- Give an overview of animal classification.
- Outline major trends in animal evolution.

Lesson Vocabulary

- **amniote**: animal that produces eggs with internal membranes that allow gases but not water to pass through, so the embryo can breathe without drying out (reptile, bird, or mammal)
- **animal**: heterotrophic, multicellular eukaryote with cells that lack cell walls; member of the animal kingdom
- **exoskeleton**: non-bony skeleton that forms on the outside of the body of some invertebrates and provides protection and support
- **invertebrate**: animal that lacks a vertebral column, or backbone
- **notochord**: stiff support rod that runs from one end of the body to the other in animals called chordates
- **vertebral column**: bony support structure that runs down the back of a vertebrate animal; also called a backbone
- **vertebrate**: animal with a vertebral column, or backbone

Teaching Strategies

Introducing the Lesson

Call on students to list familiar animals on the board. Lead the class in brainstorming characteristics the listed animals share. Tell students they will read in this lesson about characteristics that define the animal kingdom.

Activity

Direct students to the URL below to interact with the model animal cell. The activity will allow them to review the structures and functions of animal cell organelles. In the *Cell Gallery* at the same Web site, students can get a virtual microscopic view of different types of animal cells.

- http://www.cellsalive.com/cells/cell_model.htm

Differentiated Instruction

Help less proficient readers focus their reading by having them make a KWL chart about animals. Before students read the lesson, they should list what they already know about animals as well as what they want to know. After they read the lesson, they should list what they learned. **LPR**

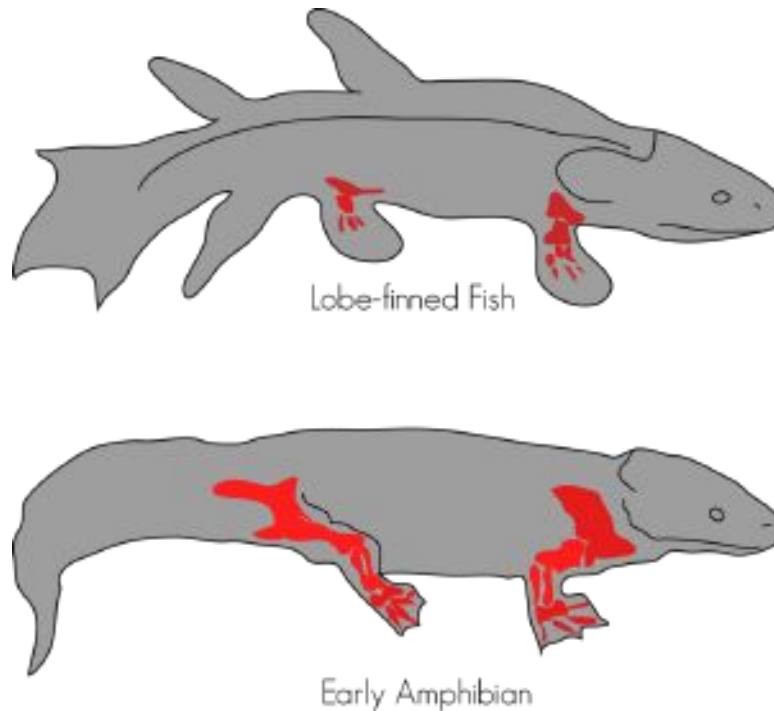
Enrichment

Ask a group of students who need extra challenges to create a Web site about one or more of the major trends in animal evolution (e.g., body symmetry, complete digestive system, segmented body). Their Web site should illustrate the trends with specific examples and also address how and why animals evolved in these ways. Encourage other students to visit the Web site to learn more about animal evolution.

Science Inquiry

Have students relate the traits of lobe-finned fish to the evolution of amphibians. They can compare a lobe-finned fish and early amphibian (see below and in FlexBook).

- **Ask:** What abilities of lobe-finned fish allowed them to spend brief periods of time on land? (They could breathe air for brief periods and use their fins to walk on land for short distances.)



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Overcoming Misconceptions

Students commonly have the misconception that most animals are vertebrates. Be sure to point out that vertebrates make up only 5 percent of animal species. Suggest that students go online to find a complete listing of known invertebrate species and images of a diversity of invertebrates.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Vertebrates are the animals with which we are most familiar. But there are far more invertebrates than vertebrates on the planet. The next lesson provides an overview of invertebrate animals.

17.1. OVERVIEW OF ANIMALS

- Before reading the next lesson, think about what you now know about invertebrates. Can you identify some invertebrate traits?
 - (*Sample answer:* lack of a backbone.)
- Invertebrates are sometimes referred to as “lower” animals. This is because they evolved earlier and are simpler than vertebrates. Do you think invertebrates are also less adapted to their environments than vertebrates? Why or why not?
 - (*Sample answer:* They must be well adapted to their environments because they have existed for such a long time.)

17.2 Overview of Invertebrates

Key Concept

The majority of living animals are invertebrates. Most invertebrates reproduce sexually, and many have one or more larval stages. Several important animal traits evolved in invertebrates, including multicellularity, tissues and organs, radial and bilateral symmetry, cephalization, mesoderm, complete digestive system, coelom, and segmented body. Most invertebrates belong to one of eight major phyla.

Standards

- CA.9–12. IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.C.5.4; NSES.9–12.C.6.1
- McREL.9–12.11.2.5, 6

Lesson Objectives

- Describe general characteristics of invertebrates.
- Outline major events in invertebrate evolution.
- Give an overview of invertebrate classification.

Lesson Vocabulary

- **bilateral symmetry**: symmetry of a body plan in which there are distinct head and tail ends, so the body can be divided into two identical right and left halves
- **cephalization**: concentration of nerve tissue in one end of an animal, forming a head region
- **coelom**: fluid-filled body cavity
- **complete digestive system**: digestive system consisting of a digestive tract and two body openings (mouth and anus)
- **ectoderm**: outer embryonic cell layer in animals
- **endoderm**: inner embryonic cell layer in animals
- **hydrostatic skeleton**: type of internal support in an animal body that results from the pressure of fluid within the body cavity known as the coelom
- **incomplete digestive system**: digestive system that consists of a digestive cavity and a single opening that serves as both mouth and anus
- **larva**: (plural, larvae) juvenile stage that occurs in the life cycle of many invertebrates, fish, and amphibians and that differs in form and function from the adult stage
- **mesoderm**: embryonic cell layer in many animals that is located between the endoderm (inner cell layer) and ectoderm (outer cell layer)

- **pseudocoelom:** partial, fluid-filled cavity inside the body of some invertebrates
- **radial symmetry:** symmetry of a body plan in which there is a distinct top and bottom but not distinct head and tail ends, so the body can be divided into two halves like a pie
- **segmentation:** division of an animal body into multiple segments

Teaching Strategies

Introducing the Lesson

Ask students to recall from the previous lesson important trends in animal evolution (e.g., evolution of cephalization, true tissues, symmetry). Tell students that these traits evolved in invertebrates, which they will read about in this lesson.

Building Science Skills

Students can build basic science skills by doing the flatworm activity at the URL below. It will lead them through several measurements and observations of living freshwater planaria. (You can obtain low-cost live planaria for the activity at www.wardsci.com.)

- http://www.biologycorner.com/worksheets/planarian_observation_lab.html

Differentiated Instruction

Work with students to make a word wall for lesson vocabulary terms they will need for later chapters (e.g., larva, ectoderm, endoderm, mesoderm, symmetry, segmentation). Each term should be defined and illustrated with an image. Refer students to the word wall whenever they encounter these terms in subsequent chapters.

Enrichment

Challenge one or more advanced students to bring to class objects that demonstrate asymmetry (e.g., natural sponge), radial symmetry (e.g., wheel), and bilateral symmetry (e.g., doll). Ask the students to use the objects to teach the rest of the class about symmetry in animals.

Science Inquiry

Have students use a dichotomous key to classify invertebrate phyla. See the URL below as an example.

- http://www.msc.ucla.edu/oceanglobe/pdf/Invertebrates/Inverts_Key_Phyla.pdf

Overcoming Misconceptions

If students hold misconceptions about the importance, variety, or intriguing nature of invertebrates, suggest that they read the engaging article *How I Learned to Love Spineless Wonders* at the URL below. They may also want to read the author's book-length work of the same title. It explores the fascinating and sometimes bizarre world of invertebrates.

- <http://www.nwf.org/News-and-Magazines/National-Wildlife/Animals/Archives/1997/How-I-Learned-to-Love-Spineless-Wonders.aspx>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

This chapter presents an overview of invertebrate phyla. The next chapter describes invertebrate phyla in greater detail.

- What questions do you have about invertebrate phyla now? For example, do you wonder where organisms in the different phyla live or what they eat?
 - (Encourage a diversity of responses.)
- Invertebrates evolved hundreds of millions of years ago. Which invertebrate phylum do you think has the greatest number of species today?
 - (Arthropoda.)

17.3 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 18

TE From Sponges to Invertebrate Chordates

CHAPTER OUTLINE

18.1 SPONGES, CNIDARIANS, FLATWORMS, AND ROUNDWORMS

18.2 MOLLUSKS AND ANNELIDS

18.3 ARTHROPODS AND INSECTS

18.4 ECHINODERMS AND INVERTEBRATE CHORDATES

18.5 WORKSHEET ANSWER KEYS



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From Sponges to Invertebrate Chordates

Outline

Lesson 18.1: Sponges, Cnidarians, Flatworms, and Roundworms

18.1.1 Sponges

- Structure and Function of Sponges
- Sponge Reproduction
- Ecology of Sponges

18.1.2 Cnidarians

- Structure and Function of Cnidarians

- Cnidarian Reproduction
- Ecology of Cnidarians
- KQED: Amazing Jellies

18.1.3 Flatworms

- Structure and Function of Flatworms
- Flatworm Reproduction
- Ecology of Flatworms

18.1.4 Roundworms

- Structure and Function of Roundworms
- Roundworm Reproduction
- Ecology of Roundworms

Lesson 18.2: Mollusks and Annelids

18.2.1 Mollusks

- Structure and Function of Mollusks
- Mollusk Reproduction
- Ecology of Mollusks
- KQED: Cool Critters: Dwarf Cuttlefish
- KQED: The Fierce Humboldt Squid
- Where's the Octopus?

18.2.2 Annelids

- Structure and Function of Annelids
- Annelid Reproduction
- Ecology of Annelids

Lesson 18.3: Arthropods and Insects

18.3.1 Arthropods

- Structure and Function of Arthropods
 - Underwater Spiders
- Arthropod Reproduction
- Evolution of Arthropods
- Classification of Arthropods

18.3.2 Insects

- Structure and Function of Insects
- Insect Flight
- Insect Reproduction
- Insect Behavior

- KQED: Ants: The Invisible Majority
- KQED: Landbugs: A Population of Millions
- Insects and Humans
- KQED: Better Bees: Super Bee and Wild Bee

Lesson 18.4: Echinoderms and Invertebrate Chordates

18.4.1 Echinoderms

- Structure and Function of Echinoderms
- Echinoderm Reproduction
- Echinoderm Classification

18.4.2 Introduction to Chordates

- Characteristics of Chordates
- Classification of Chordates

18.4.3 Invertebrate Chordates

- Tunicates
- Lancelets

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 18.1:

Lesson	Number of Class Periods
18.1 Sponges, Cnidarians, Flatworms, and Roundworms	2.0
18.2 Mollusks and Annelids	2.0
18.3 Arthropods and Insects	2.5
18.4 Echinoderms and Invertebrate Chordates	1.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. Students can investigate whether different parts of planaria have the same ability to regenerate. (Lesson 18.1)
 - http://www.hhmi.org/biointeractive/activities/planaria/planaria_regen_activity.pdf
2. In this lab, students will observe and measure the physical traits and behaviors of freshwater snails. (Lesson 18.2)

- http://www.lamer.lsu.edu/classroom/seascope/folios/snail_folio.pdf

3. This AP lab involves dissection of annelids. (Lesson 18.2)

- <http://www.insectos.cl/pdf/lab01.pdf>

4. This lab introduces students to variation in arthropod form and function. (Lesson 18.3)

- http://serendip.brynmawr.edu/sci_edu/waldron/

5. In this lab, students will dissect a preserved grasshopper and examine its internal and external anatomy. (Lesson 18.3)

- http://www.brandonsd.mb.ca/crocus/staff/McKellar/Interdisciplinary/grasshopper_dissection.htm

6. Students can examine the external anatomy of a preserved sea star and then dissect it and examine its internal anatomy. A dissecting microscope is required. (Lesson 18.4)

- <http://faculty.fmcc.edu/mcdarby/Pages/Lab%20Exercises/Echinoderms.htm>

7. Students can observe prepared slides of tunicate larvae to identify the four defining chordate features. (Lesson 18.4)

- <http://faculty.southwest.tn.edu/jiwilliams/tunicates.htm>

These Web sites may also be helpful:

1. See the URL below for PowerPoint slide sets of invertebrates, including sponges, cnidarians, flatworms, and roundworms.

- <http://www.bioedonline.org/slides/>

2. This is a PBS series with three episodes on simple invertebrates (“Origins,” “Life on the Move,” and “The First Hunter”). The Web site also has photos, articles, activities, and scientist profiles.

- <http://www.pbs.org/kcet/shapeoflife/episodes/index.html>

3. This University of Michigan Web site can be searched for photos of and articles about sponges, cnidarians, flatworms, and roundworms.

- <http://animaldiversity.ummz.umich.edu/site/index.html>

4. This 12-page PDF document provides a detailed summary of mollusks and annelids. It has excellent illustrations.

- http://ibrunet.com/files/unit11/Mollusca_Annelida.pdf

5. See these online biology chapters for more information on invertebrates.

- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookDiversity_8.html
- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookDiversity_9.html

6. At the URL below, you can find a concise compilation of useful information about the arthropod phylum. Materials include excellent labeled diagrams of arthropod body plans.

- <http://insected.arizona.edu/arthroinfo.htm>

7. This brief echinoderm tutorial includes brilliant images of a variety of echinoderms.

- <http://www.oceanicresearch.org/education/wonders/echinoderm.html>

18.1 Sponges, Cnidarians, Flatworms, and Roundworms

Key Concept

Porifera (sponges) have specialized cells and an endoskeleton but lack true tissues and body symmetry. Cnidaria (jellyfish and corals) have tissue-level organization and radial symmetry. Platyhelminthes (flatworms) have a mesoderm cell layer, simple organ systems, cephalization, and bilateral symmetry. Nematoda (roundworms) have a pseudocoelom and hydrostatic skeleton.

Standards

- NSES.9–12.C.5.4

Lesson Objectives

- Describe invertebrates in the phylum Porifera.
- Outline characteristics of cnidarians.
- Give an overview of the platyhelminths.
- Summarize traits of nematode invertebrates.

Lesson Vocabulary

- **Cnidaria**: invertebrate phylum that includes animals, such as jellyfish and corals, that are characterized by radial symmetry, tissues, and a stinger called a nematocyst
- **endoskeleton**: internal skeleton that provides support and protection
- **filter feeder**: animal that obtains organic matter for nutrition by filtering particles out of water
- **medusa**: (plural, medusae) basic body plan in cnidarians, such as jellyfish, that is bell-shaped and typically motile
- **Nematoda**: phylum of invertebrates called roundworms, which have a pseudocoelom and complete digestive system
- **Platyhelminthes**: invertebrate phylum of flatworms that are characterized by a flat body because they lack a coelom or pseudocoelom
- **polyp**: basic body plan in cnidarians, such as corals, that is tubular in shape and typically sessile
- **Porifera**: invertebrate phylum of sponges, which have a non-bony endoskeleton and are sessile as adults
- **sessile**: of or relating to an animal that is unable to move from place to place

Teaching Strategies

Introducing the Lesson

Guide students in recalling characteristics of sponges from the *Introduction to Animals* chapter.

- **Ask:** What is the simplest invertebrate animal? (Sponges, or the phylum Porifera.)
- **Ask:** What type of digestive tract do sponges have? (A simple digestive tract with one opening.)
- **Ask:** What are some other traits of sponges? (They are multicellular and capable of movement at some life stage.)
- **Ask:** What evidence suggests that sponges are well adapted? (They have been around for half a billion years.)

Building Science Skills

Divide the class into groups, and provide a piece of natural bath sponge and a hand lens to each group. Tell students to use the hand lens to examine the sponge, sketch what they observe, and then use their Flex Book to identify the structures. If possible, also provide students with a living sponge to observe (available from many aquarium stores). Ask them to observe physical traits and behaviors of the sponge. If a live sponge is not available, students can observe living sponges in a video (see URLs below).

- <http://www.junglewalk.com/video/Sponge-movie.htm>

Differentiated Instruction

Work with less proficient readers, English language learners, and any students who are struggling to create a compare/contrast table of the four invertebrate phyla described in the lesson (Porifera, Cnidaria, Platyhelminthes, and Nematoda). Include columns for structure and function, reproduction, ecology, and examples. Suggest that students save the table in their science notebook. **LPR, ELL**

Enrichment

Encourage interested students to research how global warming is affecting corals. They can start with the Web sites below. Ask them to share their findings with the class in a PowerPoint presentation.

- http://www.nsf.gov/news/news_summ.jsp?cntn_id=115558
- http://www.panda.org/about_our_earth/aboutcc/problems/impacts/coral_reefs/
- <http://www.nwf.org/coralandglobalwarming/>

Science Inquiry

Have groups of students do the flatworm activity at the URL below. In the activity, they will observe how temperature affects the movement of flatworms. The Web site provides teaching tips, background information, and ideas for assessment and extension.

- <http://www.woodrow.org/teachers/bi/1998/stride/planaria/>

Overcoming Misconceptions

Students may be unaware of the tremendous diversity of invertebrates because many types of invertebrates are seldom seen. For example, they may think that all sponges look like bath sponges and that all worms are earthworms. Expose students to a diversity of simple invertebrates when you teach this lesson.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you read about flatworms and roundworms. In the next lesson, you'll read about worms called annelids. Mollusks such as snails are also described in the next lesson.

- How are annelids different from flatworms and roundworms?
 - (Students might predict that annelids are segmented worms.)
- Why do you think annelids are placed in a lesson with mollusks instead of with flatworms and roundworms?
 - (*Sample answer:* Annelids might be more closely related to snails than to flatworms or roundworms.)

18.2 Mollusks and Annelids

Key Concept

Mollusks are invertebrates such as snails, scallops, and squids. They have a coelom, complete digestive system, and specialized organs for excretion. Most also have a hard outer shell, a layer of tissue called the mantle between the shell and the body, tentacles, and a muscular foot. Annelids are segmented worms, such as earthworms and leeches. They have a coelom, closed circulatory system, excretory system, complete digestive system, and brain.

Standards

- NSES.9–12.C.5.4

Lesson Objectives

- Describe invertebrates in the phylum Mollusca.
- Summarize the characteristics of annelids.

Lesson Vocabulary

- **Annelida:** invertebrate phylum of segmented worms such as earthworms
- **deposit feeder:** animal that obtains organic matter for nutrition by eating soil or the sediments at the bottom of a body of water
- **gills:** organs in aquatic organisms composed of thin filaments that absorb oxygen from water
- **heart:** muscular organ in the chest that pumps blood through blood vessels when it contracts
- **mantle:** layer of tissue that lies between the shell and body of a mollusk and forms a cavity, called the mantle cavity, that pumps water for filter feeding
- **Mollusca:** phylum of invertebrates that are generally characterized by a hard outer shell, a mantle, and a feeding organ called a radula
- **regeneration:** regrowing of tissues, organs, or limbs that have been lost or damaged

Teaching Strategies

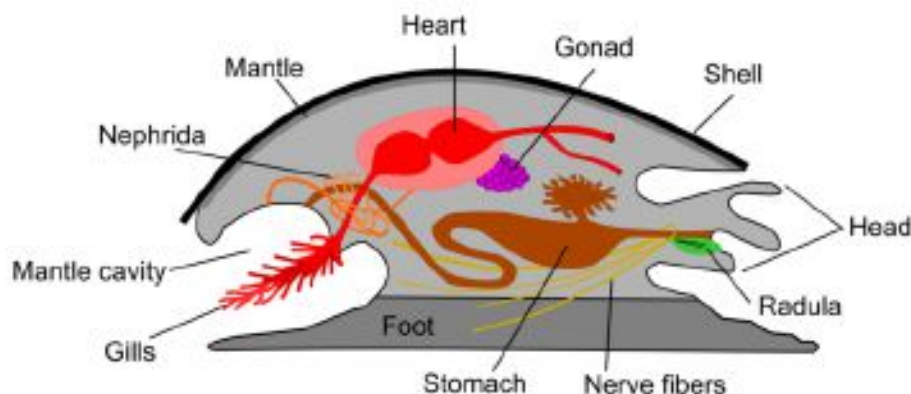
Introducing the Lesson

Show students a collection of mollusk shells (e.g., clams, snails, mussels). Ask them to identify the animals the shells came from. Tell the class that these shelled animals are invertebrates called mollusks, which they will read

about in this lesson.

Using Visuals

Call students' attention to "Basic Mollusk Body Plan" (**Figure 18.15** in the FlexBook and reproduced below) when you discuss the basic mollusk body plan. As you talk about the function of each structure, ask students to find it in the figure. Discuss with the class how the body plans of various classes of mollusks differ from the basic body plan.



(Image courtesy of CK-12 Foundation and under the Creative Commons license CC-BY-NC-SA 3.0.)

Differentiated Instruction

Pair special needs students with other students who can assist them if needed. Ask partners to work together to make a Venn diagram of mollusks and annelids. Invite them to share their Venn diagram with the class. **SN**

Enrichment

Challenge a small group of students to create a board game about mollusks and annelids. To advance around the board, players must identify features and examples of these invertebrate phyla. Encourage other students to play the game.

Science Inquiry

Divide the class into groups, and ask each group to learn about the zebra mussel problem in the United States, as well as proposed solutions to the problem (see URLs below). Have each group decide which solution they think is best. Give groups a chance to discuss and defend their choices.

- http://www.nationalatlas.gov/articles/biology/a_zm.html
- http://www.glsc.usgs.gov/main.php?content=research_invasive_zebramussel#38;title=Invasive%20Invertebrates0#38;menu=research_invasive_i
- <http://www.seagrant.umn.edu/ais/zebramussel>

Health Connection

Discuss the role of leeches in medicine. Include both historical and modern uses. You can learn more at the URLs below.

- <http://www.biol.andrews.edu/BIO/leech/leech#38;med.html>
- http://www.leechestherapy.com/history_of_leeches.php
- <http://www.bterfoundation.org/indexfiles/leechrx.htm>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Most invertebrates you have read about so far live in aquatic habitats. Many of those that are not aquatic live inside other organisms as parasites. In the next lesson, you will read about invertebrates that live mainly on land. They are the arthropods, such as insects.

- Compared with aquatic invertebrates, what challenges do you think terrestrial invertebrates might face?
 - (Sample answer: Terrestrial invertebrates might face the challenges of staying moist and moving on land.)
- How might terrestrial invertebrates meet these challenges? What special tissues, organs, or appendages might they have evolved to adapt to life on land?
 - (Answers may vary. Encourage a diversity of responses that could reasonably be adaptations to life on land.)

18.3 Arthropods and Insects

Key Concept

Arthropods are the largest phylum in the animal kingdom. They include insects, spiders, centipedes, and crustaceans. The arthropod body consists of three segments with a hard exoskeleton and jointed appendages. Terrestrial arthropods have adaptations for life on land. Insects are the most numerous organisms in the world and the only invertebrates that can fly. Flight is the main reason for their success.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.C.5.4; NSES.9–12.C.6.2
- McREL.9–12.11.2.5, 6

Lesson Objectives

- Give an overview of the phylum Arthropoda.
- Outline the characteristics and importance of insects.

Lesson Vocabulary

- **arthropod**: invertebrate in the phylum Arthropoda, characterized by a segmented body, hard exoskeleton, and jointed appendages
- **metamorphosis**: process in which a larva undergoes a major transformation to change into the adult form, which occurs in amphibians, arthropods, and other invertebrates
- **molting**: process in which an animal sheds and replaces the outer covering of the body, such as the exoskeleton in arthropods
- **pupa**: life cycle stage of many insects that occurs between the larval and adult stages and during which the insect is immobile, may be encased within a cocoon, and changes into the adult form
- **trilobite**: oldest known arthropod, which is now extinct and known only from numerous fossils

Teaching Strategies

Introducing the Lesson

Have students look at the photos of arthropods in **Figure 18.19** in the FlexBook. Call on volunteers to point out any similarities and differences they can identify among the various organisms pictured. Tell students they will learn about arthropods such as these when they read this lesson.

Demonstration

Take advantage of online insect videos (see URLs below) to demonstrate the characteristics and diversity of the class Insecta. Point out similarities and differences among different insect species as students watch the videos.

- <http://animal.discovery.com/videos/incredible-insects/>
- http://www.sciencedaily.com/videos/plants_animals/insects_and_butterflies/
- <http://www.neok12.com/Insects.htm>

Differentiated Instruction

Ask English language learners to create a Frayer model for the word “arthropod.” They should draw a large box titled Arthropod and divide it into four parts labeled “Definition,” “Drawing,” “Example,” and “Non-example.” Then they should fill in all four parts of the box. **ELL**

Enrichment

Ask a few students to create a trilobite display that includes actual trilobite fossils or pictures of trilobite fossils, as well as information about trilobites and their evolution. For example, students might include a map showing important trilobite fossil sites, a timeline of trilobite evolution, and a phylogenetic tree showing how trilobites are related to other arthropod groups. Have students set up their displays in the classroom.

Science Inquiry

Challenge small groups of students to use materials such as modeling clay, chenille stems, cardboard, and Styrofoam to create a model arthropod. The model could represent an actual arthropod or one of their own invention, but it should show the defining external features of arthropods, including a segmented body with jointed appendages and hard exoskeleton. Remind students to label the parts of their arthropod model. Put their models on display in the classroom.

Overcoming Misconceptions

Spiders, scorpions, mites, and other arachnids are commonly thought to be insects. Explain that arachnids are a class in the arthropod subphylum Chelicerata, whereas insects are a class in the arthropod subphylum Hexapoda. Be sure to emphasize the differences between arachnids and insects. For example, arachnids have eight walking legs and two body regions, whereas insects have six walking legs and three body regions.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

The invertebrates described so far in this chapter are protostomes. They differ from the other major grouping of animals, the deuterostomes, in how their embryos develop. The next lesson describes invertebrates that are deuterostomes. These invertebrates are more closely related to vertebrates, such as humans. Some of these invertebrates are even placed in the chordate phylum.

- What traits do you think might characterize deuterostome invertebrates?
 - (Students may recall from the *Introduction to Animals* chapter that deuterostomes form the coelom from mesoderm rather than endoderm and that the blastopore develops into the anus instead of the mouth.)
- How might chordate invertebrates differ from nonchordate invertebrates?
 - (The chordates have a notochord and other unique chordate traits.)

18.4 Echinoderms and Invertebrate Chordates

Key Concept

Echinoderms are marine invertebrates. They include sea stars, sand dollars, and feather stars. They have a spiny endoskeleton and a unique water vascular system with tube feet. Chordates include vertebrates and invertebrates that have a notochord. They also have a post-anal tail, dorsal hollow nerve cord, and pharyngeal slits. Vertebrate chordates have a backbone, but invertebrate chordates do not. Invertebrate chordates include tunicates and lancelets, which are primitive marine organisms.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.C.5.4
- McREL.9–12.11.2.5, 6

Lesson Objectives

- Summarize traits of echinoderm invertebrates.
- Outline the characteristics and classification of chordates.
- Describe the two subphyla of invertebrate chordates.

Lesson Vocabulary

- **chordates**: consists of all animals with a notochord, dorsal hollow nerve cord, post-anal tail, and pharyngeal slits during at least some stage of their life
- **echinoderms**: invertebrates such as sea stars and sand dollars that are characterized by a spiny endoskeleton, radial symmetry as adults, and a water vascular system
- **lancelets**: members of the subphylum Cephalochordata
- **tunicates**: members of the subphylum Urochordata are tunicates (also called sea squirts)

Teaching Strategies

Introducing the Lesson

Call students' attention to the echinoderms pictured in **Figure 18.29** of the FlexBook (reproduced below) and in **Table 18.2**.



(Sand dollar image copyright Noah Strycker, 2010, and sea star image copyright Mircea BEZERGHEANU, 2010, are used under licenses from Shutterstock.com. Feather star image courtesy of NOAA and under the public domain.)

TABLE 18.2: Classes of Living Echinoderms

	Class (includes) Crinoidea (feathers stars, sea lilies)
	
	Asteroidea (sea stars)
	
	Ophiuroidea (brittle stars)
	
	Echinoidea (sea urchins, sand dollars, sea biscuits, heart urchins)
	
	Holothuroidea (sea cucumbers)
	

(From top to bottom, images courtesy of: Eric Beach, under the public domain; NOAA, under the public domain; Larry Zetwoch/Florida Keys National Marine Sanctuary/NOAA, under the public domain; Tomasz Sienicki, under the Creative Commons license CC-BY-2.5; and NOAA, under the public domain.)

- **Ask:** Based on these examples, what traits do you think characterize the group of invertebrates called echinoderms? (*Sample answers:* radial symmetry, spiny outer covering.)

Tell students they will learn more about echinoderms in this lesson.

Discussion

The echinoderm skeleton, because of its spines, superficially resembles the exoskeleton of arthropods, but it is an endoskeleton, not an exoskeleton. Having an endoskeleton is an important trait of echinoderms, so be sure students understand how an endoskeleton differs from an exoskeleton. Discuss the differences between the two types of skeletons and also the pros and cons of each type. The *Comparison of Exoskeleton and Endoskeleton* (**Table 18.3**) lists points you may want to include in the discussion.

TABLE 18.3: short caption

Exoskeleton	Endoskeleton
develops from ectoderm	develops from mesoderm
located outside the body	located inside the body
made of chitin	made of calcium carbonate
provides support and a framework for muscle attachment	provides support and a framework for muscle attachment
provides great protection to the body	provides some protection to the body
helps the body retain water	does not help the body retain water
very rigid so may limit flexibility and growth	less rigid so less limiting to flexibility and growth

Differentiated Instruction

Provide less proficient readers with several cloze sentences, and have them complete the sentences as they read the lesson. Cloze sentences can be created by identifying the main idea sentences in each section of the lesson and leaving important terms blank for students to fill in. **LPR**

Enrichment

Ask a small group of students to make a poster of chordate embryology that includes labeled pictures of the embryos of a variety of chordates. The poster should convey two main points: (1) the embryos of chordates from diverse groups are remarkably similar in appearance; and (2) the embryonic stages typically have the four defining chordate traits even though the traits may be absent in the adult stages. Set aside some time for students to present their poster to the class.

Science Inquiry

Display examples (preserved specimens or photographs) of organisms in each of the five echinoderm classes. Ask students to try to identify the class to which each example belongs. Call on volunteers to explain the reasoning behind their classifications.

Overcoming Misconceptions

Many people confuse the notochord, which characterizes all chordates at some point in their life cycle, with the vertebral column, or backbone, that is found only in vertebrate chordates. Explain that the notochord is a rod-like

support structure that is a defining characteristic of all chordates, even those without a vertebral column. Add that the notochord may or may not be retained in adult nonvertebrate chordates and that it is replaced by the bony vertebral column in vertebrates.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

This chapter and the chapter before it describe the amazing diversity of invertebrates. The remaining chapters are devoted to vertebrates.

- How do vertebrates differ from invertebrates? What is the main distinguishing feature of vertebrates?
 - (The main distinguishing feature of vertebrates is a backbone, or vertebral column, which contains a spinal cord.)
- Many traits that evolved in invertebrates characterize all vertebrate animals as well. Which invertebrate traits do you think are also found in vertebrates such as humans?
 - (*Sample answers:* mesoderm, brain, segmentation.)

18.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER

19

TE From Fish to Birds

CHAPTER OUTLINE

19.1 OVERVIEW OF VERTEBRATES**19.2 FISH****19.3 AMPHIBIANS****19.4 REPTILES****19.5 BIRDS****19.6 WORKSHEET ANSWER KEYS**



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From Fish to Birds

Outline**Lesson 19.1: Overview of Vertebrates**

19.1.1 Characteristics of Vertebrates

- Vertebrate Endoskeleton
- Other Vertebrate Traits

19.1.2 Vertebrate Reproduction

19.1.3 Vertebrate Classification

19.1.4 Vertebrate Evolution

- Evolution of Fish
- Evolution of Other Vertebrate Classes
- Evolution of Endothermy

Lesson 19.2: Fish

19.2.1 Structure and Function in Fish

- Adaptations for Water
- Fish Organ Systems

19.2.2 Fish Reproduction and Development

- Spawning
- Fish Larvae

19.2.3 Classification of Fish

- Hagfish
- Lampreys
- Cartilaginous Fish
- Ray-Finned Fish
- Lobe-Finned Fish

19.2.4 Evolution of Fish

- Timing of Fish Evolution
- The Bony Fish

19.2.5 Ecology of Fish

- Fish Food
- Fish at Risk

Lesson 19.3: Amphibians

19.3.1 Structure and Function in Amphibians

- Amphibian Ectothermy
- Amphibian Organ Systems

19.3.2 Amphibian Reproduction and Development

- Amphibian Eggs
- Amphibian Larvae

19.3.3 Classification of Amphibians

- Frogs and Toads
- Salamanders and Newts

- Caecilians

19.3.4 Evolution of Amphibians

19.3.5 Ecology of Amphibians

- Amphibians as Prey and Predators
- The Threat of Amphibian Extinction

Lesson 19.4: Reptiles

19.4.1 Structure and Function in Reptiles

- Reptile Respiration
- Ectothermy in Reptiles
- Other Reptile Structures

19.4.2 Reptile Reproduction

- Amniotic Eggs
- Reptile Young

19.4.3 Classification of Reptiles

19.4.4 Evolution of Reptiles

- Synapsids and Sauropsids
- Rise and Fall of the Dinosaurs
- Evolution of Modern Reptile Orders

19.4.5 Ecology of Reptiles

- Reptile Diets
- Reptiles at Risk

Lesson 19.5: Birds

19.5.1 Structure and Function in Birds

- Wings and Feathers
- Organ Systems Adapted for Flight
- Nervous System and Sense Organs

19.5.2 Bird Reproduction

- Courtship and Mating
- Nesting and Incubation
- Hatchlings

19.5.3 Classification of Birds

- Flightless Birds

- Flying Birds

19.5.4 Evolution of Birds

- What was Deinonychus?
- Evolution of Flight

19.5.5 Ecology of Birds

- Bird Diets
- Birds at Risk
- KQED: The Golden Eagle
- KQED: The Great Horned Owl
- KQED: The Turkey Vulture

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 19.1:

Lesson	Number of Class Periods
19.1 Overview of Vertebrates	2.0
19.2 Fish	1.0
19.3 Amphibians	1.0
19.4 Reptiles	1.5
19.5 Birds	1.5

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. A bony fish (perch) dissection lab is available at this URL. (Lesson 19.2)

- <http://circle.adventist.org/files/nadspiritual/biosci/10.V.12-PerchBonyFish.pdf>

2. This URL provides a virtual frog dissection lab. (Lesson 19.3)

- http://www.mhhe.com/biosci/genbio/virtual_labs/BL_16/BL_16.html

3. In this lab, students will determine the relationships between leg length, stride length, and speed in humans. Then they will apply the relationships to fossil dinosaur data to determine the possible speed of bipedal dinosaurs. (Lesson 19.4)

- <http://www.accessexcellence.org/AE/AEPC/WWC/1995/dinotracks.php>

4. This URL has a chicken wing dissection lab. Students will observe the tissues that make up a bird's wing and relate wing structure to function. (Lesson 19.5)

- <http://www.accessexcellence.org/AE/ATG/data/released/0498-JimEkstrom/>

5. In this AP-level lab, students will simulate birds with different types of beaks and try to gather various kinds of seeds. After completing the simulation activity, students will relate their results to natural selection for beak type. (Lesson 19.5)

- http://www.accessexcellence.org/AE/AEC/AEF/1996/sprague_beaks.php

These Web sites may also be helpful:

1. The URLs below provide access to National Geographic's collection of videos, photographs, and news stories about fish, amphibians, reptiles, and birds.

- <http://animals.nationalgeographic.com/animals/fish/>
- <http://animals.nationalgeographic.com/animals/amphibian/>
- <http://animals.nationalgeographic.com/animals/reptile/>
- <http://animals.nationalgeographic.com/animals/bird/>

2. A comprehensive searchable fish database is available at this URL.

- <http://www.fishbase.org/search.php>

3. The Web site below provides excellent reptile photographs and numerous news stories and science articles relating to reptiles.

- <http://www.livescience.com/reptiles/>

4. At the Web site below, you can find up-to-date phylogenies (based on molecular data) of extant reptiles and detailed fact sheets about particular reptile families and subfamilies.

- <http://www.reptile-database.org/>

5. This Web site has many excellent resources on birds, including research articles, identification guides, taxonomies, and conservation news. The nest cams are a must-see for students when you talk about parental behavior in birds.

- <http://www.birds.cornell.edu/>

6. This Web site accompanies the PBS series called *The Life of Birds*. It provides interesting articles on several important topics, including bird evolution, bird brains and intelligence, and bird song. The site also describes several classroom activities related to the topics.

- <http://www.pbs.org/lifeofbirds>

7. The Berkeley Museum of Paleontology Web site has detailed information on birds, including modules on their life history, ecology, systematics, morphology, and fossil record. The site also links with an online museum exhibit entitled *Vertebrate Flight*.

- <http://www.ucmp.berkeley.edu/diapsids/birds/birdintro.html>

19.1 Overview of Vertebrates

Key Concept

Vertebrates are a subphylum of chordates that have a vertebral column and an endoskeleton of cartilage or bone. They have complex organ systems, reproduce sexually, and have three possible reproductive strategies (ovipary, ovovivipary, and vivipary). Living vertebrates are placed in nine classes: hagfish, lampreys, cartilaginous fish, ray-finned fish, lobe-finned fish, amphibians, reptiles, birds, and mammals. The earliest vertebrates resembled hagfish. Amphibians were the first tetrapod vertebrates and the first vertebrates to live on land. Reptiles were the first amniotic vertebrates. Mammals and birds both evolved from reptile-like ancestors. Birds are endotherms with many adaptations for flight.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6
- AAAS.9–12.5.F.6
- McREL.9–12.11.2.5

Lesson Objectives

- List the characteristics of vertebrates.
- Explain how vertebrates reproduce.
- Identify the nine classes of vertebrates.
- Give an overview of vertebrate evolution.

Lesson Vocabulary

- **bone:** hard tissue in most vertebrates that consists of a collagen matrix, or framework, filled in with minerals such as calcium
- **cartilage:** dense connective tissue that provides a smooth surface for the movement of bones at joints
- **cranium:** part of a vertebrate endoskeleton that encloses and protects the brain; also called the skull
- **ectothermy:** regulation of body temperature from the outside through behavioral changes, such as basking in the sun
- **endothermy:** regulation of body temperature from the inside through metabolic or other physical changes
- **kidney:** main organ of the excretory system that filters blood and forms urine
- **ovipary:** type of reproduction in which an embryo develops within an egg outside the mother's body
- **ovovivipary:** type of reproduction in which an embryo develops inside an egg within the mother's body but in which the mother provides no nourishment to the developing embryo in the egg

- **vertebrae:** (singular, vertebra) repeating bony units that make up the vertebral column of vertebrates
- **vivipary:** type of reproduction in which an embryo develops within, and is nourished by, the mother's body

Teaching Strategies

Introducing the Lesson

Remind students that vertebrates belong to the chordate phylum. Ask them to recall what they know about chordates from the *From Sponges to Invertebrate Chordates* chapter. List their responses on the board.

- **Ask:** How do vertebrate chordates differ from invertebrate chordates?
 - (Vertebrate chordates have a backbone; invertebrate chordates do not.)

Tell students they will learn more about vertebrates and how they differ from other animals when they read this lesson.

Demonstration

Obtain a model human or other vertebrate skeleton. Point out the individual vertebrae of the vertebral column, cranium, limb girdles, and limbs. Give students a chance to inspect and manipulate the skeleton. Discuss the functions of the vertebral column and the rest of the endoskeleton in vertebrates.

Differentiated Instruction

Pair beginning and advanced English language learners, and ask partners to make a Frayer model for the term “vertebrate.” The partners should draw a large box and divide it into quarters labeled “Definition,” “Drawing,” “Example,” and “Non-example.” Then they should work together to fill in the boxes. Invite the students to share their work with the rest of the class. **ELL**

Enrichment

Ask a few students to make criss-cross or other word puzzles using lesson vocabulary terms (refer them to the URL below). Make copies of the puzzles for other students to complete as a review of the terms.

- <http://www.discoveryeducation.com/free-puzzlemaker/>

Science Inquiry

The URL below provides a diversity of materials for student inquiry into the fossil record and patterns of vertebrate evolution. The materials include a PowerPoint presentation, pre- and post-activity quizzes, images of vertebrates, charts of the geologic time scale and fossil record, and student handouts.

- <http://www.indiana.edu/ensiweb/lessons/pat.in.time.html>

Overcoming Misconception

Misconceptions about ectothermy and endothermy are common. Three are listed below. Discuss these misconceptions with the class and make sure students know the facts.

- Misconception: Animals are classified as ectotherms or endotherms based on whether they have variable or constant body temperatures.
 - (*Fact:* It is the source of heat used to maintain body temperature that distinguishes ectotherms from endotherms. Ectotherms use heat in the environment; endotherms generate their own heat.)
- Misconception: Ectotherms are “cold-blooded” and endotherms are “warm-blooded.”
 - (*Fact:* Ectotherms do not necessarily have low body temperatures. In fact, when basking in the sun, an ectotherm may have a higher body temperature than an endotherm.)
- Misconception: Ectothermy and endothermy are mutually exclusive strategies.
 - (*Fact:* An animal may use both strategies. For example, a bird is an endotherm, but it may also warm itself in the sun like an ectotherm.)

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

The earliest and simplest vertebrates are fish. Fish also have the greatest number of vertebrate classes. Think about some of the fish you are familiar with, such as fish you eat or fish you may have seen in aquariums.

- Using the “Classes of Vertebrates” table (**Table 19.2** in FlexBook), which fish class or classes should these fish be placed in?
 - (Answers may vary, depending on the types of fish that students name.)
- How are all of the fish the same? In what ways do they differ?
 - (*Sample answers:* All of the fish have gills, fins, and scales. They differ in size and shape.)

19.2 Fish

Key Concept

Fish are aquatic, ectothermic vertebrates. Many structures in fish are adaptations for their aquatic lifestyle, such as their streamlined body, gills, and fins. Nearly all fish reproduce sexually, and most are oviparous. Fish eggs hatch into larvae that are different from the adult form of the species. Living species of fish are placed in five classes: hagfish, lampreys, cartilaginous fish, ray-finned bony fish, and lobe-finned bony fish. The earliest fish evolved about 550 million years ago. Over time, fish evolved a complete vertebral column, jaws, and an endoskeleton made of bones instead of cartilage. Fish live throughout the ocean and in freshwater lakes and streams. Most fish are predators. Many are threatened by human actions.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6, NSES.9–12.C.4.5; NSES.9–12.C.5.4; NSES.9–12.F.6.5
- AAAS.9–12.5.D.3
- McREL.9–12.11.2.5, 6

Lesson Objectives

- Describe structure and function in fish.
- Explain how fish reproduce and develop.
- Give an overview of the five living classes of fish.
- Summarize the evolution of fish.
- Outline the ecology of the different fish classes.

Lesson Vocabulary

- **fish:** ectothermic, aquatic vertebrate with a streamlined body and gills for absorbing oxygen from water
- **spawning:** depositing large numbers of gametes in the same place and at the same time by fish or amphibians
- **swim bladder:** balloon-like internal organ in most fish that can be used to move up or down through the water column by changing the amount of gas it contains

Teaching Strategies

Introducing the Lesson

Introduce fish by presenting students with the following facts and figures about fish:

- More than 25,000 species of fish are known on Earth.
- An estimated 15,000 fish species have yet to be identified.
- There are more species of fish than all the species of amphibians, reptiles, birds and mammals combined.

Tell students they will learn more about this important class of vertebrates in this lesson.

Activity

Have students do the fish sorting activity at the URL below. They will sort nine fish (photos) based on variables of their own choosing. Have students compare their classification with those of other students. Then discuss with the class how choice of variables affects classification. The activity will help students focus on the diversity of fish traits and also give them practice in classification.

- http://www.pbs.org/wgbh/nova/teachers/activities/2215_reef.html

Differentiated Instruction

Work with less proficient readers to make a compare/contrast table for the five classes of fish described in the lesson. Include examples of fish in each class. **LPR**

Enrichment

Ask interested students to learn more about recent and projected fish extinctions and their causes (e.g., the building of dams, overfishing, water pollution, invasive species, climate change). Then have students debate which cause or causes they think are most important. After the debate, discuss with the class how fish extinctions might affect aquatic ecosystems.

- http://www.biologicaldiversity.org/programs/biodiversity/elements_of_biodiversity/extinction_crisis/index.html
- http://www.endangeredspecieshandbook.org/dinos_fish.php
- <http://www.seaweb.org/resources/briefings/marinebio.php>

Science Inquiry

Engage students in the activity at the URL below. They will observe fish behavior and generate hypotheses about it based on their observations. They will also gather and analyze numerical data.

- http://scene.asu.edu/habitat/activities/attract_fish.html

Overcoming Misconceptions

There are many common misconceptions about sharks. You can read about several of them at the URLs below. Discuss these misconceptions with your students and make sure they know the facts.

- <http://www.sharks.org.za/popular-misconceptions.html>
- <http://www.pbs.org/wgbh/nova/sharks/masters/myths.html>
- http://news.nationalgeographic.com/news/2004/01/0123_040123_tvgreatwhiteshark.html

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Lobe-finned fish were the ancestors of amphibians, which were the first vertebrates to live on land.

- What are some examples of amphibians?
 - (*Sample answer:* frogs, toads, salamanders.)
- How do you think amphibians might differ from lobe-finned fish? What adaptations do you think amphibians needed to evolve in order to live on land?
 - (Amphibians differ in having four legs and true lungs for breathing air. These are traits they needed to live on land.)

19.3 Amphibians

Key Concept

Amphibians are ectothermic vertebrates that divide their time between freshwater and terrestrial habitats. They are the first true tetrapods. Amphibians reproduce sexually, but lacking amniotic eggs, they must reproduce in water. Their larvae go through metamorphosis to change into the adult form. Living species of amphibians are placed in three orders: frogs and toads, salamanders and newts, and caecilians. Amphibians evolved about 365 million years ago, and as the earliest land vertebrates, they were highly successful until reptiles evolved. Today, amphibians are found on every continent except Antarctica. They are predators of invertebrates and prey of other vertebrates. Many amphibian species are at risk of extinction because of human actions.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.C.4.5; NSES.9–12.C.5.4; NSES.9–12.F.6.5
- AAAS.9–12.5.D.3
- McREL.9–12.11.2.5

Lesson Objectives

- Describe structure and function in amphibians.
- Outline the reproduction and development of amphibians.
- Identify the three living amphibian orders.
- Describe how amphibians evolved.
- State where amphibians live and how they obtain food.

Lesson Vocabulary

- **amphibian**: ectothermic, tetrapod vertebrate that may live on land but must return to water in order to reproduce
- **cloaca**: body cavity with a single opening in amphibians, reptiles, and monotreme mammals that collects and excretes wastes from the digestive and excretory systems and gametes from the reproductive system
- **keratin**: tough, fibrous protein in skin, nails, and hair
- **tetrapod**: vertebrate with four legs (amphibian, reptile, bird, or mammal)

Teaching Strategies

Introducing the Lesson

Tell students that the word “amphibian” literally means “double life.” Based on what they already know about amphibians, challenge students to explain why amphibians have been given this name.

(*Sample answer:* Amphibians have an aquatic life as larvae and a terrestrial life as adults.) Tell students they will learn more about amphibians in this lesson.

Building Science Skills

Divide the class into groups, and provide each group with a photo of an unfamiliar amphibian. Try to select species that will be relatively easy to identify based on the photos alone (e.g., ringed salamander, black-spotted newt, green toad, tailed frog). You might provide a limited amount of additional information about each species as well, such as range or habitat. Then ask each group to use library or online field guides to identify its assigned amphibian (see URLs below). Give groups a chance to share their results and explain how they arrived at their answers. This activity will help students appreciate the diversity and range of amphibians and how they are classified. It will also give them practice making observations and using field guides.

- http://www.enature.com/fieldguides/view_default.asp?curGroupID=7#38;shapeID=1055
- <http://www.npwrc.usgs.gov/resource/herps/amphibid/index.htm>

Differentiated Instruction

Suggest that students outline the lesson. Outlining is a good skill to develop because it helps students read critically. In constructing an outline, they must make decisions about how content is organized and which content is most important. Show students how to use the heading structure of the lesson as a guide in constructing their outline.

ELL, LPR

Enrichment

Interested students can explore the evolution of amphibians and the amphibian fossil record at the URL below. Encourage them to make a PowerPoint to share what they learn.

- <http://www.ucmp.berkeley.edu/vertebrates/tetrapods/amphibfr.html>

Science Inquiry

Point out that thousands of amphibian species are threatened with extinction. Some of them are keystone species. They are important food sources for other vertebrates and important predators of invertebrates. Have students predict how amphibian extinctions might affect other organisms in their communities.

Overcoming Misconceptions

Ask how many students have heard the myth that toads cause warts. (Most students are likely to have heard this myth.) Explain that the “warts” on a toad are normal glands in its skin, whereas the warts on human skin are caused by a virus that spreads from person to person.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Amphibians gave rise to reptiles, which replaced them as the dominant land vertebrates.

- Besides amniotic eggs, can you think of other ways that reptiles differ from amphibians?
 - (*Sample answer:* Unlike amphibians, reptiles have scaly skin and do not go through a larval stage.)
- What other adaptations might reptiles have evolved that contributed to their success on land?
 - (*Sample answer:* Reptiles might have evolved a bigger brain, so they would be more intelligent.)

19.4 Reptiles

Key Concept

Reptiles are a class of ectothermic, tetrapod vertebrates. They have adaptations for living on dry land, such as scales and efficient lungs. Most reptiles reproduce sexually. They produce amniotic eggs that can be laid on land. Living reptiles species are placed in four orders: Crocodilia (crocodiles and alligators), Sphenodontia (tuataras), Squamata (lizards and snakes), and Testudines (turtles and tortoises). The earliest reptiles had evolved by 315 million years ago. Dinosaurs evolved around 225 million years ago and dominated animal life on land until they went extinct 65 million years ago. Other reptiles survived and evolved into the classes of reptiles that exist today. Reptiles can be found on every continent except Antarctica. They live in a wide range of habitats. Most are carnivores. Many reptile species are at risk of extinction because of human actions.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.C.4.5; NSES.9–12. C.5.4; NSES.9–12.F.6.5
- AAAS.9–12.5.D.3; AAAS.9–12.5.F.6
- McREL.9–12.11.2.5

Lesson Objectives

- Give an overview of form and function in reptiles.
- Describe the amniotic egg and reptile reproduction.
- Identify the four living orders of reptiles
- Summarize how reptiles evolved.
- Describe where reptiles live and what they eat.

Lesson Vocabulary

- **diaphragm:** large, sheet-like muscle below the lungs that allows breathing to occur when it contracts and relaxes
- **reptile:** ectothermic, tetrapod vertebrate that lays amniotic eggs; includes crocodiles, lizards, snakes, and turtles
- **sauropsid:** type of early amniote that evolved during the Carboniferous Period and eventually gave rise to dinosaurs, reptiles, and birds
- **synapsid:** type of early amniote that evolved during the Carboniferous Period and eventually gave rise to mammals

Teaching Strategies

Introducing the Lesson

Most students will have some familiarity with reptiles. Use what they already know to introduce the lesson.

- **Ask:** What are some animals that are reptiles?
 - (*Sample answers:* snakes, lizards, alligators, turtles.)
- **Ask:** What are some characteristics of reptiles?
 - (*Sample answers:* Reptiles have scales; they are “cold-blooded”; they lay eggs.)

Tell students they will learn more about reptiles when they read this lesson.

Building Science Skills

If you or any of your students have pet reptiles, try to arrange to have the reptiles in class for at least one period so students can observe them. Tell them to look for behaviors such as locomotion, feeding, and sensing. Alternatively, you might ask a local herpetologist or zoo representative to show reptiles to the class and discuss their traits. Students can also observe reptiles by watching online videos at the URLs below.

- http://www.naturefootage.com/stock_footage/reptile_footage.htm
- <http://www.reptileknowledge.com/videos.php>

Differentiated Instruction

Help less proficient readers focus on the most important points when they read by having them construct a main ideas/details chart. Tell them to draw a line down the middle of a sheet of paper and write the main ideas on the left side of the paper and corresponding details on the right side. There should be at least one main idea for each of the major headings in the lesson. **LPR**

Enrichment

Have interested students learn how global climate change is threatening the survival of certain reptiles by changing the gender of their embryos and thereby the sex ratios in reptile populations. Students can start with the Web sites below. Ask them to share what they learn with the class. As a class, discuss how changing sex ratios might affect reproduction and population growth.

- <http://news.nationalgeographic.com/news/2006/11/061110-tuataras.html>
- <http://blogs.discovermagazine.com/80beats/2008/07/02/global-warming-could-bring-single-sex-doom-to-ancient-reptile/>

Overcoming Misconceptions

Perhaps because of their role in folk tales and religion, there are many myths about snakes. Some of them are listed below. Use the myths as true-false statements to uncover student misconceptions. Call on volunteers to reword the myths as true statements.

- a. Snakes do not have bones.
- b. Snakes feel cold and slimy.
- c. Most snakes have poisonous venom.
- d. All snakebites are fatal unless treated immediately.
- e. Snakes can sting you with their tongue.
- f. Some snakes have stingers in their tail.
- g. Snakes can hypnotize you with their eyes.
- h. Snakes are aggressive and chase people.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Birds evolved from a reptile ancestor but they are very different from reptiles today. Birds are also the most numerous tetrapod vertebrates.

- What are some traits that differ in birds and modern reptiles?
 - (*Sample answer:* Unlike modern reptiles, birds have wings and feathers. They are also endothermic.)
- What traits might explain why birds have been so successful?
 - (*Sample answer:* the ability to fly and maintain a constant internal body temperature.)

19.5 Birds

Key Concept

Birds are endothermic tetrapod vertebrates. They are bipedal, with forelimbs modified as wings. Birds also have feathers and other adaptations for flight. Birds reproduce sexually and lay amniotic eggs with hard shells. Most bird species have a relatively long period of parental care. Living species of birds are divided into many different orders. The most common orders include landfowl, waterfowl, shorebirds, diurnal and nocturnal raptors, parrots, and perching birds. Birds are thought to have evolved from a dinosaur ancestor around 150 million years ago. Today they live in most terrestrial habitats on all continents. There are also aquatic species. Birds occupy a wide range of ecological positions. Human actions have caused the extinction of many bird species and many more are threatened with extinction.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.C.4.5; NSES.9–12.C.5.4; NSES.9–12.C.6.2; NSES.9–12.F.6.5
- AAAS.9–12.5.D.3; AAAS.9–12.5.F.6
- McREL.9–12.11.2.5

Lesson Objectives

- Outline structure and function in birds.
- Describe how birds reproduce and care for their young.
- Identify several common orders of modern birds.
- Give an overview of the evolution of birds.
- Summarize the diversity of bird habitats and food sources.

Lesson Vocabulary

- **bird**: bipedal, endothermic, tetrapod vertebrate that lays amniotic eggs and has wings and feathers
- **courtship**: animal behavior that is intended to attract a mate
- **crop**: sac-like structure in the digestive system of birds that stores and moistens food before it is digested
- **generalist**: organism that can consume many different types of food
- **gizzard**: food-grinding organ in the digestive system of birds and some other animals that may contain swallowed stones
- **incubation**: period of bird reproduction when one or both parents sit on, or brood, the eggs in order to keep them warm until they hatch

Teaching Strategies

Introducing the Lesson

Students may know a fair amount about birds before reading the lesson. Call on them to state any facts they already know, either from previous science classes or from personal experience. Underscore the most important facts they mention (e.g., birds are “warm-blooded,” have feathers, lay eggs, can fly). When students run out of facts, say they will learn more about birds when they read this lesson.

Building Science Skills

Give students an opportunity to observe flight and non-flight bird feathers under a microscope. You may use feathers you have collected, feathers from a pet store or craft store, or prepared slides of feathers if you have them. Ask students to sketch their observations and describe how the two types of feathers differ. Have them relate the structural differences in the feathers to their different functions.

Differentiated Instruction

To help focus their reading, ask less proficient readers to make a KWL chart about birds. Before they read the lesson, they should list what they already know about birds in the first column and what they want to know in the second column. After they read the lesson, they should write what they learned in the third column. **LPR**

Enrichment

Ask any students proficient in physical science to use diagrams to teach the class about the aerodynamics of bird flight. They should explain how differences in air pressure create lift and allow birds to fly. They can find more information at the Web sites below.

- <http://www.earthlife.net/birds/flight.html>
- <http://www.hawkquest.org/TA/XL/AirPress.pdf>
- <http://www.paulnoll.com/Oregon/Birds/flight-aerodynamics.html>

Science Inquiry

Have students make observations and keep a field log of the characteristics and behaviors of wild birds in their yard or neighborhood or on the school campus. Tell them to observe specific features, such as beaks, feathers, and feet, and to watch for different types of behavior, such as calling, singing, flying, feeding, and preening. Students should record all of their observations, including the date, time of day, and location in which each characteristic or behavior was observed. Ask students to share some of their observations and explain the purpose of the traits and behaviors they observed. Discuss the role of record keeping in scientific research.

Overcoming Misconceptions

Common misconceptions about birds and flight are listed below. Review them with students and explain why they are false. Doing so will help students understand the basic defining characteristics of the avian class.

- a. All birds can fly.

- b. All flying animals are birds.
- c. Bats are birds because they can fly.
- d. Penguins are not birds because they cannot fly.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Birds share a number of important traits with mammals, including a four-chambered heart and endothermy. The next chapter describes mammals in detail.

- What are some examples of mammals?
 - (Encourage a wide range of responses, but point out any errors.)
- What other traits do you think mammals might have? What traits do you think set mammals apart from all other vertebrates, including birds?
 - (Students might know that mammals have hair or fur and mammary glands, or that most mammals give birth to live young instead of laying eggs.)

19.6 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER

20

TE Mammals and Animal Behavior

CHAPTER OUTLINE

20.1 MAMMALIAN TRAITS**20.2 REPRODUCTION IN MAMMALS****20.3 EVOLUTION AND CLASSIFICATION OF MAMMALS****20.4 OVERVIEW OF ANIMAL BEHAVIOR****20.5 WORKSHEET ANSWER KEYS**



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Mammals and Animal Behavior

Outline**Lesson 20.1: Mammalian Traits**

20.1.1 Characteristics of Mammals

20.1.2 Structure and Function in Mammals

- How Mammals Stay Warm
- How Mammals Stay Cool
- Eating and Digesting Food
- Lungs and Heart of Mammals
- The Mammalian Brain
- Intelligence of Mammals
- Social Living in Mammals
- Locomotion in Mammals

Lesson 20.2: Reproduction in Mammals

20.2.1 Therian Mammals

20.2.2 Placental Mammals

- The Placenta
- Pros and Cons of Placental Reproduction

20.2.3 Marsupials

- The Marsupial Embryo
- Pros and Cons of Marsupial Reproduction
- KQED: The North American Marsupial: The Opossum

20.2.4 Monotremes

- Eggs and Lactation in Monotremes
- Pros and Cons of Monotreme Reproduction

Lesson 20.3: Evolution and Classification of Mammals

20.3.1 Mammalian Ancestors

- Pelycosaurs
- Therapsids
- Cynodonts

20.3.2 Evolution of Early Mammals

- Evolution of Monotremes
- Evolution of Marsupials
- Evolution of Placental Mammals

20.3.3 Evolution of Modern Mammals

- Traditional View
- View from the Mammalian Supertree

20.3.4 Classification of Placental Mammals

- Traditional Classification
- Phylogenetic Classification

Lesson 20.4: Overview of Animal Behavior

20.4.1 Studying Animal Behavior

20.4.2 Evolution of Animal Behavior

- Nature vs. Nurture

- How Behaviors Evolve

20.4.3 Innate Behavior

- Significance of Innate Behavior
- Intelligence and Innate Behavior

20.4.4 Learned Behavior

20.4.5 Types of Animal Behavior

- Social Behavior and Cooperation
- Communication
- Cyclic Behaviors
- KQED: Flyways: The Migratory Routes of Birds
- Aggression
- Competition
- Mating and Courtship
- Parental Care

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 20.1:

Lesson	Number of Class Periods
20.1 Mammalian Traits	2.0
20.2 Reproduction in Mammals	1.0
20.3 Evolution and Classification of Mammals	1.5
20.4 Overview of Animal Behavior	2.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this lab, students will create a model of the four-chambered mammalian heart and simulate the heart's pumping action. (Lesson 20.1)

- <http://www.thefreelibrary.com/Heart+smarts:+Celebrate+Valentine's+Day+with+science+activities+that...-a0130137105>

2. This lab requires students to classify mammals in their correct orders by comparing their traits. (Lesson 20.3)

- http://www.skitsap.wednet.edu/14692066152915383/lib/14692066152915383/Lab-_Classifying_Mammals.pdf

3. Students can investigate behavioral responses to stimuli in insects using materials at either of the two URLs below. (Lesson 20.4)

- http://www.redorbit.com/news/science/83594/insects_in_the_classroom_a_study_of_animal_behavior/
- <http://www.isu.edu/biolearn/Lesson%20Plans/behavior/lessonplans/LessonAnimalBehavior.doc>

4. You can choose from several online animal behavior labs at this Web site. Topics range from constructing ethograms to studying the human behavior of weight lifting. (Lesson 20.4)

- <http://www.animalbehavior.org/ABSEducation/laboratory-exercises-in-animal-behavior>

These Web sites may also be helpful:

1. The Web sites below are searchable online field guides that you and your students can use to find descriptions and photographs of mammals. They are good sources of examples when you teach this chapter.

- <http://www.mnh.si.edu/mna/>
- http://www.enature.com/guides/select_Mammals.asp

2. This American Museum of Natural History online exhibit provides virtual tours, videos, interactive activities, timelines, and articles on living and extinct mammals. It focuses on mammalian adaptations and evolution, and includes both student and teacher pages.

- <http://www.amnh.org/education/resources/rfl/web/extrememammalsguide/9-12-activities.html>

3. This Web site suggests a variety of videos, activities, and discussion topics that relate to animal behavior.

- http://www.accessexcellence.org/AE/AEC/AEF/1994/pebbles_behavior.php

4. Students can follow the field research of zoo scientists studying applied animal behavior by reading their online field diaries. The Web site also offers articles, videos, and activities.

- <http://www.lpzoo.org>

5. This issue of the National Science Teachers Association monthly newsletter focuses on animal behavior. It contains articles and links that are useful for both teachers and students.

- <http://science.nsta.org/enewsletter/2002-08/member.htm>

20.1 Mammalian Traits

Key Concept

Mammals are a class of endothermic vertebrates. They have four limbs and produce amniotic eggs. The mammal class is defined by the presence of mammary glands and hair or fur. Mammals have several ways to regulate temperature, including a high metabolic rate and sweating. They have four types of teeth, so they can eat a wide range of foods. They have a big brain and a high level of intelligence. They also have a diversity of modes of locomotion.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.C.5.4; NSES.9–12.C.6.1, 2, 3
- McREL.9–12.11.2.5

Lesson Objectives

- List characteristics of mammals.
- Describe structure and function in mammals.

Lesson Vocabulary

- **alveoli:** (singular, alveolus) tiny sacs at the ends of bronchioles in the lungs where pulmonary gas exchange takes place
- **arboreal:** of or pertaining to trees, as in arboreal, or tree-living, mammal
- **cerebrum:** largest part of the brain; controls conscious functions such as reasoning and sight
- **lactation:** production of milk for an offspring by mammary glands, which occurs in all female mammals after giving birth or laying eggs
- **mammal:** endothermic, tetrapod vertebrate that lays amniotic eggs and has mammary glands (in females) and hair or fur
- **mammary gland:** gland in female mammals that produces milk for offspring
- **neocortex:** layer of nerve cells covering the cerebrum of the mammalian brain that plays an important role in many complex brain functions

Teaching Strategies

Introducing the Lesson

Lead students in brainstorming what they already know about mammals, such as examples of mammals and mammalian traits. Tell students they will learn more about mammals in this lesson.

Activity

Have students explore mammals at the University of Michigan's Animal Diversity Web site (first URL below). They can read articles, examine pictures and specimens, hear mammal sounds, and see the classification of a huge diversity of mammals. Ask them to complete the worksheet *High School Sample Exercise* (second URL below) to organize what they learn about mammals at the Web site.

- <http://animaldiversity.ummz.umich.edu/site/accounts/information/Mammalia.html>
- <http://animaldiversity.ummz.umich.edu/site/teach/mammalHS.html>

Differentiated Instruction

Pair less proficient with more proficient readers, and have partners make a cluster diagram for mammals. Diagrams should include important traits that define the mammal class. Ask partners to discuss how the traits are related to one another (e.g., how hair and sweat glands are related to endothermy). Advise students to keep their cluster diagram in their science notebook. **LPR**

Enrichment

Interested students can explore a career in marine mammal biology by learning about the work of Dr. Kristen Laidre (see URLs below). Dr. Laidre is a polar marine mammal researcher at the University of Washington. She focuses her research on large mammalian predators in the Arctic. Invite the students to share what they learn with the rest of the class.

- <http://oceanexplorer.noaa.gov/edu/oceanage/06laidre/welcome.html>
- <http://staff.washington.edu/klaidre/>

Science Inquiry

Ask students to compare sketches of the limb bones of several mammals that have different modes of locomotion (see URL below for examples).

- http://www.pbs.org/wgbh/evolution/library/03/1/l_031_01.html
- **Ask:** How are the limb bones similar? (They include all the same bones in the same general arrangement.)
- **Ask:** How are the limb bones different? (They have different sizes and proportions.)
- **Ask:** How do the limb bones reflect evolutionary relatedness of the different mammals? (The limb bones are homologous structures. They all develop from the same embryonic structures, which were inherited from a common ancestor.)

Follow up by directing students to the URL below. They can read about newly discovered genes that control how limb bones develop in the embryos of different mammals.

- <http://anthropology.net/2008/01/24/the-majority-of-human-genome-evolved-about-500-million-years-ago/>

Overcoming Misconceptions

Use the assessment probe at the URL below to elicit student ideas about mammals. The probe was designed to reveal misconceptions about what it means to be a mammal. Call on students to share their responses, and discuss any misconceptions they reveal.

- http://onramp.nsd.edu/eserv/onramp:16090/Is_It_a_Mammal.pdf

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Most mammals are born as live young, as opposed to hatching from eggs. Giving birth to live young has certain advantages over egg laying.

- What do you think the advantages of live births might be? How might this form of reproduction help ensure that the offspring survive?
 - (*Sample answer:* The embryo is safer inside the mother's body than it is in an egg outside her body. This might help ensure that offspring survive.)
- Do you think that giving birth to live young, as opposed to laying eggs, might have disadvantages? What might the disadvantages be?
 - (*Sample answer:* It might be harder on the mother. It might even put her life in danger.)

20.2 Reproduction in Mammals

Key Concept

Therian mammals give birth to an embryo or infant rather than laying eggs. The female reproductive system of a therian mammal includes a uterus and a vagina. There are two groups of therian mammals: placental mammals and marsupials. Placental mammals give birth to a relatively large and mature fetus. This is possible because they have a placenta to nourish the fetus and protect it from the mother's immune system. Marsupials give birth to a tiny, immature embryo. It continues to grow and develop in a pouch on the mother's belly. Monotremes reproduce by laying eggs. They have a cloaca instead of a uterus and vagina.

Standards

- none

Lesson Objectives

- Describe female reproductive structures of therian mammals.
- Outline reproduction in placental mammals.
- Explain how marsupials reproduce.
- Describe monotreme reproduction.

Lesson Vocabulary

- **marsupial**: therian mammal in which the embryo is born at an early, immature stage and completes its development outside the mother's body in a pouch on her belly
- **monotreme**: type of mammal that reproduces by laying eggs
- **placenta**: temporary organ that consists of a large mass of maternal and fetal blood vessels through the mother's and fetus's blood exchange substances
- **placental mammal**: therian mammal in which a placenta develops during pregnancy to sustain the fetus while it develops inside the mother's uterus
- **therian mammal**: viviparous mammal that may be either a marsupial or placental mammal
- **uterus**: (plural, uteri) female reproductive organ in therian mammals where an embryo or fetus grows and develops until birth
- **vagina**: female reproductive organ that receives sperm during sexual intercourse and provides a passageway for a baby to leave the mother's body during birth

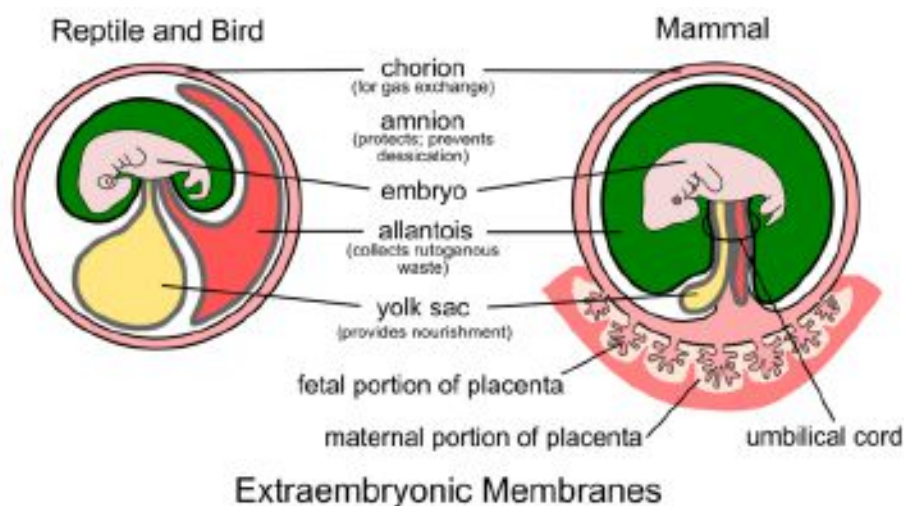
Teaching Strategies

Introducing the Lesson

Ask students if they know how long the human gestation period is, that is, how long a fetus is carried inside the mother's body (about 9 months). State that the longest gestation period in land mammals is 22 months for elephants. Point out that a female needs extra energy and may have reduced mobility during pregnancy, yet a long gestation period has reproductive advantages. Ask students to predict what the advantages might be. Tell them they can see if their predictions are correct when they read this lesson about mammalian reproduction.

Building Science Skills

Make an overhead transparency or individual student copies of the image below.



(Image courtesy of CK-12 Foundation and under the license of CC-BY-NC-SA 3.0.)

- **Ask:** Which extraembryonic structures are found in mammals but not in reptiles or birds? (Placenta and umbilical cord.)

Discuss how the placenta forms from both embryonic and maternal membranes and how it protects and nourishes the developing embryo or fetus. Have students find the fetal and maternal portions of the placenta in the figure. Discuss how the villi of the fetal portion increase the surface area for the transfer of substances between mother and fetus, and explain how this occurs.

- **Ask:** What is the role of the umbilical cord? (It connects the embryo or fetus to the placenta.)

Differentiated Instruction

Pair English language learners with native English speakers, and have partners make a table comparing and contrasting reproduction in eutherian, metatherian, and prototherian mammals. Their table should describe each type of reproduction and include at least one pro and one con of each type. **ELL**

20.2. REPRODUCTION IN MAMMALS

Enrichment

Ask any students who need extra challenges to create a Web site about marsupial and monotreme mammals. Encourage the rest of the class to visit the Web site to learn more about these less familiar mammals.

Science Inquiry

Have students assume they are biologists who have discovered an unknown species. The new species was found in South America and has the following characteristics: cloaca is not present; mother produces milk to feed the newborn; newborn nurses from a nipple on the mother's body; newborn is an embryo. Ask students to explain how they would classify the species, based on these characteristics. (The species is in the infraclass Metatheria, or marsupial mammals, which is in the subclass Theria, or viviparous mammals.)

Overcoming Misconceptions

Many people think marsupials are found only in Australia. Make sure students are aware of marsupials that are found elsewhere, such as opossums, which are found in North and South America.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Monotremes are less similar to therian mammals than the two groups of therian mammals are to each other.

- How might the different groups of mammals have evolved?
 - (*Sample answer:* They might have diverged from common ancestor at different times.)
- Which group of mammals do you think evolved first?
 - (*Sample answer:* monotremes.)

20.3 Evolution and Classification of Mammals

Key Concept

Amniotes called synapsids were the ancestors of mammals. Some of them evolved into therapsids, which became widespread during the Permian Period. The few therapsids that survived the Triassic takeover were small, arboreal insect eaters. They were also nocturnal, which may explain why they survived and evolved still more mammalian traits. Monotremes evolved about 150 million years ago, and marsupials evolved about 130 million years ago. Placental mammals evolved about 110 million years ago and became the main land animals everywhere except Australia. Traditional and phylogenetic classifications of mammals differ.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.G.1.1
- AAAS.9–12.1.A.3; AAAS.9–12.5.A.2; AAAS.9–12.5.F.2
- McREL.9–12.11.2.5, 6; McREL.9–12.11.3.3; 13.2.2, 6

Lesson Objectives

- Describe the therapsid ancestors of mammals.
- Outline the evolution of monotreme, marsupial, and placental mammals.
- Summarize the evolution of modern mammals.
- Contrast traditional and phylogenetic classifications of mammals.

Lesson Vocabulary

- **therapsid**: type of extinct organism that lived during the Permian Period and gave rise to mammals

Teaching Strategies

Introducing the Lesson

Show students a picture, like the one below, of a bat in flight. Ask them in which class of animals they would place the bat. Would they classify it as a mammal or a bird? Tell them they will learn in this lesson why these flying animals are classified as mammals.



(Image of bat copyright dean bertoncelj, 2011. Used under license from Shutterstock.com.)

Building Science Skills

Using information in the lesson, have pairs of students create a phylogenetic tree to show how monotreme, marsupial, and placental mammals evolved. Tell them to include in their tree the approximate time of divergence of each group of mammals and the fossil organisms believed to be ancestral to each group. Give students a chance to share their phylogenetic trees, or post them in the classroom. As a class, discuss the traits of the three fossil ancestors and how they relate to the traits of modern mammals in each group.

Differentiated Instruction

Pair struggling students with more advanced students, and ask pairs to create a timeline of major milestones in mammalian evolution. This will help less proficient readers focus on the most important events and their correct sequence. Ask students to share their timelines with the class. **LPR**

Enrichment

Encourage interested students to learn more about the mammalian supertree. Then have them teach the class what they learn about the supertree, such as how it was constructed, what it reveals about mammalian evolution, and how it differs from evolutionary reconstructions based on fossils.

Science Inquiry

Use the evolution of whales as an example to show students how fossil evidence is used to reconstruct the evolutionary history of specific groups of mammals. First assign the whale evolution article at the URL below. Then, divide the class into six groups, and ask each group to complete the Whale Evolution Data Table Worksheet for one of the six fossil ancestors of whales. In the meantime, on poster board, create a large timeline of the Eocene, and put it up in the classroom. After groups have completed their column of the worksheet, have them cut out and paste the column for their fossil ancestor at the appropriate place on the timeline. Give students a chance to review the completed timeline. Then discuss the questions about whale evolution that follow the activity.

- http://www.teachersdomain.org/resource/tdc02.sci.life.evo.lp_fossilevid/

Overcoming Misconceptions

A common student misconception is that mammals did not evolve until after the dinosaurs went extinct. Make sure students are aware that the first mammals evolved around the same time as the earliest dinosaurs and coexisted with them until dinosaurs went extinct about 65 million years ago.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Some mammalian traits, such as different types of teeth, evolved in ancestors of mammals. Other traits, such as placental reproduction, evolved after the first mammals appeared. Mammals also evolved many behavioral traits.

- How do mammals behave? What behaviors do you think characterize mammals?
 - (Sample answer: Mammals mate and care for their young.)
- How do you think these behaviors evolved?
 - (These behaviors increased reproductive success so they became more common through natural selection.)

20.4 Overview of Animal Behavior

Key Concept

The branch of biology that studies animal behavior is called ethology. Most animal behaviors are controlled by both genes and experiences in a given environment. To the extent that behaviors are controlled by genes, they may evolve. Innate behaviors are instinctive. They are controlled by genes and always occur in the same way. Learning is a change in behavior that occurs as a result of experience. Learned behaviors are more flexible. Types of animal behaviors include cooperation, communication, parenting behaviors, and cyclic behaviors such as migration.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.1; NSES.9–12.C.6.2, 3
- AAAS.9–12.5.F.3
- McREL.9–12.11.2.5; 12.2.3, 4

Lesson Objectives

- Describe how and why ethologists study animal behavior.
- Explain how animal behaviors evolve.
- Define innate behavior.
- State ways that animals learn.
- Identify types of animal behavior.

Lesson Vocabulary

- **aggression:** behavior that is intended to cause harm or pain
- **animal behavior:** any way that animals interact with each other or the environment
- **circadian rhythm:** regular change in biology or behavior that occurs in a 24-hour cycle
- **cooperation:** type of animal behavior in which social animals live and work together for the good of the group
- **ethology:** branch of biology that studies animal behavior
- **innate behavior:** behavior closely controlled by genes that occurs naturally, without learning or practice, in all members of a species whenever they are exposed to a certain stimulus; also called instinctive behavior
- **instinct:** ability of an animal to perform a behavior the first time it is exposed to the proper stimulus
- **learning:** change in behavior that occurs as a result of experience
- **nature-nurture debate:** debate over the extent to which genes (nature) or experiences in a given environment (nurture) control traits such as animal behaviors

- **reflex:** rapid motor response to a sensory stimulus in which nerve impulses travel in an arc that includes the spinal cord but not the brain
- **social animal:** animal that lives in a society
- **society:** close-knit group of animals of the same species that live and work together
- **stimulus:** something that triggers a behavior

Teaching Strategies

Introducing the Lesson

Introduce animal behavior by asking a volunteer to help you demonstrate examples of human behavioral responses that range from a simple reflex (the knee-jerk response) to a complex behavior based on insight learning (solving a puzzle like Rubik's cube). Tell students they will learn more about animal behavior in this lesson.

Activity

Encourage groups of students to observe animal behavior in a more-or-less natural setting, such as a park, zoo, wildlife sanctuary, or nature preserve. If possible, take the class on a field trip to observe animal behavior in such a setting. Ask students to watch for examples of specific types of behavior, such as cooperation, communication, and competition. Activity sheets for zoo field trips are available at the URL below.

- http://www.accessexcellence.org/AE/AEC/AEF/1994/peebles_behavior.php

Differentiated Instruction

Help students focus their reading by having them to make a KWL chart for the lesson. Tell them to fill in the Know and Want to Know columns before they read the lesson and the Learned column after they read the lesson. Discuss any topics that students wanted to know about but didn't learn by reading the lesson. **LPR**

Enrichment

Ask students to find research and arguments about the relative roles of genes and environment in human aggression. Have students take opposing sides of the nature-nurture continuum and debate the issue in front of the class. Ask the class to vote which side in the debate was most convincing. Follow up with a discussion of a less dichotomous approach to the issue.

Science Inquiry

Have students do the activity *Observing Siamese Fighting Fish* at the URL below. In the activity, students will design, carry out, and critique an experiment to identify the stimulus that triggers this animal behavior. You can purchase the fish at most aquarium and pet stores.

- <http://www.the-aps.org/education/k12curric/pdf/clarke.pdf>

Overcoming Misconceptions

Some students may have the misconception that animal behavior involves only volitional acts. Make sure students understand that animal behavior refers to any interaction an animal has with its environment. Describe examples of simple innate behaviors, such as animal instincts or reflex reactions like the knee-jerk response in humans.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you learned some of the ways that humans differ from other mammals. For example, humans have a larger and more complex brain than other mammals. That's why they are also the most intelligent mammals. The next chapter introduces the biology of the human animal.

- Besides their big brain and intelligence, how else might humans differ from other mammals?
 - (Sample answer: They walk upright on two legs.)
- What organs and organ systems do you think make up the human body?
 - (Students may name any human organs and organ systems.)

20.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 21 TE Introduction to the Human Body: Bones, Muscles, and Skin

CHAPTER OUTLINE

21.1 INTRODUCTION TO THE HUMAN BODY: BONES, MUSCLES, AND SKIN

21.2 OUTLINE

21.3 PACING THE LESSONS

21.4 ONLINE RESOURCES



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21.1 Introduction to the Human Body: Bones, Muscles, and Skin

21.2 Outline

Lesson 21.1: Organization of the Human Body

21.1.1 Levels of Organization

- Cells
- Tissues
- Organs and Organ Systems

21.1.2 A Well-Oiled Machine

- Maintaining Homeostasis
- Failure of Homeostasis

Lesson 21.2: The Skeletal System

21.2.1 The Skeleton

21.2.2 Structure of Bones

- Bone Cells
- Bone Tissues

21.2.3 Growth and Development of Bones

21.2.4 Joints

- Types of Joints
- Movable Joints

21.2.5 Skeletal System Problems

Lesson 21.3: The Muscular System

21.3.1 What are Muscles?

- Smooth Muscle
- Skeletal Muscle
- Cardiac Muscle

21.3.2 Skeletal Muscles

- Structure of Skeletal Muscles
- Skeletal Muscles and Bones
- Use It or Lose It

21.3.3 Muscle Contraction

- Structure of Muscle Fibers
- Sliding Filament Theory
- Muscles and Nerves

Lesson 21.4: The Integumentary System

21.4.1 The Skin

- Epidermis
- Dermis
- Functions of the Skin
- Skin Problems

21.4.2 Nails and Hair

- Nails
- Hair

21.3 Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 21.1:

Lesson	Number of Class Periods
21.1 Organization of the Human Body	1.0
21.2 The Skeletal System	2.0
21.3 The Muscular System	1.5
21.4 The Integumentary System	1.0

- Class periods are assumed to be 60 minutes long.

21.4 Online Resources

See the following Web sites for appropriate laboratory activities:

1. This lab will teach students how to identify compact and spongy bone tissues and how to classify bones by shape. Quizzes are provided so students can test their comprehension as they work through the lab. (Lesson 21.2)

- <http://www.zoology.ubc.ca/biomania/tutorial/bonets/outline.htm>

2. In this lab, students will investigate the effects of temperature and fatigue on muscle contractions, using themselves as study subjects. (Lesson 21.3)

- http://www.troy.k12.ny.us/old%20sites/thsbiology/labs_online/home_labs/muscle_lab_home.html

These Web sites may also be helpful:

1. This URL has additional information about human body systems, as well as images of tissues and individual organ systems.

- <http://web.jjay.cuny.edu/acarpi/NSC/14-anatomy.htm>

2. This URL links to lecture notes, Web pages, and PowerPoint

CHAPTER 22

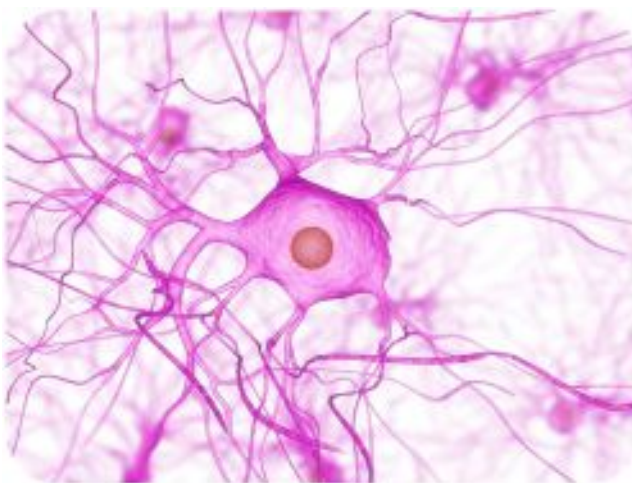
TE The Nervous and Endocrine Systems

CHAPTER OUTLINE

22.1 THE NERVOUS SYSTEM

22.2 THE ENDOCRINE SYSTEM

22.3 WORKSHEET ANSWER KEYS



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The Nervous and Endocrine Systems

Outline

Lesson 22.1: The Nervous System

22.1.1 Nerve Cells

- Neuron Structure
- Myelin Sheath
- Types of Neurons

22.1.2 Nerve Impulses

- Resting Potential
- Action Potential
- The Synapse

22.1.3 Central Nervous System

- The Brain
- Spinal Cord

22.1.4 Peripheral Nervous System

- Somatic Nervous System
- Autonomic Nervous System

22.1.5 The Senses

- Sight
- Hearing
- Balance
- Taste and Smell
- Touch
- KQED: The Flavor of Food: Smell + Taste + Touch

22.1.6 Drugs and the Nervous System

- Examples of Psychoactive Drugs
- Drug Abuse and Addiction

22.1.7 Disorders of the Nervous System

- KQED: Autism: Searching for Causes
- KQED: Alzheimer's Disease: Is the Cure in the Genes?

Lesson 22.2: The Endocrine System

22.2.1 Glands of the Endocrine System

- Hypothalamus
- Pituitary Gland
- Other Endocrine Glands

22.2.2 How Hormones Work

- Steroid Hormones
- Non-Steroid Hormones

22.2.3 Hormone Regulation: Feedback Mechanisms

- Negative Feedback
- Positive Feedback

22.2.4 Endocrine System Disorders

- Hypersecretion
- Hyposecretion
- Hormone Resistance

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 22.1:

Lesson	Number of Class Periods
22.1 The Nervous System	3.0
22.2 The Endocrine System	2.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this lab, students will map the density of sensory receptors in skin on different parts of the body. (Lesson 22.1)
 - <http://outreach.mcb.harvard.edu/teachers/Summer05/ElizabethMick/Homonculus.pdf>
2. This group inquiry lab allows students to investigate the effects of environment on memory. (Lesson 22.1)
 - http://www.accessexcellence.org/AE/AEC/AEF/1996/brown_memory.php
3. In this lab, students will model how the endocrine system uses feedback mechanisms to maintain homeostasis. (Lesson 22.2)
 - http://www.lessonplansinc.com/lessonplans/feedback_mechanism_lab.pdf

These Web sites may also be helpful:

1. These neurobiology lesson plans were developed by high school teachers for use in high school introductory or advanced biology classes. They include activities, labs, and PowerPoint presentations.
 - http://outreach.mcb.harvard.edu/lessonplans_S05.htm
2. This URL provides lesson plans to teach the endocrine system to high school biology students.
 - <http://www.eduref.org/Virtual/Lessons/Science/Anatomy/ANA0005.html>

22.1 The Nervous System

Key Concept

Neurons are the structural and functional units of the nervous system. They carry electrical messages called nerve impulses. The central nervous system includes the brain and spinal cord. The peripheral nervous system includes all the nervous tissue outside of the central nervous system. The peripheral system has several divisions and subdivisions that transmit nerve impulses between the central nervous system and the rest of the body. Human senses include sight, hearing, balance, taste, smell, and touch. Sensory organs respond to sensory stimuli and send nerve impulses to the brain, which interprets them and forms a response. Psychoactive drugs affect the central nervous system. They may be abused and lead to addiction. Disorders of the nervous system include strokes, injuries, and Alzheimer's disease.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.9.b, c, d, e
- NSES.9–12.A.1.6; NSES.9–12.C.6.1; NSES.9–12.F.1.1, 4
- AAAS.9–12.6.C.2, 3

Lesson Objectives

- Describe the structure of a neuron, and identify types of neurons.
- Explain how nerve impulses are transmitted.
- Identify parts of the central nervous system and their functions.
- Outline the divisions and subdivisions of the peripheral nervous system.
- Explain how sensory stimuli are perceived and interpreted.
- State how drugs affect the nervous system.
- Identify several nervous system disorders.

Lesson Vocabulary

- **action potential:** reversal of electrical charge across the membrane of a resting neuron that travels down the axon of the neuron as a nerve impulse
- **autonomic nervous system (ANS):** division of the peripheral nervous system that controls involuntary activities not under conscious control such as heart rate and digestion
- **axon:** long extension of the cell body of a neuron that transmits nerve impulses to other cells
- **brain:** central nervous system organ inside the skull that is the control center of the nervous system

- **brain stem:** lowest part of the brain that connects the brain with the spinal cord and controls unconscious functions such as heart rate and breathing
- **cell body:** central part of a neuron that contains the nucleus and other cell organelles
- **central nervous system (CNS):** one of two main divisions of the nervous system that includes the brain and spinal cord
- **cerebellum:** part of the brain below the cerebrum that coordinates body movements
- **dendrite:** extension of the cell body of a neuron that receives nerve impulses from other neurons
- **drug abuse:** use of a drug without the advice of a medical professional and for reasons not originally intended
- **drug addiction:** situation in which a drug user is unable to stop using a drug
- **interneuron:** type of neuron that carries nerve impulses back and forth between sensory and motor neurons
- **motor neuron:** type of neuron that carries nerve impulses from the central nervous system to muscles and glands
- **myelin sheath:** lipid layer around the axon of a neuron that allows nerve impulses to travel more rapidly down the axon
- **nerve:** one of many cable-like bundles of axons that make up the peripheral nervous system
- **nerve impulse:** electrical signal transmitted by the nervous system
- **nervous system:** human body system that carries electrical messages throughout the body
- **neuron:** nerve cell; structural and functional unit of the nervous system
- **neurotransmitter:** chemical that carries a nerve impulse from one nerve to another at a synapse
- **peripheral nervous system (PNS):** one of two major divisions of the nervous system that consists of all the nervous tissue that lies outside the central nervous system
- **psychoactive drug:** drug that affects the central nervous system, generally by influencing the transmission of nerve impulses in the brain
- **resting potential:** difference in electrical charge across the plasma membrane of a neuron that is not actively transmitting a nerve impulse
- **sensory neuron:** type of neuron that carries nerve impulses from tissue and organs to the spinal cord and brain
- **sensory receptor:** specialized nerve cell that responds to a particular type of stimulus such as light or chemicals
- **somatic nervous system (SNS):** division of the peripheral nervous system that controls voluntary, conscious activities and reflexes
- **spinal cord:** thin, tubular bundle of nervous tissue that extends from the brain stem down the back to the pelvis and connects the brain with the peripheral nervous system
- **synapse:** place where an axon terminal meets another cell

Teaching Strategies

Introducing the Lesson

Use the colorful, well-illustrated PowerPoint presentation at the URL below to introduce students to the human nervous system. The presentation covers the same topics as the FlexBook lesson and will help stimulate student interest in the nervous system.

- <http://outreach.mcb.harvard.edu/teachers/Summer05/ElizabethMick/TheNervousSystem.pptnion>

Activity

Assign the Web quest at the URL below. Students will be directed to a series of Web sites that help them understand the structure and function of neurons and the connection between neurotransmission and addiction to psychoactive

drugs. Then students will use what they learn create a poster, pamphlet, or oral presentation. The pdf document provides resources, graphics, worksheets, a quiz, and grading rubrics.

- http://outreach.mcb.harvard.edu/teachers/Summer05/SandraHolmes/Webquest_NT_Cra_Addict.pdf

Differentiated Instruction

Have kinesthetic learners and any visually impaired students do the hands-on modeling activity at the URL below. They will make bead neurons and use them to model the transmission of nerve impulses. SN

- <http://brainu.org/bead-neuron>

Enrichment

Suggest that interested students do the spinal cord injury Web quest at the URL below. They will learn more about spinal cord injuries and paralysis, as well as technological innovations to provide functional electrical stimulation to paralyzed patients. Students will be asked to reflect on how development of the innovations required the collaboration of many scientists and engineers and how it serves as model for the scientific process.

- <http://outreach.mcb.harvard.edu/teachers/Summer05/DanielPowers/SpinalWEBQUEST.pdf>

Science Inquiry

Have groups of students try to solve the case study problem presented in the first URL below. The pdf document will lead them through the case study and require them to develop a series of increasingly refined hypotheses about the cause of the patient's symptoms (the correct diagnosis is amyotrophic lateral sclerosis, or Lou Gehrig's disease). The second URL provides additional instructions for teachers, including ideas for assessment.

- <http://outreach.mcb.harvard.edu/teachers/Summer05/KatieHorne/ALSCaseStudy.pdf>
- <http://outreach.mcb.harvard.edu/teachers/Summer05/KatieHorne/ALSpresentation.pdf>

Chemistry Connection

Elaborate on the chemistry of neurotransmitters. This will help students understand how therapeutic drugs (such as antidepressants) and other psychoactive drugs (such as cocaine) affect neurotransmission and brain function. See the Web sites below for additional information.

- <http://www.chemistrydaily.com/chemistry/Neurotransmitter>
- <http://micro.magnet.fsu.edu/micro/gallery/neurotrans/neurotrans.html>
- <http://www.benbest.com/science/anatmind/anatmd10.html>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

22.1. THE NERVOUS SYSTEM

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you learned that the nervous system enables electrical messages to be sent through the body very rapidly.

- Often, it's not necessary for the body to respond so rapidly. Can you think of another way the body could send messages that would travel more slowly? What about a way that makes use of the network of blood vessels throughout the body?
 - (*Sample answer:* Messages could travel in the blood.)
- Instead of electrical nerve impulses, what other way might messages be transmitted in the body? Do you think chemical molecules could be used to carry messages? How might this work?
 - (*Sample answer:* The chemical molecules might travel to specific cells and affect how they function.)

22.2 The Endocrine System

Key Concept

The endocrine system consists of glands that secrete hormones into the bloodstream. It is regulated by the hypothalamus, which controls the pituitary gland. The pituitary is the “master gland” of the endocrine system. Its hormones regulate other endocrine glands, which include the thyroid gland and pancreas. Hormones work by binding to receptors in or on target cells. Most hormones are controlled by negative feedback, which brings things back to normal when they start to become too extreme. Endocrine system disorders include endocrine gland tumors and type 1 diabetes.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.9.c, g, i
- NSES.9–12.A.1.6
- AAAS.9–12.5.C.5, 7; AAAS.9–12.6.C.2, 3; AAAS.9–12.6.E.1; AAAS.9–12.11.A.1, 3; AAAS.9–12.11.C.5

Lesson Objectives

- List the glands of the endocrine system and their effects.
- Explain how hormones work by binding to receptors of target cells.
- Describe feedback mechanisms that regulate hormone secretion.
- Identify three endocrine system disorders.

Lesson Vocabulary

- **adrenal glands:** pair of endocrine glands located above the kidneys that secrete hormones such as cortisol and adrenaline
- **endocrine system:** human body system of glands that release hormones into the blood
- **gonads:** glands that secrete sex hormones and produce gametes; testes in males and ovaries in females
- **hypothalamus:** part of the brain that secretes hormones
- **pancreas:** gland near the stomach that secretes insulin and glucagon to regulate blood glucose and enzymes to help digest food
- **parathyroid glands:** pair of small glands in the neck that secrete hormones that regulate blood calcium
- **pineal gland:** gland of the endocrine system that secretes the hormone melatonin that regulates sleep-wake cycles
- **pituitary gland:** master gland of the endocrine system that secretes many hormones, the majority of which regulate other endocrine glands

- **target cell:** type of cell on which a particular hormone has an effect because it has receptor molecules for the hormone
- **thyroid gland:** large endocrine gland in the neck that secretes hormones that control the rate of cellular metabolism throughout the body

Teaching Strategies

Introducing the Lesson

Ask volunteers to explain how a thermostat controls the air temperature inside a house. Add to their explanation as necessary so that the process of negative feedback is adequately explained. Tell the class that similar processes are at work in the human body and they are controlled by the endocrine system, which they will read about in this lesson.

Activity

Have students work through the blood sugar homeostasis animation at the URL below. By exploring this example in depth, they will gain an appreciation of the complexity of hormone regulation and how it maintains homeostasis.

- <http://outreach.mcb.harvard.edu/animations.htm>

Differentiated Instruction

Ask students to make a Frayer model for the vocabulary term “hormone.” They should provide a definition, drawing, example, and non-example of the term. **ELL, LPR**

Enrichment

Ask a few creative students to write a rap or song about the endocrine system. It should identify the endocrine glands and their hormones and also explain how hormones work. Give the students a chance to perform their rap or song for the rest of the class.

Science Inquiry

Assign the inquiry activity at the URL below. In the activity, students will make hormone-receptor models to understand how hormones bind to specific receptors before initiating a cellular response.

- http://www.pbs.org/wgbh/nova/teachers/activities/3313_03_nsn.html

Health Connection

Tell students that hormones may play an important role in mental as well as physical health. Relate hormone imbalances to disorders such as depression and anxiety. To learn more, go to the URLs below.

- <http://www.medicinenet.com/script/main/art.asp?articlekey=50880>
- <http://www.psycheducation.org/hormones/Hormones%20Introduction.htm>
- http://www.timesonline.co.uk/tol/life_and_style/health/article3639679.ece
- <http://apt.rcpsych.org/cgi/reprint/5/2/126.pdf>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you learned that endocrine hormones can affect cells throughout the body because they travel in the blood through the circulatory system.

- Do you know what organs make up the circulatory system?
 - (The circulatory system includes the heart, blood, and blood vessels.)
- Can you explain what causes blood to move through the system?
 - (The heart pumps blood through the system.)

22.3 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER

23

TE The Circulatory, Respiratory, Digestive, and Excretory Systems

CHAPTER OUTLINE

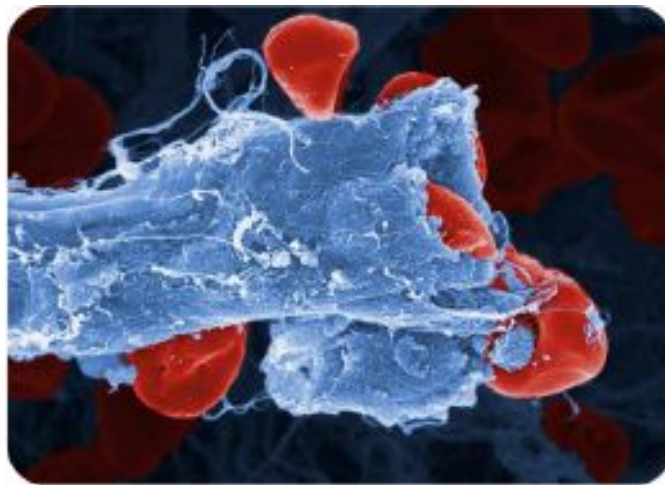
23.1 THE CIRCULATORY SYSTEM

23.2 THE RESPIRATORY SYSTEM

23.3 THE DIGESTIVE SYSTEM

23.4 THE EXCRETORY SYSTEM

23.5 WORKSHEET ANSWER KEYS



(Opening image copyright by Anne Weston, <http://io9.com/#!/373166/when-microscopic-blood-vessels-explode> and under the Creative Commons license CC-BY-NC-ND.)

The Circulatory, Respiratory, Digestive, and Excretory Systems

Outline

Lesson 23.1: The Circulatory System

23.1.1 The Heart

- Blood Flow Through the Heart
- Heartbeat

23.1.2 Blood Vessels

- Blood Vessels and Homeostasis
- Blood Vessels and Blood Pressure

23.1.3 Pulmonary and Systemic Circulations

- Pulmonary Circulation
- Systemic Circulation

23.1.4 Cardiovascular Disease

- Atherosclerosis
- Coronary Heart Disease
- Preventing Cardiovascular Disease

23.1.5 Blood

- Composition of Blood
- Blood Type

Lesson 23.2: The Respiratory System

23.2.1 Respiration

23.2.2 Organs of the Respiratory System

23.2.3 Journey of a Breath of Air

- Ventilation
- Pulmonary Gas Exchange
- Gas Transport
- Peripheral Gas Exchange
- Back to the Lungs

23.2.4 Gas Exchange and Homeostasis

23.2.5 Regulation of Breathing

- How Breathing Occurs
- Control of Breathing

23.2.6 Diseases of the Respiratory System

Lesson 23.3: The Digestive System

23.3.1 Overview of the Digestive System

- The Gastrointestinal Tract
- Accessory Organs of Digestion
- Functions of the Digestive System

23.3.2 The Start of Digestion: Mouth to Stomach

- Mouth
- Esophagus
- Stomach

23.3.3 Digestion and Absorption: The Small Intestine

- Digestion in the Small Intestine
- Absorption in the Small Intestine

23.3.4 The Large Intestine and Its Functions

- Absorption of Water and Elimination of Wastes
- Bacteria in the Large Intestine

23.3.5 Diseases of the Digestive System

- KQED: Hepatitis C: The Silent Epidemic

23.3.6 Food and Nutrients

- Macronutrients
- Micronutrients

23.3.7 Balanced Eating

- MyPyramid and MyPlate
- Food Labels
- Weight Gain and Obesity
- Eating Disorders

Lesson 23.4: The Excretory System

23.4.1 Excretion

23.4.2 Urinary System

- Kidneys and Nephrons
- Filtering Blood and Forming Urine
- Excretion of Urine

23.4.3 Kidneys and Homeostasis

23.4.4 Kidney Disease and Dialysis

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 23.1:

Lesson	Number of Class Periods
23.1 The Circulatory System	2.0
23.2 The Respiratory System	1.5
23.3 The Digestive System	2.5
23.4 The Excretory System	1.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this lab, students will determine their own blood type. (Lesson 23.1)

- <http://www.aai.org/committees/education/Curriculum/2006/BensonFelicia.pdf>

2. By solving this lung toxicology problem set, students will develop a better understanding of the physiology of the respiratory system. (Lesson 23.2)

- http://www.biology.arizona.edu/chh/problem_sets/lung_toxicology/lung_toxicology.html

3. Students will investigate the roles of amylase and pepsin in the digestion of different foods. (Lesson 23.3)

- <http://www.accessexcellence.org/AE/ATG/data/released/0334-RobertGoodman/index.php>

4. Students will use chemical reagents to test unknown food samples for specific nutrients. (Lesson 23.3)

- <http://www.geocities.com/CapeCanaveral/Hall/1410/lab-B-09.html>

These Web sites may also be helpful:

1. See this URL for more information about the heart and cardiovascular system.

- <http://www.fi.edu/learn/heart/index.html>

2. This URL accesses games, puzzles, and other activities on the respiratory system.

- <http://www.lung.ca/children/games/index.html>

3. This Web site provides numerous links to quizzes, animations, and articles on the digestive system.

- <http://www.teachers.ash.org.au/jmresources/systems/body.html>

4. This Web site provides easy online access to government information on nutrition.

- http://www.nutrition.gov/nal_display/index.php?info_center=11#38;tax_level=1

23.1 The Circulatory System

Key Concept

The circulatory system includes the heart, blood, and blood vessels. The heart contracts rhythmically to pump blood through arteries, capillaries, and veins. The pulmonary circulation carries blood between the heart and lungs, and the systemic circulation carries blood between the heart and the rest of the body. Cardiovascular disease (CVD) is any disease of the heart or blood vessels. Its leading cause is atherosclerosis. Healthy lifestyle choices can reduce the risk of CVD. Blood consists of a fluid portion called plasma and a variety of cells. Red blood cells carry oxygen, white blood cells defend the body, and platelets help blood clot.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.9.a
- NSES.9–12.A.1.6; NSES.9–12.F.1.3

Lesson Objectives

- Explain how the heart pumps blood throughout the body.
- Compare different types of blood vessels and their roles.
- Outline pathways of the pulmonary and systemic circulations.
- Define cardiovascular disease, and list its risk factors.
- Describe blood, blood components, and blood pressure.

Lesson Vocabulary

- **antigen:** molecule that the immune system identifies as foreign and responds to by forming antibodies
- **artery:** type of blood vessel that carries blood away from the heart toward the lungs or body
- **atherosclerosis:** condition in which plaque builds up inside arteries
- **blood:** fluid connective tissue that circulates throughout the body through blood vessels
- **blood pressure:** force exerted by circulating blood on the walls of blood vessels
- **blood type:** genetic characteristic associated with the presence or absence of antigens on the surface of red blood cells
- **capillary:** smallest type of blood vessel that connects very small arteries and veins
- **cardiovascular disease (CVD):** any disease that affects the heart or blood vessels
- **circulatory system:** organ system consisting of the heart, blood vessels, and blood that transports materials around the body

- **heart attack:** blockage of blood flow to heart muscle tissues that may result in the death of cardiac muscle fibers
- **hypertension:** high blood pressure
- **plasma:** golden-yellow, fluid part of blood that contains many dissolved substances and blood cells
- **platelet:** cell fragment in blood that helps blood clot
- **pulmonary circulation:** part of the circulatory system that carries blood between the heart and lungs
- **red blood cell:** type of cell in blood that contains hemoglobin and carries oxygen
- **systemic circulation:** part of the circulatory system that carries blood between the heart and body
- **vein:** type of blood vessel that carries blood toward the heart from the lungs or body
- **white blood cell:** type of cell in blood that defends the body against invading microorganisms or other threats in blood or extracellular fluid

Teaching Strategies

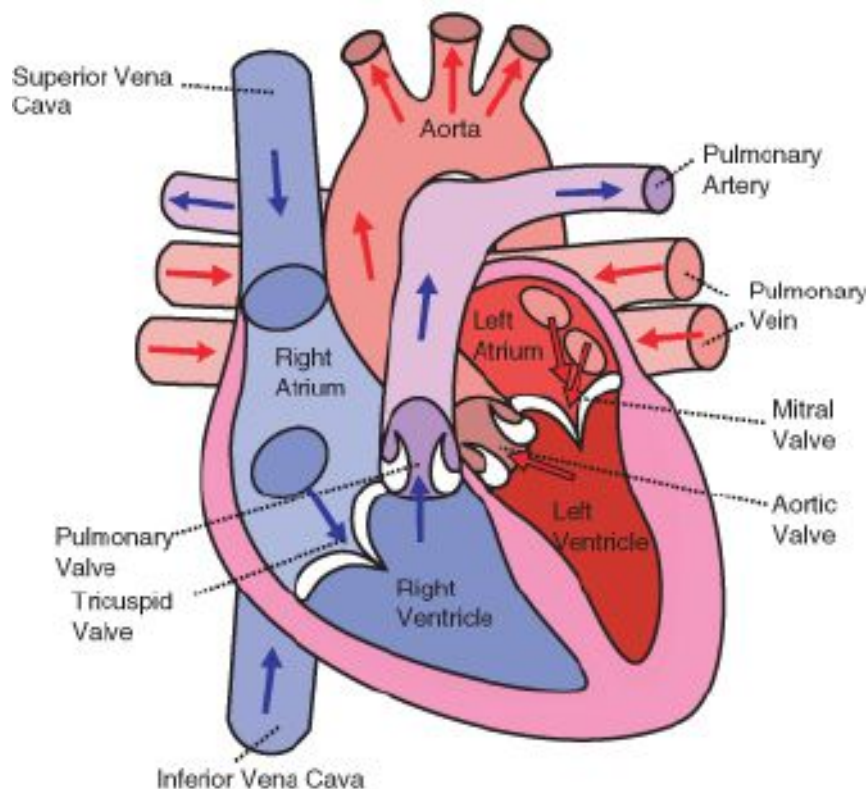
Introducing the Lesson

Show students how to feel the pulse in their neck or wrist. Call on volunteers to explain what they are feeling (the increased pressure of blood against artery walls each time the heart contracts, or beats). Tell students they will learn more about the heart and how it pumps blood in this lesson.

Using Visuals

When you discuss the dynamics of the heart, tell students to trace the flow of blood through the heart (**Figure 23.2** in FlexBook and reproduced below).

- **Ask:** What keeps blood flowing through the heart in just one direction? (One-way valves between heart chambers.)



(Image courtesy of Wapcaplet and Yaddah and under GNU-FDL 1.2.)

Differentiated Instruction

Have students make a KWL chart for the lesson. They should fill in the first two columns (Know, Want to Know) before they start reading and the last column (Learned) after they finish reading. Discuss any of their questions that remain unanswered.

Enrichment

Ask interested students to investigate the problem of creating an artificial heart to treat people with heart failure. Students should learn about the history of artificial hearts and the greatest challenges in developing a successful artificial heart. Encourage the students to share what they learn with the rest of the class.

Science Inquiry

Have small groups of students design an investigation to determine the effects of exercise on heart rate. Ask groups to share and discuss their ideas. Make sure they have identified independent and dependent variables and controls.

Overcoming Misconceptions

Many people think that the circulatory system consists of a single large circuit. Make sure students understand that the circulatory system has two interacting circuits, the pulmonary and systemic. Explain why two circuits are necessary. Suggest that students view the video at the URL below. It shows animated models of the two circuits and how they are related.

- <http://www.youtube.com/watch?v=0jznS5psypI>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

An important function of the circulatory system is transporting oxygen to cells.

- Do you know where blood gets the oxygen cells it needs?
 - (Blood absorbs oxygen in the lungs.)
- How do you think blood is able to give up its oxygen to cells?
 - (Oxygenated blood has a greater concentration of oxygen than do body cells, so oxygen diffuses from the blood into the cells.)

23.2 The Respiratory System

Key Concept

Respiration is the process in which the lungs and other organs of the respiratory system bring oxygen into the body and release carbon dioxide into the atmosphere. Respiration includes the processes of ventilation, pulmonary gas exchange, transport, and peripheral gas exchange. Breathing occurs due to repeated contractions of the diaphragm. It is controlled by the brain stem. Respiratory diseases include asthma, pneumonia, and emphysema.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.9.a
- NSES.9–12.A.1.6

Lesson Objectives

- Define respiration, and explain how it differs from cellular respiration.
- Identify the organs of the respiratory system.
- Outline the processes of ventilation, gas exchange, and gas transport.
- Describe the role of gas exchange in homeostasis.
- Explain how the rate of breathing is regulated.
- Identify diseases of the respiratory system.

Lesson Vocabulary

- **asthma**: respiratory system disease in which air passages of the lungs periodically become too narrow, making breathing difficult
- **emphysema**: lung disease, usually caused by smoking, in which walls of alveoli break down, so less gas can be exchanged in the lungs
- **larynx**: organ of the respiratory system between the pharynx and trachea that is also called the voice box because it allows the production of vocal sounds
- **lung**: organ of the respiratory system in which gas exchange takes place between the blood and the atmosphere
- **pharynx**: long, tubular organ that connects the mouth and nasal cavity with the larynx, through which air and food pass
- **pneumonia**: disease in which the alveoli of the lungs become inflamed and filled with fluid as a result of infection or injury
- **respiration**: exchange of gases between the body and the outside air

- **respiratory system:** organ system that brings oxygen into the body and releases carbon dioxide into the atmosphere
- **trachea:** long, tubular organ of the respiratory system, also called the wind pipe, that carries air between the larynx and lungs
- **ventilation:** process of carrying air from the atmosphere into the lungs

Teaching Strategies

Introducing the Lesson

Tell students to hold their breath until you tell them to start breathing again. When they start gasping for breath, ask them why they started to breathe. (The autonomic nervous system controls breathing, so it is under conscious control only up to a point.) Tell students they will learn more about breathing and the respiratory system in this lesson.

Demonstration

With the help of a student volunteer, demonstrate lung capacity using instructions at the URL below. Following the demonstration, discuss how lung capacity might be related to factors such as body size, gender, age, fitness, and activity level.

- <http://www.brighthub.com/education/k-12/articles/43891.aspx>

Differentiated Instruction

Write the three questions below on the board. Tell students to think about how they would answer the questions. Then pair struggling students with students who are excelling in the class, and have partners share and discuss their answers.

- a. What organs make up the respiratory system?
- b. What is the main function of the respiratory system?
- c. How do the organs of the respiratory system work together to perform this function?

Enrichment

Have advanced students investigate the issue of cigarette smoking and its negative effects on the health of nonsmokers as well as smokers. Then ask students to lead a class discussion of the issue. They might start the discussion with some facts and figures about the health risks of cigarette smoking to smokers and nonsmokers, and then ask questions such as:

- What if any rights do smokers have to smoke? Do you think smokers should be required to stop smoking for their own good? Or do you think they should have the right to smoke if it doesn't harm others?
- What about the rights of nonsmokers? Do they have the right to breathe clean air? Is this right more important than any rights smokers might have to smoke?
- How can the risks of smoking be prevented? What can society, the law, and medicine do? What role should education play?

Science Inquiry

Explain how the density of air decreases with increasing altitude, so that a given volume of air contains fewer oxygen molecules at high altitude than the same volume of air at sea level. Ask students to hypothesize how this might affect breathing at high altitude. Encourage them to speculate about adaptations that might evolve in human populations that live at high altitudes for many generations. Direct students to the URLs below to see if their ideas are correct.

- http://www.altitude.org/why_less_oxygen.php
- http://news.nationalgeographic.com/news/2004/02/0224_040225_evolution.html

Overcoming Misconceptions

Misconceptions about the lungs and the mechanics of breathing are common. For example, students commonly think the lungs are muscles that actively suck air into the body during inhalations and expel all the air during exhalations. To overcome these and similar misconceptions, use a simple model to demonstrate how the lungs really work (see URL below). You can make and exhibit the model as a class demonstration or assign it as a small-group project.

- <http://www.sciencenetlinks.com/lessons.php?DocID=245>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Oxygen is just one substance transported by the blood. The blood also transports nutrients such as glucose.

- What are nutrients? What other substances do you think might be nutrients?
 - (Nutrients are substances the body needs. In addition to glucose and other carbohydrates, nutrients include lipids, proteins, water, vitamins, and minerals.)
- Where do you think nutrients enter the bloodstream? How might this occur?
 - (Nutrients enter the bloodstream in the small intestine. They are absorbed by the blood across the thin walls of capillaries.)

23.3 The Digestive System

Key Concepts

The digestive system consists of organs that break down food, absorb nutrients, and eliminate waste. Mechanical digestion occurs in the mouth and stomach. Chemical digestion and absorption occur mainly in the small intestine, with the help of secretions from the liver and pancreas. The large intestine eliminates any remaining solid waste. Digestive system diseases include food allergies, ulcers, and heartburn. Macronutrients include carbohydrates, proteins, lipids, and water; micronutrients include vitamins and minerals. MyPyramid and food labels are important tools for balanced eating. Eating too much and exercising too little can lead to obesity.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.1.b; CA.9–12.LS.9.f
- NSES.9–12.A.1.6; NSES.9–12.B.3.5; NSES.9–12.C.5.3; NSES.9–12.F.1.3, 5
- AAAS.9–12.6.E.1

Lesson Objectives

- Identify the organs and functions of the digestive system.
- Outline the roles of the mouth, esophagus, and stomach in digestion.
- Explain how digestion and absorption occur in the small intestine.
- List functions of the large intestine.
- Describe common diseases of the digestive system.
- Identify classes of nutrients and their functions in the human body.
- Explain how to use MyPyramid and food labels as tools for balanced eating.

Lesson Vocabulary

- **absorption:** process in which substances such as nutrients pass into the blood stream
- **bile:** fluid produced by the liver and stored in the gall bladder that is secreted into the small intestine to help digest lipids and neutralize acid from the stomach
- **body mass index (BMI):** estimate of the fat content of the body, calculated by dividing a person's weight (in kilograms) by the square of the person's height (in meters)
- **chemical digestion:** chemical breakdown of large, complex food molecules into smaller, simpler nutrient molecules that can be absorbed by the blood
- **digestion:** process of breaking down food into nutrients that can be absorbed by the blood
- **digestive system:** organ system that breaks down food, absorbs nutrients, and eliminates any remaining waste

- **eating disorder:** mental illness in which people feel compelled to eat in a way that causes physical, mental, and emotional health problems
- **elimination:** process in which waste passes out of the body
- **esophagus:** long, narrow digestive organ that passes food from the pharynx to the stomach
- **feces:** solid waste that remains after food is digested and is eliminated from the body through the anus
- **gall bladder:** sac-like organ that stores bile from the liver and secretes it into the duodenum of the small intestine
- **gastrointestinal (GI) tract:** organs of the digestive system through which food passes during digestion, including the mouth, esophagus, stomach, and small and large intestines
- **large intestine:** organ of the digestive system that removes water from food waste and forms feces
- **liver:** organ of digestion and excretion that secretes bile for lipid digestion and breaks down excess amino acids and toxins in the blood
- **macronutrient:** nutrient such as carbohydrates, proteins, lipids, or water that is needed by the body in relatively large amounts
- **mechanical digestion:** physical breakdown of chunks of food into smaller pieces by organs of the digestive system
- **micronutrient:** nutrient such as a vitamin or mineral that is needed by the body in relatively small amounts
- **mineral:** chemical element, such as calcium or potassium, that is needed in relatively small amounts for proper body functioning
- **MyPlate:** visual guideline for balanced eating, replacing MyPyramid in 2011
- **MyPyramid:** visual dietary guideline that shows the relative amounts of foods in different food groups that should be eaten each day
- **nutrient:** substance the body needs for energy, building materials, or control of body processes
- **obesity:** condition in which the body mass index is 30.0 kg/m² or greater
- **peristalsis:** rapid, involuntary, wave-like contraction of muscles that pushes food through the GI tract and urine through the ureters
- **small intestine:** long, narrow, tube-like organ of the digestive system where most chemical digestion of food and virtually all absorption of nutrients take place
- **stomach:** sac-like organ of the digestive system between the esophagus and small intestine in which both mechanical and chemical digestion take place
- **villi:** (singular, villus) microscopic, finger-like projections in the mucous membrane lining the small intestine that form a large surface area for the absorption of nutrients
- **vitamin:** organic compound needed in small amounts for proper body functioning

Teaching Strategies

Introducing the Lesson

Call on one student after another to state anything they already know about digestion or the digestive system. Continue until no new information is forthcoming. Tell students they will learn more about digestion and the digestive system in this lesson.

Demonstration

To underscore the importance of peristalsis in the digestive system, demonstrate the process by pushing a marble through a short length of rubber tubing. Tell the class that the tubing represents part of the digestive system, such as the esophagus, and the marble represents food. Keep squeezing the tubing just above the marble until the marble moves completely through the tubing and out the other end. Give a few students a chance to squeeze the marble

through the tubing as well. Remind the class that peristalsis moves food through the entire digestive system, not just the esophagus.

Differentiated Instruction

Use a gallery walk to help students learn about the six classes of nutrients. Post the names of the classes around the room on large sheets of paper or poster board. Place any English language learners in groups with native English speakers, and have groups travel around the room from nutrient to nutrient. At each station, students should list a good food source of the nutrient and one of the nutrient's roles in the body. They can add any other relevant information as well. They should also read what other groups have posted and correct any errors. **ELL**

Enrichment

Ask students who need extra challenges to take a survey of the nutritional knowledge of friends or family members. They should first prepare a list of questions to assess what respondents know about nutrients and their role in good health. They might ask questions such as:

- How many calories does the average person need each day?
- What are examples of high-fiber foods?
- Why is it important to limit the amount of fat that you eat?

After students finish their survey, have them summarize the results and present the summary to the class. As a class, discuss the role of nutritional knowledge in healthful eating.

Science Inquiry

Explain to the class that people who exercise regularly are less likely to be obese than people who do not exercise. Point out that regular exercisers may also tend to be more careful about what they eat, and this might affect their weight as well. Ask students to develop a research plan that would allow them to correlate the effects of exercise alone on weight, without the possible confounding effects of diet.

(Student plans should compare the weights of a sample of people who exercise regularly with the weights of a sample of people who do not exercise. They should control for the effects of diet on weight by including in the samples only people who eat a similar diet.)

Overcoming Misconceptions

There are several common misconceptions about the digestive system. Some of these include:

- The stomach makes up most of the digestive system, and most digestion takes place there.
- Food goes from the stomach into the blood stream.
- Most of the food we eat is excreted through the anus.
- Foods that the body does not need stay in the intestine and are eliminated from the body.

Read these misconceptions to the class, and ask students which if any of them they think are true. Call on students who think they are false to explain why.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

In this lesson, you learned that the large intestine eliminates solid wastes that are left after digestion occurs.

- Wastes are also produced when cells break down nutrients for energy and building materials. How do you think these wastes are removed from the body? Do you think they are eliminated by the large intestine as well?
 - (Sample answer: They might be eliminated by other organs, such as the kidneys.)
- Might there be other ways to remove wastes from the body? What about liquid wastes and excess water?
 - (Sample answer: They might be removed in urine or other body fluids.)

23.4 The Excretory System

Key Concept

Excretion is the process of removing wastes and excess water from the body. The major organs of excretion are the kidneys, which filter blood and form urine. The kidneys are part of the urinary system, which also includes the ureters, bladder, and urethra. Each kidney has more than a million nephrons, which are the structural and functional units of the kidney. The kidneys maintain homeostasis by controlling the amount of water, ions, and other substances in the blood. They also secrete hormones that have other homeostatic functions. Kidney diseases include kidney stones, infections, and kidney failure due to diabetes.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.9.a, g, i
- NSES.9–12.A.1.6; NSES.9–12.F.1.2
- AAAS.9–12.
- McREL.9–12

Lesson Objectives

- Define excretion, and identify organs of the excretory system.
- Explain how the urinary system filters blood and excretes wastes.
- Describe the roles of the kidneys in homeostasis.
- Identify kidney diseases, and describe dialysis.

Lesson Vocabulary

- **bladder**: hollow, sac-like organ that stores urine until it is excreted from the body
- **dialysis**: medical procedure in which blood is filtered through a machine in patients with kidney failure
- **excretion**: process of removing wastes and excess water from the body
- **excretory system**: organ system that removes wastes and excess water from the body and includes the kidneys, large intestine, liver, skin, and lungs
- **kidney failure**: loss of the ability of nephrons of the kidney to function fully
- **nephron**: structural and functional unit of the kidney that filters blood and forms urine
- **ureter**: muscular, tube-like organ of the urinary system that moves urine by peristalsis from a kidney to the bladder
- **urethra**: muscular, tube-like organ of the urinary system that carries urine out of the body from the bladder; in males, it also carries sperm out of the body

- **urinary system:** organ system that includes the kidneys and is responsible for filtering waste products and excess water from the blood and excreting them from the body
- **urination:** process in which urine leaves the body through a sphincter at the end of the urethra
- **urine:** liquid waste product of the body that is formed by the kidneys and excreted by the other organs of the urinary system

Teaching Strategies

Introducing the Lesson

Spark interest in the excretory system by sharing with the class the following kidney facts and figures:

- a. Each kidney is only about the size of a computer mouse.
- b. Each kidney contains more than one million tiny filters.
- c. The two kidneys filter all the body's blood (about 1.5 gallons) many times each day.

Tell students they will learn more about the kidneys and excretory system in this lesson.

Demonstration

Bring to class a fresh beef kidney (available at a meat market or the meat department of a supermarket). First, point out the ureter and the renal artery and vein. Then, using a scalpel or sharp knife, dissect the kidney lengthwise so the medulla and cortex are visible. Give students a chance to inspect these structures. Discuss the function of each structure in the filtration of blood and formation of urine.

Differentiated Instruction

Use cloze prompts to help less proficient readers focus on key content. Provide students with a list of main idea sentences from the lesson that have important terms left blank. Ask students to complete the sentences as they read the lesson. Suggest that students compare their completed sentences with those of another student. If any of the completed sentences differ significantly, they should reread relevant portions of the lesson to resolve the differences.

LPR

Enrichment

Ask interested students to do an online search for a local kidney dialysis center. Then have them contact the center to obtain a brochure, flyer, or other written information about dialysis and the center. If possible, arrange for students to visit the center and interview nurses, technicians, or other personnel about the dialysis process. Ask them to report what they learn to the class.

Science Inquiry

Tell the class that high blood pressure is a leading cause of kidney failure. Then challenge students to formulate a hypothesis to explain why high blood pressure may cause kidney failure. (High blood pressure may damage capillaries in the kidneys so the kidneys can no longer do their job of removing wastes and excess water from the blood.)

Real-World Connection

State that a person with kidney failure may receive a kidney transplant. Have students do a Web quest of kidney transplantation. Suggest that they start with the URL below. They will quickly realize that there are a plethora of social, economic, and legal issues related to this medical procedure. Discuss some of the issues with the class.

- http://en.wikipedia.org/wiki/Kidney_transplantation

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Infections caused by microorganisms may affect any of the organ systems described in this chapter. For example, you have just read that bacterial infections of the bladder are common.

- What defenses do you think the body has to keep out microorganisms?
 - (Sample answer: The skin keeps out most microorganisms.)
- Do you know if there are other defenses against microorganisms if they manage to get inside the body?
 - (Sample answer: White blood cells fight microorganisms in the blood.)

23.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 24 TE The Immune System and Disease

CHAPTER OUTLINE

24.1 NONSPECIFIC DEFENSES

24.2 THE IMMUNE RESPONSE

24.3 IMMUNE SYSTEM DISEASES

24.4 ENVIRONMENTAL PROBLEMS AND HUMAN HEALTH

24.5 WORKSHEET ANSWER KEYS



(Opening image courtesy of Bruce Wetzell/Harry Schaefer/National Cancer Institute, <http://visualsonline.cancer.gov/details.cfm?imageid=1762>, colorized by Sam McCabe, and under the public domain.)

The Immune System and Disease

Outline

Lesson 24.1: Nonspecific Defenses

24.1.1 First Line of Defense

- Mechanical Barriers
- Chemical Barriers
- Biological Barriers

24.1.2 Second Line of Defense

- Inflammatory Response
- Leukocytes

Lesson 24.2: Immune Response

24.2.1 Lymphatic System

- Structures of the Lymphatic System
- Lymphatic Vessels and Lymph
- Lymphocytes
- Antigen Recognition

24.2.2 Humoral Immune Response

- B Cell Activation
- Plasma Cells and Antibody Production
- Memory Cells

24.2.3 Cell-Mediated Immune Response

- T Cell Activation
- Helper T Cells
- Cytotoxic T Cells
- Regulatory T Cells

24.2.4 Immunity

- Active Immunity
- Passive Immunity

Lesson 24.3: Immune System Diseases

24.3.1 Allergies

24.3.2 Autoimmune Diseases

24.3.3 Immunodeficiency

24.3.4 HIV and AIDS

- HIV Transmission
- HIV and the Immune System
- AIDS
- KQED: HIV Research: Beyond the Vaccine

Lesson 24.4: Environmental Problems and Human Health

24.4.1 Carcinogens and Cancer

- Types of Carcinogens
- How Cancer Occurs
- Cancer Treatment and Prevention

24.4.2 Air Pollution and Illness

- Outdoor Air Pollution
- Indoor Air Pollution

24.4.3 Bioterrorism

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 24.1:

Lesson	Number of Class Periods
24.1 Nonspecific Defenses	1.0
24.2 Immune Response	2.0
24.3 Immune System Diseases	1.5
24.4 Environmental Problems and Human Health	1.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this virtual lab, students will gain a better understanding of antibodies by learning how they are used in medical diagnostics. (Lesson 24.2)

- <http://www.hhmi.org/biointeractive/vlabs/>

2. This lab demonstrates principles of antibody-antigen binding, the secondary immune response, cross reactivity, and complement fixation. (Lesson 24.2)

- http://www.accessexcellence.org/AE/AEC/AEF/1994/ridenour_hemeagglutination.php

3. In this AP-level lab, students will learn the mechanisms of the immune system by focusing on gene variants that confer susceptibility to autoimmune disorders. (Lesson 24.3)

- <http://www.aai.org/committees/education/Curriculum/2010/Lee%20Curriculum%20Final.pdf>

4. In this lab, students will role-play CDC team members preparing for a possible bioterrorist attack on a fictitious city. (Lesson 24.4)

- <http://www.eduref.org/cgi-bin/printlessons.cgi/Virtual/Lessons/Science/Biology/BIO0204.html>

These Web sites may also be helpful:

1. This URL is a directory of links to many useful immune system Web sites.

- http://www.mult-sclerosis.org/immunesystem_link.html

2. This Web site provides virtual immunology activities and tutorials.

- <http://virtuallabs.stanford.edu/>

3. Additional immunology classroom activities are described at this Web site.

- <http://www.aai.org/committees/education/Curriculum/activities.htm>

4. This CDC Web site is a portal for information and data on HIV/AIDS.

- <http://www.cdc.gov/hiv/default.htm>

5. You can access an air pollution curriculum for grades 7–12 at the URL below.

- <http://www.k12science.org/curriculum/airproj/index.html>

6. This URL has several detailed tutorials on cancer.

- <http://newscenter.cancer.gov/cancertopics/understandingcancer/>

24.1 Nonspecific Defenses

Key Concept

Barriers that keep out pathogens are the body's first line of defense. They include mechanical, chemical, and biological barriers. The body's second line of defense comes into play if pathogens manage to enter the body. It includes the inflammatory response and phagocytosis by nonspecific leukocytes.

Standards

- CA.9–12.LS.10.a; CA.9–12.IE.1.d
- NSES.9–12.A.1.6
- AAAS.9–12.6.C.1

Lesson Objectives

- Describe the barriers that keep most pathogens out of the human body.
- Explain how the inflammatory response and nonspecific leukocytes help fight pathogens that enter the body.

Lesson Vocabulary

- **inflammatory response:** nonspecific response the body first makes to tissue damage or infection
- **leukocyte:** white blood cell produced by bone marrow to fight infections
- **mucous membrane:** epithelial tissue that lines inner body surfaces and body openings and produces mucus
- **mucus:** slimy substance produced by mucous membranes that traps pathogens, particles, and debris
- **pathogen:** disease-causing agent, such as a bacterium, virus, fungus, or protozoan
- **phagocytosis:** process in which leukocytes engulf and break down pathogens and debris

Teaching Strategies

Introducing the Lesson

Have students play Immunopoly, a board game that can be downloaded from Houston's Health Museum (see URL below). The game will introduce students to the components of the immune system and how healthy choices can enhance the body's ability to fight off infections and stay healthy.

- http://thehealthmuseum.org/ManageDetail/Detail_Default.aspx?contentid=553#38;categoryid=433

Activity

Download the mini module on the inflammatory response at the URL below. Students will learn how and why the inflammatory response occurs by comparing the “chain of command” for immune cells to a military chain of command.

- <http://peer.tamu.edu/LessonPlan.asp?id=139#38;file=lesson>

Differentiated Instruction

Work with struggling students to create a simple flowchart that shows the series of “hurdles” pathogens must overcome to cause illness in the human body. **LPR, ELL, SN**

Enrichment

Suggest that students who need extra challenges play the game Immune Attack, which is available at the URL below. In the game, students will navigate a nanobot through a 3D environment of blood vessels and connective tissue in an attempt to save a patient by retraining nonfunctional immune cells. Along the way, students will explore biological processes that enable macrophages and neutrophils to detect and fight infections.

- <http://www.fas.org/immuneattack/>

Science Inquiry

Have students simulate the spread of an infectious disease in a population. The first URL below is the student worksheet for the activity. The second URL provides teacher notes. After the activity, discuss what students learned.

- http://serendip.brynmawr.edu/sci_edu/waldron/pdf/InfectiousDiseaseProtocol.pdf
- http://serendip.brynmawr.edu/sci_edu/waldron/pdf/InfectiousDiseaseTeachPrep.pdf

Overcoming Misconceptions

Ask students to describe symptoms they think are caused by the cold virus. (They might mention stuffy nose, sore throat, and fever.) Tell the class that many disease symptoms are actually caused by the immune system fighting off pathogens, rather than by the pathogens themselves. For example, explain that a fever is part of the body’s second line of defense. It may help fight infection by slowing the growth of pathogens, increasing the metabolic rate of body cells, and stimulating phagocytosis.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

24.1. NONSPECIFIC DEFENSES

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

The body's first and second lines of defense are the same regardless of the particular pathogen involved. The body's third line of defense is different. It tailors the response to the specific pathogen.

- How do you think the immune system can identify specific pathogens?
 - (By their antigens.)
- How might a specific defense be different from a nonspecific defense? What mechanisms might be involved?
 - (*Answers may vary.* Encourage a diversity of responses.)

24.2 The Immune Response

Key Concept

The body's third line of defense is the immune response. This involves the lymphatic system, which produces lymphocytes. Lymphocytes are leukocytes (B cells and T cells) that become activated by antigens. Activated B cells produce antibodies, and activated T cells destroy infected or cancerous cells. The immune response may result in immunity, or the ability to resist infection by a particular pathogen.

Standards

- CA.9–12.LS.10.b, c, d, f; CA.9–12.IE.1.d
- NSES.9–12.A.1.6
- AAAS.9–12.6.C.1; AAAS.9–12.8.F.4

Lesson Objectives

- Describe the lymphatic system and its roles in the immune response.
- List the steps that occur in a humoral immune response.
- Identify the roles of T cells in a cell-mediated immune response.
- Define immunity, and distinguish between active and passive immunity.

Lesson Vocabulary

- **active immunity:** ability to resist a pathogen that results when an immune response to the pathogen produces memory cells
- **antibody:** large, Y-shaped proteins produced by B cells that recognize and bind to antigens in a humoral immune response
- **B cell:** type of lymphocyte that fights infections by forming antibodies
- **cell-mediated immune response:** type of immune response in which T cells destroy cells that are infected with viruses
- **humoral immune response:** type of immune response in which B cells produce antibodies against antigens in blood and lymph
- **immune response:** specific defense against a particular pathogen
- **immunity:** ability to resist a pathogen due to memory lymphocytes or antibodies to the antigens the pathogen carries
- **immunization:** deliberate exposure of a person to a pathogen in order to provoke an immune response and the formation of memory cells specific to that pathogen

- **lymph:** fluid that leaks out of capillaries into spaces between cells and circulates in the vessels of the lymphatic system
- **lymphatic system:** system of the body consisting of organs, vessels, nodes, and lymph that produces lymphocytes and filters pathogens from body fluids
- **lymph node:** small structures located on lymphatic vessels where pathogens are filtered from lymph and destroyed by lymphocytes
- **lymphocyte:** type of leukocyte that is a key cell in the immune response to a specific pathogen
- **memory cell:** lymphocyte (B or T cell) that retains a “memory” of a specific pathogen after an infection is over and thus provides immunity to the pathogen
- **passive immunity:** type of immunity to a particular pathogen that results when antibodies are transferred to a person who has never been exposed to the pathogen
- **T cell:** type of lymphocyte involved in cell-mediated immunity in which cells infected with viruses are destroyed

Teaching Strategies

Introducing the Lesson

Show students the recommended vaccination schedule for infectious childhood diseases, such as measles, mumps, rubella, diphtheria, and tetanus (see URL below for sample schedules). Ask students if they know how vaccines prevent these diseases. (Accept all responses at this point.) Tell students they will learn how in this lesson.

- <http://www.cdc.gov/vaccines/recs/schedules/child-schedule.htm>

Activity

Do the class activity described at the URL below. In the exercise, students will role-play the immune response.

- <http://www.aai.org/educating/using.htm>

Differentiated Instruction

Work with students to make a compare/contrast table of B cells and T cells (see sample **Table 24.2**).

TABLE 24.2: short caption

Type of Cells	Where They Mature	Forms They Take	What They Do
B cells	bone marrow	(a) plasma (b) memory	(a) produce antibodies (b) provide immunity
T cells	thymus gland	(a) helper (b) cytotoxic (c) memory (d) regulatory	(a) regulate B and T cells (b) destroy infected, damaged, or cancerous cells (c) provide immunity (d) end the immune response

Enrichment

Direct students who need extra challenges to the immunization activity at the URL below. They will use historical documents to learn how vaccines were developed and data on antibody production to understand how immunization prevents disease.

- <http://www.scienceteacherprogram.org/biology/Granberry04.html>

Science Inquiry

Have groups of students do the inquiry activity at the URL below. In the activity, students will build a 3D model to represent molecular recognition in the immune response.

- http://science.education.nih.gov/newsnapshots/TOC_Xeno/index/Science_Activity_1/science_activity_1.html

Overcoming Misconceptions

Misconceptions about vaccines are common and potentially dangerous. Here are just two examples:

- Vaccine-preventable diseases have been virtually eliminated, so children no longer need to be vaccinated.
 - (Reality: Most of the diseases still exist in human populations. Without vaccinations, children are at risk of getting and spreading the diseases.)
- Vaccines cause autism.
 - (Reality: The single study that led to this myth was later shown to be fraudulent. Many other studies have found no link between vaccines and autism.)

Discuss why such misconceptions endanger health. For more vaccine misconceptions, see:

- <http://www.quackwatch.com/03HealthPromotion/immu/immu00.html>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Sometimes the immune system makes mistakes and things go wrong.

- What if the immune system responded to a harmless allergen as though it were a deadly pathogen? What might happen?
 - (It might make you sick.)
- What if the immune system responded to normal body cells as though they were foreign invaders? Would the immune system destroy the body cells?
 - (*Answers may vary. Accept all reasonable responses.*)
- What if pathogens attacked and destroyed cells of the immune system itself? Would the immune system still be able to defend the body?
 - (Students might predict that the immune system would be compromised so the body could no longer fight off other pathogens.)

24.3 Immune System Diseases

Key Concept

Allergies occur when the immune system makes an inflammatory response to a harmless antigen, called an allergen. Autoimmune diseases, such as type 1 diabetes, occur when the immune system fails to distinguish self from non-self and attacks the body's own cells. In an immunodeficiency disease, such as HIV/AIDS, the immune system does not work normally, so it cannot adequately defend the body.

Standards

- CA.9–12.LS.10.e; CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.F.1.3
- AAAS.9–12.6.E.1, 4; AAAS.9–12.12.D.7
- McREL.9–12.12.4.20

Lesson Objectives

- Explain why allergies occur, and identify common allergens.
- Describe how autoimmune diseases affect the body.
- Define immunodeficiency, and list reasons for it.
- Explain how HIV is transmitted and how it causes AIDS.

Lesson Vocabulary

- **acquired immunodeficiency syndrome (AIDS)**: disorder characterized by frequent opportunistic infections that eventually develops in people who are infected with human immunodeficiency virus (HIV)
- **allergen**: any antigen that causes an allergy
- **allergy**: disease in which the immune system makes an inflammatory response to a harmless antigen
- **autoimmune disease**: type of disease, such as type 1 diabetes, in which the immune system attacks the body's cells as though they were pathogens
- **human immunodeficiency virus (HIV)**: virus transmitted through body fluids that infects and destroys helper T cells and eventually causes acquired immunodeficiency syndrome (AIDS)
- **immunodeficiency**: inability of the immune system to fight off pathogens that a normal immune system would be able to resist

Teaching Strategies

Introducing the Lesson

Take a poll of the class. Ask how many students have allergies or know someone who does. Call on a few volunteers to share what they are allergic to (if they know) and how they treat their allergies (e.g., antihistamines, allergy shots, avoidance of allergens). Tell students they will learn more about allergies and other immune system disorders when they read this lesson.

Activity

Have students do the coloring activity at the URL below. It will help them understand the structure of HIV and how it infects T cells.

- http://www.biologycorner.com/worksheets/HIV_coloring.html

Differentiated Instruction

Tell students to make a KWL chart for the lesson, where K = Know, W = Want to Know, and L = Learned. Students should fill in the K and W columns before reading the lesson and the L column after reading the lesson.

Enrichment

Interested students can research the medical and scientific literature for evidence for and against the molecular mimicry hypothesis of autoimmunity (see URLs below). Ask the students to choose sides and debate the issue in front of the class. Take a class vote on which side presented the most convincing evidence and arguments.

- <http://www.mult-sclerosis.org/MolecularMimicry.html>
- http://en.wikipedia.org/wiki/Molecular_mimicry

Science Inquiry

Have pairs of students research autoimmune diseases by doing the cooperative learning activity at the URL below. Make sure each pair of students chooses a different autoimmune disease to investigate but researches the same set of questions. Allow class time for groups to share what they learn in a PowerPoint presentation.

- <http://www.scienceteacherprogram.org/biology/mjoseph201.html>

Overcoming Misconceptions

Misconceptions about HIV/AIDS are very common. For their own health's sake, make sure your students know the facts. Assign the articles at the URLs below and then discuss them with the class.

- http://en.wikipedia.org/wiki/Misconceptions_about_HIV_and_AIDS
- <http://www.livestrong.com/article/94081-common-misconceptions-hiv-aids/>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Pathogens such as HIV are not the only cause of human disease. Many other things in our environment can also make us sick.

- Can you think of other environmental factors that negatively affect human health? What about pollutants in the environment? What are their possible health effects?
 - (*Sample answer:* Pollutants in the air can cause respiratory diseases.)
- Viruses cause some types of cancer, but cancer is more often caused by other environmental dangers. What environmental factors might increase the risk of cancer? Do you know what causes skin cancer, for example, or lung cancer?
 - (*Sample answer:* UV light causes skin cancer, and smoking causes lung cancer.)

24.4 Environmental Problems and Human Health

Key Concept

A carcinogen is anything that causes cancer. Most carcinogens produce mutations in genes that control the cell cycle. Both outdoor and indoor air may contain pollutants that can cause human illness and death. Bioterrorism is the intentional release or spread of agents of disease.

Standards

- CA.9–12.LS.4.c; CA.9–12.IE.1.d
- NSES.9–12.A.1.6; NSES.9–12.F.1.1, 2, 3; NSES.9–12.F.4.1, 3; NSES.9–12.F.5.2, 4
- AAAS.9–12.5.C.6; AAAS.9–12.6.E.2

Lesson Objectives

- Describe how carcinogens cause cancer and how cancer can be treated or prevented.
- Identify causes of air pollution and its effects on human health.
- Explain how bioterrorism threatens human health.

Lesson Vocabulary

- **Air Quality Index (AQI)**: assessment of the levels of pollutants in the outdoor air that is based on their human health effects
- **bioterrorism**: intentional release or spread of agents of disease
- **carcinogen**: anything that can cause cancer

Teaching Strategies

Introducing the Lesson

Introduce environmental health problems by asking a few students to go to the URL below and find the current air quality index (AQI) for their location. Explain what the AQI measures, and have students compare the value for their location with the AQI chart (**Figure 24.19** in the FlexBook and reproduced below). Ask the class to predict how pollutants in the air might affect health. Tell them they will learn how when they read this lesson.

- <http://www.airnow.gov/index.cfm?action=aqibasics.aqi>

(Image courtesy of the U.S. Environmental Protection Agency and under the public domain.)

Demonstration

Demonstrate particulates in outdoor or indoor air. Show students a new and a used (dirty) air filter from a car (outdoor air) or furnace (indoor air). Give them a chance to compare the two air filters. Then discuss where particulates in the air come from and how they affect human health.

Differentiated Instruction

Have students make a main ideas/details chart as they read the lesson. On the left side of a sheet of paper, they should list the main ideas, leaving several blank lines between each idea. Tell them to identify one main idea for each heading in the lesson. On the right side of the paper, they should list supporting details for each main idea.

Enrichment

Students who seek enrichment can investigate the role of clinical trials in the development of cancer therapies. They should start with the URL below. Ask the students to summarize what they learn in an oral report to the class.

- <http://www.cancer.gov/cancertopics/factsheet/Information/clinical-trials>

Science Inquiry

Have students analyze the data from the “Cancer in U.S. Adults” table (Table 24.6 in FlexBook, reproduced as Table 24.3).

TABLE 24.3: Cancers in U.S. Adults

Gender	Most Common Types of Cancer after Skin Cancer (% of all cancers)	Most Common Causes of Cancer Deaths (% of all cancer deaths)
Males	prostate cancer (33%), lung cancer (13%)	lung cancer (31%), prostate cancer (10%)
Females	breast cancer (32%), lung cancer (12%)	lung cancer (27%), breast cancer (15%)

- **Ask:** What does the graph show? (Lung cancer causes more cancer deaths in males and females, but prostate cancer in males and breast cancer in females are more common.)
- **Ask:** Why do you think more deaths are caused by lung cancer, given that breast and prostate cancer are more common? (Sample answer: Lung cancer might be harder to detect or treat than breast and prostate cancer.)

Health Connection

Describe routine screening tests for relatively common cancers, such as mammograms (breast cancer), Pap smears (cervical cancer), and colonoscopies (colon cancer). Discuss why early detection of cancer saves lives.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

High levels of certain hormones can increase the risk of some types of cancer. For example, high levels of estrogen can increase the risk of breast cancer. Estrogen is a sex hormone.

- What are sex hormones? How do sex hormones normally affect the body?
 - (Sex hormones are chemical messengers produced mainly by the gonads. They normally control sexual development and reproduction.)
- Do you think sex hormones might differ in males and females? Why?
 - (The main male sex hormone is testosterone. The main female sex hormone is estrogen. The hormones are produced by different organs and have different functions.)

24.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 25 TE Reproduction and Human Development

CHAPTER OUTLINE

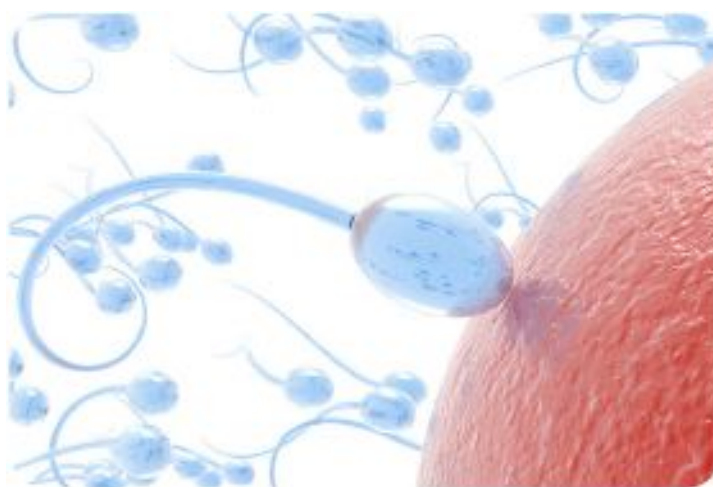
25.1 MALE REPRODUCTIVE SYSTEM

25.2 FEMALE REPRODUCTIVE SYSTEM

25.3 FROM FERTILIZATION TO OLD AGE

25.4 SEXUALLY TRANSMITTED INFECTIONS

25.5 WORKSHEET ANSWER KEYS



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Reproduction and Human Development

Outline

Lesson 25.1: Male Reproductive System

25.1.1 Male Reproductive Structures

- Penis
- Testes
- Epididymis
- Ducts and Glands
- Semen

25.1.2 Sexual Development in Males

- Development Before Birth
- Puberty and Its Changes
- Adolescent Growth Spurt

25.1.3 Production and Delivery of Sperm

- Spermatogenesis
- Sperm Maturation
- Ejaculation

Lesson 25.2: Female Reproductive System

25.2.1 Female Reproductive Structures

- External Structures
- Vagina
- Uterus
- Ovaries
- Fallopian Tubes
- Breasts

25.2.2 Sexual Development in Females

- Development Before Birth
- Changes of Puberty
- Adolescent Growth Spurt
- Menarche

25.2.3 Egg Production

- Oogenesis
- Maturation of a Follicle
- Ovulation and Fertilization

25.2.4 Menstrual Cycle

- Phases of the Menstrual Cycle
- Menopause

Lesson 25.3: From Fertilization to Old Age

25.3.1 Cleavage and Implantation

- Morula and Blastocyst Stages
- Implantation

25.3.2 Growth and Development of the Embryo

- Formation of Cell Layers
- Differentiation of Cells

- Organ Formation

25.3.3 Growth and Development of the Fetus

25.3.4 Placenta and Related Structures

- Placenta
- Amniotic Sac and Fluid

25.3.5 Pregnancy and Childbirth

- The Mother's Role
- Childbirth

25.3.6 From Birth to Adulthood

- Infancy
- Childhood
- Adolescence

25.3.7 Adulthood and Aging

- Early Adulthood
- Middle Adulthood
- Old Age
- Causes of Aging

25.3.8 KQED: Embryonic Stem Cell Research

Lesson 25.4: Sexually Transmitted Infections

25.4.1 Understanding Sexually Transmitted Infections

- Pathogens that Cause STIs
- How STIs Spread
- Preventing STIs

25.4.2 Bacterial STIs

- Chlamydia
- Gonorrhea
- Syphilis

25.4.3 Viral STIs

- Genital Herpes
- Hepatitis B
- Genital Warts and Cervical Cancer

Pacing the Lessons

Use the **Class Periods per Lesson** table below as a guide for the time required to teach the lessons of this chapter.

TABLE 25.1:

Lesson	Number of Class Periods
25.1 The Male Reproductive System	1.5
25.2 The Female Reproductive System	2.0
25.3 From Fertilization to Old Age	2.0
25.4 Sexually Transmitted Infections	1.0

- Class periods are assumed to be 60 minutes long.

Online Resources

See the following Web sites for appropriate laboratory activities:

1. In this lab, students will learn about human organ systems through the creation of 3-D models and other materials. Tailor the lab to the chapter by having students focus on the male and female reproductive systems. (Lessons 25.1 and 25.2)

- http://www.accessexcellence.org/AE/AEC/AEF/1995/allard_voyage.php

2. This lab will allow students to model the spread of a sexually transmitted infection (HIV) through a population of teens. Students will also address ethical issues associated with sexual behavior and the spread of HIV and other STIs. (Lesson 25.4)

- http://www.accessexcellence.org/AE/AEC/AEF/1994/glasscock_hiv.php

These Web sites may also be helpful:

1. The URL below provides questions and reliable Web site links to guide student investigations of fetal development and pregnancy, changes in boys and girls during puberty, and sexually transmitted infections. The Web site is useful for student research projects and additional information on chapter topics.

- http://serendip.brynmawr.edu/sci_edu/waldron/#sex

2. At the Web site below, you or your students can access several online videos and photographs relating to human reproduction and the male and female reproductive systems. The Web site also has a feature that allows you to create a presentation with the photos.

- <http://www.neok12.com/Reproductive-System.htm>

3. This Web site has an informative tutorial on human reproduction, from fertilization through birth.

- http://www.biology-online.org/7/1_fertilisation.htm

4. The Web sites below have more information on specific STIs. You may want to share these Web sites with students.

- <http://www.iwannaknow.org/stiwatch.html>
- <http://www.birdsandbees.org/STIWhatIsIt.htm>

25.1 Male Reproductive System

The male reproductive system consists of structures that produce sperm and secrete testosterone. They include the penis, testes, and epididymes. The male reproductive system forms before birth but does not become capable of reproduction until it matures during puberty. Sperm are produced in the testes in the process of spermatogenesis. They mature in the epididymes before being ejaculated from the body through the penis.

Key Concept

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6

Lesson Objectives

- Identify male reproductive structures and their functions.
- Explain how the male reproductive system develops.
- Describe how sperm are produced.

Lesson Vocabulary

- **adolescent growth spurt:** period of rapid growth that occurs during puberty
- **ejaculation:** muscle contractions that propel sperm from the epididymes and out through the urethra in males
- **epididymis:** (plural, epididymes) one of two male reproductive organs where sperm mature and are stored until they leave the body
- **luteinizing hormone (LH):** pituitary gland hormone that stimulates the testes to secrete testosterone and the ovaries to secrete estrogen
- **penis:** male reproductive organ containing the urethra, through which sperm and urine pass out of the body
- **puberty:** period during which humans become sexually mature
- **reproductive system:** system of organs that produces gametes and secretes sex hormones
- **semen:** fluid containing sperm and gland secretions that nourish sperm and carry them through the urethra and out of the body
- **sex hormone:** chemical messenger that controls sexual development and reproduction
- **spermatogenesis:** process of producing sperm in the testes
- **testis:** (plural, testes) one of two male reproductive organs that produces sperm and secretes testosterone
- **testosterone:** male sex hormone secreted by the testes

Teaching Strategies

Introducing the Lesson

Students are likely to have heard the term puberty before. Write the term on the board, and call on volunteers to define it (physical changes associated with sexual maturation). Tell students they will learn about puberty in this chapter, starting with puberty in boys in this lesson.

Activity

Students can learn more about the male reproductive system at the interactive InnerBody Web site (see URL below). This is a good way for students to find answers to questions they may be too embarrassed to ask in class. They can click on specific organs to read more about them and to see enlarged, cross-sectional images. After students explore the site, ask them to write a brief description of what they learned.

- <http://www.innerbody.com/image/repmov.html#>

Differentiated Instruction

Pair English language learners with native English speakers, and ask each pair to create a simple flow chart showing the steps of spermatogenesis. Tell them to draw sketches of the cells involved at each step in the process. The sketches should show whether the cells are haploid or diploid. Students should also label the cells at each step with the correct terms. **ELL**

Enrichment

Challenge a few students to make crossword puzzles using lesson vocabulary terms. They can create the puzzles by hand or use an online puzzle maker (see URL below). Make copies of their puzzles and pass them out to the class for vocabulary review.

- <http://www.discoveryeducation.com/free-puzzlemaker>

Science Inquiry

Tell the class that human actions have added chemicals to the environment that act like estrogens, which are female sex hormones. Divide the class into groups, and have each group formulate a hypothesis regarding how exposure to environmental estrogens might affect male embryonic development, male development during puberty, or spermatogenesis in adult males. Give groups a chance to share their hypotheses and explain the reasoning behind them. See the Web sites below for more information on this problem.

- <http://www.envtox.ucdavis.edu/cehs/TOXINS/estrogens.htm>
- http://www.energeticnutrition.com/vitalzym/xeno_phyto_estrogens.html

Math Connection

Tell students that semen contains an average of 66 million sperm per mL, and the average ejaculate consists of 2.75 mL of semen.

25.1. MALE REPRODUCTIVE SYSTEM

- **Ask:** How many sperm are there in an average ejaculate? (182 million.)

Discuss why millions of sperm are needed to ensure that one is able to reach and penetrate an egg. You can learn more at the URLs below.

- <http://www.goaskalice.columbia.edu/2267.html>
- <http://www2.oakland.edu/biology/lindemann/spermfacts.htm>

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

By the time they finish puberty, males have developed the traits of mature adults of their own sex. Adult males differ from adult females in many ways. Many of the differences come about because females and males develop differently during puberty.

- How do you think females change during puberty?
 - (Their reproductive organs develop, they go through a growth spurt, and they become sexually mature.)
- Do you know when females begin puberty? Do you think it's the same age as males?
- What hormones do you think control puberty in females?
 - (LH, FSH, and estrogen control puberty in females.)

25.2 Female Reproductive System

Key Concept

The female reproductive system consists of structures that produce eggs and secrete female sex hormones. They also provide a site for fertilization and enable the development and birth of a fetus. They include the vagina, uterus, ovaries, and Fallopian tubes. Starting in puberty, as part of the menstrual cycle, one egg matures and is released from an ovary each month. Menopause occurs when menstruation slows down and eventually stops, usually in middle adulthood.

Standards

- CA.9–12.IE.1.d
- NSES.9–12.A.1.6

Lesson Objectives

- Identify female reproductive structures and their functions.
- Explain how the female reproductive system develops.
- Describe how eggs are produced.
- Outline the phases of the menstrual cycle.

Lesson Vocabulary

- **estrogen**: female sex hormone secreted by the ovaries
- **Fallopian tube**: one of two female reproductive organs that carry eggs from the ovary to the uterus and provide the site where fertilization usually takes place
- **follicle-stimulating hormone (FSH)**: pituitary gland hormone that stimulates the ovaries to secrete estrogen and follicles in the ovaries to mature
- **menarche**: beginning of menstruation; first monthly period in females
- **menopause**: period during which menstrual cycles slow down and eventually stop in middle adulthood
- **menstrual cycle**: monthly cycle of processes and events in the ovaries and uterus of a sexually mature human female
- **menstruation**: process in which the endometrium of the uterus is shed from the body during the first several days of the menstrual cycle; also called monthly period
- **oogenesis**: process of producing eggs in the ovary
- **ovulation**: release of a secondary oocyte from the uterus about half way through the menstrual cycle
- **vulva**: external female reproductive structures, including the labia and vaginal opening

Teaching Strategies

Introducing the Lesson

Based on the knowledge that students now have about the male reproductive system, challenge them to predict and record answers to the following five questions about the female reproductive system:

- Why do female embryos develop female reproductive organs?
- What triggers the start of puberty in girls?
- What changes occur during puberty in girls?
- What is the major sex hormone in females?
- What organ produces gametes in females?

Tell students to save their answers and check to see if they were correct after they read this lesson.

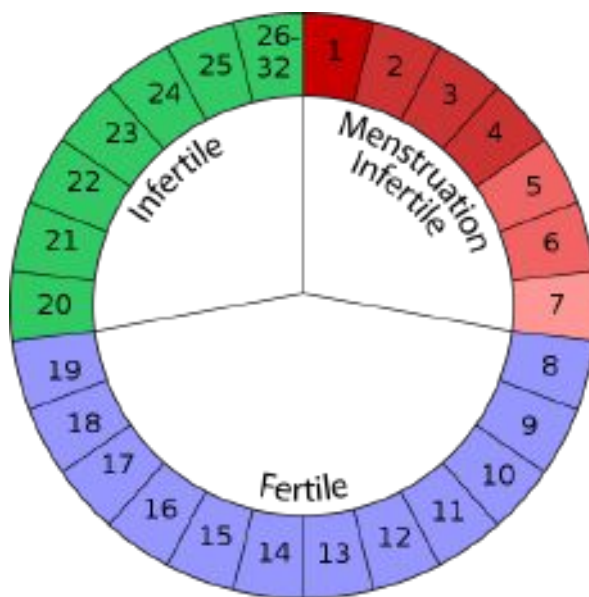
Demonstration

Demonstrate how the timing and events of the adolescent growth spurt differ in females and males by showing students graphs that compare the rates of growth and heights attained at each age in girls and boys. (The graphs demonstrate that the growth spurt in height occurs earlier and is over sooner in girls and that the peak rate of growth is not as rapid in girls. They also demonstrate that girls are shorter, on average, when they begin the spurt, because it starts earlier for them.) Discuss how differences in the growth spurt result in the average female being shorter than the average male by adulthood.

- http://www.racgp.org.au/AM/images/afp/200509simm_fig1.gif
- <http://www.bbc.co.uk/schools/ks3bitesize/science/images/heights.gif>

Differentiated Instruction

Pair less proficient readers with more proficient readers of the same gender, and ask pairs to make a cycle diagram of the menstrual cycle. They can base it on **Figure 25.10** in the FlexBook, reproduced below, and add other events, such as follicles maturing and ovulation occurring. **LPR**



(Image courtesy of Vargklo and under the public domain.)

Enrichment

Ask a small group of students who demonstrate in-depth understanding of the lesson to create a poster about one of the lesson topics, such as egg production or the menstrual cycle. Set aside a few minutes of class time for students to present their poster to the class.

Science Inquiry

Divide the class into groups, and have each group research factors that may influence the age at which girls begin menstruating (e.g., stress, nutrition, genes). Suggest that they start their research with the Web sites below. After students do their research, have each group develop a research plan to test the effects of one of the factors on age at menarche in girls. Specifically, they should identify the dependent and independent variables they would test and which variables they would control. Give groups a chance to present their research plans to the class. Encourage other students to provide feedback.

- <http://www.mum.org/menarage.htm>
- http://en.wikipedia.org/wiki/Menarche#Timing_of_menarche

Overcoming Misconceptions

Many people have misconceptions about when during the menstrual cycle fertilization is possible. For example, some people think fertilization is most likely during menstruation. Make sure students understand that fertilization is most likely around the time of ovulation, and that ovulation occurs around day 14 of the cycle.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

If an egg is fertilized by a sperm and implants in the uterus, the endometrium helps nourish it. However, as the new organism grows, it soon needs more nutrients than the endometrium can provide. These nutrients are provided by the mother's bloodstream.

- How do you think the fetus is able to obtain nutrients from the mother's blood? What structures and processes might be involved?
 - (The fetus obtains nutrients from the mother's blood in the placenta via the blood vessels in the umbilical cord.)
- The fetus also produces wastes. How do you think the wastes are excreted?
 - (Through the umbilical cord to the mother's circulation.)

25.3 From Fertilization to Old Age

Key Concept

Fertilization is the union of a sperm and egg, resulting in the formation of a zygote. The embryonic stage begins with implantation in the uterus. The fetal stage begins about two months after fertilization and continues until birth. After birth, growth and development are most rapid during infancy and slower throughout the rest of childhood until adolescence, when puberty takes place. Adulthood is divided into three stages: young and middle adulthood and old age. Aging occurs as cells lose their ability to divide.

Standards

- NSES.9–12.C.1.6; NSES.9–12.C.2.2
- AAAS.9–12.6.B.1

Lesson Objectives

- Outline the events that occur between fertilization and the embryonic stage.
- Explain how the embryo forms specialized cells and organs.
- Identify major events in the growth and development of the fetus.
- Explain the role of the placenta during fetal development.
- Describe pregnancy and childbirth.
- List milestones in growth and development from birth to adulthood.
- Describe the stages of adulthood, and explain why aging occurs.

Lesson Vocabulary

- **adolescence**: period of transition between the beginning of puberty and adulthood, during which significant physical, mental, emotional, and social changes occur
- **amniotic sac**: enclosed membrane containing fluid that surrounds and protects a fetus
- **blastocyst**: fluid-filled ball of cells that develops a few days after fertilization in humans
- **differentiation**: process by which unspecialized cells become specialized into one of many different types of cells, such as neurons or epithelial cells
- **embryo**: stage of growth and development that occurs from implantation through the eighth week after fertilization in humans
- **fetus**: developing human organism between weeks 8 and 38 after fertilization
- **implantation**: process in which a blastocyst embeds in the endometrium lining the uterus
- **infancy**: first year of life after birth in humans

- **pregnancy:** carrying of one or more offspring from fertilization until birth

Teaching Strategies

Introducing the Lesson

Share these facts and figures with students to generate interest in lesson content:

- a. The average human gestation period is 38 weeks from fertilization to childbirth.
- b. During this time, the zygote grows from 0.1 mm in diameter to a newborn about 500 mm long.
- c. During the same time, the volume of the uterus grows from 6 mL (about 1 tsp) to about 5 L.

Tell students they will learn more about the amazing process of human gestation in this lesson.

Activity

Students can learn more about fertilization, fetal development, and birth at the interactive InnerBody Web site (see the first URL below). By clicking on a specific stage, they can read more about it and follow the development of the embryo or fetus through that stage. The Visual Embryo Web site (see the second URL below) is another good source of information about, and images of, embryonic and fetal development.

- <http://www.innerbody.com/image/repo04.html>
- <http://www.visembryo.com/baby/>

Differentiated Instruction

Place less proficient readers in small groups with more proficient readers, and ask each group to make a simple flow chart that shows the stages of development from fertilization to birth. Tell students to use their FlexBook to identify important milestones that occur at each stage. Display their flow charts in the classroom. **LPR**

Enrichment

Ask a few students to interview three trusted adults, one in each stage of adulthood as defined in the FlexBook, about their own experiences with the changes of adulthood. For example, students might ask such questions as:

- What do you think are the best and worst aspects of this stage of adulthood?
- What physical changes or health problems have you experienced during this stage?
- In what ways are you different now than you were in the previous stage of life?

Have the students summarize what they learn in a brief written report.

Science Inquiry

Divide the class into small groups, and have each group build three-dimensional models that show the growth and development of an embryo from fertilization through gastrulation, including the blastocyst stage. Provide them with modeling clay in different colors to create their models, and ask students to be as detailed as possible. Give groups a chance to explain their models to the class, including the changes that have occurred between each stage.

Overcoming Misconceptions

Students may hold one or more of the common misconceptions below about fertilization or fetal development. Discuss the misconceptions with the class and make sure students are aware of the relevant facts.

- Fertilization occurs in the vagina.
- The sex of an embryo is determined only after the cells have started to divide.
- The fetus does not produce waste products.
- The fetus does not need oxygen until after birth.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

Most diseases become more common as people grow older, but sexually transmitted diseases (STDs) are much more common in teens and young adults. These diseases are now usually called sexually transmitted infections (STIs).

- Can you name any STIs? Do you know how STIs spread?
 - (STIs include chlamydia and genital herpes. They spread through sexual contact or other contact with body fluids.)
- What might explain why STIs are so common in young people?
 - (*Answers may vary.* Encourage a diversity of responses.)

25.4 Sexually Transmitted Infections

Key Concept

Sexually transmitted infections (STIs) are diseases caused by pathogens that spread mainly through sexual contact. Abstinence from sexual activity and other risk behaviors is the only completely effective way to prevent the spread of STIs. Bacterial STIs include chlamydia, gonorrhea, and syphilis. These diseases usually can be cured with antibiotics. Viral STIs include genital herpes, hepatitis B, genital warts, and cervical cancer. These diseases cannot be cured, but some of them can be prevented with vaccines.

Standards

- CA.9–12.IE.1.d; CA.9–12.LS.10.d
- NSES.9–12.A.1.6; NSES.9–12.F.1.2, 3

Lesson Objectives

- Explain what causes STIs and how they can be prevented.
- Identify and describe three common bacterial STIs.
- Identify and describe three common viral STIs.

Lesson Vocabulary

- **chlamydia**: sexually transmitted bacterial infection that is the most common STI in the United States
- **genital herpes**: sexually transmitted infection caused by a herpes virus that is characterized by periodic outbreaks of blisters on the genitals
- **genital warts**: small, rough growths on the genitals caused by a sexually transmitted infection with human papilloma virus (HPV)
- **gonorrhea**: common sexually transmitted infection that is caused by bacteria
- **hepatitis B**: inflammation of the liver caused by infection with hepatitis B virus, which is often transmitted through sexual contact
- **human papilloma virus (HPV)**: sexually transmitted virus that causes genital warts and cervical cancer
- **sexually transmitted infection (STI)**: infection caused by a pathogen that spreads mainly through sexual contact; also known as sexually transmitted disease (STD)
- **syphilis**: sexually transmitted infection caused by bacteria that may eventually be fatal if untreated
- **trichomoniasis**: common sexually transmitted infection that is caused by protozoa

Teaching Strategies

Introducing the Lesson

Introduce STIs and impress students with their prevalence by sharing these facts and figures:

- More than half of all people will have an STI at some point in their lifetime.
- Each year, one in four teens contracts an STI, many in their first sexual encounter.
- One in two sexually active people will contract an STI by age 25.

Tell students they will learn more about STIs, including how to prevent them, in this lesson.

Activity

Divide the class into groups, and assign each group a different sexually transmitted disease. Ask groups to learn more about their assigned disease, starting with the Web sites below, and to prepare a fact sheet on the disease. Fact sheets should include signs and symptoms of the disease, the organism that causes it, its incidence, and how it is treated and prevented. Students should also print at least one illustration to add to their fact sheet, such as a picture of the organism that causes the disease. Finally, have groups assemble their fact sheets to create an STD bulletin board or mobile.

- <http://www.cdc.gov/STD/>
- <http://www.ashastd.org/>
- http://kidshealth.org/teen/sexual_health/stds/std.html
- <http://www.healthline.com/channel/sexually-transmitted-diseases.html>

Differentiated Instruction

Pair beginning and advanced English language learners, and ask partners to make a Venn diagram comparing and contrasting bacterial and viral STDs. Tell them to include examples of each type of STD in their diagram. **ELL**

Enrichment

Arrange for interested students to interview a public health worker at their local or state health department regarding STIs in their community or state. Students should ask about rates of specific STIs, how STIs are monitored and reported, and what the health department does to reduce their spread. Give students a chance to report to the class on what they learn.

Science Inquiry

Divide the class into groups, and direct them to the interactive CDC Web site *Sexually Transmitted Diseases—Interactive Data 1996-2008* (or most recent year). The Web site allows users to generate data tables and graphs of STD rates for any combination of parameters, including by specific disease, state, year, gender, and/or age group. Instruct students to use the Web site to generate tables or graphs that allow them to address such questions as:

- How do rates of all STDs combined (or of specific STDs) compare in people aged 15–19 and people aged 20–24?
- Which gender of teens aged 15–19 has higher rates of all STDs combined (or of specific STDs)?

- c. Which specific STD has the highest rate in this age group?
- d. Which state has the highest (or lowest) rate of STDs in this age group?
- e. What is the annual trend in rates of all STDs combined (or of specific STDs) in this age group?

- <http://wonder.cdc.gov/std-std-v2008-race-age.html>

Overcoming Misconceptions

Misconceptions about how STIs spread are common. They are also dangerous because they can increase the risk of exposure to infection. Ask students whether the following STI myths are true or false. Call on students who know they are false to explain why.

- You can get STIs from toilet seats.
- You cannot get STIs through oral sex.
- You cannot get STIs from tattooing or body piercing.

Reinforce and Review

Lesson Worksheets

Copy and distribute the lesson worksheets in the *CK-12 Biology Workbook*. Ask students to complete the worksheets alone or in pairs as a review of lesson content.

Review Questions

Have students answer the Review Questions that are listed at the end of the lesson in their FlexBook.

- **Sample answers to these questions will be provided upon request. Please send an email to teachers-requests@ck12.org to request sample answers.**

Points to Consider

From fertilization to old age, the human body is like a fantastic machine. It controls its own growth and development, protects itself from dangers in the outside world, and has amazing abilities to act, think, and feel. Like all living things, human beings are marvels of nature.

- What have you learned about human beings and other organisms by reading this FlexBook?
 - (Call on several students for their input.)
- Has studying biology given you a greater understanding and appreciation of the living world?
 - (Use this question to initiate a final class discussion. Encourage all students to contribute.)

25.5 Worksheet Answer Keys

- The worksheet answer keys are available upon request. Please send an email to teachers-requests@ck12.org to request the worksheet answer keys.

CHAPTER 26

Standards: Biology

CHAPTER OUTLINE

26.1 SCIENCE CONTENT STANDARDS FOR CALIFORNIA PUBLIC SCHOOLS

26.2 NSES: NATIONAL SCIENCE EDUCATION STANDARDS

26.3 AAAS: AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

26.4 McREL: MID-CONTINENT RESEARCH FOR EDUCATION AND LEARNING

26.1 Science Content Standards for California Public Schools

- <http://www.cde.ca.gov/be/st/ss/>
- <http://www.cde.ca.gov/be/st/ss/documents/sciencestd.pdf>

Biology/Life Sciences Grades 9-12 Standards

Cell Biology

1. The fundamental life processes of plants and animals depend on a variety of chemical reactions that occur in specialized areas of the organism's cells. As a basis for understanding this concept:

- a. Students know cells are enclosed within semi permeable membranes that regulate their interaction with their surroundings.
- b. Students know enzymes are proteins that catalyze biochemical reactions without altering the reaction equilibrium and the activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings.
- c. Students know how prokaryotic cells, eukaryotic cells (including those from plants and animals), and viruses differ in complexity and general structure.
- d. Students know the central dogma of molecular biology outlines the flow of information from transcription of ribonucleic acid (RNA) in the nucleus to translation of proteins on ribosomes in the cytoplasm.
- e. Students know the role of the endoplasmic reticulum and Golgi apparatus in the secretion of proteins.
- f. Students know usable energy is captured from sunlight by chloroplasts and is stored through the synthesis of sugar from carbon dioxide.
- g. Students know the role of the mitochondria in making stored chemical-bond energy available to cells by completing the breakdown of glucose to carbon dioxide.
- h. Students know most macromolecules (polysaccharides, nucleic acids, proteins, lipids) in cells and organisms are synthesized from a small collection of simple precursors.
- i. Students know how chemiosmotic gradients in the mitochondria and chloroplast store energy for ATP production.
- j. Students know how eukaryotic cells are given shape and internal organization by a cytoskeleton or cell wall or both.

Genetics

2. Mutation and sexual reproduction lead to genetic variation in a population. As a basis for understanding this concept:

- a. Students know meiosis is an early step in sexual reproduction in which the pairs of chromosomes separate and segregate randomly during cell division to produce gametes containing one chromosome of each type.
- b. Students know only certain cells in a multi cellular organism undergo meiosis.
- c. Students know how random chromosome segregation explains the probability that a particular allele will be in a gamete.

- d. Students know new combinations of alleles may be generated in a zygote through the fusion of male and female gametes (fertilization).
- e. Students know why approximately half of an individual's DNA sequence comes from each parent.
- f. Students know the role of chromosomes in determining an individual's sex.
- g. Students know how to predict possible combinations of alleles in a zygote from the genetic makeup of the parents.

3. A multi cellular organism develops from a single zygote, and its phenotype depends on its genotype, which is established at fertilization. As a basis for understanding this concept:

- a. Students know how to predict the probable outcome of phenotypes in a genetic cross from the genotypes of the parents and mode of inheritance (autosomal or X-linked, dominant or recessive).
- b. Students know the genetic basis for Mendel's laws of segregation and independent assortment.
- c. Students know how to predict the probable mode of inheritance from a pedigree diagram showing phenotypes.
- d. Students know how to use data on frequency of recombination at meiosis to estimate genetic distances between loci and to interpret genetic maps of chromosomes.

4. Genes are a set of instructions encoded in the DNA sequence of each organism that specify the sequence of amino acids in proteins characteristic of that organism. As a basis for understanding this concept:

- a. Students know the general pathway by which ribosomes synthesize proteins, using tRNAs to translate genetic information in mRNA.
- b. Students know how to apply the genetic coding rules to predict the sequence of amino acids from a sequence of codons in RNA.
- c. Students know how mutations in the DNA sequence of a gene may or may not affect the expression of the gene or the sequence of amino acids in an encoded protein.
- d. Students know specialization of cells in multi cellular organisms is usually due to different patterns of gene expression rather than to differences of the genes themselves.
- e. Students know proteins can differ from one another in the number and sequence of amino acids.
- f. Students know why proteins having different amino acid sequences typically have different shapes and chemical properties.

5. The genetic composition of cells can be altered by incorporation of exogenous DNA into the cells. As a basis for understanding this concept:

- a. Students know the general structures and functions of DNA, RNA, and protein.
- b. Students know how to apply base-pairing rules to explain precise copying of DNA during semi conservative replication and transcription of information from DNA into mRNA.
- c. Students know how genetic engineering (biotechnology) is used to produce novel biomedical and agricultural products.
- d. Students know how basic DNA technology (restriction digestion by endonucleases, gel electrophoresis, ligation, and transformation) is used to construct recombinant DNA molecules.
- e. Students know how exogenous DNA can be inserted into bacterial cells to alter their genetic makeup and support expression of new protein products.

Ecology

6. Stability in an ecosystem is a balance between competing effects. As a basis for understanding this concept:

- a. Students know bio diversity is the sum total of different kinds of organisms and is affected by alterations of habitats.

- b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.
- c. Students know how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.
- d. Students know how water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem and how oxygen cycles through photosynthesis and respiration.
- e. Students know a vital part of an ecosystem is the stability of its producers and decomposers.
- f. Students know at each link in a food web some energy is stored in newly made structures but much energy is dissipated into the environment as heat. This dissipation may be represented in an energy pyramid.
- g. Students know how to distinguish between the accommodation of an individual organism to its environment and the gradual adaptation of a lineage of organisms through genetic change.

Evolution

7. The frequency of an allele in a gene pool of a population depends on many factors and may be stable or unstable over time. As a basis for understanding this concept:

- a. Students know why natural selection acts on the phenotype rather than the genotype of an organism.
- b. Students know why alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool.
- c. Students know new mutations are constantly being generated in a gene pool.
- d. Students know variation within a species increases the likelihood that at least some members of a species will survive under changed environmental conditions.
- e. Students know the conditions for Hardy-Weinberg equilibrium in a population and why these conditions are not likely to appear in nature.
- f. Students know how to solve the Hardy-Weinberg equation to predict the frequency of genotypes in a population, given the frequency of phenotypes.

8. Evolution is the result of genetic changes that occur in constantly changing environments. As a basis for understanding this concept:

- a. Students know how natural selection determines the differential survival of groups of organisms.
- b. Students know a great diversity of species increases the chance that at least some organisms survive major changes in the environment.
- c. Students know the effects of genetic drift on the diversity of organisms in a population.
- d. Students know reproductive or geographic isolation affects speciation.
- e. Students know how to analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction.
- f. Students know how to use comparative embryology, DNA or protein sequence comparisons, and other independent sources of data to create a branching diagram (cladogram) that shows probable evolutionary relationships.
- g. Students know how several independent molecular clocks, calibrated against each other and combined with evidence from the fossil record, can help to estimate how long ago various groups of organisms diverged evolutionarily from one another.

Physiology

9. As a result of the coordinated structures and functions of organ systems, the internal environment of the human body remains relatively stable (homeostatic) despite changes in the outside environment. As a basis for understanding this concept:

- a. Students know how the complementary activity of major body systems provides cells with oxygen and nutrients and removes toxic waste products such as carbon dioxide.
- b. Students know how the nervous system mediates communication between different parts of the body and the body's interactions with the environment.
- c. Students know how feedback loops in the nervous and endocrine systems regulate conditions in the body.
- d. Students know the functions of the nervous system and the role of neurons in transmitting electrochemical impulses.
- e. Students know the roles of sensory neurons, interneurons, and motor neurons in sensation, thought, and response.
- f. Students know the individual functions and sites of secretion of digestive enzymes (amylases, proteases, nucleases, lipases), stomach acid, and bile salts.
- g. Students know the homeostatic role of the kidneys in the removal of nitrogenous wastes and the role of the liver in blood detoxification and glucose balance.
- h. Students know the cellular and molecular basis of muscle contraction, including the roles of actin, myosin, Ca^{+2} , and ATP.
- i. Students know how hormones (including digestive, reproductive, osmoregulatory) provide internal feedback mechanisms for homeostasis at the cellular level and in whole organisms.

10. Organisms have a variety of mechanisms to combat disease. As a basis for understanding the human immune response:

- a. Students know the role of the skin in providing nonspecific defenses against infection.
- b. Students know the role of antibodies in the body's response to infection.
- c. Students know how vaccination protects an individual from infectious diseases.
- d. Students know there are important differences between bacteria and viruses with respect to their requirements for growth and replication, the body's primary defenses against bacterial and viral infections, and effective treatments of these infections.
- e. Students know why an individual with a compromised immune system (for example, a person with AIDS) may be unable to fight off and survive infections by microorganisms that are usually benign.
- f. Students know the roles of phagocytes, B-lymphocytes, and T-lymphocytes in the immune system.

Investigation #38; Experimentation

1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

- a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
- b. Identify and communicate sources of unavoidable experimental error.
- c. Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
- d. Formulate explanations by using logic and evidence.
- e. Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.
- f. Distinguish between hypothesis and theory as scientific terms.
- g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.
- h. Read and interpret topographic and geologic maps.
- i. Analyze the locations, sequences, or time intervals that are characteristic of natural phenomena (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).
- j. Recognize the issues of statistical variability and the need for controlled tests.
- k. Recognize the cumulative nature of scientific evidence.

- l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.
- m. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings. Examples of issues include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions in California.
- n. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e.g., the Piltdown Man fossil or unidentified flying objects) and that the theory is sometimes wrong (e.g., the Ptolemaic model of the movement of the Sun, Moon, and planets).

26.2 NSES: National Science Education Standards

http://www.nap.edu/openbook.php?record_id=4962

Content Standard A: Science as Inquiry

- a. Abilities necessary to do scientific inquiry
- b. Understandings about scientific inquiry

Content Standard B: Physical Science

- a. Structure of atoms
- b. Structure and properties of matter
- c. Chemical reactions
- d. Motions and forces
- e. Conservation of energy and increase in disorder
- f. Interactions of energy and matter

Content Standard C: Life Science*

- a. The cell
- b. Molecular basis of heredity
- c. Biological evolution
- d. Interdependence of organisms
- e. Matter, energy, and organization in living systems
- f. Behavior of organisms

***Only this standard is expanded below. For the other standards, see the NSES site.**

Content Standard D: Earth and Space Science

- a. Energy in earth systems
- b. Geochemical cycles
- c. Origin and evolution of the earth system
- d. Origin and evolution of the universe

Content Standard E: Science and Technology

- a. Abilities of technological design
- b. Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- a. Personal and community health
- b. Population growth
- c. Natural resources
- d. Environmental quality
- e. Natural and human-induced hazards
- f. Science and technology in local, national, and global challenges

Content Standard G: History and Nature of science

- a. Science as a human endeavor
- b. Nature of scientific knowledge
- c. Historical perspectives

Content Standard C: Life Science

1. The Cell

1.1 Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures that carry out such cell functions as energy production, transport of molecules, waste disposal, synthesis of new molecules, and the storage of genetic material.

2.1 Most cell functions involve chemical reactions. Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules. Both breakdown and synthesis are made possible by a large set of protein catalysts, called enzymes. The breakdown of some of the food molecules enables the cell to store energy in specific chemicals that are used to carry out the many functions of the cell.

3.1 Cells store and use information to guide their functions. The genetic information stored in DNA is used to direct the synthesis of the thousands of proteins that each cell requires.

4.1 Cell functions are regulated. Regulation occurs both through changes in the activity of the functions performed by proteins and through the selective expression of individual genes. This regulation allows cells to respond to their environment and to control and coordinate cell growth and division.

5.1 Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment. This process of photosynthesis provides a vital connection between the sun and the energy needs of living systems.

6.1 Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues and organs that comprise the final organism. This differentiation is regulated through the expression of different genes.

2. The Molecular Basis of Heredity

2.1 In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome.

2.2 Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome—and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next.

2.3 Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism's offspring.

3. Biological Evolution

3.1 Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring.

3.2 The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.

3.3 Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.

3.4 The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.

3.5 Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

4. The Interdependence of Organisms

4.1 The atoms and molecules on the earth cycle among the living and nonliving components of the biosphere.

4.2 Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers.

4.3 Organisms both cooperate and compete in ecosystems. The interrelationships and interdependencies of these organisms may generate ecosystems that are stable for hundreds or thousands of years.

4.4 Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms.

4.5 Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and if not addressed, ecosystems will be irreversibly affected.

5. Matter, Energy, and Organization in Living Systems

5.1 All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations. With death, and the cessation of energy input, living systems rapidly disintegrate.

5.2 The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes.

5.3 The chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken and new compounds with lower energy bonds are formed. Cells usually store this energy temporarily in phosphate bonds of a small high-energy compound called ATP.

5.4 The complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism.

5.5 The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy and the ability of the ecosystem to recycle materials.

5.6 As matter and energy flows through different levels of organization of living systems—cells, organs, organisms, communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.

6. The Behavior of Organisms

6.1 Multicellular animals have nervous systems that generate behavior. Nervous systems are formed from specialized cells that conduct signals rapidly through the long cell extensions that make up nerves. The nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules. In sense organs, specialized cells detect light, sound, and specific chemicals and enable animals to monitor what is going on in the world around them.

6.2 Organisms have behavioral responses to internal changes and to external stimuli. Responses to external stimuli can result from interactions with the organism's own species and others, as well as environmental changes; these responses either can be innate or learned. The broad patterns of behavior exhibited by animals have evolved to ensure reproductive success. Animals often live in unpredictable environments, and so their behavior must be flexible enough to deal with uncertainty and change. Plants also respond to stimuli.

6.3 Like other aspects of an organism's biology, behaviors have evolved through natural selection. Behaviors often have an adaptive logic when viewed in terms of evolutionary principles.

6.4 Behavioral biology has implications for humans, as it provides links to psychology, sociology, and anthropology.

26.3 AAAS: American Association for the Advancement of Science

<http://www.project2061.org/publications/bsl/online/index.php?home=true>

Grades 9-12 Standards

- a. The Nature of Science*
- b. The Nature of Mathematics
- c. The Nature of Technology
- d. The Physical Setting
- e. The Living Environment*
- f. The Human Organism*
- g. Human Society
- h. The Designed World
- i. The Mathematical World
- j. Historical Perspectives
- k. Common Themes
- l. Habits of Mind

***Only these standards (1, 5, and 6) are expanded below. For the other standards, see the AAAS site.**

1. The Nature of Science

A. The Scientific Worldview

- a. Science is based on the assumption that the universe is a vast single system in which the basic rules are everywhere the same and that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study.
- b. From time to time, major shifts occur in the scientific view of how things work. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Continuity and change are persistent features of science.
- c. No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations.
- d. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to a better understanding of how things work in the world but not to absolute truth.
- e. In matters that can be investigated in a scientific way, evidence for the value of a scientific approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions.

B. Scientific Inquiry

- a. Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare theories.

- b. Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available).
- c. Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible, practical, or ethical, they try to observe as wide a range of natural occurrences as possible to discern patterns.
- d. There are different traditions in science about what is investigated and how, but they all share a commitment to the use of logical arguments based on empirical evidence.
- e. Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings. For that reason, scientific teams are expected to seek out the possible sources of bias in the design of their investigations and in their data analysis. Checking each other's results and explanations helps, but that is no guarantee against bias.
- f. In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism.
- g. In the long run, theories are judged by the range of observations they explain, how well they explain observations, and how useful they are in making accurate predictions.
- h. New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators.
- i. Scientists' nationality, sex, ethnic origin, age, political convictions, and so on may incline them to look for or emphasize one or another kind of evidence or interpretation.
- j. To be useful, a hypothesis should suggest what evidence would support it and what evidence would refute it. A hypothesis that cannot, in principle, be put to the test of evidence may be interesting, but it may not be scientifically useful.
- k. Bias attributable to the investigator, the sample, the method, or the instrument may not be completely avoidable in every instance, but scientists want to know the possible sources of bias and how bias is likely to influence evidence.
- l. To avoid biased observations, scientific studies sometimes use observers who don't know what the results are "supposed" to be.

C. The Scientific Enterprise

- a. The early Egyptian, Greek, Chinese, Hindu, and Arabic cultures are responsible for many scientific and mathematical ideas and technological inventions. Modern science is based on traditions of thought that came together in Europe about 500 years ago. People from all cultures now contribute to that tradition.
- b. Progress in science and invention depends heavily on what else is happening in society.
- c. History often involves scientific and technological developments.
- d. Science disciplines differ from one another in what is studied, techniques used, and outcomes sought, but they share a common purpose and philosophy, and all are part of the same scientific enterprise. Although each discipline provides a conceptual structure for organizing and pursuing knowledge, many problems are studied by scientists using information and skills from many disciplines. Disciplines do not have fixed boundaries, and it happens that new scientific disciplines are being formed where existing ones meet and that some subdisciplines spin off to become new disciplines in their own right.
- e. Current ethics in science hold that research involving human subjects may be conducted only with the informed consent of the subjects, even if this constraint limits some kinds of potentially important research or influences the results.
- f. When applications of research could pose risks to society, scientists' decisions to participate in that research are based on personal as well as professional ethics.
- g. Scientists can bring information, insights, and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people understand the likely causes of events and estimate their possible effects.
- h. Outside their areas of expertise, scientists should enjoy no special credibility.
- i. Where a scientist's own personal, institutional, or community interests are at stake, he or she may be as biased

as others are.

- j. The strongly held traditions of science, including its commitment to peer review and publication, serve to keep the vast majority of scientists well within the bounds of ethical professional behavior. Deliberate deceit is rare and likely to be exposed sooner or later by the scientific enterprise itself. When violations of these scientific ethical traditions are discovered, they are strongly condemned by the scientific community, and the violators then have difficulty regaining the respect of other scientists.
- k. Funding influences the direction of science by virtue of the decisions that are made on which research to support. Research funding comes from various federal government agencies, industry, and private foundations.
- l. Scientists often cannot bring definitive answers to matters of public debate. There may be little reliable data available, or there may not yet be adequate theories to understand the phenomena involved, or the answer may involve the comparison of values that lie outside of science.
- m. Because science is a human activity, what is valued in society influences what is valued in science.
- n. The direction of scientific research is affected by informal influences within the culture of science itself, such as prevailing opinion on which questions are most interesting or which methods of investigation are most likely to be fruitful. Elaborate processes involving scientists themselves have been developed to decide which research proposals receive funding, and committees of scientists regularly review progress in various disciplines to recommend general priorities for funding.
- o. The dissemination of scientific information is crucial to its progress. Some scientists present their findings and theories in papers that are delivered at meetings or published in scientific journals. Those papers enable scientists to inform others about their work, to expose their ideas to criticism by other scientists, and, of course, to stay abreast of scientific developments around the world.

5. The Living Environment

A. Diversity of Life

- a. The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions.
- b. A great diversity of species increases the chance that at least some living things will survive in the face of large changes in the environment.
- c. The degree of relatedness between organisms or species can be estimated from the similarity of their DNA sequences, which often closely match their classification based on anatomical similarities.
- d. Similar patterns of development and internal anatomy suggest relatedness among organisms.
- e. Most complex molecules of living organisms are built up from smaller molecules. The various kinds of small molecules are much the same in all life forms, but the specific sequences of components that make up the very complex molecules are characteristic of a given species.
- f. A classification system is a framework created by scientists for describing the vast diversity of organisms, indicating the degree of relatedness between organisms, and framing research questions.

B. Heredity

- a. Some new gene combinations make little difference, some can produce organisms with new and perhaps enhanced capabilities, and some can be deleterious.
- b. The sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations in the offspring of any two parents.
- c. The information passed from parents to offspring is coded in DNA molecules, long chains linking just four kinds of smaller molecules, whose precise sequence encodes genetic information.
- d. Genes are segments of DNA molecules. Inserting, deleting, or substituting segments of DNA molecules can

alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment.

- e. Gene mutations can be caused by such things as radiation and chemicals. When they occur in sex cells, they can be passed on to offspring; if they occur in other cells, they can be passed on to descendant cells only. The experiences an organism has during its lifetime can affect its offspring only if the genes in its own sex cells are changed by the experience.
- f. The many body cells in an individual can be very different from one another, even though they are all descended from a single cell and thus have essentially identical genetic instructions.
- g. Different parts of the genetic instructions are used in different types of cells, influenced by the cell's environment and past history.
- h. Heritable characteristics can include details of biochemistry and anatomical features that are ultimately produced in the development of the organism. By biochemical or anatomical means, heritable characteristics may also influence behavior.

C. Cells

- a. Every cell is covered by a membrane that controls what can enter and leave the cell.
- b. In all but quite primitive cells, a complex network of proteins provides organization and shape and, for animal cells, movement.
- c. Within the cells are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, passing information, and even movement.
- d. In addition to the basic cellular functions common to all cells, most cells in multicellular organisms perform some special functions that others do not.
- e. The work of the cell is carried out by the many different types of molecules it assembles, mostly proteins. Protein molecules are long, usually folded chains made from 20 different kinds of amino acid molecules. The function of each protein molecule depends on its specific sequence of amino acids and its shape. The shape of the chain is a consequence of attractions between its parts.
- f. The genetic information encoded in DNA molecules provides instructions for assembling protein molecules.
- g. The genetic information encoded in DNA molecules is virtually the same for all life forms.
- h. Before a cell divides, the instructions are duplicated so that each of the two new cells gets all the necessary information for carrying on.
- i. Complex interactions among the different kinds of molecules in the cell cause distinct cycles of activities, such as growth and division. Cell behavior can also be affected by molecules from other parts of the organism or even other organisms.
- j. Gene mutation in a cell can result in uncontrolled division called cancer. Exposure of cells to certain chemicals and radiation increases mutations and thus the chance of cancer.
- k. Most cells function best within a narrow range of temperature and acidity. At very low temperatures, reaction rates are too slow. High temperatures and/or extremes of acidity can irreversibly change the structure of most protein molecules. Even small changes in acidity can alter the molecules and how they interact.
- l. A living cell is composed of a small number of chemical elements mainly carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. Carbon, because of its small size and four available bonding electrons, can join to other carbon atoms in chains and rings to form large and complex molecules.
- m. Some protein molecules assist in replicating genetic information, repairing cell structures, helping other molecules get in or out of the cell, and generally catalyzing and regulating molecular interactions.

D. Interdependence of Life

- a. Ecosystems can be reasonably stable over hundreds or thousands of years. As any population grows, its size is limited by one or more environmental factors: availability of food, availability of nesting sites, or number of predators.

- b. If a disturbance such as flood, fire, or the addition or loss of species occurs, the affected ecosystem may return to a system similar to the original one, or it may take a new direction, leading to a very different type of ecosystem. Changes in climate can produce very large changes in ecosystems.
- c. Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems.

E. Flow of Matter and Energy

- a. At times, environmental conditions are such that land and marine organisms reproduce and grow faster than they die and decompose to simple carbon containing molecules that are returned to the environment. Over time, layers of energy-rich organic material inside the earth have been chemically changed into great coal beds and oil pools.
- b. The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment. Continual input of energy from sunlight keeps the process going.

F. Evolution of Life

- a. The basic idea of biological evolution is that the earth's present-day species are descended from earlier, distinctly different species.
- b. Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another.
- c. Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within every species; some of these characteristics give individuals an advantage over others in surviving and reproducing; and the advantaged offspring, in turn, are more likely than others to survive and reproduce. As a result, the proportion of individuals that have advantageous characteristics will increase.
- d. Heritable characteristics can be observed at molecular and whole-organism levels—in structure, chemistry, or behavior.
- e. Heritable characteristics influence how likely an organism is to survive and reproduce.
- f. New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells of an organism cannot be passed on to the next generation.
- g. Natural selection leads to organisms that are well-suited for survival in particular environments.
- h. Chance alone can result in the persistence of some heritable characteristics having no survival or reproductive advantage or disadvantage for the organism.
- i. When an environment, including other organisms that inhabit it changes, the survival value of inherited characteristics may change.
- j. Modern ideas about evolution and heredity provide a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms.
- k. Life on earth is thought to have begun as simple, one-celled organisms about four billion years ago. Once cells with nuclei developed about a billion years ago, increasingly complex multi-cellular organisms evolved.
- l. Evolution builds on what already exists, so the more variety there is, the more there can be in the future. But evolution does not necessitate long-term progress in some set direction. Evolutionary change appears to be like the growth of a bush: Some branches survive from the beginning with little or no change; many die out altogether; and others branch repeatedly, sometimes giving rise to more complex organisms.
- m. The continuing operation of natural selection on new characteristics and in diverse and changing environments, over and over again for millions of years, has produced a succession of diverse new species.

6. The Human Organism

A. Human Identity

- a. The similarity of humans in their cell chemistry and DNA sequences reinforces the idea that all humans are part of a single species.
- b. Fossil and molecular evidence supports the idea that human beings evolved from earlier species.

B. Human Development

- a. As successive generations of an embryo's cells form by division, small differences in their immediate environments cause them to develop slightly differently, by activating or inactivating different parts of the DNA information.
- b. The availability of artificial means to prevent or facilitate pregnancy raises social, moral, ethical, and legal issues.
- c. The complexity of the human brain allows humans to create technological, literary, and artistic works on a vast scale, and to develop a scientific understanding of the world.
- d. The development and use of technologies to sustain, prolong, or terminate life raise social, moral, ethical, and legal issues.
- e. Both genes and environmental factors influence the rate and extent of development.
- f. Following fertilization, cell division produces a small cluster of cells that embeds itself in the wall of the uterus. As the embryo develops, it receives nourishment and eliminates wastes by the transfer of substances between its blood and the blood of its mother.
- g. Patterns of human development are similar to those of other vertebrates.

C. Basic Functions

- a. The immune system functions to protect against microscopic organisms and foreign substances that enter from outside the body and against some cancer cells that arise within.
- b. Communication between cells is required to coordinate their diverse activities. Cells may secrete molecules that spread locally to nearby cells or that are carried in the bloodstream to cells throughout the body. Nerve cells transmit electrochemical signals that carry information much more rapidly than is possible by diffusion or blood flow.
- c. Some drugs mimic or block the molecules involved in communication between cells and therefore affect operations of the brain and body.
- d. The human body is a complex system of cells, most of which are grouped into organ systems that have specialized functions. These systems can best be understood in terms of the essential functions they serve for the organism: deriving energy from food, protection against injury, internal coordination, and reproduction.

D. Learning

- a. Even instinctive behavior may not develop well if the individual is exposed to abnormal conditions.
- b. The expectations, moods, and prior experiences of human beings can affect how they interpret new perceptions or ideas. People tend to ignore evidence that challenges their beliefs and to accept evidence that supports them.
- c. The context in which something is learned may limit the contexts in which the learning can be used.
- d. Human thinking involves the interaction of ideas, and ideas about ideas. People can produce many associations internally without receiving information from their senses.

E. Physical Health

- a. Some allergic reactions are caused by the body's immune responses to usually harmless environmental substances. Sometimes the immune system may attack some of the body's own cells.
- b. Faulty genes can cause body parts or systems to work poorly. Some genetic diseases appear only when an individual has inherited a certain faulty gene from both parents.
- c. New medical techniques, efficient health care delivery systems, improved diet and sanitation, and a fuller understanding of the nature of health and disease give today's human beings a better chance of staying healthy than their ancestors had.
- d. Conditions now are very different from the conditions in which the species evolved. But some of the differences may not be good for human health.
- e. Some viral diseases, such as AIDS, destroy critical cells of the immune system, leaving the body unable to deal with multiple infection agents and cancerous cells.

F. Mental Health

- a. Stresses are especially difficult for children to deal with and may have long-lasting effects.
- b. Biological abnormalities, such as brain injuries or chemical imbalances, can cause or increase susceptibility to psychological disturbances.
- c. Reactions of other people to an individual's emotional disturbance may increase its effects.
- d. Human beings differ greatly in how they cope with emotions and may therefore puzzle one another.
- e. Ideas about what constitutes good mental health and proper treatment for abnormal mental states vary from one culture to another and from one time period to another.
- f. Psychological distress may also affect an individual's vulnerability to biological disease.
- g. According to some theories of mental disturbance, anger, fear, or depression may result from exceptionally upsetting thoughts or memories that are blocked from becoming conscious.

26.4 McREL: Mid-Continent Research for Education and Learning

- <http://www.mcrel.org/>
- <http://www.mcrel.org/compendium/SubjectTopics.asp?SubjectID=2>

Nature of Science Standards: Level IV (Grades 9-12)

Earth and Space Sciences

1. Understands atmospheric processes and the water cycle
2. Understands Earth's composition and structure
3. Understands the composition and structure of the universe and the Earth's place in it

Life Sciences

4. Understands the principles of heredity and related concepts
5. Understands the structure and function of cells and organisms
6. Understands relationships among organisms and their physical environment
7. Understands biological evolution and the diversity of life

Physical Sciences

8. Understands the structure and properties of matter
9. Understands the sources and properties of energy
10. Understands forces and motion

Nature of Science

11. Understands the nature of scientific knowledge*
12. Understands the nature of scientific inquiry*
13. Understands the scientific enterprise*

***Only these standards (11-13) are expanded below. For the other standards, see the McREL site.**

Standard 11. Understands the nature of scientific knowledge

1. Knows ways in which science distinguishes itself from other ways of knowing and from other bodies of knowledge (e.g., use of empirical standards, logical arguments, skepticism).

- a. Knows ways that science distinguishes itself from other ways of knowing.
- b. Knows ways that science distinguishes itself from other bodies of knowledge.
- c. Knows that the use of empirical standards distinguishes science.
- d. Knows that the use of logical arguments distinguishes science.
- e. Knows that the use of skepticism distinguishes science.

2. Knows that scientific explanations must meet certain criteria to be considered valid (e.g., they must be consistent with experimental and observational evidence about nature, make accurate predictions about systems being studied, be logical, respect the rules of evidence, be open to criticism, report methods and procedures, make a commitment to making knowledge public, include an adequate sample size).

- a. Knows that scientific explanations must report methods and procedures.
- b. Knows that scientific explanations must be consistent with experimental evidence about nature.
- c. Knows that scientific explanations must be consistent with observational evidence about nature.
- d. Knows that scientific explanations must make accurate predictions about systems being studied.
- e. Knows that scientific explanations must be logical.
- f. Knows that scientific explanations must respect the rules of evidence.
- g. Knows that scientific explanations must be open to criticism.

3. Understands how scientific knowledge changes and accumulates over time (e.g., all scientific knowledge is subject to change as new evidence becomes available; some scientific ideas are incomplete and opportunity exists in these areas for new advances; theories are continually tested, revised, and occasionally discarded).

- a. Understands how scientific knowledge changes over time.
- b. Understands how scientific knowledge accumulates over time.
- c. Understands that scientific knowledge is subject to change as new evidence becomes available.
- d. Understands that some scientific ideas are incomplete.
- e. Understands that an opportunity exists in incomplete areas for new advances.
- f. Understands that theories are continually tested.
- g. Understands that theories are continually revised.
- h. Understands that theories are occasionally discarded.

4. Knows that from time to time, major shifts occur in the scientific view of how the world works, but usually the changes that take place in the body of scientific knowledge are small modifications of prior knowledge.

- a. Knows that sometimes major shifts occur in the scientific view of how the world works.
- b. Knows that usually the changes in scientific knowledge are small modifications of prior knowledge.

5. Understands different types of scientific explanations (e.g., theories, laws, hypotheses) and their usefulness and limitations (e.g., a new theory might fit the observations just as well or better than the old theory, or might fit a wider range of observations than the old theory).

- a. Understands theories as a type of scientific explanation.
- b. Understands laws as a type of scientific explanation.
- c. Understands hypotheses as a type of scientific explanation.
- d. Understands the usefulness and limitations of theories.
- e. Understands the usefulness and limitations of laws.
- f. Understands the usefulness and limitations of hypotheses.
- g. Knows that a new theory might fit the observations just as well or better than the old theory.
- h. Knows that a new theory might fit a wider range of observations than the old theory.

6. Understands criteria (e.g., accuracy of predictions, appropriateness, limitations, usefulness) used to evaluate a model's representation of the real world.

- a. Knows that criteria are used to evaluate a model's representation of the real world.
- b. Knows that the accuracy of predictions is a criterion used to evaluate a model's representation of the real world.
- c. Knows that appropriateness is a criterion used to evaluate a model's representation of the real world.
- d. Knows that limitations is a criterion used to evaluate a model's representation of the real world.
- e. Knows that usefulness is a criterion used to evaluate a model's representation of the real world.

7. Knows that science is based on assumptions about the universe (e.g., nature is the same everywhere, the objects and events in the universe occur in a predictable pattern that is comprehensible through careful, systematic study).

- a. Knows that science is based on assumptions about the universe.
- b. Knows that science is based on the assumption that nature is the same everywhere.
- c. Knows that science is based on the assumption that the objects and events in the universe occur in a predictable pattern.
- d. Knows that science is based on the assumption that the predictable pattern of objects and events is comprehensible through careful, systematic study.

Standard 12. Understands the nature of scientific inquiry

1. Understands the use of hypotheses in scientific investigations (e.g., selecting and narrowing the focus of data, determining additional data to be gathered, guiding the interpretation of data).

- a. Understands the use of hypotheses in guiding the interpretation of data.
- b. Understands the use of hypotheses in selecting the focus of data.
- c. Understands the use of hypotheses in narrowing the focus of data.
- d. Understands the use of hypotheses in determining if additional data needs to be gathered.

2. Designs and conducts scientific investigations (e.g., formulates testable hypotheses; identifies and clarifies the method, controls, and variables; analyzes, organizes, and displays data; revises methods and explanations; presents results; receives critical response from others).

- a. Designs scientific investigations.
- b. Conducts scientific investigations.
- c. Formulates testable hypotheses for scientific investigations.
- d. Identifies the method in a scientific investigation.
- e. Clarifies the method in a scientific investigation.
- f. Clarifies the chosen controls in a scientific investigations.
- g. Clarifies the chosen variables in a scientific investigations.
- h. Displays data from a scientific investigation.
- i. Organizes data from a scientific investigation.
- j. Analyzes data from a scientific investigation.
- k. Revises methods in a scientific investigation.
- l. Revises explanations in a scientific investigation.
- m. Presents results from a scientific investigation.
- n. Receives critical response from others in a scientific investigation.
- o. Knows that scientific investigations include formulating a testable hypotheses.
- p. Knows that scientific investigations include identifying and clarifying the method.
- q. Knows that scientific investigations include identifying and clarifying the controls.
- r. Knows that scientific investigations include identifying and clarifying the variables.
- s. Knows that scientific investigations include analyzing, organizing, and displaying data.
- t. Knows that scientific investigations include the presentation of results.
- u. Knows that scientific investigations may include revising methods and explanations.
- v. Knows that scientific investigations are subject to critical response from others.

3. Evaluates the results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists (e.g., reviewing current scientific understanding, using evidence to validate conclusions, examining the logic to determine which explanations and models are the best, examining the involvement of control groups, examining the adequacy of the sample).

- a. Evaluates the results of scientific investigations by reviewing current scientific understanding.

- b. Evaluates the results of scientific investigations by using evidence to validate conclusions.
- c. Evaluates the results of scientific investigations by examining the logic to determine which explanations and models are the best.
- d. Evaluates the results of scientific investigations by examining the involvement of control groups.
- e. Evaluates the results of scientific investigations by examining the adequacy of the sample.
- f. Knows that evaluating a proposed scientific explanation includes reviewing current scientific understanding.
- g. Knows that evaluating a proposed scientific explanation includes using evidence to validate conclusions.
- h. Knows that evaluating a proposed scientific explanation includes examining the logic to determine which explanations and models are the best.
- i. Knows that evaluating a proposed scientific explanation includes examining the involvement of control groups.
- j. Knows that evaluating a proposed scientific explanation includes examining the adequacy of the sample.

4. Uses technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) to perform accurate scientific investigations and communications.

- a. Uses technology to perform accurate scientific investigations.
- b. Uses technology to facilitate accurate scientific communications.
- c. Uses mathematics to perform accurate scientific investigations.
- d. Uses mathematics to facilitate accurate scientific communications.
- e. Uses hand tools to perform accurate scientific investigations.
- f. Uses hand tools to facilitate accurate scientific communications.
- g. Uses measuring instruments to perform accurate scientific investigations.
- h. Uses measuring instruments to facilitate accurate scientific communications.
- i. Uses calculators to perform accurate scientific investigations.
- j. Uses calculators to facilitate accurate scientific communications.
- k. Uses computers to perform accurate scientific investigations.
- l. Uses computers to facilitate accurate scientific communications.
- m. Uses measurement to perform accurate scientific investigations.
- n. Uses measurement to facilitate accurate scientific communications.
- o. Uses formulas to perform accurate scientific investigations.
- p. Uses formulas to facilitate accurate scientific communications.
- q. Uses charts to perform accurate scientific investigations.
- r. Uses charts to facilitate accurate scientific communications.
- s. Uses graphs to perform accurate scientific investigations.
- t. Uses graphs to facilitate accurate scientific communications.
- u. Understands the concept of accuracy as it relates to the use of formulas in scientific investigations.
- v. Understands the concept of accuracy as it relates to the use of measurement in scientific investigations.
- w. Understands the concept of accuracy as it relates to the use of hand tools in scientific investigations.
- x. Understands the concept of accuracy as it relates to the use of measuring instruments in scientific investigations.
- y. Understands the concept of accuracy as it relates to the use of calculators in scientific investigations.
- z. Understands the concept of accuracy as it relates to the use of computers in scientific investigations.
- . Understands the concept of accuracy as it relates to the use of charts and graphs in scientific communications.

5. Knows that conceptual principles and knowledge guide scientific inquiries; historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists.

- a. Knows that conceptual principles guide scientific inquiries.
- b. Knows that knowledge guides scientific inquiries.
- c. Knows that historical scientific knowledge influences the design of investigations.

- d. Knows that historical scientific knowledge influences the interpretation of investigation.
- e. Knows that historical scientific knowledge influences the evaluation of explanations made by other scientists.
- f. Knows that current scientific knowledge influences the design of investigations.
- g. Knows that current scientific knowledge influences the interpretation of investigations.
- h. Knows that current scientific knowledge influences the evaluation of explanations made by other scientists.

6. Knows that scientists conduct investigations for a variety of reasons (e.g., to discover new aspects of the natural world, to explain recently observed phenomena, to test the conclusions of prior investigations, to test the predictions of current theories).

- a. Knows that scientists conduct investigations to test the predictions of current theories.
- b. Knows that scientists conduct investigations to discover new aspects of the natural world.
- c. Knows that scientists conduct investigations to explain recently observed phenomena.
- d. Knows that scientists conduct investigations to test conclusions of prior investigations.

7. Knows that investigations and public communication among scientists must meet certain criteria in order to result in new knowledge and methods (e.g., arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge; the methods and procedures used to obtain evidence must be clearly reported to enhance opportunities for further investigation).

- a. Knows that investigations among scientists must meet certain criteria in order to result in new knowledge.
- b. Knows that investigations among scientists must meet certain criteria in order to result in new methods.
- c. Knows that public communication among scientists must meet certain criteria to result in new knowledge.
- d. Knows that public communication among scientists must meet certain criteria to result in new methods.
- e. Knows that arguments must be logical to result in new knowledge and methods.
- f. Knows that arguments must connect natural phenomena, investigations, and historical bodies of scientific knowledge to result in new knowledge and methods.
- g. Knows that methods used to obtain evidence must be clearly reported for future investigations to result in new knowledge and methods.
- h. Knows that procedures used to obtain evidence must be clearly reported for future investigations to result in new knowledge and methods.

Standard 13. Understands the scientific enterprise

1. Knows that, throughout history, diverse cultures have developed scientific ideas and solved human problems through technology.

- a. Knows that throughout history, diverse cultures have developed scientific ideas through technology.
- b. Knows that throughout history, diverse cultures have solved human problems through technology.

2. Understands that individuals and teams contribute to science and engineering at different levels of complexity (e.g., an individual may conduct basic field studies; hundreds of people may work together on a major scientific question or technological problem).

- a. Understands that individuals contribute to science at different levels of complexity.
- b. Understands that teams contribute to science at different levels of complexity.
- c. Understands that individuals contribute to engineering at different levels of complexity.
- d. Understands that teams contribute to engineering at different levels of complexity.
- e. Understands that individuals conduct basic field studies.

- f. Understands that hundreds of people may work together on a major scientific question.
- g. Understands that hundreds of people may work together on a technological problem.

3. Understands the ethical traditions associated with the scientific enterprise (e.g., commitment to peer review, truthful reporting about the methods and outcomes of investigations, publication of the results of work) and that scientists who violate these traditions are censored by their peers.

- a. Understands the ethical traditions associated with scientific enterprise.
- b. Understands the importance of peer review in scientific enterprise.
- c. Understands the importance of truthful reporting about the methods of investigations.
- d. Understands the importance of truthful reporting about the outcomes of investigations.
- e. Understands the importance of the publication of results.
- f. Understands that scientists who violate ethical traditions are censored by their peers.

4. Knows that science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen.

- a. Knows that science is essentially a social enterprise.
- b. Knows that technology is essentially a social enterprise.
- c. Knows that science alone can only indicate what can happen, not what should happen.
- d. Knows that technology alone can only indicate what can happen, not what should happen.

5. Understands that science involves different types of work in many different disciplines (e.g., scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations; many scientific investigations require the contributions of individuals from different disciplines; new disciplines of science, such as geophysics and biochemistry, often emerge at the interface of older disciplines).

- a. Understands that biochemistry emerged at the interface of older disciplines.
- b. Understands that scientists in different disciplines ask different questions.
- c. Understands that scientists in different disciplines use different methods of investigation.
- d. Understands that scientists in different disciplines accept different types of evidence to support their explanations.
- e. Understands that scientific investigations require the contributions of individuals from different disciplines.
- f. Understands that new disciplines of science often emerge at the interface of older disciplines.
- g. Understands that geophysics emerged at the interface of older disciplines.

6. Knows that creativity, imagination, and a good knowledge base are all required in the work of science and engineering.

- a. Knows that creativity is required in the work of science.
- b. Knows that creativity is required in the work of engineering.
- c. Knows that imagination is required in the work of science.
- d. Knows that imagination is required in the work of engineering.
- e. Knows that a good knowledge base is required in the work of science.
- f. Knows that a good knowledge base is required in the work of engineering.

