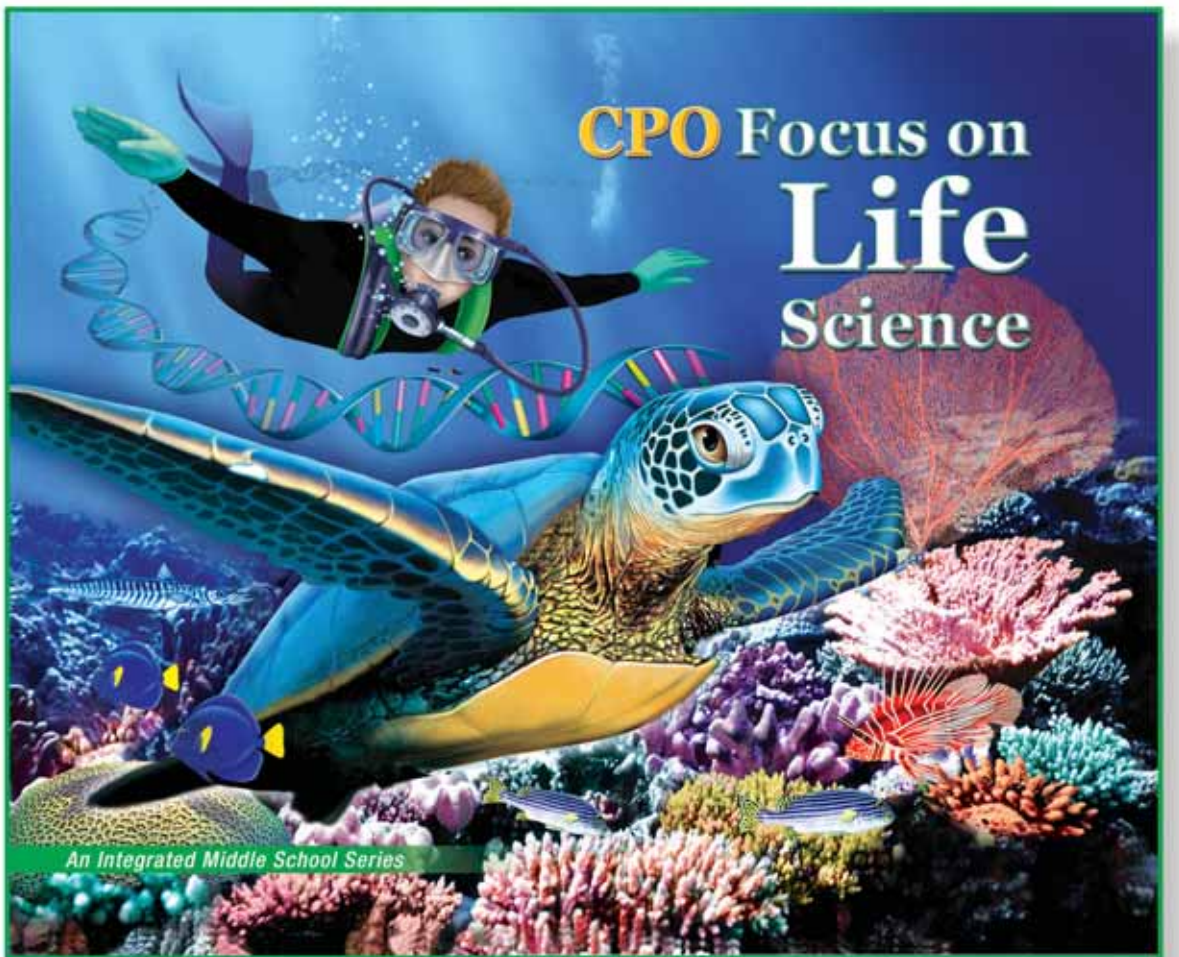

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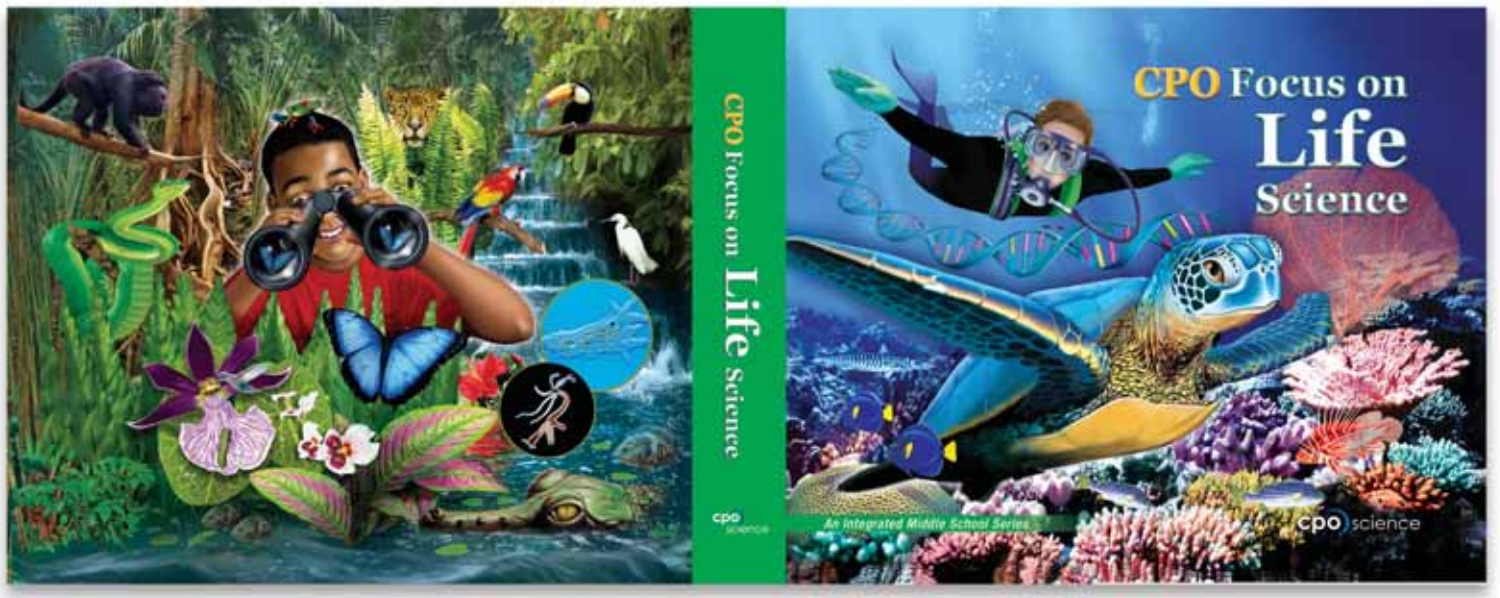

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CPO Science
80 Northwest Boulevard
Nashua, New Hampshire 03063
(866)588-6951
http://www.cposcience.com

Printed and Bound in the United States of America

Credits

Writers

Scott Eddleman – Author
B.S., Biology, Southern Illinois University; M.Ed., Harvard University.

Taught for 13 years in urban and rural settings. Developed two successful science-based school-to-career programs. Nationally recognized teacher trainer in inquiry-based and project-based instruction. Participated in Brown University fellowship conducting research on the coral reefs of Belize. Worked on National Science Foundation-funded projects at TERC. Scott has been a principal writer and curriculum developer for CPO Science for six years.

Mary Jo Carabatsos – Content review
Ph.D., Cell, Molecular, and Developmental Biology, Tufts University School of Medicine.

Worked as a research scientist before teaching high school biology and physical science for the past four years. Mary Jo advises on and edits material.

Sylvia Gutman – Content review
B.S., Science Education, University of New Orleans; M.S., Curriculum and Instruction, University of San Diego.

Teacher of the Year Award from the Lake Elsinore (Calif.) Unified School District and the 2001 California Science Teachers Association Distinguished Science Award for Middle School.

Kelly McAllister – Content review
B.S., Biology, M.Ed., Science Education

Eighth-grade team leader and mentor teacher at Gage Middle School in Riverside, Calif. Kelly has taught life and physical science and served as department chair.

Senior Editor

Lynda Pennell – Executive Vice President
B.A., English; M.Ed., Administration, Reading Disabilities, Northeastern University; CAGS Media, University of Massachusetts, Boston.

Nationally known for high school restructuring and integrating academic and career education. Served as director at an urban school for five years and has 17 years teaching/administrative experience in Boston public schools. Lynda has led development at CPO Science for six years.

Editorial Consultants

Christine Golden
B.A., Psychology, Gordon College; M.B.A., Rivier College

Project manager at Imperial Communications since 1999. With 22 years in publishing, now owner and managing editor of Big Dog Publishing Services. Christine's work centers on editing K-12 textbook material.

Contributing Writers

Kristin Dolcimascolo
B.S., Biology, University of Delaware.

Teaches science at Wayland (Mass.) Middle School, where she has taught for six years. Has taught middle school math.

Patricia Davidson
BA in Biology from Bowdoin College, Brunswick ME, M.Ed.,University of New England, Biddeford ME

Teaches seventh-grade life science. Has been teaching for eight years and also teaches nature classes in New Hampshire.

Suzanne Densmore
B.S., Zoology UMass Amherst, B.S., Medical Technology UMass Amherst, M.Ed., Science Education, Harvard University

Teaches Biology and AP environmental science at Masconomet Regional High School in Topsfield, MA.

Patsy Eldridge
B.S., Biology, Grove City College; M.Ed., Tufts University.

Experienced high school Physical Science teacher and national hands-on science trainer and presenter. As an adjunct professor for Endicott College in Beverly, MA, and the College of Charleston, developed content-intensive Physical Science courses for pre- and in-service educators. Technical background in the medical device field. Patsy has developed curriculum and training materials with CPO for six years.

Laine Ives
B.A., Gordon College; graduate coursework at Cornell University's Shoals Marine Laboratory and Wheelock College.

Taught high school English overseas and environmental education at a middle school in New England.

Shannon Donovan
B.S., Botany, University of Rhode Island; M.S., Biological Sciences, University of Rhode Island

Teaches biology, physical science, and advanced biology at Scituate (Mass.) High School.

Melissa Vela
M.S., Secondary Education, Boston College; M.S., Agricultural and Biological Engineering, Cornell University.

Teaches sixth-grade physical science and eighth-grade algebra at Weston (Mass.) Middle School. Taught earth and space science for six years at Lexington (MA) High School.

Art and Illustration

Polly Crisman – Designer, illustrator
B.F.A., University of New Hampshire.

Graphic artist with expertise in advertising and marketing design, freelance illustrating, and caricature art. Polly is the CPO primary illustrator and manages all files.

Bruce Holloway – Cover designs
Pratt Institute, N.Y.; Boston Museum School of Fine Arts.

Created all CPO Science book covers and many of the CPO specific designs. Expertise in product design, advertising, and three-dimensional exhibit design. Commissioned for the New Hampshire Duck Stamp for 1999 and 2003.

Jesse Van Valkenburgh - Illustrator
B.F.A., Illustration, Rochester Institute of Technology.

Has worked in prepress film production and design. Jesse has worked at PC Connection in Merrimack, N.H., as a graphic designer doing catalog and direct mailing design, logo design, and illustration.

James Travers
A.A.S., Business and Commercial Art, Akron University.

Has held positions as a graphic designer and art development manager. He remains a commissioned artist.

Connections

Catherine C. Reed
B.S., Secondary Education, Akron University; M.Ed., Administration and Curriculum, Baldwin-Wallace College.

Middle school science curriculum specialist. Catherine has worked as a freelance curriculum developer and writer for years.

Sharon O. Faulkner is an educational freelance writer who lives in Andover, Mass.

John K. Manos is an educational freelance writer who lives in Evanston, Ill.

Laura J. Tierney is a freelance writer living in Chelmsford, Mass.

Assesssment

Mary Ann Erickson
B.S, Naval Architecture and Marine Engineering, Massachusetts Institute of Technology

Ran a technical writing consulting business, writing process control manuals for water treatment plants, software design documentation for simulation software, and operator manuals for mining equipment.

Kelly A. Story
B.S., Chemistry, Gordon College; M.S., Chemistry, University of Massachusetts, Lowell.

Taught chemistry and maintains a position as lab instructor at Gordon College, Wenham, Mass.

Equipment Design

Thomas Narro – Senior Vice President
B.S., Mechanical Engineering, Rensselaer Polytechnic Institute.

Accomplished design and manufacturing engineer; experienced consultant in corporate reengineering and industrial-environmental acoustics.

Danielle Dzurik
Bachelor of Industrial Design, Auburn University.

Focused on product development, new product design, and improving on older designs.

Material Support

Michael Grady – Tech services coordinator
A.A., Arranging and Performing, Berklee College of Music; Medical Technician Diploma, Middlesex Community College.

Professional musician for more than 20 years, with 10 years experience in customer service fields.

Kathryn Gavin – Quality Control and Purchasing Manager

Responsible for quality control and purchasing and works with product engineering on all new development. Kerry has been assuring total quality of CPO Science equipment for ten years.

Lisa LaChance – Senior materials specialist
A.S., Accounting

Lisa evaluates samples to ensure that materials meet project requirements, developing and managing the release of specifications. She also evaluates changes to current products to enhance them and/or reduce manufacturing costs.

Reviewers

Nancy Joplin
English-language arts department chairwoman
Ray Wiltsey Middle School, Ontario, Calif.

Jodye Selco, Ph.D.
Professor, Center for Education and Equity in Math, Science, and Technology
California State Polytechnic University, Pomona, Calif.

Brian E. Goodrow
Physical science teacher
Apple Valley Middle School, Apple Valley, Calif.

Philip L. Hunter
Science department chairman
Johnson Middle School, Westminster, Calif.

Bianca N. McRae
Science teacher, department chairwoman
Menifee Valley Middle School, Menifee, Calif.

Tia L. Shields
Life science/health and English language learning teacher
Nicolas Junior High School, Fullerton, Calif.

Kelly McAllister
Science teacher
Gage Middle School, Riverside, Calif.

Brad Joplin
Science teacher
Ray Wiltsey Middle School, Ontario, Calif.

Tony Heinzman
Science teacher
Apple Valley, Calif.

Sylvia Gutman
Science teacher, department chairwoman
David A. Brown Middle School
Wildomar, Calif.

Lake Elsinore Unified School District

Technical Support

Tracy Morrow – Framemaker specialist, technical editor and trainer
B.A., English, Texas A&M University; M.A., English, Sam Houston State University.

Taught middle school in Klein, Texas, a suburban region outside Houston, for nine years; at Tomball College in Tomball, Texas, for five years; and worked as a technical writer in the oil and gas, airlines, and real estate industries. Tracy offers consulting services and technical training; her expertise is in the editing program Framemaker.

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Johns Hopkins University
Baltimore, Md.

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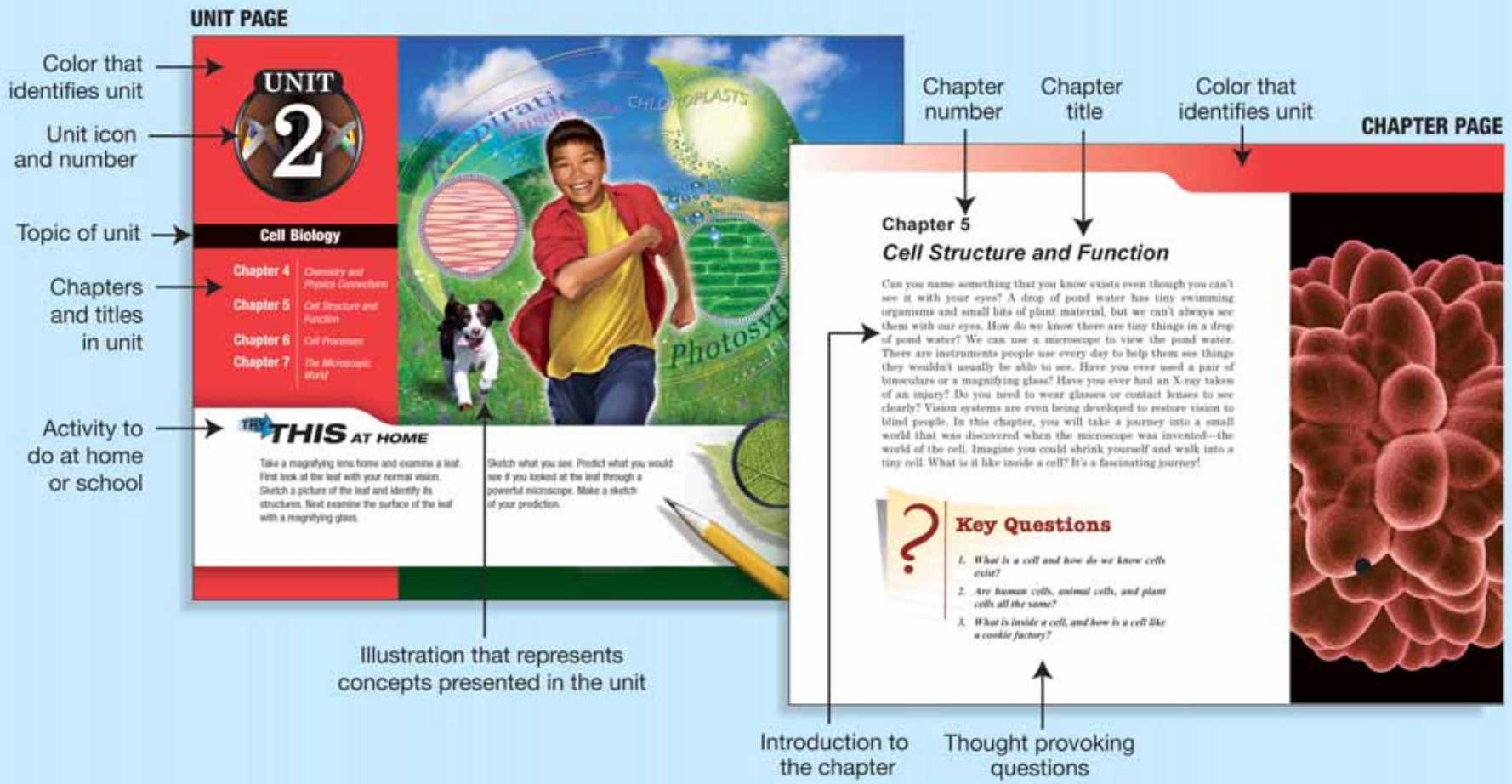
Independent photographer

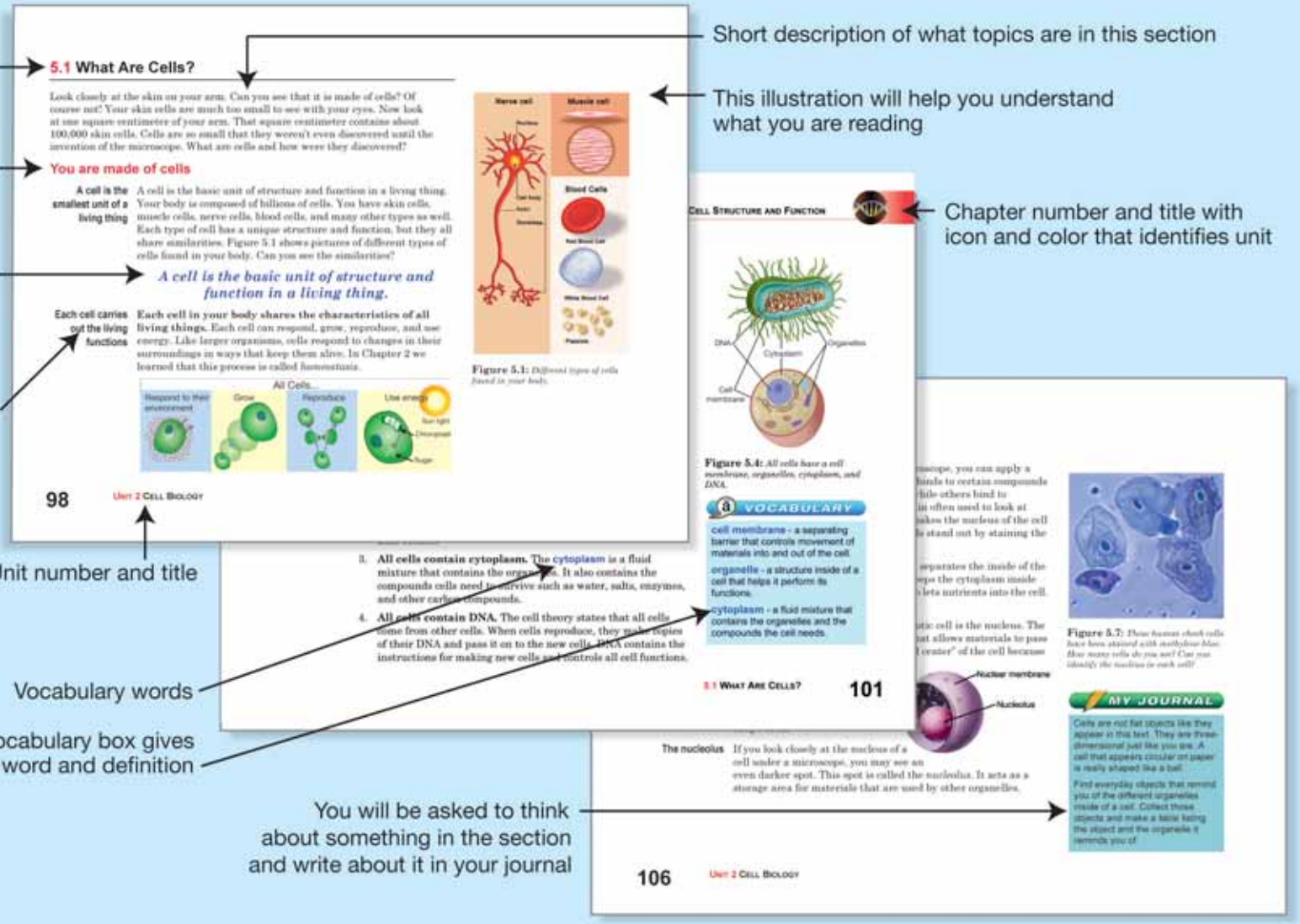
Stock Photography provided by ShutterStock, Inc.

On each page of the student text you will find aids to help find information, understand concepts and answer questions. The following introduction includes sample pages with indicators that point out the page contents and reading aids.

Unit Pages and Chapter Pages



Student Text Pages



Connection Pages and Activity Pages

CONNECTION

The **Connection** is like a magazine article about an interesting science fact. There is a Connection at the end of each chapter.

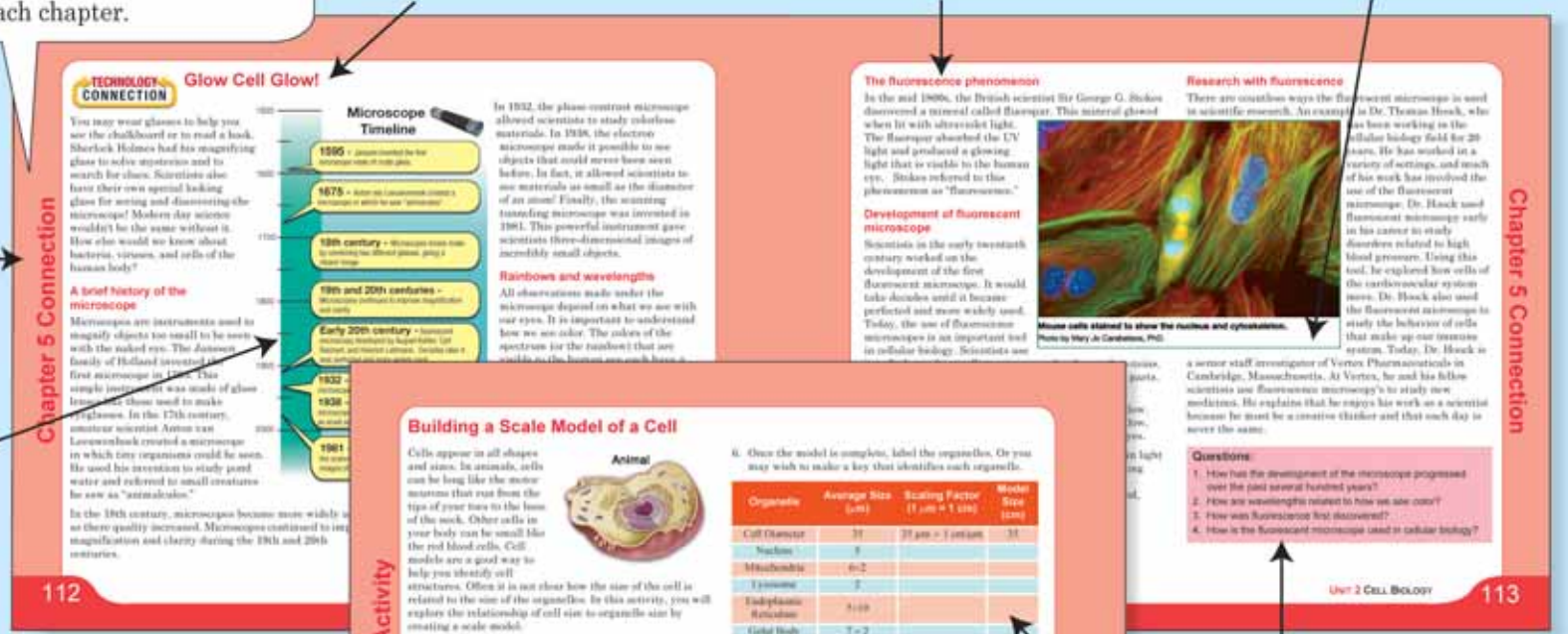
Title of the Connection

Main idea heading

Explanation of photo

Unit color and Chapter number

Timeline chart



Questions to help you understand the article's main idea

Data table for recording results

Questions to help you apply what you learned from this activity

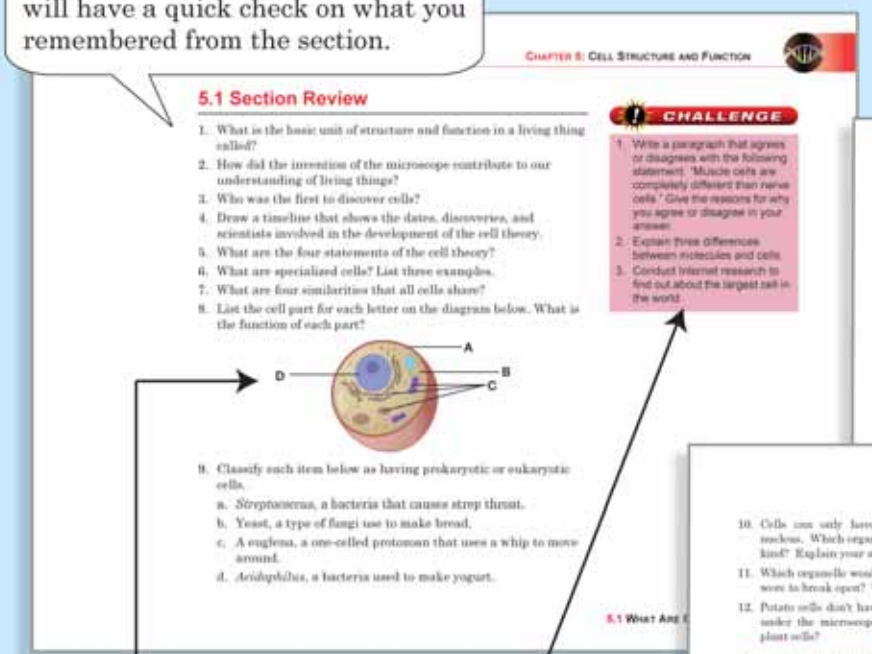
ACTIVITY

An Activity is another hands-on project that you can do in school or at home. This activity will help you learn more about the information in the chapter.

Assessment Pages

SECTION REVIEW

By answering these questions, you will have a quick check on what you remembered from the section.



CHAPTER 5: CELL STRUCTURE AND FUNCTION

5.1 Section Review

1. What is the basic unit of structure and function in a living thing called?
2. How did the invention of the microscope contribute to our understanding of living things?
3. Who was the first to discover cells?
4. Draw a timeline that shows the dates, discoveries, and scientists involved in the development of the cell theory.
5. What are the four statements of the cell theory?
6. What are specialized cells? List three examples.
7. What are four similarities that all cells share?
8. List the cell part for each letter on the diagram below. What is the function of each part?

9. Classify each item below as having prokaryotic or eukaryotic cells.
   a. *Streptococcus*, a bacteria that causes strep throat.
   b. Yeast, a type of fungi use to make bread.
   c. A euglena, a one-celled protozoan that uses a whip to move around.
   d. *Acidophilus*, a bacteria used to make yogurt.

CHALLENGE

1. Write a paragraph that agrees or disagrees with the following statement: "Muscle cells are completely different than nerve cells." Give the reasons for why you agree or disagree in your answer.
2. Explain three differences between molecules and cells.
3. Conduct Internet research to find out about the largest cell in the world.

5.1 WHAT ARE

Graphs,diagrams, or charts will help you in answering questions

This gives you an interesting way to learn more about information in the section

These questions ask you to answer questions in writing or solve a problem

CHAPTER TEST

These questions are answered after reading the chapter.

This tells you where to find the information

Chapter 5 Test

Vocabulary

Select the correct term to complete the sentences.

cell membrane	cytoskeleton	mitochondria
cell wall	endoplasmic reticulum	organelle
nucleus	golgi body	prokaryotic
cytoplasm	lysosome	ribosome

Section 5.1

1. Bacteria are _____ cells.
2. The _____ controls what enters and exits the cell.
3. A structure inside a cell that does a certain job is called an _____.
4. The fluid mixture with organelles and other vital compounds in cells is the _____.
5. Eukaryotic cells all have a _____ that contains DNA.

Concepts

Section 5.1

1. Which of the following is not part of the cell theory?
   a. Cells only come from existing cells.
   b. All of an organism's life functions occur within cells.
   c. The two major types of cells are prokaryotic cells and eukaryotic cells.
   d. All living things are made of one or more cells.
2. Identify each characteristic as either a feature of prokaryotic cells (P) or as a feature of eukaryotic cells (E).
   a. _____ name means "before nucleus" in Greek
   b. _____ believed to have originated 2 billion years ago
   c. _____ DNA is contained in nucleus
   d. _____ larger of the two types - 10 times the size of the other

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10. Cells can only have one of certain organelles like the nucleus. Which organelles can a cell have many of the same kind? Explain your answer.
11. Which organelle would cause a lot of damage to the cell if it were to break open? Why?
12. Potato cells don't have chloroplasts. If you saw these cells under the microscope, how could you tell that they were plant cells?

Math and Writing Skills

Section 5.1

1. Imagine that you are Anton van Leeuwenhoek and you have just observed the first blood cells, bacteria, and single-celled protists. Write a letter to a friend describing your amazing discoveries.
2. Write an imaginary dialogue that could have taken place between Matthias Schleiden and Theodore Schwann after they observed plant and animal tissue under a microscope.
3. Many of the cells in your body are 0.01 mm long. Use that measurement to complete these calculations.
   a. An amoeba – a unicellular protist – is 1 mm long. How many body cells would you have to stack end to end to equal the size of an amoeba?
   b. Figure out what your height is in millimeters by multiplying your height in meters by 1000. How many body cells would you have to stack end to end to equal your height?
   c. The length of a swimming pool is 25,000 mm. How many body cells would you have to stack end to end to equal the length of the pool?
   d. Prokaryotic cells are approximately 1/10 the size of eukaryotic cells. How big are prokaryotic cells?
4. If you were trying to classify an unknown organism by looking at its cells, what could its cells tell you?

Section 5.2

5. Describe what goes on in a typical animal cell. Be sure to mention all the organelles listed in the text.
6. Which organelles does a spinach cell have that a rabbit cell does not? Explain your answer.
7. Explain the connection between a wilted plant and cell parts like the vacuole and the cell wall.

Chapter Project

Cells have organelles with weird names like golgi body and endoplasmic reticulum. It is often helpful to invent a way to help you remember the names of the structures and their functions. Create a song or poem about cell structure, using the guidelines below. Record the song or poem and play it back for the class or perform it live. If you don't like solo work, join some classmates and do this as a group project. Make sure everyone contributes verses to the song or poem!

1. Choose one type of cell, either a plant cell or an animal cell.
2. Choose a popular song for the melody or rap. If you create a poem, make the verses rhyme.
3. The song or poem must include each structure listed on the animal or plant cell diagram in your book. In addition to naming the structures, you must use the song or poem to help you remember the function of each structure.
4. Submit your creation for approval, memorize it, and then share the song or poem with your classmates. When it comes time for a written test on cell structure, you might be humming a tune to help you remember the answers!

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This gives you a different way of practicing or learning information from the chapter

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Living Systems

Chapter 1	*Studying Life*
Chapter 2	*Living Things*
Chapter 3	*Interactions of Living Things*

TRY THIS AT HOME

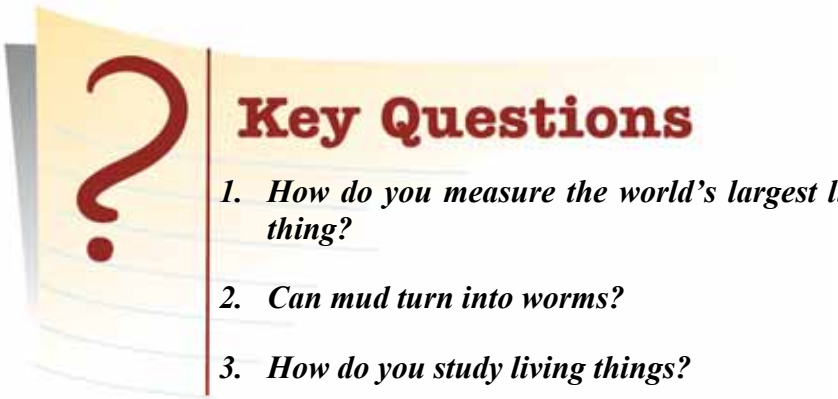
Visit a local park, field, or any natural area. Make a list of all of the living things you see. Choose one living thing from your list. Write down what you have observed about the living thing.

Next, write down what you know about it. Finally, write down what you would like to learn about the living thing. Present your ideas on your next day of class.

Chapter 1

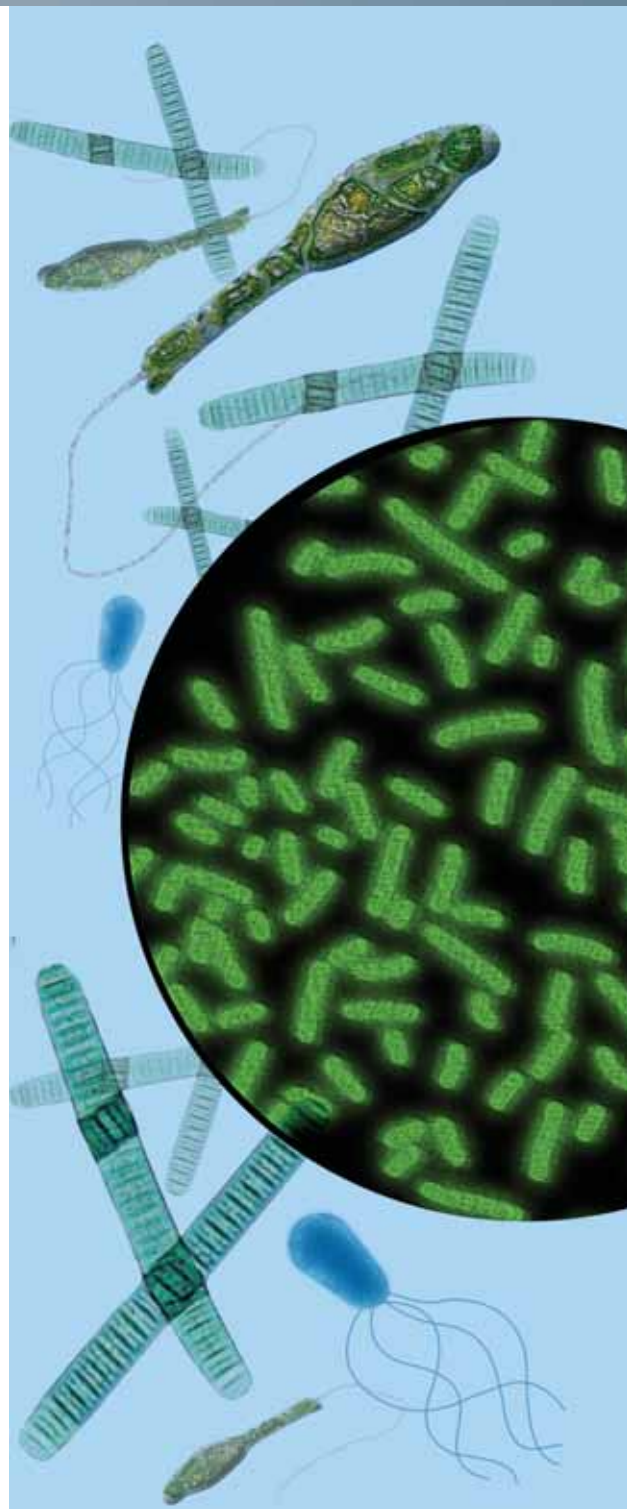
Studying Life

Earth is a living planet. Life can be found in places where you least expect it! Tiny living things can be found in the extremely hot openings of undersea volcanoes, and even in hot springs full of acid. Scientists from the University of Colorado have studied tiny organisms that survived for twenty years at the bottom of a dry stream bed in cold Antarctica. When water finally reached them, the organisms sprang to life after only one day, and within a week, an entire community had formed! Researchers wonder if these tough life forms could even exist on the cold, dry surface of Mars. In this chapter you will begin studying life science, a fascinating and sometimes surprising subject.



Key Questions

1. ***How do you measure the world's largest living thing?***
2. ***Can mud turn into worms?***
3. ***How do you study living things?***



1.1 Measurements

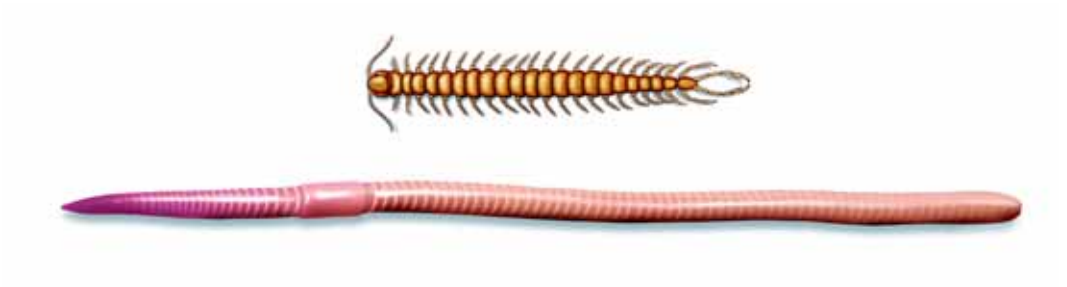
What may be the largest living thing on Earth was discovered in a forest in Oregon. A fungus, known as the honey mushroom, lives 3 feet underground and covers 10 square kilometers (over 1,000 football fields) of the forest floor. Small mushrooms visible above the ground are only a tiny part of this humongous fungus (Figure 1.1). When scientists study living things, they often take measurements like *length* and *mass*. In this section, you will learn about different measurements used by scientists.

Figure 1.1: *These small mushrooms are only a tiny part of the giant fungus that lives underground.*

Measurement and units

Measurements A **measurement** is a value that tells the amount of something. A measurement has a *quantity* and a *unit*. For example, 5 centimeters is a measurement because it has a quantity, 5, and a unit, centimeters.

Units A **unit** is a fixed amount of something. If you asked someone to walk 5, she would not know how far to go. The units you could use include 5 feet, 5 meters, 5 miles, and 5 kilometers. The centipede in the picture below is 5 centimeters in length. The earthworm is 5 inches in length. Which is a larger unit, centimeters or inches?



VOCABULARY

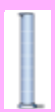
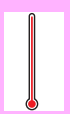
measurement - a value that tells the amount of something.

unit - a fixed amount of something.

The International System of Measurement (SI)

Units allow people to communicate amounts. To make sure their measurements are accurate, scientists use a set of standard units that have been agreed upon around the world. Table 1.1 shows the units in the International System of Measurement, known as the SI.

Table 1.1: Common SI Units

Quantity	Unit	Value
Length	**meter (m)** kilometer (km) decimeter (dm) centimeter (cm) millimeter (mm) micrometer (μm) nanometer (nm)	 1 km = 1,000 m 1 dm = 0.1 m 1 cm = 0.01 m 1 mm = 0.001 m 1 μm = 0.000001 m 1 nm = 0.000000001 m
Volume 	**cubic meter (m^3)** cubic centimeter (cm^3) liter (L) milliliter (mL)	 1 cm^3 = 0.000001 m^3 1 L = 0.001 m^3 1 mL = 0.001 L
Mass	kilogram (kg) gram (g) milligram (mg)	 1 g = 0.001 kg 1 mg = 0.000001 kg
Temperature 	Kelvin (K) Celsius (°C)	 0°C = 273 K 100°C = 373 K

SOLVE IT!

The United States uses the English system of measurement. This system uses miles, yards, feet, and inches for length. Conversion factors are useful in converting from English to SI and back again. For example,
1 inch = 2.54 cm.
Use this conversion factor to solve the following problems. The first one is done for you.

1. 10 in. × (2.54 cm/1 in.) = 25.4 cm.
2. 0.50 in. = _____ cm
3. 300 cm = _____ in.
4. 1 m = _____ in.
5. 2 km = _____ in.

Length and area

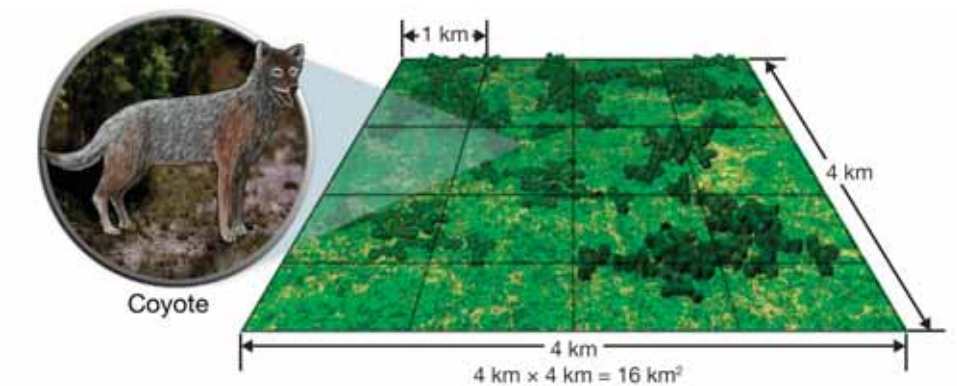
Measuring length

Length is a measurement of distance. Life scientists measure the length of a living thing along its *greatest* dimension. Figure 1.2 shows a scale that compares the lengths of different living things and the appropriate SI unit to measure each.

What is the length of the fish below? If you measured it to be 10.5 cm, you are correct!

Measuring area

Area is a measurement of how much surface something has. A coyote occupies a certain area of land called its *territory*. A coyote's territory is about 16 square kilometers (km^2). While this area probably has an irregular shape, if a coyote's territory was a perfect square, you could measure the area as shown below.



VOCABULARY

length - a measurement of distance.

area - a measurement of how much surface something has.

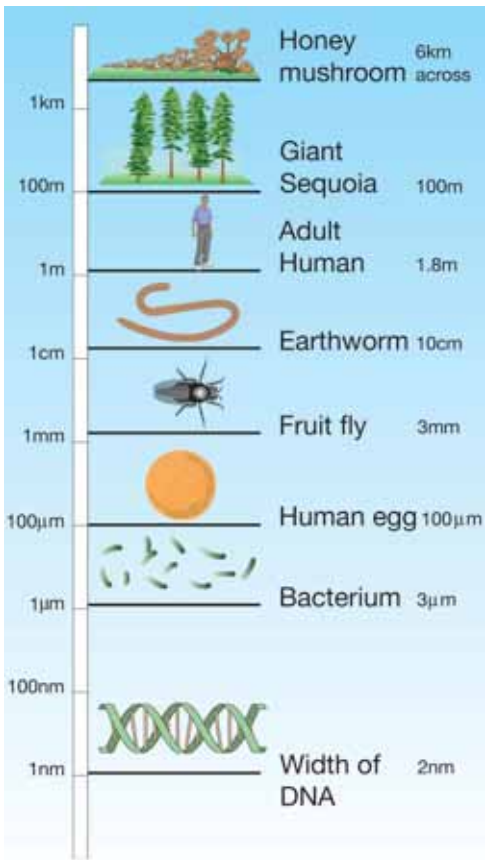


Figure 1.2: *Comparing the size of living things and compounds.*

Volume

What is volume?

Volume is a measurement of the amount of space something occupies. The volume of a solid object is usually measured in cubic meters (m^3) or cubic centimeters (cm^3). To find the volume of an aquarium, multiply length × width × height as shown below.

VOCABULARY

volume - a measurement of the amount of space something occupies.

Measuring the volume of liquids

The volume of a liquid is usually measured in liters (L) or milliliters (mL). One milliliter is equal to one cubic centimeter. Measuring the volume of liquid matter is easy. You simply pour it into a marked container such as a measuring cup, graduated cylinder, or beaker, and read the volume mark. To get the greatest accuracy, there are two things to keep in mind. First, read the mark at eye level. Second, you may notice that the surface of the liquid forms a curve rather than a straight line. That curve is called a *meniscus*. If the meniscus curves downward, (liquid water does this) read the volume at the bottom of the curve as shown in Figure 1.3. A few liquids, like mercury, will form an upward curve. In this case, read the volume mark at the top of the curve.

1 milliliter (mL) = 1 cubic centimeter (cm^3)

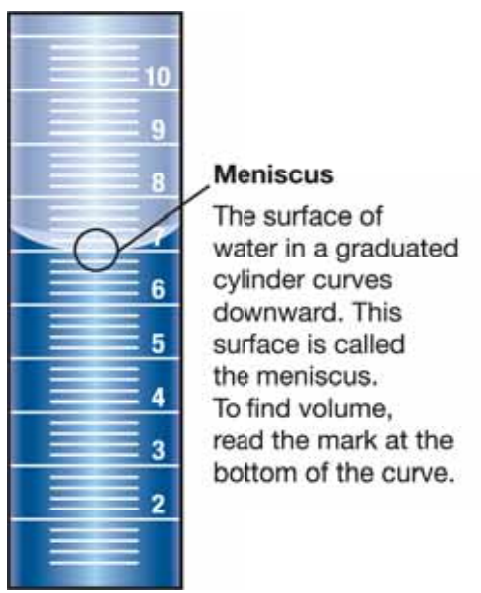


Figure 1.3: *The surface of water curves downward. Read the mark at the bottom of the curve.*

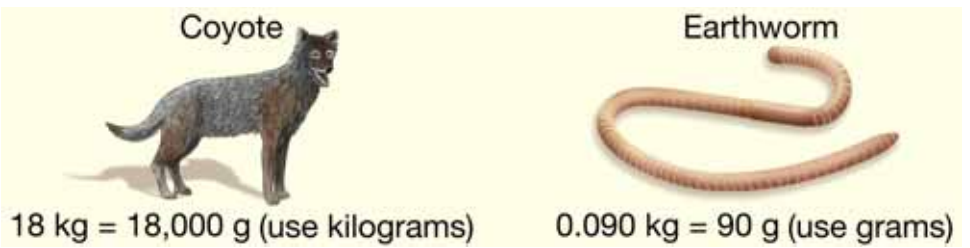
Mass and temperature

Matter and mass

Everything around you is made of matter and has mass. **Matter** is defined as anything that has mass and takes up space. You are matter and so is air. **Mass** is the measure of the amount of matter that makes up something. The kilogram (kg) is the basic unit for mass. A typical coyote has a mass of about 18 kg.

Use grams for small living things

There are 1,000 grams in 1 kilogram. The average mass of an earthworm is about 90 grams. This is equal to 0.090 kilograms. Do you see why it's easier to use grams with smaller living things?



What is temperature?

Most living things can only survive within a certain range of temperatures. For example, corals grow best in waters with a temperature of between 21 and 29 degrees Celsius. **Temperature** is a measure of how hot or cold something is. It has to do with the average motion of the tiny particles (atoms and molecules) that make up matter. As those particles move faster on average, the temperature goes up. As they move slower on average, the temperature goes down.

Temperature scales

You are most familiar with the Fahrenheit temperature scale (°F). Scientists use the Celsius scale (°C) and Kelvins (K) to describe temperature. In this book, we will use the Celsius scale. Figure 1.4 shows a comparison between the Fahrenheit and Celsius scales.

VOCABULARY

matter - anything that has mass and takes up space.

mass - a measure of the amount of matter that makes up something.

temperature - a measure of how hot or cold something is.

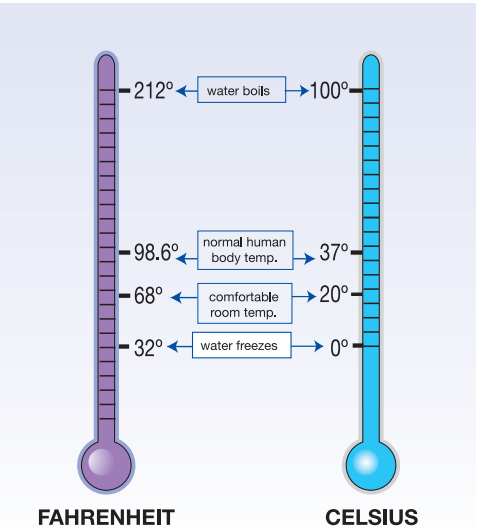


Figure 1.4: *The Fahrenheit and Celsius temperature scales.*

Solutions

Most of Earth's water is in the form of a solution

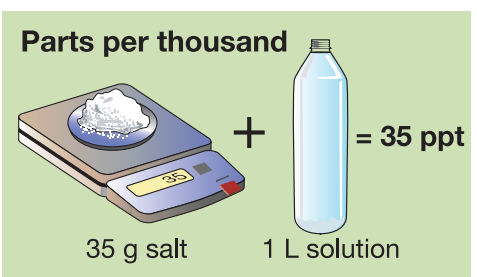
All life depends on water. It's a good thing 70 percent of Earth's surface is covered with it! Almost all of that water exists in solutions. A **solution** is a mixture of two or more substances that are evenly distributed at the molecular level.

A solution has two parts

A solution has two parts. The *solvent* is the part of a solution that dissolves another other part called the *solute* (Figure 1.5). Seawater (water found in the oceans) is a solution made of water (the solvent) and dissolved salts (the solute). Spring water is a solution made of water and dissolved minerals. Air is a solution in which nitrogen is the solvent and other gases like oxygen, carbon dioxide, and water vapor are the solutes.

Measuring concentration

Scientists use units of *concentration* when measuring levels of dissolved substances in water. A unit of concentration used in studying living things is called *parts per thousand* (ppt). Parts per thousand means that there is 1 part of a solute dissolved in 1,000 parts of a solution. In metric units, parts per thousand is equal to grams of a solute per liter of solution. For example, the concentration of salt in the ocean is 35 parts per thousand. This means that there are 35 grams of salt (the solute) dissolved in every liter of water (the solvent).



VOCABULARY

solution - a mixture of two or more substances that are evenly distributed at the molecular level.

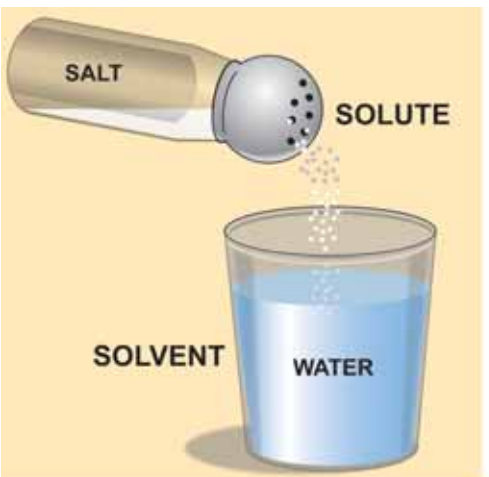
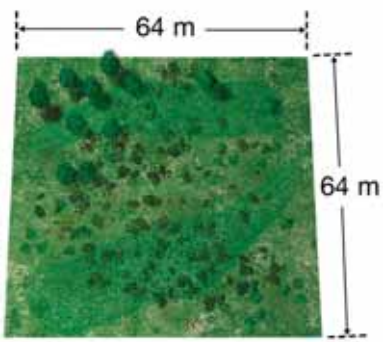


Figure 1.5: *Solutions are made when solutes dissolve in solvents. Here, salt is the solute, and water is the solvent.*

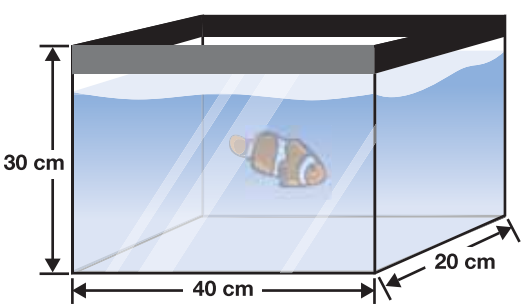
1.1 Section Review

1. Measure the length of the millipede below. Give your answer in meters, centimeters, and millimeters. Which is the best unit to describe its length?

2. An acre of land measures 64 meters by 64 meters. What is the area of an acre of land in square meters?



3. What is the volume of the fish tank (right) in cm^3? Given that one cm^3 equals one mL, what is the volume of the tank in liters?



4. A marine aquarium is found to contain a salt concentration of 40 ppt. How may grams of salt are in one liter of the solution?

CHALLENGE

Metric conversions

1. A graduated cylinder contains 50 mL of water. After a marble was added, the volume of the graduated cylinder was 75 mL. What is the volume of the marble? (HINT: 1 mL = 1 cm^3)
2. A beetle measure 1 cm across. What is the measurement in millimeters?
3. An aquarium has a volume of 0.45 m^3. What is its volume in liters?
4. To convert between degrees Celsius and degrees Fahrenheit, use the following relationships:

   °C = (°F - 32) × 0.56
   °F = (1.8 × °C) + 32

   Convert the following temperatures:

   a. 80°F = ____°C
   b. 32°F = ____°C
   c. 98°C = ____°F
   d. 21°C = ____°F

1.2 Thinking Like a Scientist

Science is a process of thinking and learning about the world around us. There are many fields of science, each dealing with a different part of our world. For example, the study of matter is called chemistry. The study of outer space is called astronomy. The study of life is called **biology**, and is the subject of this course. How do we go about studying life? In this section, you will learn how to think like a scientist.

VOCABULARY

biology - the study of life.

scientific method - a process used by scientists to find the answers to questions.

The scientific method

Worms from mud?

Last spring, heavy rains turned the soil in Maria's backyard into mud. Maria noticed many worms crawling on top of the mud that weren't there before (Figure 1.6). Did she conclude that the worms were made from the mud? Of course not! It is common scientific knowledge that nonliving objects (like mud) cannot turn into living things (like worms). But hundreds of years ago, people actually thought that simple living things like worms and beetles came from nonliving things like mud, dirt, and spoiled food.

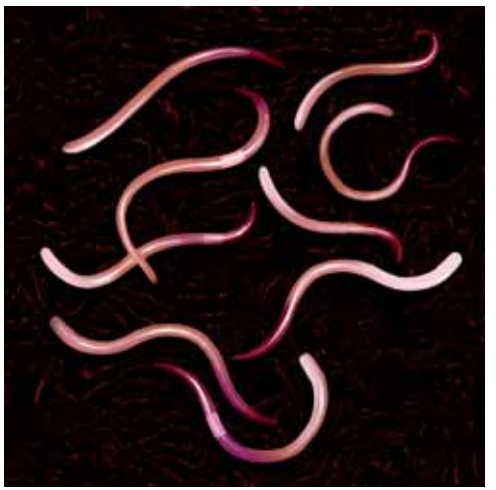


Figure 1.6: *Can mud turn into worms?*

The scientific method

We often take scientific knowledge for granted even though it is the result of the work of many scientists over many years. The **scientific method** is a process used by scientists to answer questions like, "Can a nonliving object turn into a living thing?" It involves asking questions, developing explanations, and testing those explanations to see if they are correct. You can think of the scientific method as an organized way of asking and answering questions.

Untested observations

The explanation that nonliving objects can give rise to living things was based on untested observations. When scientists started using the scientific method (in the 1600s), they eventually disproved this idea.

Steps to the scientific method

Back to the worms

Even though Maria knew that worms couldn't possibly come from mud, she wondered why they appeared after a heavy rain and weren't seen when it was dry. She had an idea that the worms came to the surface so they wouldn't drown in the wet mud and that they preferred to live underground in moist soil. How could she prove her idea?

Steps to the scientific method

Like a scientist, Maria decided to follow the scientific method to try and prove her ideas. While scientists don't always follow the exact same path toward finding answers, it is useful to show the scientific method as a series of steps. The table below shows the steps along with Maria's example.

Table 1.2: Steps to the scientific method

1. Make observations or research something.	Maria noticed worms on the surface of the mud after a heavy rain.
2. Ask a question or state a problem.	Why do worms come to the surface after a heavy rain?
3. State a hypothesis.	Worms come to the surface after a heavy rain so they won't drown in wet mud.
4. Test the hypothesis with an experiment.	Maria set up two tanks. She put 20 worms into each tank. Then she put normal soil into one tank and wet mud into the other. She left both tanks in a window for the day.
5. Draw conclusions based on the test.	Seventeen of the worms in the wet mud came to the surface while all 20 worms in the other tank stayed under the soil. Maria concluded that worms do not like to stay under wet mud.

The hypothesis

A **hypothesis** is a possible explanation that can be tested with an experiment. A hypothesis is based on observation, prior knowledge, or the results of other experiments.

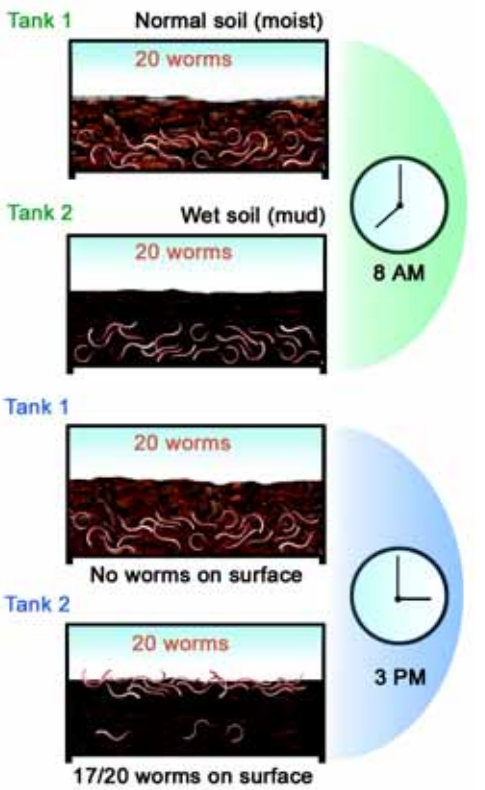


Figure 1.7: *Maria's experiment*

VOCABULARY

hypothesis - a possible explanation that can be tested with an experiment.

Designing experiments

Experiments and systems

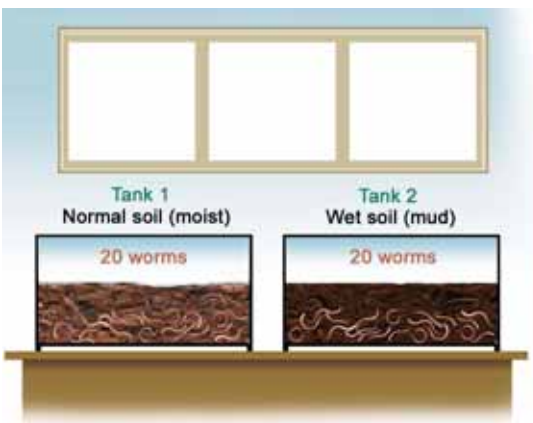
An **experiment** is a controlled test to determine if a hypothesis is supported or refuted. An experiment is designed around a system. A **system** is a group of factors that are related in some way. You choose the system to include the factors you wish to investigate and exclude the factors you think are not important.

Variables

A **variable** is a factor that affects how a system works. When designing an experiment, you identify the important variables in the system and change only one variable. You change the variable you want to investigate and keep all of the other variables the same. The variable you change is called the **experimental variable**. The variables you keep the same are called **control variables**.

Maria's experiment

When Maria designed her worm experiment, she created a smaller *model* of the system she was studying (her backyard). Her model did not include many of the variables found in her backyard such as plants or other animals. Because of her hypothesis, Maria chose the wetness of the soil as her experimental variable. Her control variables were temperature, light, kind of soil, number of worms, type of worms, and time.



Experimental Variable: Wetness of soil
Tank 1: Normal soil (moist)
Tank 2: Wet soil (mud)
Control variables: same for both tanks

Temperature	21°C (11 AM temp)
Light	Window
Kind of soil	Soil from back yard
Type of worm	Earthworms
No. of worms	20
Time	7 hours

VOCABULARY

experiment - a controlled test to determine if a hypothesis is supported or refuted.

system - a group of objects, effects, and variables that are related.

variable - a factor that affects how a system works.

experimental variable - the variable you change in an experiment.

control variables - the variables you keep the same in an experiment.

Data and conclusions

Multiple trials

Scientists do the exact same experiment many times to make sure their results are valid. Each time you do the same experiment, it is called a *trial*. The results of an experiment are valid only if you get similar results from each trial. Maria conducted four trials of the same experiment. Her data are shown in Figure 1.8.

Presenting your data

It is important to organize your data so that it can be analyzed and presented. You can organize data into tables, charts, and graphs. Maria put her data into a *bar graph* as shown in Figure 1.9. Which is easier to understand, the table in Figure 1.8 or the bar graph in Figure 1.9?

Drawing conclusions

After analyzing the data, you should be able to state whether your hypothesis is correct, partially correct, or incorrect. When the data does not support the hypothesis, scientists try to find another explanation for what they observed. Sometimes finding out that a hypothesis is wrong is just as helpful as finding out that it's correct. The results help scientists make another hypothesis and design another experiment. Eventually, they get closer to a correct hypothesis. Does Maria's data support her hypothesis?

Communicating your results

A *lab report* is a good way to communicate the results of an experiment to others. It should contain your research question, hypothesis, experiment procedures and data, and your conclusion. If you give an oral report to your class, colorful charts and graphs are a good way to show your data. This is the same way scientists present the results of their experiments to other scientists.

Data from worm experiment:

	Number of worms on surface	
Trial	Tank 1	Tank 2
1	1	14
2	3	16
3	2	17
4	1	18

Figure 1.8: *Maria's data from four trials.*

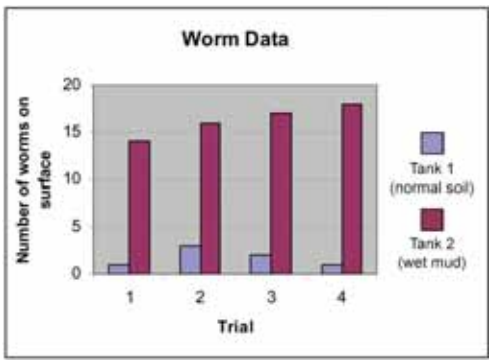


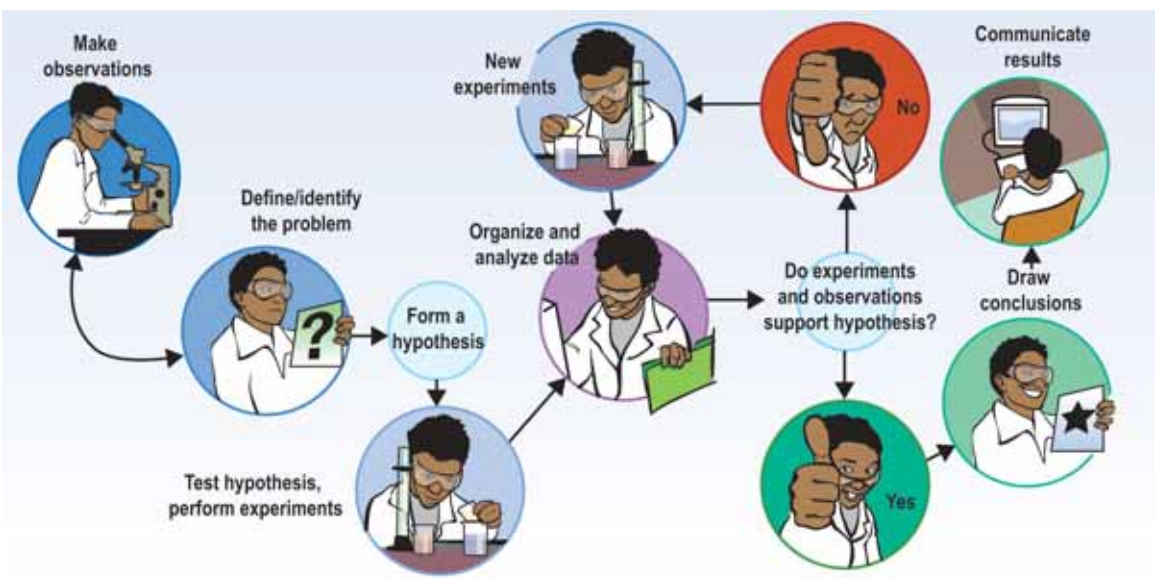
Figure 1.9: *A bar graph of Maria's data.*

Science is an ongoing process

Theories When repeated experiments confirm a hypothesis, scientists usually accept it as valid. When repeated experiments support one or more *related* hypotheses, a new theory may develop. A **theory** is an explanation of how a natural process or event is thought to occur. In science, a group of hypotheses becomes a theory only after repeated experiments and observations with similar results.

Theories can change In science, no theory is accepted as the absolute truth. Theories often change as more experiments are done. The invention of new technology such as microscopes also leads to changes in theories and the development of entirely new theories. You should think of a theory as the best explanation for something that scientists have come up with to date. But if you wait long enough, it may change!

As you can see, the scientific method is an ongoing process. The diagram below shows how the process often works.



VOCABULARY

theory - an explanation of how a process or event is thought to occur.

STUDY SKILLS

A *mnemonic* is a device used as an aid in remembering. You may be familiar with a mnemonic used to remember the names of the planets, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Here is an example:

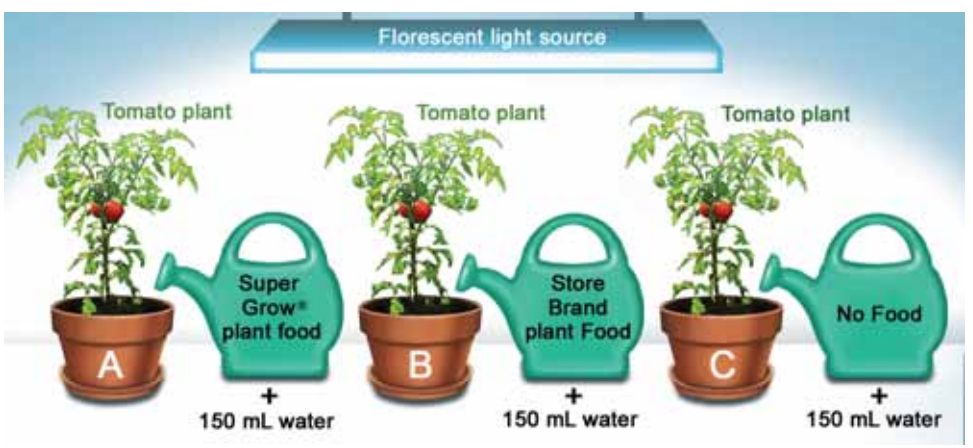
My Very Eager Mother Just Served Us Nectarines

Make up a mnemonic to remember the process of the scientific method. Use the first letter from each step in your mnemonic.

Observations
Question
Hypothesis
Experiment
Analyze results
Conclusions
Communicate

1.2 Section Review

1. Write a hypothesis for the following question: "When a plant is placed near a window, why does it lean and grow toward the window?"
2. A good hypothesis can be tested with an experiment. Which of the following statements is the best hypothesis? Explain your answer.
   a. There were many students absent from class today.
   b. Many students were absent today because the flu is going around.
3. Explain how you would test the hypothesis you chose in the question above.
4. Use the illustration of an experiment below to answer questions a, b, and c.



   a. What is the experimental variable?
   b. What are the control variables?
   c. Write a hypothesis that the experiment could be designed to test.

CHALLENGE

In the 1600s, people believed that living things could come from nonliving objects. For example, unrefrigerated meat eventually becomes full of maggots. People living in the 1600s thought the meat actually turned into maggots. In 1668, Francisco Redi, an Italian physician, did an experiment with flies and jars containing meat. His experiment showed that meat does not turn into maggots. This may have been the first controlled experiment!

1. Design an experiment to test the hypothesis that meat does not turn into maggots. Sketch your design and list the experimental and control variables.
2. Present your experiment and results to your class. You could even give your presentation as if it were 1668.

1.3 Graphs

A **graph** is a visual way to organize data. Scientists sometimes use graphs to see how changing one variable affects another variable. Graphs are also useful for making comparisons between different sets of data. In this section, you will learn about the types of graphs and how to make a line graph.

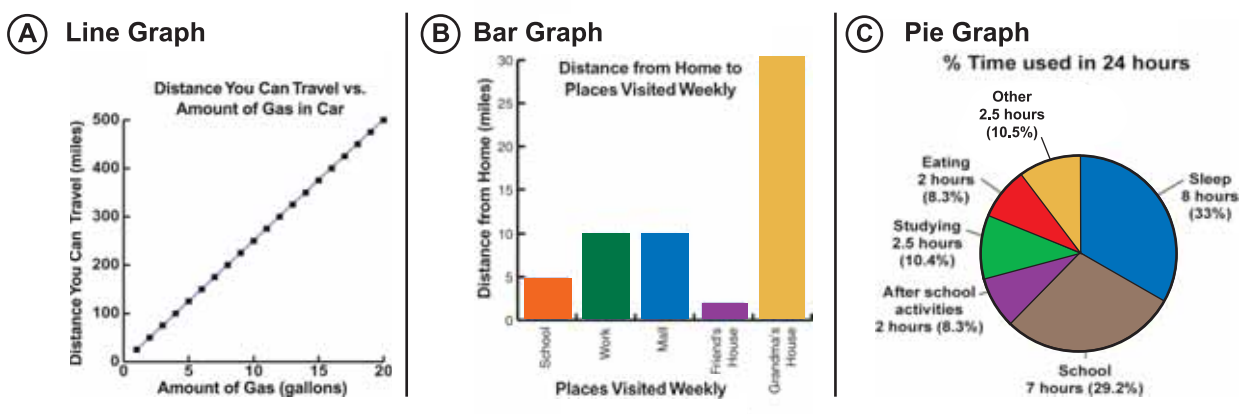
Types of graphs

A graph is a picture

A graph is a picture that shows how variables are related. Graphs are easier to read than tables of numbers, so they are often used to analyze data collected during an experiment.

Types of graphs

Some types of graphs are line, bar, and pie graphs. A *line graph* is used when one variable causes a second variable to increase or decrease in value. For example, the more gas you put in a car, the farther it travels (Graph A). A *bar graph* compares categories of information (Graph B). A *pie graph* is a circular graph that compares categories of information. The data are usually written in percentages.



VOCABULARY

graph - a visual way to represent data.

MY JOURNAL

Graph C (left) shows how a student spends her time during 24 hours. Answer the following questions about Graph C:

- What percentage of time is spent with after school activities?
- What would the graph look like if the student spent half of her day in school and the other half asleep?

Make a pie graph of how you spent your day. Draw your pie graph in your journal and use colored pencils for each segment.

Making a line graph

Independent and dependent variables

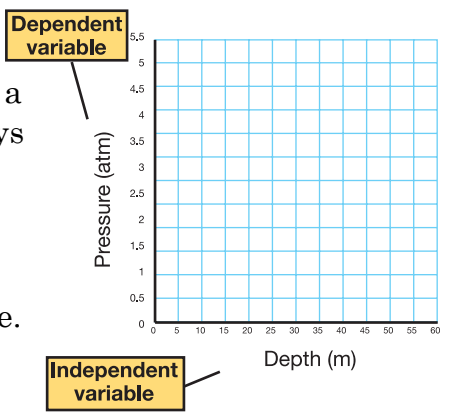
A line graph shows how a change in one variable influences another variable. The **independent variable** is the variable you believe might influence another variable. It is often controlled by the experimenter. The **dependent variable** is the variable that may be influenced by the independent variable. The following example illustrates how to graph variables.

An example

As a scuba diver goes deeper under water, she has to think about pressure. How does an increase in depth affect the pressure? Pressure is measured in units of *atmospheres*. You live at Earth's surface under a pressure of 1 atmosphere. Figure 1.10 shows depth and pressure data. A graph can help you visualize the relationship between the depth of water and pressure.

Step 1: choose x- and y-axis

Depth is the independent variable because we are interested in how it affects pressure. The independent variable always goes on the *x*-axis of a graph. The dependent variable always goes on the *y*-axis. In this example, pressure is the dependent variable.



Step 2: make a scale

To create a scale for a depth versus pressure graph, you first make a scale. The word *scale* refers to size of something. When talking about a graph, scale refers to how each axis is divided up to fit the range of data values. Use the formula below to make a scale for any graph.

Data range ÷ number of boxes on the axis = value per box

VOCABULARY

independent variable - a variable that you believe might influence another variable. The independent variable is sometimes called the *manipulated variable*.

dependent variable - the variable that you believe is influenced by the independent variable. The dependent variable is sometimes called the *responding variable*.

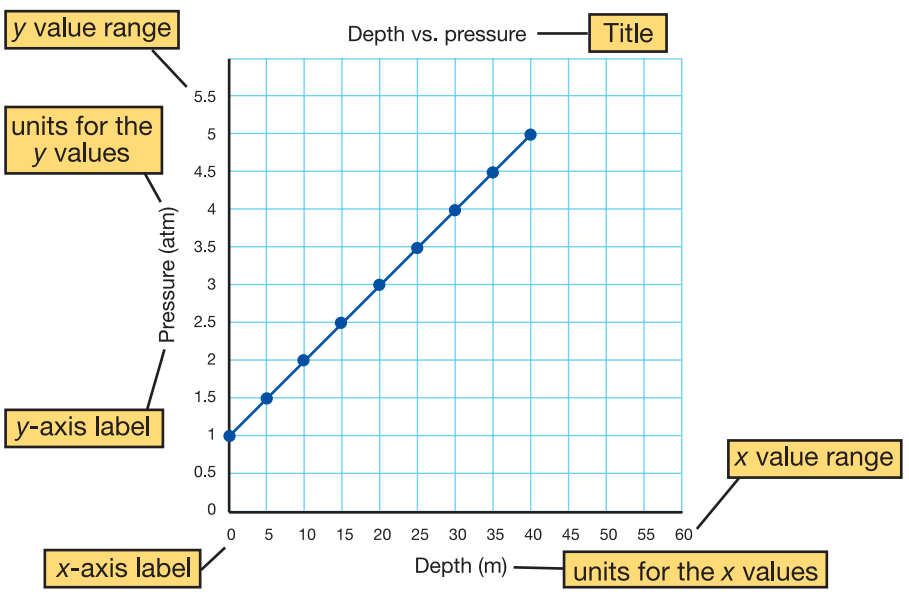
Depth (m)	Pressure (atm.)
0	1.0
5	1.5
10	2.0
15	2.5
20	3.0
25	3.5
30	4.0
35	4.5
40	5.0

Figure 1.10: *Depth of the ocean and pressure data.*

Suppose your graph has 12 boxes on each axis. Figure 1.11 shows how you would create a scale for the *x*-axis. Figure 1.11 also shows how you would create a scale y-axis of the graph for depth and pressure.

Step 3: plot your data

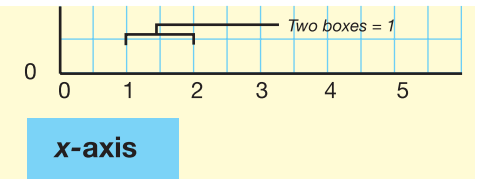
Plot each point by finding the *x*-value and tracing the graph upward until you get to the right *y*-value. Make a dot for each point. Draw a smooth curve that shows the pattern of the points (shown below).



Step 4: create a title

Create a title for your graph. Also, be sure to label each axis and show units (shown above).

Do you see a relationship between the variables? The next page explains how to recognize relationships on a graph. Read the next page, then see if you can explain what type of relationship is shown in the graph above.



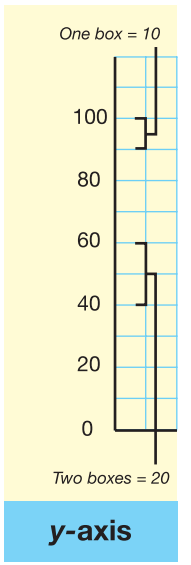


Figure 1.11: *How to make a scale for the x- and y-axes for the depth and pressure data.*

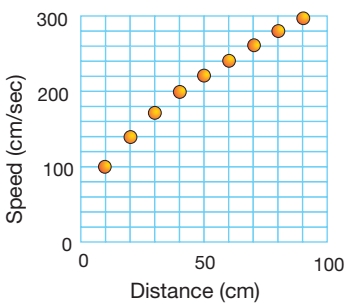
Identifying relationships between variables on a graph

Patterns indicate relationships

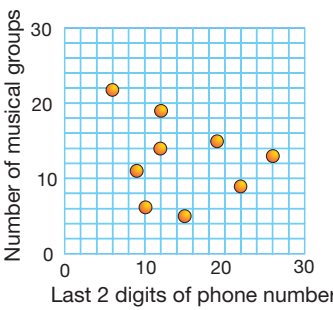
When there is a relationship between the variables the graph shows a clear pattern. The speed and distance variables below show a direct relationship. In a **direct relationship**, when one variable increases, so does the other. When there is no relationship the graph looks like a collection of dots. No pattern appears. The number of musical groups a student listed in one minute and the last two digits of his or her phone number are an example of two variables that are not related.

Strong Relationship between Variables

Distance (cm)	Speed (cm/sec)
10	99
20	140
30	171
40	198
50	221
60	242
70	262
80	280
90	297



No Relationship between Variables



# of groups	Last 2 digits
10	6
15	5
19	15
6	22
22	9
9	11
26	13
12	14
11	19

Inverse relationships

Some relationships are inverse. In an **inverse relationship**, when one variable increases, the other decreases. If you graph how much money you spend against how much you have left, you see an inverse relationship. The more you spend, the less you have. Graphs of inverse relationships always slope down to the right (Figure 1.12).

Describe the relationship in the depth versus pressure graph on the previous page. Did you know that life can exist even under the extreme pressures at the bottom of the ocean?

VOCABULARY

direct relationship - a relationship in which one variable increases with an increase in another variable.

inverse relationship - a relationship in which one variable decreases when another variable increases.

Inverse Relationship Between Variables

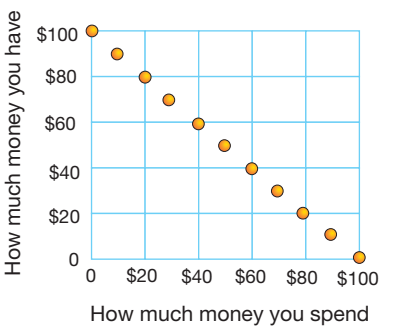


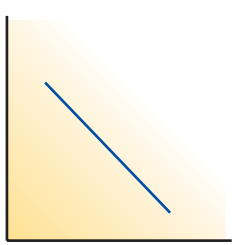
Figure 1.12: *Graphs of inverse relationships slope down to the right.*

1.3 Section Review

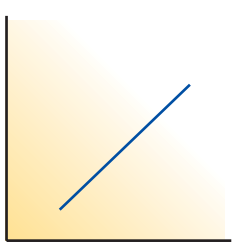
1. What is a graph? What are three types of graphs?
2. Name a situation where you would use a pie graph.
3. List the steps to making a graph.
4. Suppose you want to make a graph of the average temperature for each month of the year. What is the independent variable? What is the dependent variable?
5. Make a line graph of the monthly average temperature. Use the data below:

Month	Average temperature (°C)	Month	Average temperature (°C)
January	15	July	22
February	14	August	21
March	15	September	18
April	16	October	17
May	18	November	16
June	19	December	16

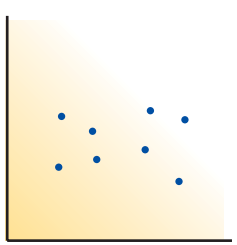
6. For each graph, tell whether it is a direct relationship, inverse relationship, or no relationship.



A



B



C

SOLVE IT!

Make a bar graph and pie graph

1. A bar graph compares categories of information. Here is a data set for making a bar graph. Use this data set to make a bar graph.

Number of students who bring lunch to school each day

Day	Number of Students
Mon	30
Tue	30
Wed	30
Thurs	30
Fri	5

2. A pie graph also compares categories of information. Here is a data set for making a pie graph. Use this data set to make a pie graph.

Percent of students in afterschool activities

Activity	% of Students
Soccer	25%
Dance	25%
Karate	25%
Drama Club	12.5%
Math Team	12.5%

TECHNOLOGY CONNECTION

The Role of a Scientist

Imagine waking in the morning knowing what you do may help someone to see. That is what Dr. Lotfi Merabet feels like each morning. He is a scientist and optometrist working to help the blind see again. An optometrist is an eye doctor.

Dr. Merabet thinks about science every day and uses this knowledge to study problems. As a child, he enjoyed science. He was fascinated with understanding how the brain works. Dr. Merabet felt that the brain was the ultimate machine

Meaningful questions

Asking questions is the first step of the scientific method. Forming meaningful questions is daily routine for Dr. Merabet. His day may include conducting experiments, discussing results, visiting patients, and writing reports. As a research scientist, Dr. Merabet wants to answer one very important question. What happens to the brain when a person is blind?

The scientific method and the blindfold experiment

Scientists wonder if the brain can change. In order to explore this question, a hypothesis or educated guess is developed. Does the brain change when sight is lost? How does the brain change?

An experiment was set up with two groups of people who could see. One group wore blindfolds and the other group did not. A teacher taught both groups Braille for five days.

Braille is a code that lets blind people read and write. The code feels like bumps or dots on paper. This blindfold experiment used all the steps of the scientific method. Scientists asked questions, made a hypothesis, conducted experiments, collected information, and made conclusions.

A large part of the brain is used for seeing. What would happen to the brain when someone could no longer see? Who would learn Braille better - people with or without blindfolds?

The experiment showed that the blindfolded people had an easier time learning Braille. Scientists concluded that Braille is best learned through touching rather than seeing. For the blindfolded, the brain was no longer concerned with seeing. The brain adapted to the change by improving a person's sense of touch. Where inside the brain did this adjustment take place? Additional experiments must be done to answer this question.

Scientists used a functional magnetic resonance imaging (fMRI) tool for the blindfold study.

The fMRI scanned the brain for activity in the "vision" area. Scientists believe the brain adapted by using different "pathways." The brain was able to adapt to change much like a car driver may change his route due to a detour. The new "pathway" or road has always been there, but is not used until needed.

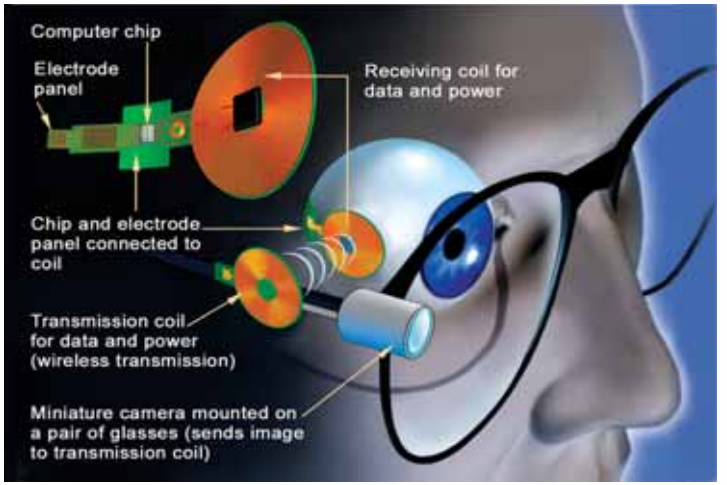
The Boston Retinal Implant Project

Everyday scientists try to understand and explain the world in which we live. Understanding why things happen will help them find solutions to problems. A goal of science is to study a problem and then create ways to improve the problem. Dr. Merabet is part of a team working on the Retinal Implant Project in Boston, Massachusetts. They are studying how to teach the "blind brain" to see again. The blindfold study was used to understand how the brain adjusts to the loss of sight. This is an important part of the research process - answering meaningful questions. If Dr. Merabet wants to restore sight, he needs to understand how the brain adjusts when vision is lost. The goal of the project is to improve the sight of the blind.

The retina is the part of the eye that helps us to see. It takes in light and creates electrical energy that is sent to the brain. Damage to the retina can cause blindness. The retinal implant is an electronic device. It stimulates the retina by sending a "visual" message to the brain. The implant is very tiny - thinner than a human hair! The implant is considered a prosthesis. A prosthesis is a man-made device that replaces a damaged part of the body. You have probably seen people with an artificial leg or arm. These are prostheses that do the work of a real arm or leg.

Scientists are hoping to develop a prosthetic implant that will help restore sight. For the implant to work, patients wear special glasses containing a small camera. The camera sends signals to the implant using wireless technology.

So far six people have tested the retinal implants. Time has been limited to just a few hours with each person. Some have seen dots of light. Work continues with the hope that the blind will be able to see clear pictures of the world around them.



Science is a team effort

Science cannot be done in isolation. For the Boston Retinal Implant Project, a team of scientists includes the following: physicians, optometrists, physiologists, biologists, and engineers. Scientists learn from others and must work together each day towards a common goal. Scientific success relies on sharing knowledge with others. A scientist cannot be locked in a lab. He must be an active part of the world in which he lives. Dr. Merabet and other scientists look forward to the new challenges presented each day.

Questions:

1. What is the role of a scientist?
2. Describe how the "blindfold study" uses the scientific method.
3. Why do scientists ask meaningful questions?

CHAPTER ACTIVITY What's Inside the Box?

Science is sometimes like a sealed, black box. You can't always open it to see what's inside. You have to piece together clues and make a model of what you think is inside. For example, scientists can describe what the internal structure of Earth is like, but Earth certainly cannot be cut in half and examined!

The object for a scientist is to narrow the possible explanations to the best one, based on scientific evidence and agreement among different researchers. In this activity, you will investigate some black boxes. You will try to describe what's inside without opening them.

What you will do

1. Obtain 6 black boxes labeled A through F from your teacher.
2. Perform "tests" on each of 6 different sealed containers, and describe what the internal structure is like. You may shake, rattle, roll, and listen to the sealed containers, but you may not open or destroy the container. No violent shaking!
3. There are three different internal structures. Determine which containers have similar interiors.
4. Make and label a diagram to show what the interior of the sealed container looks like.
5. Pair up with another group and work together to agree on the best explanations and diagrams, as well as proper pairing of similar interiors.
6. Opening the sealed containers may be very tempting, but scientists cannot do this with their black boxes! To really get the point across about black boxes, and to keep the containers usable for other students, we will not open the containers.

Applying your knowledge

a. Explain further tests that you could do that might require additional equipment, but would not destroy the sealed containers.
b. Explain how you used the scientific method to come to your conclusions about the interior structure of each sealed container. Use the following terms: hypothesis, experiment, data, conclusion, peer review.

Chapter 1 Assessment

Vocabulary

Select the correct term to complete the sentences.

length	experiment	independent variable
volume	variables	graph
mass	scientific method	dependent variable
measurement	control variable	
unit	theory	
	experimental variable	

Section 1.1

1. A value that has a quantity and a unit is a ____.
2. A ____ defines the amount of something that is being measured.
3. When measuring the ____ of an insect, scientists calculate the distance from the tip of the head to end of its abdomen.
4. The ____ of an object is calculated differently depending upon its shape but still determines how much space it occupies.
5. When wildlife biologists measure the ____ of a mountain beaver, they determine the amount of matter it occupies.

Section 1.2

6. When testing hypotheses and solving problems, scientists use a process called the ____.
7. The test used to determine whether or not the hypothesis is correct is the ____.
8. Scientists identify and test different ____ within the experiment to see how they affect the system.
9. The ____ is a factor within the experiment that changes.
10. By keeping the ____ the same, scientists can investigate the effect of other factors on the system.
11. When a widely accepted explanation of process or event is believed to be true, a ____ is formed which is further supported by many repeated experiments.

Section 1.3

12. A _____ shows how variables are related.
13. The _____ is plotted on the *y*-axis of a graph.
14. The _____ is plotted on the *x*-axis of a graph.

Concepts

Section 1.1

1. Which of the following is not a proper SI unit of measurement?

    a. meter
    b. liter
    c. gram
    d. Fahrenheit

2. When measuring the volume of water in a graduated cylinder:
    a. read the mark at eye level and at the bottom of the meniscus.
    b. look down from the top of the cylinder and read the mark just above the curve.
    c. read the mark at the top edges of the meniscus.
    d. raise the cylinder in your hand to eye level to get the most accurate result.
3. An organism that has more mass:
    a. is larger than an organism that has less mass.
    b. weighs more than an organism with less mass.
    c. cannot have more matter than an organism with less mass.
    d. will never have the same mass as an animal that takes up more space.

Section 1.2

4. After testing, the hypothesis appears to be false. This indicates:
   a. The experiment is a failure.
   b. The results are of no use.
   c. The design of the experiment was bad.
   d. The data may be useful, but further testing and redesign of the experiment may be needed.
5. A student designs an experiment and gets favorable results after one trial. The student should:
   a. write a paper and publish the results.
   b. redesign the experiment to get more favorable data.
   c. repeat the experiment several times to verify the results.
   d. form a new experiment that supports a related hypothesis.
6. Explain the relationship between hypotheses and theories.

Section 1.3

7. What are three types of graphs? Name a situation where you would use each type of graph.

Math and Writing Skills

Section 1.1

1. A freshwater lake extends 12 miles westward 10 miles south and is on average 12 feet deep (1 mile=5280 feet). Determine the surface area and volume of the lake using appropriate units.
2. Calculate the concentration of each solution in ppt:
   a. 12 grams of salt per 2-liters of solution.
   b. 0.5 grams of sugar per 1-liter of solution.

Section 1.2

3. A botanist wants to understand if exposure to St. John's wort, a flowering roadside flower, causes skin irritation. In this experiment several types of plants including St. John's wort are rubbed onto the arms of ten volunteers. A skin rash develops in all ten individuals. Can the scientist clearly say that St. John's wort causes skin irritation? Why or why not? Identify any variables and state any changes that could be made to make this experiment more valid.

Section 1.3

4. Using the following data, create a graph that clearly and accurately represents the results.

	# Eggs	# Hatchlings	# Adults 1st year	#Adults 5th year
Species A	200	180	50	26
Species B	60	50	28	15
Species C	5	4	4	3

   Give a possible explanation of the results. Is the data easier to understand in graphical form? Why?

Chapter Project

Measurement scavenger hunt

Find and measure the items in the scavenger hunt list. Make a sketch for each item and include labels with measurements. Submit a report with sketches on notebook paper or create a poster of your findings. Creativity and neatness count!

1. Find something that is 2 meters high.
2. Find something that has a volume of 237 milliliters.
3. Find something that is approximately 3 centimeters thick.
4. Measure the length and width of your bedroom or living room floor in meters and find the area in square meters.

Chapter 2

Living Things

Imagine adding water to a packet of powder and ending up with a tank full of swimming creatures. This may seem like science fiction, but it's true. Brine shrimp are small relatives of crabs and lobsters. Brine shrimp eggs can live for many years in tiny hard cases. When you add water and set up a proper environment for the eggs, the brine shrimp hatch and thrive! A class of seventh graders from Pennsylvania designed an experiment to see if space travel would affect brine shrimp eggs. They sent a packet of the tiny eggs on the space shuttle Discovery in 1998 with U.S. Senator John Glenn. You can find articles about the results of the experiment on the Internet using the search phrase "brine shrimp in space." In this chapter you will learn how to tell if something is living or not, and you will see how the incredible variety of life on Earth is described, categorized, and named.

Key Questions

1. ***Is a cloud in the sky a living thing?***
2. ***How do sweating and shivering keep you alive?***
3. ***How is life on Earth classified?***

2.1 Is It Alive?

Do you know how bread is made? One of the most important ingredients is yeast. Open a packet of yeast and you'll see a bunch of tiny, dried specks. If you drop those specks into a cup of warm water with a little sugar, they'll start to bubble and froth. If you look at the mixture under a microscope (Figure 2.1), you will see individual clumps of yeast growing and even multiplying! Is yeast a living organism? In this section, you'll learn what it means to be alive.

What does it mean to be alive?

What is an organism?

An **organism** is an individual form of life. A tree is an organism and so is yeast. So are you. What makes something alive? As with many questions in science, the answer is not easy and is still argued among scientists. If you've ever had a cold or the flu, you're familiar with the effects of viruses. Viruses are very tiny things that have some of the characteristics of living things, but are not considered alive by many scientists.

The characteristics of living things

So what makes something alive? Having a set of rules is a good way to get closer to the answer. Biologists often use five basic rules to classify something as living or nonliving.

Five Characteristics of Living Things

1. Living things **respond** to their surroundings.
2. Living things **grow** and **develop**.
3. Living things are able to **reproduce**.
4. Living things **use energy**.
5. Living things are made of smaller building blocks called **cells**.

STUDY SKILLS

Make a list of all of the vocabulary terms in this section. For each term:

1. Write its definition, in your own words.
2. Use the term in a sentence.

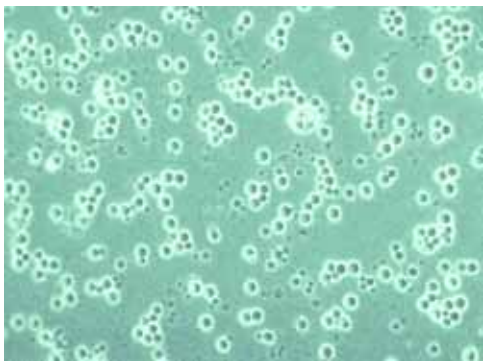


Figure 2.1: *Yeast magnified 100 times. Yeast is a living organism. Each tiny sphere is an individual organism.*

VOCABULARY

organism - an individual form of life.

Response and stimulus Have you ever gone from a dark room out into the sunshine? You respond by squinting your eyes. The brightness of the sun is called a **stimulus** and your reaction to it is called a **response**. All living things respond to a stimulus.

Growth You may think of growth as an increase in size. You have increased in size since you were born. **Growth** also refers to an increase in mass and to an increase in number of cells.

Reproduction The process of making more of the same kind of organism is called reproduction. Because all living things eventually die, reproduction allows life to continue.

Energy All living things take materials from their surroundings such as food, water, and gases. They use these materials to get energy. This energy is needed to carry out all of the life functions.

Cells A **cell** the smallest unit of a living thing. It is the simplest structure that can carry out all of the functions described above. You'll learn more about cells in Unit 2.

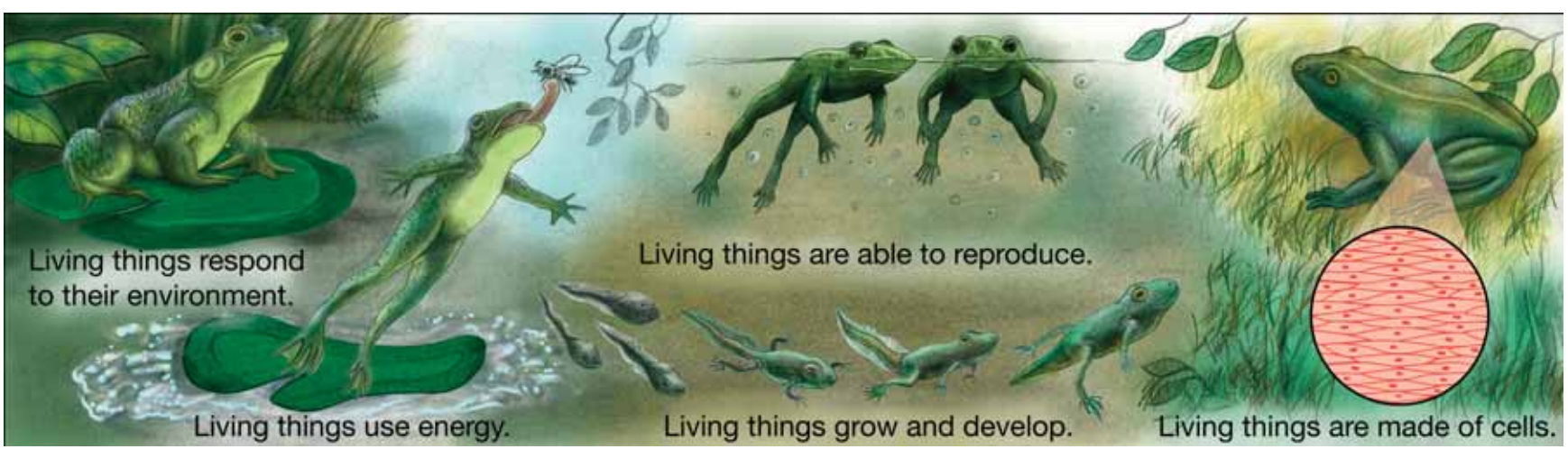
VOCABULARY

stimulus - something that causes a response.

response - how an organism reacts to a stimulus.

growth - an increase in mass.

cell - the smallest unit of a living thing.



Is a barnacle alive?

A trip to the beach

One day at the beach, Zeke picked up one of many rocks that were covered in white bumps (Figure 2.2). He thought the rock would look nice in his marine aquarium so he brought it home and dropped it into his tank. One day, while watching the fish in his tank, Zeke got a surprise. The white bumps on the rock had sprouted tiny legs and were waving back and forth in the water. The rock was alive! (Actually, the white bumps were alive.)

Figure 2.2: *What are the white bumps covering this rock?*

Barnacles

Zeke's rock was covered with tiny organisms called *barnacles* (Figure 2.3). These creatures live in tide pools along the seacoast where waves crash and tides cause water to flow in and out. Inside its shell the barnacle can hold seawater to survive the many hours of drought at low tide. At high tide the shell opens and the barnacle begins to feed. Its long, comb-like legs sweep back and forth to catch tiny organisms called plankton.

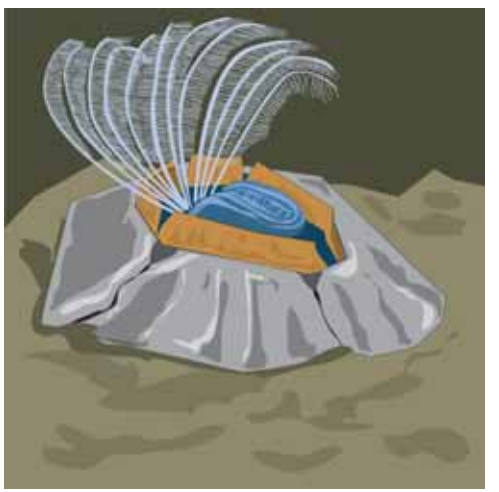


Figure 2.3: *Each bump is an individual barnacle. Barnacles feed by waving their legs back and forth.*

Is a barnacle alive? Let's use the five criteria to decide.

1. Barnacles **respond** to their environment by closing their shells at low tide, and opening them at high tide.
2. Barnacles **grow** and **develop**. They begin life as free-swimming creatures. Once they find a good spot, they "glue" themselves to a rock and form a shell.
3. Barnacles **reproduce**. After fertilization from a male barnacle, females hold the eggs in their shells until they hatch.
4. By waving their legs, barnacles capture food. They **use energy** from the food to move their legs, open and close their shells, and carry out all life processes.
5. If you examined the legs of a barnacle with a microscope you would see that they are made of individual **cells**.

Types of energy

What is energy? You have read that living things use energy. **Energy** is sometimes defined as the ability to cause change or do work. There are many forms of energy (Figure 2.4). Any form can be converted into any other form. Living things can convert one form of energy into another.

Radiant energy *Radiant energy* is also known as electromagnetic energy. Light is made up of waves called electromagnetic waves. There are many different types of electromagnetic waves, including the light we see, ultraviolet light, x-rays, infrared radiation, radio waves, and microwaves. This is the type of energy that reaches Earth from the Sun and is captured by plants.

Chemical energy *Chemical energy* is energy stored in molecules. Energy stored by living things can be in this form. When molecules are rearranged, chemical energy is released. When animals eat plants, they use the chemical energy stored by the plants to move, grow, and reproduce.

Mechanical energy *Mechanical energy* is the energy an object has due to its motion or position. You store mechanical energy when you climb a hill. The energy is released when you go back down the hill.

Electrical and thermal energies *Electrical energy* is carried by the flow of electric current. Nerve impulses in your body are electrical energy. *Thermal energy* flows whenever there is a temperature difference. Heat is a form of thermal energy. Thermal energy flows from your hand to any cooler object that you touch, such as ice cream.

Nuclear energy *Nuclear energy* results from splitting or combining the nuclei of atoms. Nuclear energy gained by splitting uranium atoms is converted to electrical energy in power plants. Nuclear energy from combining hydrogen atoms is how the Sun makes energy.

VOCABULARY

energy - the ability to cause change or do work.

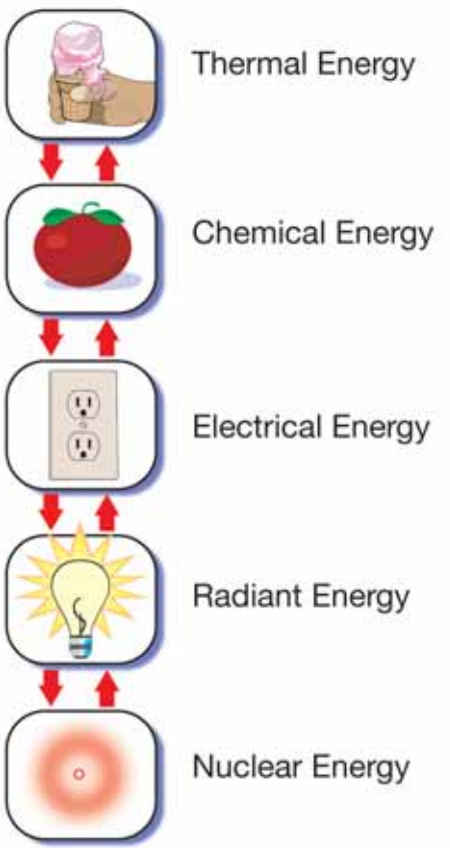
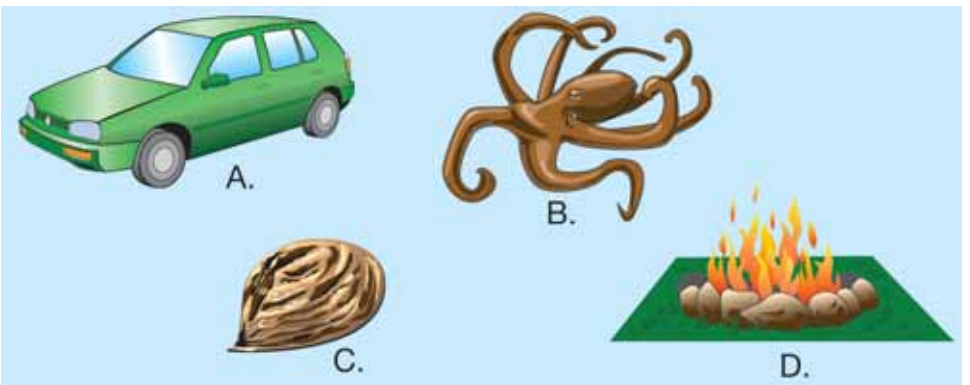


Figure 2.4: *There are many forms of energy. Energy can be converted from one form to another.*

2.1 Section Review

1. List the five rules for classifying something as alive.
2. Which characteristics of a cloud in the sky might qualify it as a living thing? Which rules does a cloud not meet?
3. Classify each object below as living or nonliving. Explain your answer for each.



4. In the picture below, energy is being changed from one form into another. Make a flow chart that shows each form of energy in the order of change.

CHALLENGE

Imagine you are a space scientist. You have landed on a distant planet and are searching for life. You encounter the object below. You take data and make the following observations about the object:

- It is 9.5 cm tall and has a mass of 250 g.
- There are several smaller objects on the ground below it.
- It occasionally sways back and forth.

1. Make a hypothesis whether or not the object is alive. Justify your hypothesis.
2. Design an experiment to test your hypothesis. Sketch your experimental design and list the materials you would use.

2.2 What is a Living System?

You have learned that a *system* is a group of factors that are related in some way. You can think of an individual organism as a *living system*. What variables affect *you* as a system? An obvious answer is the temperature around you (Figure 2.5). The type of food you eat is another variable. Your body responds to different variables in different ways. In this section, you will learn about how living systems are organized and the variables that affect them.

Figure 2.5: *A living system is affected by outside variables. What are the variables affecting the girl in the picture?*

The organization of living systems

Living systems are organized

Is your room disorganized? Even if it is, *you* are not! As a living system, your body is organized to use matter and energy to move, grow, and survive. Living systems—like you—contain many levels of organization. These are described on the next few pages.

Molecules

A *molecule* is a basic unit of matter. Living systems are made of many different molecules. Each type of molecule has an important function. Your body contains molecules that store energy, control life functions, and even hold all of the information needed to make another you! You'll learn more about molecules in Chapter 4.

Cells

A cell is the basic unit of a living system. Each cell is made up of different types of molecules including proteins, carbohydrates, and others. Your body contains trillions of cells, each one a living system on its own. Some organisms are made up of only one cell. Figure 2.6 shows what a one-celled organism called a *euglena* looks like. Organisms that are made of more than one cell are called *multicellular* organisms. You'll learn much more about cells in Chapters 4, 5, and 6.

A cell is the basic unit of a living system.

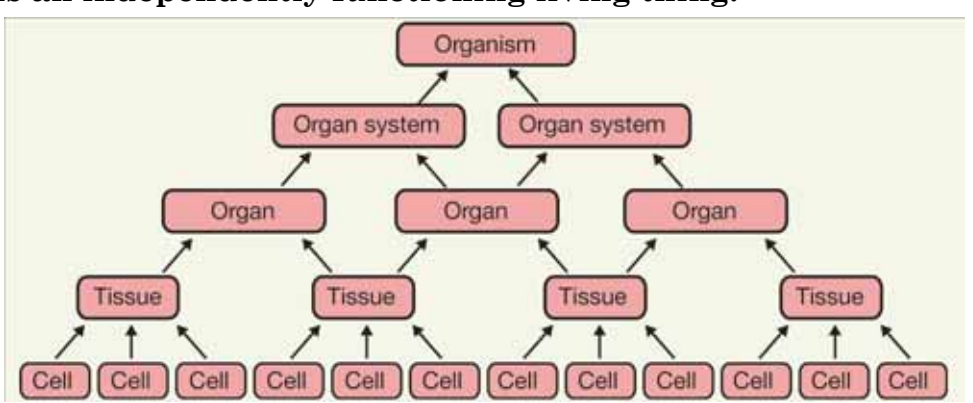
Figure 2.6: *A euglena is a one-celled organism.*

Tissues Your body is made up of many different types of cells. You have skin cells, muscle cells, liver cells, nerve cells, and blood cells, to name just a few. A group of specialized cells that performs a particular function is called a **tissue**. For example, muscle tissue is a tissue that is able to contract. Figure 2.7 shows what your muscle tissue looks like under a microscope.

Organs Tissues combine to form organs, the next level of organization. An **organ** is a group of tissues that works together to carry out a set of functions. For example, your stomach is an organ that contains several types of tissue. Muscle tissue in your stomach contracts to mix food. Another type of tissue makes a chemical that breaks down the food.

Organ systems A group of organs that works together to perform a set of functions is called an **organ system**. For example, your digestive system consists of many organs including the esophagus, stomach, small intestine, and large intestine. Each organ in the system performs a different function that is part of the digestive process.

Organism In multicellular organisms like you, different body parts and organ systems take on different functions. The network of organ systems works together to keep the organism alive. **An organism is an independently functioning living thing.**



VOCABULARY

tissue - a group of specialized cells that performs a particular function.

organ - a group of tissues that works together to carry out a set of functions.

organ system - a group of organs that works together to perform a set of functions.

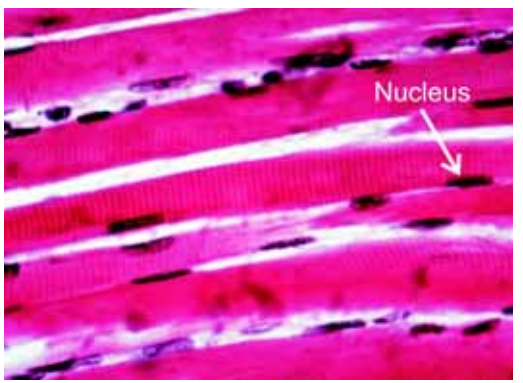


Figure 2.7: *Muscle tissue is made of individual muscle cells. Each individual cell has a dark spot called a nucleus.*

Variables and living systems

Homeostasis

Living things can respond to changes in their surroundings to maintain a steady internal environment. The process of maintaining a life-supporting system is called **homeostasis**. Homeostasis happens at all levels of organization, including the cellular level, and is a characteristic of all living things.

Variables that affect life

All sorts of variables affect an organism's ability to stay alive. These include temperature, food, water, and the level of oxygen (Figure 2.8). All organisms have built-in processes to help them survive when variables change. Organisms can survive within a range of values for each variable. If a change in a variable is too severe, the organism may not be able to maintain homeostasis and could die.

Why do we sweat and shiver?

You experience homeostasis every day, as you'll see in the following story. It was a hot day so Sarah decided to go for a swim in the neighborhood pool. She packed a towel and headed out on her bicycle. As Sarah climbed up a hill, she began to drip with sweat. She couldn't wait to jump into the pool! When she started to swim though, the water was so cold she couldn't stay in very long. Once Sarah got out of the water, she started shivering. The shivering stopped once she felt warm again.

Sweating and shivering are examples of homeostasis

Sweating and shivering are good examples of how your body responds to maintain a steady temperature. Normal human body temperature is 37°C (98.6°F). At this temperature, your cells can perform their functions. When it's too hot and your body temperature begins to rise, glands in your skin produce sweat to cool the temperature back down. When it's too cold and your body temperature begins to lower, shivering is a response that warms your body temperature back up (Figure 2.9).

VOCABULARY

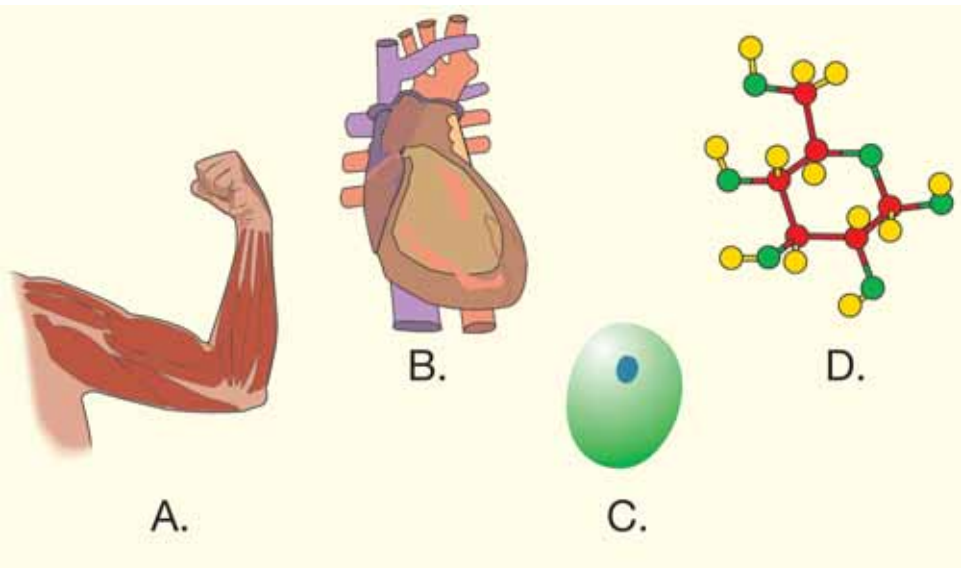
homeostasis - the process of maintaining a life-supporting internal environment.

Figure 2.8: *A few of the variables that affect an organism's ability to stay alive.*

Figure 2.9: *Your normal body temperature is 37°C. Sweating and shivering are your body's way of maintaining that temperature.*

2.2 Section Review

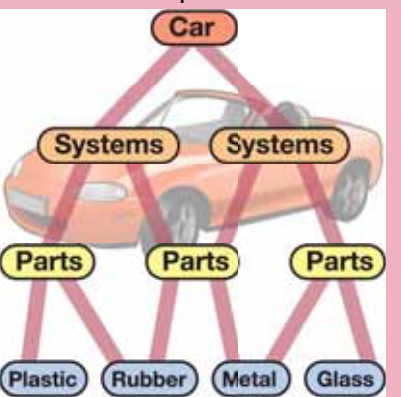
1. Why is a living thing a system?
2. Name three variables that affect a living system.
3. What is a cell?
4. What is a multicellular organism? Name three examples.
5. Identify each picture below as either a molecule, a cell, a tissue, or an organ. Give a reason for your choices.



6. Explain why each of the following scenarios is a good example of homeostasis. What is the variable involved? What is the response?
   a. During the 100 meter run at a track meet, Sonja's heart rate and breathing increased.
   b. Roberto's stomach began to growl during science class.
   c. Because they do not have sweat glands, dogs pant when they're hot.

CHALLENGE

Like a living thing, a car has different levels of organization. A car is made of different materials like rubber and steel. Different materials are grouped into parts like the wheels and headlights. Different parts are grouped together into systems like the cooling system and the drive system. Together, all of the systems make up the car.



Make a chart showing the levels of organization for one of the following systems. You may need to do some research!

1. Your school building.
2. A city.
3. A cookie factory.
4. Choose a system that is not listed.

2.3 Types of Living Things

Look around you. What types of living things do you see? You probably see plants and animals. If you could shrink down to the size of a cell, you'd see other types of living things. At this size, you might see dust mites crawling across the floor (Figure 2.10). You would definitely see bacteria, a microscopic life form that lives just about everywhere. What are the different types of life and how do we classify them?

Figure 2.10: *Dust mites are tiny organisms that live in your home.*

Classifying life

A trip to the grocery store

Ryan was cooking chicken and rice for his family. He looked in the cupboard and found that they were out of rice. He had to get some quick so he ran to the grocery store. The huge store contained thousands of products. He located the aisle marked "pasta, beans, and rice" and quickly found exactly what he was looking for.

The importance of classification

Grocery stores are organized so you can find things easily. Products are grouped in aisles according to their similarities. You wouldn't look in the dairy aisle if you wanted to find canned pineapple! In a similar way, *living things* are classified by similar characteristics. Each different type of organism is called a *species*. It is estimated that there are over ten million different species on Earth. Can you see why it is important to classify living things?

Kingdoms

One system of classification groups all living things into one of six kingdoms: *Archaebacteria*, *Eubacteria*, *Protista*, *Fungi*, *Plantae*, or *Animalia*. To classify a living thing into one of the kingdoms, scientists ask three questions (Figure 2.11):

- Does it have *prokaryotic* (simple) or *eukaryotic* (complex) cells?
- Is it *single-celled* or *multicellular?*
- Does it get energy by making its own food (a *producer*) or by getting food from other organisms (a *consumer*)?

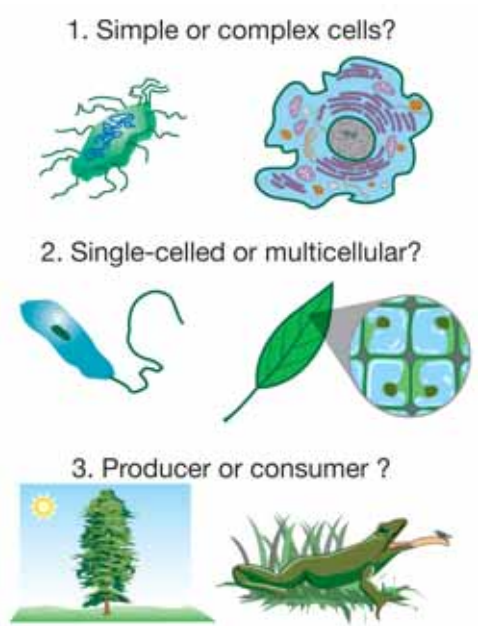


Figure 2.11: *Three questions asked when classifying an organism into a kingdom.*

Bacteria, Kingdom Protista, and Kingdom Fungi

Two Kingdoms of bacteria

Bacteria are the simplest of all living things. They have prokaryotic cells and are single-celled organisms. Some bacteria can produce their own food while others break down food and absorb it. Primitive bacteria have been found living in hot springs and deep sea vents (Figure 2.12). Because of this discovery, many scientists divide bacteria into *two* kingdoms. Under this system, *Kingdom Archaebacteria* are the primitive bacteria and *Kingdom Eubacteria* are the "true" bacteria. Bacteria are discussed in Chapter 7.

Figure 2.12: *These bacteria were found living in a hot spring.*

Kingdom Protista

Members of the Kingdom Protista are called *protists*. Protists are an odd group of organisms. They are mostly single-celled, though there are some multicellular protists. All protists have eukaryotic cells. Some protists can produce their own food while others get their energy by eating other organisms. Figure 2.13 shows a few examples of protists. Protists are discussed in Chapter 7.

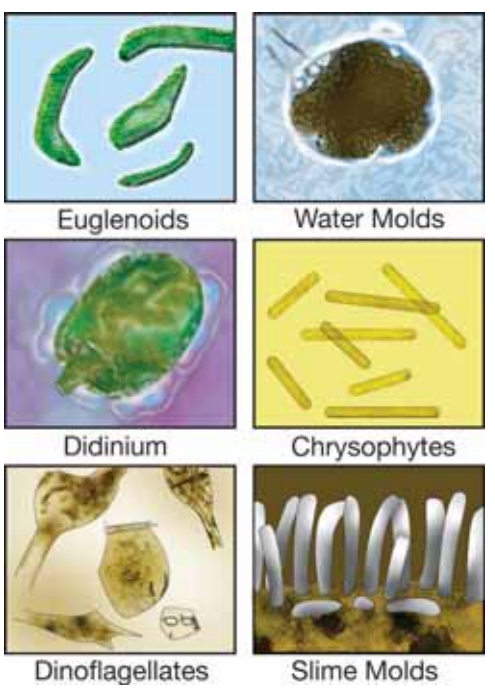


Figure 2.13: *These are just a few members of Kingdom Protista.*

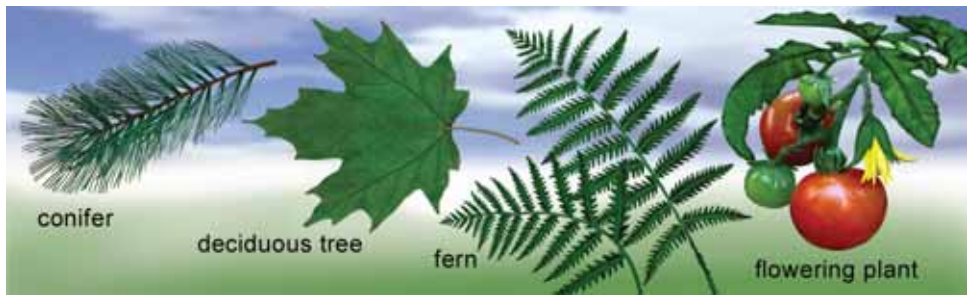
Kingdom Fungi

Kingdom Fungi includes the fungi, mushrooms, molds, and yeasts. You may have seen members of this kingdom growing on rotting logs in the woods. Fungi are important because they break down rotting things and return the nutrients to the soil. Fungi have eukaryotic cells and most (except yeasts) are multicellular. They get their energy by breaking down and absorbing dead organisms like trees. You'll learn more about fungi in Chapter 13.

Kingdoms Plantae and Animalia

Kingdom Plantae

The Kingdom Plantae is made up of multicellular organisms that have eukaryotic cells. In a process called *photosynthesis,* plants harness energy from the sun and store it in the form of molecules. When animals eat the plants, they use these molecules as energy to survive. Examples of plants include mosses, ferns, trees, and flowering plants. Figure 2.14 shows the characteristics of a typical plant. Plants are discussed in Chapter 14.



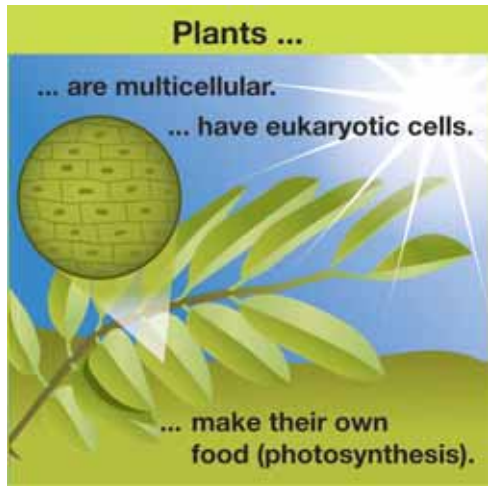
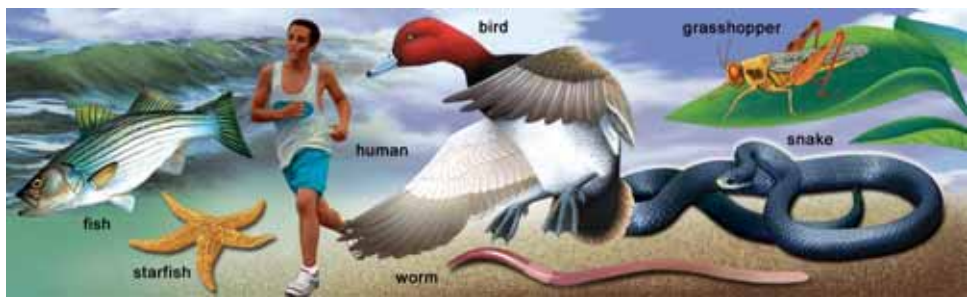


Figure 2.14: *The characteristics of a typical plant.*

Kingdom Animalia

Like plants, animals are multicellular organisms that have eukaryotic cells. Unlike plants, all animals need to eat other organisms to get their energy. Beetles, worms, snakes, and birds are animals. You are also an animal. Figure 2.15 shows the characteristics of a typical animal. Animals are discussed in Chapter 15.



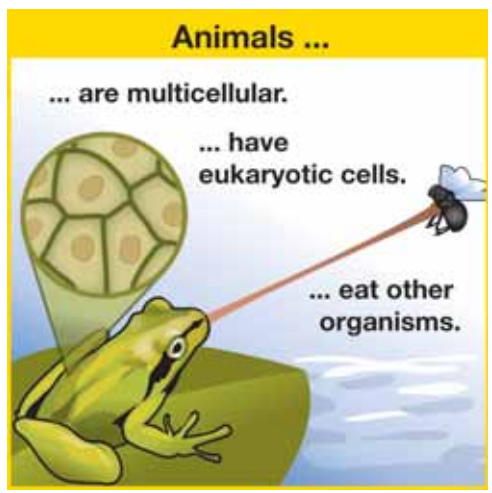


Figure 2.15: *The characteristics of a typical animal.*

Levels of classification

Taxonomy is the process of identifying and classifying living things. The Swedish scientist Carolus Linnaeus (1707–1778) developed this system for identifying and classifying living things. Taxonomy is based on the characteristics of organisms. Organisms with shared characteristics are grouped together.

For animals, the levels of classification are kingdom, phylum, class, order, family, genus, and species.

Levels of classification

For animals, the levels of classification are kingdom, phylum, class, order, family, genus, and species. Organisms belonging to the same kingdom are not necessarily very similar. As levels get smaller, organisms share more characteristics. Organisms in the same *order* share more characteristics than organisms in the same *class*. Organisms belonging to the same **species** are very similar and can produce offspring together. Table 2.1 shows the classification of some animals.

VOCABULARY

taxonomy - the process of identifying and classifying living things.

species - a group of similar organisms that can produce offspring.

MY JOURNAL

How many different species of organisms can you identify in your backyard or local park? Visit a local park or your backyard. List all of the different species of organisms you see.

Table 2.1: Classification of some common animals

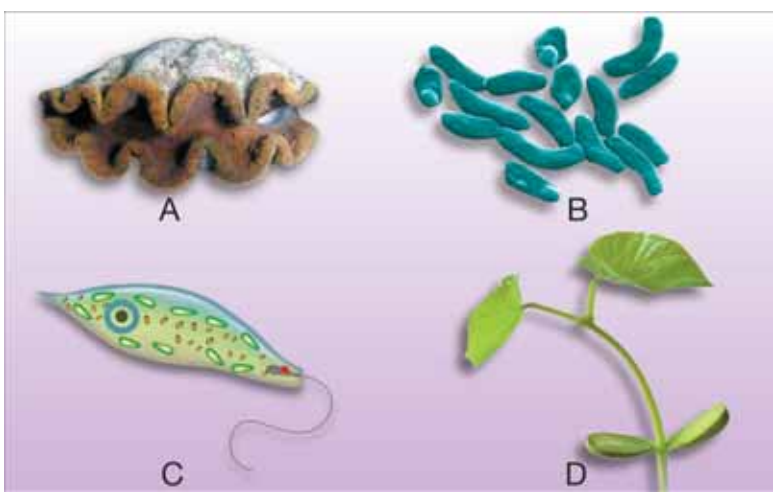
Level	Human	Dog	Bull frog	Brine shrimp
Kingdom	Animalia	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata	Arthropoda
Class	Mammalia	Mammalia	Amphibia	Crustacea
Order	Primates	Carnivora	Anura	Brachiopoda
Family	Homonidae	Canidae	Ranidae	Anostraca
Genus	Homo	Canis	Rana	Artemia
Species	*Homo sapiens*	*Canis familiaris*	*Rana catesbeiana*	*Artemia gracillus*

2.3 Section Review

1. Why is it important to classify living things?
2. Complete the following table.

Kingdom	Prokaryotic or eukaryotic cells?	Single-celled or multicellular?	Producers or consumers?
Eubacteria			
Protista			
Fungi			
Plantae			
Animalia			

3. For each organism below, (a) name the kingdom; and (b) give a reason for your answer.



4. At which level of classification do a dog and a human get separated? What about a frog and a brine shrimp?

CHALLENGE

What IS this?

Euglenas are one-celled, eukaryotic organisms that live in ponds. They have the following characteristics:

- They are green and can make their own food.
- They have a whip-like structure called a flagella that they use to move around.
- They sometimes find food instead of making their own.

Answer the following questions:

1. To which Kingdom do Euglenas belong?
2. Before the invention of the microscope, scientists classified all organisms as either animals or plants. Explain why they needed to invent a new Kingdom when they discovered Euglenas.

ASTRONOMY CONNECTION

Is There Proof of Life on Mars?

Do you think there is life on other planets? Not long ago, most people would have said "no." The search for life on other planets switched from science fiction to real science during the last century. The search for life elsewhere has followed on the heels of our greater understanding of the universe itself.

We now know that the universe is huge. It contains billions of galaxies. Because the universe is so big, the chances of life existing beyond Earth are very good.

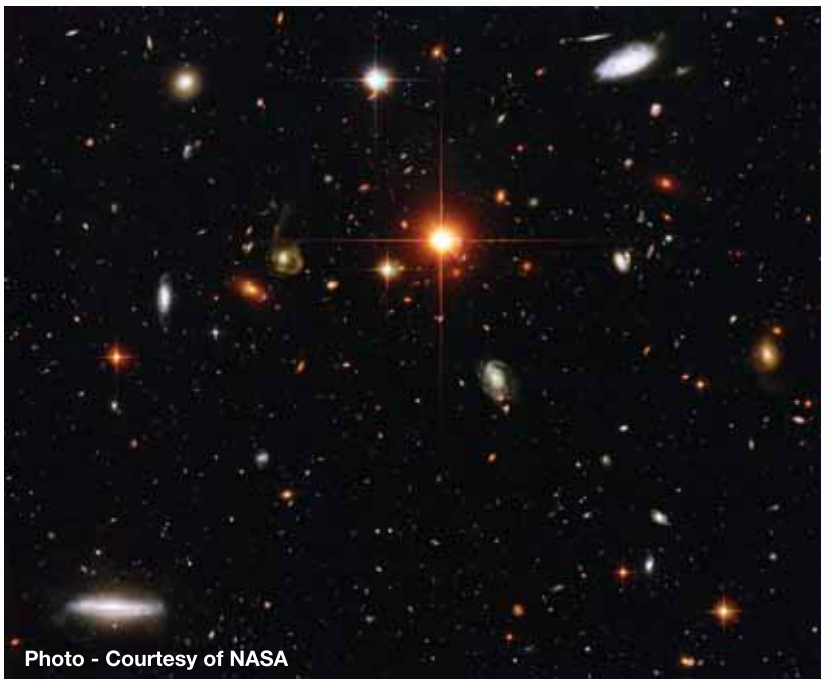


Photo - Courtesy of NASA

What do we mean by life when we talk about other parts of the universe? Definitions vary. We know that all living things on Earth are made of carbon compounds. We also know that all living things on Earth need water. Some scientists believe that if we find life elsewhere, it will have to be carbon-based. Other scientists think the universe is too vast to know this for sure. Our search for life beyond Earth starts with the search for evidence of water. If we find evidence of water, this suggests the existence of life.

Journeys to Mars

Our "near" neighbor Mars is the fourth planet from our sun. Mars is a little like our planet. It has long been the focus of our search for life beyond the Earth.

In the 1880s, better telescopes showed what seemed to be canals on Mars. Some even believed that people lived on Mars. These ideas lasted until the 1960s. At that point, improved techniques gave us a closer look at Mars. The "canals" were an optical illusion.

Photo - Courtesy of NASA

In 1976, the Viking mission landed on Mars. It found a thin atmosphere made mostly of carbon dioxide. Soil samples were tested. Viking found no signs of life or liquid water. Photos sent back revealed Mars as a barren place. Yet these images showed landforms that suggested liquid water might have existed on Mars long ago. Since then, scientists have tried to find out if Mars had water in the ancient past.

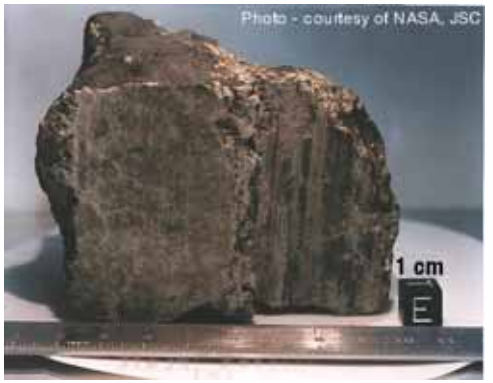
Proof from Earth?

In 1996, some scientists made a startling claim. They said that they had evidence suggesting that life existed on Mars more than 3 billion years ago. Perhaps most amazing of all, they found the evidence on Earth!

The evidence was found in a meteorite in Antarctica. You might wonder how can we know the meteorite came from Mars? Scientist discovered that the gases trapped in the meteorite match those found on Mars by Viking.

Here is what some scientists think may have happened. The rock was originally beneath the surface of Mars. About 3.6 billion years ago, meteorites hit Mars. The meteor impact cracked the rock. A liquid seeped into the cracks leaving mineral deposits behind. The deposits included carbon and iron compounds. These compounds are associated with some bacteria on Earth.

Then, about sixteen million years ago, an asteroid hit Mars. The rock was blasted into space. It finally fell to Earth in Antarctica about 13,000 years ago.



Scientists have studied the meteorite and found what might be fossils of ancient bacteria. Similar tiny bacteria have been found on Earth. These discoveries suggest that water once existed on Mars. This is just one conclusion from the evidence.

Other evidence

More evidence needs to be collected. Recent missions to Mars are looking for water. In 2003, the NASA rovers Spirit and Opportunity landed on Mars. They have sent back many amazing photographs.

Close-up images from Mars show textures that geologists recognize. Inside of some rocks, crystals form in salty water. Later the crystals dissolve. They leave marks on the rocks. Geologists see this on Earth. If the same process caused the textures on Mars, it would indicate the presents of water.

So far, we are not sure if water ever existed on Mars, much less if there are living things there now. Each new piece of evidence takes us a step closer to an answer.

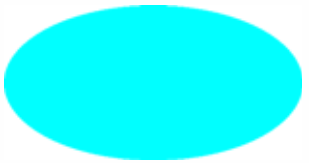
Questions:

1. How likely is it that life exists in other parts of the universe? Why?
2. What possible evidence of liquid water on Mars did Viking find?
3. What evidence of possible life on Mars was found on the Earth? Explain.

CHAPTER ACTIVITY Making a Key

Living organisms are classified into different groups to make it easier to understand the similarities and differences between these organisms. Scientists that study the characteristics of organisms and their relationships to other organisms are called *taxonomists*. One tool taxonomists use to identify unfamiliar organisms is called a *key*. A key asks a series of questions about an organism. As you answer each question, you are led to a different question depending on how you answered the first question. This continues until you are finally able to figure out what the organism is. Let's look at an example of a key used not for organisms, but for regular shapes.

Consider this shape:



1. Is the shape two-dimensional or three-dimensional?
   a. If two-dimensional, go to question 2.
   b. If three-dimensional, go to question 7.
2. Are all the edges of this two-dimensional shape all curved?
   a. If yes, go to question 3.
   b. If no, go to question 4.
3. If you place a point in the center of this shape, are all locations along the perimeter at an equal distance from the center point.
   a. If yes the shape is a circle.
   b. If no, the shape is an oval.

Get the idea? In this activity, you will create a key to identify some objects your teacher gives you.

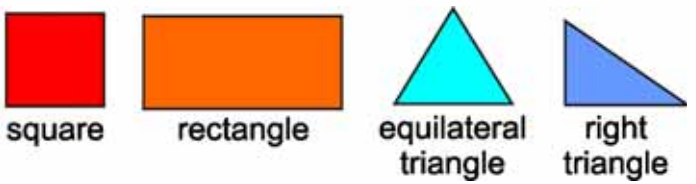
What you will do

1. Obtain a collection of objects from your teacher.
2. Give each item a silly name. The name should not be something that someone could easily guess.
3. Separate the objects into two groups based on some simple, easily observed difference between them. Write a question that when it is answered will determine the placement of an object into one group or the other. This question should be designed so that it only has two answers, for groups a and b.
4. Examine group a and repeat step 2 for this group. Keep repeating this for each group until the answer to a question leaves you with only one object. In this case, give the name of the object.

Applying your knowledge

a. Pair up with another group in the class. Randomly pick one of their objects. Draw a picture of this object. Use the key that your partner group wrote to try to correctly identify the chosen item and find out its silly name. What was the object's name? Did you get stuck at any steps? Is this group's key very different from yours?

b. You are a shape taxonomist. The key found in the introduction needs more work. You want people to be able to use this key to identify the shapes below. Write additional steps for the shape key so that it can be used to identify these shapes.



Chapter 2 Assessment

Vocabulary

Select the correct term to complete the sentences.

stimuli	energy	organ systems
species	tissues	homeostasis
organism	response	cells
taxonomy	organs	

Section 2.1

1. An ____ exhibits the characteristics of life.
2. Organisms react to environmental ____, such as heat, sunlight and nutrient availability.
3. An expected ____ to touching a hot stove is to flinch away from the heat.
4. All living things are made up of ____, the basic unit of life.
5. Life requires ____ in different forms to perform functions.

Section 2.2

6. ____ are groups of similar cells that are specialized to carry out a particular function.
7. ____ are groups of tissues that organize to perform a function.
8. Organs interact in groups called ____ to perform related tasks.
9. ____ is a process by which organisms maintain stable internal conditions suitable for life.

Section 2.3

10. The science of identifying and grouping organisms based on similarities is named ____.
11. Populations of interbreeding individuals who can produce fertile offspring are called a ____.

Concepts

Section 2.1

1. While hiking in the Sierra Nevada, you find an strange object. What steps are needed to determine if the object is alive?
2. During metamorphosis, tadpoles gradually lose their tail and form legs. This is an example of
   a. reproduction.
   b. growth and development.
   c. responding to the surrounding environment.
   d. evolving to the change in oxygen availability.
3. A world-class cyclist training for the Tour de France increases his respiration rate while pedaling up hills. What characteristic of life does this represent?
4. Zeedonks, animals that are the cross between a zebra and a donkey, cannot breed on their own. If zeedonks were isolated how would this affect their population? Using the zeedonk as an example, explain why reproduction is such an important characteristic of life?
5. Which is an example of chemical energy?
   a. The breakdown of large carbohydrate molecules into smaller glucose molecules.
   b. Solar powered space probes providing images of distant planets.
   c. Energy from the wind turns large turbines to provide electricity to homes and businesses.
   d. The splitting of uranium atoms to provide electricity for cities and towns

Section 2.2

6. Describe examples of how the human body is organized to perform life functions.

7. The liver is an example of:
   a. a tissue
   b. an organ system
   c. an organ
   d. none of the above

8. Paramecium have contractile vacuoles that pump water out their body cavities. This is an example of
   a. the organism maintaining homeostasis
   b. growth and development.
   c. an organism converting radiant energy into chemical energy.
   d. an organ system.

Section 2.3

9. Species from the kingdom Protista include:
   a. mushrooms
   b. bacteria
   c. algae
   d. starfish

10. Clams of the same order, must be classified in the same:
   a. genus
   b. species
   c. family
   d. class

11. Describe the major differences between plants and protists.

12. Carolus Linnaeus
   a. used DNA evidence identify relationships among species.
   b. strictly based his classification system on evolutionary relationships.
   c. created a classification system that identifies only multicellular organisms such as plants and animals.
   d. unified the science of taxonomy by identifying and classifying organisms based on structural and evolutionary relationships.

Math and Writing Skills

Section 2.1

1. Write a paragraph describing how your pet, or a friend's pet, meets the criteria of a living thing.

Section 2.2

2. Write a one page story about how you experience homeostasis each day.

Section 2.3

3. Suppose you discovered the creature shown here. Make up a scientific name for the creature and write a short story about a day in its life.

Chapter Project

Classification chart

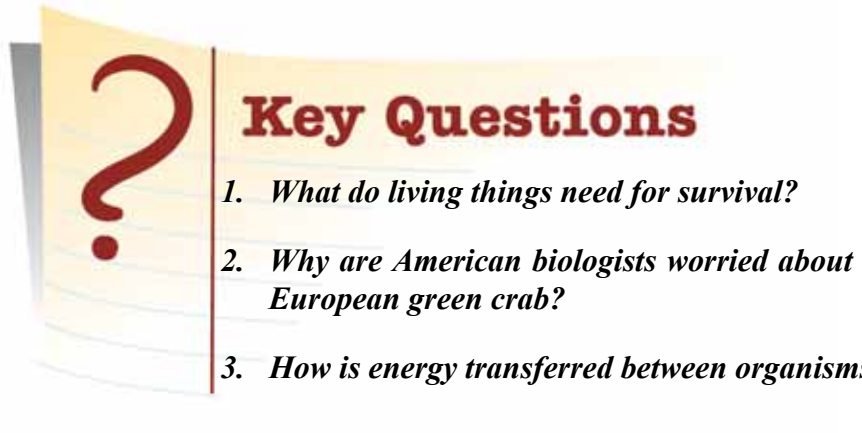
The list below has scientific names for 12 different animals, most of which you could find at a zoo. Choose one of the scientific names. Create a chart and present it on a large poster, showing the correct classification of the animal, from kingdom to species. Find the common name too! Table 2.1 in this chapter shows an example classification chart. Include a correct photograph (printed from the internet, an actual camera photo, photocopied from a book, or cut from a magazine) and some interesting facts about the animal.

Scientific names (choose one for your project): *Bubo virginianus*, *Desmodus rotundus*, *Echinotriton andersoni*, *Ginglymostoma cirratum*, *Marelia boeleni*, *Pongo pygmaeus*, *Procyon lotor*, *Pygocentrus natterei*, *Sarcoramphus papa*, *Uncia uncia*, *Varanus komodoensis*, or *Zalophus californianus*.

Chapter 3

Interactions of Living Things

What lives in a pond? The plants, fish, reptiles, birds, and even microscopic organisms in a pond interact in many ways, creating a natural balance. A fisherman from Maryland made an alarming discovery in 2002. He caught a northern snakehead fish, which is native only to Asia and Africa. It may have been dumped in the pond by someone who imported the species from China. This torpedo-shaped fish can grow to a length of one meter. A female can lay over 100,000 eggs each year. It can breathe air and travel on land, so it has been nicknamed the walking fish. The walking fish eats other fish. There is nothing that eats the walking fish. What affects might this fish have on the pond? In the previous chapter, you studied individual living things. In this chapter, you will see how different organisms interact in living systems.



Key Questions

1. ***What do living things need for survival?***
2. ***Why are American biologists worried about the European green crab?***
3. ***How is energy transferred between organisms?***

3.1 Variables in Habitats

Living things are found on or near Earth's surface where the conditions for life are the best. Earth's life-supporting layer of land, water, and air is known as the *biosphere* (Figure 3.1). Within this layer there are millions of species of living things and millions more that have yet to be classified by scientists. In this section, you will learn about the systems of the biosphere.

Figure 3.1: *The biosphere is Earth's life-supporting layer.*

Ecosystems and habitats

Living systems As you have learned, an individual organism is made up of many smaller systems that work together. Each system has a *structure* (its parts) and a *function* (what it does). This is true for cells, tissues, organs, organ systems, and the entire organism. For example, your heart is a system made of muscle (its structure) that allows it to pump blood throughout your entire body (its function).

Ecosystems A higher level of organization is called an ecosystem. An **ecosystem** is made up of a group of living things and their physical surroundings. An ecosystem can be as big as the entire biosphere, or as small as a drop of water containing one-celled organisms. The living and nonliving things in an ecosystem function together—kind of like a single organism.

Habitats A **habitat** is a place where a particular type of organism lives. A dolphin's habitat is the ocean. A goldfish in a fishbowl has a much smaller habitat (Figure 3.2). There are land habitats, freshwater habitats, and saltwater habitats. Each type of habitat has a set of physical variables such as the amount of sunlight, temperature, and amount of moisture. An organism lives in a habitat where the range of variables is suitable for keeping it alive. For example, a dolphin wouldn't survive very long in your habitat.

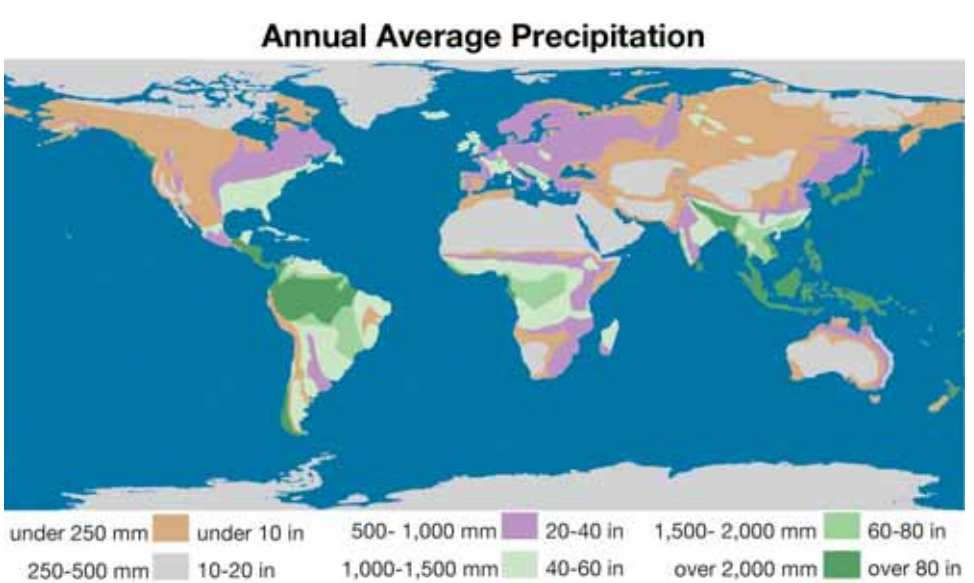
Figure 3.2: *What is the habitat of this goldfish?*

Land habitats

Land variables Many variables affect life on land. Five important ones are *temperature*, *precipitation*, *sunlight*, *type of soil*, and *oxygen*.

Temperature Most living things can survive in temperatures above freezing and below 70°C. Extreme temperatures limit the number and kinds of organisms that can survive. Tropical rainforests have moderate temperatures and support more species of animals and plants than any other land habitat. Polar regions are very cold and do not support as many species. The polar bear is adapted to live in the cold temperatures of the Arctic (Figure 3.3).

Precipitation Living things need water to survive. The amount of precipitation (rain or snow) determines the kinds of living things that can survive in a land habitat. The amount of precipitation on Earth is not evenly distributed. Some parts of Earth's surface are very dry, while others are very wet. The map below shows the average precipitation that falls on different parts of Earth each year.



VOCABULARY

(from previous page)

ecosystem - a group of living things and their physical surroundings.

habitat - a place where an organism lives.

Figure 3.3: *The polar bear lives in the Arctic. It has dense fur and a thick layer of fat to keep it warm.*

MY JOURNAL

Describe your habitat. What is the range of temperatures? How much precipitation does it receive each year? How much sunlight? What type of soil is present? What is your altitude? List the types of organisms that live in your habitat.

Sunlight Sunlight provides the energy for living things to grow and survive. Plants capture the energy from sunlight and store it in the form of molecules. Animals get their energy by eating plants or by eating other animals that eat plants. The amount of sunlight determines the amount of energy available in an ecosystem. Some plants, like ferns, can survive with very little sunlight. A cactus needs a lot of sunlight to grow (Figure 3.4).

Figure 3.4: *Ferns can survive with very little sunlight. A cactus needs a lot of sunlight to grow.*

Type of soil *Soil* is a mixture of decayed plant and animal parts and very small rock particles (Figure 3.5). It provides an anchor for plants that have roots. It also holds water and nutrients to help plants grow. The type of soil varies in different land habitats. *Sand* does not hold water very well and contains few nutrients. *Clay* has smaller particles than sand and holds water. The best soils for growing plants contain a mixture of particle sizes and some decayed matter. Soil is a habitat for many organisms such as bacteria and worms. In fact, a cup of soil contains billions of living bacteria!

Oxygen Most organisms need oxygen to live. The air you breathe is about 21% oxygen. The amount of oxygen in the air varies depending on altitude. Habitats at higher altitudes, like mountain tops, have less oxygen than habitats at lower altitudes. People who live at high altitudes have adapted to breathing less oxygen. If you live at a low altitude and visit a higher altitude, you may notice that you are short of breath. If you spend enough time there though, your body will adapt.

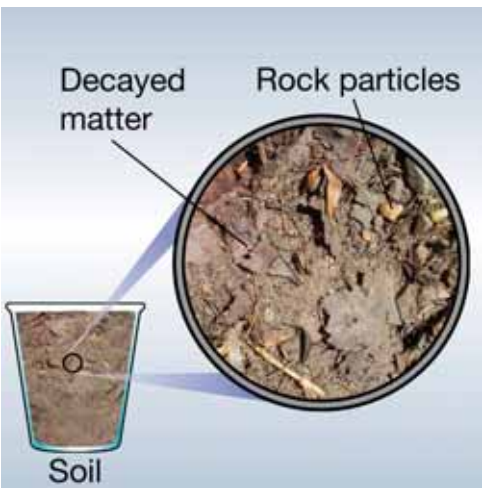


Figure 3.5: *Soil is a mixture of decayed matter and rock particles.*

Air habitats Some organisms spend much of their time in the air. However, most occasionally return to land. Organisms that spend time in the air are affected by the same variables as those that live on land. Can you name some organisms that spend much of their time in the air?

Freshwater habitats

Distribution of water on Earth

Water covers 71% of Earth's surface. The oceans contain just about all of the water available to living things. About 2.5% of Earth's water is frozen at the poles or is deep underground. Less than 0.01% of Earth's water is found in freshwater habitats such as rivers, streams, lakes, and ponds (Figure 3.6).

Water source	Percent of total water
Oceans	97.24%
Icecaps, Glaciers	2.14%
Ground water	0.61%
Fresh water lakes	0.009%
Inland sea	0.008%
Soil moisture	0.005%
Atmosphere	0.001%
Rivers	0.0001%

Figure 3.6: *The distribution of Earth's water.*

Variables in freshwater habitats

Variables that affect life on land also affect life in fresh water. These include temperature, precipitation, sunlight, type of soil on surrounding land, and oxygen. The chemical content of the water is very important in determining which types of life can survive there.

pH

pH is a measure of chemicals called *acids* and *bases* in water. pH ranges from 0 to 14. Pure water is pH 7 (neutral). Lower pH values indicate the presence of acids. Most aquatic plants and animals function best when pH is between 6 and 8. Most fish have trouble reproducing when the pH is too acidic (Figure 3.7).

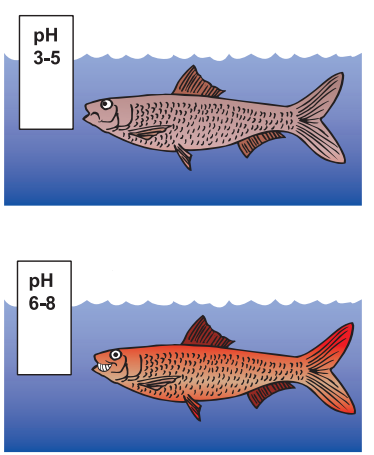


Figure 3.7: *Most fish can survive within the 6 to 8 pH range.*

Dissolved oxygen

The oxygen available to living things in water is called *dissolved oxygen*. Fish "breathe" by passing water over their gills to extract the dissolved oxygen. A good amount of dissolved oxygen for most aquatic life is about 9 parts per million. The amount of dissolved oxygen in freshwater varies with temperature and movement. Cooler waters hold more oxygen than warmer waters. Fast-moving streams contain more oxygen than standing waters like ponds.

Nitrates and phosphates

Nitrates and *phosphates* are important nutrients for living things. They are often used as fertilizers for land crops. Runoff from rain washes these chemicals into bodies of water. Too many nitrates and phosphates cause large growths of water plants. As the water plants die, they are eaten by bacteria in the water that use dissolved oxygen. This process lowers the amount of dissolved oxygen available to other organisms.

The oceans

Chemicals in ocean water

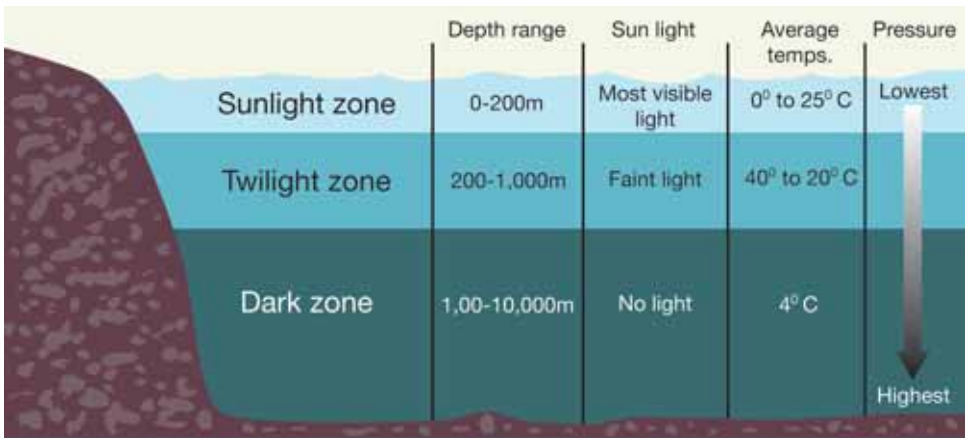
The salty oceans are the most stable of Earth's habitats. The salt content of the oceans has remained stable for 600 million years! The chemicals that the dissolved salts are made of include sodium, chloride, sulfate, magnesium, calcium, and potassium (Figure 3.8). The concentration of salts in the ocean is 35 parts per thousand (ppt). This means that there are 35 grams of salts dissolved in every liter of seawater.

Chemical	Concentration (ppt)
chloride	19.3
sodium	10.8
sulfate	2.7
magnesium	1.3
calcium	0.4
potassium	0.4
bicarbonate	0.1

Figure 3.8: *The main chemicals dissolved in ocean water.*

Oceans are divided into zones

Scientists divide the ocean into layers called *zones*. Zones extend from the surface to the bottom of the deepest trenches. As you go deeper, temperature and light decrease, and pressure increases.



Life in the zones

Most life in the oceans is concentrated in zones where light can penetrate. In most places, light does not reach deeper than 200 meters. Plants that use sunlight to make food cannot live beyond this depth. Life is difficult for organisms in the deep zones. They must overcome lack of light, low temperatures, and extremely high pressures. Some organisms are able to produce their own light so they can find food and locate others of their same species (Figure 3.9).

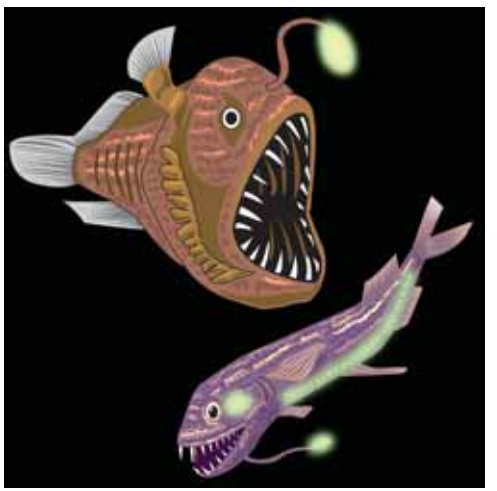


Figure 3.9: *These deep-sea fish can produce their own light.*

Pollutants

What is a pollutant?

Human activities affect ecosystems in both positive and negative ways. One negative effect is pollution. A **pollutant** is a variable that causes harm to an organism. The harmfulness of a pollutant is often determined by three things:

1. Its ability to cause harm to a living thing;
2. Its concentration per unit of air, water, or soil (usually measured in ppt or ppm); and
3. How long it stays in the air, water, or soil.

Sulfur dioxide is an example of a pollutant

Sulfur dioxide is a good example of a pollutant (Figure 3.10). In high concentrations in the air, it can make breathing difficult even for healthy people. It may increase the incidence of asthma, bronchitis, and other respiratory problems. It also reacts with water in the atmosphere to make acid rain. Natural areas like forests and lakes can be harmed by acid rain if they are downwind from a city or industrial area. Acid rain can kill trees and lower the pH of lakes and ponds, harming the life forms there.

Sources of pollutants

Pollutants enter ecosystems naturally and through human activities. For example, volcanic eruptions are a natural source of sulfur dioxide. Coal-burning power plants are a human source of this pollutant.

Mercury is an example of a pollutant

Mercury is another toxic substance that occurs naturally in the environment. It is released into the atmosphere from Earth's crust and oceans. Human activities like industry also cause the release of mercury into the atmosphere. Mercury is deposited from both sources on land and in water. It is taken in by different organisms and builds up in their tissues. When concentrations of mercury get high enough, an organism can get sick and even die.

VOCABULARY

pollutant - a variable that causes harm to an organism.

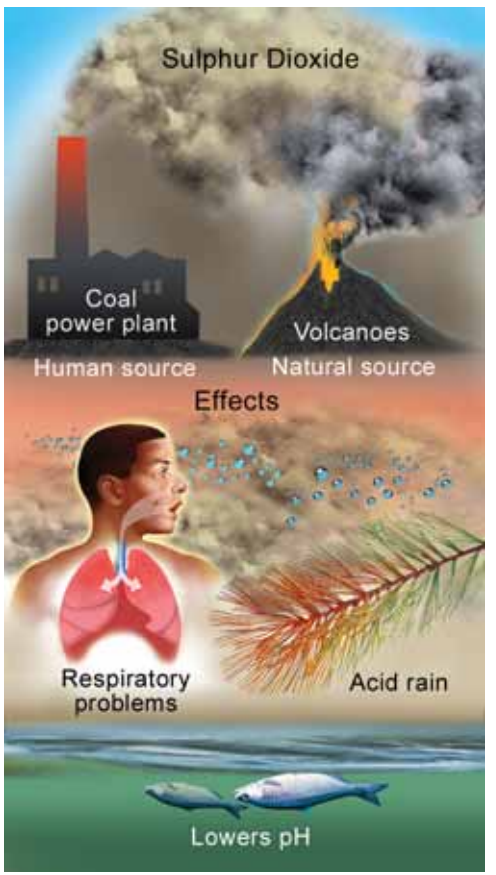


Figure 3.10: *Sulfur dioxide is a good example of a pollutant.*

3.1 Section Review

1. Explain the difference between an ecosystem and a habitat. Give two examples of each.
2. Describe the habitat of the organism in the picture to the right. List three physical variables of the habitat.

3. List and describe the physical variables of land habitats.
4. Sand is a type of soil best described as:
   a. mostly decayed matter with tiny rock particles.
   b. large rock particles and very little decayed matter.
   c. very small rock particles that hold water well.
   d. found only on beaches.
5. Carlos wants to set up a freshwater fish tank.
   a. List the variables he should consider when setting up his tank.
   b. Explain how Carlos could keep a good level of dissolved oxygen in his tank.
   c. Why should Carlos test for pH?
6. Hatchetfish live in very deep parts of the ocean. What challenges must they overcome to survive in this environment?
7. What three factors determine if something is a pollutant?
8. Nitrates and phosphates are important chemicals to living things. Explain why these chemicals can also be pollutants.

MY JOURNAL

Certain populations have specific names like a herd of cows or a pride of lions. These terms are referred to as *collective nouns*.

Write a short story about populations of organisms. Your story should include at least five different collective nouns.

SOLVE IT!

In a typical food pyramid of a community, about 65% of the organisms are producers. 20% are primary consumers, 10% are secondary consumers, and only 5% are top consumers. Imagine that your class is a community that is split into these groups. First, count how many students are in your class. Then, use the information above to determine what percent of the students would be producers, primary consumers, secondary consumers, and top consumers.

3.2 Populations and Communities

Individual living things can be grouped into higher levels of organization. Organisms of the same species are grouped into *populations*. Populations of different species are grouped into *communities*. Different communities form *ecosystems*, which as a whole, make up the *biosphere* (Figure 3.11). In this section, you will learn about populations and communities, and how organisms interact with each other in these systems.

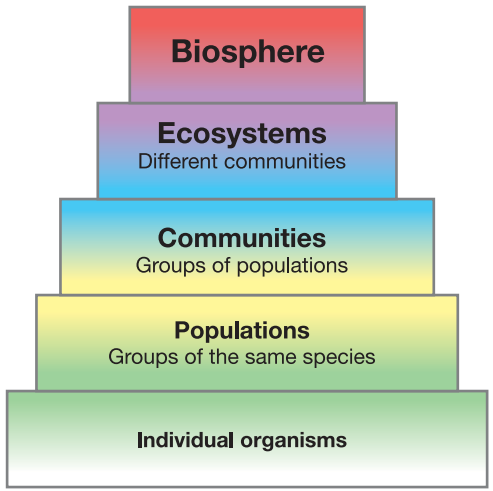


Figure 3.11: *Levels of organization of living things on Earth.*

Interactions create balance

Organisms interact in an area

Organisms living together in an area interact in many ways. Their interactions create a natural balance. Sometimes a species that doesn't belong finds its way into a new area. This can upset the interactions that create the natural balance.

The European green crab

The European green crab is a native of the coasts of Europe and Northern Africa (Figure 3.12). Recently, green crabs have been found in California. Scientists think they may have arrived in a cargo ship carrying seawater from another region.

Cause for concern

The arrival of the green crab is cause for concern. These small crabs could change any ecosystem they enter. In the 1950s, they were blamed for the destruction of soft-shell clam populations in Maine. Because they can survive a wide range of temperatures, green crabs have the potential to spread up and down the West Coast of the U.S.

How might green crabs affect others?

Green crabs eat many types of organisms including clams, mussels, and the young of other crab species. Studies have shown that the green crab is much quicker and a better predator than most other crabs. How might the presence of green crabs affect other types of organisms? To come up with a good hypothesis, you need to learn more about populations and communities.

Figure 3.12: *The European green crab.*

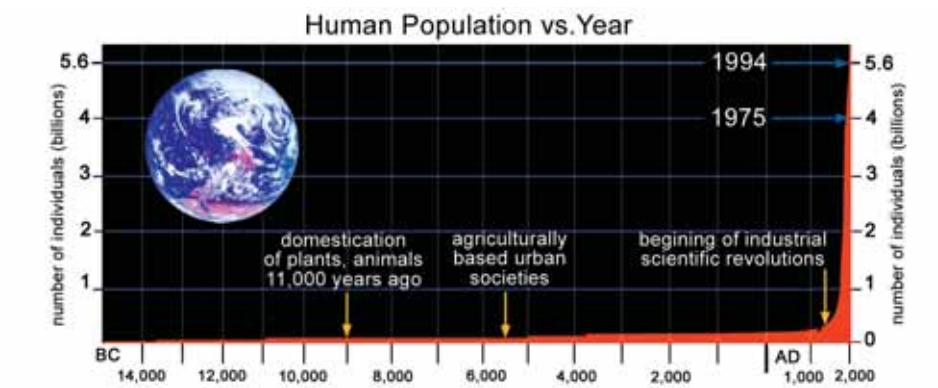
Populations

What is a population?

A **population** is a group of individuals of the same species living in a given area. A population of clover plants in a tray consists of the total number of plants in that tray. A population of clover plants in a field consists of the total number of plants in that field (Figure 3.12).

Growth rate

Populations change as old members die and new members are born. In nature, populations often stay about the same size from year to year. Other times, populations grow or decline very fast. The change in size of a population over time is called its **growth rate**. Growth rates can be positive, negative, or neutral. The graph below shows the growth rate of the human population. What can you tell about human population growth from this graph?



Limits to population growth

In order to grow, a population needs energy, nutrients, and space. Energy and nutrients both come from food. Therefore, population growth is limited by the amount of food available. Population growth is also limited by space. Different organisms require different amounts of space in which to live. If any of these variables are too limited, a population will not continue to grow.

Figure 3.13: *Two different populations of clover plants.*

VOCABULARY

population - a group of individuals of the same species living in a given area.

growth rate - the change in size of a population over time.

Types of interactions

Communities

A species' population growth also depends on the other organisms with which it interacts. A **community** is made up of all of the organisms that interact in a given area. On land, forests and prairies are examples of communities. In the ocean, bays and reefs are examples. A community can also be very small—like the organisms living in an aquarium (Figure 3.14).

Predator-prey relationships

Most interactions between species in a community involve food. Organisms that hunt and feed on other organisms are called *predators*. Those that are eaten are called *prey*. The green crab is a predator that eats clams and mussels, its prey. Predator-prey relationships help keep population growth in balance. Introducing a new species to a community, like the green crab, can upset this balance.

Competition

Often, organisms of the same or different species vie for the same food supply. This type of interaction is called **competition**. When introduced into a new community, the green crab competes with native species of crabs for food. If the green crab is more successful, it can cause negative population growth for other crab species.

Types of symbiosis

There are many cases where two species live together for long periods of time. This type of interaction is called **symbiosis**. In symbiosis, one member always benefits from the interaction. In *commensalism*, the other member is unaffected. In *mutualism*, the other member is helped. In *parasitism*, the other member is harmed. For example, a species of barnacle is a parasite of the green crab in its native community (Europe and North Africa). The barnacles weaken some of the crabs and prevent them from reproducing. This helps keep the green crab's population in balance.

Figure 3.14: *The organisms in an aquarium are a community.*

VOCABULARY

community - all of the organisms that interact in a given area.

competition - when organisms in a community vie for the same food supply.

symbiosis - an interaction where two species live together for a long time.

Food chains

Food chains

A **food chain** shows how each organism in a community gets its food. Some animals eat plants and some animals eat other animals. Plants and some protists are called *producers* because they store energy from the Sun. Animals that eat plants are called *herbivores*. Animals that eat other animals are called *carnivores*. A simple food chain links a producer, a herbivore, and one or more carnivores.

Energy and food chains

Arrows in the food chain above show how energy is passed from one link to another. In any community, there are always more producers than herbivores or carnivores. When a herbivore eats a plant, only a fraction of the plant's energy becomes part of the herbivore's body. The rest is lost as waste or used for movement. Also, when a carnivore eats another animal, only a portion of that energy becomes part of the carnivore's body. This means that organisms along a food chain pass on less energy than they get from the food they eat. Therefore, the amount of energy decreases as you move up a food chain.

Organisms along a food chain pass on less energy than they get from the food they eat.

VOCABULARY

food chain - shows how each organism in a community gets its food.

MY JOURNAL

Visit a local park or pond

1. Write down a list of producers, herbivores, and carnivores that live there.
2. Make several food chains using these organisms. Draw arrows to show the direction of energy flow.
3. Be creative! Use photos or drawings of the organisms in your food chains.

Food pyramids

You can show a food chain as a pyramid (Figure 3.15). The pyramid shows that a large number of living things at the base is needed to support a few at the top. There cannot be too many links in any food chain because the animals at the end of the chain (or at the top of the pyramid) would not get enough energy to stay alive.

Figure 3.15: *A food chain can also be shown as a pyramid.*

Food webs

Most animals are part of more than one food chain. They eat more than one kind of food to get enough energy and nutrients. You can connect many food chains to form a *food web*.

Organisms in a food chain are interrelated

A change in the size of one population in a food chain affects other populations. This maintains the balance of different populations in a community. If a snail population becomes too large, there won't be enough food to go around. Many snails will starve and die. Fewer snails means more time for seagrass to reproduce and grow. Fewer snails also means less food for their predators. Once there are fewer predators, the snail population increases again (Figure 3.16). Introducing a new species, like the green crab, into a food chain can upset the balance. The green crab reproduces quickly and eats just about anything, animal or plant. Can you see why the presence of the European green crab is cause for alarm?

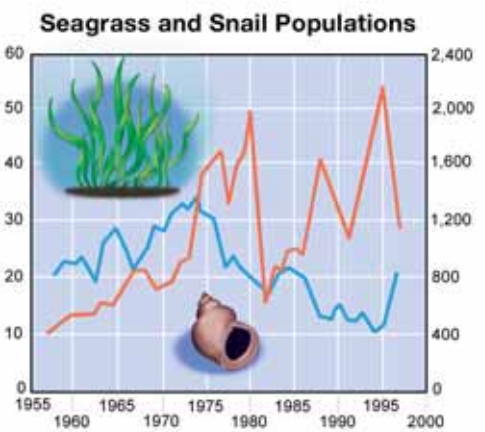
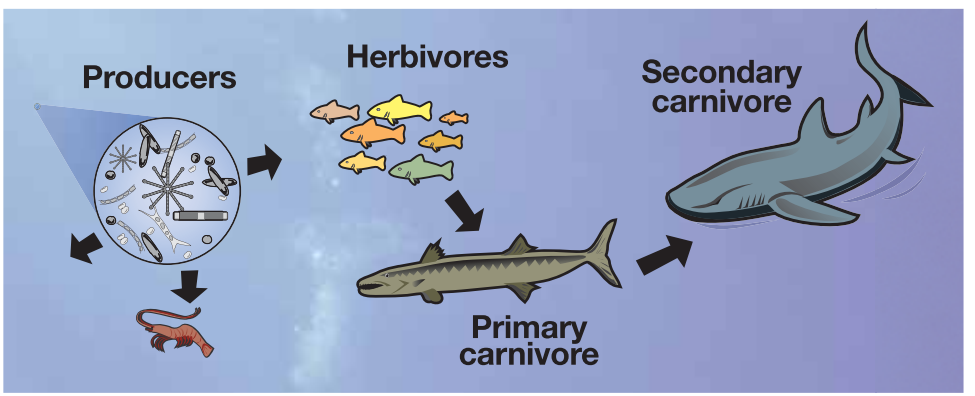


Figure 3.16: *A change in size of one population affects the other populations.*

Toxins in the food chain

What are toxins? Human activities create toxic pollutants (*toxins*). Toxins eventually end up in lakes and oceans (Figure 3.17). High concentrations of toxins can impact populations. They can cause slowed growth, decreased reproduction, and even death. When these substances enter lakes and oceans, they spread out and become less concentrated. Food chains concentrate some toxic pollutants, like mercury, into the tissues of animals. To understand how this happens, let's look at a marine food chain.



Concentration of toxins Toxins are concentrated at each link in a food chain. As producers store energy, they absorb molecules of toxins from the water. Next, herbivores eat large numbers of producers. Toxins like mercury dissolve in fat, not water. They are stored in the fatty tissues of herbivores and are not passed out of their bodies.

Toxins can be passed on to offspring When carnivores eat many herbivores, they accumulate even higher levels of toxins in their tissues. *Secondary carnivores,* who prey on other carnivores, can accumulate dangerous levels of toxic pollutants. These toxins can sometimes be passed on to their young. Figure 3.18 shows how the amount of a toxic pollutant can multiply as it travels up the food chain.

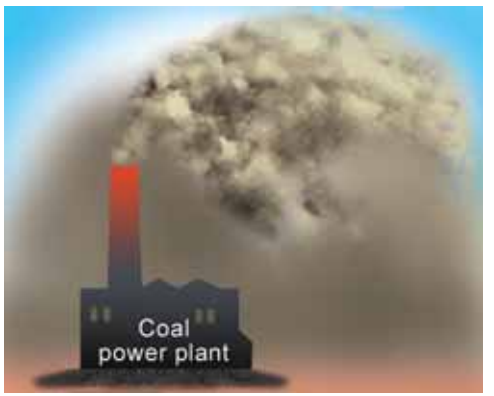


Figure 3.17: *Some power plants send mercury into the air. This eventually falls to Earth with the rain and ends up in lakes and oceans.*

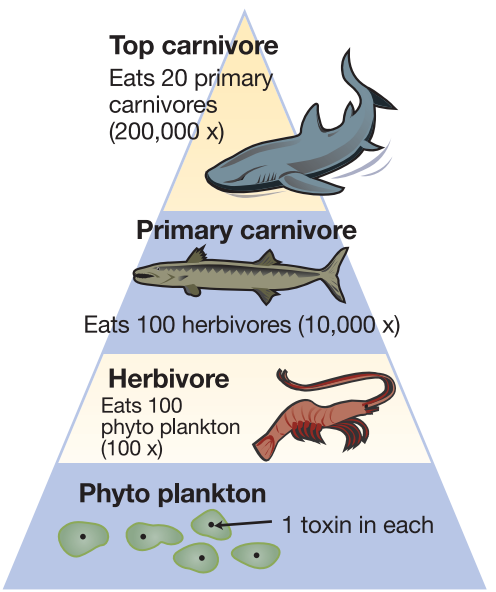
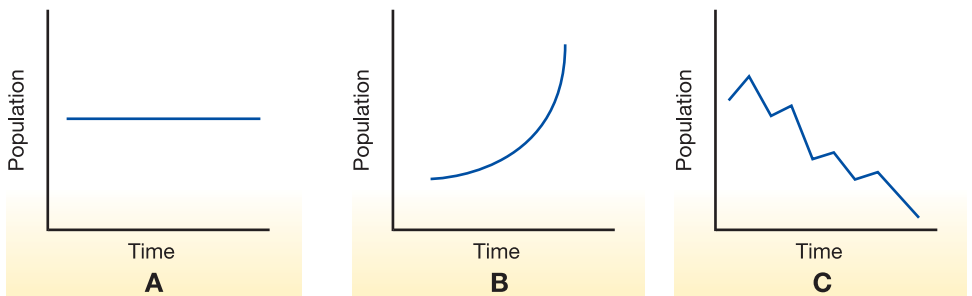


Figure 3.18: *The pyramid shows how toxins are concentrated at each link in a food chain.*

3.2 Section Review

1. What is a population? Give three examples of populations.
2. What three things does a population need to grow?
3. Which graph shows negative population growth?



4. What is the difference between a population and a community? Give two examples of communities.
5. A *remora* is a small fish that follows sharks around and eats their scraps. The shark does not benefit from the remora. This is an example of:
   a. competition
   b. predator-prey
   c. parasitism
   d. commensalism
6. Cans of tuna often carry warning labels. They state that pregnant women should limit the amount of tuna they eat each month.
   a. Explain why tuna could contain dangerous toxins.
   b. Draw a food chain showing how toxins could concentrate in the tissues of a tuna.

CHALLENGE

Find three real-life examples of each of the following interactions:

1. Competition
2. Predator-prey
3. Commensalism
4. Parasitism
5. Mutualism

Use encyclopedias and/or the Internet as resources.

SOLVE IT!

An ecologist studied the presence of a toxic chemical in a lake. She found that the water had one molecule of the toxin for every one billion molecules of water, or one part per billion (1 ppb). The algae had one part per million (1 ppm) of the toxin. Small animals, called zooplankton, had 10 ppm. Small fish had 100 ppm. Large fish had 1,000 ppm. How do you explain the increase in this toxin to 1,000 ppm for large fish? Use a drawing to help support your answer.

ECOLOGY CONNECTION

Yellow Star Thistle

Chances are, you have seen this stuff, maybe in a scene from a movie or a travel photograph of the Golden State. It blankets over 15 million acres of California wildland and pasture, roadsides and vacant lots, with thick patches of brilliant golden-yellow flowers that stand three to five feet tall. From the safe distance of a car or camera, yellow star thistle probably seemed like a beautiful wildflower brightening the landscape.

If, on the other hand, you were unlucky enough to wipe out on a mountain bike and land in one of these patches, you have discovered that yellow star thistle has a sinister side: spiky five-centimeter spines sticking out in every direction.

The painful jabs these spines inflict are not soon forgotten. And the plant is even crueler to horses. When they eat large amounts of this thistle, their lips and tongues become stiff and swollen, so that eating and drinking are difficult. Eventually it causes brain damage and death.

Peggy Greb, USDA Agricultural Research Service, www.forestryimages.org

A costly problem

Yellow star thistle is painful in other ways, too. Ranchers despise this plant because their livestock don't like to eat it. (What creature would want to eat something that can poke it in the eye?) It grows so thick that it crowds out grazing grasses, rendering expensive ranch land useless for pasture.

Even worse, this plant has an amazing ability to suck water out of the soil. It has a long central taproot that can extend more than a meter. Over the course of its growing season, one thistle plant takes as much water out of the soil as does a mature oak tree. A report quoted by the University of California Weed Research and Information Center states that these thistles may cost the state from $16 million to $56 million in water conservation annually.

How did it get here?

Yellow star thistle is native to Europe. The thistle's seeds have been found in California adobe bricks dating to the mid-1800s. Scientists believe the plant was brought from Spain to Chile in the 1600s, then from Chile to California in the 1800s, when farmers imported alfalfa seed that had some yellow star thistle seed mixed in.

Each yellow star thistle seedhead produces about 35 to 80 seeds. On their own, few seeds move more than two feet from the parent plant. It is human activity that is mainly responsible for spreading the seeds: they stick to the tractors that mow roadside areas; construction equipment spreads them across new housing developments; sheep and cattle carry them in their coats to new grazing areas. Some seeds are still spread the way they were when they first came to California 200 years ago: among contaminated alfalfa seed.

What can be done?

It's not easy to get rid of yellow star thistle. You cannot burn the plants out because their seeds survive unharmed in the soil. Herbicides work, but they are too expensive to be used against a weed problem this large.

Scientists are studying insects from Greece and a fungus from Turkey, hoping that some of the plant's natural enemies could be imported to get it under control in California. But first they have to make sure these animals and plants wouldn't instead attack native California plants or crops.

In the meantime, further spread of the yellow star thistle can be prevented by cleaning trucks, tractors, and livestock to remove seeds before moving them to uninfested areas.

The Weed Research and Information Center helps ranchers and conservationists create management plans tailored to a specific area. Often, a combination of chemical, biological, and mechanical methods (like mowing) is used. Different methods are effective during different parts of the plant's life cycle. Used together, they could in a few years make a big dent in the yellow star thistle population.

The long view …

Evolutionary biologists remind us it is useful to take a step back from the current problems of such pesky invaders. While yellow star thistle has certainly been no friend to ranchers, horses, or mountain bike riders, its long-term impact on California's ecosystems may not be disastrous.

Dr. Dov Sax of the University of California-Santa Barbara's Department of Ecology, Evolution, and Marine Biology cautions that it is easy to label invaders as “bad” and native plants as “good.” In reality, many species that are now considered native were once invaders themselves.

The fossil record shows that over the course of Earth's history, massive shifts have occurred in the plants and animals that inhabit California. Invasions and extinctions have been caused by asteroid impacts, movement of land masses, rise and fall of sea levels, and glacial cycles. While painful in the short term, over the long term these events did not permanently reduce the total number of plant and animal species or cause long-lasting ecological damage. Perhaps a thousand years from now, the current wave of invasions will be seen as another interesting population shift that changed, but did not destroy, the California ecosystem.

Questions:

1. Name two ways that yellow star thistle costs Californians money.
2. Some clever Californians have found a way to make money from yellow star thistle. Use an Internet search engine to see if you can discover which agricultural enterprise uses this plant to benefit.
3. Look up the term “biodiversity” in an encyclopedia. Write a paragraph that defines biodiversity and give three reasons it is important to our planet.

CHAPTER ACTIVITY Analyzing Population Growth

The human population is growing. Currently there are over 6 billion people on Earth. Table 3.1 below gives estimates of the human population over the past 2000 years. From the table, you can tell that the population has risen. A graph of the data is a better tool for analyzing the data. Using graph paper, make a graph of the data in Table 3.1.

Table 3.1: ***Human population (in billions)***

Year	Population	Year	Population	Year	Population
0	0.30	1850	1.26	1950	2.52
1000	0.31	1900	1.65	1960	3.02
1250	0.40	1910	1.75	1970	3.70
1500	0.50	1920	1.86	1980	4.44
1750	0.79	1930	2.07	1990	5.27
1800	0.98	1940	2.30	2000	6.06

Applying your knowledge

a. Based on the graph that you created, describe what has been happening to the global population over the last 200 years. How much did world's population change in the last 40 years?

b. Graphs can be used to make predictions. Use your graph to predict the global population in the years 2040 and 2080 if the pattern you observe on this graph continues.

The number of individuals a given area can support is called the *carrying capacity*. When a species of organisms comes into a new area for the first time there are lots of resources available. The size of that population increases rapidly. Use the graph titled Carrying Capacity (right) to answer questions c through f.

c. During what time period did the population increase rapidly for the organism?

d. Eventually resources like space and food become limited. If there are more organisms in an area than the resources can support, some organisms will die off. During what time periods did this occur on the graph?

e. Eventually, populations adjust to available resources and become more stable. What part of the graph indicates a stable population?

f. Compare your graph of the human population to the graph above. Are there any similar features found in both graphs? What does this say about the human population?

Chapter 3 Assessment

Vocabulary

Select the correct term to complete the sentences.

ecosystem	population	competition
food chain	growth rate	symbiosis
pollutants	community	habitat

Section 3.1

1. ____ can enter an ecosystem because of natural causes or human activities.
2. An organism must live in a certain ____ that suits its particular needs.
3. An ____ includes the living and non-living things functioning together.

Section 3.2

4. There are three types of ____: parasitism, mutualism, and commensalism.
5. A _____ always starts with a producer storing energy from the sun.
6. A group of organisms of the same species living together in a certain place is a ____.
7. Predator-prey relationships, competition, and symbiosis are the three types of interactions among organisms in a ____.
8. How populations increase or decrease in numbers over time is called the ____.
9. Organisms in the same community may be in ____ for food, water, or living space.

Concepts

Section 3.1

1. Name a habitat where you predict that there are species that have yet to be classified by scientists. Give an explanation for your prediction.
2. Which is not a variable that affects organisms that live on land?
   a. sunlight
   b. oxygen
   c. temperature
   d. pH
3. List and describe the three variables of freshwater habitats that are different than variables that affect land habitats.
4. Why is most life in the ocean concentrated near the surface? Discuss sunlight, temperature, and pressure in your answer.

Section 3.2

5. Put these terms in order from smallest to largest level of organization: organ system, biosphere, tissue, organism, ecosystem, population, community, organ, cell.
6. Which of the following limit population growth?
   a. space
   b. nutrients
   c. food
   d. all of the above
7. The amount of energy _____ as you move further up a food chain.
   a. increases
   b. decreases
   c. remains the same

8. Identify the following examples as: predator-prey relationship, competition, or symbiosis.
   a. Purple loosestrife, *Lythrum salicaria*, an invasive introduced plant species, needs the same wetland habitat as a native plant, cattails, *Typha spp*. Purple loosestrife is a fast growing plant that forms dense mats and can produce as many as 2.7 million seeds per flower.
   b. The barnacle, *Sacculina carcini,* bores into the tissue of the European green crab, *Carcinus maenas*, to form an egg sac. This egg sac, which makes the crabs sterile, also turns the crab into an egg production facility for the barnacle.
   c. The California sea lion, *Zalophus californianus*, is the fastest aquatic carnivore, swimming at speeds up to 25 mph. Sea lions feed on squid, octopus, abalone, and as many as fifty different species of fish. *Opalescent squid, Loligo opalescens,* can change color and patterns very quickly as it swims to camouflage.
9. A food ____ can also be shown as a food ____. Many food chains connected make up a food ____.
   a. web, pyramid, chain
   b. chain, web, pyramid
   c. pyramid, web, chain
   d. chain, pyramid, web
10. Identify what type of symbiosis is being described below. List the organisms involved in the relationship. Next to each organism, indicate if it is helped or hurt. Use a + sign if the organism is helped, a - sign if the organism is harmed, and a 0 to show that it is neither helped nor harmed.
    a. A lichen is an organism made up of a green alga and a fungus that is often found on the surface of rocks or trees. The alga supplies the fungus with sugar by performing photosynthesis. The fungus protects the alga from intense sunlight and extreme temperatures by providing shelter.
    b. Desert night lizards, *Xantusia vigilis*, are very secretive reptiles that feed, reproduce, and live most of their lives under cover. Desert night lizards are usually found under dead leaves or dead branches of the Joshua Tree, *Yucca brevifolia*. Cover allows desert night lizards to hide from their predators like larger lizards, snakes, and predatory birds.
    c. Pacific mistletoe, *Phoradendron villosum*, is a unique type of plant that has no roots, but does have chlorophyll like other plants. It lives in the crowns of oak trees, *Quercus spp*., in order to get the nutrients that other plants would get using their roots. By living in the tops of the oak trees, the Pacific mistletoe is also sure to get enough sunlight for photosynthesis. The oak tree loses nutrients and sunlight to the Pacific mistletoe plant.

Math and Writing Skills

Section 3.1

1. Invent your own creature that is adapted to life in the deep ocean. Be sure to include adaptations to deal with the challenges of no sunlight, cold temperatures, and extreme pressure.
2. Describe ways that you as an individual can help stop pollution in the environment.

Use < (is less than) or > (is greater than) to complete these comparison sentences about variables that affect habitats.

3. Precipitation in the rainforest ____ Precipitation in the coniferous forest
4. Oxygen in the air at the base of a mountain ____ Oxygen in the air at the top of a mountain
5. Dissolved oxygen in warm water ____ Dissolved oxygen in cool water
6. Dissolved oxygen in a pond ____ Dissolved oxygen in a stream
7. Temperature near the surface ____ Temperature on the ocean floor of the ocean
8. Pressure in a tide pool ____ Pressure in a deep ocean trench
9. Amount of sunlight near the surface of the ocean ____ Amount of sunlight on the ocean floor

Section 3.2

10. Make a graph of the data (below) showing the population of deer and wolf in a given area. Then, answer the questions a through e.

Year	Deer Population	Wolf Population
1945	180	40
1950	170	40
1955	150	30
1960	180	30
1965	200	25
1970	220	25
1975	220	10
1980	290	8
1985	320	8
1990	360	3
1995	420	0

a. From 1975 to 1995, the deer population increased by how much? The wolf population decreased by how much during the same time?
b. What would you have expected to happen to the wolf population from 1975 - 1995 as the deer population was growing?
c. What might be some causes for the deer population to increase so rapidly?
d. What might be some causes for the wolf population to decrease so rapidly?
e. What might happen if the deer population continues to grow so fast? What factors will eventually limit the deer population that can live on a certain area of land?

Chapter Project

Researching a community

A community is made up of all the organisms that interact in a given area. There are interesting communities all over the world, such as forest, dessert, ocean reef, mountain-top, and grassland communities. Choose a particular community that interests you. Do research and find several examples of producers, herbivores, primary carnivores, and secondary carnivores. You may not find many examples of primary and secondary carnivores, but find as many as possible. Find a photo of each animal from a photocopied book or magazine, or printed from a computer. Make a label for each animal that shows its common name and scientific name (genus and species). Construct a *food chain mobile* out of the photos and labels, using yarn, string, straws, or some other material to make the proper connections. Use a coat hanger or some other object that will allow you to hang your mobile in the classroom. Your finished mobile should show how each member of the community is related in the food chain. Don't identify the community on the mobile - see if your classmates can guess it!

Cell Biology

Chapter 4	*Chemistry and Physics Connections*
Chapter 5	*Cell Structure and Function*
Chapter 6	*Cell Processes*
Chapter 7	*The Microscopic World*

TRY THIS AT HOME

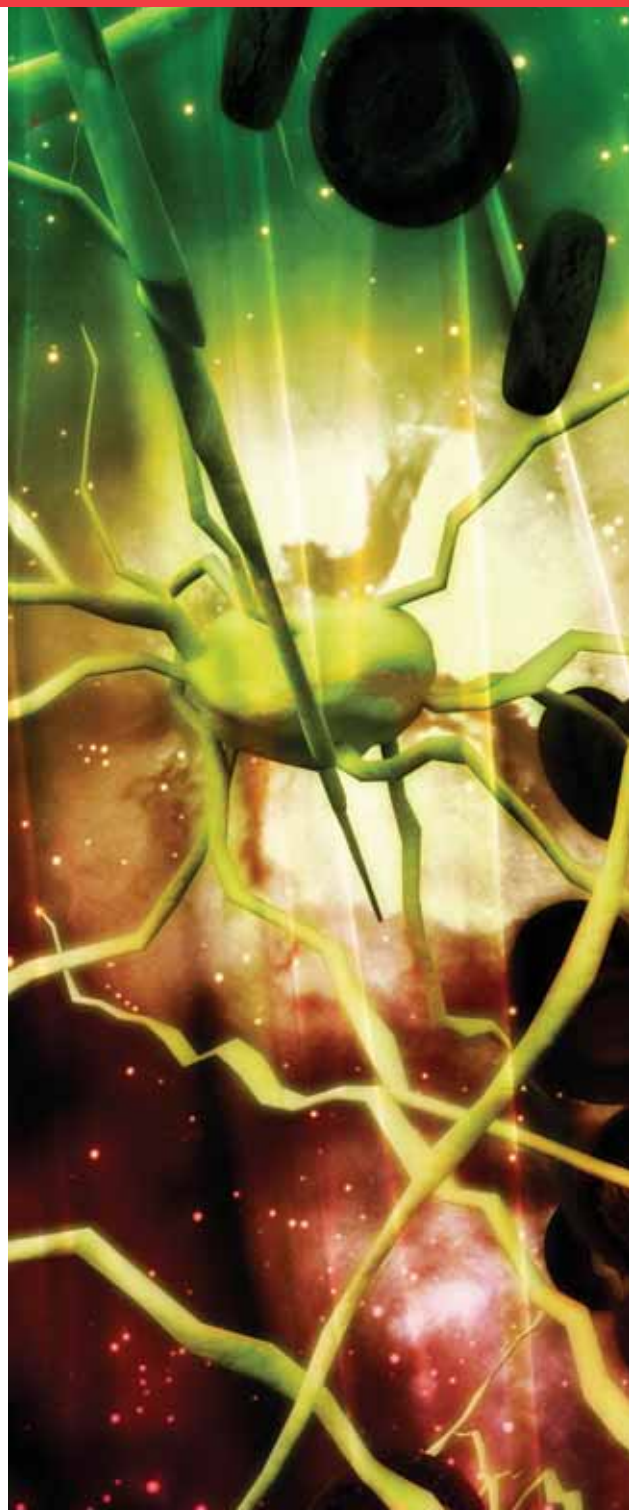
Take a magnifying lens home and examine a leaf. First look at the leaf with your normal vision. Sketch a picture of the leaf and identify its structures. Next examine the surface of the leaf with a magnifying glass.

Sketch what you see. Predict what you would see if you looked at the leaf through a powerful microscope. Make a sketch of your prediction.

Chapter 4

Chemistry and Physics Connections

To learn about life, you need a few tools. In the last chapter, you learned about some of those tools including measurement, the scientific method, graphing, and how life is organized. Another tool you need is some knowledge of chemistry and physics. *Chemistry* is the study of matter. Life is made of matter in the form of complex compounds. In this chapter, you will learn about those compounds. *Physics* is the study of how matter interacts with energy. For example, energy from the Sun powers life on Earth. In this chapter you will learn about a form of energy from the Sun called *light*. Biologists use light when they observe cells and other microscopic organisms under a microscope. In other chapters, you will learn about how living things use light for other processes.



Key Questions

1. ***What are the ingredients of life?***
2. ***Why is life referred to as "carbon-based"?***
3. ***What is light and how do we use it to observe living things?***

4.1 Elements, Compounds, and Reactions

In the 1950s, American scientist Stanley Miller tried to find a recipe for life. He put chemicals found in Earth's early atmosphere into a closed container. Then he sent an electric charge through that mixture to simulate lightning going through the atmosphere (Figure 4.1). When he analyzed the container after a few days, he found amino acids. Amino acids are the building blocks of proteins—one of the compounds that make up all living things. But he did not find a recipe for making life.

Scientists know the basic ingredients for life. They just don't know the recipe. In this section, you'll learn about the simplest ingredients that make up living things.

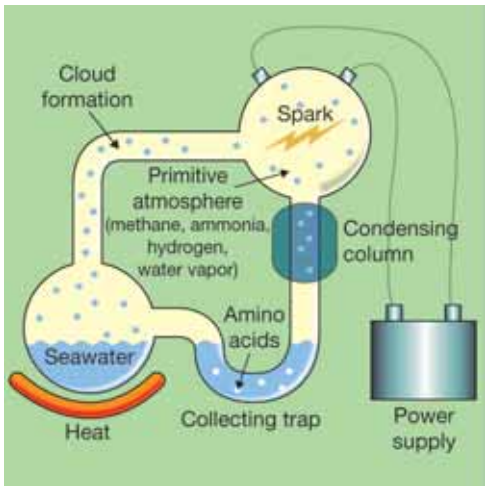


Figure 4.1: *Stanley Miller's experiment.*

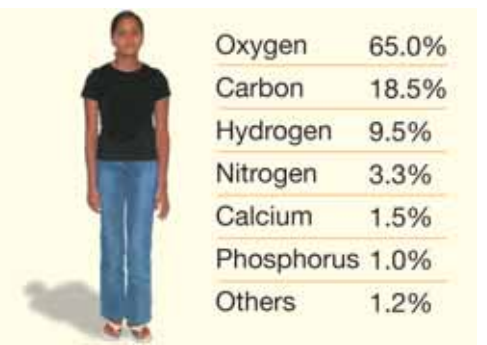


Figure 4.2: *The elements that make up living things (percent by mass).*

The ingredients for life

Life is a form of chemistry

You have learned that all living things are made of cells. A cell is the basic unit of life. Where did the first cells come from? How did things go from nonliving to living? Scientists really don't know the answers to these questions. We do know that life is a form of chemistry. So learning some chemistry is a good place to start.

Elements in living things

The ingredients for life are simple. Your body is made mostly of three elements: carbon, oxygen, and hydrogen. An **element** is the simplest form of matter. Your body also contains sulfur, nitrogen, phosphorus, and about a dozen other elements. These are found in your body in smaller amounts than carbon, hydrogen, and oxygen. Every living thing is made from these ingredients (Figure 4.2).

Living things have complex molecules

Like you, the atmosphere is also made mostly of carbon, hydrogen, and oxygen. But the atmosphere is not alive. The key to life is how these elements are put together. In the atmosphere, they are in the form of simple compounds like carbon dioxide and water. In living things, elements are found in very complex molecules that work together in cells. There are also simple compounds, like water, in living systems.

VOCABULARY

element - the simplest form of matter.

Atoms, compounds, and molecules

Atoms A single **atom** is the smallest particle of an element that keeps the chemical identity of the element. Each element has a unique type of atom. Carbon atoms are different from hydrogen atoms, and hydrogen atoms are different from oxygen atoms. All atoms of a given element are similar to each other. If you examined a million atoms of carbon you would find them all to be similar.

Compounds Sometimes elements are found in their pure form, but more often they are combined with other elements. Most substances contain several elements combined together. A **compound** is a substance that contains two or more different elements that are chemically joined. For example, water is a compound that is made from the elements hydrogen and oxygen.

Molecules If you could magnify a sample of pure water so you could see its atoms, you would notice that the hydrogen and oxygen atoms are joined together in groups of two hydrogen atoms to one oxygen atom. These groups are called molecules. A **molecule** is a group of two or more atoms joined together chemically. Many substances you encounter are a *mixture* of different elements and compounds. Air is an example of a mixture that contains nitrogen, oxygen, water vapor, carbon dioxide, argon, and other gases. The elements and compounds in a mixture are not chemically joined together.

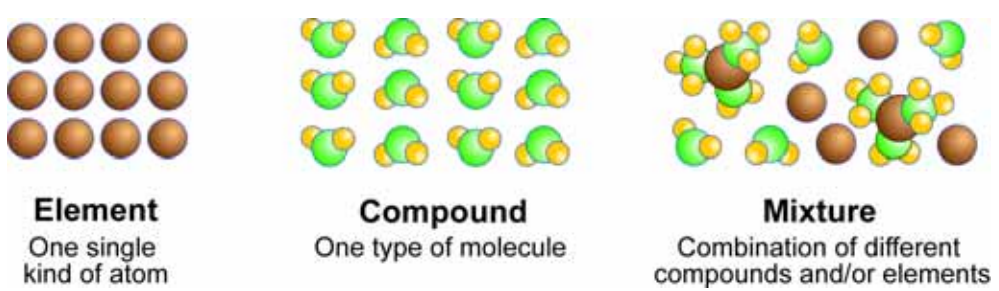


Figure 4.3: *Compounds.*

VOCABULARY

atom - the smallest particle of an element that keeps the chemical identity of that element.

compound - a substance that contains two or more different elements that are chemically joined.

molecule - a group of two or more atoms joined together chemically.

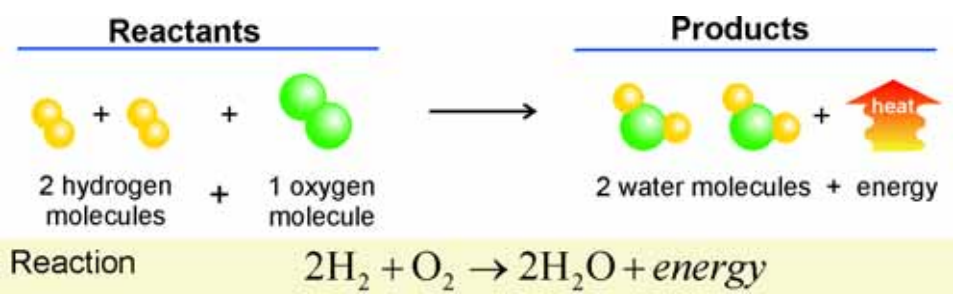
Chemical reactions

What are chemical reactions?

All of the millions and millions of different compounds are made of only 92 elements combined in different ways. Just as you can spell thousands of words with the same 26 letters, you can make all of chemicals in the world from just 92 elements. How are all of these different compounds made? The answer is chemical reactions. A **chemical reaction** is a process that rearranges the atoms of one or more substances into one or more new substances.

A simple chemical reaction

Hydrogen reacts with oxygen to produce water and energy. How do we show this chemical reaction? In cooking you start with *ingredients* that are combined to make different *foods*. In chemical reactions you start with *reactants* that are combined to make *products*. The reactants and products may include atoms, molecules, and energy. Two hydrogen molecules combine with one oxygen molecule to make two water molecules. Hydrogen and oxygen are the reactants. Water and energy are the products.



Life uses chemical reactions

Cells use many chemical reactions. You might say that life is a series of chemical reactions (Figure 4.4). Your cells constantly rearrange molecules to make energy for movement, thinking, and even sleeping. Plant cells use a chemical reaction to store energy from the sun in the form of molecules.

VOCABULARY

chemical reaction - a process that rearranges the atoms of one or more substances into one or more new substances.

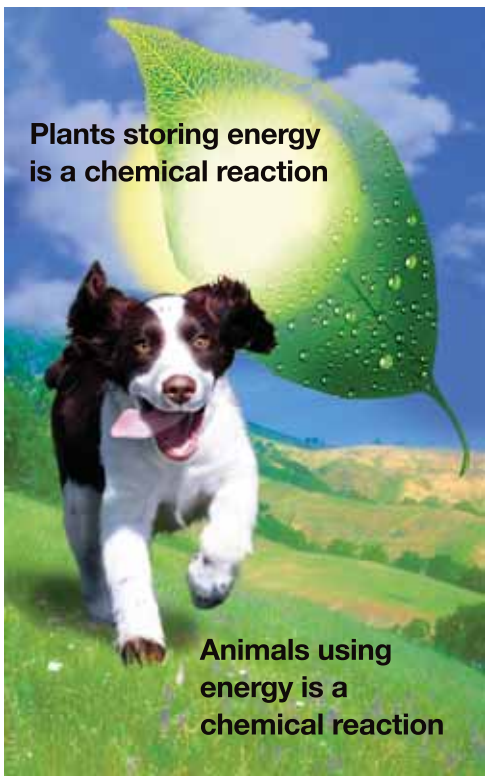


Figure 4.4: *Life is a series of chemical reactions.*

The importance of water

Why is water important?

When scientists search for life in other parts of our solar system, they begin by looking for water. Why? Water (in its liquid state) is essential to life as we know it. Your body is about 60% water. The reactions that sustain life need liquid water to work. Liquid water is also used to transport molecules where they need to go, inside and outside of cells.

Why water supports life

Water has many properties that help sustain life. Three of the most important properties are:

1. **Water is a good solvent.** A *solvent* is a substance that is capable of dissolving another substance. Water dissolves just about anything. In fact, it's such a good solvent that water rarely exists as pure water. When water has one or more substances dissolved in it, we call it a *solution* (Figure 4.5). Even the water that comes out of your faucet is a solution. All of the water in your body has dissolved substances in it. Many reactions in living systems occur in solutions.
2. **Water exists as a liquid at a large range of temperatures.** Pure water freezes at 0°C (32°F) and boils at 100°C (212°F). Add salt and you can lower the freezing temperature. Some salty solutions have freezing points below –10°C. Increase the pressure and the boiling temperature is raised. Deep-sea vent waters can reach over 340°C before boiling (Figure 4.6).
3. **Water has a high specific heat.** *Specific heat* is the amount of heat needed to raise one mL of water by 1°C. Water has one of the highest specific heats of any substance known. This means that it takes a lot of energy to raise the temperature of water even a few degrees. This high specific heat helps stabilize the temperatures in living systems.

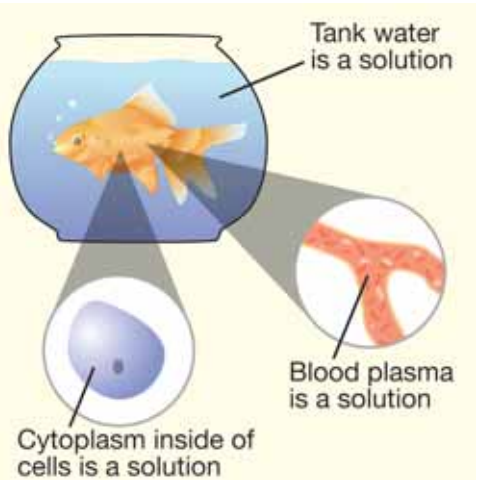


Figure 4.5: *Solutions in living systems.*

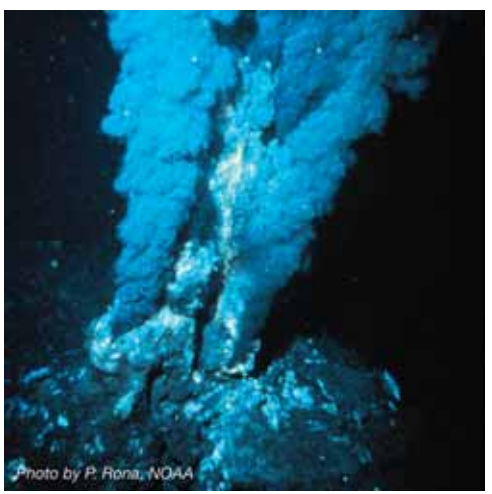
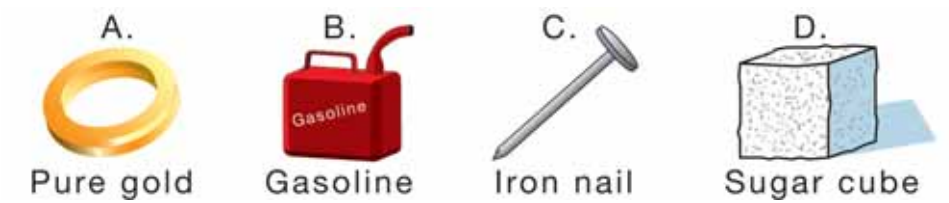


Figure 4.6: *The boiling temperature of water in deep-sea vents can reach over 340°C.*

4.1 Section Review

1. What are the three main elements that make up living things?
2. Which statement best describes the molecules found in living systems?
   a. They contain mostly sulfur, gold, and lead.
   b. They are very simple molecules made of carbon and hydrogen.
   c. They are very complex molecules made mostly of carbon, hydrogen, and oxygen.
3. Classify each example below as an element or a compound.



4. Many homes are heated with a compound called methane, or natural gas. Methane reacts with oxygen to produce carbon dioxide and water.
   a. What are the reactants in this reaction?
   b. What are the products in this reaction?
5. List the three properties of water that make it a good supporter of life.
6. Give an example of a solution found inside of a living system.

MY JOURNAL

How much water do you use?

You could not live without a supply of freshwater. You drink water when you're thirsty because every cell in your body needs it. You also use water every day for other things besides drinking. Do you know how much water you use each day? Find out by following the steps below. Record your findings in your journal.

1. From the moment you wake up on a typical school day, keep track of all of your activities that use water.
2. Estimate how much water (in gallons) each activity uses. On average, a faucet uses about one gallon per minute. Water-saving toilets use about 1.5 gallons of water per flush. Older toilets use about 5 gallons of water per flush.
3. Add up the total amount of water you use in a day. Compare your amount to others in your class.
4. Make a list of ways you can conserve water. For example, you could turn off the faucet while brushing your teeth.

4.2 Carbon Compounds and Cells

So now you know the basic ingredients found in living things. But how are these ingredients put together? Most molecules that make up living things are very large and complex. In this section, you will learn about their structure and function.

Carbon compounds

Life is carbon based

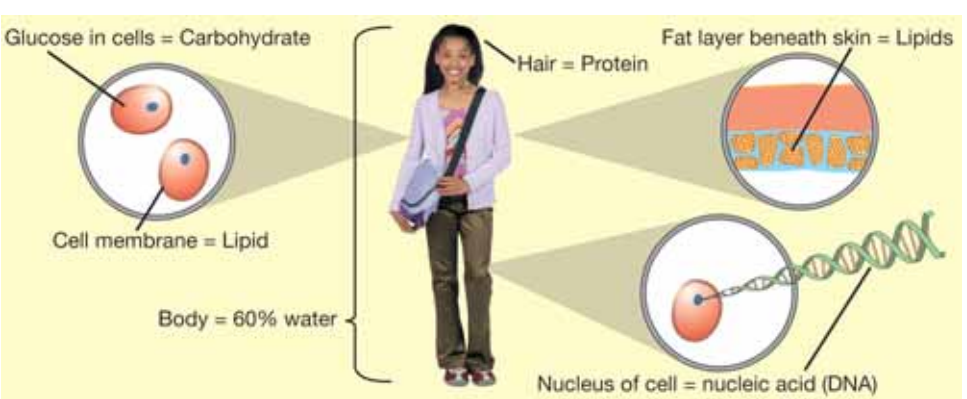
Life as we know it is *carbon based*. This means that most of the compounds you are made of contain the element carbon. Carbon is unique among the elements. A carbon atom can form chemical bonds with other carbon atoms in long chains or rings (Figure 4.7). Some carbon compounds contain several thousand carbon atoms.

You use carbon compounds every day

Carbon compounds are not only found in living things. You use carbon compounds every day. Plastic, rubber, and gasoline are carbon compounds. In fact, there are over 12 million known carbon compounds!

Carbon compounds in living things

The carbon compounds in living things are classified into four groups: carbohydrates, lipids, proteins, and nucleic acids.



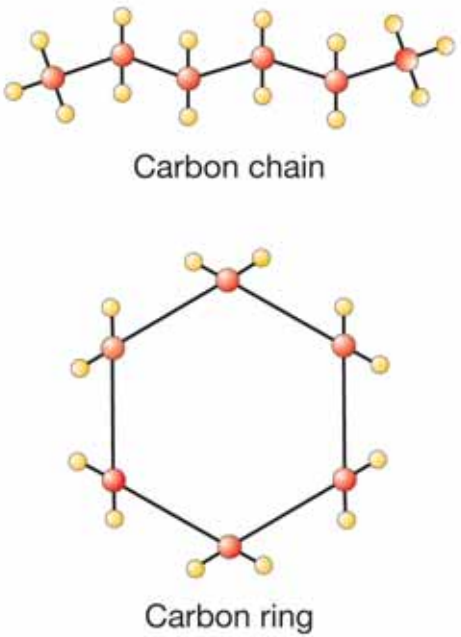


Figure 4.7: *A carbon chain and a carbon ring.*

Carbohydrates, fats, and proteins

Foods contain the compounds you are made of

The compounds that your cells are made of and that they use to function come from the foods you eat. Foods contain carbohydrates, fats (also known as lipids), and proteins. The amount of each varies with different foods. What are carbohydrates, fats, and proteins?

What is a carbohydrate?

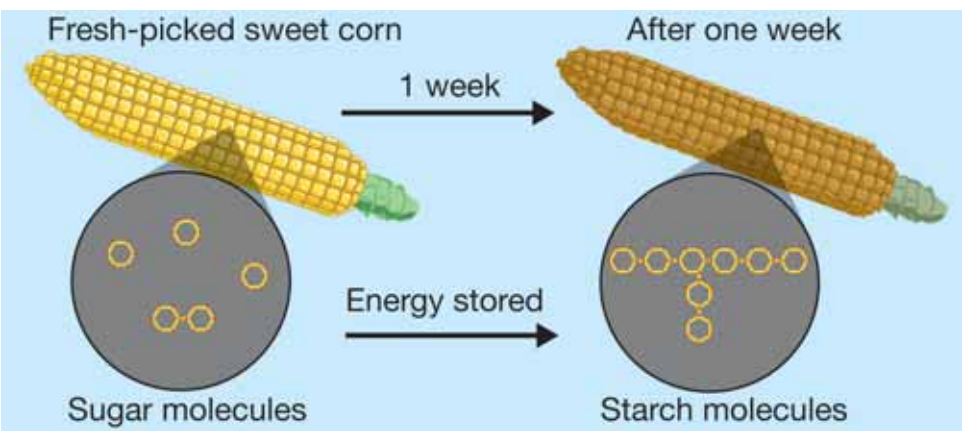
Carbohydrates are energy-rich compounds made from carbon, hydrogen, and oxygen. Cells use carbohydrates to get and store energy. Plants contain *cellulose*, a carbohydrate that gives them a rigid structure.

Sugars are simple molecules

Carbohydrates are classified as *sugars* and *starches*. Sugars are smaller molecules. *Glucose* is a simple sugar made of 6 carbon, 12 hydrogen, and 6 oxygen atoms. The sugar you use to sweeten food is called *sucrose*. A sucrose molecule is made from two glucose molecules.

Starches are larger molecules

Starch molecules are very large. They consist of many sugar molecules combined. Plant cells store energy as starch. Many foods that contain starch come from plants. These include rice, potatoes, corn, and wheat.



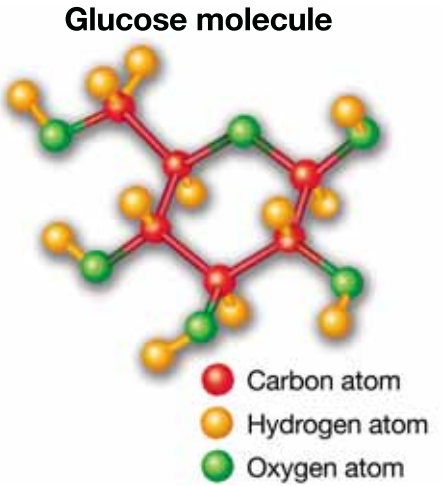


Figure 4.8: *A glucose molecule*

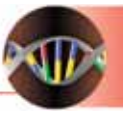
VOCABULARY

carbohydrates - energy-rich compounds such as sugars and starches made from carbon, hydrogen, and oxygen.

(*discussed on next page*)

lipids - energy-rich compounds such as fats, oils, and waxes made from carbon, hydrogen, and oxygen.

proteins - complex molecules made from smaller molecules called amino acids.



Lipids

Like carbohydrates, **lipids** are energy-rich compounds made from carbon, hydrogen, and oxygen (Figure 4.9). **Lipids include fats, oils, and waxes**. Lipids are made by cells to store energy for long periods of time. Animals that *hibernate* (sleep through the winter) live off of the fat stored in their cells. Polar bears have a layer of fat beneath their skin to insulate them from very cold temperatures. Can you name some foods that contain lipids?

Cholesterol is a lipid

Like fat, cholesterol is listed on food labels. *Cholesterol* is a lipid that makes up part of the outer membrane of your cells. Your liver normally produces enough cholesterol for your cells to use. Too much cholesterol in some people's diet may cause fat deposits on their blood vessels. This may lead to coronary artery disease. Foods that come from animals are often high in cholesterol.

Proteins

Proteins are very large molecules made of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur. Many animal parts like hair, fingernails, muscle, and skin, contain proteins. *Hemoglobin* is a protein in your blood that carries oxygen to your cells. Foods high in protein include meats, dairy products, and beans.

Enzymes are proteins

An *enzyme* is a type of protein that cells use to speed up chemical reactions. Digestive enzymes are made by the pancreas. These enzymes help break down the foods you eat into smaller molecules that can be absorbed by your cells.

Proteins are made of amino acids

Protein molecules are made of smaller molecules called *amino acids*. Your cells combine different amino acids in various ways to make different proteins. There are 20 amino acids used by cells to make proteins. You can compare amino acids to letters in the alphabet. Just as you can spell thousands of words with just 26 letters, you can make thousands of different proteins from just 20 amino acids (Figure 4.10).

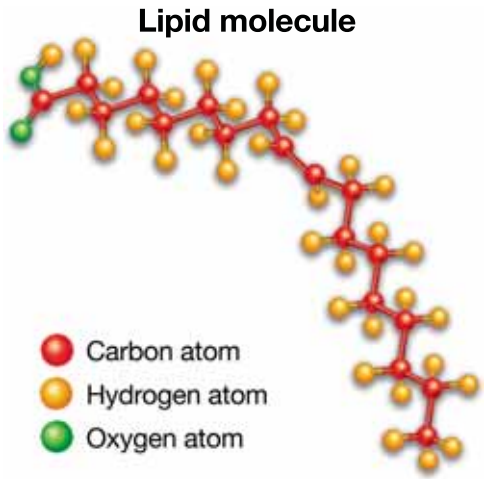


Figure 4.9: *A lipid molecule.*

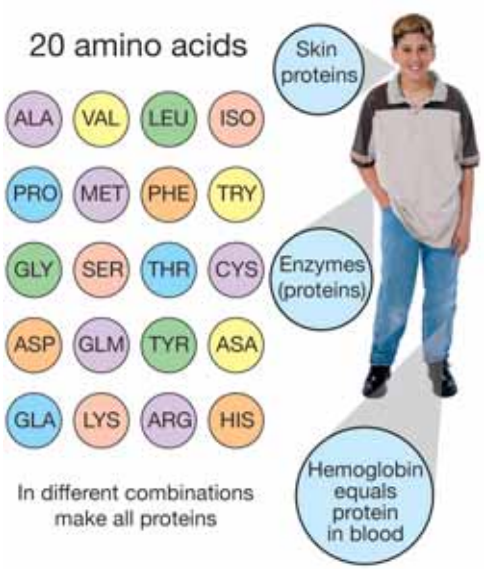
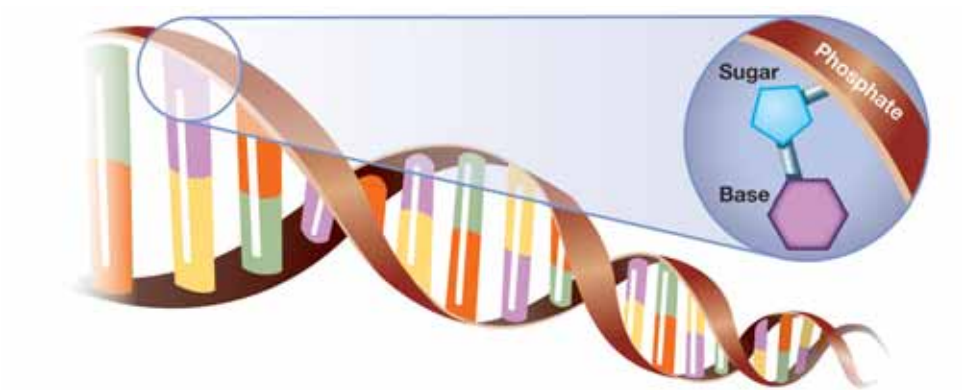


Figure 4.10: *Proteins are made from smaller molecules called amino acids.*

Nucleic acids

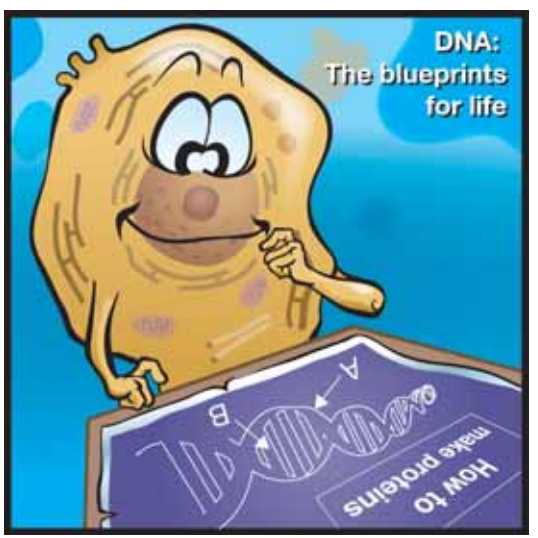
What are nucleic acids?

Nucleic acids are compounds made of long, repeating chains called *nucleotides*. Nucleotides are made from carbon, hydrogen, oxygen, nitrogen, and phosphorus. Each nucleotide contains a sugar molecule, a phosphate molecule, and a base molecule. DNA is a nucleic acid that contains the information cells need to make all of their proteins.



DNA

A DNA molecule can be compared to a book that contains "recipes" for making all of the proteins that you are made of. Some scientists refer to DNA as the "blueprints" for life. You'll learn more about DNA in Chapter 10.



MY JOURNAL

Nutrition and snack foods

1. List your three favorite snack foods.
2. Collect a nutrition label from each food.
3. If any of the foods on your list don't come in a package, you can look up the nutrition information on the Internet.
4. Write a paragraph about each food. Is it a good source of carbohydrates, lipids, and protein? Would you consider this food healthy? Why or why not?

VOCABULARY

nucleic acids - molecules that contain information needed for making proteins.

4.2 Section Review

1. Explain why life is often referred to as "carbon-based."
2. What are the four groups of carbon compounds found in living things?
3. You may have heard the saying, "You are what you eat." Use information learned in this section to explain what this statement means.
4. Classify each substance as either sugar, starch, protein, or nucleic acid.
   a. the major compound that makes up the skin
   b. glucose
   c. the major compound in potatoes
   d. DNA
5. Complete the table below.

Carbon compound	Elements that it is made from	Function in cells	Example
Carbohydrate			
Lipid			
Protein			
Nucleic acid			

SOLVE IT!

Counting Calories

A food calorie tells you how much energy is in different foods. Each type of carbon compound has a certain number of food calories per gram. Fat contains 9 food calories per gram. Carbohydrate and protein each contain 4 food calories per gram. Based on this information, solve the following:

1. How many food calories in the product above come from fat?
2. How many food calories come from carbohydrate?
3. How many food calories come from protein?
4. How many food calories are in a serving of the product?

4.3 Light and Living Things

An important tool for studying life is the microscope. The **microscope** magnifies objects so you can see their very small features. For instance, if you look at a tiny brine shrimp in a tank of water, you can barely make out its features. When you put one under a microscope, you'll be amazed at what you can see (Figure 4.11). In this section, you will learn about the properties of light and how a microscope works. Light is very important to life and you'll learn more about it in other chapters.

Figure 4.11: *A brine shrimp under a microscope at 100X magnification.*

The behavior of light

What is light?

Light is a form of energy—like heat and sound. It travels very fast and over long distances. Light travels at the amazing speed of 299,792,458 (approximately 300,000,000) meters per second! This is called the *speed of light*.

Light travels in straight lines

Light given off from objects like a light bulb or the Sun travels in straight lines. We can show how light travels using imaginary lines called light rays. Each **light ray** represents a thin beam of light and is drawn with an arrow head that shows the direction of travel. A diagram of the light rays coming from a light bulb or the Sun is shown in Figure 4.12.

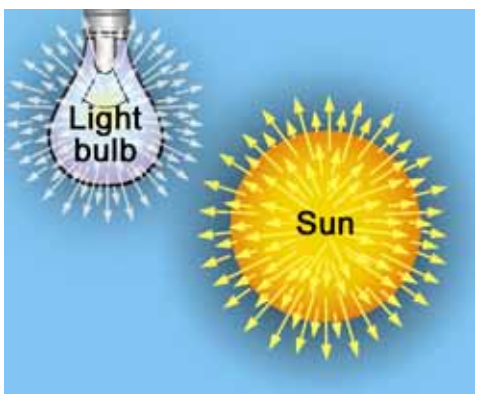


Figure 4.12: *Light emitted from the Sun or from a light bulb travels in straight lines from the surface.*

What happens when light hits a different material?

Light travels in straight lines through a material (like air) until it hits a different material. Then, it can be absorbed, reflected, or transmitted (which means "passed through"). Usually, all three things happen.

Absorption

When light is *absorbed*, its energy is transferred to the absorbing material. Black objects absorb almost all of the light that falls on them. That is why a black road surface gets hot on a sunny day. Light energy from the Sun is absorbed by the road.

VOCABULARY

microscope - magnifies objects so you can see their features.

light ray - an imaginary line that represents a thin beam of light.

Reflection

What is reflection?

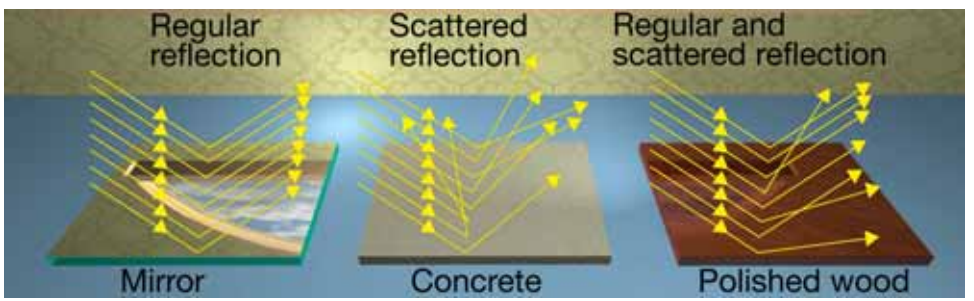
Reflection occurs when light bounces off of a surface. Imagine a ray of light striking a mirror. The **incident ray** is the light ray that strikes the surface of the mirror. The **reflected ray** is the light ray that bounces off the surface of the mirror (Figure 4.13, top).

The angle of incidence equals the angle of reflection

The lower part of Figure 4.13 shows the reflection of a light ray. The angle of incidence is the angle between the incident ray and an imaginary line drawn perpendicular to the surface of the mirror called the *normal line*. *Perpendicular* means "at a 90 degree angle," also called a *right angle*. The angle of reflection is the angle between the reflected light ray and the normal line. **The angle of incidence is always equal to the angle of reflection.**

Regular and scattered reflection

When you look in a mirror, you can see your image because when parallel light rays hit the mirror at the same angle, they are all reflected at the same angle. This is called *regular reflection*. You can't see your image when you look at a white piece of paper because even though it seems smooth, its surface has tiny bumps on it. When parallel light rays hit a bumpy surface, the bumps reflect the light rays at different angles. Light rays reflected at different angles cause *scattered reflection*. Many surfaces, for example, polished wood, are in between rough and smooth and create both types of reflection.



VOCABULARY

reflection - occurs when light bounces off a surface.

incident ray - the light ray that strikes a surface.

reflected ray - the light ray that bounces off a surface.

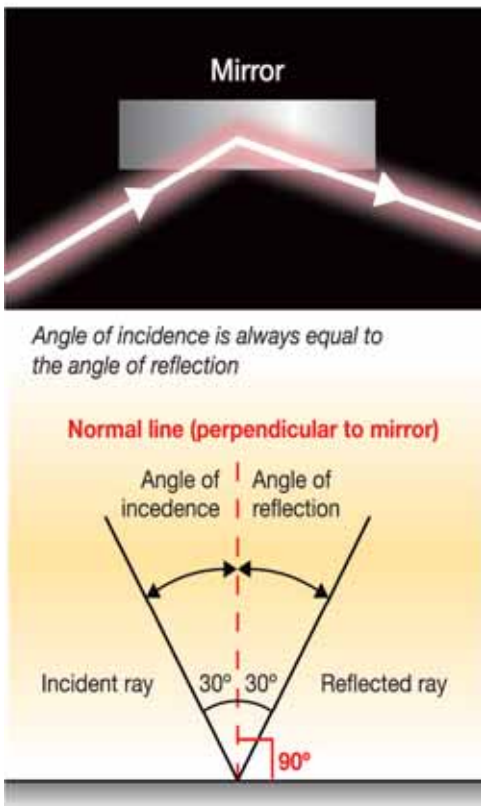
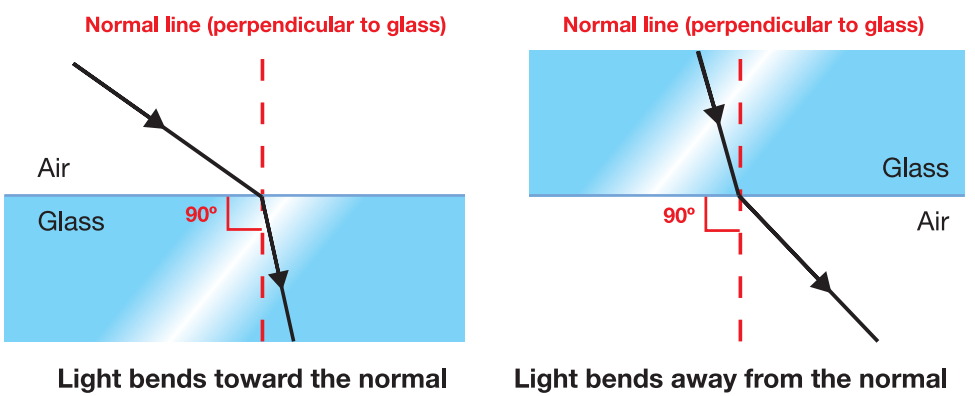


Figure 4.13: *The angle of incidence is always equal to the angle of reflection.*

Refraction

Refraction is the bending of light

Transparent materials like air, glass and water allow light to be transmitted. **Refraction** is the bending of light as it crosses a boundary between two different transparent materials. Almost every time light passes from one type of matter into another, it will change speed. For example, light travels slightly faster in air than in water. When a light ray traveling through air enters glass it slows down and refracts, bending toward the normal line. This bending effect takes place whenever light slows as it moves from one material into another. The opposite effect happens when light speeds up as it moves from one material into another. For example, when light goes from glass to air, it speeds up, bending away from the normal line.



Light bends toward the normal **Light bends away from the normal**

Refraction changes how objects look

A glass rod in water is a good example of refraction (Figure 4.15). The glass rod appears to break where it crosses the surface of the water, but this is just an illusion. The illusion is caused by refracted light rays. The light rays from the glass rod are refracted (or bent) when they cross from water, into glass, and back into air before reaching your eyes. Do you think the illusion would still happen if there were no water in the glass? Try it and see.

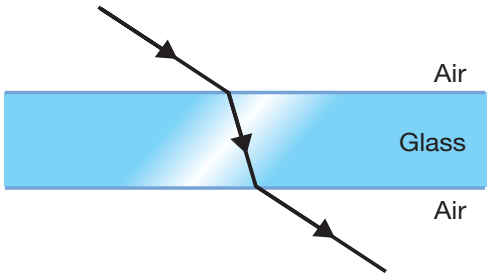


Figure 4.14: *Refraction is the bending of light as it crosses a boundary between two different materials.*

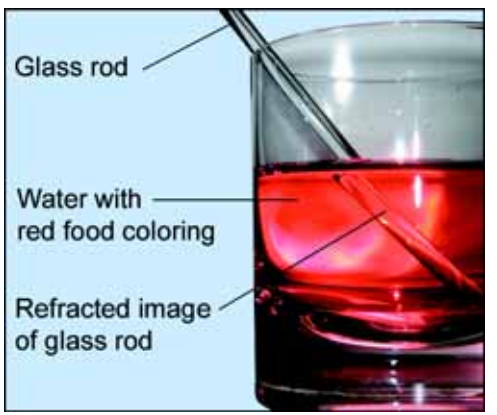


Figure 4.15: *This illusion is created because light is refracted as it travels from air to water.*

VOCABULARY

refraction - the bending of light as it crosses a boundary between two different transparent materials.

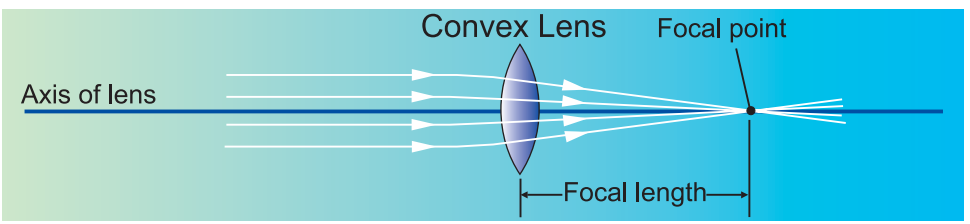
Lenses

A lens and its optical axis

A **lens** is an object that is designed to refract light in a specific way. Many devices you use contain lenses (Figure 4.16). All lenses have an imaginary line that goes through the center called an *axis*. While there are different kinds of lenses, light traveling along the axis of any lens is not bent. **There are two basic kinds of lenses; convex and concave**.

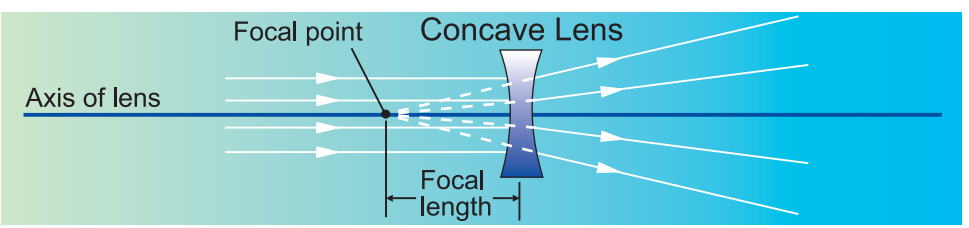
Convex lenses

Light rays that enter a convex lens parallel to its axis refract and meet at a point called the **focal point**. The distance from the center of the lens to the focal point is the **focal length**. Convex lenses are sometimes called *converging lenses*.



Concave lenses

Light rays that enter a concave lens parallel to its axis refract and spread out, *diverging* (moving apart from each other) as they exit the lens. The focal point of a concave lens is located on the same side of the lens as the light source. Imaginary lines are drawn backward in the opposite direction of the diverging rays. The focal point is where the imaginary lines meet. The distance from the focal point to the center of the lens is its focal length. Concave lenses are sometimes called *diverging lenses*.



VOCABULARY

lens - an object designed to refract light in a specific way.

focal point - a point where light rays meet.

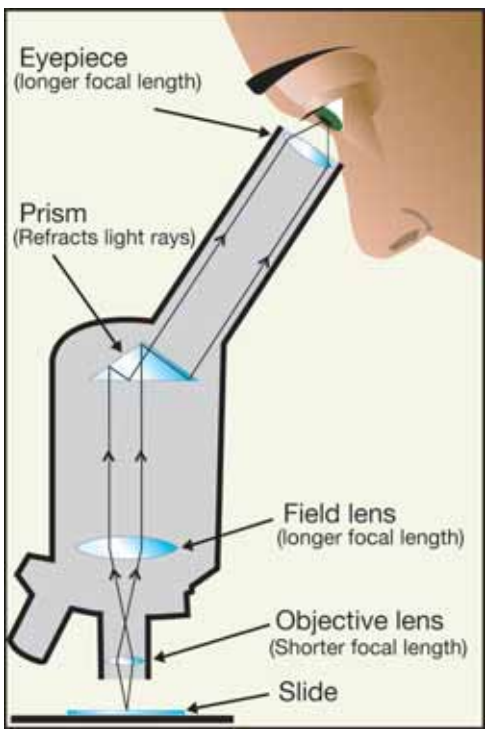
focal length - the distance from the center of the lens to the focal point.

Figure 4.16: *Some devices that use lenses.*

How a microscope works

Microscopes have an objective lens and an eyepiece

Most microscopes use at least two lenses. The lens closest to the object to be viewed is called the *objective*. It has a very short focal length and creates a larger, *inverted* image of the object inside the microscope. Inverted means that the image appears upside down or backward compared with the actual object. The lens you look through is called the *eyepiece* and has a longer focal length. The image from the objective lens is closer than one focal length to the eyepiece. That means the eyepiece acts like a magnifying glass, magnifying the (already larger) image from the objective.



Focusing the image

A microscope has a *stage* where the object to be viewed is placed. The stage can be moved up or down to focus the image. Most microscopes also have a light source to illuminate the object to be viewed or shine light through a semitransparent object on a slide.

Magnification

Each lens on a microscope has a magnification value. The total magnification of the image is the power of the objective lens multiplied by the power of the eyepiece. For example, a 10× eyepiece lens with a 6× objective lens produces an overall magnification of 60× (10 × 6). Figure 4.17 shows an image at 40×, 100×, and 400× total magnification.

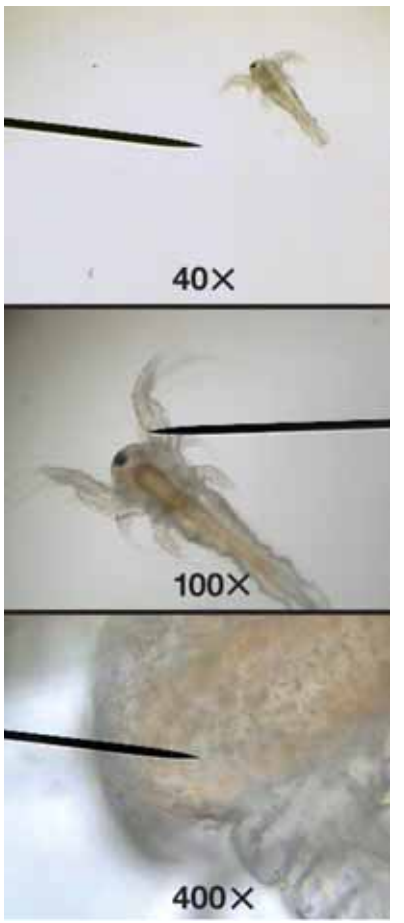
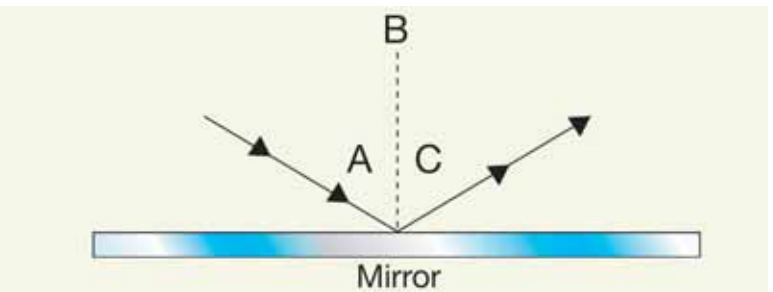


Figure 4.17: *A brine shrimp magnified 40× and 100×. and 400x. Which magnification is best when you want to see the entire organism?*

4.3 Section Review

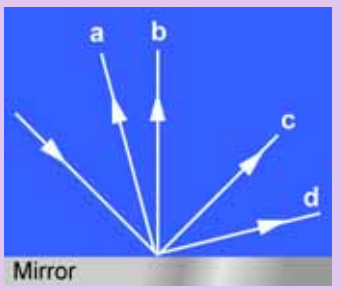
1. Name three things that can happen when light moves from one material, like air, to another, like water.
2. The picture below shows a light ray striking a mirror and bouncing off. Use the picture to answer the questions below.



   a. What is A called?
   b. What is B called?
   c. What is C called?
   d. If A measures 30 degrees, what is the measurement of C?
3. Why does light refract when it crosses from air to glass?
4. Calculate the total magnification for each combination of lenses on a microscope:
   a. objective lens: 10× eyepiece: 10×
   b. objective lens: 2× eyepiece: 5×
5. Explain how reflection and refraction are involved in how a microscope works.

SOLVE IT!

A ray of light strikes a mirror. Which of the following rays (a, b, c, or d) best describes the path of the light ray leaving the mirror?



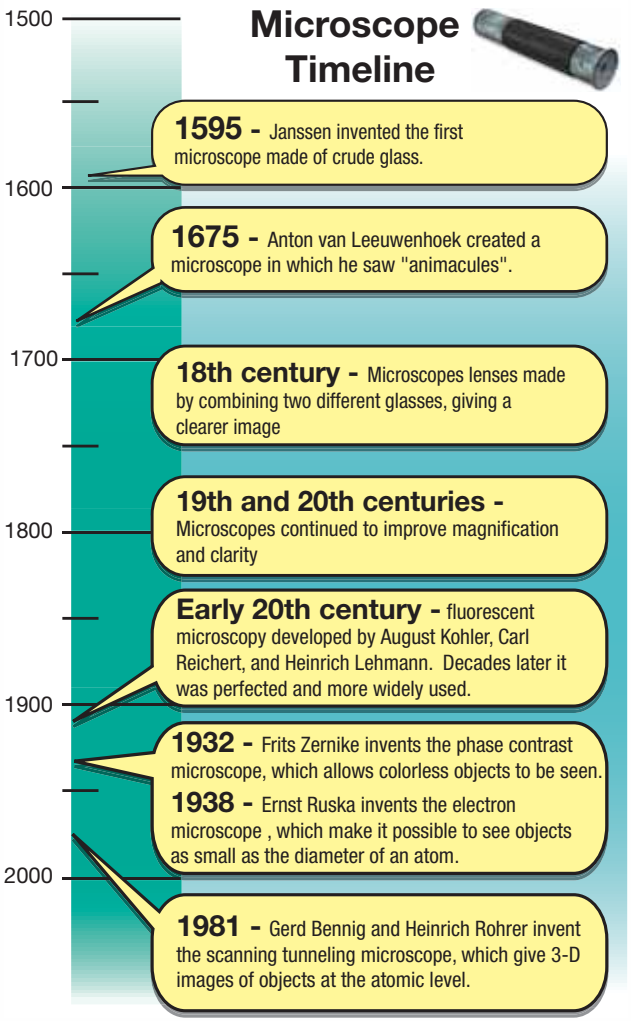
TECHNOLOGY CONNECTION

Glow Cell Glow!

You may wear glasses to help you see the chalkboard or to read a book. Sherlock Holmes had his magnifying glass to solve mysteries and to search for clues. Scientists also have their own special looking glass for seeing and discovering-the microscope! Modern day science wouldn't be the same without it. How else would we know about bacteria, viruses, and cells of the human body?

A brief history of the microscope

Microscopes are instruments used to magnify objects too small to be seen with the naked eye. The Janssen family of Holland invented the first microscope in 1595. This simple instrument was made of glass lenses like those used to make eyeglasses. In the 17th century, amateur scientist Anton van Leeuwenhoek created a microscope in which tiny organisms could be seen. He used his invention to study pond water and referred to small creatures he saw as “animalcules.”

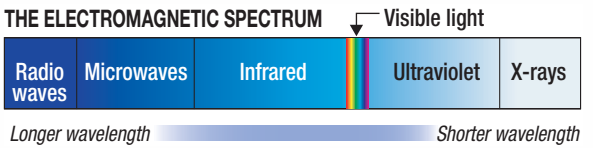


In the 18th century, microscopes became more widely used as there quality increased. Microscopes continued to improve magnification and clarity during the 19th and 20th centuries.

In 1932, the phase contrast microscope allowed scientists to study colorless materials. In 1938, the electron microscope made it possible to see objects that could never been seen before. In fact, it allowed scientists to see materials as small as the diameter of an atom! Finally, the scanning tunneling microscope was invented in 1981. This powerful instrument gave scientists three-dimensional images of incredibly small objects.

Rainbows and wavelengths

All observations made under the microscope depend on what we see with our eyes. It is important to understand how we see color. The colors of the spectrum (or the rainbow) that are visible to the human eye each have a unique wavelength. The visible colors from shortest to longest wavelength are violet, blue, green, yellow, orange, and red. Our eyes cannot detect light that falls outside of this visible rainbow. For example, ultraviolet (UV) light has a shorter wavelength than the violet we see on the rainbow. Infrared light has a longer wavelength than the red we see on the rainbow.

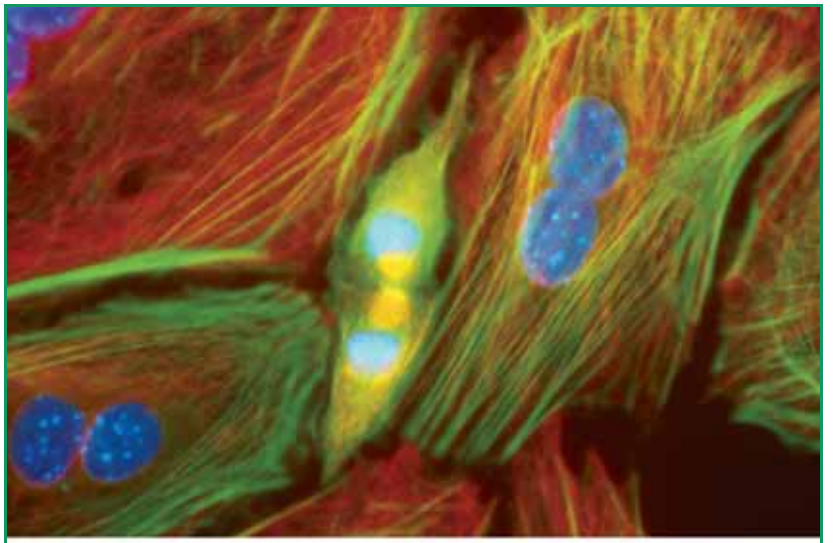


The fluorescence phenomenon

In the mid 1800s, the British scientist Sir George G. Stokes discovered a mineral called fluorspar. This mineral glowed when lit with ultraviolet light. The fluorspar absorbed the UV light and produced a glowing light that is visible to the human eye. Stokes referred to this phenomenon as "fluorescence."

Development of fluorescent microscope

Scientists in the early twentieth century worked on the development of the first fluorescent microscope. It would take decades until it became perfected and more widely used. Today, the use of fluorescence microscopes is an important tool in cellular biology. Scientists use it to find out about cell structures, molecules, and proteins. They are able to study the function of cells and their parts.



Mouse cells stained to show the nucleus and cytoskeleton.
Photo by Mary Jo Carabatsos, PhD.

Cells usually do not glow. Researchers use various fluorescent proteins known as probes to make cells glow. They have developed probes that are green, blue, yellow, orange, and red. The cells absorb these probes like dyes.

The fluorescent microscope uses filters that only let in light of wavelengths matching the fluorescing material being studied. All other wavelengths are blocked out. The fluorescing areas shine out against a dark background, making cells and their structures glow.

Research with fluorescence

There are countless ways the fluorescent microscope is used in scientific research. An example is Dr. Thomas Hoock, who has been working in the cellular biology field for 20 years. He has worked in a variety of settings, and much of his work has involved the use of the fluorescent microscope. Dr. Hoock used fluorescent microscopy early in his career to study disorders related to high blood pressure. Using this tool, he explored how cells of the cardiovascular system move. Dr. Hoock also used the fluorescent microscope to study the behavior of cells that make up our immune system. Today, Dr. Hoock is a senior staff investigator of Vertex Pharmaceuticals in Cambridge, Massachusetts. At Vertex, he and his fellow scientists use fluorescence microscopy's to study new medicines. He explains that he enjoys his work as a scientist because he must be a creative thinker and that each day is never the same.

Questions:

1. How has the development of the microscope progressed over the past several hundred years?
2. How are wavelengths related to how we see color?
3. How was fluorescence first discovered?
4. How is the fluorescent microscope used in cellular biology?

CHAPTER ACTIVITY

Cereal Nutrition Facts

Scientists have learned over the years that what you eat can affect your health. Food packages are required by law to have Nutrition Facts labels. In this activity, you will study some breakfast cereal Nutrition Facts labels. Maybe you will learn some new things about your favorite cereal!

How to read a Nutrition Facts label

1. Each group should have one box of cereal. The first piece of information on the Nutrition Facts label is serving size. This is very important, because all of the nutrition content information is based on this serving size. Measure out one serving of the cereal and pour it into a small bowl. Is this the amount that you would usually eat?
2. Find the number of Calories in one serving of the cereal. Calories measure how much energy you get from the food you eat. The major nutrients present in the foods we eat are called fats, carbohydrates, and proteins, and each of these nutrients contributes to the number of total Calories. Why do you suppose Calories from fat is listed next to the number of Calories, but not Calories from carbohydrates or protein?
3. Nutrients listed on the label can be divided into three categories: nutrients you should limit, nutrients that may or may not be an issue, and nutrients you should be sure to include enough of in your diet. The nutrients you should limit are fat, cholesterol, and sodium. What do you know about health problems related to high intakes of these nutrients? Carbohydrates and protein are nutrients that most Americans eat plenty of, but some may want to limit sugars. Dietary fiber, vitamin A, calcium, vitamin C, and iron are all nutrients that we should be sure to get enough of in our diet. Why are these important?
4. The % daily value numbers provide a quick, helpful guideline for you to follow when you are trying to limit or eat more of certain nutrients. The percentages are based on an average daily intake of 2000 Calories. Look at your cereal label. Are there any % daily value numbers that surprise you?
5. Design a data table that will allow you to organize the following information about each of 6 different breakfast cereals: cereal name, serving size, total Calories, Calories from fat, total fat (g), saturated fat (g), cholesterol (mg), sodium (mg), total carbohydrate (g), dietary fiber (g), sugars (g), protein (g), vitamin A (%), calcium (%), vitamin C (%), iron (%).
6. Record the nutrition data from your cereal box, and then trade with other groups until you have recorded data from each box of cereal. Use the data you collected to answer the questions.

Applying your knowledge

a. Determine which cereal is the healthiest. Explain how you arrived at your answer, and refer to specific data from your comparison table.
b. Determine which cereal is the least healthy, and use data to justify your choice.
c. Compare your choices with others in your group. Did everyone agree?
d. Why are Nutrition Facts labels so important that the government requires them?
e. Write one question that you still have about Nutrition Facts labels.

Chapter 4 Assessment

Vocabulary

Select the correct term to complete the sentences.

atom	carbohydrates	chemical reaction
compound	element	lipids
molecule	reflection	focal point
refraction	nucleic acids	proteins
		lens

Section 4.1

1. Propane and water are both examples of ____s.
2. Plants use a ____ to store energy from the sun in the form of molecules.
3. A(n) ____ is the smallest particle of an element that keeps the chemical identity of that element.
4. All the different compounds in the world are made up of only 92 different ____s.

Section 4.2

5. Sugars and starches are two types of ____, energy compounds made from carbon.
6. ____ are made from amino acids.
7. Cells use ____, such as waxes, oils, and fats, to store energy for long periods of time.
8. ____ contain the information needed to make proteins.

Section 4.3

9. ____ happens when light passes from air into water.
10. ____ happens when light bounces off a surface.
11. A ____ is designed to refract light in a certain way.
12. The ____ of a lens is where converging light rays meet.

Concepts

Section 4.1

1. Why do you think oxygen and hydrogen are two of the most abundant elements found in living things? Explain your answer.
2. Explain the relationship between atoms, elements, compounds, and mixtures.
3. The chemical reaction for respiration is:
   $C_6H_{12}O_6$ (Glucose) + $6O_2$ (Oxygen) →
   $6CO_2$ (Carbon dioxide) + $6H_2O$ (Water) + Energy (ATP)
   Identify the following in the equation:
   a. reactants
   b. products
   c. elements
   d. compounds

Section 4.2

4. Identify each of the following as a carbohydrate, lipid, protein, or nucleic acid.
   a. glucose
   b. hemoglobin
   c. DNA
   d. digestive enzymes
   e. cholesterol
   f. cellulose
5. An organic compound contains carbon, hydrogen, oxygen, and nitrogen. Could this compound be a lipid? Could it be a nucleic acid? Explain.
6. Which two organic compounds serve as energy sources? How do these two groups differ?
7. How are proteins and nucleic acids related?

Section 4.3

8. When light hits a material, what are three things that can happen?
9. Explain the differences between a converging lens and a diverging lens. For each lens: discuss the shape, how each bends parallel light rays, and how the images are formed.

Math and Writing Skills

Section 4.1

1. Create a pie graph to represent the elements found in living things. Use the data found in Figure 4.2.
2. The chemical reaction for respiration is:
   $C_6H_{12}O_6$ (Glucose) + $6O_2$ (Oxygen) → $6CO_2$ (Carbon dioxide) + $6H_2O$ (Water) + Energy (ATP)
   a. How many molecules of oxygen are needed to break down each molecule of glucose?
   b. In the reactants, how many atoms of oxygen are there? Atoms of carbon? Atoms of hydrogen?
   c. In the products, how many atoms of oxygen are there? Atoms of carbon? Atoms of hydrogen?

Section 4.2

3. Suppose that there are only three amino acids that are called 1, 2, and 3. If all three are needed to make a protein, how many different proteins could be made? Each amino acid may only appear in each protein once. Also, the position of the amino acid is important - 123 is not the same as 321. Show your number arrangements to support your answer.
4. You are entering a contest to design a new advertising campaign for National Nutrition Awareness Week. Create a slogan and written advertisement that encourages teens to eat the right amounts of carbohydrates, lipids, or proteins. Use at least three facts to make your advertisement convincing.

Section 4.3

5. A light ray strikes a mirror at an angle of 35 degrees. At what angle does the light ray reflect off the mirror?

Chapter Project

Create a nutrition card game

Find 6 - 10 nutrition facts labels. Cut them from food packages or print them out from the website www.nutritiondata.com. Try to make the labels about the size of a regular playing card. Paste the labels onto cardboard. Make sure the serving size shows on the label, but no information that could give away the identity of the type of food. Place a number in one corner of the label so you can identify the label later. Choose many different types of foods. Make 6 - 10 identical cards pasted onto the same type of backing. On these cards, carefully print the name of each food that you have found nutrition facts labels for. Place a letter in one corner of each name card. Make an answer key for yourself that shows which nutrition facts label number goes with each food name letter. That way, as your classmates compete to make matches, you can determine if the matches are correct.

To play the game, shuffle the cards and place them face down on a table in several rows. On each turn, a player will turn over two cards and determine if a match is made. If they think they have a match, you must verify by looking at your answer key. If the match is correct, the player takes the cards and takes another turn. If the match is incorrect, or if two of the same type of card is chosen, the player's turn ends. Once all matches have been made, players count up the number of cards they have won and the player with the most cards wins!

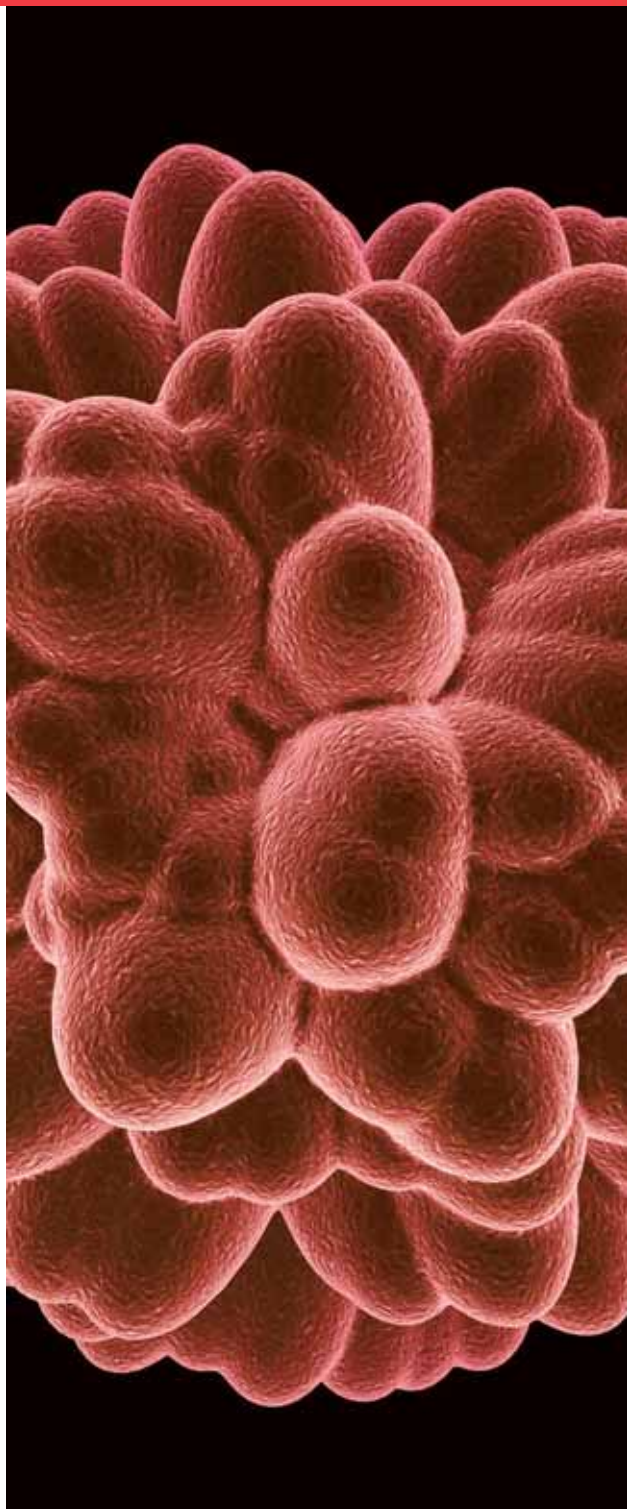
Chapter 5

Cell Structure and Function

Can you name something that you know exists even though you can't see it with your eyes? A drop of pond water has tiny swimming organisms and small bits of plant material, but we can't always see them with our eyes. How do we know there are tiny things in a drop of pond water? We can use a microscope to view the pond water. There are instruments people use every day to help them see things they wouldn't usually be able to see. Have you ever used a pair of binoculars or a magnifying glass? Have you ever had an X-ray taken of an injury? Do you need to wear glasses or contact lenses to see clearly? Vision systems are even being developed to restore vision to blind people. In this chapter, you will take a journey into a small world that was discovered when the microscope was invented—the world of the cell. Imagine you could shrink yourself and walk into a tiny cell. What is it like inside a cell? It's a fascinating journey!

Key Questions

1. ***What is a cell and how do we know cells exist?***
2. ***Are human cells, animal cells, and plant cells all the same?***
3. ***What is inside a cell, and how is a cell like a cookie factory?***



5.1 What Are Cells?

Look closely at the skin on your arm. Can you see that it is made of cells? Of course not! Your skin cells are much too small to see with your eyes. Now look at one square centimeter of your arm. That square centimeter contains about 100,000 skin cells. Cells are so small that they weren't even discovered until the invention of the microscope. What are cells and how were they discovered?

You are made of cells

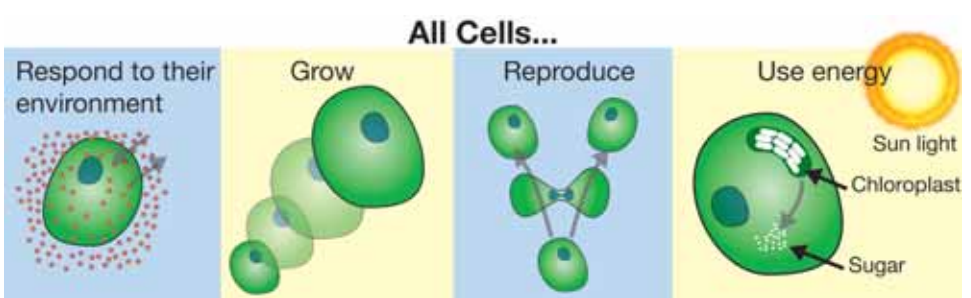
A cell is the smallest unit of a living thing

A cell is the basic unit of structure and function in a living thing. Your body is composed of billions of cells. You have skin cells, muscle cells, nerve cells, blood cells, and many other types as well. Each type of cell has a unique structure and function, but they all share similarities. Figure 5.1 shows pictures of different types of cells found in your body.

A cell is the basic unit of structure and function in a living thing.

Each cell carries out the living functions

Each cell in your body shares the characteristics of all living things. Each cell can respond, grow, reproduce, and use energy. Like larger organisms, cells respond to changes in their surroundings in ways that keep them alive. In Chapter 2 we learned that this process is called *homeostasis*.



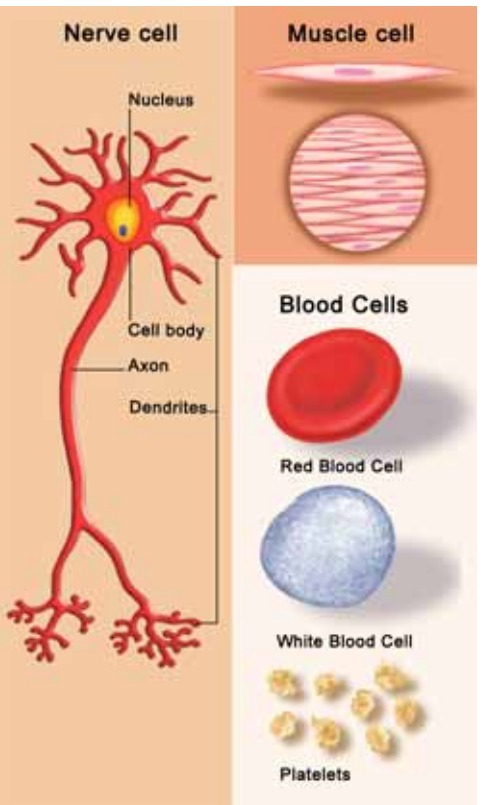


Figure 5.1: *Different types of cells found in your body. Platelets are found in your blood but are particles, not cells.*

Finding out about cells

Robert Hooke discovered cells

How did we learn about cells? It all started with the invention of the microscope in the late 1500s. English scientist Robert Hooke (1635–1703) was the first to record his observations of cells. In 1663, he took a thin slice of cork and placed it under a microscope that he built. *Cork* is made from the bark of the cork oak tree, but its cells are no longer alive. Hooke made detailed sketches of his observations. An artist's version of one of his sketches is shown in Figure 5.2. Hooke called each of the square structures a *cell* because they reminded him of tiny rooms.

Figure 5.2: *Robert Hooke's sketch of cork cells looked like this.*

Some organisms are made of a single cell

Anton van Leeuwenhoek (1632–1723) was not a scientist. He was a Dutch craftsman who made lenses. Yet with skill and curiosity, Leeuwenhoek made some of the most important discoveries in biology. He used his lenses to build a simple microscope. With his microscope, he looked at pond water, blood, and scrapings from his teeth. He was the first to observe single-celled protists, blood cells, and bacteria.

All living things are made from cells

As microscopes improved, scientists made more discoveries. In 1839, two German scientists, Matthais Schleiden and Theodore Schwann, viewed plant and animal tissues under a microscope. They concluded that all plants and animals were made up of cells.

Fluorescent microscopy

A new technique is called a fluorescent microscope. Cells usually do not glow. Scientists use fluorescent proteins to make cells glow. The cells absorb these proteins like stains. The fluorescent microscope uses filters that only let in light that matches the fluorescing material being studied. All other types of light are blocked out. The fluorescing areas shine out against a dark background, making certain cell structures glow. The mouse egg cells in Figure 5.3 have been treated to show DNA as a glowing blue.

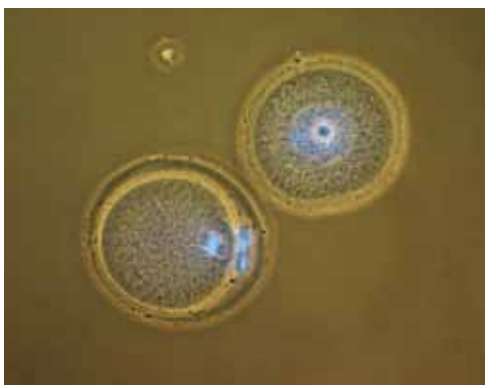


Figure 5.3: *Mouse egg cells. The DNA is the glowing blue.*

The cell theory

Cells only come from other cells

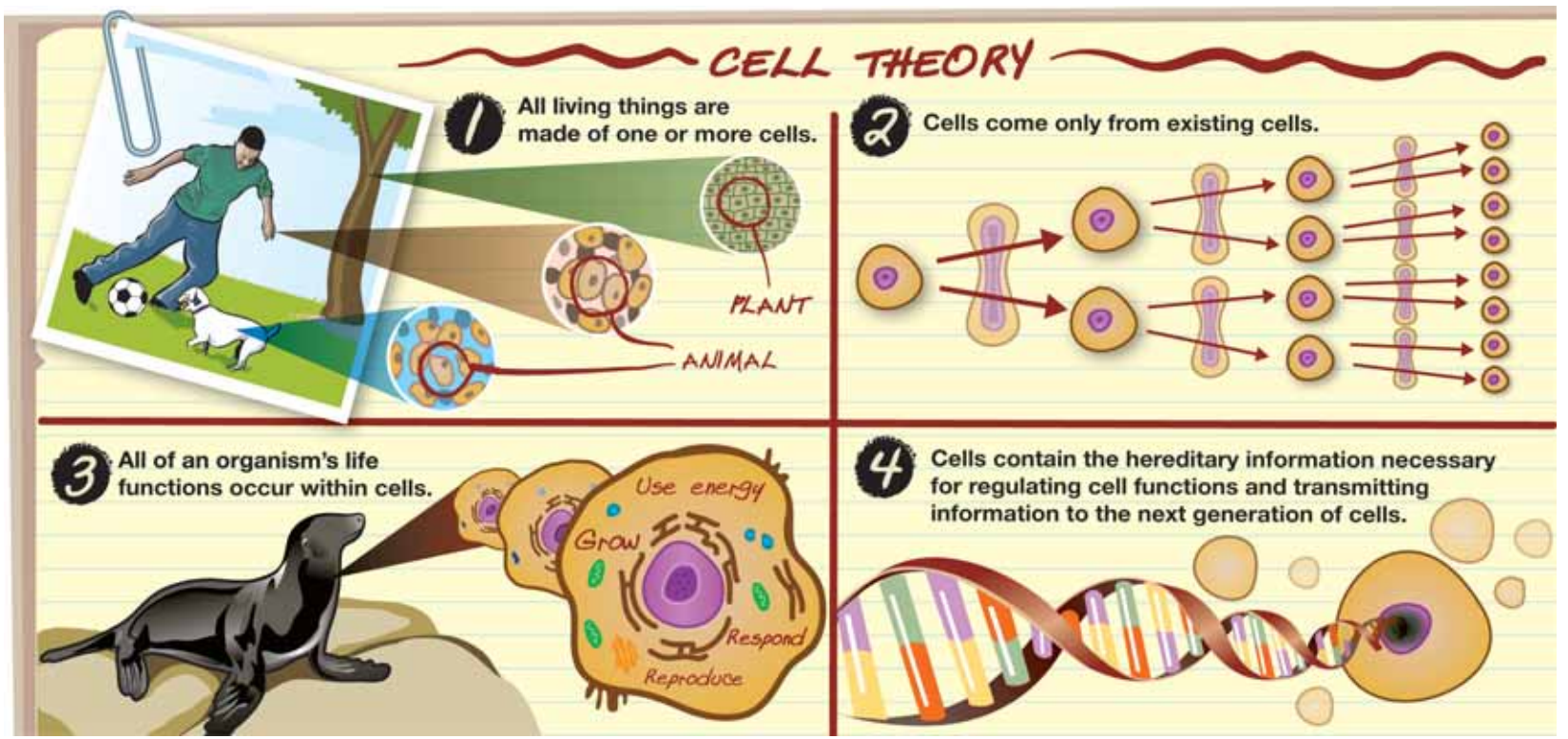
Schleiden and Schwann's theory was widely accepted by other scientists. But where did cells come from? In the 1800s it was believed that living things came from nonliving objects. Did cells come from some tiny, nonliving objects? In 1855, a German physician named Rudolf Virchow (1821–1902) proposed that cells can only come from other cells.

Statements of the cell theory

The work of Hooke, Leeuwenhoek, Schleiden, Schwann, Virchow, and others led to an important theory in life science. The **cell theory** explains the relationship between cells and living things.

VOCABULARY

cell theory - a theory that explains the relationship between cells and living things.



Similarities among cells

There are many different types of cells

Some organisms are made of only a single cell. You are made of billions of cells. In multicellular organisms like you, there are many different types of *specialized* cells. For example, the cells that line the retina of your eye have a structure and function that is very different from your skin cells. About 200 different types of specialized cells make up the tissues and organs of your body.

There are different types of cells but all cells share similar characteristics.

All cells share some similarities

Even though there are many different types of cells, they all share similar characteristics (Figure 5.4). These include:

1. **All cells are surrounded by a cell membrane.** The **cell membrane** is a barrier between the inside of the cell and its environment. It also controls the movement of materials into and out of the cell.
2. **All cells contain organelles.** An **organelle** is a structure inside of a cell that helps the cell perform its functions. Although all cells contain organelles, they don't all contain the same kinds. You'll learn more about the organelles in the next section.
3. **All cells contain cytoplasm.** The **cytoplasm** is a fluid mixture that contains the organelles. It also contains the compounds cells need to survive such as water, salts, enzymes, and other carbon compounds.
4. **All cells contain DNA.** The cell theory states that all cells come from other cells. When cells reproduce, they make copies of their DNA and pass it on to the new cells. DNA contains the instructions for making new cells and controls all cell functions.

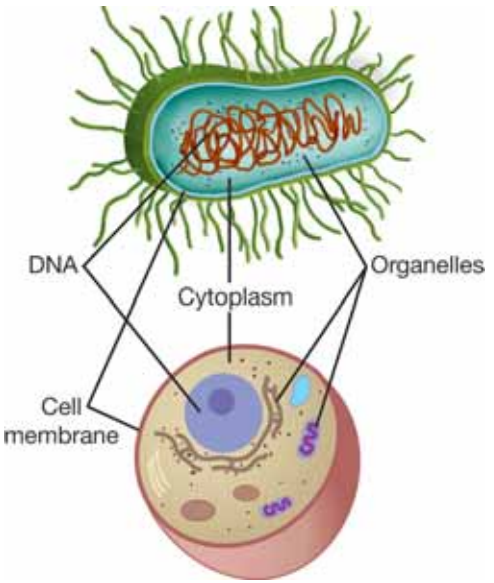


Figure 5.4: *All cells have a cell membrane, organelles, cytoplasm, and DNA.*

VOCABULARY

cell membrane - a separating barrier that controls movement of materials into and out of the cell.

organelle - a structure inside of a cell that helps it perform its functions.

cytoplasm - a fluid mixture that contains the organelles and the compounds the cell needs.

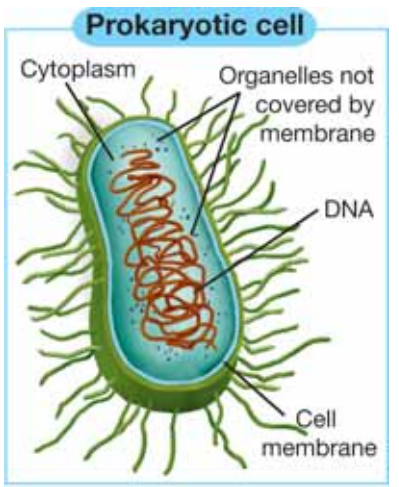
Classifying cells

Two types of cells

Based on the organization of their structures, all living cells can be classified into two groups: prokaryotic and eukaryotic (Figure 5.5). Animals, plants, fungi, and protozoans all have eukaryotic cells. Only bacteria have prokaryotic cells.

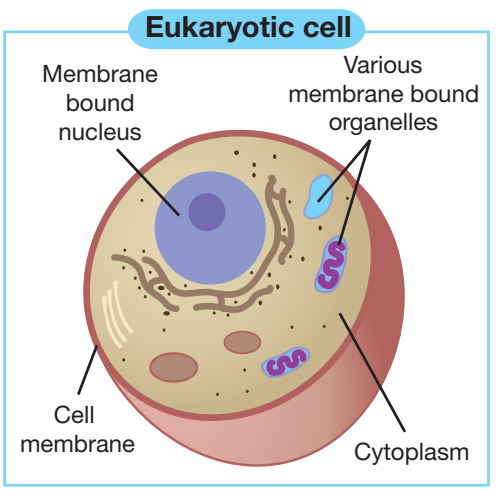
Prokaryotic cells

Prokaryotic cells do not have a nucleus. The word *prokaryotic* means "before nucleus" in Greek. Scientists believe that all life on Earth came from these cells. The oldest fossils of bacteria are estimated to be 3.5 billion years old. The DNA in a prokaryotic cell is bunched up in the center of the cell. The organelles are not covered with a membrane. All prokaryotic cells are much smaller than eukaryotic cells.



Eukaryotic cells

Eukaryotic cells have a nucleus and membrane-covered organelles. The word *eukaryotic* means "true nucleus" in Greek. The oldest fossils of eukaryotic cells are about 2 billion years old. There is more DNA in these types of cells and it is found in the nucleus. These cells have membrane-covered organelles. They tend to be about ten times larger than prokaryotic cells.



VOCABULARY

prokaryotic cell - a cell that does not have a nucleus or membrane-covered organelles.

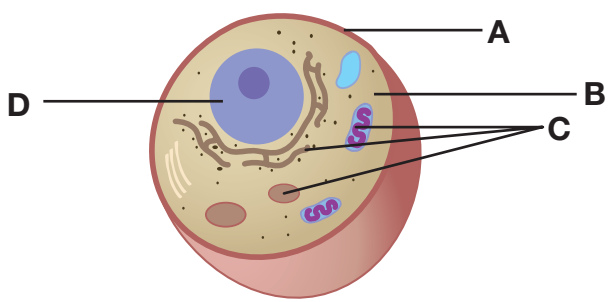
eukaryotic cell - a cell that has a nucleus and membrane-covered organelles.

Prokaryotic cells	Eukaryotic cells
Bacteria	All other cells
No nucleus	Nucleus
Organelles not membrane-covered	Membrane-covered organelles
DNA is bunched up in the center of the cell	DNA is found in the nucleus

Figure 5.5: *Comparing prokaryotic and eukaryotic cells.*

5.1 Section Review

1. What is the basic unit of structure and function in a living thing called?
2. How did the invention of the microscope help scientists learn more about living things?
3. Who was the first to discover cells?
4. Draw a timeline that shows the dates, discoveries, and scientists involved in the development of the cell theory.
5. What are the four statements of the cell theory?
6. What are specialized cells? List three examples.
7. What are four similarities that all cells share?
8. List the cell part for each letter on the diagram below. What is the function of each part?



9. Classify each item below as having prokaryotic or eukaryotic cells.
   a. *Streptococcus*, a bacteria that causes strep throat.
   b. Yeast, a type of fungi use to make bread.
   c. A euglena, a one-celled protozoan that uses a whip to move around.
   d. *Acidophilus*, a bacteria used to make yogurt.

CHALLENGE

1. Write a paragraph that agrees or disagrees with the following statement: "Muscle cells are completely different than nerve cells." Give the reasons for why you agree or disagree in your answer.
2. Explain three differences between molecules and cells.
3. Conduct Internet research to find out about the largest cell in the world.

5.2 Cells: A Look Inside

Imagine a factory that makes thousands of cookies a day. Ingredients come into the factory, get mixed and baked, then the cookies are packaged. The factory has many parts that contribute to the process. Can you name some of those parts and their functions? A cell is a lot like a cookie factory. It too has many parts that contribute to its processes. Let's compare a cell to a cookie factory.

Comparing a cell to a cookie factory

Parts and functions

A cookie factory has many parts. The cytoplasm of a cell has many *organelles*. Figure 5.6 shows a fictional cookie factory. A typical animal cell and its parts are shown on the next page. Table 5.1 compares a cookie factory to an animal cell. As you read this section, refer to the table to help you remember the cell parts and their functions.

Table 5.1: Comparing a cell and a cookie factory

Process	Cookie factory part	Cell part
Ingredients in/products out	Factory gate and doors	Cell membrane
Control center	Manager's office	Nucleus
Energy	Power plant	Mitochondria
Storage	Storage room	Vacuole
Making the product	Mixing/baking room	Ribosome
Transport of materials	Conveyer belts	Endoplasmic reticulum
Packaging and distribution	Shipping room	Golgi body
Clean up and recycling	Custodial staff	Lysosome
Structure/support	Walls and studs	Cytoskeleton

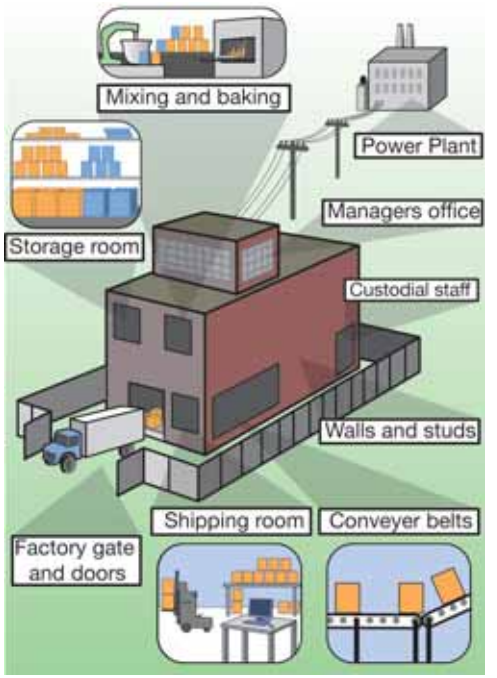
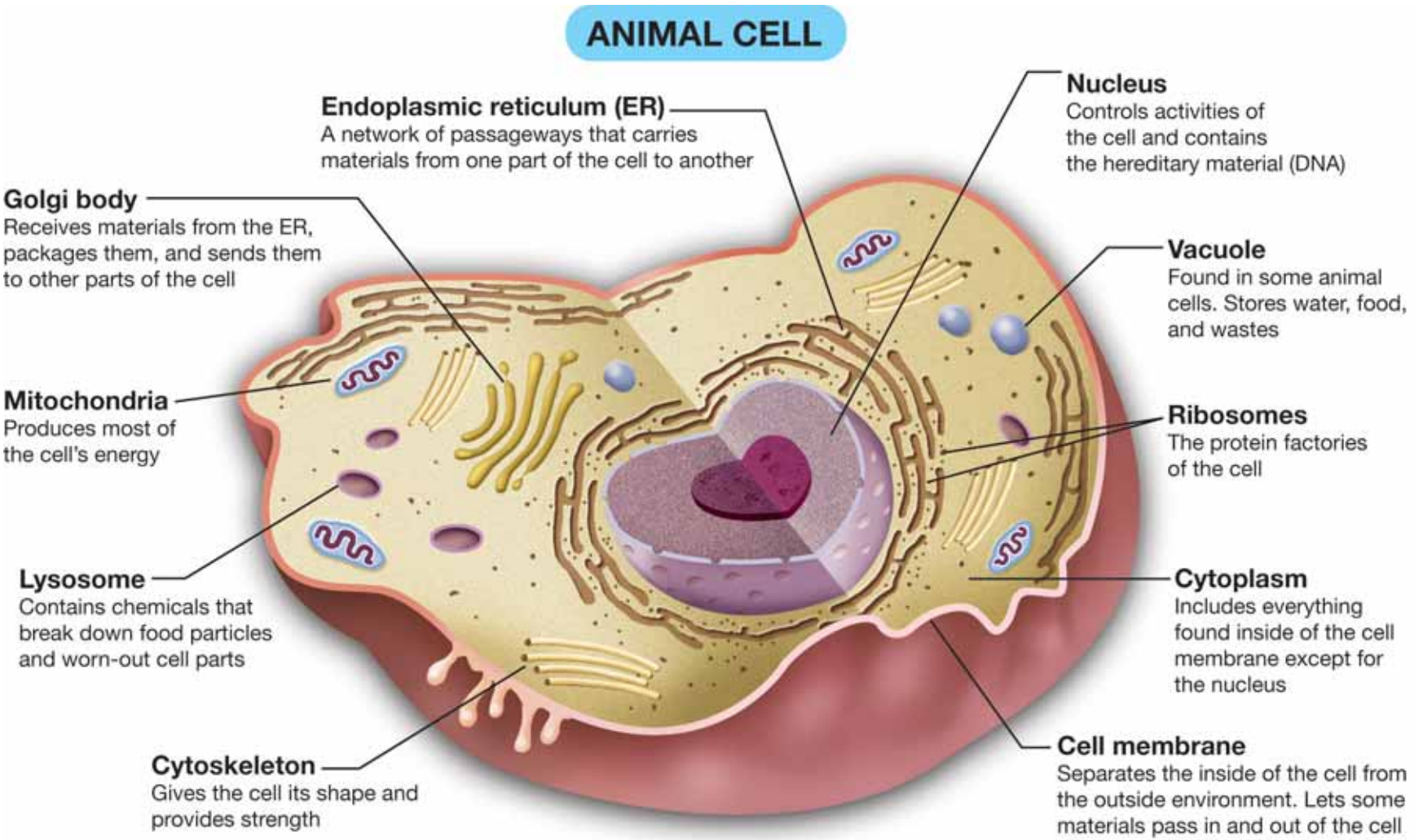


Figure 5.6: *The parts of a cookie factory.*

An **analogy** is a comparison of one thing to another different thing. The cookie factory is a good analogy for remembering cell parts and their functions. After reading this section, make another analogy comparing your school to a cell.

Diagram of an animal cell

The picture below is a schematic drawing of an animal cell. Under a microscope, you would not be able to see many of the organelles.



The cell membrane and nucleus

Looking at cells under a microscope

To make cell parts visible under a microscope, you can apply a stain to the cells. A *stain* is a dye that binds to certain compounds in cells. Some stains bind to proteins while others bind to carbohydrates. Methylene blue is a stain often used to look at animal cells. It binds to proteins and makes the nucleus of the cell stand out. It also makes individual cells stand out by staining the cell membrane (Figure 5.7).

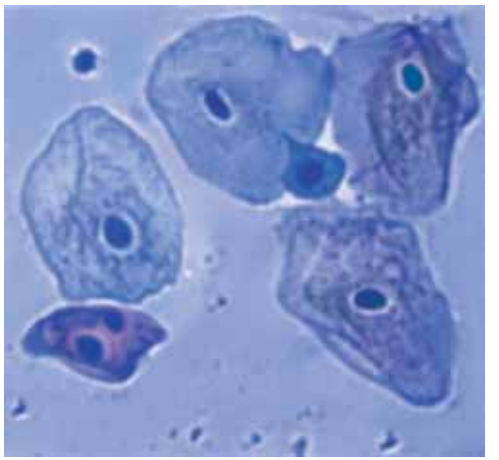


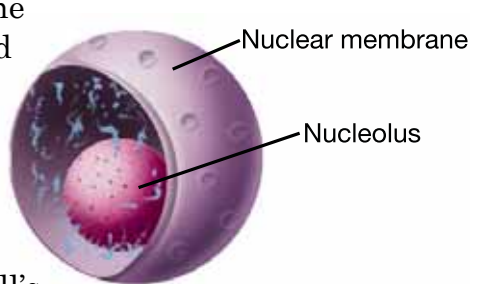
Figure 5.7: *These human cheek cells have been stained with methylene blue. How many cells do you see? Can you identify the nucleus in each cell?*

The cell membrane

The cell membrane is a thin layer that separates the inside of the cell from its outside environment. It keeps the cytoplasm inside while letting waste products out. It also lets nutrients into the cell. It is made out of lipids and proteins. A cell membrane is kind of like your skin. Your skin lets water and other materials pass through and separates your internal parts from the outside.

The nucleus is the control center

The most visible organelle in a eukaryotic cell is the nucleus. The nucleus is covered with a membrane that allows materials to pass in and out. It's often called the "control center" of the cell because it contains DNA. As you have learned, DNA is the hereditary material that carries all of the information on how to make the cell's proteins. You might say it's kind of like a recipe book.



The nucleolus

If you look closely at the nucleus of a cell under a microscope, you may see an even darker spot. This spot is called the *nucleolus*. It acts as a storage area for materials that are used by other organelles.

MY JOURNAL

Cells are not flat objects like they appear in this text. They are three-dimensional just like you are. A cell that appears circular on paper is really shaped like a ball.

Find everyday objects that remind you of the different organelles inside of a cell. Collect those objects and make a table listing the object and the organelle it reminds you of.

Organelles and their functions

Seeing the other organelles

Even with a powerful microscope, it's difficult to see organelles other than the nucleus. Scientists use different techniques like fluorescent microscopy to make organelles stand out. Figure 5.8 shows cells that have been treated to make the mitochondria stand out (the red dots).

Many discoveries about organelles were made using an *electron microscope*. This type of microscope uses tiny particles called *electrons,* instead of reflected light, to form images.

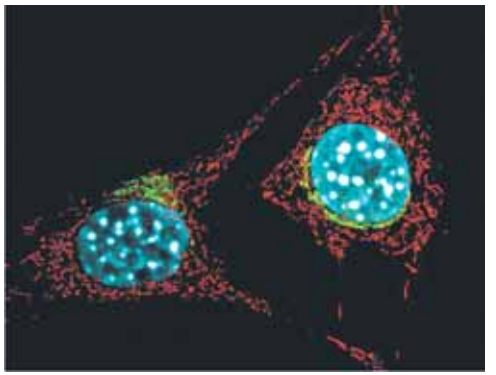
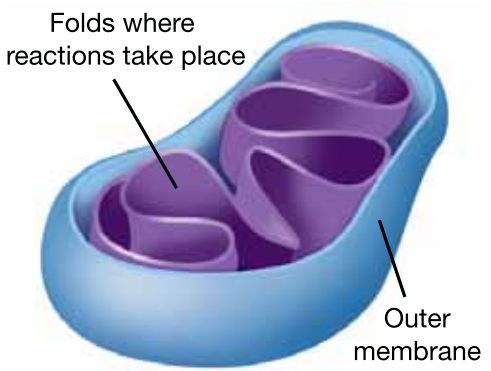


Figure 5.8: *These mouse cells have been prepared to show mitochondria and the nucleus. The mitochondria appear as glowing red structures.*

Mitochondria: the powerhouse of the cell

Mitochondria are called the "powerhouses" of cells because they produce much of the energy a cell needs to carry out its functions. They are rod-shaped organelles surrounded by two membranes. The inner membrane contains many folds, where chemical reactions take place. Mitochondria can only work if they have oxygen. The reason you breathe air is to get enough oxygen for your mitochondria. Cells in active tissues—like muscle and liver cells—have the most mitochondria.



Mitochondria produce much of the energy a cell needs to carry out its functions.

Vacuoles: storage areas of the cell

In some animal cells, you will find small, fluid-filled sacs called vacuoles. A **vacuole** is the storage area of the cell. Vacuoles store water, food, and waste. Plant cells usually have one large vacuole that stores most of the water they need.

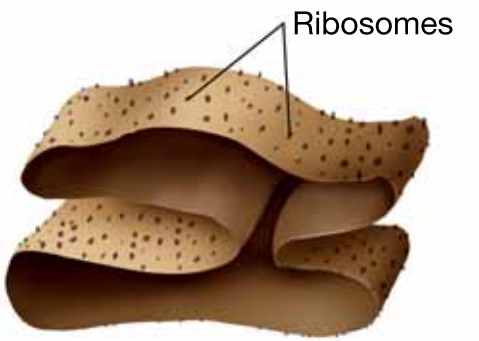
VOCABULARY

mitochondria - an organelle that produces much of the energy a cell needs to carry out its functions.

vacuole - an organelle that stores food, water, and other materials needed by the cell.

Endoplasmic reticulum

The **endoplasmic reticulum** (ER) is a series of tunnels throughout the cytoplasm. They transport proteins from one part of the cell to another. You can think of the ER as a series of folded and connected tubes. There are different places to enter and exit in various locations.

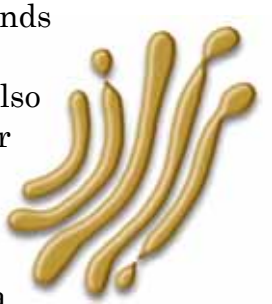


Ribosomes

If you look closely at the ER, you can sometimes see little round grains all around it. Each of those tiny grains is an individual ribosome. **Ribosomes** are the protein factories of the cell. When ribosomes make proteins, they release them into the ER. Some ribosomes are not attached to the ER, but float in the cytoplasm.

Golgi bodies

Golgi bodies receive proteins and other compounds from the ER. They package these materials and distribute them to other parts of the cell. They also release materials outside of the cell. The number and size of Golgi bodies found in a cell depends on the quantity of compounds produced in the cell. The more compounds produced, the more and larger Golgi bodies there are. For example, a large number of Golgi bodies are found in cells that produce digestive enzymes.



Lysosomes

Lysosomes contain enzymes that can break things down. Lysosomes pick up foreign invaders such as bacteria, food, and old organelles and break them into small pieces that can be reused.

Cytoskeleton

The **cytoskeleton** is a series of fibers made from proteins. It provides structure to the cell and gives it its shape. Figure 5.9 shows a cell that has been treated so the cytoskeleton stands out.

VOCABULARY

endoplasmic reticulum - an organelle that transports proteins inside of the cell.

ribosome - an organelle that makes proteins.

Golgi body - an organelle that receives proteins, packages them, and distributes them.

lysosome - an organelle that contains enzymes that break things down to be reused by the cell.

cytoskeleton - a series of protein fibers inside of a cell that give structure and shape to the cell.

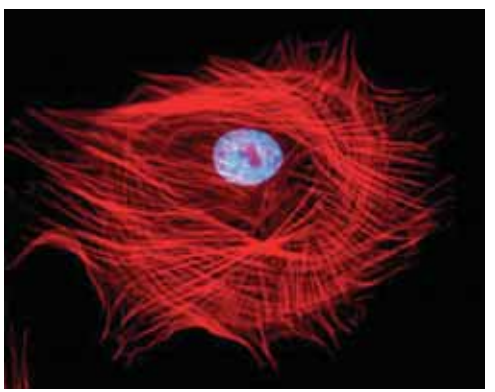
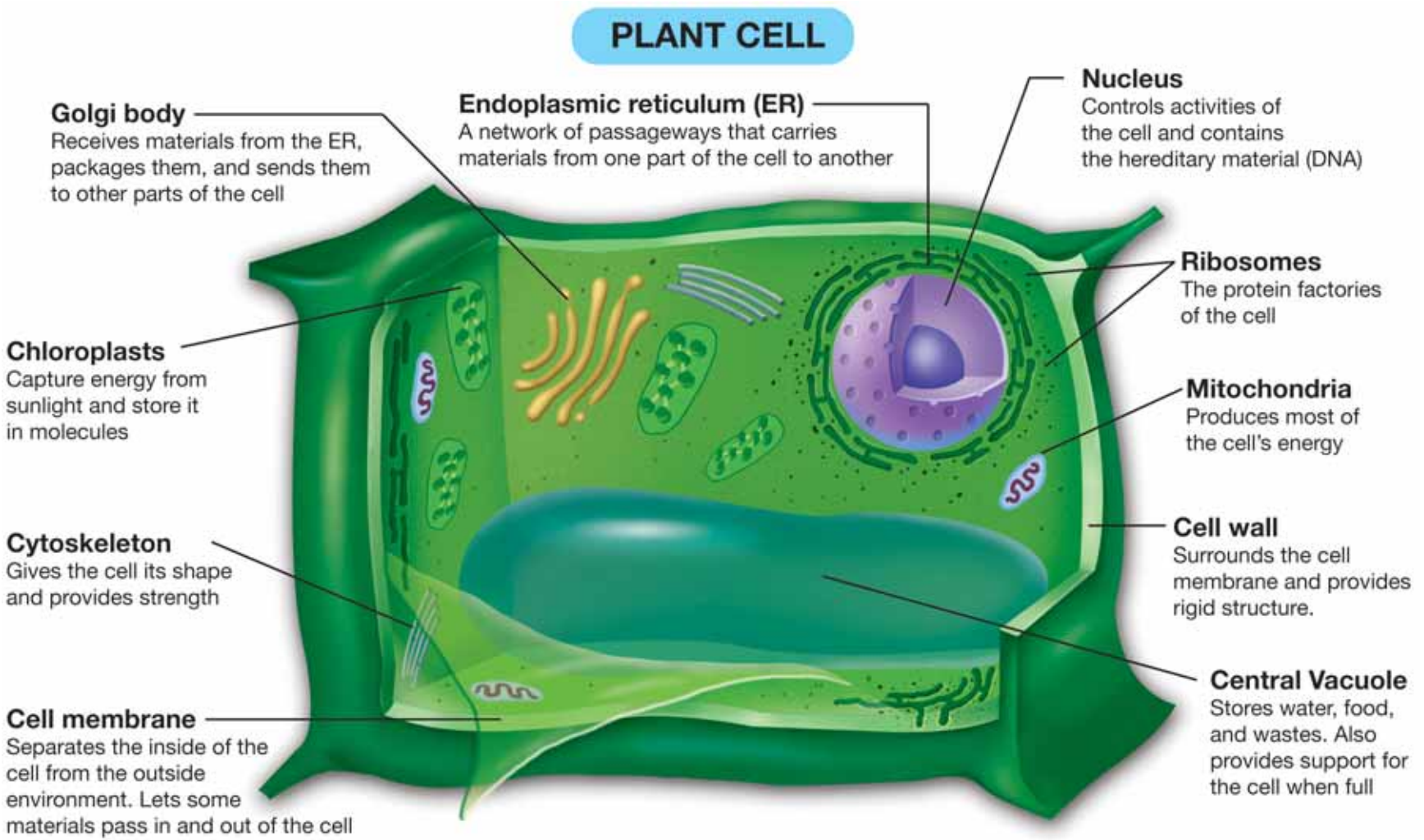


Figure 5.9: *This cell was treated to make the cytoskeleton stand out.*

Diagram of a plant cell

Plant cells are different from animal cells. Here is a diagram of a typical plant cell.



How plant cells are different from animal cells

Figure 5.10 shows that plant and animal cells look very different. Their differences are described below.

Plant cells have chloroplasts

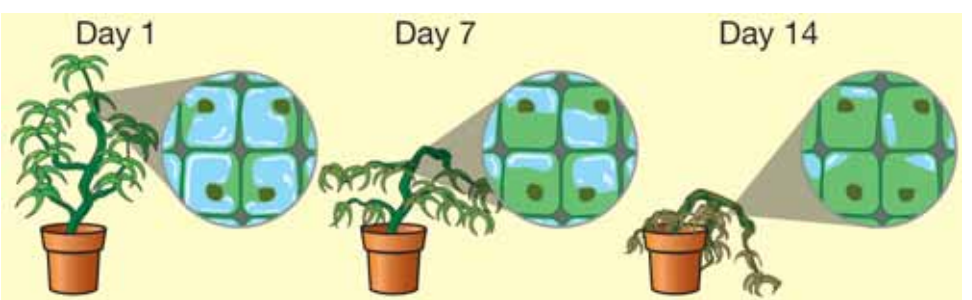
Plant cells have chloroplasts, but animal cells do not. A **chloroplast** is an organelle that contains a pigment called *chlorophyll*. Chloroplasts are organelles that convert light energy into chemical energy in the form of molecules. This process is called *photosynthesis*.

Plant cells have a large, central vacuole

Plant cells have a large central vacuole that stores *cell sap*. The major component of cell sap is water. Cell sap also consists of sugars, amino acids, and ions. When these vacuoles are full of cell sap, they help give plant cells their structure and rigidity.

Plant cells have a cell wall

Plant cells have a cell wall, but animal cells do not. The **cell wall** is made of a carbohydrate called *cellulose*. Cell walls provide structure and support for the plant. Unlike the cell membrane, the cell wall is able to withstand high internal pressure. The buildup of water inside the central vacuole provides pressure against the cell wall. When a plant needs water it wilts because the central vacuoles in its cells are empty. They no longer push against the cell walls to keep the plant upright. Watering the plant restores water in the central vacuoles.



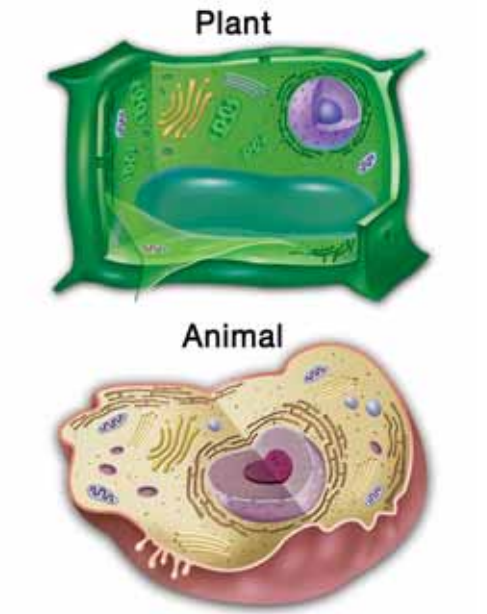


Figure 5.10: *How are plant cells different from animal cells?*

VOCABULARY

chloroplast - an organelle that converts light energy into chemical energy in the form of molecules.

cell wall - the outer layer of a plant cell that is made from cellulose and makes plant cells rigid.

5.2 Section Review

1. Name the correct organelle for each function in the table below.

Organelle	Function
	Produces much of the energy a cell needs to carry out its functions
	Makes proteins.
	Controls all activities of the cell and contains the hereditary material
	Packages proteins and distributes them to other parts of the cell
	Lets materials pass into or out of the cell
	Stores water, food, and wastes
	Transports proteins inside of the cell

2. The plant cell wall is made of:
   a. glucose
   b. protein
   c. cellulose
   d. lipids
3. A *Venn diagram* shows how two or more things are similar and different. Place the organelles into the Venn diagram in Figure 5.11. What do your results tell you about the differences between plant and animal cells?
4. What is the function of the cell wall? Why do plant cells need a cell wall?

CHALLENGE

What effect on the function of a cell would occur if one of the following organelles was missing? Write a sentence for each organelle.

1. ribosome
2. lysosome
3. vacuole
4. mitochondria
5. chloroplast
6. cell membrane

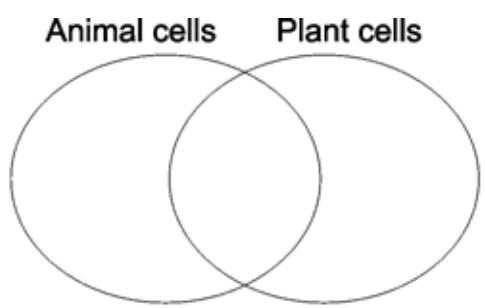


Figure 5.11: *Complete the Venn diagram for question 3.*

MEDICINE CONNECTION

Organ Transplants

How many ways do living things protect themselves? You can probably think of dozens of examples. Roses have thorns. Rabbits are quick. Pigeons fly in flocks. Have you ever thought about this? What is the most important way that many living things, including people, protect themselves? The answer might surprise you.

All living things must protect themselves against disease. Like other living things, people are under constant assault from bacteria, viruses, and other organisms. Our immune systems fight off these organisms.

Photo - courtesy of CDC

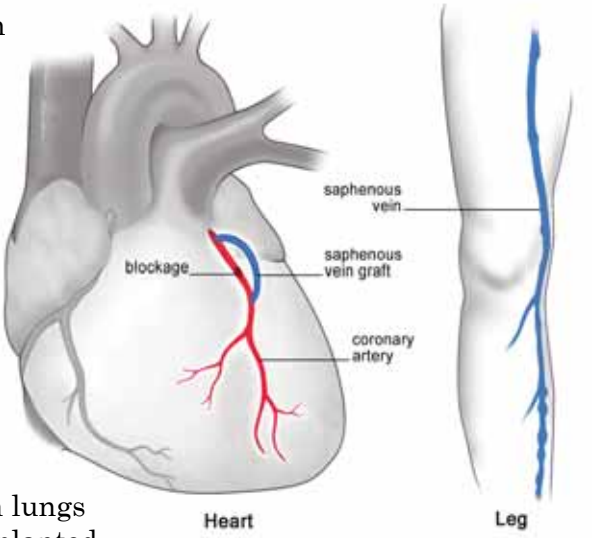
What happens when a foreign cell enters your body? It causes a quick response from your immune system. A variety of cells attack the invader. At the heart of your immune system are cells called *lymphocytes*. These are a type of white blood cell. Lymphocytes can grab onto foreign cells and help remove them from your body.

For your immune system, the world divides into "us" and "them." "Us" means every cell in your body. "Them" means almost everything else on Earth. The immune system attacks "them." This can be a problem with organ transplants.

The problem with transplants

Hindu doctors in South Asia may have transplanted skin 2,600 years ago. Such grafts took skin from one part of a person's body. It replaced damaged skin in another part of the same person's body. This is still done today.

The immune system ignores this kind of transplant. The tissues "match" exactly. All of the cells came from the same body. For the same reason, heart bypass operations use blood vessels from the patient's own body to replace blocked heart arteries.



Modern medicine is able to transplant many organs besides skin and blood vessels. Kidneys, livers, hearts, and even lungs have been transplanted. Transplants save people's lives. In each case, the patient's immune system must be overcome. The immune system may see the transplant as an invader. This is called "rejection."

Antigens are on the surface of cells. They tell your immune system whether a cell is "us" or "them." Two types of antigens cause rejection. One is found on red blood cells. The other is called transplantation, or *histocompatibility*, antigens. These are found on every cell in your body except red blood cells. The main transplantation antigens are called the human leukocyte antigens, or HLA. Your genes

determine your HLA. Only identical twins have the same genes. An organ could be transplanted from one identical twin to another without rejection. In every other case, doctors need to match organs. Doctors look for as close a match as they can between the HLA of the patient and the person who donated the organ.

Tissue-matching

Matching antigens is more often called "tissue matching" or "tissue typing." Both blood type and HLA are matched as closely as possible.

Photo - courtesy of CDC

Lymphocytes are used for HLA matching. Blood typing is simple. But there are many more HLA antigens. Tissue matching is more complicated than blood typing. In simple terms, lymphocytes from the donor and the patient are tested. The same chemicals are used on each set of cells. A certain chemical may kill both. Then the donor and patient have that one antigen in common. The lymphocytes may both survive. Then the donor and patient both lack that antigen. The lymphocytes of just the donor may be affected, but not the patient. The HLA does not match.

This process is repeated many times to test for different antigens. Even when the donor and patient seem to match well, there is a final test. Lymphocytes from the donor are tested against blood serum from the patient. If this test fails, the transplant is usually not done.

These tests are done in a laboratory. Trained technicians do the tests under the direction of a pathologist. This medical doctor specializes in body tissues and fluids.

The future of transplants

A transplant has the best chance of success when the donor and the patient are related. The chance of a complete match is best between siblings. Brothers and sisters may donate bone marrow or a kidney to one another. Most other transplants, however, come from people who donate their organs when they die.

An exact tissue match can only happen with identical twins. Most transplant patients must take drugs to stop their immune systems from rejecting the new tissue. There are side effects with this approach.

Many more people could be helped if organs could be transplanted as easily as blood. One idea is to change a patient's immune system so that it would still fight infections but not attack a donated organ.

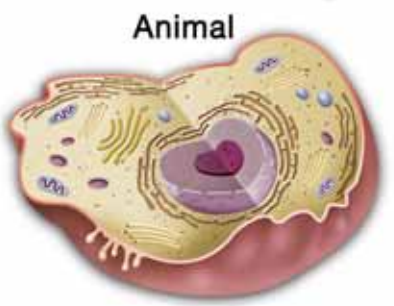
Scientists have made this work in laboratory mice. In 2005, Navy doctors made it work with monkeys. If it can work safely in people, organ transplants might become the easiest way to treat many diseases in the future.

Questions:

1. What specialized cells are the "heart" of your immune system?
2. What doctors are believed to have done the first organ transplants, and when did they do them?
3. Why do you think a living thing's immune response is called its "most important" way of protecting itself?
4. How might organ transplants in the future be done as easily as blood is transfused today?

CHAPTER ACTIVITY Building a Scale Model of a Cell

Cells appear in all shapes and sizes. In animals, cells can be long like the motor neurons that run from the tips of your toes to the base of the neck. Other cells in your body can be small like the red blood cells. Cell models are a good way to help you identify cell structures. Often it is not clear how the size of the cell is related to the size of the organelles. In this activity, you will explore the relationship of cell size to organelle size by creating a scale model.



What you will do

1. Complete the table (right). Use a scale factor of 1 micrometer = 1 centimeter. The calculation for the diameter of the cell is completed for you.
2. Obtain a large sheet of paper from your teacher.
3. Measure the diameter of the cell (35 centimeters) and draw a circle on your paper. This will be the outline of your animal cell. Cut out the circle out of the paper.
4. Using your calculation, make a nucleus to scale using the colored-construction paper your teacher has provided.
5. Make and add the rest of the organelles. Be sure to use the animal cell diagram on page 99 as a guide in making your organelles. For example, you could make a golgi body that consists of 5 separate parts, 7 × 2 micrometers each.
6. Once the model is complete, label the organelles. Or you may wish to make a key that identifies each organelle.

Organelle	Average Size (μm)	Scaling Factor (1 μm = 1 cm)	Model Size (cm)
Cell Diameter	35	35 μm × 1 cm/μm	35
Nucleus	5		
Mitochondria	6×2		
Lysosome	2		
Endoplasmic Reticulum	5×10		
Golgi Body	7 × 2		
Vacuole	2		
Ribosome	.02		

Applying your knowledge

a. What is the smallest organelle in a typical animal cell?
b. What is the largest organelle in a typical animal cell?
c. How is your model of the cell different than models the teacher used in class, or models you may see in a text book?
d. This method does not apply only to cells. Can you think of other examples where scale models are used?
e. How might you build a 3-dimensional scale model of a cell? With a classmate, propose a method for creating a scaled 3-dimensional model of a cell with all the organelles. What types of things could one use to represent the cell boundaries? What things might one use to represent the organelles? Begin by writing up your ideas in a proposal. Your teacher may ask you to build your model as a project.

Chapter 5 Assessment

Vocabulary

Select the correct term to complete the sentences.

cell membrane	cytoskeleton	mitochondria
cell wall	endoplasmic reticulum	organelle
nucleus	golgi body	prokaryotic
cytoplasm	lysosome	ribosome

Section 5.1

1. Bacteria are _____ cells.
2. The _____ controls what enters and exits the cell.
3. A structure inside a cell that does a certain job is called an _____.
4. The fluid mixture with organelles and other vital compounds in cells is the _____.
5. Eukaryotic cells all have a _____ that contains DNA.

Section 5.2

6. The _____ is the organelle that transports materials like proteins around the cell.
7. Fibers inside the cell that give structure and shape are called the _____.
8. Muscle cells have a lot of _____ to produce the large amounts of energy necessary to do their work.
9. A _____ is a protein factory in the cell.
10. Enzymes found in a _____ are used to break down old cell parts that are then recycled by the cell.
11. Proteins move from the ribosome to the _____ for packaging before distribution around the cell.
12. Animal cells can change shape to move because they don't have a _____, which is what makes plant cells rigid.

Concepts

Section 5.1

1. Which of the following is not part of the cell theory?
   a. Cells only come from existing cells.
   b. All of an organism's life functions occur within cells.
   c. The two major types of cells are prokaryotic cells and eukaryotic cells.
   d. All living things are made of one or more cells.
2. Identify each characteristic as either a feature of prokaryotic cells (P) or as a feature of eukaryotic cells (E).
   a. _____ name means “before nucleus” in Greek
   b. _____ believed to have originated 2 billion years ago
   c. _____ DNA is contained in nucleus
   d. _____ larger of the two types - 10 times the size of the other
   e. _____ have organelles without membrane covers

Section 5.2

Match the organelles to the most appropriate item that performs the same function to complete these analogies.

_____ 3. ER	a. nutshell
_____ 4. cell wall	b. warehouse
_____ 5. vacuole	c. brain
_____ 6. cell membrane	d. highway
7. nucleus	e. skin

8. Which part of the cell is like a recipe book?
   a. nucleolus
   b. DNA
   c. cell membrane
   d. none of the above
9. The _____ is the largest organelle in the cell.

10. Cells can only have one of certain organelles like the nucleus. Which organelles can a cell have many of the same kind? Explain your answer.
11. Which organelle would cause a lot of damage to the cell if it were to break open? Why?
12. Potato cells don't have chloroplasts. If you saw these cells under the microscope, how could you tell that they were plant cells?

Math and Writing Skills

Section 5.1

1. Imagine that you are Anton van Leewenhoek and you have just observed the first blood cells, bacteria, and single-celled protists. Write a letter to a friend describing your amazing discoveries.
2. Write an imaginary dialogue that could have taken place between Matthais Schleiden and Theodore Schwann after they observed plant and animal tissue under a microscope.
3. Many of the cells in your body are 0.01 mm long. Use that measurement to complete these calculations.
    a. An amoeba - a unicellular protist - is 1 mm long. How many body cells would you have to stack end to end to equal the size of an amoeba?
    b. Figure out what your height is in millimeters by multiplying your height in meters by 1000. How many body cells would you have to stack end to end to equal your height?
    c. The length of a swimming pool is 25,000 mm. How many body cells would you have to stack end to end to equal the length of the pool?
    d. Prokaryotic cells are approximately 1/10 the size of eukaryotic cells. How big are prokaryotic cells?
4. If you were trying to classify an unknown organism by looking at its cells, what could its cells tell you?

Section 5.2

5. Describe what goes on in a typical animal cell. Be sure to mention all the organelles listed in the text.
6. Which organelles does a spinach cell have that a rabbit cell does not? Explain your answer.
7. Explain the connection between a wilted plant and cell parts like the vacuole and the cell wall.

Chapter Project

Cellular song

Cells have organelles with weird names like golgi body and endoplasmic reticulum. It is often helpful to invent a way to help you remember the names of the structures and their functions. Create a song or poem about cell structure, using the guidelines below. Record the song or poem and play it back for the class, or perform it live. If you don't like solo work, join some classmates and do this as a group project. Make sure everyone contributes verses to the song or poem!

1. Choose one type of cell, either a plant cell or an animal cell.
2. Choose a popular song for the melody or rap. If you create a poem, make the verses rhyme.
3. The song or poem must include each structure listed on the animal or plant cell diagram in your book. In addition to naming the structures, you must use the song or poem to help you remember the function of each structure.
4. Submit your creation for approval, memorize it, and then share the song or poem with your classmates. When it comes time for a written test on cell structure, you might be humming a tune to help you remember the answers!

Chapter 6

Cell Processes

How many cells are in the human body? Cells are so small that you can only see them with a microscope; this means that the average human body must contain billions of cells. Old cells are constantly being replaced with new cells. Every minute you lose 30,000 to 40,000 worn-out skin cells. If you live to be 80 years old, you have grown about 1000 skins in a lifetime! You can see how challenging it is to estimate the number of cells. Most scientists agree that the human body contains trillions of cells. If you had to individually count the cells in your body, it would take over 2000 years! It is hard to imagine how many cells there must be in a giant redwood tree. There is a redwood tree in California that measures over 360 feet tall (110 meters). How can a massive tree like that come from a tiny seed? Read this chapter on how cells work to satisfy your curiosity.

Key Questions

1. ***How do things move in and out of cells?***
2. ***How do cells get energy?***
3. ***Why are plants green?***

6.1 The Structure and Function of the Cell Membrane

The cell membrane is kind of like a soap bubble (Figure 6.1). A soap bubble consists of a thin, flexible membrane. The soapy membrane seals the inside air from the outside. Likewise the cell membrane is a thin, flexible layer that seals the inside of the cell from its outside environment. In this section, you'll learn about the structure and function of the cell membrane.

Figure 6.1: *Soap bubbles are similar to cell membranes.*

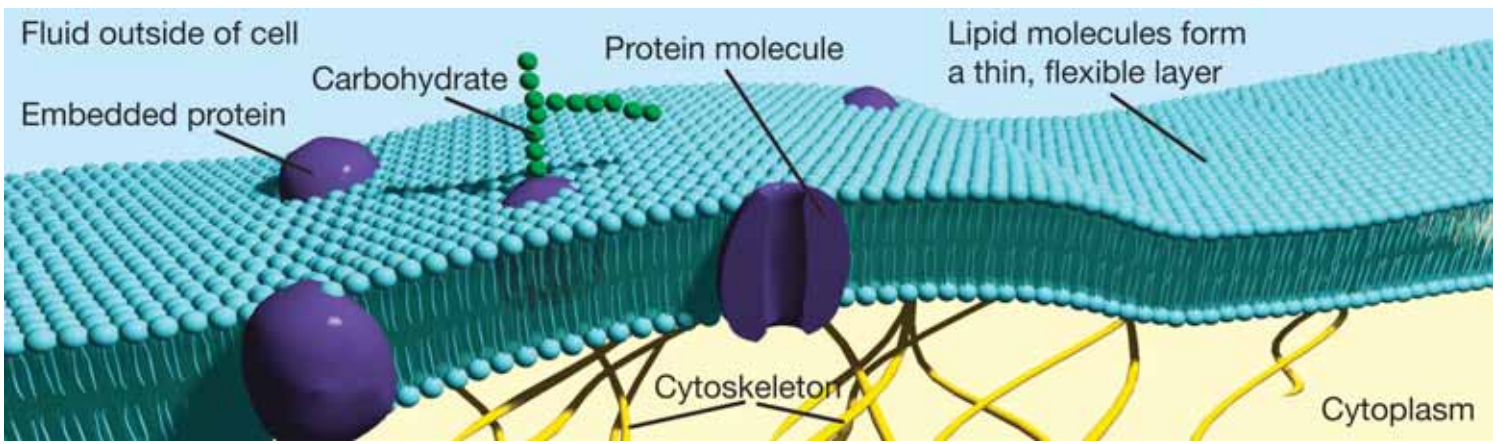
A closer look at the cell membrane

The functions of the cell membrane

The cell membrane has many functions. It protects the cell from its environment and takes in food and other compounds that the cell needs. It also gets rid of waste from inside of the cell. The cell membrane even allows cells to communicate and interact.

The structure of the cell membrane

The cell membrane is made of several types of molecules. Lipid molecules form a double layer. This creates a thin, fluid layer like a soap bubble. Embedded protein molecules can move around within this layer. Carbohydrates attached to some proteins face outward. Some of these serve as "identification cards" so cells can recognize each other.



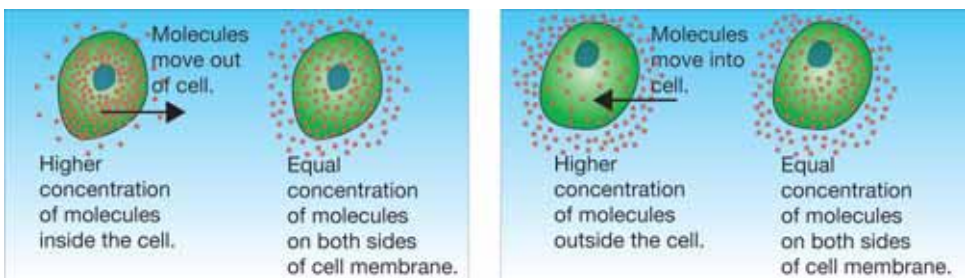
Diffusion

What is diffusion?

Cells live in a watery environment. The cytoplasm is 80% water. Every cell in your body is also surrounded by a watery solution. Solutions make it easier for molecules to move into or out of the cell. Molecules move across the cell membrane by a process called diffusion. **Diffusion** is the movement of molecules from areas of greater concentration to areas of lesser concentration.

How diffusion works in a cell

In order for diffusion to occur, there must be an unequal number of molecules on each side of the cell membrane. If there are more molecules on the outside of the membrane compared to the inside, the molecules will move to the inside of the cell until there is an equal number of molecules on both sides. Can you predict what will happen if there are more molecules on the *inside* of the cell?



Molecules move into or out of the cell until there is an equal number on both sides of the cell membrane.

Not all molecules can pass through by diffusion

Not all molecules can move across the cell membrane by diffusion. You can compare the cell membrane to a tea bag. Only smaller particles can pass through the tea bag. Larger particles are left inside of the bag. The same is true of the cell membrane. Small molecules like oxygen and carbon dioxide can pass through. You'll learn how larger molecules diffuse later in this chapter.

VOCABULARY

diffusion - the movement of molecules from areas of greater concentration to areas of lesser concentration.

MY JOURNAL

Observing diffusion

1. Fill a clear glass with water.
2. Carefully add a drop of food coloring to the water.
3. Observe the glass every 2 minutes and record your observations in your journal.

4. What happens to the food coloring? Explain what is happening at the molecular level.
5. You observed a process called *diffusion*. How might the cell membrane use diffusion to move molecules in or out?

Osmosis

What is osmosis? Water molecules are small enough to pass through the cell membrane by diffusion. **Osmosis** is the diffusion of water across the cell membrane. Like other molecules, water moves from areas of greater concentration of water molecules to areas of lesser concentration.

Cells take in water by osmosis When you put a cell into a solution, it will either take in water, stay the same, or lose water. What happens depends on the amount of water in the solution. For example, a sugar solution (sugar dissolved in water) contains fewer water molecules than the same amount of pure water.

More water molecules outside If the solution outside the cell has more water molecules than inside the cell, the cell gains water. Water molecules are free to pass across the cell membrane in both directions, but more water comes into the cell than leaves. The cell swells up (Figure 6.2, top).

Water molecules equal on both sides If the solution outside the cell has the same amount of water molecules as inside the cell, the amount of water inside the cell stays the same. Water crosses the membrane in both directions, but the amount going in is the same as the amount going out. Thus, the cell stays the same size (Figure 6.2, middle).

Fewer water molecules outside If the solution outside the cell has fewer water molecules than inside the cell, the cell loses water. Again, water crosses the cell membrane in both directions, but this time more water leaves the cell than enters it. The cell shrinks (Figure 6.2, bottom).

Animal and plant cells If animal cells take in too much water they can burst. That's why your cells are surrounded by a solution that has the same amount of water as inside the cell membrane. Plant cells can take in more water than animal cells because of their strong cell walls.

VOCABULARY

osmosis - the diffusion of water across the cell membrane.

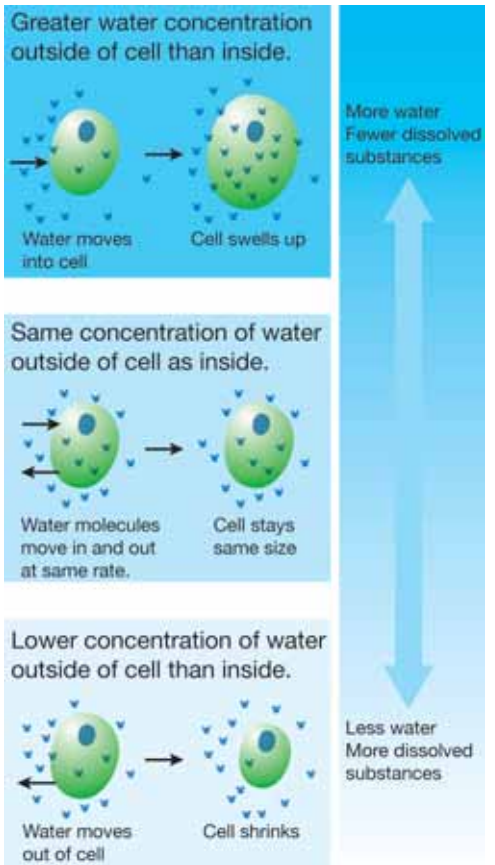


Figure 6.2: *When you put a cell into a solution, one of three things can happen.*

Other types of transport

Protein channels

Diffusion and osmosis do not require energy from the cell. This is because the molecules move *with* a concentration difference (from higher to lower). Larger molecules like sugars, starches, and proteins sometimes diffuse through *protein channels* (Figure 6.3). Because the molecules move from greater to lesser concentration through the channels, this process also does not require energy.

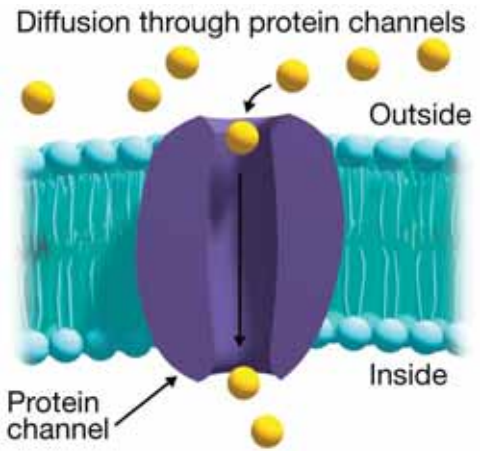
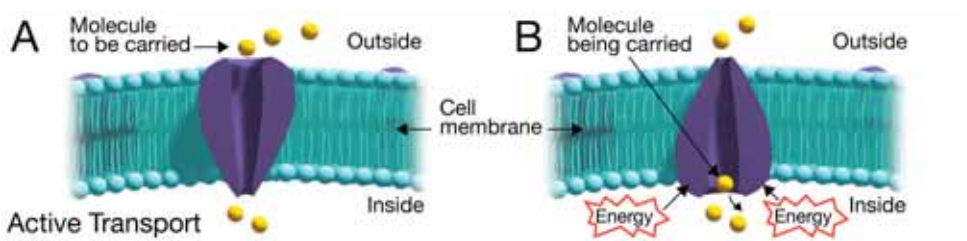


Figure 6.3: *Larger molecules can diffuse through protein channels.*

Active transport

Sometimes a cell needs to move molecules *against* a concentration difference (from lower to higher concentration). **Active transport** is a process that allows molecules to move across the cell membrane from lower to higher concentrations. Active transport requires energy. Protein molecules act as "pumps" to move the molecules across the cell membrane as shown below. Your nerve cells have lots of protein pumps to move ions across the cell membrane. This is how signals travel through your nervous system.



Other types of active transport

A cell can take in larger particles of food by "engulfing" them. The cell membrane forms a pocket around the particle. Once inside the cell, the pocket breaks loose from the cell membrane. It forms a vacuole within the cytoplasm (Figure 6.4). Cells also send material out of the cell in the same way. When this happens, a vacuole fuses with the cell membrane and the contents are forced outside of the cell. Both of these processes are types of active transport because they require energy.

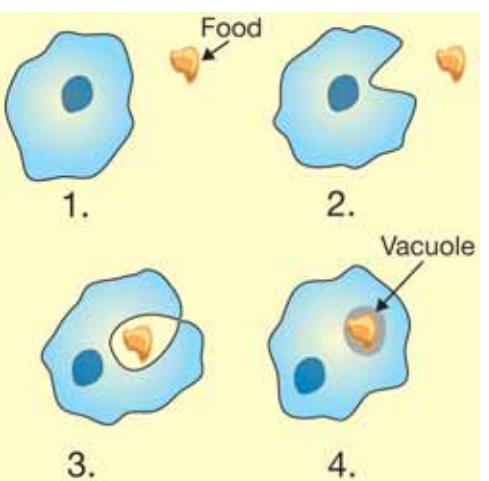


Figure 6.4: *A cell can also take in larger amounts of material by engulfing them.*

Why are cells so small?

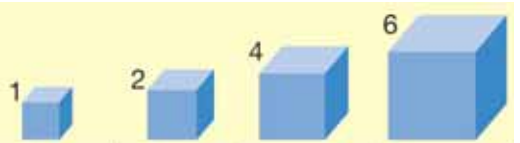
One characteristic of cells is that they are very small. Why are cells so small? The answer has to do with the cell membrane.

Cells need a large surface area

Everything the cell needs to take in or has to get rid of has to go through the cell membrane. Therefore the cell membrane needs to have a large surface area in relation to the volume of the cell. As a cell gets bigger, so does its surface area. However, the volume of a cell increases at a faster rate than the surface area of its cell membrane. If a cell gets too large, its cell membrane will not have enough openings to meet the demands of its volume. This limits the size of cells.

The volume of a cell increases faster than its surface area

To understand why the volume of a cell increases faster than its surface area, let's imagine a perfectly square cell. The *surface-area-to-volume ratio* is the area of the cell's outer surface in relationship to its volume.



Surface area (cm²)	6	24	96	216
Surface area (cm³)	1	8	64	216
Surface area: Volume	6:1	3:1	1.5:1	1:1

Long and thin cells

One way to increase surface area is to make the cell long and thin or skinny and flat. The nerve cells in your body are very long and thin. A thin, flat cell has a volume of: $16 \times 4 \times 0.125 = 8$. The cell's surface area is: $2(16 \times 0.125) + 2(16 \times 4) + 2(4 \times 0.125) = 133$. The surface-area-to-volume ratio is 133:8 (Figure 6.5).

VOCABULARY

(Discussed on previous page.)

active transport - a process that allows molecules to move across the cell membrane from lower to higher concentrations.

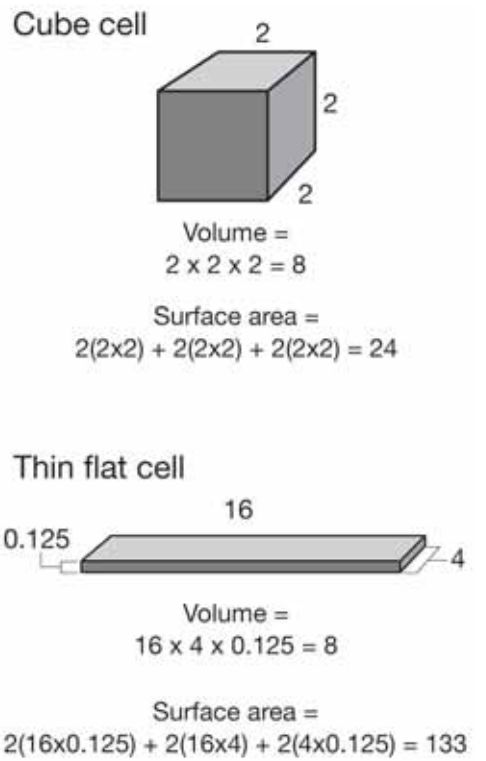
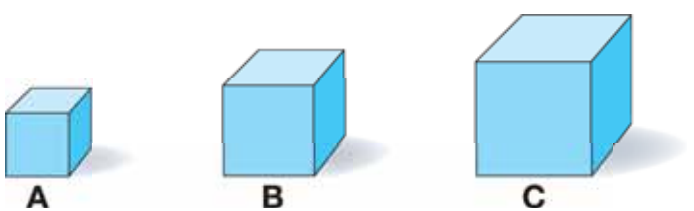


Figure 6.5: *A thin, flat cell has a higher surface-area-to-volume ratio than a square cell of the same volume.*

6.1 Section Review

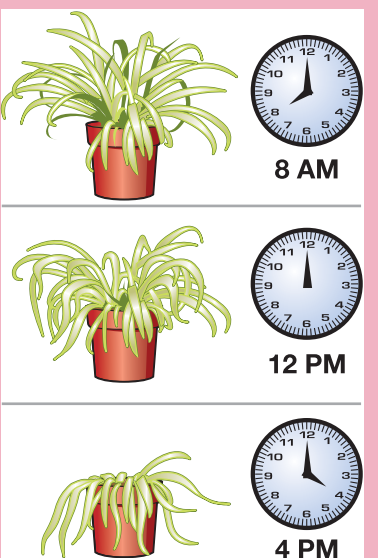
1. List four functions of the cell membrane.
2. How is the cell membrane like a soap bubble?
3. What is diffusion? Name one example of diffusion.
4. What is osmosis? What structure in a plant cell helps protect it from osmosis?
5. For each situation below, state whether water will move into the cell, move out of the cell, or stay the same.

6. How is active transport different from diffusion?
7. Name two situations in which a cell would need to use active transport instead of diffusion.
8. Explain why cells are so small.
9. Which figure below has the highest surface-area-to-volume ratio? Explain your reasoning.



CHALLENGE

The owner of this plant watered it with salt water by mistake. The pictures below show what happened to the plant at 8:00 a.m., 12:00 p.m., and 4:00 p.m.



1. Describe what happened to the plant and its cells over time.
2. Explain why you think these things happened. State your explanation as a hypothesis.
3. Design an experiment to test if your hypothesis is correct.

6.2 Cells and Energy

To stay alive, you need a constant supply of energy. You need energy to move, think, grow, and even sleep. Where does that energy come from? It all starts with the sun. Plant cells store energy from the sun in the form of molecules. In this section you'll learn about how cells store and release energy.

What is photosynthesis?

Solar cells and chloroplasts

A solar calculator has *solar cells* that convert light energy into electrical energy. The electrical energy powers the calculator. A plant cell has chloroplasts that also convert energy. *Chloroplasts* are where photosynthesis occurs. **Photosynthesis** is a process where plants use the energy of sunlight to produce energy-rich molecules (carbohydrates).

Photosynthesis takes place in the chloroplasts.

How does a tiny seed grow into a massive tree?

Before our knowledge of photosynthesis, gardeners wondered how a tiny seed could grow into a massive tree. Where did all of that mass come from? In the 1600s, a Flemish scientist named Jan Van Helmont (1580–1644) conducted an important experiment. He grew a willow tree in a carefully weighed amount of soil. He noticed that the mass of the soil barely changed while the mass of the tree greatly increased. He concluded that the extra mass came from water, not from the soil.

Photosynthesis is a chemical reaction

Later experiments carried out by other scientists showed that plants use carbon dioxide (from the air) and water to make a simple carbohydrate (*glucose*) and oxygen. This chemical reaction (photosynthesis) takes place only in the presence of light (Figure 6.6).

VOCABULARY

photosynthesis - a process where plants use the energy of sunlight to produce carbohydrates.

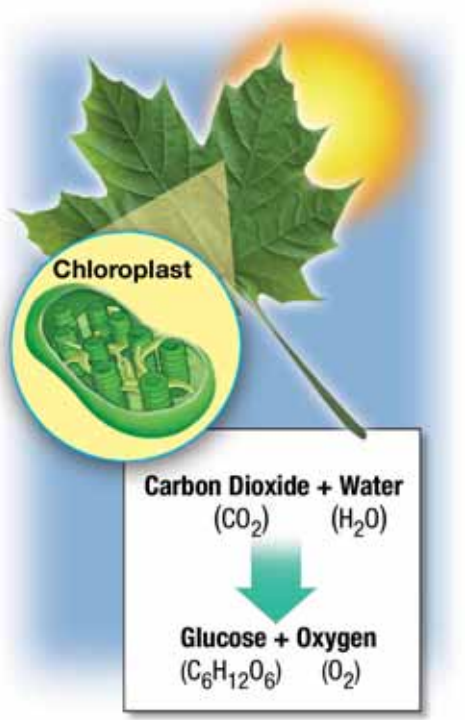
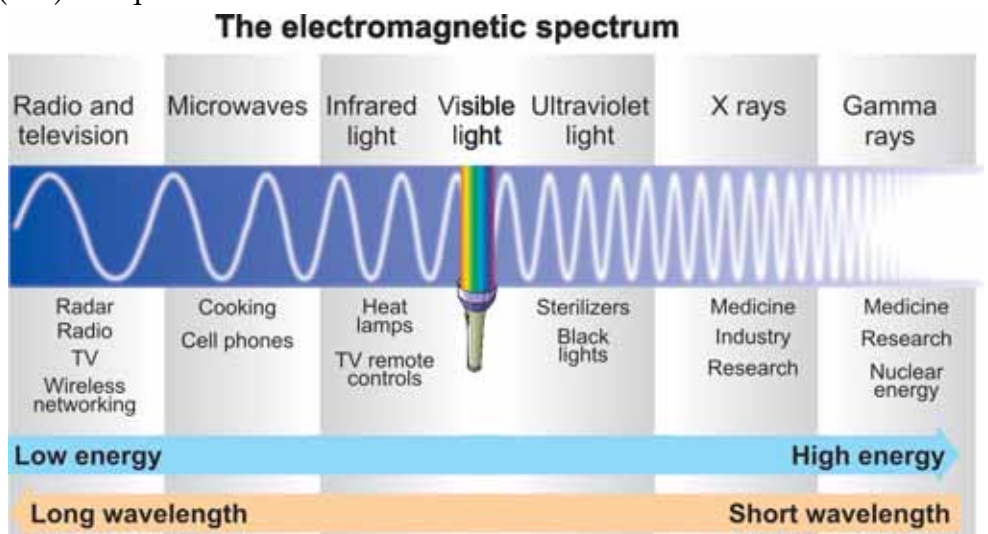


Figure 6.6: *The chemical reaction of photosynthesis. What are the reactants of the reaction? What are the products?*

Light and color

Visible light The Sun provides Earth with a steady source of light. Your eyes perceive sunlight as *white light*. However, it is really made up of different colors of light. The colors that make up sunlight are called *visible light*. There are other forms of light we cannot see such as *ultraviolet* and *infrared light*.

Light is a wave Light is a wave, like a ripple on a pond. Waves can be described by their *wavelength* (the length from peak to peak), and *energy*. Light is part of a continuum of waves known as the **electromagnetic spectrum**. Light waves have very short wavelengths. They range from 800 nm (red light) to 400 nm (violet light). One *nanometer* (nm) is equal to one-*billionth* of a meter!



Color A prism splits white light into all of its colors. **Color** is how we perceive the energy of light. All of the colors of visible light have different energies. Red light has the lowest energy and violet light has the highest energy. As we move through the rainbow from red to violet, the energy of the light increases (Figure 6.7).

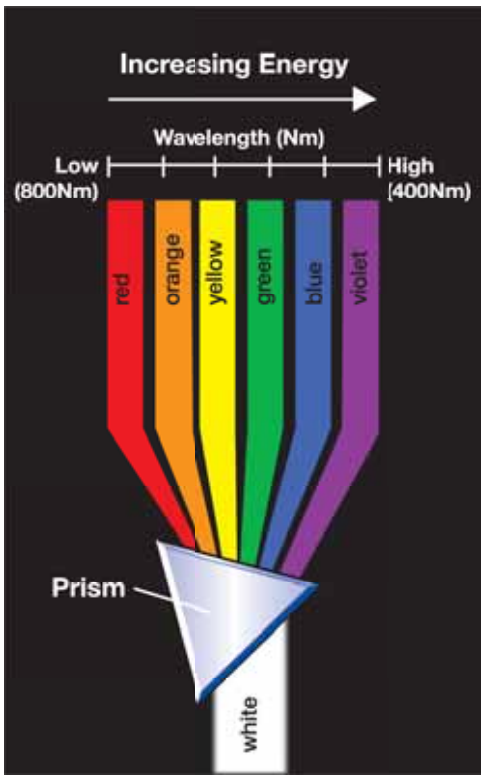


Figure 6.7: *A prism splits light into all of its colors. All of the colors of light have different energies and wavelengths.*

VOCABULARY

color - how we perceive the energy of light.

Chlorophyll

Why most plants are green

A **pigment** is a molecule that absorbs some colors of light and reflects others. **Chlorophyll** is the main pigment used in photosynthesis. It is found inside the chloroplasts of plant cells. Chlorophyll absorbs mostly blue and red light, and reflects green light. This is why most plants look green.

Light is necessary for photosynthesis

The vertical (y) axis of the graph in Figure 6.8 shows the percentage of light absorbed by a plant. The horizontal (x) axis shows the colors of light. The curve shows how much and which colors of visible light are absorbed by plants. The graph shows that plants need red and blue light to grow. Based on this graph, can you explain why plants look green? Do you think a plant would grow if it were placed under only green light?

Plants reflect some light to keep cool

Why don't plants absorb all colors of light? The reason is the same reason you wear light-colored clothes when it's hot outside. Like you, plants must reflect some light to avoid absorbing too much energy and overheating. Also, certain colors of visible light have just the right amount of energy to make photosynthesis occur. Ultraviolet light has more energy but would cause other chemical reactions. Infrared light has too little energy to make photosynthesis occur.

Why leaves change color

In some parts of the world, the leaves of some plants, such as sugar maple trees, turn brilliant red or gold in the autumn. Chlorophyll masks other plant pigments during the spring and summer. In the autumn photosynthesis slows down. Chlorophyll breaks down and red, orange, and yellow pigments in the leaves are revealed!

VOCABULARY

pigment - a molecule that absorbs some colors of light and reflects others.

chlorophyll - the main pigment used in photosynthesis that absorbs blue and red light and reflects green light.

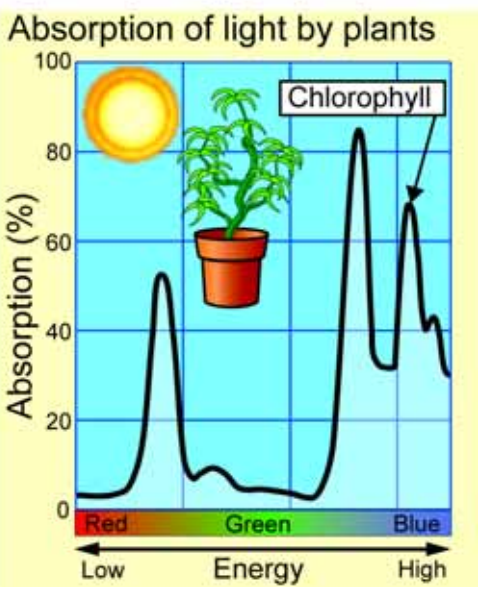


Figure 6.8: *Plants need to absorb light to grow. The plant pigment chlorophyll absorbs red and blue light, and reflects green light. This is why plants look green!*

Cellular respiration

What is cellular respiration?

Your cells get the energy they need from the food you eat. Your digestive system breaks down food into molecules. Your cells convert those molecules into a form of energy they can use. **Cellular respiration** is the process in which the chemical bonds of energy-rich molecules (like glucose) are converted into a form of energy that cells can use. In eukaryotic (including animal *and* plant) cells, cellular respiration takes place in the mitochondria.

Cellular respiration takes place in the mitochondria.

The reactants and products of cellular respiration

Respiration is the process of breathing. Cellular respiration is not the same thing as breathing but they are closely related. You breathe in to get oxygen. You breathe out to get rid of carbon dioxide. Cellular respiration is a chemical reaction that uses oxygen and glucose to produce carbon dioxide, water, and energy (Figure 6.9). When you breathe in, you take in the oxygen your cells need for cellular respiration. When you breathe out, you get rid of the carbon dioxide that your cells produce during cellular respiration. Try breathing onto a mirror or glass surface. Can you see evidence of another product of cellular respiration?

Cellular respiration and energy

During cellular respiration, some energy is stored and some is released. Energy is stored in a molecule called ATP. **ATP** is a molecule that stores and transfers chemical energy within cells. It is used to power cell functions such as muscle contractions, nerve impulses, and molecule-building. Energy released from cellular respiration is often given off in the form of heat. Your body is warm because of the released energy from cellular respiration.

VOCABULARY

cellular respiration - the process in which the chemical bonds of energy-rich molecules are converted into a form of energy that cells can use.

ATP - a molecule that stores and transfers energy within cells.

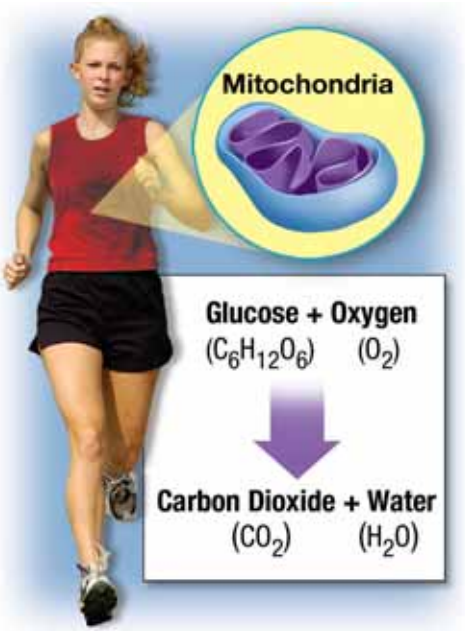
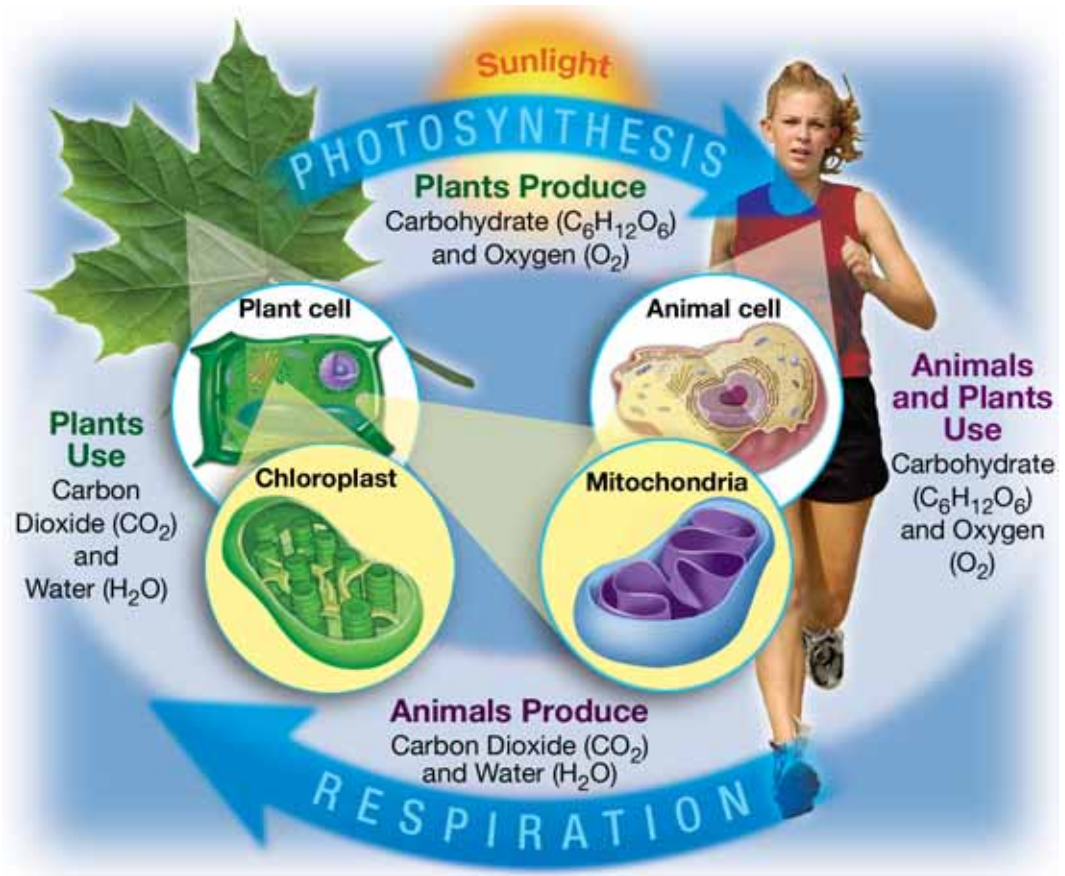


Figure 6.9: *The chemical reaction for cellular respiration. What are the reactants? What are the products?*

Comparing photosynthesis and cellular respiration

Comparing the reactions for photosynthesis and cellular respiration shows how living things on Earth are connected. The reactants in photosynthesis are the products in cellular respiration. The reactants in cellular respiration are the products in photosynthesis. The elements involved are carbon, hydrogen, and oxygen.



MY JOURNAL

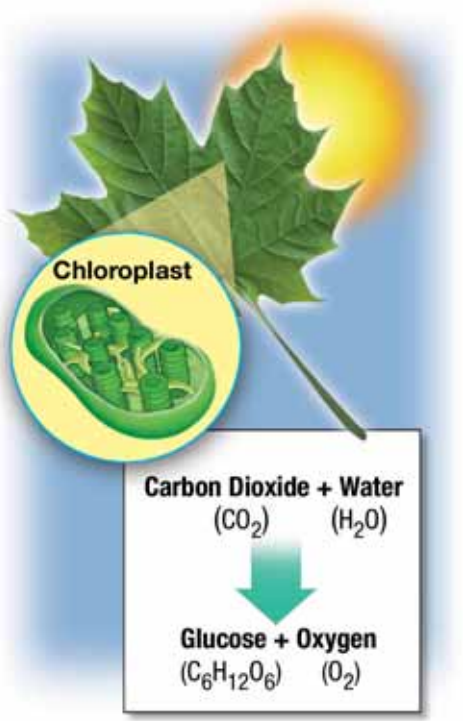
Write the story of a carbon atom as it travels through photosynthesis and cellular respiration. Include the following information in your story:

- the molecules in which the carbon atom is found.
- the organisms, cells, and organelles through which it travels.

Be creative!

6.2 Section Review

1. How are solar cells and chloroplasts similar?
2. What is the electromagnetic spectrum? Which part of the electromagnetic spectrum do plants use for photosynthesis?
3. When white light is passed through a prism, what happens?
4. The chemical reaction for photosynthesis is shown to the right. Use it to answer questions a through d.
   a. Name the reactants in the reaction.
   b. Name the products in the reaction.
   c. What is the function of sunlight in the reaction?
   d. What is the function of chlorophyll?
5. Where does cellular respiration take place?
6. What are the similarities between cellular respiration and respiration (breathing)? What are the differences?
7. What is the function of ATP in cellular respiration?
8. How are photosynthesis and cellular respiration related?
9. Do you think animals could survive without plants? Explain your answer.



CHALLENGE

All plants that use sunlight to grow have chlorophyll, but some do not look green. Come up with a hypothesis to explain this observation.

SOLVE IT!

1. Arrange the following colors from highest to lowest energy:

   green, yellow, red, blue, orange, violet

2. Arrange the following types of electromagnetic waves from longest to shortest wavelength:

   visible light, radio waves, ultraviolet light, microwaves, gamma rays, infrared waves

RESEARCH CONNECTION

Amazing Cells!

Did you know your body is made of trillions of cells? There are millions of different types. Where did all of these different types come from? Part of the answer is a special type of cell called *stem cells*.

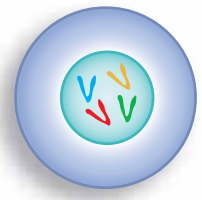
Many living things need stem cells including animals and plants. An organism that is not fully developed is called an *embryo*. In animal embryos, stem cells can develop into different types of cells. Your body has over 200,000 different types of cells. It has blood cells, muscle cells, skin cells, and stomach cells just to name a few. Each type of cell has its own structure and function.

The process of differentiation

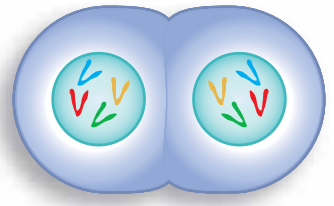
All stem cells have some certain properties:

- Stem cells divide to make more stem cells.
- Stem cells also have the ability to develop into different types of cells.

A stem cell divides into two daughter cells. Each daughter cell is identical to the original parent cell. When mature, these cells also divide. This is how embryos get a supply of stem cells. A growing embryo needs a lot of stem cells to develop tissues and organs. In the laboratory, starting with a few stem cells, scientists have grown millions in a few months.



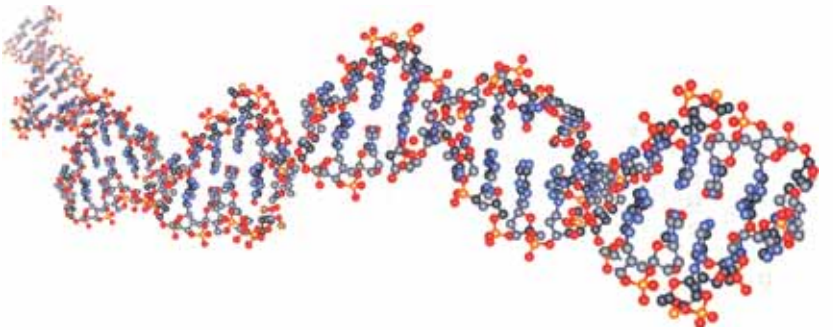
Parent cell



Two daughter cells

So how do stem cells change into other types of cells? Scientists are studying this problem.

Something called a signal tells stem cells to become different types of cells. Genes are pieces of DNA that carry information from the parent cell to the offspring cells. The genes inside stem cells provide internal signals. The environment outside of the cell provides external signals. The cell's environment includes chemicals from other cells.



Different types of specialized animal cells

There are two main types of animal stem cells. More than twenty years ago, scientists extracted stem cells from the embryos of mice. These stem cells are described as embryonic. The other main type of stem cells is described as adult. Embryonic stem cells and adult stem cells are very different.

Embryonic stem cells can divide to make more stem cells. They wait for a signal. Then they start producing specialized cells. These specialized cells form the tissues, which in turn form the organs.

Embryonic stems cells are like new players on a soccer team. Until the players are trained, they are reserves. They have the potential to do a lot of different things. Once they are trained, they become specialized in a position. The players might be defenders or forwards. They might play goalie or mid field. Similarly, embryonic stem cells are generic cells at first. They get "training" from a signal. Then they develop tissue for the kidneys, liver, or other organs.

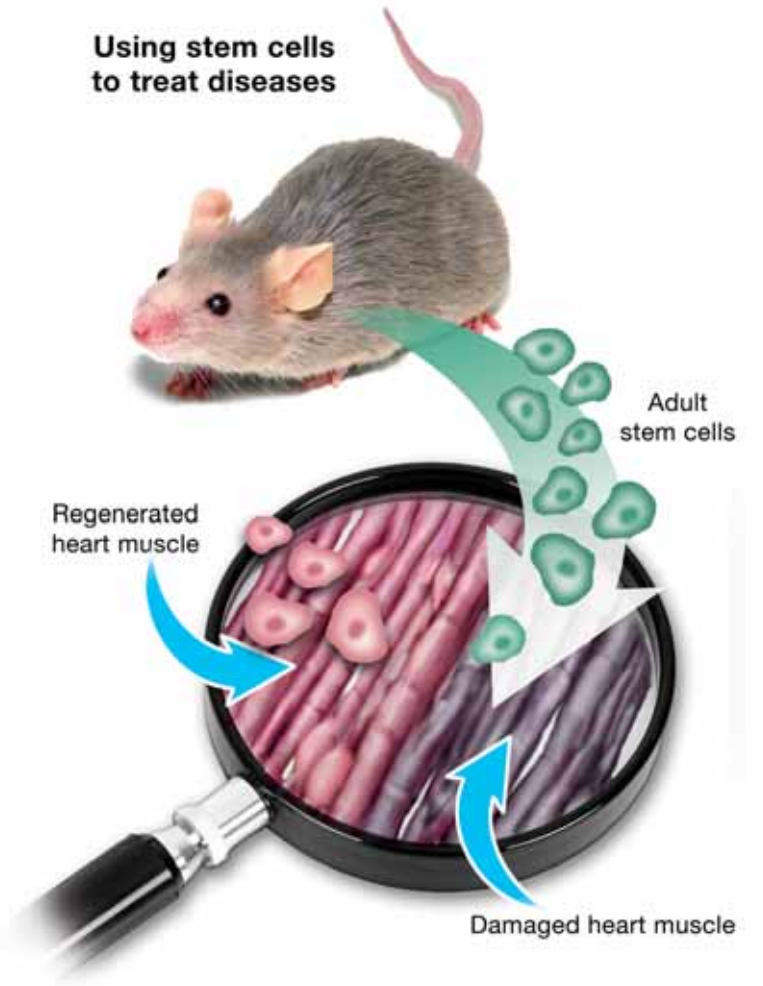
While the main job of embryonic stem cells is growth, the main job of adult stem cells is repair. They do not have as much potential as embryonic stem cells. They seem to already carry genetic information that determines which type of cells they can become. They exist alongside the types of cells they can produce. Adult stem cells in the skin, for example, develop into skin cells to help new skin grow after an injury.

The potential for treating diseases

Scientists think stem cells may help treat diseases. Can you think how this might work? Embryonic stem cells can develop into many other types of cells. If the right signals can be discovered, these cells might be able to replace or repair diseased tissue. Scientist's hope that diseases such as diabetes and heart disease may be treated this way someday.

Adult stem cells are already used in medicine. For 30 years, adult stem cells have been used in bone marrow transplants. The potential of adult stem cells is more limited, but scientists hope to use them to fight diseases. For example, research in mice indicates that putting adult stem cells into a damaged heart may help repair heart tissue.

Scientists are trying to better understand what triggers the differentiation of stem cells. As knowledge and understanding of stem cells increase, so does the potential for many new disease therapies.

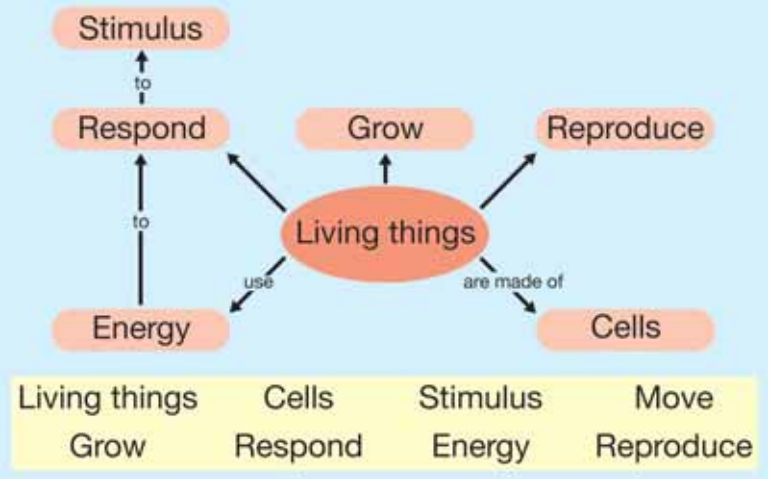


Questions:

1. What are the properties of stem cells?
2. Explain how stem cells change into different cell types.
3. What is the major difference between embryonic stem cells and adult stem cells?
4. How are adult stem cells used in medicine today?

CHAPTER ACTIVITY Making a Concept Map

A concept map is a way to represent information visually. A concept map consists of nodes that contain written concepts. The nodes are connected with lines to to show relationships. The lines are labeled with an arrowhead to describe the direction of the information.



In this activity you will create a concept map that explains how cells get and use energy. Your concept map should address the following question: **How do animal and plant cells use energy for life's processes?**

What you will do

1. Write the concepts below on separate index cards or sticky notes so they can be moved around.

mitochondria	growth	ATP	energy
chloroplasts	plant cell	food	carbon dioxide
oxygen	carbohydrates	energy	pigments
photosynthesis	carbon	sunlight	plants
animals	air	cellular respiration	chlorophyll

2. Obtain a large sheet of paper or poster board from your teacher.
3. Rank the concepts in order by placing the most general concepts at the top to the most specific term at the bottom. Think about the focus question to help rank the question. Begin with only one to three of the most general concepts at the top of the map.
4. Choose two to four sub concepts to place under each general concept.
5. Connect the concepts by lines. Label the lines with one or a few linking words that define the relationship between the two concepts. These should read as a statement. Draw arrow heads to show the direction of the information.
6. Look at your map and revise any part if necessary.
7. Look for cross links between concepts in different sections of the map. Draw and label these lines.
8. Present your concept map to the class and compare it to others.

Applying your knowledge

a. Explain the relationship between photosynthesis and growth.
b. Do plants take in organic food substances such as starch, sugar or protein from the soil?
c. As a plant grows it gains weight (mass). Where does this weight come from?
d. Where is carbon dioxide and water absorbed by most plants?
e. What is the role of chlorophyll in a plant cell?
f. How does the food you eat aid in cellular respiration?
g. How did your concept map change as you made it?
h. Revise your concept map again if you wish, after your class discussion.

Chapter 6 Assessment

Vocabulary

Select the correct term to complete the sentences.

chlorophyll	photosynthesis	active transport
pigment	ATP	osmosis
cellular respiration		diffusion

Section 6.1

1. Movement of molecules that requires energy is called ____.
2. ____ is a kind of diffusion that involves water moving across the cell membrane.
3. Osmosis and ____ are two types of passive transport because they do not require energy.

Section 6.2

4. ____ stores and transfers chemical energy in cells.
5. Plant cells perform ____ to store energy from the sun in the form of molecules.
6. When ____ breaks down in the autumn, leaves change color as red, orange, and yellow pigments become visible.
7. ____ uses oxygen and glucose to produce carbon dioxide, water, and energy.
8. Chlorophyll is a ____, which is a molecule that absorbs some colors of light and reflects others.

Concepts

Section 6.1

1. Draw and label a diagram of the cell membrane.
2. How do different cells recognize each other?
3. Distinguish between diffusion and osmosis.
4. Identify each situation as an example of diffusion, osmosis, or active transport.
   a. making a cup of tea
   b. leftover salad wilting in the refrigerator
   c. smoke escaping from the chimney
   d. pumping up a tire with air
   e. stained cotton t shirt soaking in sink
   f. smell of perfume spreading through the room

Section 6.2

5. Why do plants look green?
6. How are breathing and cellular respiration related?
7. Do plant cells need to carry out respiration? Explain.
8. Create a table that compares photosynthesis and cellular respiration including: definitions, reactants, products, what organisms perform the process, and where it occurs in the cell.

Math and Writing Skills

Section 6.1

1. The concentration of a solution can be expressed as a *ratio* - a comparison of two numbers. For example if you dissolved 10 grams of sugar in one liter of water, you could say the concentration as a ratio - 10 g: 1L or 10g/L. Calculate these concentrations and ratios.
   a. You dissolve 120 g of sugar in 2 L of water. What is the concentration per liter? State the concentration as a ratio.
   b. You dissolve 50 g of salt in 3 L of water. What is the concentration per liter? State the concentration as a ratio.

2. Helium balloons float because helium is lighter than the mixture of gases in the surrounding air. Use what you learned about diffusion to explain why helium balloons deflate after a few days. How is the balloon like the cell membrane?

3. This chart shows the time (minutes) that it took for a substance to diffuse completely in a liquid of increasing temperature. (degrees Celsius). Use the data to help answer the questions and predict the affect of temperature on the rate of diffusion.

Temperature (degrees Celsius)	Time for diffusion (minutes)
10	8
20	4
30	2
40	1.8
50	1.6
60	1.4
70	1.2
80	1
90	.8
100	.5

   a. At what temperature was the rate of diffusion the fastest?
   b. At what temperature was the rate of diffusion the slowest?
   c. How does temperature affect the rate of diffusion?

Section 6.2

4. Fill in the greater than (>) or less than (<) symbol as appropriate to complete these statements about energy and wavelengths.
   a. the energy used in x rays ____ the energy used in microwaves
   b. the wavelengths of gamma rays ____ the wavelengths of radar
   c. the energy of blue visible light ____ the energy of orange visible light
   d. the wavelength of tv remote controls ____ the wavelengths of black lights

5. The word “photosynthesis” means “putting together with light.” Explain how the meaning of the word photosynthesis is related to the process.

6. Why are mitochondria sometimes called the powerhouses of cells? Explain.

Chapter Project

Potato experiment

Try this easy experiment, and then complete the project by answering the questions. Carefully slice a potato into thin round or oval pieces so that each slice has two flat, cut sides. USE EXTREME CARE WHEN USING A SHARP KNIFE! Place potatoes on a proper cutting surface such as a cutting board, and be sure the potato can't roll and move around while you cut it. It is best to have an adult do the cutting. Place a couple of potato slices in a bowl filled with plain water. Place some different potato slices in a second bowl of water to which 2 spoonfuls of salt has been added and dissolved. Wait about 15 minutes, and compare the potato slices. Pick them up out of the water and see if they feel different. Try bending the slices.

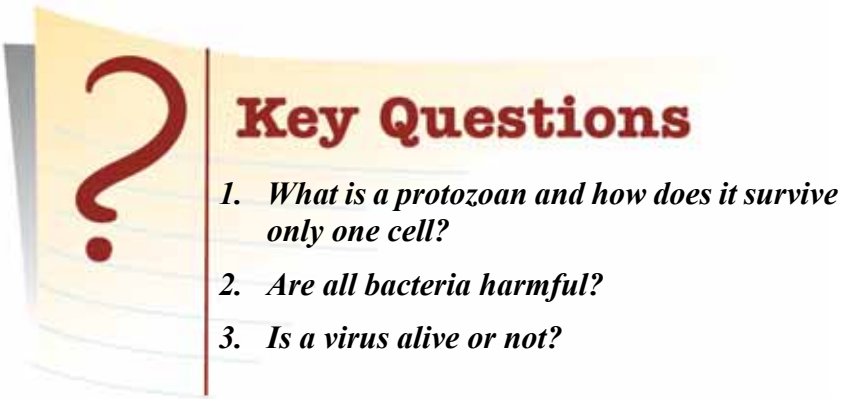
1. Describe the differences you noticed in the potatoes after they soaked for 15 minutes. Explain, using the terms cells and osmosis, what happened to cause these results.

2. Draw a labeled "before and after" diagram that can explain to someone who did not do the experiment exactly what happened and what the science is that explains the results. Use arrows to show movement of molecules.

Chapter 7

The Microscopic World

In previous chapters, you learned what cells are like on the inside and how they work. Most living things contain many cells. The human body contains *trillions* of cells. Did you know that some living organisms are made up of only ONE cell? Some of these single-celled creatures have been found living in volcano openings, polar ice, and even inside a human stomach! In this chapter, you will learn how organisms made up of only one cell carry out necessary life functions. You'll also learn about invaders of cells called *viruses.* Viruses aren't considered alive by most scientists. They invade cells and turn them into factories that make more viruses. It's a strange world when you start looking under a microscope!



Key Questions

1. ***What is a protozoan and how does it survive with only one cell?***
2. ***Are all bacteria harmful?***
3. ***Is a virus alive or not?***

7.1 Protozoans

Imagine shrinking down to the size of a cell and going for a swim in a drop of pond water (Figure 7.1). You enter a world filled with strange-looking creatures. One propels itself with a long whip. Another has hairs all over its body and uses them to swim. Watch out! There's a blob coming toward you and he looks hungry! This world might sound strange but it's real. Just look at a drop of water from a pond under a microscope. The creatures described are single-celled organisms known as *protozoans*. In this section, you will learn about their structure and function.

Figure 7.1: *What kind of life would you encounter in a drop of pond water?*

What are protozoans?

Protozoans are single-celled eukaryotes

A **protozoan** (in Greek *protos* = first and *zoon* = animal) is a single-celled *eukaryote* (an organism that has a cell nucleus) that has some animal-like characteristics. Many protozoans move about and feed like animals. Most protozoans exist as a single, eukaryotic cell. Some gather together in groups called *colonies*.

Protozoan habitats

Protozoans need a moist environment to survive. Ponds are ideal habitats for freshwater protozoans. They are also found in the ocean, in moist soil, and in the cells and tissues of plants and animals. In dry conditions, some protozoans can form a thick, protective wall around their cells. In this form, they can be blown about by the wind just like dandelion seeds. When they come in contact with moist conditions, they return to their normal form.

Classification of protozoans

Protozoans are most often placed in the Kingdom Protista. This kingdom also includes the plant-like algae, and strange fungus-like organisms called *slime molds*. Algae live in aquatic environments and make their own food like plants (Figure 7.2). Slime molds grow in damp environments and absorb their food.

VOCABULARY

protozoan - a single-celled eukaryote that has some animal-like characteristics.

Figure 7.2: *Fucus is a type of algae.*

Structure and function of protozoans

Protozoans have specialized organelles

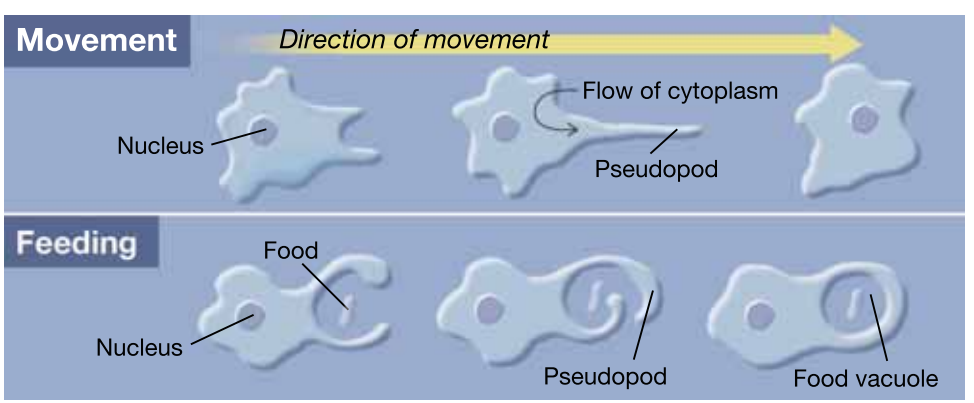
Protozoans come in an amazing variety of forms even though they consist of a single cell. While animals and plants have specialized cells and tissues, protozoans have specialized organelles. These organelles are used for movement, feeding, and other functions.

Ciliates

Ciliates are a group of protozoans that move by waving tiny, hair-like organelles called *cilia* (Figure 7.3). A *paramecium* is an example of a ciliate. It waves its cilia like tiny oars to move through the water. It also uses its cilia to sweep food into an organelle called a *gullet*. The *contractile vacuole* helps control the amount of water inside the paramecium. Since paramecia live in freshwater, there is a tendency for water to move into the cell by osmosis. The contractile vacuole pumps out excess water.

Amoebas

Amoebas are protozoans that move by means of *pseudopods* (in Latin, "false feet.") *Amoeba proteus* is a species found in ponds. An amoeba stretches its cytoplasm in the direction it will move. The stretched part becomes a pseudopod. The rest of the amoeba flows into the pseudopod. Amoebas also use their pseudopods to get food. An amoeba stretches out two pseudopods to surround a piece of food. The food is then taken in to form a *food vacuole*.



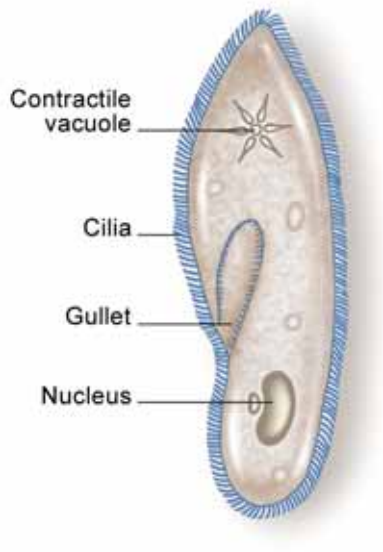


Figure 7.3: *A diagram of a paramecium.*

VOCABULARY

ciliates - a group of protozoans that move by waving tiny, hair-like organelles called cilia.

amoebas - a group of protozoans that move by means of pseudopods.

Flagellates

Flagellates are a group of protozoans that move using a whip-like organelle called a *flagella*. Many flagellates are a combination of plant and animal. They contain chlorophyll and can make their own food, like a plant. But they also eat other things, like an animal.

The euglena is a common flagellate

A *euglena* is a flagellate commonly found in pond water (Figure 7.4). It has a flagella located at one end of its body. Its mouth is located at the base of the flagella and leads to a gullet. At the same end, the euglena has a light-sensitive eyespot. This eyespot helps the euglena swim towards light so it can make its own food. If the euglena is kept from sunlight for long periods of time, its chlorophyll disappears and it loses the ability to make its own food. Then, it survives on food that it takes from its habitat.

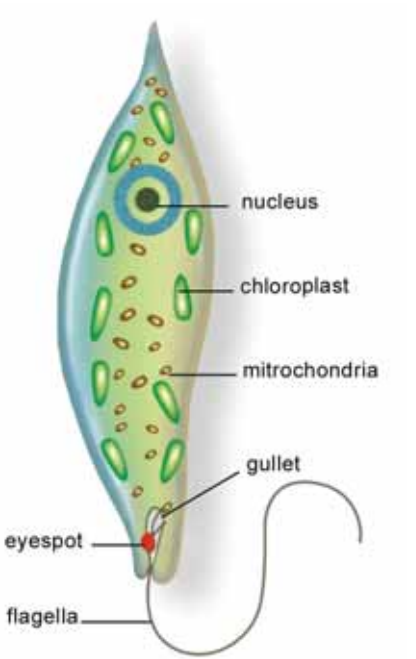
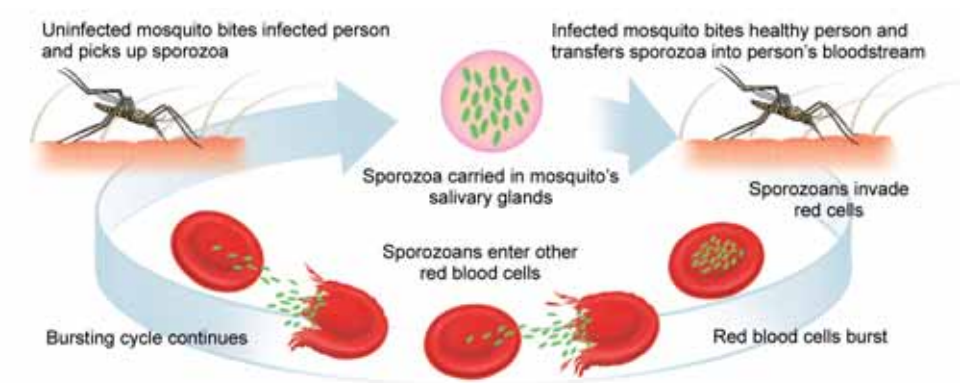


Figure 7.4: *A diagram of a euglena.*

Sporozoans

Sporozoans are a group of protozoans that do not have organelles for movement. All members of this group are parasites and live in the bodies of animals. A **parasite** is an organism that lives in or on another organism called a *host*. Parasites cause harm to their hosts. Malaria is caused by a sporozoan called *plasmodium*. Malaria is transmitted by mosquitoes. When the mosquito bites, plasmodium gets into the blood and infects red blood cells. Infected blood cells eventually burst causing sickness and death.



VOCABULARY

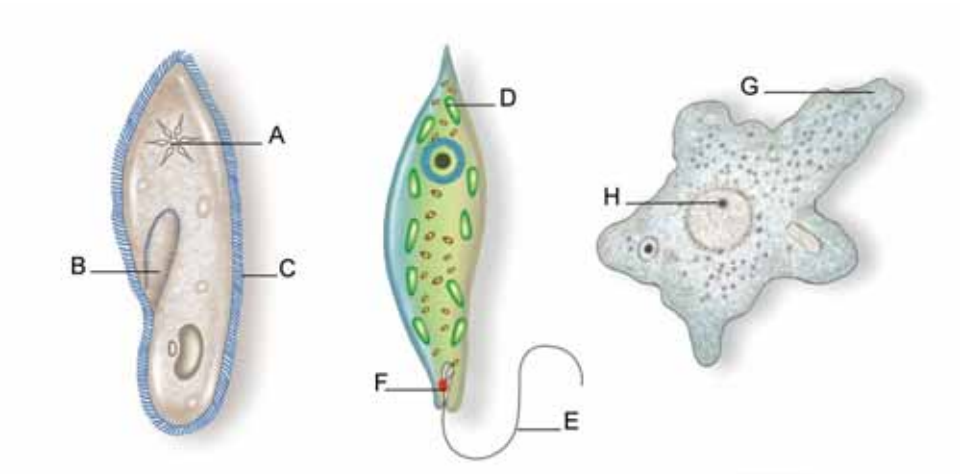
flagellates - a group of protozoans that move using a whip-like organelle called a flagella.

sporozoans - a group of protozoans that do not have organelles for movement and are parasites.

parasite - an organism that lives in or on a host organism and causes it harm.

7.1 Section Review

1. To which kingdom do protozoans belong? What other organisms are in that kingdom?
2. What are some animal-like characteristics of protozoans? Which characteristic of protozoans is not animal-like?
3. What type of environment do protozoans need to survive?
4. Label the parts of the organisms below:



5. Complete the table below:

Protozoan group	Type of movement	Other characteristics	Example
Ciliates			paramecium
Amoebas		use pseudopods to get food	
Flagellates	flagella		
Sporozoans		many species are parasites	

CHALLENGE

Each group of protozoans (ciliates, amoebas, flagellates, and sporozoans) has parasitic species. Use the Internet and books to find at least one disease that affects humans and is caused by a member of each group.

Next, pick one of the diseases and make an informational brochure about it. Include the following information in your brochure.

1. What is the name and group of the organism that causes the disease?
2. How is the disease transmitted?
3. What are the symptoms of the disease?
4. What parts of the world does the disease affect?
5. What are the treatments for the disease?
6. How can the disease be prevented?

7.2 Bacteria

"Wash your hands—you don't want to get sick from bacteria!" How many times have you heard a command like that? Bacteria are everywhere and some can make you sick. But did you know that many types of bacteria are helpful? In fact, life on Earth depends on them. Bacteria take elements like carbon and nitrogen out of the air and turn them into compounds living things can use. They recycle nutrients from dead plants and animals so they can be reused. There are even bacteria in your digestive system (Figure 7.5)! In this section, you'll learn about the structure and function of bacterial cells.

Figure 7.5: *Bacteria in your digestive tract help you digest food.*

What are bacteria?

Bacteria are the only prokaryotes

Bacteria are organisms that consist of a single, prokaryotic cell. Bacteria are the only *prokaryotes* (cells with no nuclei). All other life forms on Earth are eukaryotes. Bacterial cells have a cell membrane that is surrounded by a tough cell wall (Figure 7.6).

VOCABULARY

bacteria - organisms that consist of a single, prokaryotic cell.

Where do bacteria live?

Bacteria live on or in just about every material and environment on Earth. They live in soil, water, and air. They are found in the coldest regions of the Arctic and even in boiling waters near undersea volcanoes. There are many bacteria in each environment. A square centimeter of your skin has thousands of bacteria. A teaspoon of soil contains more than a billion bacteria.

1 or 2 kingdoms of bacteria?

Some scientists group all bacteria into the Kingdom Monera. Others divide bacteria into two kingdoms, Archaebacteria and Eubacteria. Archaebacteria are found in extreme environments like volcanic vents in the ocean. They are thought to be the first organisms on Earth. Eubacteria are found almost everywhere else and have a different chemical makeup than archaebacteria. Both types of bacteria are prokaryotic, single-celled organisms. As future discoveries are made, these groups may change.

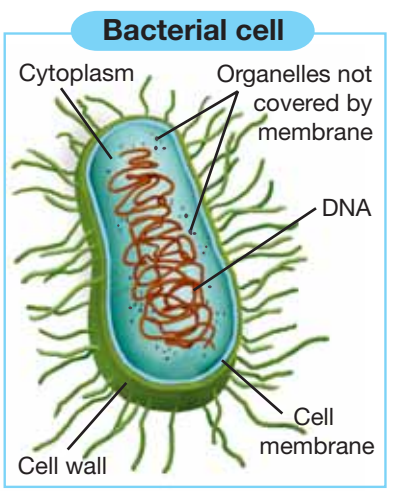


Figure 7.6: *A bacterium is a prokaryotic cell.*

Size and shape of bacteria

How big are bacteria?

The average bacterial cell is about 1.5 million times smaller than the average person. Bacteria are not easy to measure using meters, centimeters, or even millimeters. *Micrometers* (µm) are used to measure them. One micrometer is equal to one-millionth of a meter. The size of bacteria range from 1µm to 5µm. Eukaryotic cells tend to be about ten times larger than bacterial cells (Figure 7.7).

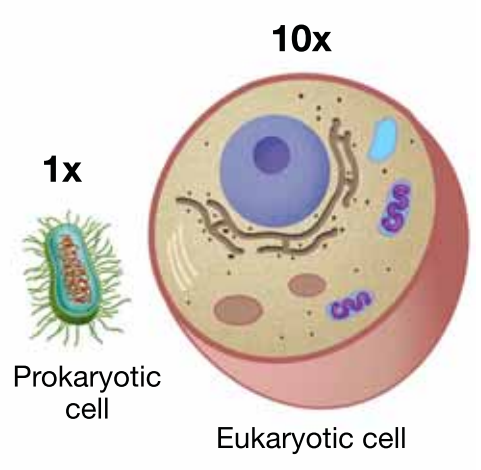
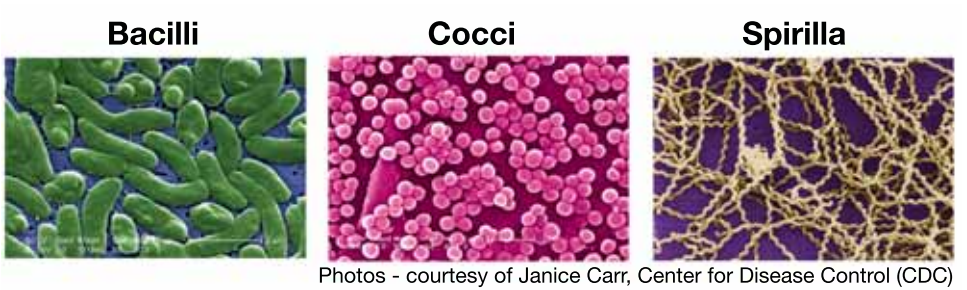


Figure 7.7: *Comparing the size of a typical bacteria to a typical eukaryotic cell.*

Shapes of bacterial cells

Bacteria are often described according to the shape of their cells. Rod-shaped bacteria are called *bacilli*. Ball-shaped bacteria are called *cocci*. Spiral-shaped bacteria are called *spirilla*. Some bacterial cells exist as individuals while others exist in pairs, chains, or clusters. The graphic below shows the shapes of bacteria.



Photos - courtesy of Janice Carr, Center for Disease Control (CDC)

Rod-shaped bacteria are called bacilli. Ball-shaped bacteria are called cocci. Spiral-shaped bacteria are called spirilla.

Make a set of study flash cards to help you remember the terms you learn in this chapter. Place the term on one side of the card and its definition on the other. Draw pictures along with the definition where appropriate.

Movement and feeding

How bacteria move

Bacteria move around in many ways. Some bacteria move using flagella. They rotate their flagella to propel themselves through liquid environments (Figure 7.8). Other bacteria have a slimy layer on the outside. They use it to slide over surfaces. Many types of bacteria do not have their own means of movement. Bacteria are simply carried by the movement of air or liquid. They can also be transferred from surface to surface. For example, when you touch a surface, bacteria are transferred from that surface to your skin.

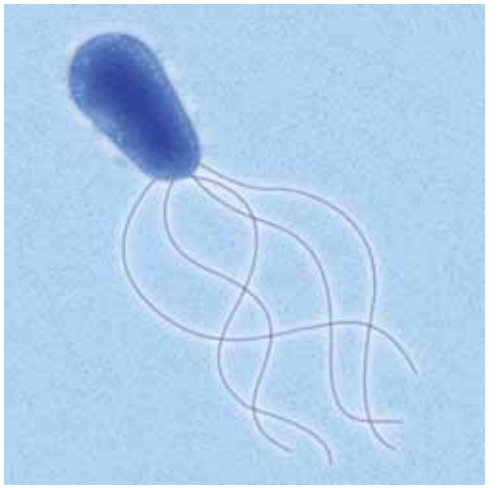
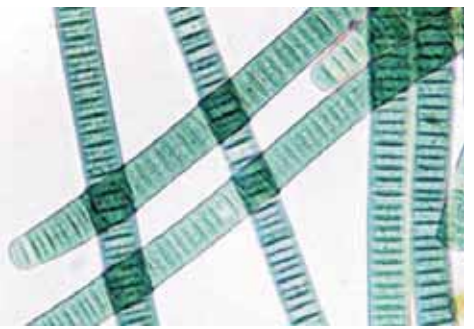


Figure 7.8: *Some bacteria move using flagella.*

Some bacteria make their own food

Bacteria get their food in many ways. **Photosynthetic bacteria** make their own food from sunlight and carbon dioxide, just like plants. Also like plants, they produce oxygen. *Cyanobacteria* are examples of photosynthetic bacteria (right). Bacteria that live around volcanic vents or other harsh environments can make their own food without sunlight. They use chemicals to produce their food instead of energy from the sun. This process is called *chemosynthesis*.



VOCABULARY

photosynthetic bacteria - bacteria that produce their own food through photosynthesis.

Some bacteria get their food from outside

Many types of bacteria absorb food from the material they live on or in. Bacteria that break down dead organisms get their food in this way. You have bacteria in your digestive system that absorb nutrients from the food you eat. Termites have bacteria in their stomach that absorb and break down cellulose. Cellulose is the compound that makes up wood, a termite's favorite food. The bacteria help the termite get energy and nutrients from wood.

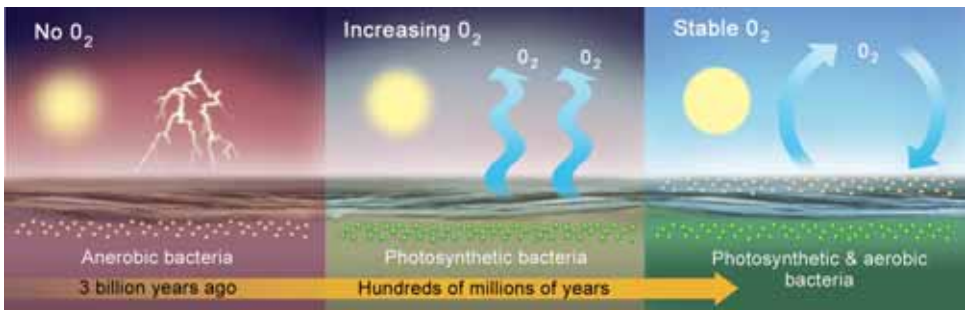
Bacteria and the beginning of life on Earth

Bacteria were the first organisms

Scientists believe that bacteria were the first organisms on Earth. Evidence comes from fossils of single-celled prokaryotes found in rocks that are more than 3 billion years old. At that time, there was little oxygen in the atmosphere. The earliest life was therefore *anaerobic* (Latin for "without oxygen"). **Anaerobic bacteria** do not require oxygen for cellular respiration. Today, anaerobic bacteria thrive in places that have little or no oxygen, like swamps.

Bacteria increased oxygen in Earth's atmosphere

Over time, some bacteria developed the ability to use photosynthesis. Cyanobacteria, still in existence today, were one of the first photosynthetic bacteria. One of the products of photosynthesis is oxygen. Over hundreds of millions of years, the amount of oxygen in Earth's atmosphere increased. This allowed *aerobic* bacteria to develop. **Aerobic bacteria** use oxygen for cellular respiration. There are many different species of aerobic bacteria living today.



Eukaryotic cells developed from prokaryotic cells

Eventually, eukaryotic cells developed from bacteria. A scientific theory states that long ago, smaller prokaryotic cells were engulfed by larger prokaryotic cells. The smaller cells began to survive by living inside of the larger cells. Over time they took on specific functions inside the larger cells like producing energy. Eventually, the smaller cells became the organelles (like mitochondria) inside of eukaryotic cells (Figure 7.9).

VOCABULARY

anaerobic bacteria - bacteria that do not require oxygen to survive.

aerobic bacteria - bacteria that use oxygen for cellular respiration.

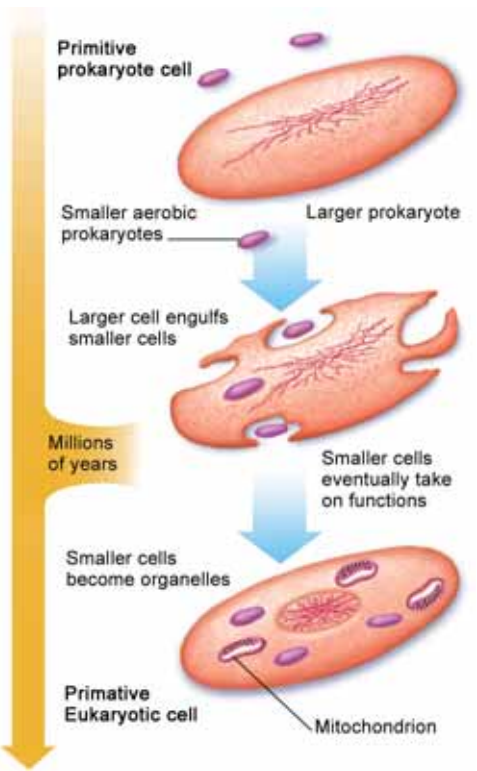


Figure 7.9: *How eukaryotic cells developed from prokaryotic cells.*

The importance of bacteria

Bacteria and industry Bacteria are used in many areas of industry. Yogurt and cheese are made with certain types of bacteria. Some important drugs like insulin are made with the help of bacteria. Sewage treatment plants use bacteria to break down waste products. Other bacteria are used in mining and to clean up oil spills. There is a good chance that you've benefitted from bacteria today!

Symbiosis Many kinds of bacteria have developed close relationships with other organisms. In many relationships the bacteria and the organism it lives with benefit. We learned in Chapter 3 that this type of symbiosis is called *mutualism*. One species of bacteria lives in your intestines. You provide the bacteria with a warm, safe place to live. In return, the bacteria help you break down and absorb certain compounds in foods. Bacteria even make some vitamins that your cells cannot make on their own.

Life on Earth depends on bacteria Bacteria are an important part of the nutrient cycles that all life depends upon. For example, plants need nitrogen to make amino acids, the building blocks of protein. Bacteria in the soil take nitrogen out of the air and turn it into a form plants can use. When animals eat plants, they rearrange the amino acids into other proteins. When an organism dies, bacteria break down the dead material and turn it back into compounds that living things can use again (Figure 7.10). Bacteria are "nature's recyclers."

Bacteria and antibiotics Have you ever had a bacterial infection? If so, you've experienced one of the harmful effects of bacteria. Bacteria cause diseases like strep throat, respiratory infections, and infected wounds. Bacterial diseases are treated with drugs called *antibiotics*. Antibiotics kill bacteria without harming your own cells. Different antibiotics are used for fighting different types of bacteria.

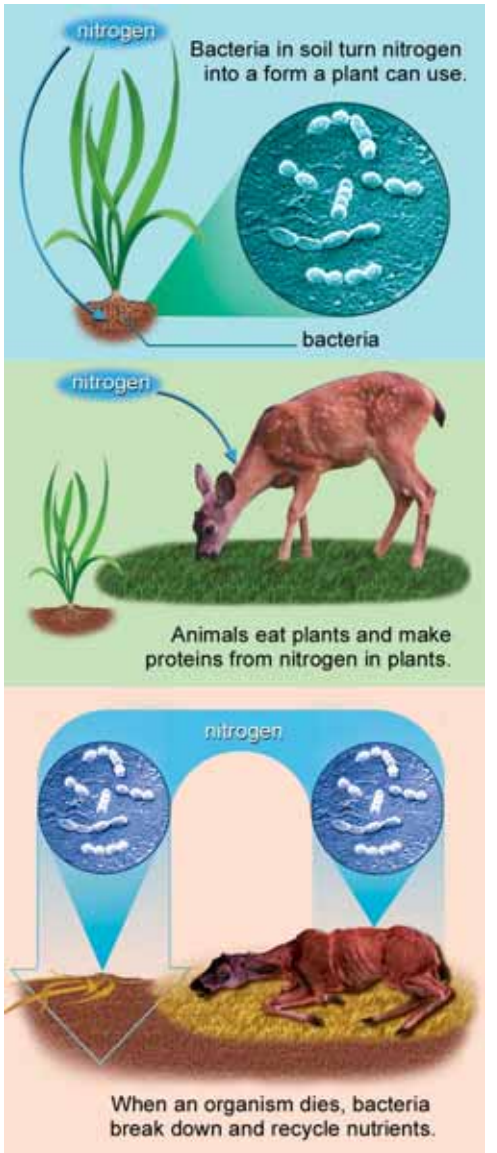
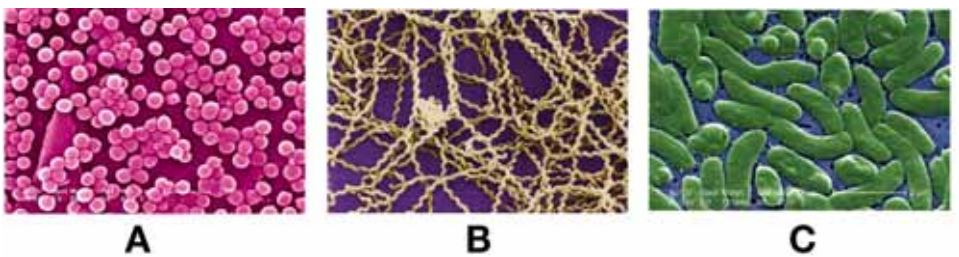


Figure 7.10: *Bacteria are an important part of nutrient cycles.*

7.2 Section Review

1. How are bacteria similar to and different from protozoans?
2. Name the two major groups of bacteria.
3. Which units are used to measure bacteria?
4. Name each type of bacteria in the picture below.



5. What is the difference between aerobic and anaerobic bacteria?
6. Explain how bacteria changed Earth's atmosphere.
7. What is mutualism? Give one example of mutualism that involves bacteria.
8. List four important things about bacteria.
9. How do plants depend on bacteria?
10. Why are bacteria sometimes referred to as "nature's recyclers?"
11. What are antibiotics and how are they used?
12. Beginning with ancient anaerobic bacteria, list the sequence of steps leading to the first eukaryotic cells.

CHALLENGE

Scientists believe that cyanobacteria were the first photosynthetic organisms. Explain how this may have helped more oxygen-breathing organisms to develop.

SOLVE IT!

Bacteria reproduce rapidly. Suppose a population of bacteria doubled every 24 hours. You start out with only 2 bacteria. Make a population vs. time graph. Use days as your units of time and graph the population from 0 to 14 days.

7.3 Viruses

Have you ever had the flu? Your muscles ache and your throat is sore. You also get a fever and an upset stomach. The flu is a disease caused by a *virus*. Viruses infect cells and cause many diseases, including smallpox, flu, AIDS, and the common cold. To *infect* means to invade and produce an infection. Viruses infect virtually all types of cells: bacterium, protozoan, fungus, plant, animal, and human. In this section you will learn about viruses and how they infect cells.

VOCABULARY

virus - a tiny, nonliving particle made up of genetic material and protein.

host cell - a cell that is, or becomes, infected with a virus.

The structure of viruses

What is a virus?

A **virus** is a tiny, nonliving particle made up of genetic material and protein. Viruses are not cells and are not made of cells. By itself, a virus can do nothing. It does not eat, produce its own food, or reproduce. All a virus can do is wait for a *host cell* to infect. A **host cell** is a cell that is, or becomes, infected with a virus. Both prokaryotic and eukaryotic cells can be hosts to viruses. Flu viruses may infect cells of your respiratory tract (Figure 7.11). When the virus spreads to many of your cells, you get sick.

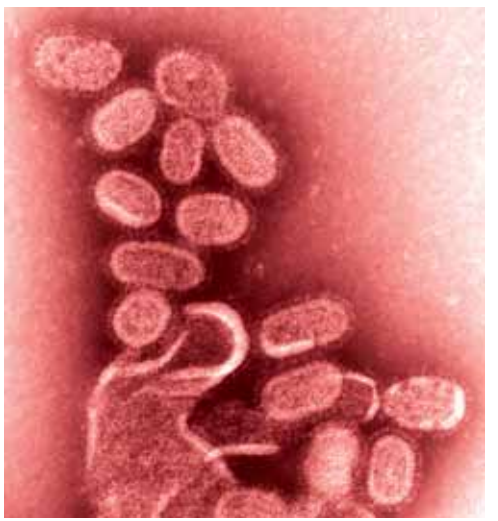
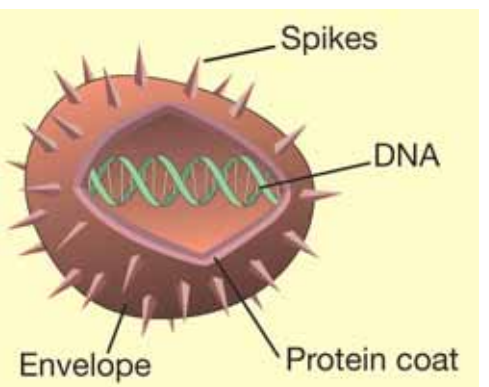


Figure 7.11: *An image of flu viruses bursting out of a cell. The image was captured using an electron microscope. Photo courtesy CDC Public Health Image Library.*

The structure of viruses

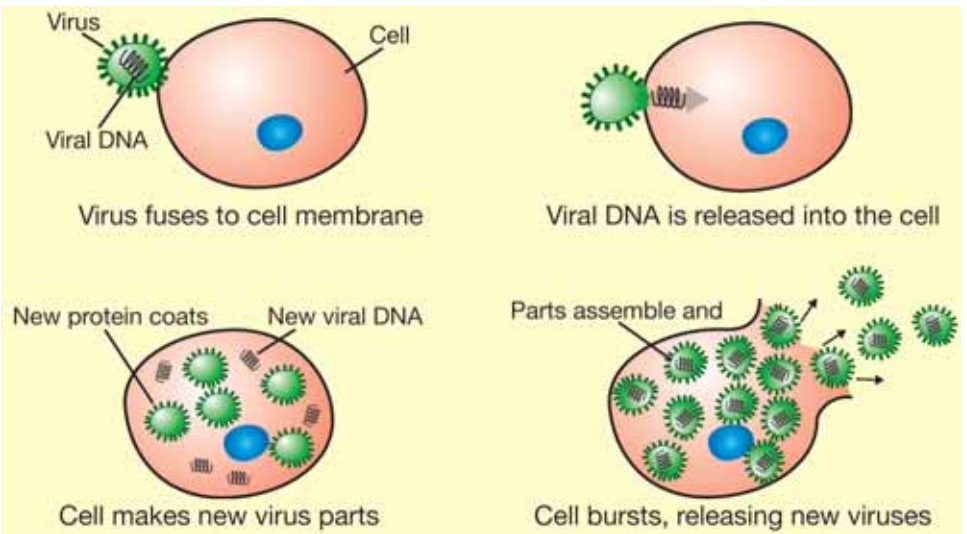
Viruses can be as much as 10,000 times smaller than bacteria. A virus contains a core DNA. Surrounding that core is a *protein coat*. In some viruses, the protein coat is covered by an envelope made of proteins, lipids, and carbohydrates. That envelope may have spikes made of carbohydrates and proteins that help the virus particles attach to host cells.



How viruses infect cells

Host cells become factories for the virus

When some viruses come into contact with host cells, they trigger the cells to engulf them. Other viruses fuse themselves to the cell membrane and release their DNA into the cell. Once inside, the viral DNA changes the function of the cell. The cell now becomes a factory that produces new viruses. Eventually the infected cell dies and bursts, freeing the new viruses. In some cases, new viruses just pinch off so the cell remains alive.



Viruses and host cells

A virus must be able to get its DNA inside of a cell before it can multiply. The cell membrane controls what enters the cell. How does a virus trick a cell into letting it enter? The "lock and key" mechanism is the most common explanation. Certain proteins on the virus' protein coat must fit certain receptor sites on the host's cell membrane (Figure 7.12). If the proteins fit, the virus can enter and infect the cell. If the proteins do not fit, the virus cannot enter the cell or fuse with its cell membrane. Thus the viral DNA cannot enter the cell and cause an infection.

STUDY SKILLS

A tank crashes through the walls of a car factory. People in the tank get out and turn the car factory into a tank factory. An *analogy* is a way to find similarities between things that are different. How does this analogy explain how a virus reproduces? Try and think of another analogy for how a virus reproduces.

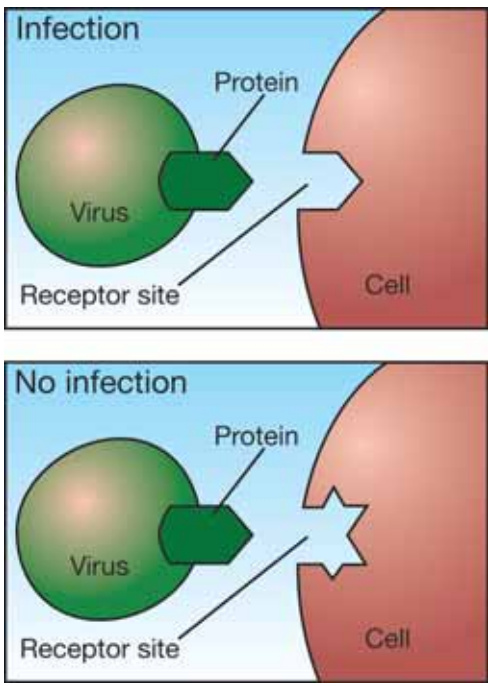


Figure 7.12: *If the proteins fit, the virus can infect the cell.*

The spread of viruses and immunity

The spread of a viral infection

Once free from the host cell, new viruses infect other cells. Because one virus causes a cell to produce thousands of new viruses, viral infections spread quickly throughout the body. Catching the flu is a good example of how this process works.

1. An infected person sneezes near you.
2. You inhale a virus, and it attaches to cells lining the inside of your nose.
3. The virus attacks those cells and causes them to make new viruses.
4. The host cells break and new viruses spread into your bloodstream and also into your lungs. Infected tissues cause different symptoms like muscle aches and sore throat.

The immune system

Your **immune system** protects your cells from unfamiliar objects like viruses and bacteria (Figure). With the flu virus, your immune system produces chemicals that cause your body temperature to increase. You get a fever. That fever slows down the production of new viruses. This is because most of your body's chemical reactions work best at a temperature of 98.6 °F (37 °C). If your temperature rises, the reactions slow down.

Antibodies

Once the cells of your immune system recognizes a virus, they make antibodies to stop further infections. **Antibodies** are proteins that bind to viruses and prevent them from infecting cells (Figure 7.13). If you come in contact with the same virus again, the cells of your immune system recognize it and immediately start producing antibodies to stop the virus's spread. The cells of your immune system produce different antibodies for different viruses.

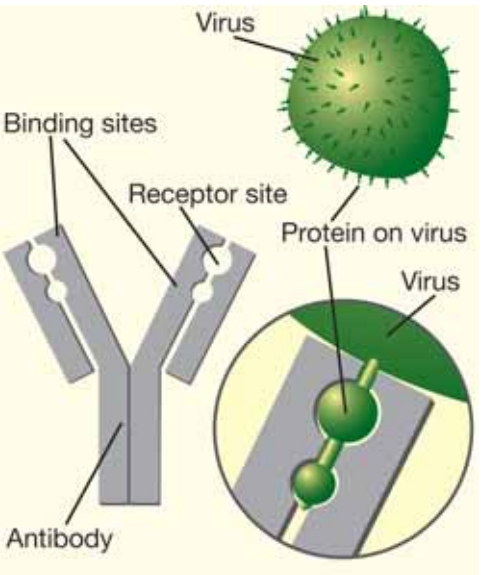


Figure 7.13: *Antibodies prevent viruses from entering cells.*

VOCABULARY

immune system - a system that protects an organism from unfamiliar objects like viruses.

antibodies - proteins that bind to viruses and prevent them from infecting cells.

Vaccines

A vaccine causes your immune system to produce antibodies to a particular virus. A **vaccine** is a preparation made from weakened virus particles or their empty protein coats. That is why vaccines do not make you sick. Your immune system mounts a response against the particles and makes antibodies. When you come in contact with the real virus, your immune system acts quickly to prevent illness (Figure 7.14).

Changes in the protein coat

New vaccines must be made each year to prevent some viral infections. The flu is a good example. After multiplying many times, flu viruses end up with mistakes in their genetic instructions. These mistakes may alter the protein coat slightly. With a different protein coat, the immune system may not recognize the virus. This means that one year's batch of flu vaccines might not be as effective against the flu virus the next year.

7.3 Section Review

1. Why is a virus not considered a living thing?
2. Explain using steps, how a virus multiplies.
3. Name three diseases caused by a virus.
4. Explain how a virus tricks a cell so it can enter it through the cell membrane.
5. Describe, using several steps, how a virus infects cells and spreads throughout an organism.
6. How does the immune system try to fight off a virus?
7. What is a vaccine? Why do you think a vaccine is sometimes referred to as "artificial immunity?"
8. Explain why a new flu vaccine has to be produced each year.

VOCABULARY

vaccine - a preparation of virus particles that, when injected into the body, causes the immune system to produce antibodies.

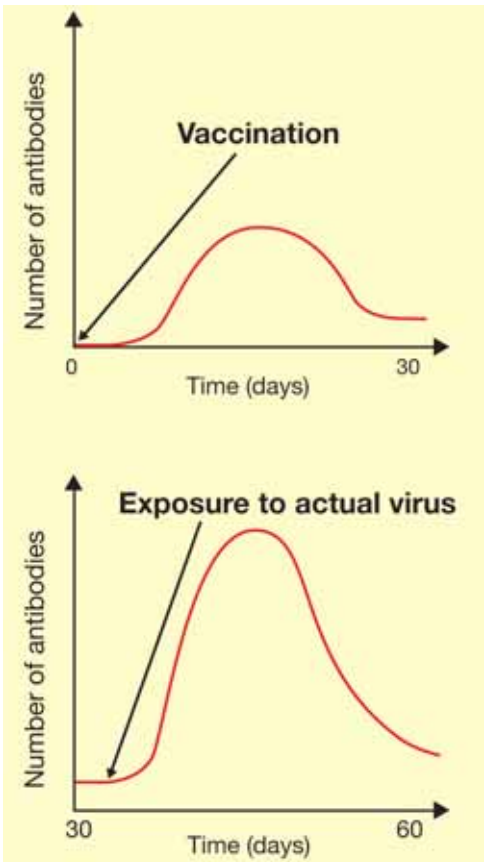


Figure 7.14: *A vaccination helps your immune system produce antibodies quickly when exposed to a virus.*

ECOLOGY CONNECTION

The Good, The Bad, The Microbe

What are our bodies made of? Water, oxygen, tissue, yes - but you might be surprised to learn that living creatures also make up much of the human body. They are called microbes and billions of them are swirling inside you and on your skin right now. We cannot see or feel them, but microbes are all over us. And we can't live without them.

What is a microbe?

Microbes are single-celled organisms too small to see with the human eye. Scientists use microscopes to study them and understand how they work. There are four major types of microbes: bacteria, viruses, fungi, and protozoa.

Microbes live all around us, in air and soil, in rocks and water. They also live in plants, animals, and in our bodies. Microbes are the oldest life form on Earth. Scientists estimate that these creatures date more than 3.5 billion years.

Microbiologists are scientists who study microbes. They work in a variety of settings: helping to keep our food and water from contamination, working in hospitals to determine what germs make us sick, or trying to solve environmental problems.

A friend and an enemy

Microbes are often called by the nickname "bugs." Some microbes can cause sicknesses like the common cold, strep throat, and chicken pox. However, more than 95 percent of microbes are harmless, despite their bad reputation. For example, *Escherichia coli* (*E. coli*) lives safely in our intestines. *E. coli* produces vitamins K and B-complex, two essential nutrients we cannot make otherwise. We also have many other useful bacteria living in our intestines that prevent dangerous bacteria from infecting our bodies.

Although most *E. coli* is helpful to our bodies, a rare strain causes severe food poisoning. It has a slightly different genetic makeup than the *E. coli* in our intestines. That other strain of *E. coli* is usually spread through contaminated animal meat, but can be killed easily by heat. All the more reason why the meat we eat be cooked to an internal temperature of 160° Fahrenheit.

Bacteria play an important role in producing food and medicine. For example, yogurt, sauerkraut, and cheese are all made with bacteria. Streptomyces, a bacteria found in soil, is used to make the antibiotic streptomycin.

Photo - courtesy of USGS

Microbes can live in all kinds of environments. Some require oxygen, others thrive without it. Also, microbes can survive along a huge spectrum of temperatures. Psychrophiles are cold-loving bacteria that live in the Arctic and Antarctic at subfreezing temperatures. In great contrast, thermophiles are heat-loving bacteria that exist at extremely high temperatures. Thermophiles are found in the hot springs of Yellowstone National Park, where temperatures are about 160°F. Extreme thermophiles, or hyperthermophiles, live near volcanic vents on the ocean floor, where temperatures reach as high as 235°F.

Bacteria of Searles Lake

Searles Lake, located in the Mohave Desert of southeastern California, is also home to bacteria living in extreme conditions. In the summer, temperatures in this area reach 100°F. The lake is about 10 times saltier and 70 times more alkaline than seawater. To make matters worse for living creatures, it has high concentrations of toxic elements like arsenic and boron. The arsenic levels are 29,000 times higher than that allowed in drinking water. Not surprisingly, given such a harsh environment, very few organisms live in Searles Lake. But scientists have discovered bacteria that are able to survive. In fact, these microbes use the dissolved arsenic as a source of energy. By learning more about them, scientists hope to find ways to clean drinking water that has been polluted by arsenic. They also believe such knowledge may aid in their search for life on other planets.

Photos - courtesy of USGS

Questions:

1. What are the four major types of microbes?
2. What are the good and bad features associated with bacteria?
3. What are some of the extreme environments in which microbes can live?
4. How do scientists hope to use what they learn from studying the bacteria of Searles Lake?

CHAPTER ACTIVITY Outbreak! Patient Zero

An *epidemic* spreads rapidly by infection and affects many individuals in a population at the same time. Examples of epidemics could be the flu, measles, and strep throat. *Patient zero* is the first patient in a population to become infected.

Imagine that there is an outbreak of a bacterial infection at your school. You know that the infection spreads through physical contact. Patient zero could have caught the bacteria by touching an object that was infected. This person then spread the bacteria by touching other items and individuals. In fact, you could be patient zero and don't even know it! In order to contain the infection, you need to isolate its source. See if you can figure out the source of the infection in the following simulation.

For the activity, you will need a deck of cards.

What you will do

1. Shake hands with 3 different classmates hands and record the names of the students.
2. Your teacher will randomly choose one card from the deck and NOT disclose its identity to the class. The card will then be reinserted back into the deck.
3. Each student will then select one card from the deck.
4. The teacher will ask for all students who have the same card number or face card to stand up. For example, all students holding the number 8 card. There can be up to 4 students with the number 8 card. Or, all students with a King. Again, there can be up to 4 students with a King.
5. The students standing are the infected students. List the name or names on the board.
6. Record the name of the student whom you suspect is patient zero. Use evidence to support your hypothesis.
7. Take a class poll to see who is the number one suspect.
8. After you identify the student that is believe to be patient zero, make a flow chart as a class to see if your hypothesis is correct. Use the information from the hand-shaking activity. If the flow chart does not work out, repeat the process until you are satisfied with the answer.

Applying your knowledge

a. Identify at least 2 ways that the outbreak activity is realistic.
b. You often come in contact with sick students but don't become ill. What defenses does the human body have to fight off an infection?
c. Are there any extra precautions that you and your classmates could have taken to reduce the spread of the disease?
d. Not all diseases are spread by physical contact. How else might diseases spread? List at least 2 other forms of spreading a disease.

Chapter 7 Assessment

Vocabulary

Select the correct term to complete the sentences.

amoebas	aerobic bacteria	anaerobic bacteria
antibodies	bacteria	ciliates
flagellates	host cell	immune system
parasite	photosynthetic bacteria	protozoan
sporozoans	vaccination	virus

Section 7.1

1. ____ move using tiny hair-like organelles.
2. Ciliates, flagellates, amoebas, and sporozoans are the major groups of ____s.
3. A ____ lives in or on a host organism and causes it harm.
4. ____ include the Euglena, which is a common pond organism that has characteristics of both plants and animals.
5. The group of protozoans that have no organelles for movement are ____.
6. ____ use their pseudopods for movement and feeding.

Section 7.2

7. Just like plants, ____ make their own food from sunlight and carbon dioxide.
8. Bacteria that use oxygen for cellular respiration are called ____.
9. Scientists believe that the first life on earth were ____ because there was little oxygen in the atmosphere more than 3 billion years ago.
10. ____ are prokaryotes.

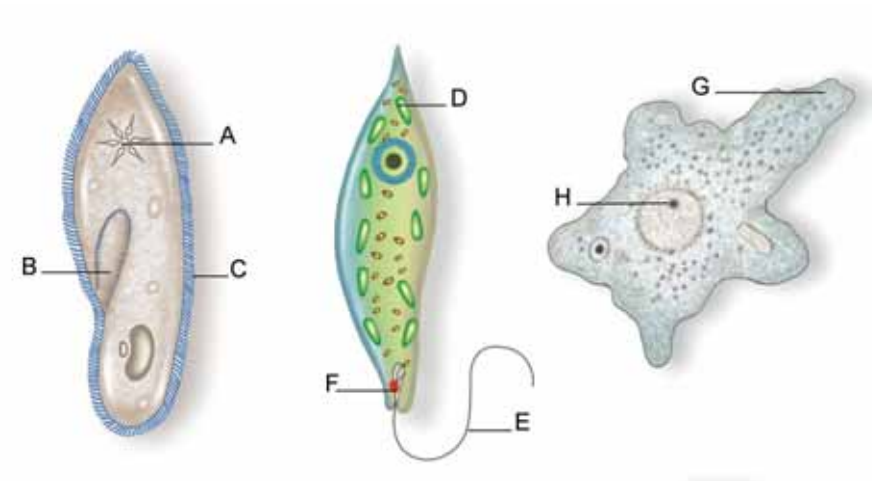
Section 7.3

11. A ____ of an organism becomes infected with a virus.
12. Your _____ protects you from unfamiliar objects like bacteria and viruses.
13. A _____ is not considered a living thing because it is not a cell and cannot eat, move, or reproduce without a host.
14. You get a ____ to teach your immune system to produce the antibodies to fight off viruses.
15. Once your immune system recognizes a virus, it produces ____ to stop further infections.

Concepts

Section 7.1

1. What does the word "protozoan" mean?
2. Name each labeled structure and explain its function.



3. What can some Protozoans do to survive through dry conditions?
4. How are protozoans divided into major groups?
5. Classify these Protozoan characteristics into the correct subgroup:
   a. pseudopods
   b. tiny oar-like hairs
   c. no special structure for movement
   d. whip-like tail

Section 7.2

6. Compare and contrast prokaryotic and eukaryotic cells.
7. Draw and a label a bacterial cell.
8. Describe three different methods that bacteria have for locomotion and nutrition.
9. Explain four ways that bacteria are used in industry.
10. The names of bacteria often give clues about their shape and arrangement. Read about these prefixes:
    - *diplo* - two
    - *tetra* - four
    - *strepto* - chain
    - *staphylo* - clumps

    Draw what these bacteria would probably look like:
    a. tetracoccus
    b. diplobacillus
    c. streptobacillus
    d. staphylococcus

Section 7.3

11. Create a chart to compare protozoans, bacteria, and viruses including these characteristics: cell type, size, structures, nutrition, locomotion, ways helpful, ways harmful.
12. How do viruses trick cells so that it can enter?
13. How do antibodies work to stop further infection?
14. Why do scientists need to make new vaccinations each year?

Math and Writing Skills

Section 7.1

1. Write a letter to a friend from the perspective of one of these protozoans: amoeba, paramecium, or euglena. Tell your friend about what you have been up to recently. Be creative.
2. Create an acrostic for one of the groups or examples of protozoans. An acrostic is a series of lines in which certain letters, usually the first in each line, form a word or message when read in order.

Section 7.2

3. A bacterium divides once every half an hour. How many bacteria would there be after 3 hours?
4. How large are eukaryotic cells? Remember that eukaryotic cells are 10 times larger than bacteria cells, which range from 1 to 5 micrometers in length.
5. Your friend thinks that the world would be a better place without bacteria. Convince him that bacteria are vital to life on Earth using at least three specific examples.

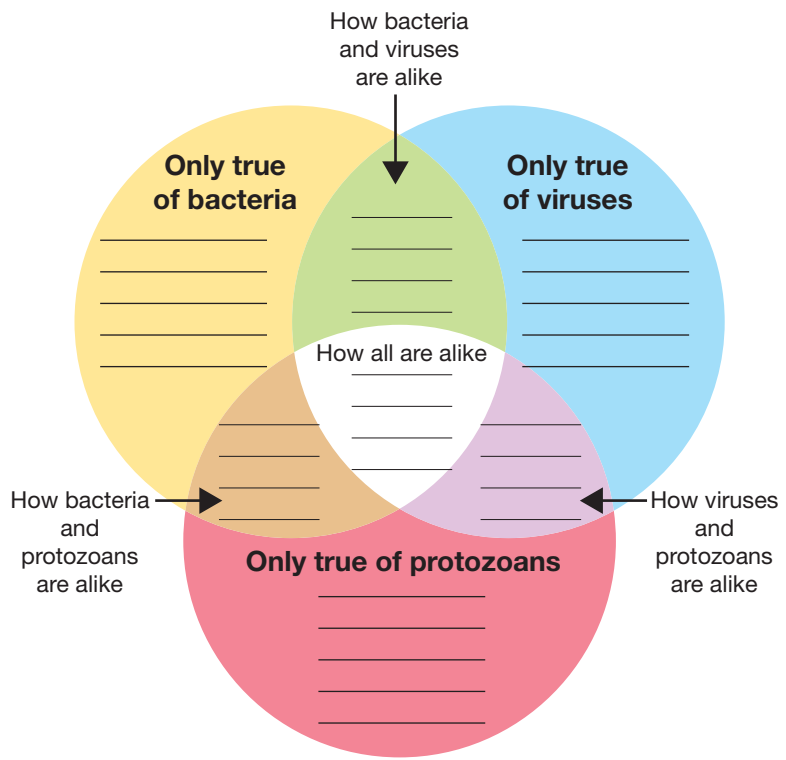
Section 7.3

6. If a virus was enlarged 10,000 times, it would be the size of a grain of salt. How tall would you be if you were enlarged 10,000 times?
7. How do you think computer viruses got their names? Compare and contrast computer viruses and viruses.
8. Write a public service announcement for a radio show that teaches young children how to stay healthy during cold and flu season.
9. Interview your parents or family members to find out what kind of vaccinations you have had and when you received them.

Chapter Project

Bacteria vs. Viruses

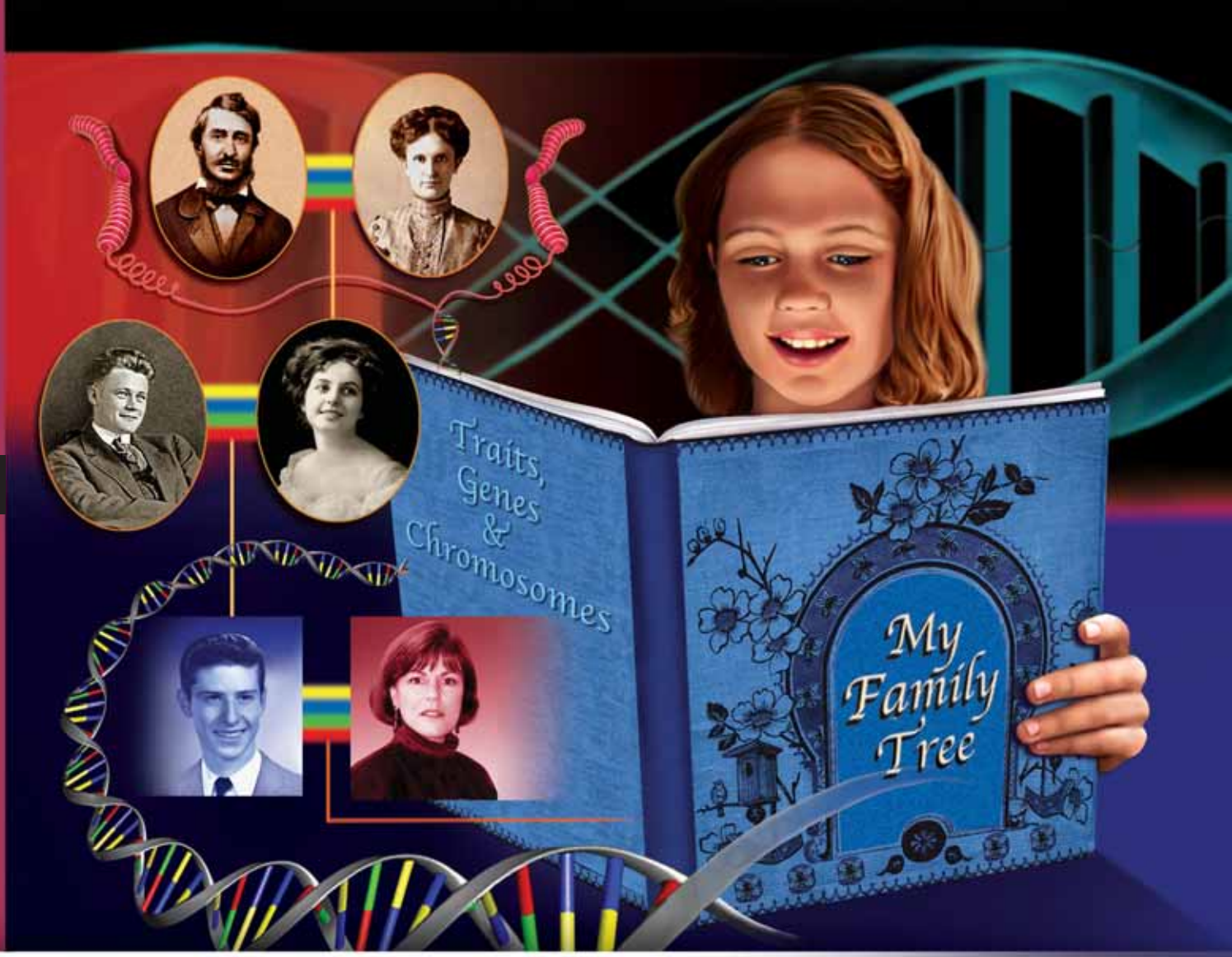
Bacteria and viruses are discussed daily on TV news reports, in the newspapers, and in magazines. How are bacteria and viruses alike? How are they different? You could make lists of characteristics, but a list isn't always helpful when you are trying to learn concepts. A *graphic organizer* is a chart, diagram, or illustration that presents information in a visual way to help you understand ideas and concepts. For this project, create your own graphic organizer to show how bacteria and viruses are alike and how they are different. Draw your graphic organizer on a computer or sketch it neatly on poster board. The blank organizer to the right is a suggestion - you can use this idea or come up with a graphic organizer of your own.



UNIT 3

Genetics

Chapter 8	*Reproduction*
Chapter 9	*Heredity*
Chapter 10	*The Code of Life*



TRY THIS AT HOME

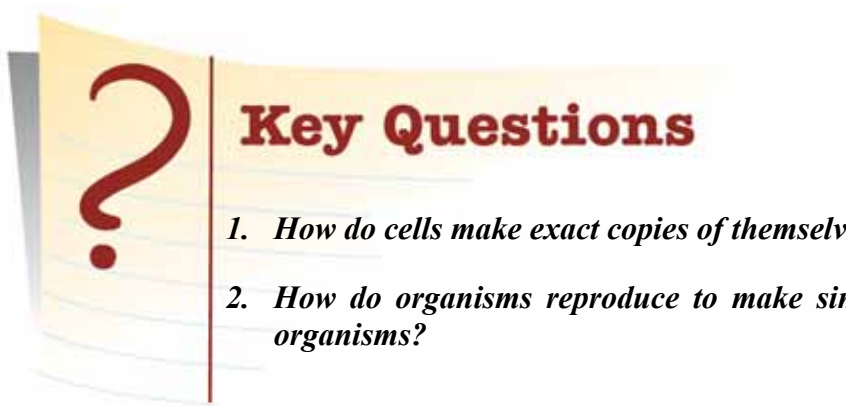
What are some human traits? Some obvious traits are hair color, height, and eye color. Brainstorm a list of human traits including the ones mentioned above. Compare your traits with another person in your home or neighborhood.

Which traits do you share? Which traits are different? Write a paragraph explaining the differences and similarities in your traits. Where did your traits come from? Write down your thoughts about this question.

Chapter 8

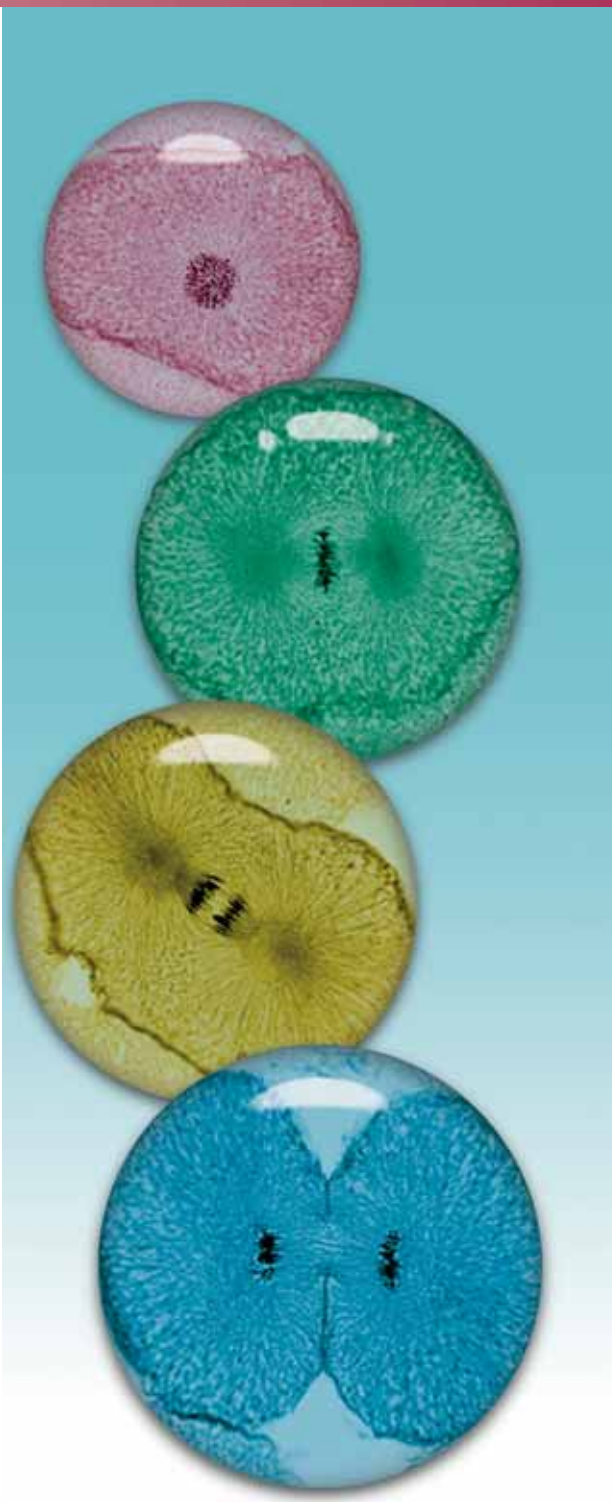
Reproduction

Your school probably has at least one copy machine. When a teacher has a quiz or a letter that she wants each student to have, she runs the pages through the copier. The copier reproduces the pages, making exact copies so each student can have one. Your cells undergo a process that makes exact copies of themselves too, but of course, they don't use a copy machine! You grow because your cells multiply. How did you end up with billions of cells when you started as the union of only two cells? Cells have fascinating ways of making copies of themselves. Take a trip into the world of the cell to learn how organisms can reproduce and grow—the processes are amazing!



Key Questions

1. ***How do cells make exact copies of themselves?***
2. ***How do organisms reproduce to make similar organisms?***



8.1 Growth and Cell Reproduction

Growth is a characteristic of all living things. You started out as a single cell. That cell quickly divided into two cells. Two cells became four and four became eight. Eventually, you grew into an organism made of *billions* of cells. As you continue to grow, your cells will divide to make more and more cells. Also, your cells divide to replace cells that have died, or to repair damaged tissues. Each new cell contains an exact copy of the DNA that's found in all of your body cells. How do cells divide to make exact copies of themselves?

What is cell division?

Cells reproduce by dividing

Most of the cells in your body reproduce by dividing into two cells called *daughter cells*. Each daughter cell contains an exact copy of the DNA found in the original (parent) cell (Figure 8.1). The process of one cell dividing into two daughter cells is called **cell division**. Most cells reproduce by cell division.

The process of one cell dividing into two daughter cells is called cell division. Each daughter cell contains an exact copy of the DNA found in the parent cell.

Cell division in prokaryotic cells

As you learned earlier, prokaryotic cells like bacteria do not have a nucleus. Their DNA is found bunched up in the cytoplasm. Because of this, their cell division is simpler than the division of eukaryotic cells. Bacteria reproduce by splitting in two. Each daughter cell contains one copy of the DNA from the original cell.

VOCABULARY

cell division - the process of one cell dividing into two daughter cells.

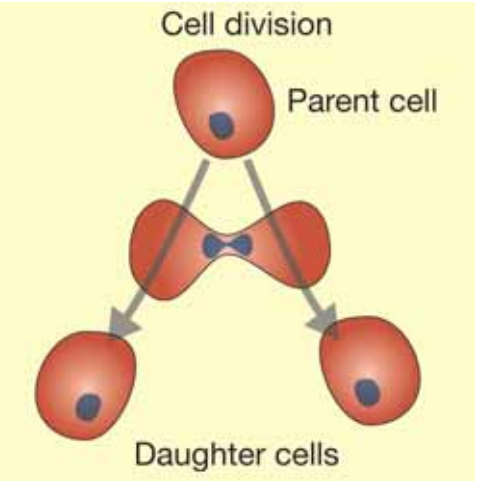


Figure 8.1: *Most of the cells in your body reproduce by dividing into two daughter cells.*

MY JOURNAL

Most organisms grow by producing more cells. Why couldn't an organism grow simply by allowing its cells to get larger and larger? Write your thoughts on this question in your notebook. You may wish to review Chapter 6 before you answer.

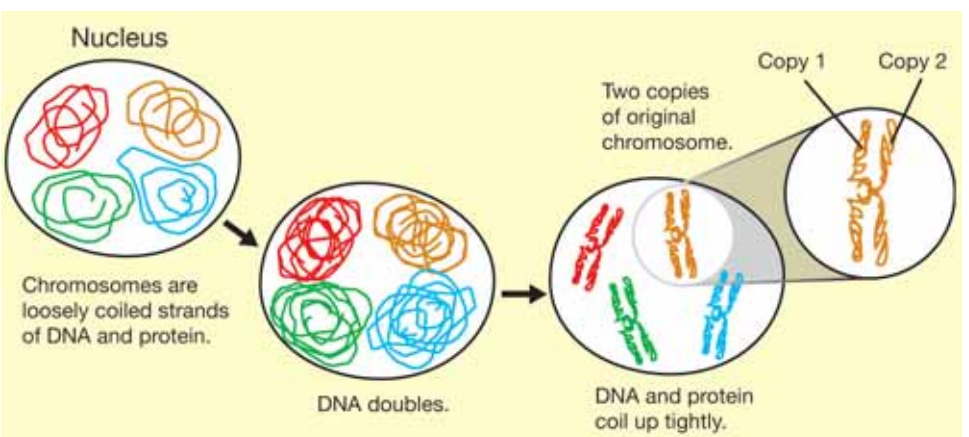
Chromosomes

What are chromosomes?

Eukaryotic cells are usually larger and more complex than prokaryotic cells. The DNA of a eukaryotic cell is found in the nucleus. That DNA is organized into structures called chromosomes. A **chromosome** is a structure made of DNA and protein in the nucleus of a eukaryotic cell. Chromosomes organize DNA into distinct units. Different organisms have different numbers of chromosomes (Figure 8.2). Humans for example, have 46 chromosomes. The proteins in a chromosome help support its structure and function. But the genetic information of the cell is stored in the DNA.

Chromosome doubling

Individual chromosomes are not clearly visible under a microscope until just before a cell begins to divide. Before cell division, chromosomes exist as long strands of DNA loosely coiled in the nucleus. Just before cell division begins, the amount of DNA doubles and so do the chromosomes. The DNA and protein in the doubled chromosomes coil up tightly. Each doubled chromosome consists of two copies of the original chromosome joined at the center.



VOCABULARY

chromosome - a structure made of DNA and protein in the nucleus of a eukaryotic cell.

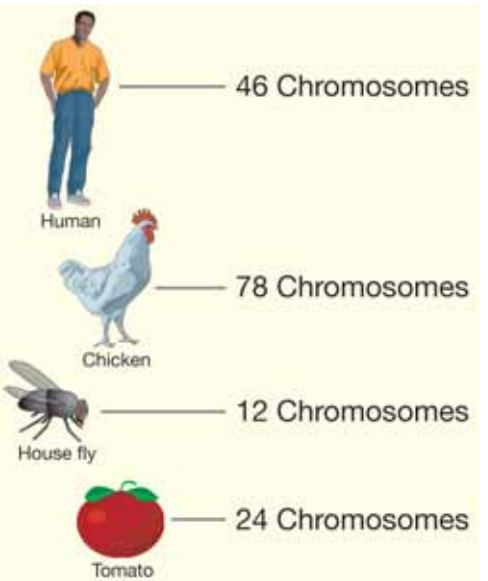


Figure 8.2: *Different organisms have different numbers of chromosomes. Does the number of chromosomes have anything to do with the complexity of the organism?*

The cell cycle

The life cycle of a cell

As you grow from an infant to an adult, you pass through different stages of your life cycle. Similarly, a cell passes through different stages of its life. The life cycle of a cell is called the cell cycle. The **cell cycle** is the period of time from the beginning of one cell division to the beginning of the next. It consists of three stages: interphase, mitosis, and cytokinesis (Figure 8.3).

Interphase

The longest stage of the cell cycle is called interphase. **Interphase** is the stage that occurs in between cell divisions. During interphase the cell grows and develops and performs its functions. Toward the end of interphase (just before the cell begins to divide), the amount of DNA doubles. Organelles of the cytoplasm (like mitochondria) also double in number.

Mitosis

The second stage of the cell cycle is called mitosis. **Mitosis** is the process in cell division where the nucleus divides into two nuclei, each with an identical set of chromosomes. Mitosis is divided into four phases: *prophase, metaphase, anaphase,* and *telophase.* The illustration on the facing page shows what happens during each phase.

Cytokinesis

The shortest stage of the cell cycle is called cytokinesis. In **cytokinesis**, the cytoplasm and its organelles divide into two daughter cells. Each daughter cell contains a nucleus with an identical set of chromosomes. The two daughter cells then start their own cycles, beginning again with the interphase stage.

The cell cycle results in two daughter cells with identical sets of chromosomes.

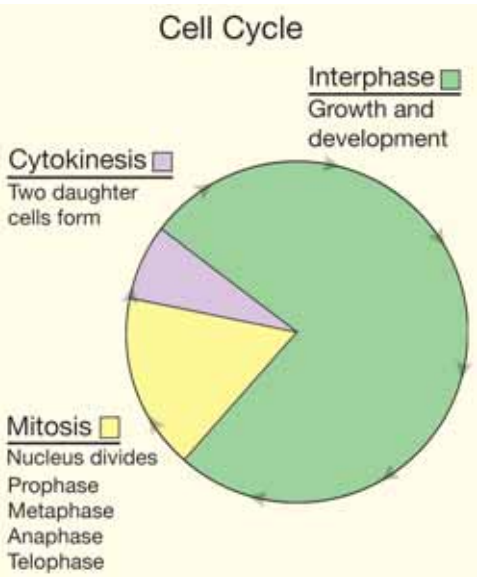


Figure 8.3: *The cell cycle consists of three phases.*

VOCABULARY

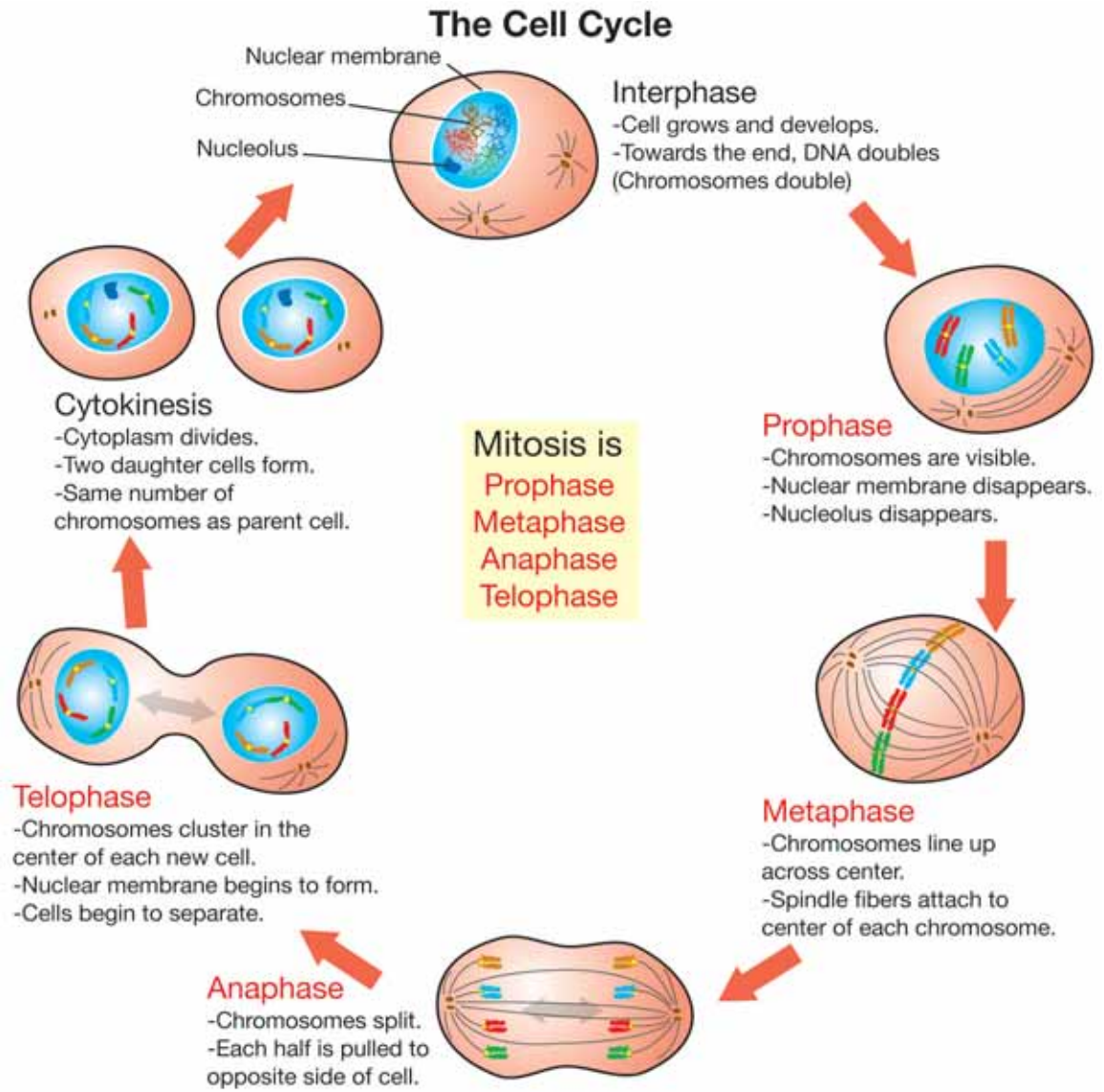
cell cycle - the period of time from the beginning of one cell division to the beginning of the next.

interphase - the stage of the cell cycle that occurs between cell divisions.

mitosis - the process of cell division where the nucleus divides into two nuclei.

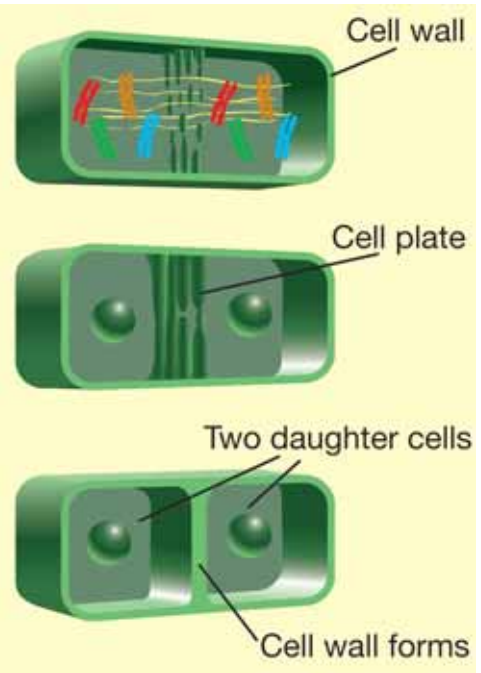
cytokinesis - the process where the cytoplasm and its organelles divide into two daughter cells.

You have 46 chromosomes in your body cells. The diagram below shows the cell cycle in an organism with only 4 chromosomes.



Cytokinesis in plant cells

In plant cells, a cell plate forms between the two nuclei. The cell plate grows outward until a new cell wall separates the two cells as shown below.



Observing the cell cycle with a microscope

With a microscope and specially prepared slides, you can observe the cell cycle and identify each part. Figure 8.4 shows pictures of plant cells in each stage of the cell cycle.

Interphase During most of interphase, the chromosomes are not visible. They appear as a grainy substance inside of the nucleus. Another way to identify interphase is to look for the nucleolus inside of the nucleus. The nucleolus disappears before mitosis begins.

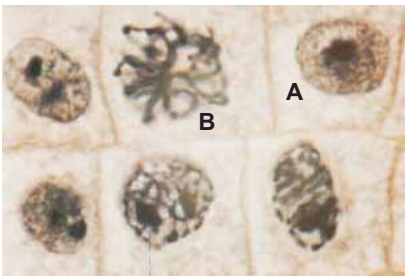
Prophase The first clue that mitosis has begun is the appearance of chromosomes. Because the amount of DNA has doubled, each chromosome appears as two identical strands joined at the center. Also, the nuclear membrane breaks down during this phase. You may also be able to see threads of protein called *spindle fibers*.

Metaphase In metaphase, you can see the chromosomes lined up across the center of the cell. Each half is pointing in the opposite direction. The spindle fibers are attached to the center of each chromosome.

Anaphase In anaphase, the chromosomes split. Each half is pulled toward the point where the spindle fibers come together. Anaphase is the phase of mitosis where the doubled chromosomes separate from each other.

Telophase You can identify telophase by finding cells where the chromosomes are clustered at separate ends of the cell. The forming daughter cells begin to separate. A nuclear membrane forms around each cluster of chromosomes.

Cytokinesis In cytokinesis, you can see that the cytoplasm is divided. Two separate daughter cells have formed, each with a complete set of chromosomes. Because it is so quick, this stage is hard to catch under a microscope.



Interphase (A) and prophase (B)

Metaphase

Anaphase

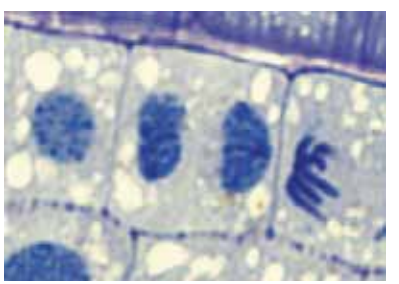

Telophase

Figure 8.4: *Photographs of plant cells in different stages of the cell cycle.*

8.1 Section Review

1. What is a daughter cell?
2. Why is cell division simpler in prokaryotes than in eukaryotes?
3. What is the major function of cell division and mitosis?
4. What is a chromosome? What are chromosomes made from?
5. Match each term below with the appropriate number on the diagram in Figure 8.5.
   a. cytokinesis
   b. metaphase
   c. interphase
   d. prophase
   e. telophase
   f. anaphase
6. What is the longest stage of the cell cycle? What is the shortest stage of the cell cycle?
7. What is the end result of mitosis and cytokinesis?
8. What is the first clue that mitosis has begun?
9. What happens to the amount of DNA in the nucleus just before the beginning of mitosis?
10. Why are chromosomes called "doubled chromosomes" just before mitosis begins?

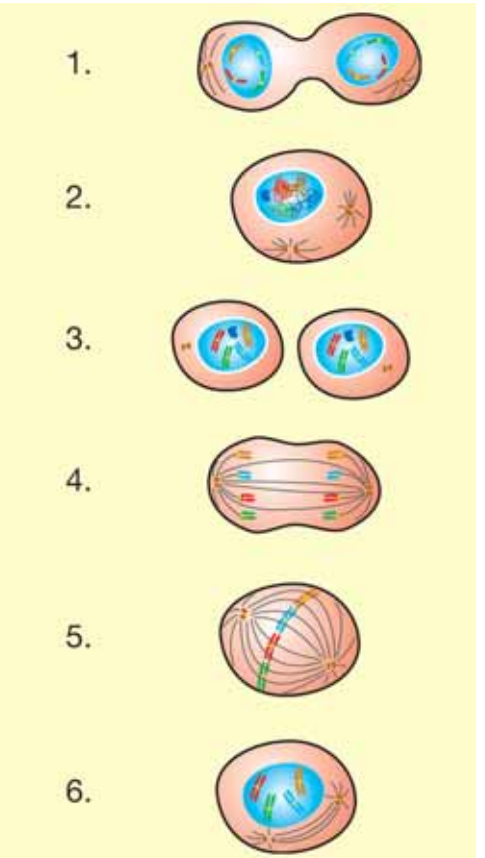


Figure 8.5: *Use this diagram to answer question 5.*

8.2 Sexual Reproduction and Meiosis

There are thousands of different species of organisms. Each species produces more of its own. A species of bacteria splits to make two identical bacteria. A eucalyptus tree produces more eucalyptus trees. Humans produce more humans. The formation of new organisms of the same species is called **reproduction**. Reproduction is an important life function. In this section, you will learn about the process of reproduction.

Two types of reproduction

Asexual reproduction

There are two types of reproduction: asexual and sexual. **Asexual reproduction** is reproduction that requires only one parent. Most single-celled organisms like bacteria and protozoans reproduce this way. Cell division is a type of asexual reproduction. Your body cells reproduce this way. In asexual reproduction, the DNA and internal structures are copied. Then the parent cell divides, forming two cells that are exact copies of the original.

Sexual reproduction

Sexual reproduction is a type of reproduction that involves special types of cells called sex cells. **Sex cells** contain half the number of chromosomes as *body cells* (all of the other cells in a multicellular organism). Human body cells have 46 chromosomes. Human sex cells have 23 chromosomes. The male sex cells are called *sperm*. The female sex cells are called *eggs*.

Homologous chromosomes

In body cells, the chromosomes occur in pairs. The chromosomes in each pair are called *homologous* (equivalent) pairs. Figure 8.6 shows a complete set of chromosomes found in a human body cell. **Each sex cell has only one of the chromosomes from each homologous pair**.

VOCABULARY

reproduction - the formation of new organisms of the same species.

asexual reproduction - a type of reproduction that requires only one parent.

sexual reproduction - a type of reproduction that involves special cells called sex cells.

sex cells - special cells that contain half the number of chromosomes as body cells.

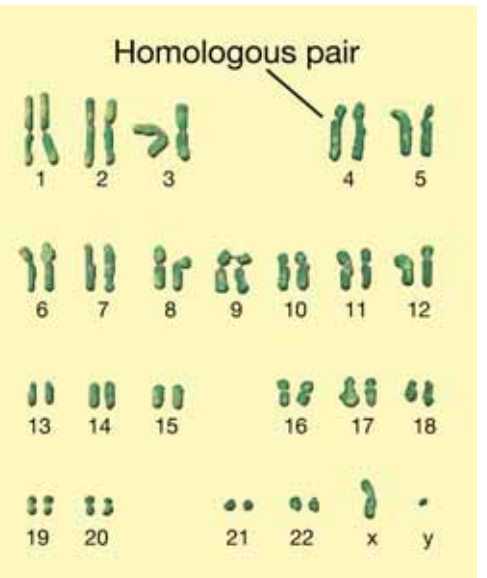


Figure 8.6: *A complete set of human chromosomes found in a body cell.*

Meiosis

What is meiosis? A body cell has the same number of chromosomes as its parent cell. How do sex cells end up with only *half* the number of chromosomes? **Meiosis** is cell division that produces sex cells with half the number of chromosomes. During meiosis, a cell undergoes two divisions to produce four sex cells, each with half the number of chromosomes of the parent cell. Figure 8.7 shows slides of meiosis in the part of a plant that produces the male sex cells.

The first division of meiosis **In the first division of meiosis, the homologous pairs of chromosomes separate.** Remember, just before a cell divides, the chromosomes double. The doubled chromosome pairs line up along the center of the cell. Spindle fibers attach and pull the pairs apart. Two cells form. Each cell contains one doubled chromosome from each homologous pair.

The second division of meiosis **In the second division of meiosis, the doubled chromosomes are split apart.** The doubled chromosomes line up in the center of the cell. Spindle fibers pull the chromosomes apart at the center. The two halves move to opposite ends of the cell.

The final result of meiosis **The final result of meiosis is four sex cells, each with half the number of chromosomes of the original parent cell.** Each cell has only one chromosome from each original homologous pair. When male and female sex cells combine to form offspring, each sex cell contributes half the normal number of chromosomes. The offspring has the normal number of chromosomes, half from the male parent and half from the female parent.

VOCABULARY

meiosis - cell division that produces sex cells with half the number of chromosomes.

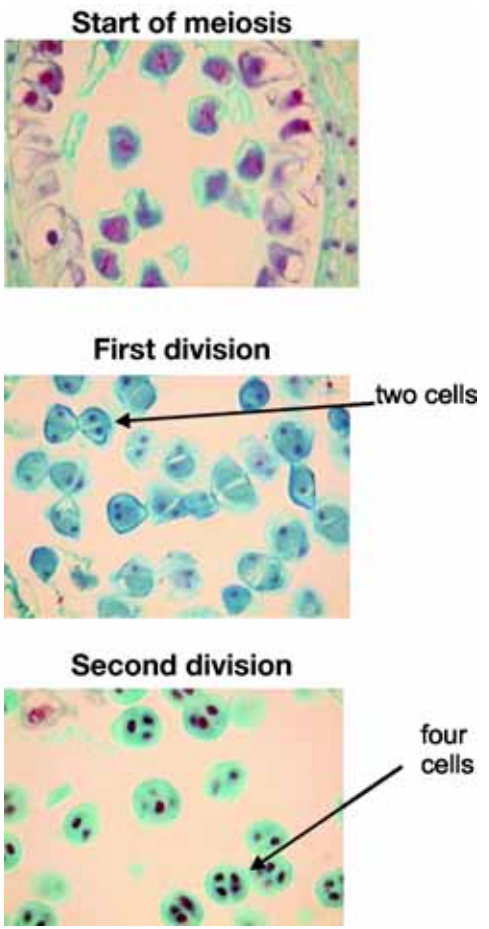
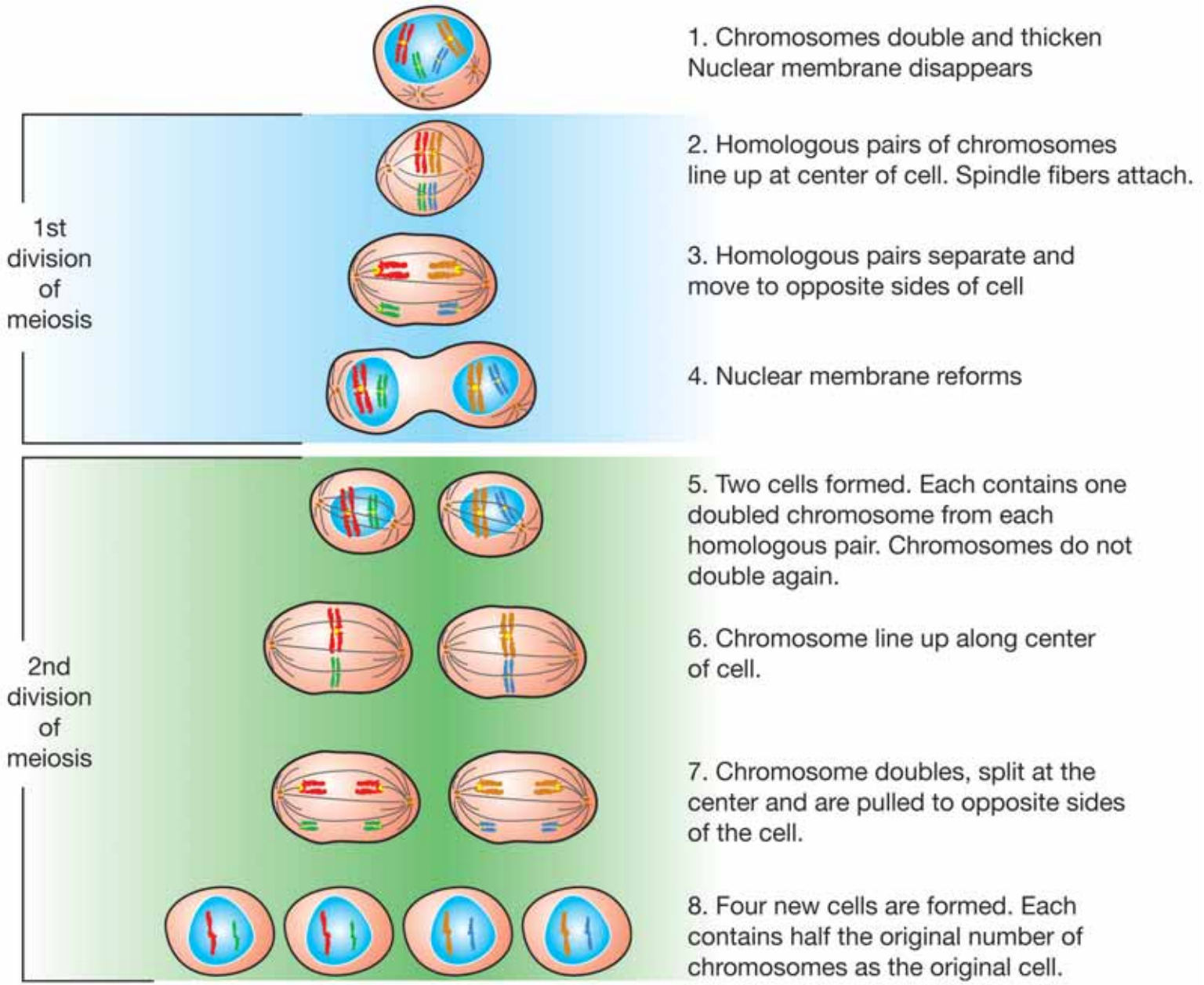


Figure 8.7: *Prepared slides showing meiosis in plant tissues.*

What happens during meiosis?



Diploid, haploid, and fertilization

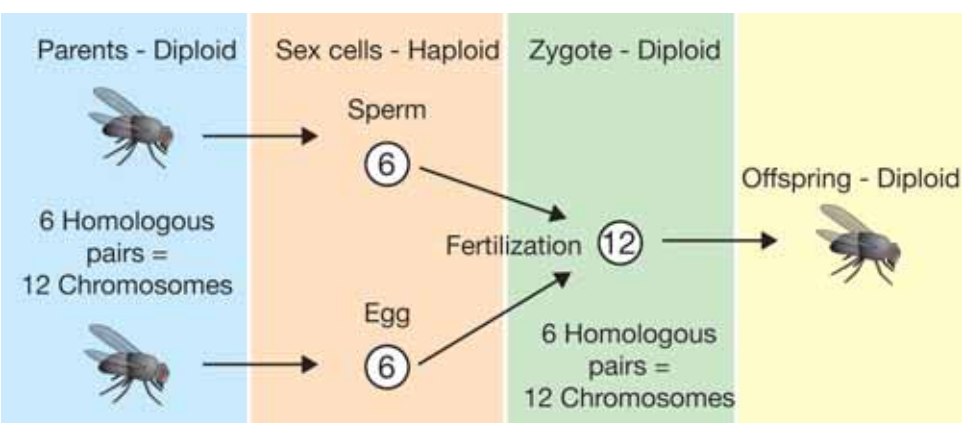
Diploid and haploid sets

A complete set of chromosomes is called a **diploid** set. Most animal cells except the sex cells have a diploid set of chromosomes. The diploid human set has 23 *pairs* of chromosomes (a total of 46). Sex cells have half of a complete set of chromosomes, or only one chromosome from each homologous pair. A half set of chromosomes is called a **haploid** set. Humans have 23 chromosomes in their sex cells—a haploid set. Figure 8.8 shows the diploid and haploid number of chromosomes for various organisms.

What is fertilization?

Fertilization is the union of egg and sperm to form a new organism. When an egg is fertilized by a sperm, the haploid set of chromosomes from the father unites with the haploid set of chromosomes from the mother. A fertilized egg, called a **zygote**, has a diploid set of chromosomes. For each homologous pair, one chromosome comes from the mother, and one from the father.

In a diploid set, chromosomes are found in homologous pairs. For each pair, one chromosome comes from each parent.



VOCABULARY

diploid - a double set of chromosomes.

haploid - a half set of chromosomes.

fertilization - the union of egg and sperm.

zygote - a fertilized egg.

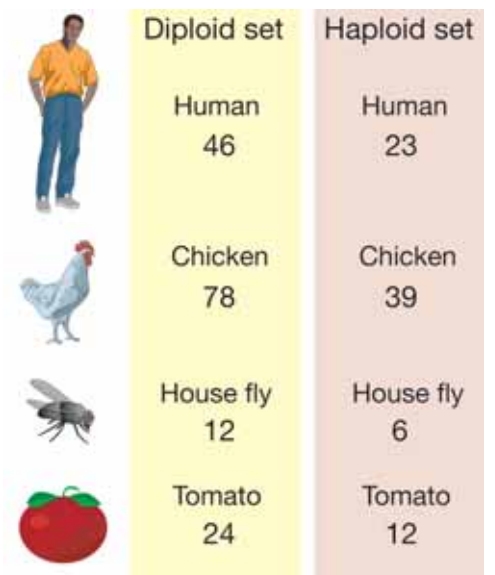
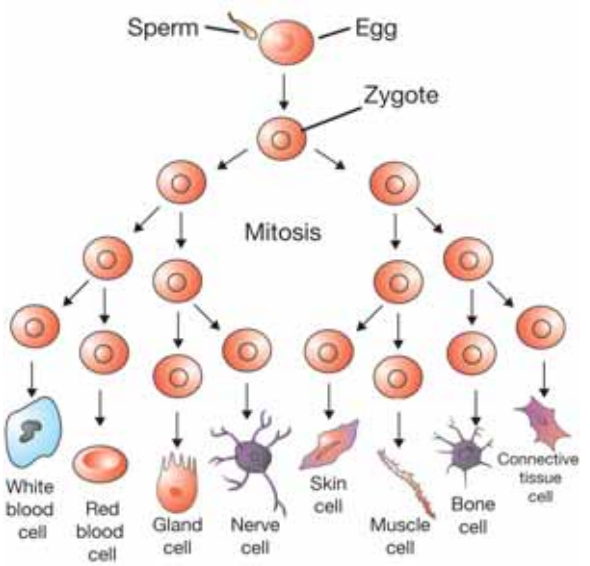


Figure 8.8: *The diploid and haploid number of chromosomes for various organisms.*

Cell differentiation

Specialized cells

After fertilization, the zygote rapidly divides by mitosis and becomes an embryo. An **embryo** is an organism in its earliest stages of development. Figure 8.9 shows embryo development of a fish, calf, and rabbit. The final outcome is a multicellular organism with many different types of *specialized* cells. You have brain cells, stomach cells, skin cells, and muscle cells to name just a few. All of those cells can be traced back to the zygote.



Differentiation

Where do all of the different types of cells come from? An organism that is not fully developed is called an *embryo*. In the developing embryo, cells begin to *differentiate*. **Cell differentiation** is the process of cell specialization. For example, cells that eventually divide to become part of the stomach are different from those that will become part of the nervous system. As cells differentiate, they give rise to different tissues. These tissues eventually form the organs.

Further specialization

As the embryo continues to develop, some cells become even more specialized. For example, some cells in the retina of your eye become *rod cells* (for vision in dim light) and others become *cone cells* (for color vision). After differentiation is complete, most cells lose the ability to become other types of cells.

VOCABULARY

embryo - an organism in its earliest stage of development.

cell differentiation - the process of cell specialization.

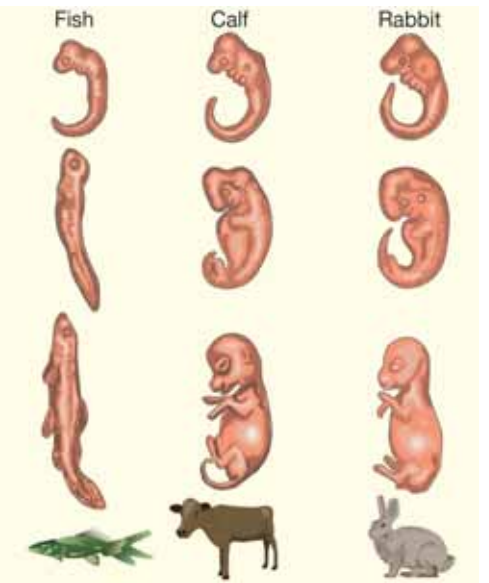


Figure 8.9: *An embryo is an organism in its earliest stages of development. The embryos of a fish, calf and rabbit, over time, develop into young organisms.*

8.2 Section Review

1. Fill in the table below for a human cell.

	Mitosis	Meiosis
Type of cell produced		
Number of cell divisions		
Number of cells produced		
Number of chromosomes in each cell (diploid or haploid)		

2. Look at Figure 8.10. Match each number on the diagram to the statements below.
   a. Cells contain half the number of chromosomes.
   b. Homologous pairs of chromosomes are pulled to opposite sides of the cell.
   c. The total amount of DNA is doubled.
   d. Doubled chromosomes are split apart.
3. A chicken has 78 chromosomes in its body cells. How many chromosomes are in its sex cells?
4. What is fertilization?
5. How does the process of fertilization explain the need to have half the number of chromosomes in sex cells?
6. You started out as a single cell and are now made of over 200,000 different types of cells. Explain how this happens.

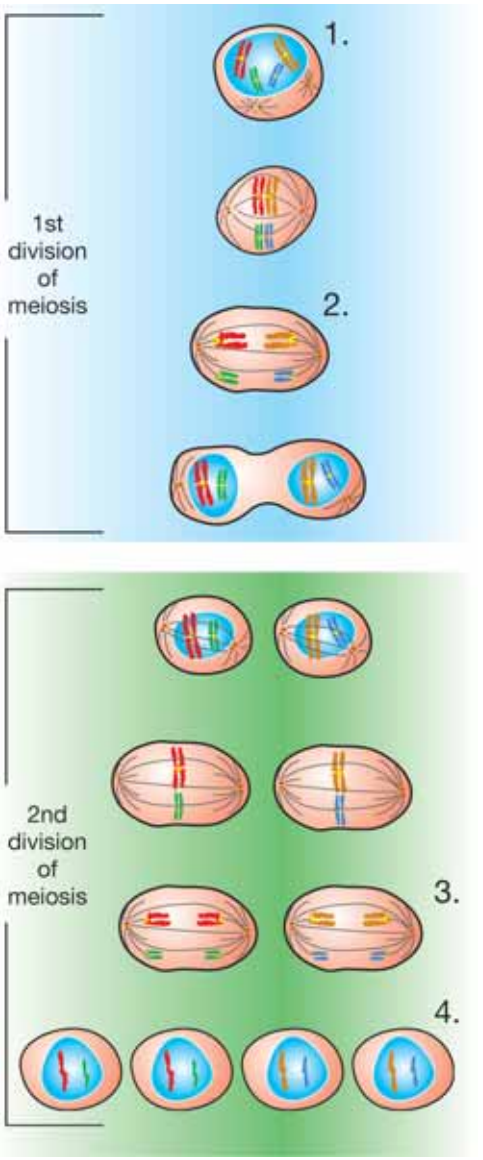


Figure 8.10: *Use this diagram to answer question 2.*

MEDICINE CONNECTION

Differences Between Twins Start With Cells

You are a completely unique individual. No one is just like you. Yet what if there was an exact duplicate of you? Same hair, nose and size. You look exactly the same. No one can tell the two of you apart. You even have the same genes. There is only one way that can happen. If you and another person have the same genes, you are identical twins.

Identical Twins

Identical twins develop from an egg that has been fertilized by a single sperm. The zygote divides into two separate zygotes.

Out of every thousand births in the United States, about 25 will be twins. Of these, some are identical twins. The rest are fraternal twins. The difference comes from how the twins formed.

Fraternal twins start as two

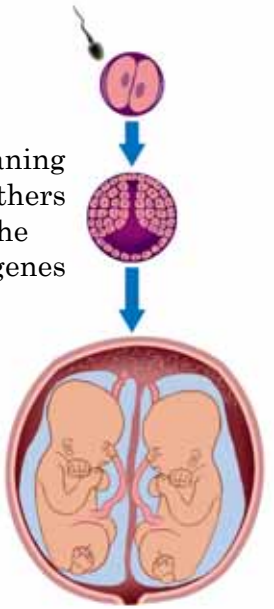
The word fraternal comes from a word meaning "brother." Fraternal twins are like any brothers and sisters, except that they are born on the same day. They each have some the same genes as their parents. But they do not share an identical genetic makeup. Fraternal twins may resemble each other, but they usually will not be mistaken for each other. Fraternal twins might both be girls. They could both be boys, or one girl and one boy.

How do fraternal twins happen? It's simple. Two different sperm cells fertilize two different eggs. Each fertilized egg develops into an embryo. Each embryo becomes a fetus. The mother gives birth to both babies on the same day.

Fraternal twins are also called dizygotic twins. When an egg cell and a sperm cell join, the resulting cell is called a zygote. It is a fertilized egg. The prefix *di* means "two." Dizygotic twins develop from two zygotes, or two fertilized eggs. In other words, the mother has produced two eggs. Each joins with a sperm cell. Each becomes a fetus. The two babies are born one right after the other.

Fraternal Twins

Fraternal twins develop from two different eggs that have been fertilized by two different sperms.



Identical twins start as one

Identical twins are not like other brothers and sisters. Other brothers and sisters share half of their genes. Identical twins have the same genetic makeup. Like fraternal twins, they are born on the same day. But that's where the similarity to fraternal twins ends. Identical twins are always the same sex. They will always be either two boys or two girls. The twins usually look very much the same. Many people cannot tell them apart at first.

Fraternal twins come from two eggs. Identical twins develop from a single fertilized egg. Shortly after the egg cell and sperm cell join, the zygote splits into two parts. Each new part is an identical copy of the original. Each has identical genetic material. After the split, each new

part develops into an embryo. From that point on, each fetus grows just like fraternal twins. Finally, two babies are born. With identical twins, the births are usually just minutes apart. The two babies have the same genes. As they grow, they usually appear to be identical to each other. People who know identical twins well can tell who is who, but a stranger may not be able to tell identical twins apart.

Identical twins are also called monozygotic twins. The prefix mono means "one." These twins develop from one zygote.

The same genes

What does it mean to have the same genes? It means that identical twins have the same genetic potential. Other factors affect how individuals develop. The environment plays a part. For example, identical twins may have different weights at birth. This is because each fetus may develop in slightly different conditions inside the mother. Identical twins that grow up in different homes often develop differently. Their diets may be different and they might not get the same exercise. If these twins come together later in their lives, they may not look alike. They may not seem to be identical twins at all.

Scientists want to know more about how our environment affects the way we develop. For this reason, identical twins are often studied. They start out with the same genes. However, differences that occur may be caused by environmental factors.

Transplants and tissue matching

Organ transplants save many lives. The science of transplants has benefited by the study of identical twins. In the early 1950s, scientists observed that most donated organs were rejected. Then in 1954, a kidney transplant was done between identical twins.

Richard Herrick was dying of kidney disease. Ronald, his identical twin brother gave one of his kidneys to him. Both twins had the same genetic makeup. Richard's body recognized Ronald's kidney as being the same tissue as itself. It did not reject the kidney and the transplant was a success.

The Herrick twins and members of the first successful kidney transplant team after the 1954 surgery. Standing from left, Drs. Joseph Murray, John Merrill and J. Hartwell Harrison. Seated, from left: Richard (recipient) and Ronald Herrick (donor). Credit: Courtesy of Brigham and Women's Hospital

This case was very important in the understanding of organ transplants. It helped scientists know more about matching tissue. Since then, many of the problems of organ rejection have been overcome with the use of tissue matching.

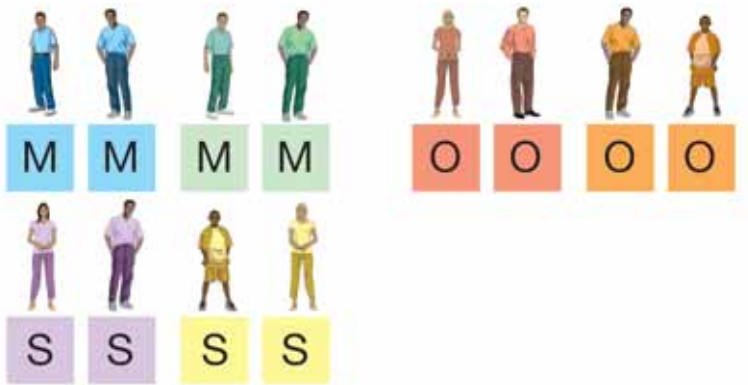
Questions:

1. What is a zygote?
2. In terms of zygotes, how are fraternal twins and identical twins different?
3. How does the genetic makeup of fraternal and identical twins differ?
4. What could explain differences in appearance between 50-year old identical twins?

CHAPTER ACTIVITY Chromosome Square Dance

It's sometimes easier to visualize a process like meiosis using people to act out the parts. In this activity, you will imagine you and your classmates are chromosomes at a square dance. In a square dance, a "caller" calls out orders. The dancers follow the caller's orders.

The diagram below shows students playing homologous pairs of chromosomes just before the first division of meiosis. The amount of DNA has doubled so each chromosome is doubled. Therefore, for each homologous pair, you will need four students. Look at the diagram then answer the questions below it.



a. How many homologous pairs are in the diagram?
b. What is the diploid number of the organism?
c. What is the haploid number of the organism?

What you will do

1. Your class will choose one person to be the caller. He or she will read from the orders (right).
2. Your teacher will assign students as chromosomes. You will be given a colored sign to wear around your neck. The letter and color on the sign indicates the chromosome to which you belong. Place your sign around your neck and wait for instructions from your teacher to begin.

Meiosis event	Caller orders
Before meiosis begins, the chromosomes double. But they are randomly arranged in the nucleus.	"Two people with the same letter and sign color link arms and move around at random. You are now doubled chromosomes. Dance!"
Just before the first division, homologous pairs find each other and pair up.	"Each doubled chromosome find another doubled chromosome with the same color sign. You are now homologous pairs. Group together!"
Homologous pairs of chromosomes line up along the center of the cell.	"Now find your way to the center line. Homologous pairs line up along the center!"
Spindle fibers attach and pull the pairs apart. Two cells form. Each cell has one double chromosome from each homologous pair. The first division is complete.	"Homologous pairs—you are being pulled apart. Move to opposite sides of the center line. Doubled chromosomes should stay together!"
The second division starts. The doubled chromosomes line up in the center of each new cell.	"Doubled chromosomes—line up along the center line of the cell."
Spindle fibers pull the doubled chromosomes apart. Each half moves to opposite ends of the cell.	"Doubled chromosomes—you are being pulled apart. Release arms and move to opposite ends of the cell. Drift apart!"
Four cells form. Each cell has a haploid set of chromosomes—one chromosome from each homologous pair. The second and final division is complete.	"You are now single chromosomes. Get together with the other single chromosomes in your cell. Congratulations—you are now haploid! The dance is over."

Applying your knowledge

a. Why were there two students for each chromosome in the beginning?
b. Why were there four students per homologous pair?
c. Which letters and sign colors ended up in each cell after the second division?
d. How many chromosomes ended up in each cell after the second division?

Chapter 8 Assessment

Vocabulary

Select the correct term to complete the sentences.

cell cycle	cytokinesis	sexual reproduction
sex cells	fertilization	meiosis
differentiation	chromosomes	interphase
mitosis	reproduction	asexual reproduction
	cell division	

Section 8.1

1. _____ is the process of cell reproduction.
2. Made up of protein and DNA, _____ contain genetic information within a eukaryotic cell.
3. The continuous sequence of events from the beginning of one cell division to the next is the _____.
4. During _____, the cell grows and develops.
5. _____ is the process of eukaryotic nuclear division in which two nuclei with identical sets of chromosomes are formed.
6. A cell whose cytoplasm and organelles divide in two is in the stage of _____.

Section 8.2

7. _____ is the process of producing offspring.
8. _____ involves a single parent producing identical offspring without the aid of sex cells.
9. In _____, sperm and eggs unite to form new offspring.
10. _____ contain half the number of parental chromosomes.
11. Sex cells are formed during _____, when the nucleus divides twice, forming cells with half the original chromosome number.
12. In the process of _____, egg and sperm cells unite.
13. As cells develop they specialize in different functions, this is the result of _____.

Concepts

Section 8.1

1. Distinguish between mitosis and cell division.
2. Chromosomes
   a. are structures made of DNA and protein in the nucleus of prokaryotic cells.
   b. are only visible during mitosis.
   c. are doubled along with their DNA prior to cell division.
   d. within two daughter cells contain half the original DNA after mitosis.
3. A researcher has discovered a way to disrupt the cell cycle by allowing cytokinesis to take place before mitosis. What would be the result if a cell with four chromosomes underwent this cycle?
4. Which does not occur during prophase.
   a. The nuclear membrane breaks down.
   b. Chromosomes can be seen for the first time.
   c. Threads of spindle fibers are visible.
   d. Doubled chromosomes separate to opposite ends of the cell.
5. Mitosis
   a. increases the number of cells without changing genetic information.
   b. alters the information passed down to daughter cells.
   c. creates four daughter cells containing half the number of original chromosomes.
   d. is the stage where cells grow and develop.
6. Create a diagram illustrating the stages during mitosis. Include a short explanation of each step in your own words.

Section 8.2

7. There are 38 chromosomes in the liver cells of a cat. The sperm of male cat would contain ___ chromosomes.
   a. 38 b. 19 c. 24 d. 56
8. Explain two major differences between mitosis and meiosis.
9. Describe what happens to homologous chromosomes during each division of meiosis.
10. What are homologous pairs of chromosomes? How are these different than the doubled chromosomes in the second division of meiosis?
11. A fertilized egg
    a. contains only half the number of parental chromosomes.
    b. divides into new cells by mitosis.
    c. divides into new cells by meiosis.
    d. cannot undergo cell divisions.

Math and Writing Skills

1. Specialized cells in within the body divide at different rates. A researcher studying the rate of two different cells has determined cell A divides once every 1.5 minutes while cell B divides every 30 seconds. The researcher places one of each dividing cell in culture, how many cells should he expect in each dish after 4.5 minutes? Create a table like the one below that goes up to 270 seconds and fill in your answers.

Time (seconds)	Cell A (# of divisions)	Cell B (# of divisions)
30 60 up to 270		

2. Explain how chemicals that disrupt mitosis could be potentially used as an herbicide (weed killer). How would the mechanism of these chemicals differ if they disrupted meiosis instead?

Chapter Project

Cell Division Flip Book

A flip book is a stack of at least twenty pages with individual drawings that change position slightly on each page. When you flip through the pages quickly, the individual drawings look like they are moving!. Here's how to create your own flip book of cell division.

1. Plan a sequence of at least twenty drawings on scrap paper before starting to draw the flip book. The drawings should take one cell completely through the stages of cell division, with slight changes from one drawing to the next. Start with Interphase and draw the stages all the way to cytokinesis. It's easiest to limit your chromosome count to 4 pairs. Color coding works nicely.
2. Begin your flip book by drawing the first picture on the LAST page of the book. Draw the next picture on the second-to-the last page and so on. When the next page is placed on top of the previous, you will be able to see the drawing on the previous page as it shows through the post-it paper. Trace or redraw most of that image, changing a small part of it only slightly.
3. Continue to flip, cover, trace, and change slightly until the action sequence is complete. Keep the figure as close as possible to the edge of the page.
4. Flip through the booklet and watch the animation. Hold the flip book in your right hand and flip the pages from back to front (start to finish) with your left thumb.

Chapter 9

Heredity

The fruits, vegetables, and grains you eat are grown on farms all over the world. Tomato seeds produce tomatoes, which in turn produce more seeds to grow more tomatoes. Each new crop of tomatoes carries *genes* for characteristics that were inherited from the previous crop's seeds. Some scientists are trying to manipulate the information contained in the seeds to produce different tomatoes. They have even tried inserting a gene from a winter flounder (a type of fish) into a tomato so that the tomato is cold-resistant! Why would this be beneficial? This chapter will help you understand how traits in plants and animals are inherited from one generation to the next.

Key Questions

1. ***What is "genetics" and who was Gregor Mendel?***
2. ***How are traits passed from one generation to the next?***
3. ***How can you predict the traits of the next generation?***

9.1 Traits

Tyler has free earlobes like his father. His mother has attached earlobes. Why does Tyler have earlobes like his father? In this section you will learn about traits and how they are passed on to offspring. Look at your earlobes. Are they free or attached? (Figure 9.1). The type of earlobes you have is a trait that you inherited from your parents. A **trait** is a characteristic that an organism can pass on to its offspring.

Figure 9.1: *The type of earlobes you have is a trait you inherited from your parents.*

Studying traits

Breeds and traits

Did you know there are over 150 dog breeds, but they are all the same species (*Canis familiaris*)? A pug looks completely different than a black lab, yet they both came from the same ancestors. For thousands of years, dog breeders have selected certain traits to produce dog breeds for different purposes. People knew how to breed in order to obtain certain traits long before scientists knew about DNA, chromosomes, or meiosis.

Genetics is the study of heredity

An organism's **heredity** is the set of traits it receives from its parents. **Genetics** is the study of heredity. Ancient dog breeders thought that the traits inherited by a dog were a blend of those from the mother and father. For example, a large dog crossed with a small dog in many cases would produce a medium-sized dog—a blend of both parents. It turns out that heredity is not that simple. A monk named Gregor Mendel was one of the first to find that out.

VOCABULARY

trait - a characteristic that an organism can pass on to its offspring.

heredity - a set of traits an organism receives from its parents.

genetics - the study of heredity.

The priest and the pea

Who was Gregor Mendel?

Gregor Mendel (1822 to 1884) was an Austrian monk. He is often called the "father of genetics." Through many years of experiments in breeding pea plants, Mendel arrived at some important conclusions about inheritance. However, nobody in his lifetime (including Mendel) realized the importance of his work. It was ignored by scientists until the early 1900s. Eventually Mendel's ideas led to the science of genetics.

Gregor Mendel

Disappearing traits

Mendel worked in a garden at the monastery where he lived. Through his work, he became interested in the traits of plants and how those traits were passed on to offspring. For example, he noticed that a trait that appeared in the parent generation of plants did not show up in their offspring (the first generation), but in the second generation, the trait showed up again (Figure 9.2)! Mendel wanted to find out why. So, he decided to study inheritance in peas. Peas were a good choice because they grow quickly and are easy to breed.

Peas and pollination

Peas are flowering plants. They have male and female parts on the same plant. Flowering plants reproduce by *pollination*. During pollination, pollen containing sperm from the male part of the plant is carried to the female part of the plant called the *ovule*. Fertilization occurs when a sperm from the pollen travels to an egg in the ovule. In a pea plant, pollen can fertilize eggs on the same plant (self-pollination). Or, the pollen can be carried by the wind or an animal to another plant. Figure 9.3 shows how pollination can occur.

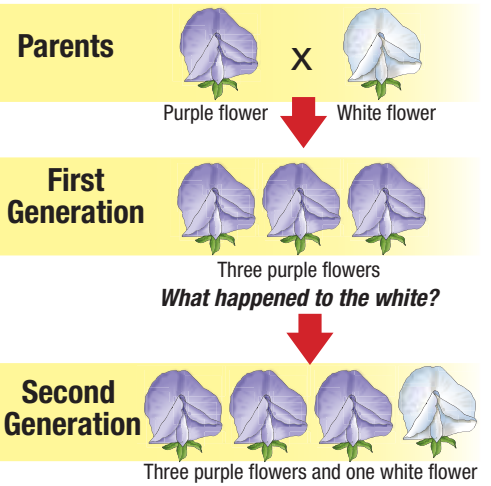


Figure 9.2: *Why do traits disappear and then reappear?*

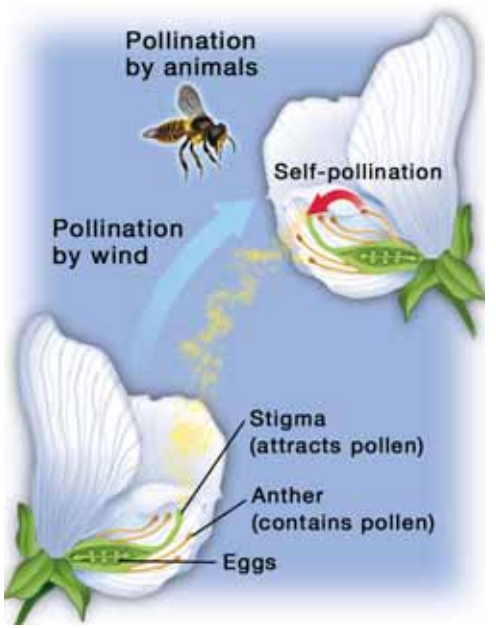


Figure 9.3: *Flowering plants reproduce by pollination.*

Mendel's experiment

Pea plant traits

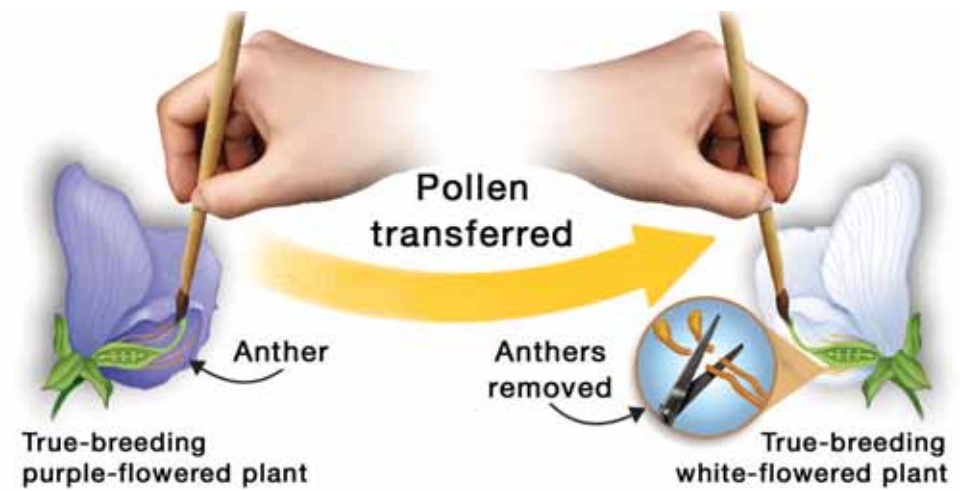
Mendel studied pea plants and identified several traits that had only two forms. For example, he observed that peas produced plants with either purple flowers or white flowers. Figure 9.4 shows four of the traits Mendel studied and their two forms.

True-breeding plants

For his experiments, Mendel was careful to start out with true-breeding plants. When a **true-breeding plant** self-pollinates, it will always produce offspring with the same form of the trait as the parent plant. For example, a true-breeding plant with purple flowers will only produce plants with purple flowers.

Mendel's procedure for his experiments

Mendel wanted to find out what would happen if he crossed two plants with different forms of a trait. He used a method called cross-pollination. In **cross-pollination**, the parts that contain pollen (anthers) are removed from one plant so it cannot self-pollinate. Next, the pollen from the other plant is used to fertilize the plant without pollen. The example below shows how Mendel crossed a purple-flowered plant with a white-flowered plant.



Four Pea Traits

TRAIT	FORM 1	FORM 2
Flower color	Purple	White
Seed shape	Smooth	Wrinkled
Seed color	Yellow	Green
Pod color	Green	Yellow

Figure 9.4: *Four of the traits Mendel studied in pea plants.*

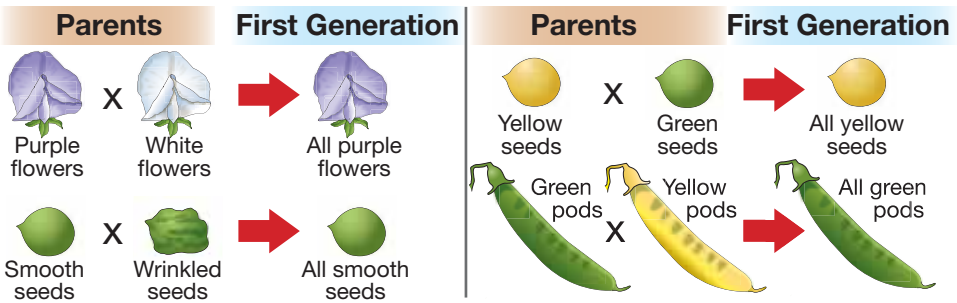
VOCABULARY

true-breeding plant - a plant that will always produce offspring with the same form of a trait when it self-pollinates.

cross-pollination - when the pollen from one plant is used to fertilize another plant.

The first generation

When Mendel crossed true-breeding, purple-flowered plants with true-breeding, white-flowered plants, the first generation produced all purple-flowered plants. Mendel got similar results for the other traits he studied. In each case, one form of the trait always showed up in the first generation and the other form of the trait always seemed to disappear.

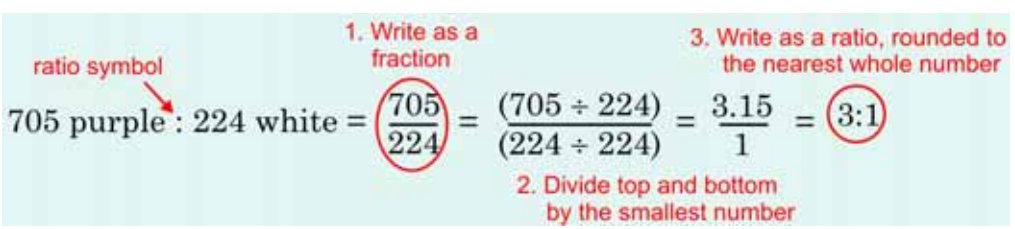


The second generation

Next, Mendel allowed the first generation of plants to self-pollinate. When the purple-flowered plants of the first generation self-pollinated, white flowers showed up again in the second generation! Figure 9.5 shows Mendel's crosses with peas for the flower-color trait.

Calculating ratios

Mendel counted the plants in the second generation. He found 705 plants with purple flowers and 224 plants with white flowers. He calculated the ratio of purple-flowered plants to white-flowered plants. A *ratio* is a way to compare two numbers. Here's how to calculate the ratio of purple flowers to white flowers:



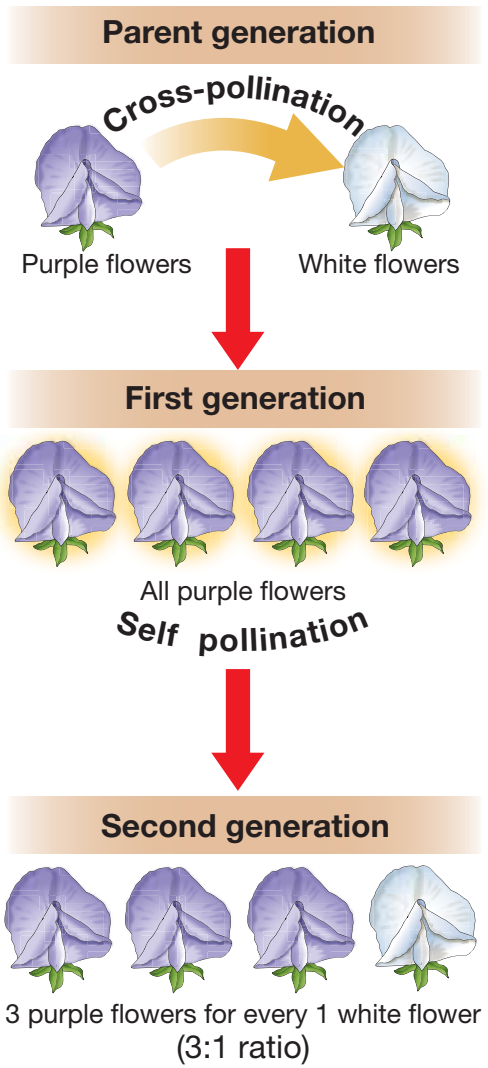


Figure 9.5: *Mendel's experiment.*

Mendel's conclusions

Second generation results

Mendel got similar results for the second generation of all the traits he studied. The data from four of the traits he studied is shown in Table 9.1. For practice, calculate the ratio for the last three traits.

Table 9.1: The second generation from Mendel's peas

Trait	Form 1	Form 2	Ratio
Flower color	purple 705	white 224	**3:1**
Seed shape	round 5,474	wrinkled 1,850	**?**
Seed color	yellow 6,002	green 2,001	**?**
Pod color	green 428	yellow 152	**?**

Genes

From the results, Mendel proved that all traits do not blend. For instance, purple flowers mixed with white flowers did not produce pink flowers. Mendel concluded that traits like flower color must be determined by individual *units*. Today, we call those units genes. A **gene** is a unit that determines traits.

Dominant and recessive alleles

Mendel concluded that for each trait he studied, a pea plant must contain *two forms* of the same gene. Different forms of the same gene are called **alleles**. The **dominant allele** is the form of a gene that, when present, covers up the appearance of the recessive allele. The **recessive allele** is the form of a gene that is hidden when the dominant allele is present. The gene for flower color in peas has a dominant allele that causes purple flowers and a recessive allele that causes white flowers (Figure 9.6).

Alleles are different forms of the same gene. Organisms have at least two alleles for each gene—one from each parent.

VOCABULARY

gene - a unit that determines traits.

alleles - different forms of a gene.

dominant allele - the form of a gene that, when present, covers up the appearance of the recessive allele.

recessive allele - the form of a gene that is hidden when the dominant allele is present.

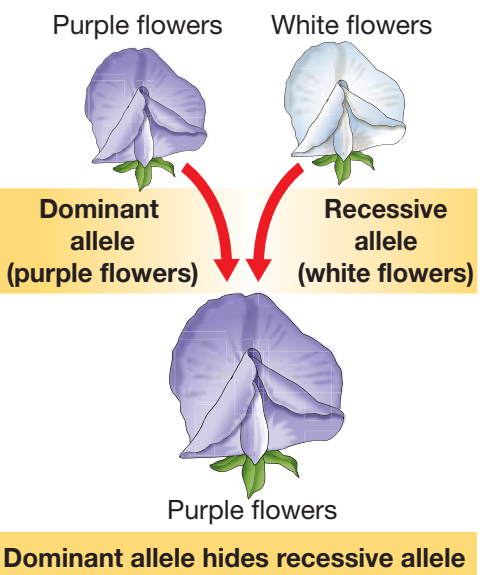


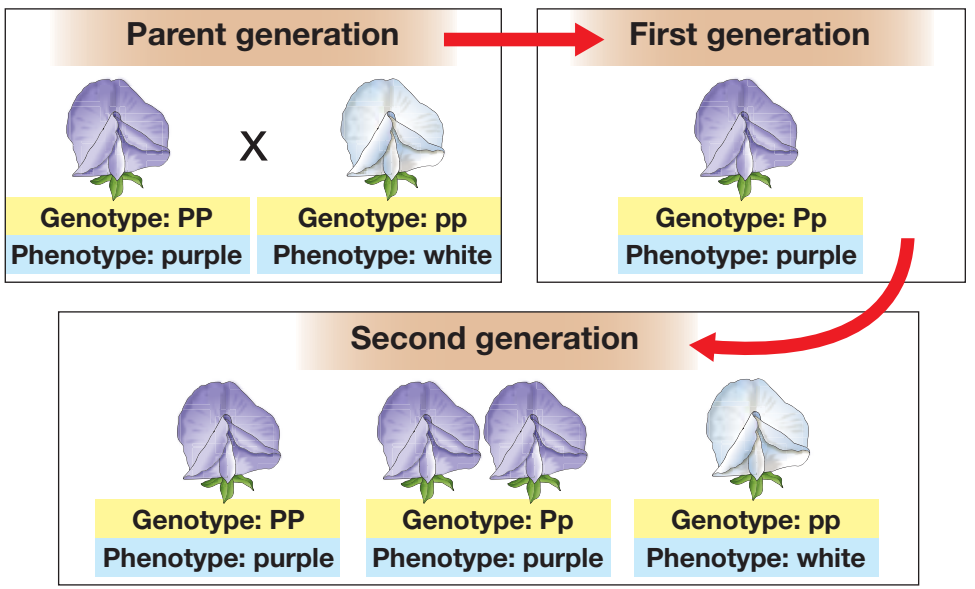
Figure 9.6: *Flower color in peas is determined by two alleles of the gene—one from each parent.*

Phenotype and genotype

An organism's **phenotype** is the form of a trait that it displays. For flower color, a pea plant can display a phenotype of purple or white flowers. An organism's **genotype** is the alleles of a gene it contains. Based on his data, Mendel concluded that a phenotype can be determined by more than one genotype.

Symbols for genes

Mendel used upper and lower case letters to symbolize the alleles of a gene. For flower color, he used upper case ***P*** for purple (the dominant allele) and lower case ***p*** for white (the recessive allele). A pea plant with purple flowers could have a genotype of either ***PP*** or ***Pp***. A pea plant with white flowers could only have a genotype of ***pp***. As long as at least one dominant allele is present, the plant will always have a phenotype of purple flowers. Figure 9.7 shows the genotypes and phenotypes of four pea plant traits. The graphic below shows the alleles present in each generation of pea plants from Mendel's experiment.



VOCABULARY

phenotype - the form of a trait that an organism displays.

genotype - the alleles of a gene an organism contains.

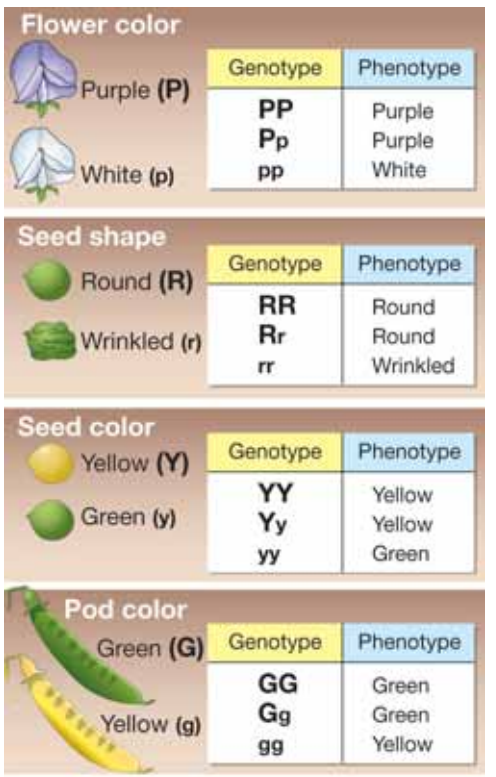


Figure 9.7: *The genotypes and phenotypes of four of the traits Mendel studied in pea plants.*

9.1 Section Review

1. Give two reasons why Mendel chose pea plants for his experiments with traits.
2. Name two ways pollination can occur.
3. What is a true-breeding plant? Why did Mendel start out his experiments with true-breeding plants?
4. What happened when Mendel crossed a true-breeding, green-seeded plant with a true-breeding, yellow-seeded plant?
5. What is the best way to determine the phenotype of a bird's feathers?
   a. analyze the bird's genes
   b. look at the bird's feathers
   c. look at the bird's offspring
   d. look at the bird's parents
6. Which statement best describes how to write the genotype for a trait?
   a. A capital letter represents the dominant allele and a different capital letter represents the recessive allele.
   b. A capital letter represents the dominant allele and a different lowercase letter represents the recessive allele.
   c. A capital letter represents the dominant allele and the lower case of that letter represents the recessive allele.
7. Write all of the possible genotypes for each pea plant:
   a. A plant with purple flowers.
   b. A plant with round seeds.
   c. A plant with green seeds.
   d. A plant with yellow pods.

Calculating ratios

Calculate the ratio of the following pairs of numbers. Give your answers as whole-number ratios.

1. 500:250
2. 2020:1599
3. 675:1280
4. 25:499
5. 1327:1327

Free earlobes are determined by a dominant allele. Attached earlobes are determined by a recessive allele. Tyler has free earlobes. His father has free earlobes but his mother has attached earlobes. What is Tyler's genotype?

9.2 Predicting Heredity

When Mendel published his work in the 1800s, he did not use the word "gene" to describe his units of heredity. He also wasn't sure where his units might be found or how to identify them. His work went unnoticed for almost thirty years. In 1902, American scientist Walter Sutton (1877 to 1916) examined the nuclei of grasshopper cells under a microscope. He observed that chromosomes occurred in homologous pairs that separated during meiosis. A year later, Sutton found that chromosomes contained *genes*. He had discovered Mendel's units of heredity! In this section you will learn how Mendel's work is used to predict the heredity of offspring.

How traits are passed on to offspring

Genes and alleles

Mendel developed the basic laws of how traits are passed on to offspring (Figure 9.8). He did not know about genes, chromosomes, DNA, or meiosis. The laws stated below combine the work of Mendel and Sutton.

1. **Individual units called genes determine an organism's traits.**
2. **A gene is a segment of DNA, located on the chromosomes, that carries hereditary instructions from parent to offspring.**
3. **For each gene, an organism typically receives one allele from each parent.**
4. **If an organism inherits different alleles for a trait, one allele may be dominant over the other.**
5. **The alleles of a gene separate from each other when sex cells are formed during meiosis.**

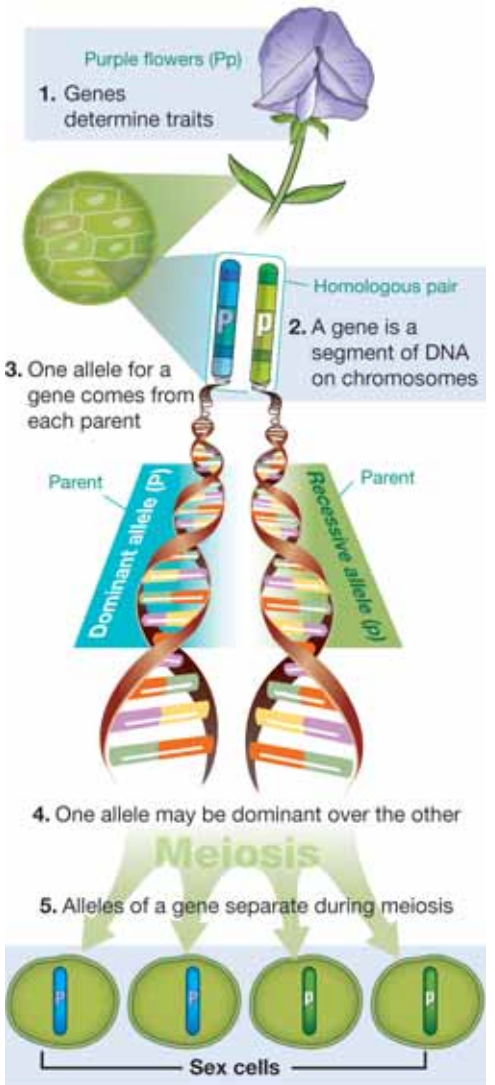


Figure 9.8: *The principles of how traits are passed on to offspring.*

Alleles and meiosis

Alleles of a gene separate during meiosis

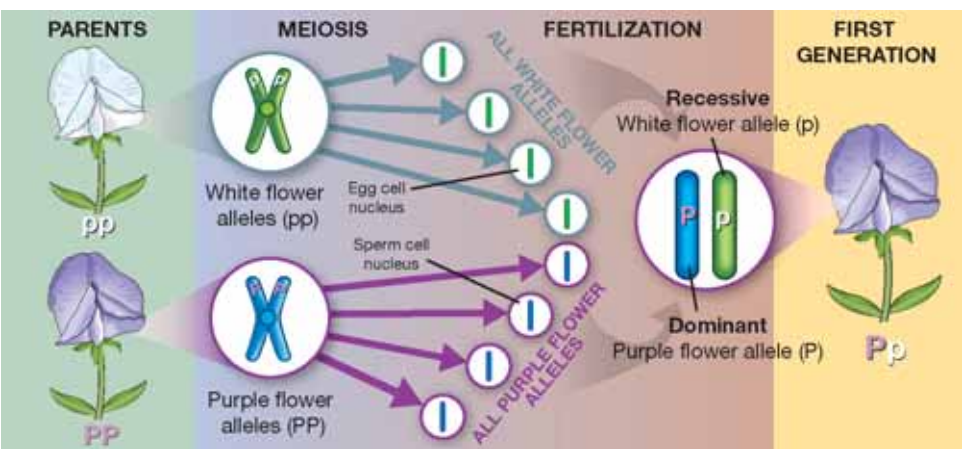
In the last chapter, you read that homologous pairs of chromosomes separate during meiosis. Since alleles of a gene are found in corresponding locations on homologous pairs of chromosomes, they also separate during meiosis.

How do alleles separate?

To illustrate how alleles separate, let's follow the alleles for the flower color trait in a pea plant with the genotype ***Pp***. The plant in our example has a dominant allele (***P***) and a recessive allele (***p***). What is the phenotype of the plant? You are correct if you said purple! Figure 9.9 shows what happens to the alleles during meiosis. To keep it simple, only one pair of chromosomes is shown. A real pea plant has 14 chromosomes (7 pairs).

Fertilization

When fertilization occurs, offspring inherit one homologous chromosome in a pair from each parent. As a result, one allele for a gene also comes from each parent. When Mendel crossed pure-breeding, purple-flowered plants with pure-breeding, white-flowered plants, the first generation offspring were purple with the genotype ***Pp***. The diagram below traces the alleles from parent to offspring.



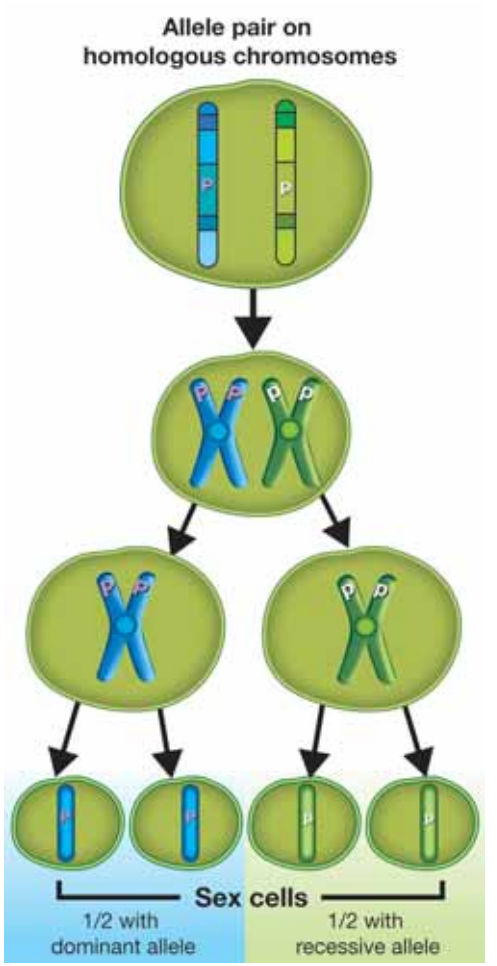


Figure 9.9: *Alleles of a gene are found in corresponding locations on homologous pairs of chromosomes.*

Predicting genotype and phenotype

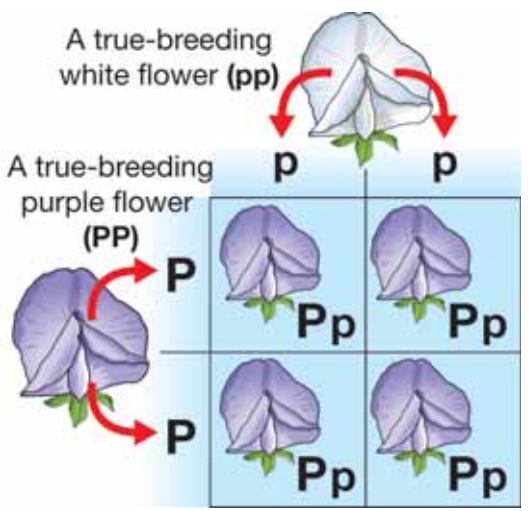
Punnett squares

You can predict the genotypes and phenotypes of offspring if you know the genotypes of the parents. A **punnett square** shows all of the possible combinations of alleles from the parents. Figure 9.10 shows how a punnett square is made.

You can predict the possible genotypes and phenotypes of offspring if you know the genotypes of the parents.

A punnett square of Mendel's first cross

You can use a punnett square to show Mendel's first cross. He crossed a true-breeding, purple-flowered plant with a true-breeding, white-flowered plant. Since the purple-flowered plant is true-breeding, it has two dominant alleles. The genotype of the purple-flowered plant is ***PP***. Since white flowers are recessive, the only possible genotype for a white-flowered plant is ***pp***.



Analyzing the punnett square

As you can see, all of the offspring in Mendel's first cross had a genotype of ***Pp***. That's why all of the plants in the first generation had purple flowers. Using a punnett square, you can predict the possible genotypes and phenotypes of the offspring. In the example above, the only possible genotype is ***Pp*** and the only possible phenotype is purple flowers.

VOCABULARY

punnett square - shows all of the possible combinations of alleles from the parents.

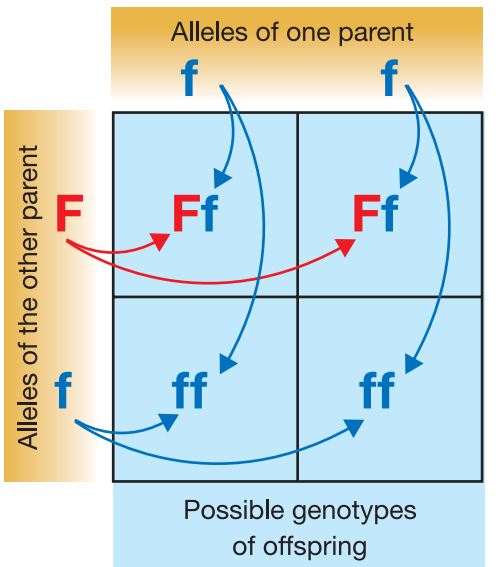


Figure 9.10: *The parts of a punnett square.*

SOLVE IT!

In the punnett square shown in Figure 9.10, F = free earlobes and f = attached earlobes. What is the genotype and phenotype of each parent? What are the possible genotypes and phenotypes of their children?

Punnett squares and probability

A punnett square of Mendel's second cross

When Mendel let the ***Pp*** plants self-pollinate, white flowers showed up in the second generation. Figure 9.11 shows a punnett square of the cross. Recall that when Mendel counted the plants, he found a 3:1 ratio of purple to white flowers. There are three possible genotypes from the cross. Of the three, ***PP***, and ***Pp*** are purple because they have the dominant allele. Only one of the three (***pp***) is white. From looking at Figure 9.11, can you see why there is a 3:1 ratio of purple-flowered to white-flowered plants?

Probability

When you flip a coin, there is a 50 percent chance you'll get heads and a 50 percent chance you'll get tails. The way the coin lands is completely random. Like flipping a coin, the chance of inheriting a certain genotype and phenotype is random. **Probability** is the mathematical chance that an event will occur.

Punnett squares and probability

Probability can be expressed as a fraction or a percentage. A punnett square represents all of the *possible* genotypes of offspring. In Figure 9.11, 1 out of the 4 squares is ***pp***. The probability of offspring having ***pp*** is therefore 1/4. To convert this to a percentage, take the numerator of the fraction divided by the denominator and multiply by 100:

$$\frac{1}{4} \times 100 = 25\%$$

There is a 25 percent chance of offspring having the ***pp*** genotype. What is the probability of offspring having purple flowers? ***PP***, and ***Pp*** have purple flowers. That's 3 out of the 4 squares. The probability is:

$$\frac{3}{4} \times 100 = 75\%$$

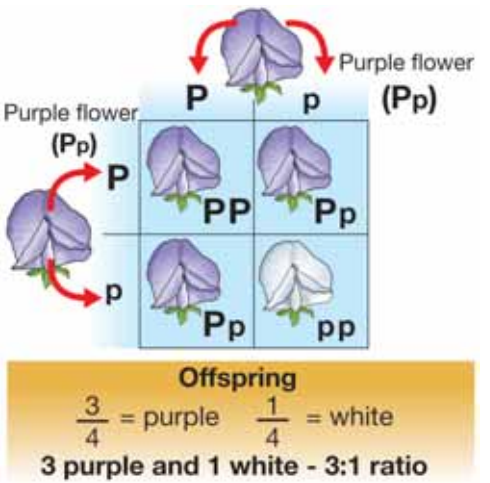


Figure 9.11: *A cross between pea plants of the first generation. The plants have a dominant and recessive allele. Can you see why white flowers showed up in the second generation?*

VOCABULARY

probability - the mathematical chance that an event will occur.

9.2 Section Review

1. Explain the relationship between each pair of terms:
   a. gene and chromosome
   b. gene and DNA
   c. gene and allele
   d. allele and meiosis
2. The table below summarizes four traits in humans. Use the information to answer questions a through d.

Trait	Dominant allele	Recessive allele
earlobes	free (***F***)	attached (***f***)
chin	cleft (***C***)	no cleft (***c***)
thumb	straight (***S***)	hitch hiker's (***s***)

   a. What is the phenotype of a person with a genotype of ***Cc***?
   b. What are the possible genotypes of a person with a straight thumb?
   c. A man with a genotype of ***FF*** marries a woman with a genotype of ***ff***. What are the possible genotypes and phenotypes of their offspring?
   d. A woman with a genotype of ***Cc*** marries a man with a genotype of ***Cc***. What is the probability that their offspring will have a chin with no cleft?
3. Use the punnett square in Figure 9.12 to answer the following questions:
   a. What are the genotypes and phenotypes of the parents?
   b. What is the probability that their offspring will have free earlobes? Attached earlobes?

SOLVE IT!

Use Figure 9.11 on the previous page to calculate the probability that an offspring will have one dominant allele and one recessive allele.

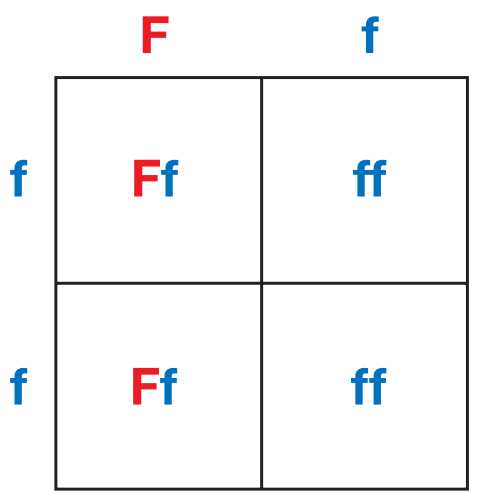


Figure 9.12: *Use this punnett square to answer question 3.*

9.3 Other Patterns of Inheritance

Perhaps it was luck for Mendel (and science) that he happened to use pea plants to discover the principles of heredity. Peas happen to have a number of traits that are determined by just two alleles. Also, for the traits he studied, one allele happened to be dominant and the other recessive. Mendel discovered an important pattern of inheritance and his laws are the foundation of genetics. Since plant and animals have *thousands* of genes, some have patterns of inheritance that are different from the ones Mendel discovered. In this section, you will learn about some of those patterns.

Male or female?

Sex chromosomes

Mendel worked with peas that had female and male parts on the same plant. Many organisms, like humans, have separate female and male individuals. In humans, sex is determined by the last pair of chromosomes, called sex chromosomes (Figure 9.13). **Sex chromosomes** carry genes that determine whether an individual is female or male.

Male and female genotypes

The female chromosome is symbolized with an ***X*** and the male with a ***Y***. A female has two ***X*** chromosomes in her body cells. Her genotype is ***XX***. A male has an ***X*** and a ***Y*** chromosome in his body cells. His genotype is ***XY***. During meiosis, the sex chromosome pairs separate. Females produce eggs with an ***X*** chromosome. Males produce sperm with an ***X*** or a ***Y*** chromosome. Figure 9.14 shows a punnett square that crosses a male and a female. What are the chances of having a boy or a girl?

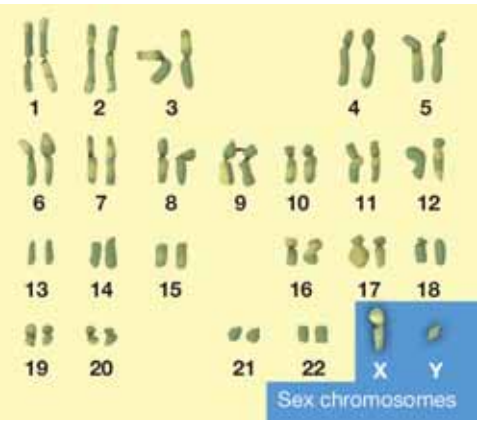


Figure 9.13: *In humans, sex is determined by the last pair of chromosomes. What is the sex of this person?*

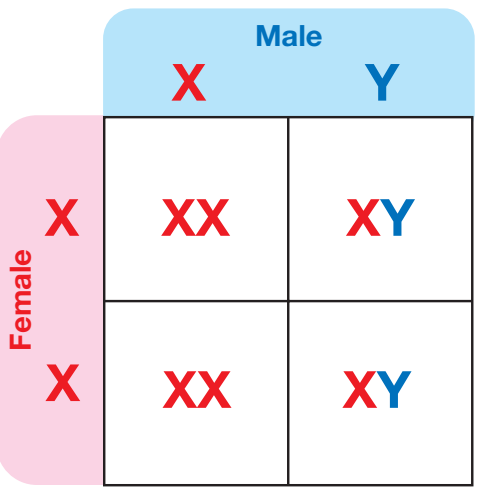


Figure 9.14: *A cross between a male and a female.*

Incomplete dominance and codominance

Pink flowers from red and white!

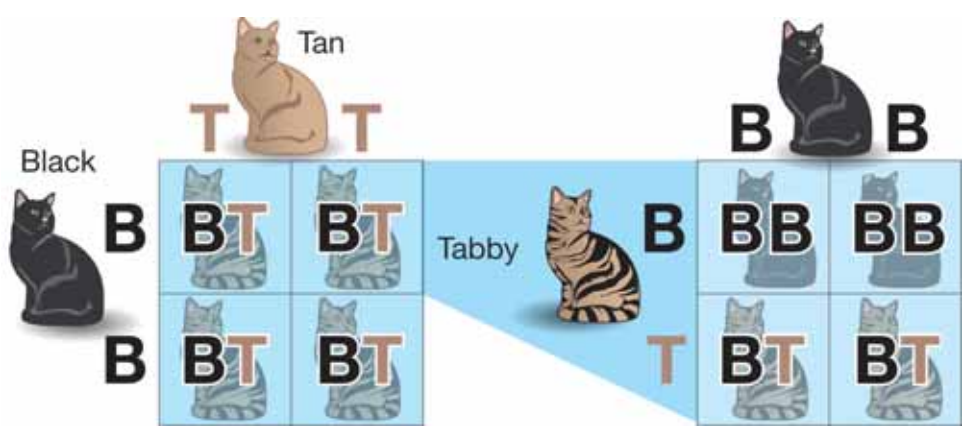
Sometimes one allele isn't completely dominant over the other. If you cross a true-breeding, red-flowered snapdragon (***RR***) with a true-breeding, white-flowered snapdragon (***WW***), you may expect the first generation to have all red flowers. In snapdragons, this does not happen. The first generation has *pink* flowers (Figure 9.15)! When you cross two pink-flowered snapdragons (***RW***), the second generation of plants will have 25% red flowers, 50% pink flowers, and 25% white flowers.

Incomplete dominance

Flower color in snapdragons is an example of incomplete dominance. In **incomplete dominance**, the phenotypes of the two alleles blend—just like mixing paints. Notice that in Figure 9.15, we use ***R*** for the red allele and ***W*** for white allele instead of upper and lower cases of the same letter.

Codominance

In **codominance**, an organism that has both alleles of a gene displays *both* phenotypes at the same time. For example, a cross between a black cat (***BB***) and a tan cat (***TT***) results in a tabby cat (black and tan mixed together). Suppose a tabby cat (***BT***) crossed with a black cat (***BB***). What is the probability that one of their kittens would have tabby fur?



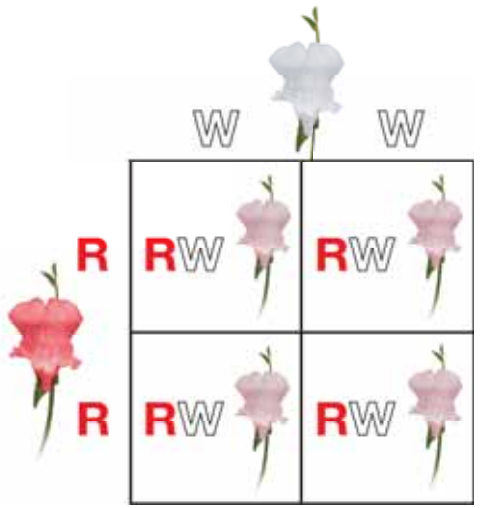


Figure 9.15: *A cross between red-flowered snapdragons and white-flowered snapdragons produces pink-flowered snapdragons. The second generation has red, pink, and white flowers.*

VOCABULARY

incomplete dominance - when the phenotype of the two alleles blend.

codominance - when an organism that has both alleles of a gene displays both phenotypes at the same time.

Other patterns of inheritance and environmental factors

Multiple alleles

So far you have learned about genes that have just two alleles. *Multiple alleles* are also common in organisms. In humans for example, *three* alleles determine blood type (***A***, ***B***, and ***O***). Each person can have only two of the alleles at one time, but there are three alleles in the human population. If a person inherits a B allele from one parent and a O allele from the other parent, she will have type B blood. The diagram (right) shows the possible genotypes and phenotypes for human blood type.

Parent Alleles ▶ / ▼	A	B	O
A	AA (Type A)	AB (Type AB)	AO (Type A)
B	AB (Type AB)	BB (Type B)	BO (Type B)
O	AO (Type A)	BO (Type B)	OO (Type O)

Polygenic traits

Inherited traits that are determined by more than one gene are called **polygenic traits**. Have you ever seen parakeets in a pet store? Feather color in parakeets is determined by two genes. One gene controls yellow color and the other controls blue color. Figure 9.16 shows the possible genotypes and phenotypes. In humans, eye color and skin color are polygenic traits. The range in skin colors of humans is determined by no less than four genes!

Environmental factors

Genes aren't the only influence on the traits of an organism. Environmental factors may also influence traits. For instance, in some turtle species, sex is determined by temperature. During the development of the embryo, higher temperature favors the production of males. Human height is determined by genes. But if a person does not get the proper nutrients, he or she may not reach his or her potential height.

VOCABULARY

polygenic traits - traits that are determined by more than one gene.

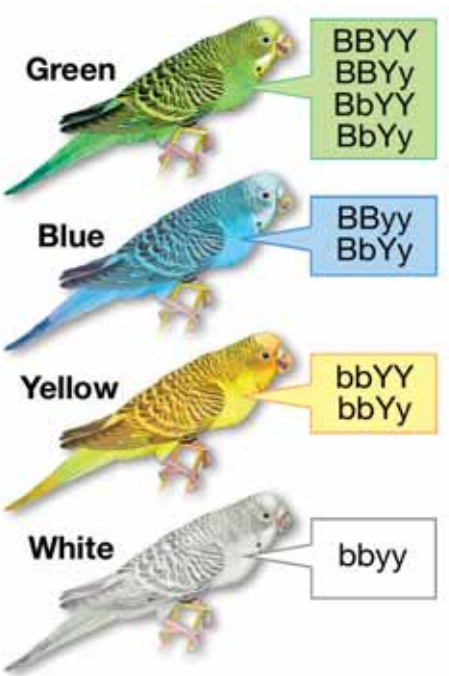


Figure 9.16: *Feather color in parakeets is determined by two genes.*

MY JOURNAL

Can you think of other environmental influences on your traits? Make a list of as many influences as you can think of.

9.3 Section Review

1. True or false: A single gene determines the sex (male or female) of a human.
2. Explain why the probability of a human giving birth to a male baby is always 50%.
3. What is incomplete dominance? Give one example.
4. How is codominance different than incomplete dominance? Give one example of codominance.
5. Figure 9.17 shows a cross between a tabby cat and a tan cat. What is the probability of offspring with black fur? Tabby fur? Tan fur?
6. Blood type is determined by three alleles, A, B, and O. Use the punnett square below to answer questions a through c.

	A	O
B	AB	BO
O	AO	OO

   a. What is the probability of an offspring with type A blood?
   b. What is the probability of an offspring with type O blood?
   c. What are the genotypes and phenotypes of the parents?

	T	T
B	BT	BT
T	TT	TT

Figure 9.17: *Use the diagram above to answer question 5.*

CHALLENGE

1. A red snapdragon is crossed with a pink snapdragon. Make a punnett square of the cross. List the possible genotypes and phenotypes of the offspring.
2. A person with type AB blood marries a person with type O blood. Make a punnett square of the cross. List the possible genotypes and phenotypes of their offspring.

HEALTH CONNECTION An Inherited Blood Disease

Sickle cell anemia is an inherited blood disease that affects more than 70,000 Americans. The disease causes severe joint pain and weakness and often leads to an early death. The disease has been present in Africa for hundreds of years. Would you believe that some members of families that carry the sickle cell trait can actually benefit? Read on to find out how.

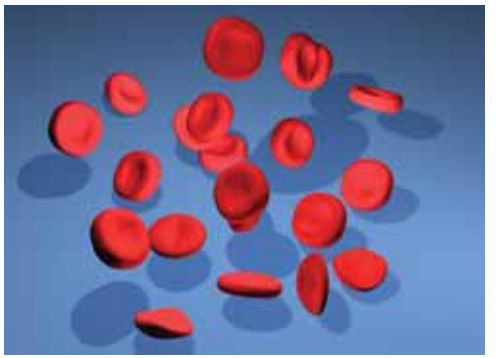
Comparing red blood cells

Sickle cell describes the shape of red blood cells in people who have the disease. The other part of the name, *anemia*, means there are too few red blood cells. In turn, this can mean that too little oxygen is being carried through the body. Red blood cells carry oxygen from the lungs to the tissues in our bodies.

Normally, red blood cells are round. They look like disks (top, right). With sickle cell anemia the red blood cells are sickle-shaped (bottom, right). A sickle is a tool shaped like the letter C.

Normal red blood cells flow easily through small blood vessels. Sickle-shaped red blood cells clog small blood vessels.

Normal red blood cells live about 120 days. Sickle-shaped red blood cells live only 10 to 20 days. This causes a constant shortage of red blood cells, a condition known as anemia.



Genes: the good and the bad

Sickle cell anemia affects populations in Africa, India, the Mediterranean area, and South America. It is most common in Africa and in people with African ancestors. About 1 in every 500 African Americans has the disease.

Some diseases are inherited just like your physical traits. Sickle cell anemia is one such inherited disease.

Everyone carries a gene that is responsible making hemoglobin. Hemoglobin is a protein in red blood cells that carries oxygen. People with sickle cell anemia have two *mutated* alleles of that gene. They produce abnormal hemoglobin. This causes the sickle-shaped cells and lowers their ability to carry oxygen to other cells. You'll learn about mutations in Chapter 10.

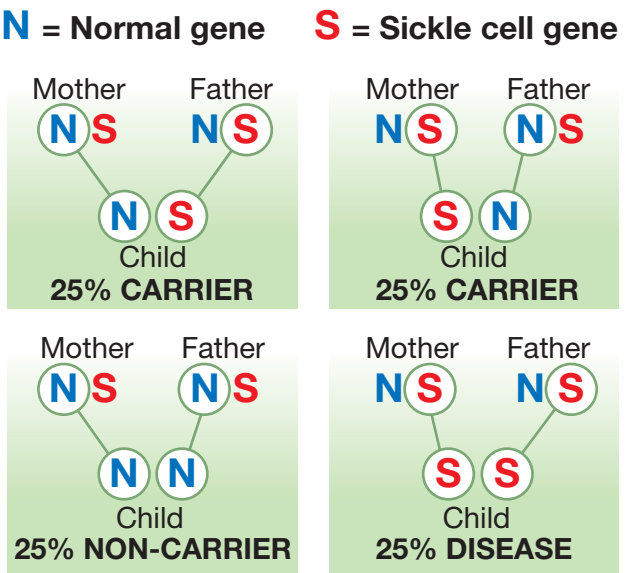
The dominant allele of the hemoglobin gene causes normal hemoglobin. The recessive allele of the gene causes sickle cell anemia. People who have sickle cell anemia have two recessive alleles for the disease. This means that one recessive allele came from each parent.

Some people have both the dominant allele and the recessive allele. These people are called *carriers*. About 8 in every 100 have the recessive allele for sickle cell anemia. Carriers may have normal lives. But the child of two carriers may have the disease.

The genetic chances

If both parents are carriers of the sickle cell trait, they each have one normal allele and one sickle cell allele. Each parent contributes one gene to the child. What are the chances of a child getting sickle cell anemia?

- There is a 50 percent chance that the child will end up with one sickle cell allele. In this case, the child has the sickle cell trait and is a carrier.
- There is a 25 percent chance that the child will get one sickle cell allele from each parent. This child will have sickle cell anemia.
- There is a 25 percent chance that the child will get no sickle cell alleles.



The malaria connection

The sickle cell allele has not disappeared because it helps some people. People with the trait are much more resistant to malaria than people without the trait.

Malaria is caused by a single-celled parasite. Mosquitoes carry the parasite from person to person, spreading the deadly disease. Malaria has killed millions of people throughout the world. The majority of the victims are children.

While non-existent in the United States, malaria is a risk in other places. The disease is still common in Africa. Sickle cell anemia carriers are more common there also. In some parts of Africa as much as 40 percent of the population has the sickle cell trait.

Why do carriers of the sickle cell trait resist malaria? The parasite causes normal red blood cells to become sickle shaped. Somehow the sickle cell carrier's body produces a resistance to the disease. Carriers of the sickle cell trait are partially protected from malaria. The trait does not provide an absolute protection, but these individuals are more likely to survive the malaria illness. The exact reason why sickle cell traits act as a resistance to malaria is still unknown.

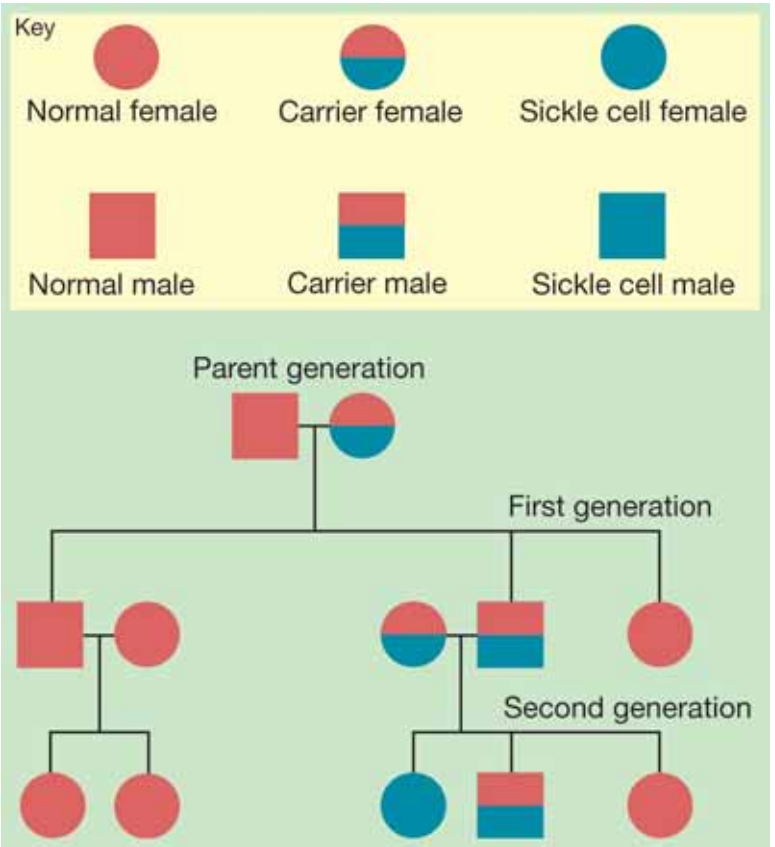
Even though sickle cell anemia is harmful to people with the disease, the trait persists in places where malaria is common. This is an example of *natural selection*. People with the sickle cell trait have an advantage where malaria thrives.

Questions:

1. How can you get sickle cell anemia?
2. If you mother and father are both sickle cell carriers, what are the chances that you will not have the trait?
3. How does sickle cell anemia affect the red blood cells?
4. Why are people with the sickle cell trait able to resist malaria?

CHAPTER ACTIVITY Making a Pedigree

A **pedigree**, or family tree, is a diagram that shows the generations of a family. A pedigree is often used to trace one or more traits from generation to generation. Pedigrees are often used to predict the chances of offspring having a genetic disorder like sickle cell anemia. The diagram below shows a pedigree of a family that carries the sickle cell trait. The mother is a carrier and the father does not carry the allele. In the first generation, one of their sons is a carrier who marries another carrier. One of their daughters has sickle cell anemia, one son is a carrier, and another daughter does not carry the allele. Use the pedigree below as a model for this activity.



What you will do

For the activity, you will need pencils and a ruler. Make a pedigree for the family described below.

1. A woman who is a carrier of sickle cell marries a man who does not carry sickle cell. Start by drawing the parents.
2. The parents have two girls and two boys. One of the boys and one of the girls each carries the sickle cell allele. The other two children are not carriers. Add the first-generation children to your chart.
3. One of the first-generation boys who carries the sickle cell allele marries a woman who also carries the allele. They have two children, one boy with sickle cell, and a girl who is not a carrier. Add their children (the second generation) to your chart.
4. A first generation girl who does not carry the sickle cell allele marries a man who also is not a carrier. They have two girls and a boy. Add their children to your chart.

Applying your knowledge

a. What are the genotypes of the original parents (the parent generation)? Use ***S*** for the normal allele and ***s*** for the sickle cell allele. Add their genotypes to your chart.

b. Add the genotypes of the first and second generation children to your chart.

c. In step four, you were not give the phenotypes of the children. Why wasn't it necessary for you to be given the phenotypes?

d. Cystic fibrosis is a genetic disorder in which the body produces abnormally thick mucus in the lungs and intestines. It is carried on a recessive allele. Make up a fictional family that has the cystic fibrosis allele. Start with the parent generation and trace the family through two generations. Create names for the family members. Make your chart on a poster board. Be creative!

Chapter 9 Assessment

Vocabulary

Select the correct term to complete t

alleles	cross-pollination	dominant allele
heredity	incomplete dominance	polygenic traits
recessive allele	sex chromosomes	true-breeding
codominance	phenotype	trait
genotype	punnett square	genetics
gene		probability

Section 9.1

1. A(n) _____ is always expressed if it is present in an organism.
2. A unit that determines traits is a(n) _____.
3. Gregor Mendel is often called the "father of _____."
4. The organism's _____ can't be seen because it is the actual alleles of a gene that the organism contains.
5. A(n) _____ is only expressed in an organism if no dominant allele is present.
6. Flower color is an example of a _____ in pea plants.
7. Mendel used all _____ in his experiments.
8. A set of traits that an organism receives from its parents is called _____.
9. The organism's _____ for a given trait can be seen because it is the form that the organism displays.
10. _____ occurs when animals or the wind carry pollen from one flowering plant to another.
11. Organisms have at least two _____ for each gene - one from each parent.

Section 9.2

12. The mathematical chance that an event will occur is called _____.
13. If the genotypes of the parents are known, a(n) _____ can be used to show the possible genotypes and phenotypes of the offspring.

Section 9.3

14. Eye color and skin color in humans are examples of _____.
15. _____ is when the phenotypes of two alleles blend together.
16. The human blood type AB is an example of _____ - when an organism shows the phenotypes of two different alleles at the same time.

Concepts

Section 9.1

1. List three examples of traits from the chapter.
2. Explain the process of pollination in flowering plants.
3. Why did Mendel remove the anthers from the pea plants when performing cross pollination in his experiments?
4. Which of these traits did not show up in Mendel's first generation at all?
   a. purple flowers
   b. yellow seeds
   c. wrinkled seeds
   d. green pods

5. From Mendel's work, choose which of each pair is the dominant form of the gene.
   a. white flowers or purple flowers
   b. smooth seeds or wrinkled seeds
   c. green seeds or yellow seeds
   d. yellow pods or green pods
6. Summarize what Mendel concluded from his pea plant experiments.
7. Label these examples as one of the following heredity terms: trait, dominant allele, recessive allele, genotypes, or phenotypes.
   a. ***R*** for smooth
   b. seed shape
   c. either smooth or wrinkled
   d. ***r*** for wrinkled
   e. ***RR***, ***Rr***, or ***rr***
8. Explain how you can have the same phenotype, but a different genotype for a given trait. Given an example to support your answer.

Section 9.2

9. Explain how Walter Sutton's work built on Gregor Mendel's work.
10. Which of these is part of the basic laws of how traits are passed onto offspring?
    a. an organism usually receives one allele for each gene from each parent
    b. a gene is a piece of DNA found on a chromosome that carries information from parent to offspring
    c. when organisms receive different alleles for one trait, one form may be dominant to the other
    d. all of the above
11. How does meiosis ensure that an organism receives only one allele from each parent for each trait?
12. What is the tool that scientists use to predict the possible genotypes and phenotypes of offspring?
13. If black fur color is dominant to white fur color in guinea pigs, explain how two parents with black fur could possibly have a white offspring.
14. From your understanding of probability, explain why it was important that Gregor Mendel used thousands of pea plants in his experiments? Would Mendel have found the same results if he had used only twenty plants? Explain.

Section 9.3

15. Who determines the sex of the baby in humans, the mother or the father? Explain.
16. What is the difference between incomplete dominance and codominance? Give an example of each in your explanation.
17. If a black chicken is crossed with a white chicken in a certain species, the offspring are black and white chickens. These chickens are an example of which pattern of inheritance?
    a. polygenic inheritance
    b. multiple alleles
    c. codominance
    d. incomplete dominance
18. In another species of chickens, a cross between a black chicken and a white chicken produces blue chickens. These chickens are an example of which pattern of inheritance?
    a. polygenic inheritance
    b. multiple alleles
    c. codominance
    d. incomplete dominance

19. Describe how Mendel's pea plant experiments are not an example of multiple alleles.
20. Explain why it makes sense that there are no less than four genes that control human skin color.
21. Give one example of how environmental factors can influence traits.

Math and Writing Skills

Section 9.1

1. Write a letter as if you were Gregor Mendel explaining your work with pea plants to a friend. Be sure to include how you actually carry out your experiments as well as what you have discovered through your work.
2. Write an obituary for Gregor Mendel. Include the important facts of Mendel's life including the years he was alive, where he lived, what his job was, and why his work was important.
3. Dr. X is a geneticist that studies fruit flies. She crossed long winged fruit flies with a short winged fruit flies. She found that 776 fruit flies had long wings and 260 had short wings.
   a. What was the ratio of long winged fruit flies to short winged fruit flies?
   b. Which is the dominant allele - long or short wings?
4. Farmer Davidson sells rabbits in the springtime. For the last few years, the solid colored rabbits have been way more popular than spotted rabbits. Unfortunately for Farmer Davidson, spotted fur color is dominant to solid fur color in rabbits. Suppose Farmer Davidson's rabbits have 200 offspring. 50 of the offspring are solid color. About how many offspring with spotted fur will Farmer Davidson have to sell?

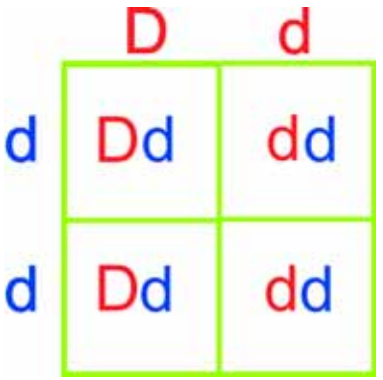
Section 9.2

5. Write a dialogue that might have happened if Gregor Mendel and Walter Sutton had met one another.
6. What advancements in science and technology do you think allowed Walter Sutton to add onto the work of Gregor Mendel?
7. In the punnett square below, ***F*** = free earlobes and ***f*** = attached earlobes. Use the punnett square to answer the questions below.

	F	f
f	Ff	ff
f	Ff	ff

   a. What are the genotypes of the parents?
   b. Suppose the parents had 12 children. What are the chances that one of their children will have free earlobes?
   c. Predict how many of their children have attached earlobes.
   d. 7 out of their 12 children have attached earlobes. Does this agree with your prediction? Explain how the numbers could be different.

8. Dark fur (D) is dominant to light fur (d) in dogs. Use the punnett square to answer these questions:



   a. What are the genotypes and phenotypes of the parents?
   b. What is the most likely ratio of dark fur to light fur dogs in the offspring?
   c. What is the probability that the offspring will have dark fur? light fur?
   d. Explain why this cross could never produce a DD offspring.

Section 9.3

9. Mrs. Allen is about to have another baby. She already has three daughters. What is the probability that her fourth child will also be a girl?

10. If you flipped a coin and it landed on heads five times in a row, what is the probability that the sixth coin toss to land on heads?

11. Use masking tape to mark both sides of a coin - one side G for the dominant allele and the other side g for the recessive allele. Toss the coin twenty times and record the tosses. Create a table to display your results.

Chapter Project

Punnett squares on the Internet

You can construct a punnett square to predict the possible genotypes and phenotypes of offspring when you know the parents' genotypes. There are many excellent websites with interactive tutorials on how punnett squares work. Simply go to a search engine and type in the key words “punnett square.”

For this project, search for a website that contains a helpful punnett square tutorial and practice using the punnett square. When you have found the website and practiced with it, write a one-page paper about your experience. Write about your experience in your own words, and include the following information in your paper:

1. Full address of website
2. What person or group is the author of the punnett square tutorial?
3. When was this website last updated?
4. What did you like about this tutorial?
5. Copy down at least three punnett squares you constructed.
6. What unique features did this tutorial have?
7. What would you change about the tutorial to improve it?

Chapter 10

The Code of Life

Police detectives, crime labs, and private investigators need to collect evidence to link a suspect to a crime scene. Fingerprints have been used as evidence for years, since everyone's fingerprints are unique. Now forensic scientists, like the ones depicted on popular television programs, use DNA sequencing techniques to identify individuals. What exactly is DNA, and why is yours unique? Study this chapter to learn all about DNA, which is sometimes called the "code of life."

Key Questions

1. ***What is DNA and what does it do?***
2. ***What is a genetic disorder?***
3. ***How is DNA used in the latest technologies?***

10.1 The Role of DNA in Heredity

Only in the last 50 years have scientists understood the role of DNA in heredity. That understanding began with the discovery of DNA's structure. In 1952, Rosalind Franklin (1920–1958) used a technique called *x-ray crystallography,* to capture the first image of a DNA molecule. With the help of Franklin's photo, James Watson (1928–present) and Francis Crick (1916–2004) were able to piece together the first accurate model of DNA. In this section, you will learn how the structure of DNA is related to its function as the hereditary molecule.

MY JOURNAL

DNA is in the news almost every day. Find an article in a newspaper, magazine or on the Internet that mentions DNA. Write a reflection about the article. How does the article make you feel about studying DNA?

DNA structure

The DNA molecule

A DNA molecule looks like a twisted ladder (Figure 10.1). Its shape is called a *double helix*. A helix is a shape that twists. The two sides of the DNA ladder are made of sugar molecules alternating with phosphate molecules. The rungs of the DNA molecule are made of chemical building blocks called *bases*. The four bases found in DNA are adenine (**A**), thymine (**T**), cytosine (**C**), and guanine (**G**).

Figure 10.1: *A DNA molecule looks like a twisted ladder.*

Base pairs

Each rung of the DNA ladder consists of a *base pair*. The base on one side of the molecule always matches up with a certain base on the other side. The base **A** only pairs with **T** and **C** only pairs with **G**. This base pairing is very important to the function of DNA.

DNA replication

What is DNA replication?

We learned in Chapter 8 that before mitosis, the amount of DNA doubles. **DNA replication** is the process of a DNA molecule making a copy of itself. DNA replication occurs before mitosis begins and before the first division of meiosis. It ensures that each daughter cell has an exact copy of the genetic material from the parent cell.

VOCABULARY

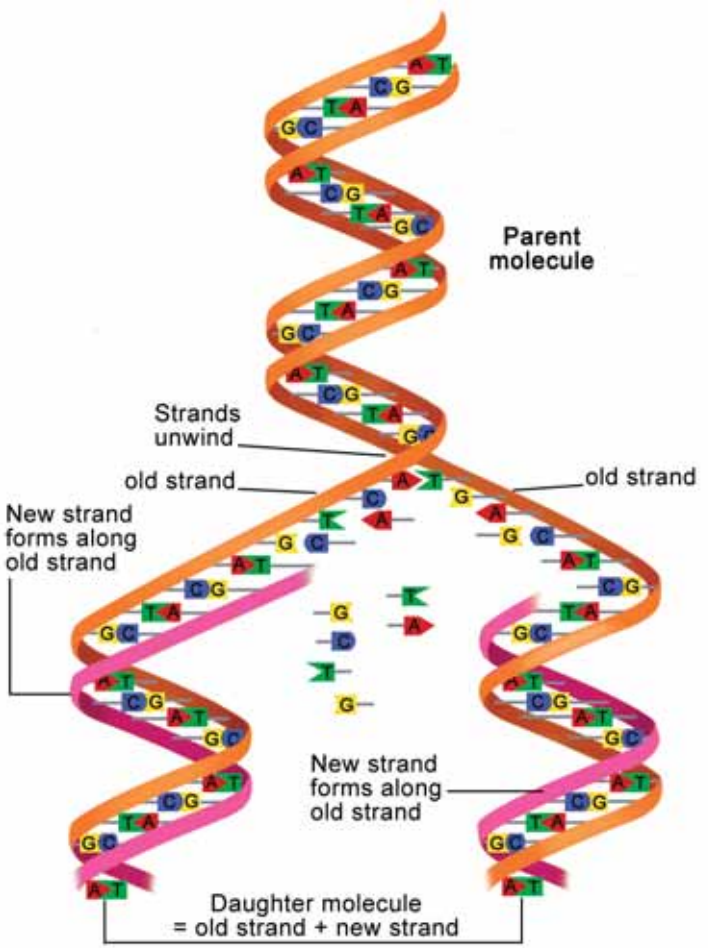
DNA replication - the process of a DNA molecule making a copy of itself.

DNA replication ensures that each daughter cell has an exact copy of the DNA from the parent cell.

The process of DNA replication

DNA replication results in one DNA molecule becoming two *daughter molecules*—each an exact copy of the original molecule. The steps of the process are outlined below.

1. DNA replication begins with the partial unwinding of the double helix. The base pairs separate.
2. A special molecule moves along each original strand of DNA and "reads" the bases.
3. A new strand is assembled along each original strand. The pieces are assembled from molecules in the cytoplasm.
4. When the process is complete, two daughter molecules will have been produced. Each daughter molecule is identical to the original molecule.
5. Both strands of the original DNA molecule have remained intact. Each daughter molecule is made of one original strand and one new strand.



Protein synthesis

Chromosomes, genes, and DNA

With the exception of red blood cells, which have no nucleus or nuclear DNA, each one of your body cells contains a complete (diploid) set of chromosomes. Each chromosome is made up of thousands of genes. Each gene consists of a sequence of DNA base pairs (Figure 10.2). In total, the DNA in one of your cells contains about 3 billion base pairs! The order of base pairs along a gene is called its **base sequence**.

Genes and proteins

Genes control the production of proteins. Your body structures are made of proteins. As a result, those proteins help determine your traits. For example, the color of your eyes is determined by a protein. Proteins are made of long chains of smaller molecules called *amino acids*. The production of proteins in the cell is called **protein synthesis**.

Amino acids make up proteins

The order of base pairs along a gene forms a code that tells a cell which protein to make. Sets of three bases along a strand of DNA form three-letter codes that tell the cell which amino acids make up the protein. There are 20 different amino acids. Those amino acids can be put together in many ways to make millions of different proteins. During protein synthesis, the cell reads the three-letter codes along the DNA molecule and uses that information to build a protein from different amino acids.

The role of RNA

Protein synthesis takes place in the ribosomes which are found in the nucleus. It involves another nucleic acid called *RNA*. RNA is different from DNA because it consists of a single strand. Also, instead of the base thymine (**T**), RNA has the base uracil (**U**). In RNA, **A** pairs with **U** instead of with **T**. *Messenger RNA* carries the three-letter codes from the DNA in the nucleus to the ribosome. *Transfer RNA* decodes the base sequence and carries the correct amino acids to the ribosome.

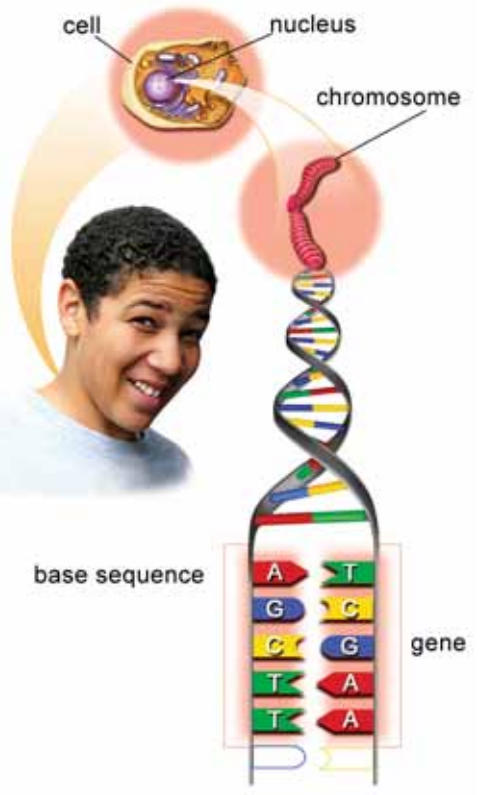


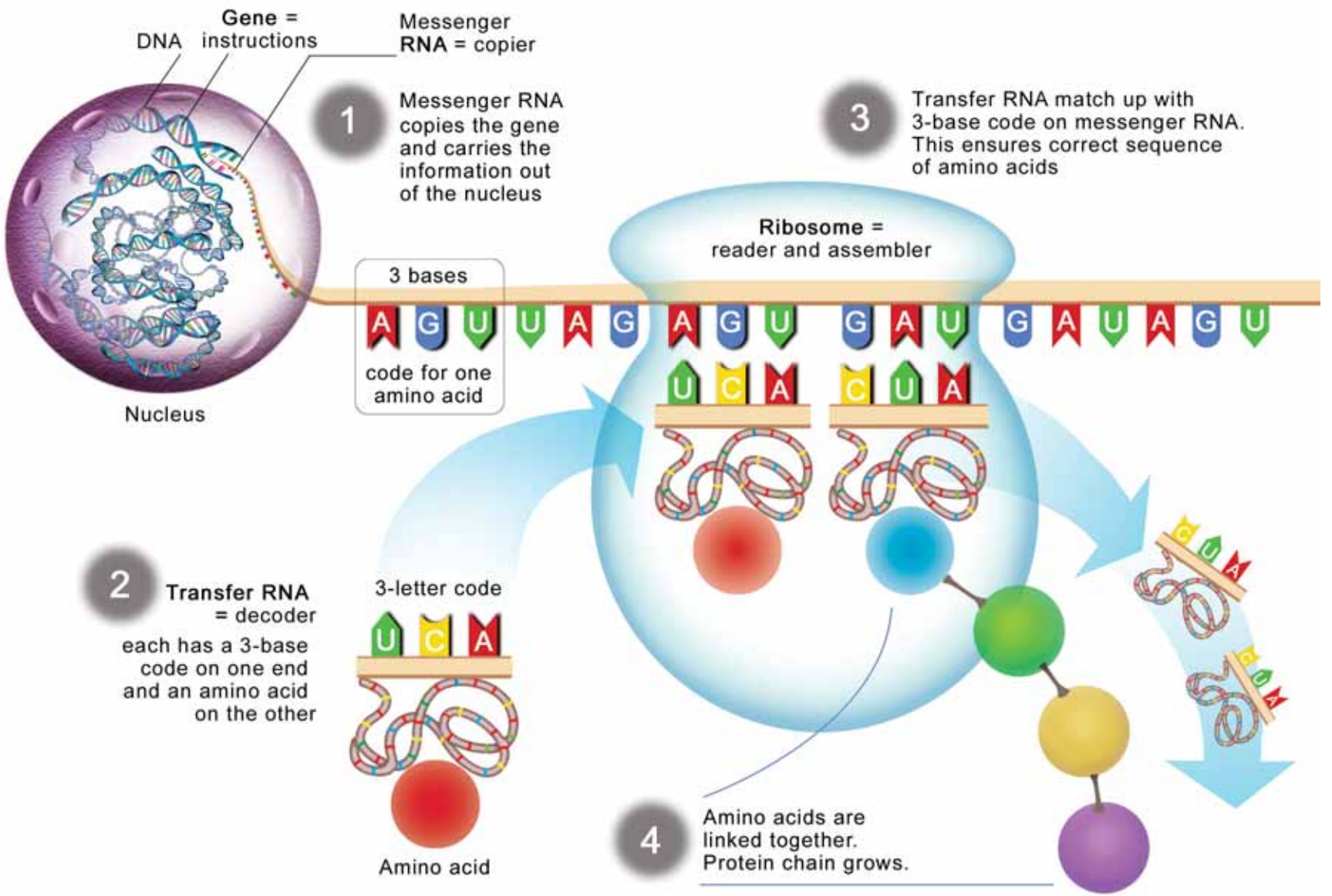
Figure 10.2: *The relationship between chromosomes, genes, and DNA.*

VOCABULARY

base sequence - the order of base pairs along a gene.

protein synthesis - the production of proteins in the cell.

How protein synthesis works



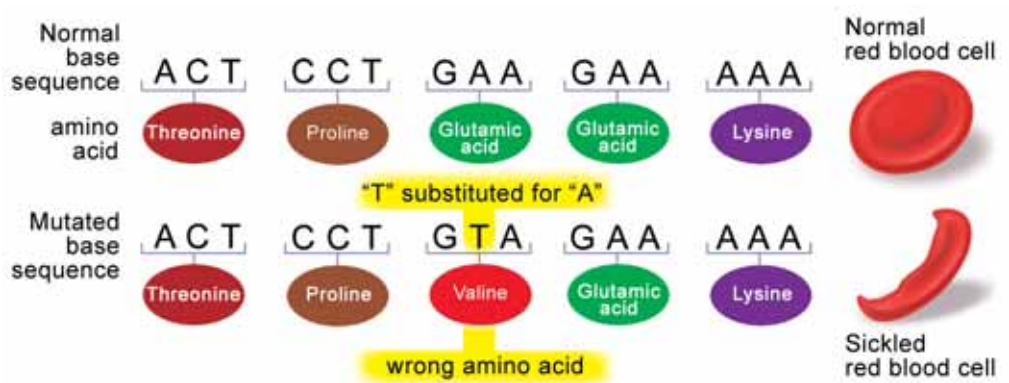
Mutations

What are mutations?

Usually, the processes of DNA replication and meiosis happen without mistakes. However, mistakes do happen. Those mistakes are called mutations. A **mutation** is a change in the hereditary material of an organism. Mutations can happen in any cell and in any gene. They are sometimes caused by exposure to chemicals or other environmental conditions.

Gene mutations

A gene mutation involves a change in one of the bases in the sequence along a gene. A change in the base sequence changes one of the three-letter codes for an amino acid. This may cause the cell to produce the wrong protein. In the example below, one of the bases in the sequence is substituted for another. The mutation causes *sickle cell anemia,* a blood disorder.



Chromosome mutations

Other mutations involve a change in the structure or number of chromosomes. For instance, during meiosis one or more pairs of chromosomes may fail to separate. Sex cells with extra sets of chromosomes may be produced (Figure 10.3). In plants, a complete extra set of chromosomes can cause desirable traits. Some varieties of strawberries are bred with extra sets of chromosomes. This causes the berries to grow extra large.

VOCABULARY

mutation - a change in the hereditary material of an organism.

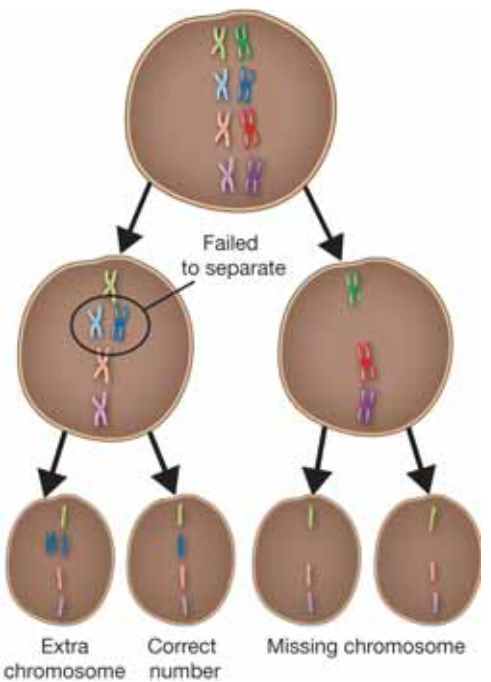


Figure 10.3: *A mutation in the number of chromosomes.*

Genetic disorders

What are genetic disorders?

Some mutations are helpful while others are harmful. You'll learn how mutations can help a population of organisms in Chapter 11. Genetic disorders are a harmful effect of mutations. A **genetic disorder** is an abnormal condition that an organism inherits from its parents. Genetic disorders can result from mutation of a single gene or mutation of the chromosomes. In order to be passed on to offspring, the mutation must be present in the sex cells.

Mutations of a single gene

Some genetic disorders result when a mutation causes the product of a single gene to be altered or missing. An example of this kind of disorder is *cystic fibrosis*. Cystic fibrosis affects about 30,000 children and adults in the United States. A recessive allele causes the body to produce an abnormally thick, sticky mucus that clogs the lungs and leads to life-threatening lung infections. Thick mucus also clogs the organs of the digestive system and often leads to digestive problems and liver damage. Other examples of this type of genetic disorder include *hemophilia* and *sickle cell anemia*—both diseases of the blood.

Too many or too few chromosomes

Some genetic disorders result from too many or too few chromosomes. *Down's syndrome* is a genetic disorder in which a person's cells have an extra copy of chromosome 21 (Figure 10.4). People with Down's syndrome have some mental and physical limitations. However, they can lead normal, productive lives.

Determining genetic disorders

Doctors use a procedure called *amniocentesis* to find out if a baby will have a genetic disorder. In amniocentesis, the doctor removes a small amount of the fluid that surrounds the developing baby. That fluid contains cells from the baby. Next, the chromosomes from the cells are analyzed to look for abnormal genes or chromosome numbers (Figure 10.5).

VOCABULARY

genetic disorder - an abnormal condition that an organism inherits.

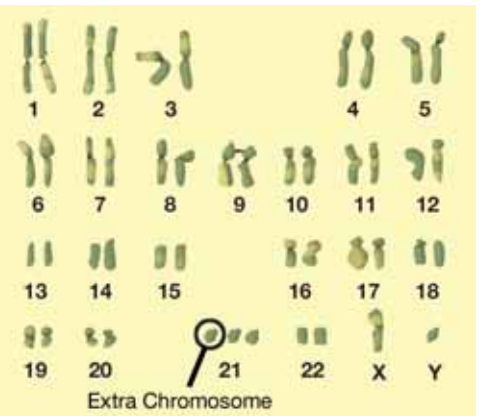


Figure 10.4: *Down's syndrome is caused by an extra copy of chromosome number 21.*

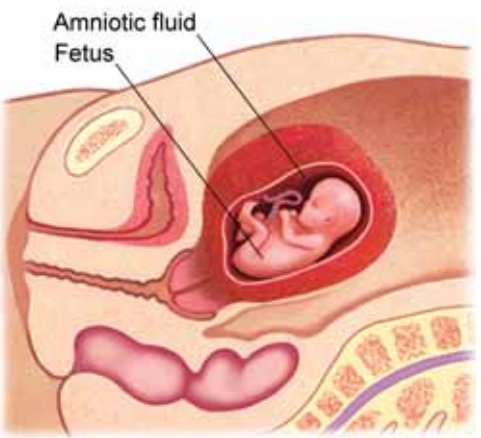


Figure 10.5: *Amniotic fluid.*

10.1 Section Review

1. Below is a sequence of bases along one side of a DNA molecule. Write out the sequence of DNA bases that would pair with the ones shown.

2. What is DNA replication and why is it important?
3. Name the function of each in protein synthesis: messenger RNA, transfer RNA, DNA, and ribosome.
4. Write out the messenger RNA bases that would pair with the DNA strand shown in question 1.
5. A certain species of squirrel is usually gray. Occasionally a white squirrel, called an *albino*, is born. An albino squirrel happens because:
   a. DNA replication does not occur
   b. mitosis produces too many white fur cells
   c. a mutation in the gene for fur color occurs
   d. both of the parents have white fur
6. Name two genetic disorders and explain the type of mutation that causes each.
7. Which process could result in the type of mutation that causes Down's syndrome?
   a. cellular respiration
   b. meiosis
   c. mitosis
   d. amniocentesis

SOLVE IT!

How many amino acids are present in a protein that requires 1,500 bases in its code?

CHALLENGE

A haploid cell has one chromosome from each homologous pair and is symbolized by **N**. A diploid cell has chromosomes in homologous pairs and is symbolized by **2N**. Polyploidy is a mutation where the cells of an organism have chromosomes that occur in groups of three (**3N**), four (**4N**), or more (**xN**). Use this information to answer the following questions:

1. A corn plant has 80 chromosomes and is **4N**. What is the normal number of chromosomes in a corn plant's body cells?
2. In peas, **2N** = 14. How many chromosomes are in a pea egg cell?

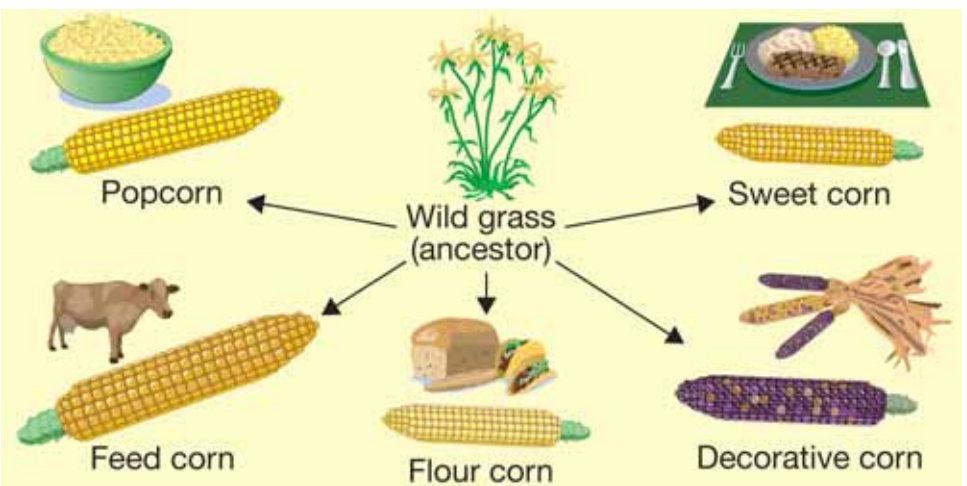
10.2 DNA and Technology

Over a period of thousands of years, Native Americans transformed a type of wild grass into *maize*—better known as corn. Maize was developed from a wild grass originally growing in Central America 7,000 years ago. The seeds of that grass looked very different from today's kernels of corn. By collecting and growing the plants best suited for eating, Native Americans encouraged the formation of larger kernels on cobs (Figure 10.6).

Selective breeding

Selecting desirable traits

Native Americans used selective breeding to produce maize. **Selective breeding** is the process of selecting organisms with desired traits to serve as parents for the next generation. Native Americans began by selecting seeds of wild grass that were the best for eating. They grew those seeds and then selected the best seeds from that generation. By repeating this process over many generations of plants, they developed a variety of maize that produced the most food per plant. Today we have many varieties of corn. All are descendents of those early plants.



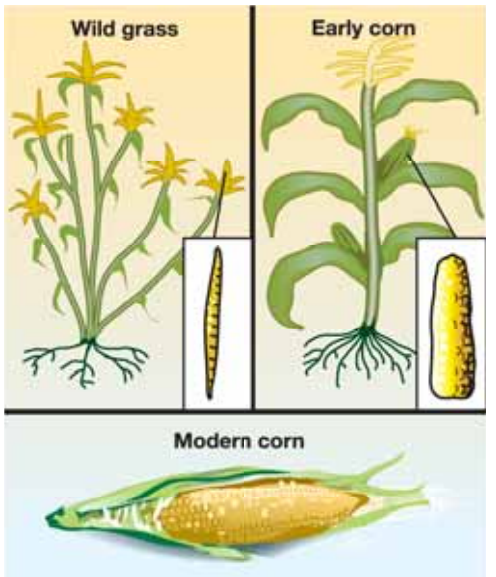


Figure 10.6: *Native Americans transformed a wild grass into maize.*

VOCABULARY

selective breeding - the process of selecting organisms with desired traits to serve as parents for the next generation.

Genetic engineering

What is genetic engineering?

Since the discovery of DNA, scientists have found new methods of producing organisms with desired traits. One of those methods is called genetic engineering. **Genetic engineering** is the process of transferring genes from one organism into the DNA of another organism. Walk down the produce aisle at your grocery store and you'll find some products of genetic engineering. Supersweet corn and cold-resistant tomatoes are examples.

Genetically engineered bacteria

Another example of genetic engineering is the production of insulin to treat people with diabetes. *Insulin* is a protein that regulates carbohydrates in the blood. People with diabetes can't produce enough insulin. Scientists insert a human gene for insulin into the circular DNA of bacteria (called a *plasmid*). The transformed bacteria are tricked into producing insulin. When the transformed bacterial cells divide, their offspring carry the gene for insulin (Figure 10.7). Because bacteria reproduce rapidly, large amounts of insulin can be produced in a short amount of time.

Treatments for genetic disorders

Scientists routinely insert genes into the plasmids of bacteria, which are prokaryotes. Eukaryotic cells are more complex and usually do not contain plasmids. Therefore it is more difficult to use genetic engineering in eukaryotic cells. One method is to inject new DNA into a cell with a tiny needle. Sometimes the cell accepts the DNA. Other times it destroys the DNA. In one case, scientists were able to insert a cold-water fish gene into a tomato plant, making the plant more cold-resistant.

Important questions

Genetic engineering raises many ethical questions. For example, should we genetically engineer humans to be taller and stronger? Are genetically engineered foods bad for you? Learning genetics can help you make informed decisions about genetic engineering.

VOCABULARY

genetic engineering - the process of transferring genes from one organism into the DNA of another organism.

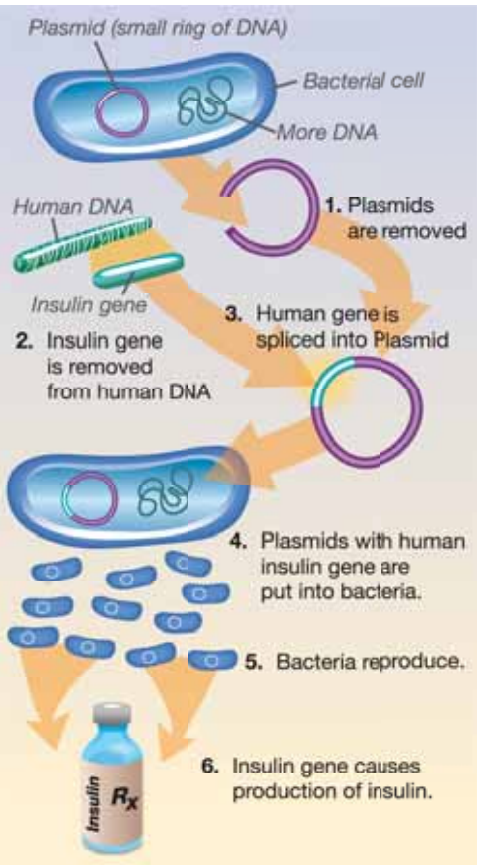


Figure 10.7: *How genetic engineering is used to make insulin.*

DNA fingerprinting

DNA is unique from person to person

The DNA of all organisms contains the same four bases: **A**, **G**, **T**, and **C**. However, the base sequence varies for all organisms. There are also variations in the base sequence within the same species of organisms. The base sequence in your DNA is different from that of every other person on Earth—unless you have an identical twin. **Human DNA is unique from person to person, but the same from cell to cell**.

What is DNA fingerprinting?

As scientists have learned more about DNA, they have found a way to use it to identify individuals. A technique called **DNA fingerprinting** produces an image of patterns made by a person's DNA. Using an enzyme, scientists "cut" DNA strands in specific places. The DNA fragments are injected into a gel and an electric current is applied. As the fragments migrate across the gel, they create patterns. Those patterns (DNA fingerprints) are related to the base sequences along the DNA strand.

Each person has a unique fingerprint

Like normal fingerprints, the patterns produced by DNA are unique to each individual person. Therefore, DNA fingerprints can be used to identify suspects in a crime. They can also be used to identify relationships among children and their parents, or among siblings (brothers and sisters). The DNA fingerprints of parents and their offspring show similarities but are not identical.

Using DNA fingerprints to solve a crime

Suppose a serious crime has been committed. There are seven suspects. How can police prove which suspect actually committed the crime? Since blood was found at the crime scene, DNA fingerprints can be produced. Blood is drawn from the seven suspects and DNA fingerprints are produced. By comparing the DNA fingerprints of the suspects to the blood from the crime scene, police quickly determine who committed the crime (Figure 10.8).

VOCABULARY

DNA fingerprinting - the process of producing an image of patterns from someone's DNA.

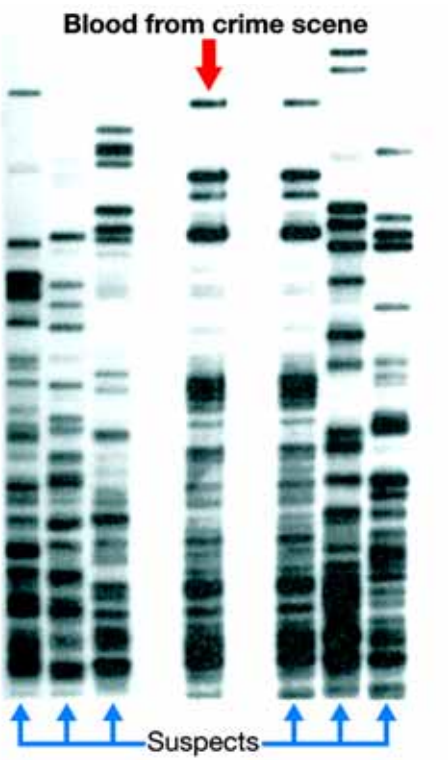


Figure 10.8: *The DNA fingerprints in the middle are from the crime scene. Which one of the suspects committed the crime?*

The human genome

What is a genome?

Scientists use DNA technology to study the human genome. A **genome** is the total amount of hereditary material in a single cell of an organism. If you think of a *genome* as a set of books, each *chromosome* is a book from the set. Each *gene* is a paragraph from the book and each *base* is a letter from the paragraph (Figure 10.9). The *Human Genome Project* is a study of the human genome. One of the goals of the project is to map the base sequence of the entire human genome.

Using DNA technology to trace human origins

Scientists also use DNA technology to trace the origins of humans. In the past, scientists could only analyze the bones and skulls of our human ancestors. Now they have tools to determine the base sequences of their DNA. Most of the ancient DNA scientists can recover is broken into fragments. Recently though, scientists have developed a way to make copies of those fragments, making them easier to analyze. They have also found a way to recover DNA from preserved bones and teeth.

Mitochondrial DNA

Not all of your genome is found in the nuclei of your cells. **Mitochondrial DNA** is DNA that is found in the mitochondria of a cell. Human mitochondrial DNA consists of about 16,000 base pairs contained in 5–10 rings. Unlike nuclear DNA, which is equally inherited from both the father and mother, mitochondrial DNA is inherited only from the mother. That's because all of our mitochondria are descended from those in our mother's egg cell. Mitochondria in the sperm cell are destroyed during fertilization.

The origin of humans

Mitochondrial DNA is often used to study human origins. Since it is inherited only from the mother, mitochondrial DNA allows scientists to trace human origins along a direct ancestral line. Recent evidence suggests that modern humans descended from Africa about 100,000 years ago.

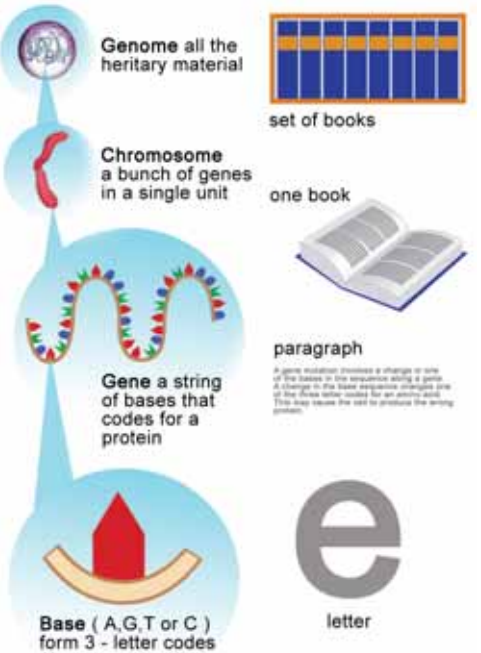


Figure 10.9: *One of the goals of the human genome is to map the base sequence of the entire human genome.*

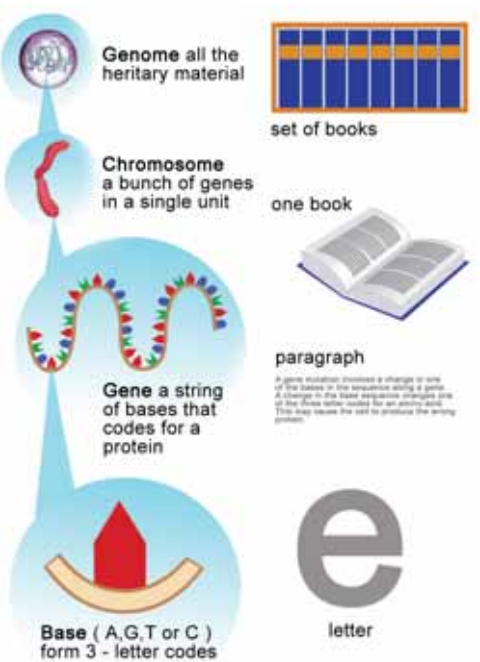
VOCABULARY

genome - the total amount of hereditary material in a single cell of an organism.

mitochondrial DNA - DNA that is found in the mitochondria of a cell.

10.2 Section Review

1. What is selective breeding? Name three instances where people use selective breeding.
2. What is genetic engineering? How is it similar to selective breeding? How is it different?
3. List the steps to genetic engineering and explain what happens in each step.
4. Figure 10.10 shows DNA fingerprints of four suspects. DNA fingerprints from blood collected at the crime scene are shown in the middle column. Which suspect committed the crime? Explain your reasoning.
5. What is a genome? Where is an organism's genome found?
6. STUDY SKILLS: The graphic to the right is an analogy. An analogy shows the similarities between two things that are otherwise different. Think of another analogy for DNA that compares it to something else.
7. What is mitochondrial DNA? Why is mitochondrial DNA used to study human origins?



MY JOURNAL

There is much debate on the topic of genetic engineering. What are the potential advantages and disadvantages of genetic engineering?

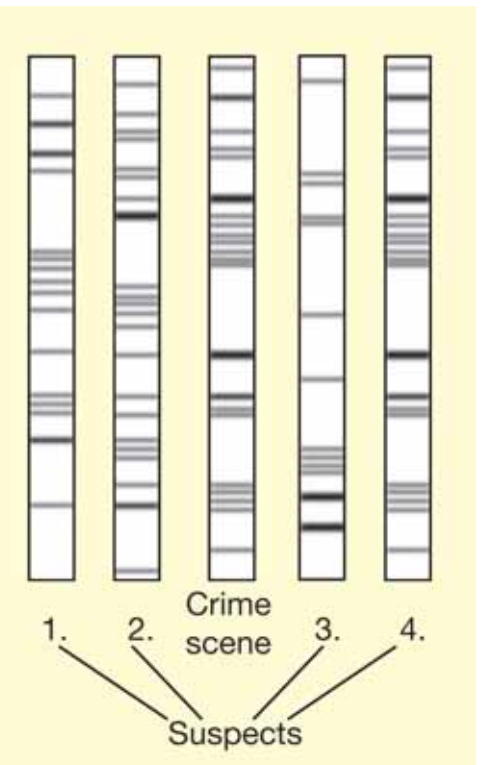


Figure 10.10: *Use the image above to answer question 4.*

TECHNOLOGY CONNECTION

Cracking the Code

Have you ever tried to break a code? Suppose that 2-21-19 is code for a common word. The coded word is used in a sentence. "We took the 2-21-19 to school this morning." Using the clue in the sentence, the code is easy to crack. The word is bus. Each letter equals the number of its order in the alphabet.

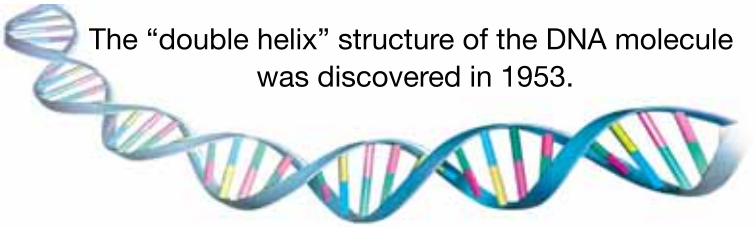
Sometimes breaking a code can add to human knowledge. One example is Egyptian hieroglyphics. This ancient Egyptian writing is very complex. For a long time, its meaning was unknown. The system of writing was a key to understanding the people of ancient Egypt. Yet no one could translate the system for hundreds of years.

Then in 1799, the Rosetta Stone was discovered. It was a stone tablet. It had the same words written in three languages. One of the languages was Greek. Another was the system of writing used by the ancient Egyptians and helped to break the code.

The human genome

Scientists are now breaking the most important code in human history. This code is the human genome. The human genome is the complete set of DNA in a human being. DNA is a chemical compound. It carries all of the instructions an organism needs to develop and function.

The DNA molecule is made of two connected, twisted strands. The shape of the molecule is called a double helix. The two strands connect at many points. Each point is a pair of connected base chemicals. DNA can be described as two spiral ladders running together. The pairs of base chemicals make the "rungs" in the ladders.



The "double helix" structure of the DNA molecule was discovered in 1953.

The human genome contains more than 3 billion of these base pairs. DNA is "packaged" in compact units called chromosomes. Every human has a total of 46 chromosomes. We get 23 from each parent. Each chromosome has between 50 million and 300 million base pairs.

Chromosomes contain genes. Some contain many more genes than others. Genes are specific sequences of base pairs. These sequences are coded instructions. The instructions tell cells to make proteins. Organisms make proteins in order to develop and function. Scientists estimate that the human genome contains between 20,000 and 25,000 genes.

The Human Genome Project

To find the genes and break the code, we need to know the exact order of their base pairs. This is called "sequencing." In 1990, scientists began a project to sequence the human genome. It was called the Human Genome Project. The goals of the project were to:

- Find the sequences of the 3 billion base pairs in the human genome.
- Identify all the genes of the human genome.
- Make the information available to other scientists.
- Address ethical and social issues questions that surrounded the project.

Scientists all around the world added their efforts to the task. In 2003, the Human Genome Project announced that the sequencing of the human genome was completed. This was a major step in cracking the code of human DNA. But the code is still not broken.

Scientists had long known that DNA was a code. In 1953, Watson and Crick identified the structure of DNA. They recognized a pattern in the double helix and new it was a code. This is like recognizing that the letters in a code are grouped in words. But the meanings of the words are still unknown.

Likewise, sequencing the human genome does not crack the code of DNA. Finding the sequence is like recognizing that the words in the code are grouped in sentences and paragraphs. But the meanings of the sentences and paragraphs are still not completely known.

The final step will be to find out which genes have instructions for building which proteins. This is knowing what genes do. This is like understanding the meanings of sentences and paragraphs in the code. The process is underway. However, the function of most human genes is still unknown.

The future

Eventually, scientists will understand the meanings of human genes. They will understand what all the individual genes do. Why is this so important? It will lead to a better understanding of genetic diseases, and treatments for these diseases. It should also lead to ways to prevent diseases in humans.

Understanding our genes will help science better understand human development. Dangers in the environment may be better understood by studying damaged genes. Breaking the code of human genes may even help us understand some of the basic mysteries of life.

Questions:

1. How did the Rosetta stone help to crack a code?
2. What is the human genome?
3. How many base pairs are there in the human genome? How many chromosomes are there is the human genome? How many genes are there in the human genome?
4. What is the final step in cracking the code of the human genome?

CHAPTER ACTIVITY Gene Drama

In this activity, your class will perform a skit to show how genes work.

What you will do

1. Each person will wear a sign that identifies his or her role in the skit. The blocks in the table below show what to write on each of 24 different signs. Colors refer to suggested choices of colored paper.

Original DNA segment	Complementary DNA Segment	Messenger molecule Segment	Transfer Molecule Segment	Amino Acid	Misc.
Red	Blue	Orange	Green	Purple	Yellow
C	G	C	GGU	glycine	ribosome
C	G	C	GCU	alanine	narrator
A	T	A			
C	G	C			
G	C	G			
A	T	A			

2. Make signs as directed by your teacher.
3. Divide your classroom into two areas. Identify one area as the "nucleus" and the other as the "cytoplasm."
4. Act out the skit! The narrator reads the steps while members of the class act it out. Perform the skit several times, switching roles each time.

Narrator	Action	Location
1. Our story begins with a segment of a DNA strand. Ours has 6 bases, but actual DNA can be made up of millions of bases!	Original DNA strand bases stand in order, shoulder-to-shoulder, from Left to Right CCACGA	Nucleus
2. DNA is double-stranded. The DNA bases pair up in specific combinations.	Complementary DNA bases join hands with original DNA bases to create correct pairings: GGTGCT	Nucleus
3. A copy of the DNA code has to be made before it can be used to build a protein. First, the double DNA strand "unzips".	DNA base pairs drop hands and move apart, but strands remain shoulder-to-shoulder	nucleus
4. Next, messenger RNA bases pair up with the original DNA strand segment and then detach from the DNA strand. The DNA base pairs re-join to form the double strand of DNA.	Perform the action.	Nucleus
5. The messenger RNA leaves the nucleus and meets up with the ribosome in the cytoplasm.	Perform the action.	Cytoplasm
6. The messenger RNA base sequence is a code that tells the cell which protein to make. Amino acids are the building blocks of proteins. Each amino acid is paired with a transfer RNA.	GGU should have both hands placed on shoulders of glycine. GCU should have both hands placed on shoulders of alanine. They move around in the cytoplasm, not far from the ribosome.	Cytoplasm
7. The ribosome binds the correct transfer molecule code to the messenger strand.	Perform the action.	Cytoplasm
8. The amino acids bond together in the start of a long chain that will become a protein. The transfer molecule leaves the amino acids.	Amino acids link arms at the elbows and the transfer molecules leave.	Cytoplasm
9. Our story ends with the amino acid chain. We have started a protein with two amino acids. In an actual cell, the amino acid chain that becomes the protein can contain 100 to 10,000 amino acids or more!	Take a bow!	Cytoplasm

Applying your knowledge

a. Blueprints are directions that a builder needs to construct a house. What part of the protein synthesis process could be referred to as a blueprint? Explain your answer.
b. Create a table that compares the process of making proteins to the process of making cookies.

Chapter 10 Assessment

Vocabulary

Select the correct term to complete the sentences.

base sequence	DNA replication	genetic engineering
genome	mutation	selective breeding
DNA fingerprinting	genetic disorder	protein synthesis
mitochondrial DNA		

Section 10.1

1. Sickle cell anemia, a blood disorder, is caused by a _____.
2. During _____, the cell reads the three letter codes of the DNA to build proteins from amino acids.
3. _____ ensures that each daughter cell has an exact copy of the genetic information of the parent cell.
4. Cystic fibrosis is an example of a _____.
5. The _____ provides the code that directs the cell to make specific proteins.

Section 10.2

6. _____ can be used to identify suspects in a crime.
7. Cold-resistant tomatoes, super sweetcorn, and maize are all the results of _____.
8. Scientists use _____ to study human origins because it is only inherited from the mother.
9. Insulin for people with diabetes is produced by _____.
10. There is a major project underway to map the entire human _____.

Concepts

Section 10.1

1. Of the four nitrogen base pairs, cytosine always pairs with:
   a. adenine
   b. guanine
   c. thymine
   d. cytosine
2. Draw and label a DNA molecule with these terms: sugar, phosphate, A, T, C, and G.
3. Write out the bases that pair with the base sequence shown below.

4. When does DNA replication occur?
5. Put these steps of DNA replication in the correct order from beginning to end.
   a. Two daughter molecules have been produced - each of one original strand and one new strand.
   b. The double helix partially unwinds.
   c. A new strand is put together along each original strand using pieces made from molecules in the cytoplasm.
   d. The base pairs separate.
6. Which body cells have no nuclear DNA?
7. Proteins are made of smaller molecules called _____.

8. Fill in this chart to compare DNA and RNA.

	DNA	RNA
# of strands		
Letter names of bases		
Where found?		

9. If the base sequence of the DNA is GTCAGGATC, what would be the corresponding base sequence of the messenger RNA?
10. Predict what might happen if the three letter "stop code" was missing from a DNA sequence.
11. The type of protein made in the ribosomes depends on which of the following? You may choose more than one answer.
    a. The base sequence of the gene
    b. The sequence of the amino acids
    c. The number of codons in the gene
    d. The number of messenger RNA molecules present
12. If a mutation takes place in a human skin cell, will that mutation be passed on to the person's offspring? Explain your answer.
13. What is an amniocentesis? Explain how it works.

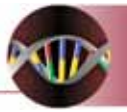
Section 10.2

14. Explain how selective breeding and/or genetic engineering might be used to solve these problems:
    a. low apple production from trees
    b. lack of human hormone
    c. poor fur quality of alpacas
    d. corn crops destroyed by disease
15. What kind of cells are most commonly used in genetic engineering? Why?
16. How is DNA like a fingerprint?
17. Who has DNA fingerprints that are similar to your DNA fingerprints?
18. What is one possible benefit of the Human Genome Project?
19. What is mitochondrial DNA? Why do you inherit your mitochondrial DNA only from your mother?

Math and Writing Skills

Section 10.1

1. Describe the accomplishments of Franklin, Watson, and Crick that added to the understanding of DNA structure.
2. Suppose adenine makes up 23% of an organism's nitrogen bases. What percent of that organism's nitrogen bases would be guanine? Explain your answer.
3. The four nitrogen base pairs combine in sets to create three-letter codes used in the creation of proteins. How many possible three-letter codes are there? (HINT: bases can be repeated in a three letter code and the order of the bases is important.)
4. Imagine that you are DNA writing a thank you letter to RNA. Explain how critical RNA is to your work in a cell.
5. Write a dialogue that might occur between messenger RNA and transfer RNA working together in a cell.
6. Why is more known about harmful mutations than beneficial ones?



Section 10.2

7. Pretend that you are a farmer explaining to your daughter how you use selective breeding to get the best quality animals and crops that you possibly can.
8. Cloning technology is one result of DNA research. Think about whether you believe human cloning should be allowed. Write a paragraph supporting your opinion.
9. Create an analogy to explain how bases, genes, chromosomes, and genomes fit together. Explain your analogy.
10. If 16,000 base pairs of human mitochondrial DNA are contained in 5 - 10 rings, what is the maximum number of base pairs that each ring could be? What is the minimum number of base pairs that each ring must be?

Chapter Project

Genetic Disorder Brochure

A genetic disorder is an abnormal condition that an organism inherits from its parents. Genetic disorders are not contagious, and a parent with a genetic disorder does not always pass it to offspring. Some genetic disorders appear at birth, and others do not show up until later in life.

For this project you will choose a particular genetic disorder and create a tri-fold brochure that could be displayed in the waiting room of a doctor's office. Make your brochure creative and informative so people will want to read it. You need to list four sources of information on the very back of your brochure. Only two of the sources can be websites. Things to include in your brochure:

1. Name of disorder
2. sketch of chromosome with location of disorder gene clearly marked and labeled
3. symptoms of disorder
4. complications associated with disorder
5. how the disorder is detected
6. treatment
7. two other interesting, unique facts about this disease
8. places to go for more information (4 sources; only 2 websites)

Choose one of these genetic disorders (if you are interested in one that isn't on the list, check first with your teacher).

Alzheimer disease

Cystic Fibrosis

Down's Syndrome

Hemophilia

Marfan Syndrome

Muscular Dystrophy

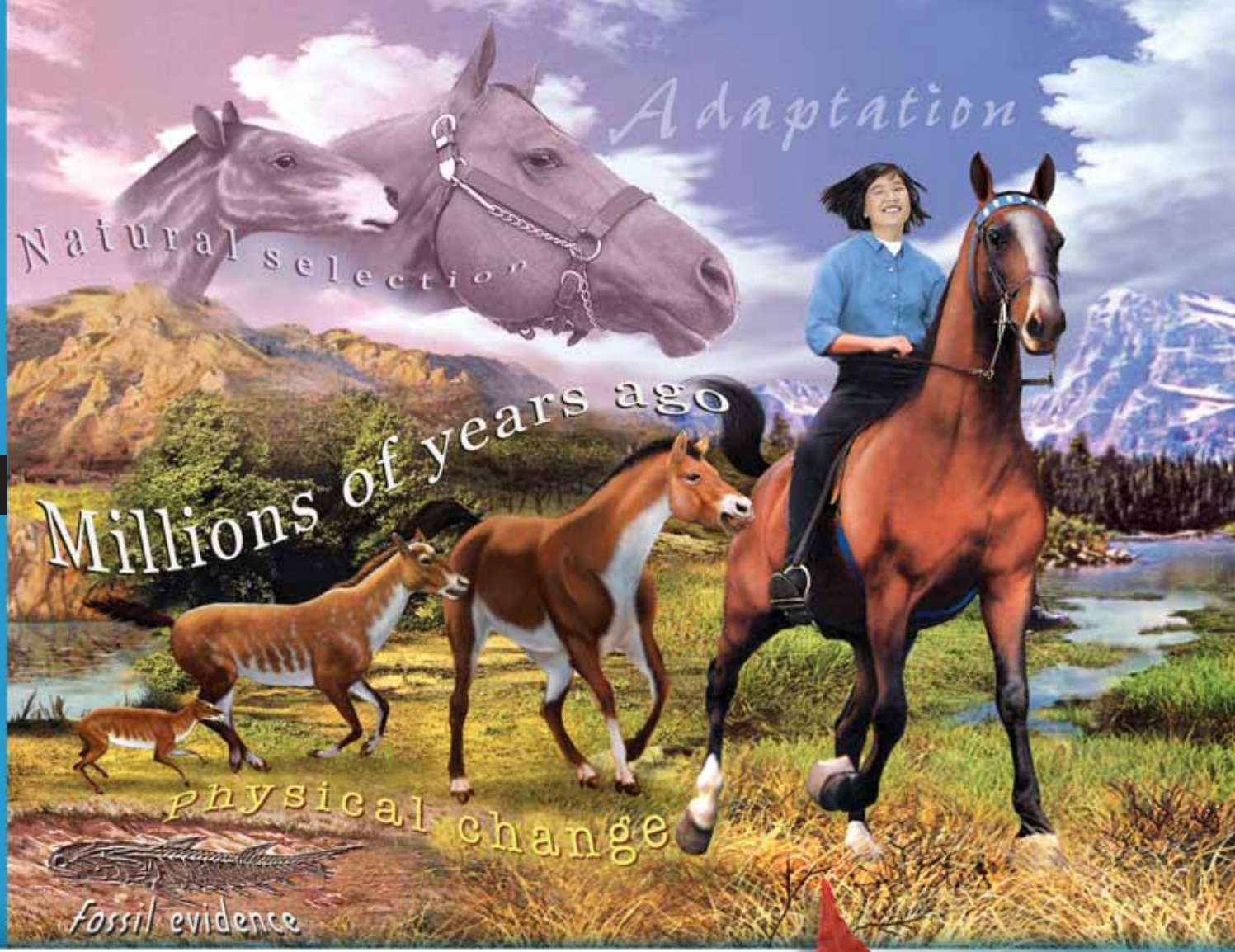
Sickle Cell Anemia

Huntington Disease

Phenylketonuria (PKU)

Diabetes

Familial hypercholesterolemia



UNIT 4

Evolution and Change

Chapter 11 *Evolution*

Chapter 12 *Earth and Life History*

TRY THIS AT HOME

Make your own fossils!

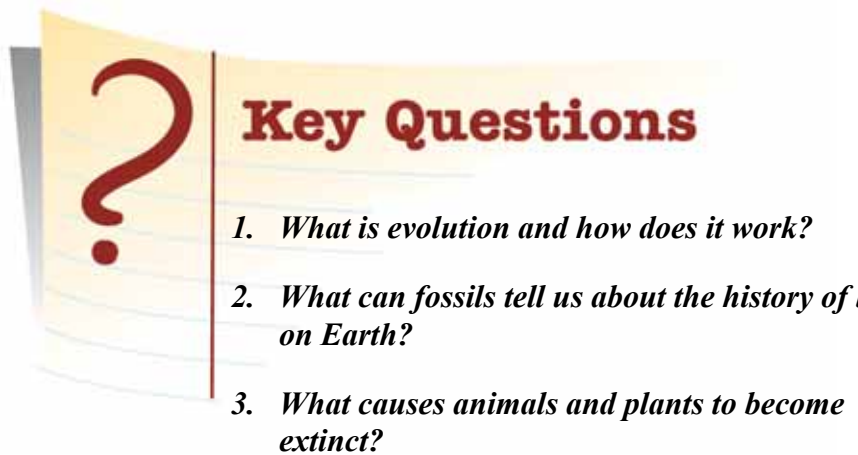
Take some modeling clay and roll it out into a flattened circle or square about a half inch thick. Choose some parts of organisms like shells, leaves, and twigs.

Press the objects into the clay to make an impression. Take the objects off and you have a fossil! How do you think fossils were created millions of years ago? Write your thoughts down in a paragraph.

Chapter 11

Evolution

Why are polar bears white instead of brown or black? White fur helps polar bears blend into the Arctic ice and snow so they can hunt more successfully. White fur has a survival advantage for polar bears. As millions of years passed, and generations upon generations of polar bears survived and reproduced, natural selection occurred in the bear population to favor white fur. Evolutionary concepts like adaptation and natural selection are featured in this chapter.



11.1 Evidence for Evolution

Imagine going back in time 50 million years. You see a horse about the size of a cat. Would you believe you are looking at an ancestor of the modern horse (Figure 11.1)? *Eohippus* was only 20 cm tall at the shoulders and had five toes. A modern horse is about 150 cm tall at the shoulders and has only one toe. A scientific theory states that newer species have descended from older species through a process called *evolution*. What is evolution and what is the evidence that supports it as a theory?

Figure 11.1: *Eohippus is an ancestor of the modern horse.*

What is evolution?

Adaptation and evolution

An **adaptation** is an inherited trait that helps an organism survive. Adaptations include body structures that help an organism feed, move around, and protect itself. **Evolution** is the process of how organisms acquire adaptations over time.

A moth and a bird

Through evolution, the structures of organisms become adapted for their functions. Look at the organisms below. The one on the left is a sphynx moth (an insect). The one on the right is a hummingbird. Both species have evolved similar adaptations for feeding on flower nectar. Can you identify how they are similarly adapted for feeding? How are they different?

VOCABULARY

adaptation - an inherited trait that helps an organism survive.

evolution - the process of how organisms acquire adaptations over time.

Evolution is a branching process

All life forms had a common beginning

There is great diversity in living species. *Diversity* means variety. Scientists estimate that there are between 5 and 50 million living species. Among those species are single-celled bacteria that lack cell nuclei, single-celled eukaryotes that have cell nuclei, and multicellular fungi, plants, and animals. Where did all of these different species come from? Scientists hypothesize that **all life forms evolved from a common ancestor and new species branch off from earlier species.** An **ancestor** is an organism from which others have descended.

Cell evidence

You have learned that all living things are made of cells. There are striking similarities among all cells. For example, all cells have a similar cell membrane. Many cells have the same type of cellular respiration. Also, all cells have DNA as their hereditary material. Similarities among all cells support the hypothesis that all life evolved from a common ancestor.

Bacteria were the first living things

In Chapter 7, you learned that bacteria were the first organisms on Earth. Evidence for this comes from fossils of single-celled prokaryotes found in rocks that are more than 3 billion years old. Scientists hypothesize that all species evolved from a single prokaryotic cell such as a bacteria. Eukaryotic cells evolved from bacteria. Multicellular organisms followed. From there, more and more species branched off through the process of evolution.

Branching diagrams

A **cladogram** displays evolutionary relationships among living species and their ancestors. A cladogram resembles a branching tree. Each branch represents a different evolutionary path. The point where two branches come together represents a common ancestor that shares evolved characteristics with the species that branch off from it. Figure 11.2 shows a simple cladogram.

VOCABULARY

ancestor - an organism from which others have descended.

cladogram - a tree-like diagram that displays evolutionary relationships among living species and their ancestors.

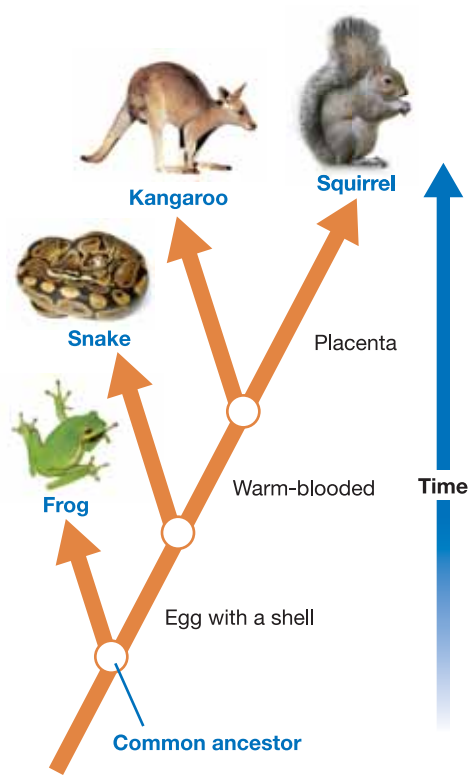
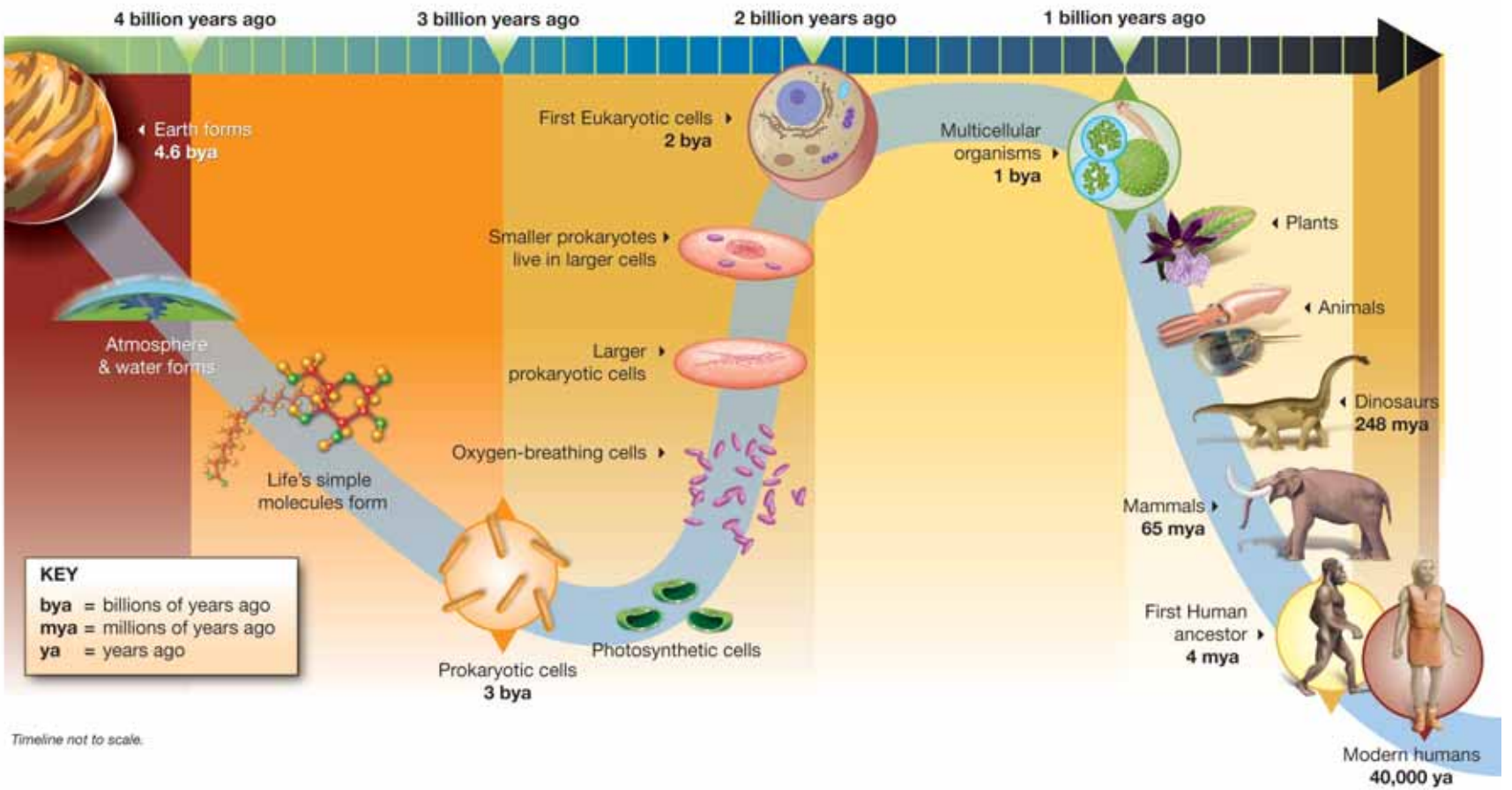


Figure 11.2: *An example of a cladogram.*

An evolutionary timeline

Scientists believe that Earth is about 4.6 billion years old. The first life appeared over 3 billion years ago in the form tiny, single-celled prokaryotes. About 2 billion years ago, those cells evolved into larger cells with a nucleus. Smaller prokaryotic cells took up residence inside the larger cells and eventually evolved into organelles like mitochondria. Multicellular organisms appeared about a billion years ago. Larger animals and plants have been evolving for the past 500 million years. The diagram below shows a theoretical timeline of how the diversity of life evolved.



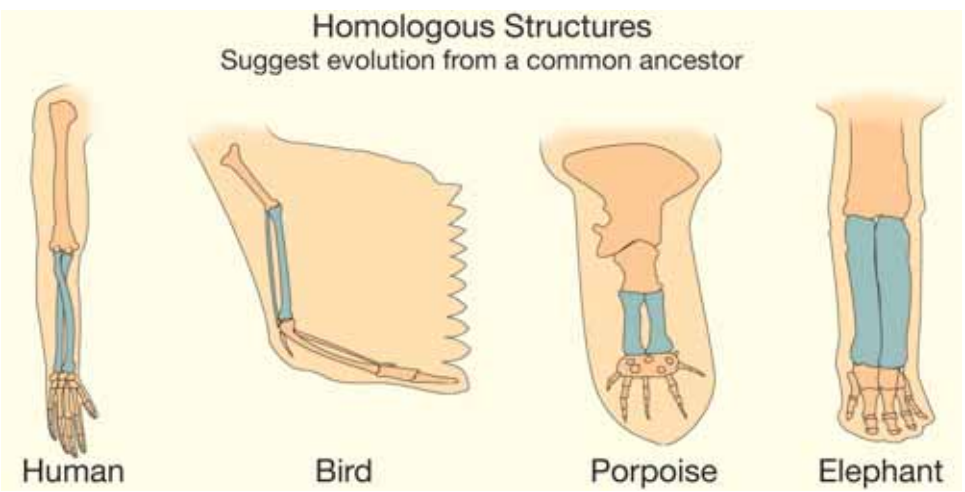
Lines of evidence

Three major lines of evidence

Evolution is a scientific theory that explains how life changes through time. A theory is based on scientific evidence gathered from data and observations. **Many lines of evidence provide the basis for the theory of evolution. These include comparative anatomy, DNA analysis, and the fossil record.**

Comparative anatomy

Comparative anatomy is the study of anatomical similarities and differences among species. For example, what does your arm have in common with the wing of a bird, the flipper of a porpoise, and the forelimb of an elephant? The diagram below shows that each has a similar bone structure. **Homologous structures** have a common origin, but do not necessarily perform the same function. The structures in the limbs below indicate that the organisms are related by a common ancestor.



Analogous structures

Analogous structures serve the same function but come from different origins. Though structurally similar, they do not arise from a common ancestor. An example of analogous structures is the wing of an insect and the wing of a bird (Figure 11.3).

VOCABULARY

homologous structures - body structures that have a common origin but do not necessarily perform the same function.

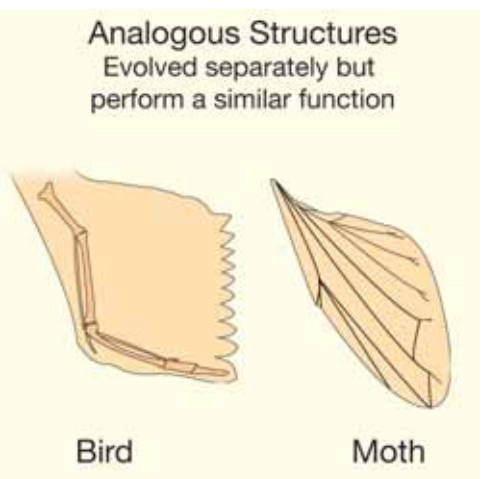


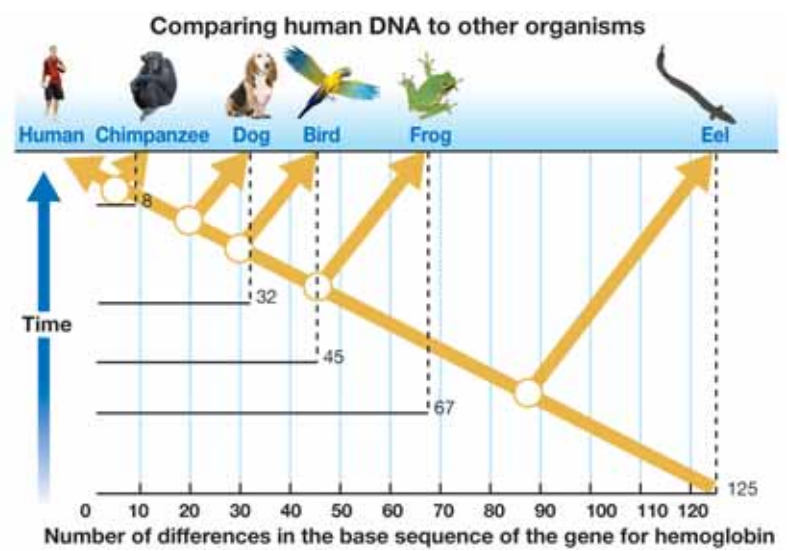
Figure 11.3: *An insect wing and the wing of a bird are both similar in function but do not come from a common ancestor.*

Comparing embryos

Another way to compare the anatomy of different species is to compare their embryos. Comparative anatomists have discovered similarities in embryos of vertebrates (Figure 11.4). **Vertebrates** are animals with a backbone. You are a vertebrate. So are other mammals, birds, reptiles, and fish. Adult vertebrates also share many similarities in their skeletons and muscles. This is evidence that all vertebrates descended from a common ancestor.

DNA evidence

All species of organisms have DNA as their hereditary material. Scientists compare the DNA base sequences of different species to determine evolutionary relationships. **Species that share more similarities in their DNA base sequences are more closely related than those that share fewer similarities.** Scientists hypothesize that if two species have similarities in their base sequences, they share a common ancestor. The diagram compares the DNA base sequences in the gene that codes for hemoglobin in vertebrates. The greater the number of differences in base sequences, the farther the evolutionary distance from humans.



VOCABULARY

vertebrates - animals with a backbone.

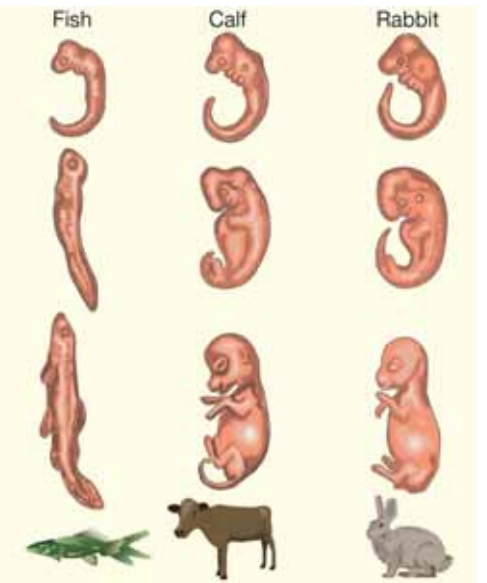


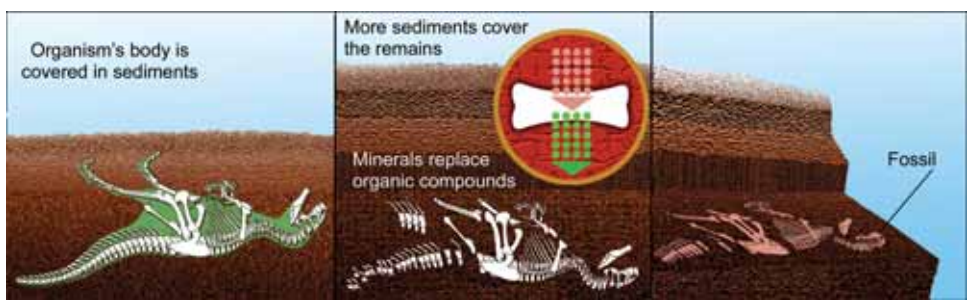
Figure 11.4: *Comparing the embryos of different vertebrates.*

Fossils

What are fossils? Much of the evidence for evolution comes from studying fossils. A **fossil** is a remnant or trace of an organism from the past, such as a skeleton or leaf imprint, embedded and preserved in Earth's crust. Earth's crust is its outermost layer made mostly of rock.

Sedimentary rock Most fossils are dug up from sedimentary rock layers. *Sedimentary rock* is rock that has formed from *sediments*, like sand, mud, or small pieces of rock. Over long periods of time, sediments are squeezed together as they are buried under more and more layers that pile up. Eventually, those sediments are compressed into sedimentary rock. The layers that are farther down in Earth's crust are older than the upper layers. Figure 11.5 shows layers of sedimentary rock that have been exposed along a river. Each layer contains fossils. Which fossils are oldest?

How fossils are formed Many fossils are formed from the hard parts of an organism's body like bones and teeth. Fossil formation begins when an organism's body is quickly covered in sediments from an event like a mudslide or a sand storm. Over time, more and more sediments cover the remains. The body parts that do not rot are buried under layers of sediments. After a long time, the chemicals in the body parts are replaced with rock-like minerals. This process results in a heavy, rock-like copy of the original object—a fossil.



VOCABULARY

fossil - a remnant or trace of an organism from the past, such as a skeleton or leaf imprint, embedded and preserved in Earth's crust.

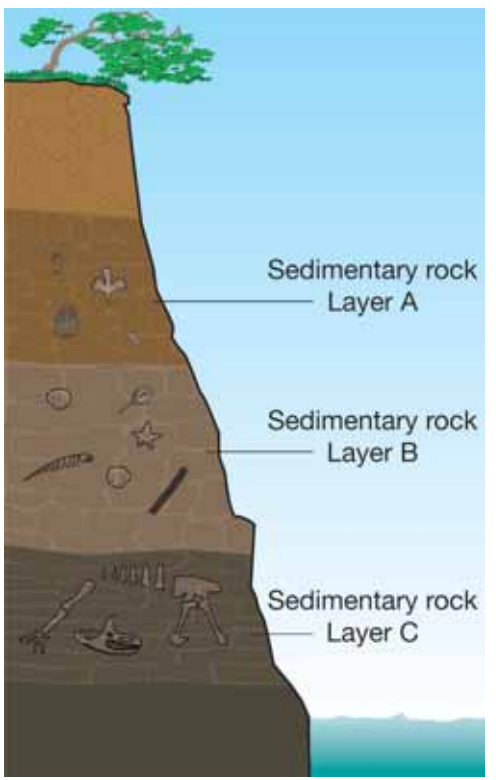


Figure 11.5: *Which fossils are oldest? Which are youngest?*

The fossil record

What is the fossil record?

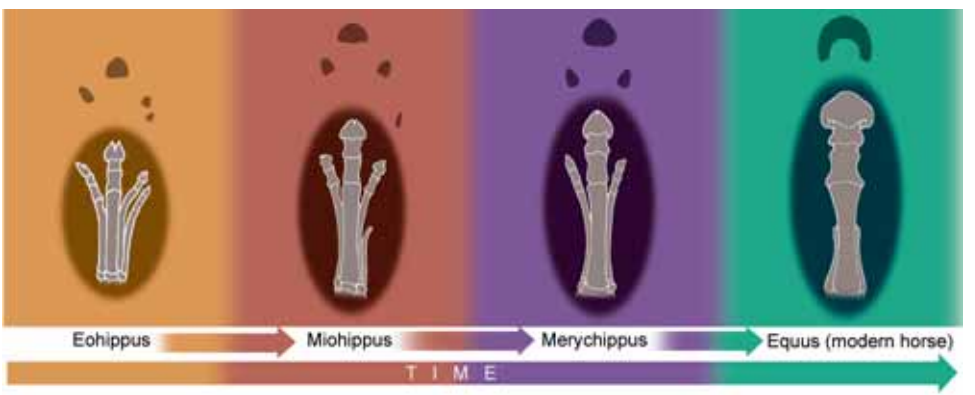
Fossils provide a historical sequence of life on Earth known as the **fossil record**. Fossils found in the upper (newer) sedimentary layers more closely resemble present-day organisms than fossils found in deeper (older) layers. Through that information, scientists have been able to piece together parts of the fossil record. Scientists use the fossil record to trace the order in which evolutionary changes occurred.

Gaps in the fossil record

Although scientists have collected thousands of fossils, there are many gaps in the fossil record. That is because most ancient species did not fossilize. They simply decayed and were lost from the fossil record. Scientists estimate that only a small percentage of past organisms have been (or will be) found as fossils.

Using the fossil record

A good example of how scientists use the fossil record to trace evolution is the horse. Scientists have found many fossils of horse ancestors. Figure 11.6 shows how some of the horse's ancestors may have looked. Below are the limb bones of horse ancestors and the modern horse. The evolution of a species takes millions of years and does not occur in a straight line. There are many branches that lead to different species with different adaptations.



VOCABULARY

fossil record - a historical sequence of life on Earth based on the sequence of fossils.

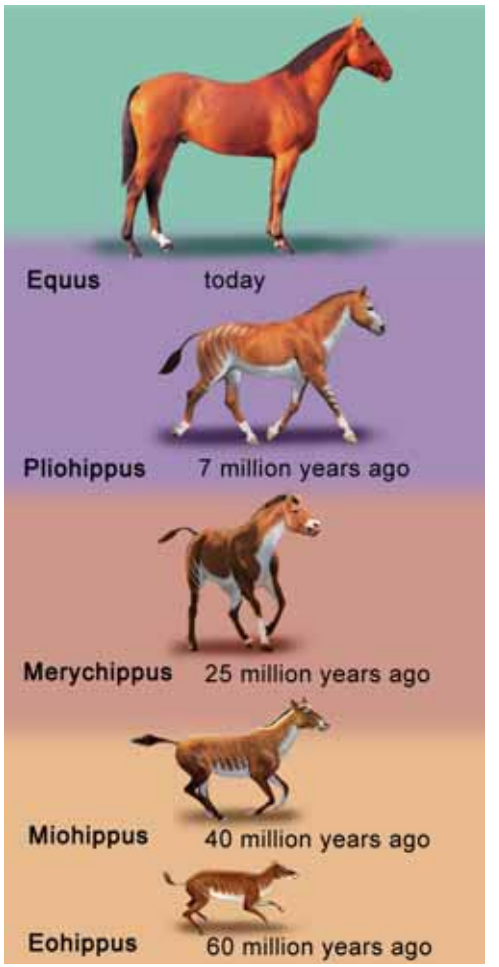
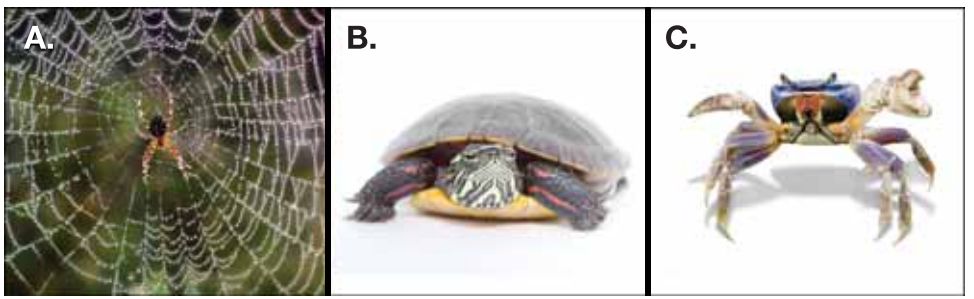


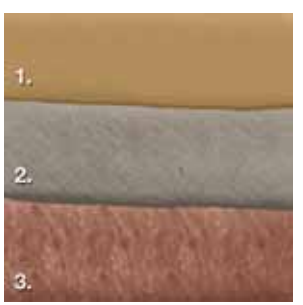
Figure 11.6: *Ancestors of the modern horse.*

11.1 Section Review

1. What are adaptations? Give an example of an adaptation.
2. For each organism, name one adaptation and its function.



3. Use the words *evolution* and *ancestor* in a sentence.
4. Name one reason scientists believe that all life evolved from a single common ancestor.
5. Match the organism with its place on the cladogram (Figure 11.7). Explain the reasoning behind your placement.
6. How do similarities in the bones of humans, dolphins, horses, and birds provide evidence for evolution?
7. How is DNA evidence used to show evolutionary relationships?
8. The diagram (right) shows different fossil layers. Match each layer with the ages of the fossils that would be found there.
   a. 150 million years ago
   b. 140 million years ago
   c. 120 million years ago



9. Explain why there are gaps in the fossil record.

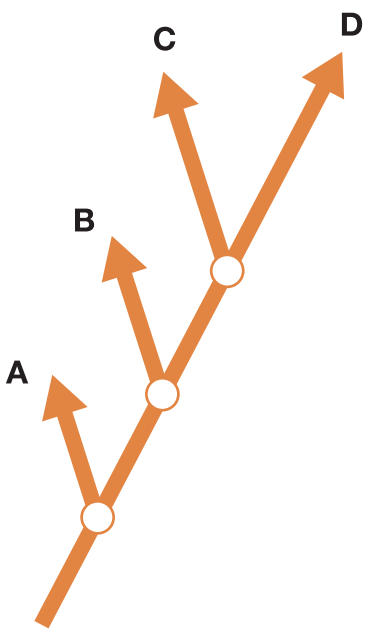


Figure 11.7: *Use the diagram above to answer question 5.*

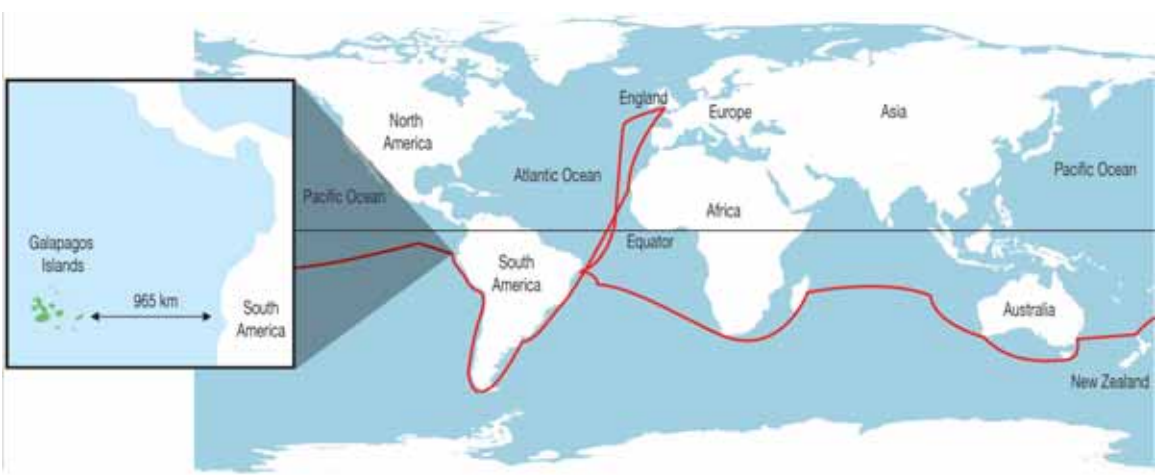
11.2 How Evolution Works

In 1831, the research ship *H.M.S. Beagle* left England for a five-year cruise around the world. On the ship was a young man named Charles Darwin (1809–1882). During the trip, Darwin collected thousands of plant and animal species. He was amazed at the diversity of life he encountered. Darwin wrote down his observations and collected evidence about evolution. That evidence led him to propose a theory about how evolution works called *natural selection*.

The finches of the Galapagos

The voyage of the *Beagle*

One of the places where the *Beagle* stopped was the Galapagos Islands, located 965 km west of South America. There, Darwin observed that the finches were different than those found on the mainland. He also noted differences in finches from island to island. One difference he found was in the shape of their beaks. The shape of finch beaks appeared to differ with the type of food eaten (Figure 11.8). Darwin concluded that finch beaks were adapted for the type of food they ate. He began to think about why and how the finches became different from each other.



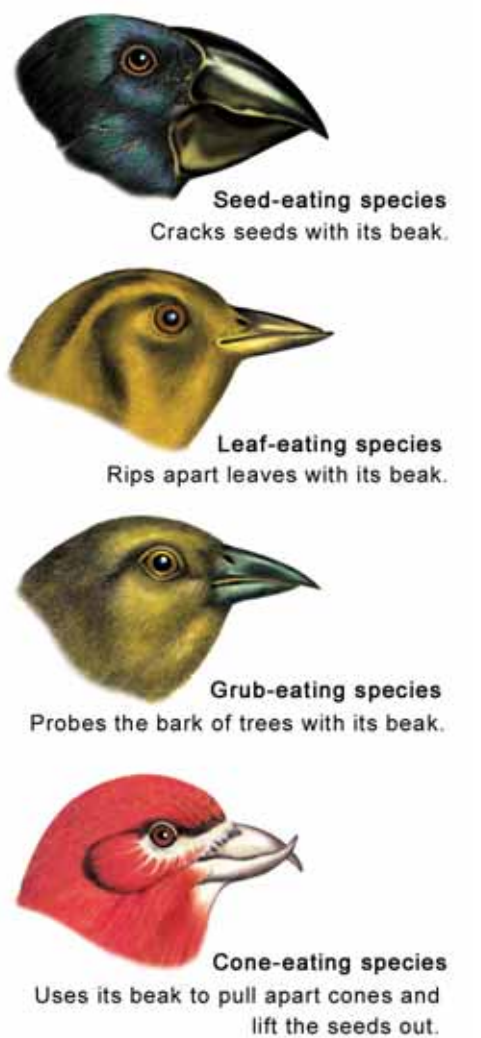


Figure 11.8: *The beaks of finches are adapted to obtain food in different ways.*

Darwin's hypothesis about finches

Darwin hypothesized that an ancestral species of finch from the mainland somehow ended up on the Galapagos Islands. The finches of that species scattered to different environments. There, they had to adapt to different conditions. Over many generations, they evolved adaptations that allowed them to get enough food to survive and reproduce. Each group of finches became isolated from the other groups. Eventually, each group became a different species (Figure 11.9). When Darwin returned to England from his voyage, he began to develop a theory about how the adaptations evolved.

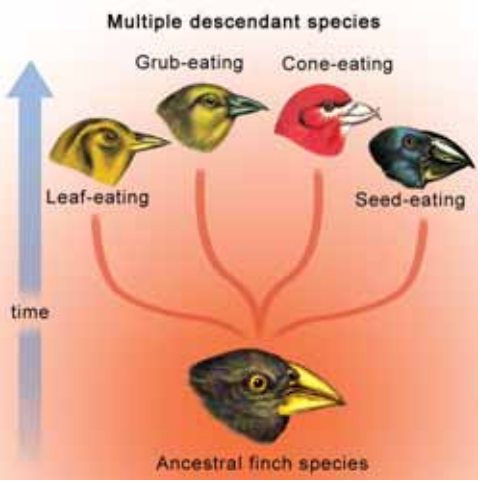


Figure 11.9: *New finch species evolved from a common ancestor.*

Earth formed slowly

From geologists, Darwin learned that Earth was formed very slowly over a long period of time. Its surface also changed slowly over time through natural processes like sedimentation and erosion. Darwin reasoned that populations of organisms changed slowly as their environment slowly changed. If the environment changes rapidly from an event like a flood, an earthquake, or a volcanic eruption, a species could become *extinct* (all members die off completely).

Fossil evidence

Darwin used fossils as evidence that different species evolve over a long period of time. He found fossils of species that lived a few million years ago that resembled living species. For example, the *glyptodon*, an extinct mammal, resembled the armadillo, an organism Darwin knew as a living species (Figure 11.10).

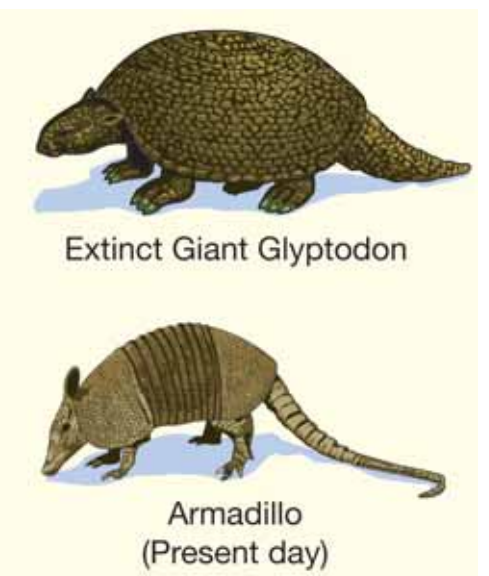


Figure 11.10: *The ancient glyptodon resembles the modern armadillo.*

Artificial and natural selection

In Darwin's time, animal and plant breeders used selective breeding to produce organisms with the traits they desired. Darwin called selective breeding *artificial selection* because the breeders selected the desired traits to produce changes in a species over a few generations. In wild animals and plants, Darwin believed that traits were selected by the environment. He called this process *natural selection*. He believed that natural selection took longer than artificial selection because it happened by chance.

Darwin's theory of evolution and natural selection

Darwin publishes his results

In 1859, Darwin published the results of his study in a book called *On the Origin of Species by Means of Natural Selection*. Based on his research and evidence, Darwin concluded that:

1. **Organisms change over time.**
2. **All organisms are descended from common ancestors by a process of branching.**
3. **Evolution is gradual, taking place over a long time.**
4. **The mechanism of evolution is natural selection.**

What is natural selection?

Natural selection is the process by which organisms with favorable adaptations survive and reproduce at a higher rate than organisms with less-favorable adaptations. Darwin based his ideas about natural selection, in part, on the work of British professor Thomas Malthus (1766–1834).

Populations grow faster than their food supply

In 1798, Malthus published his *Essay on Population*. In that essay, he argued that humans have a tendency to grow faster than their food supply (Figure 11.11). This causes food shortages and a "struggle for existence." Darwin's observations in the Galapagos Islands led him to apply Malthus' ideas to animals and plants.

Darwin's conclusions

Darwin proposed that environmental variables affect the size of a population. Variables include predators, food supply, disease, and climate. He reasoned that if a species produces too many offspring and only a certain number survive, the survivors must be better adapted to their environment than those that die. Darwin concluded that offspring of the survivors would inherit the favorable adaptations. Organisms with unfavorable adaptations die before they can pass them on to offspring.

VOCABULARY

natural selection - the process by which organisms with favorable adaptations survive and reproduce at a higher rate than organisms with less-favorable adaptations.

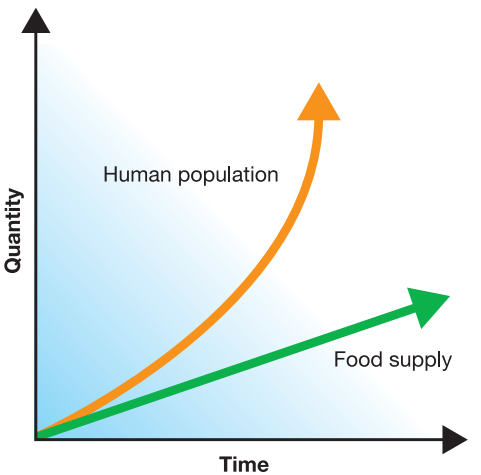


Figure 11.11: *Populations tend to grow faster than their food supply.*

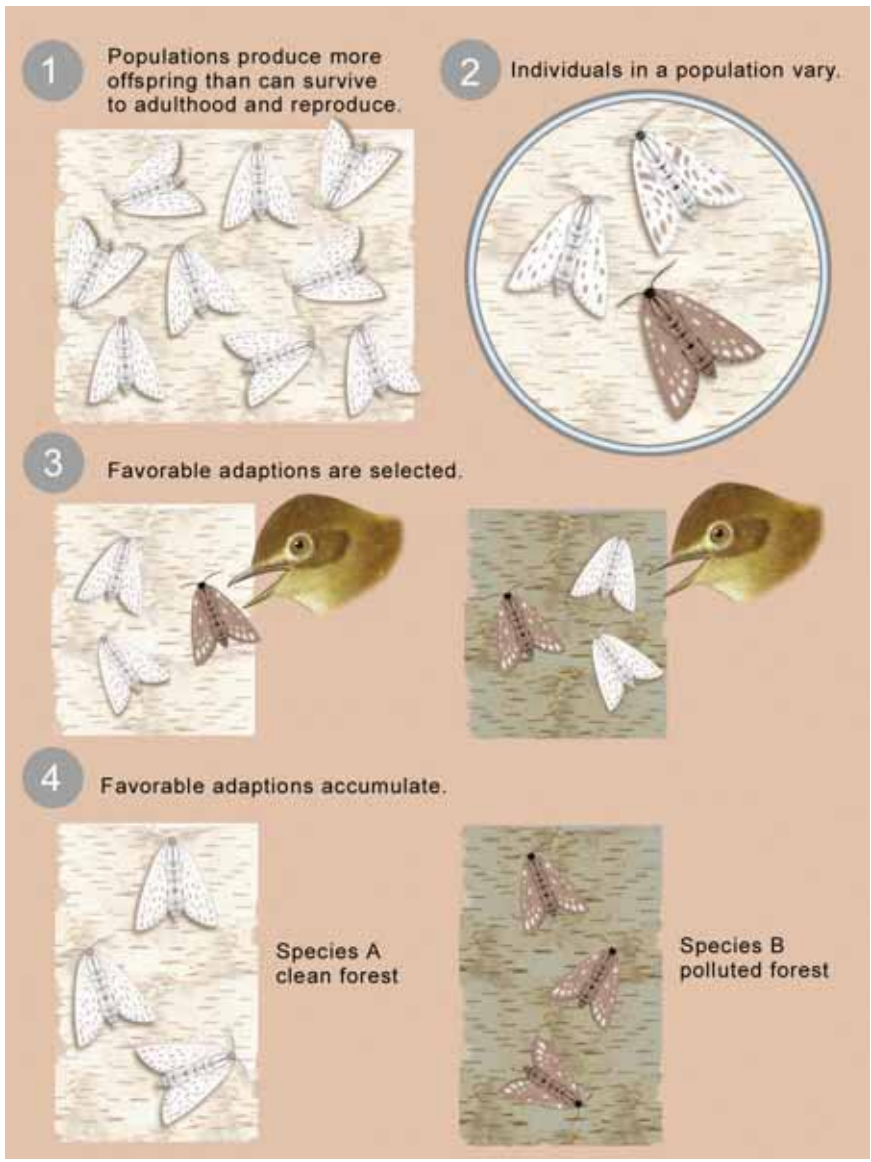
MY JOURNAL

When wolves hunt deer, they are usually able to catch only the weak or sick deer. The stronger and faster deer can escape. Explain how the wolf population may influence the adaptations of the deer population over time.

The process of natural selection

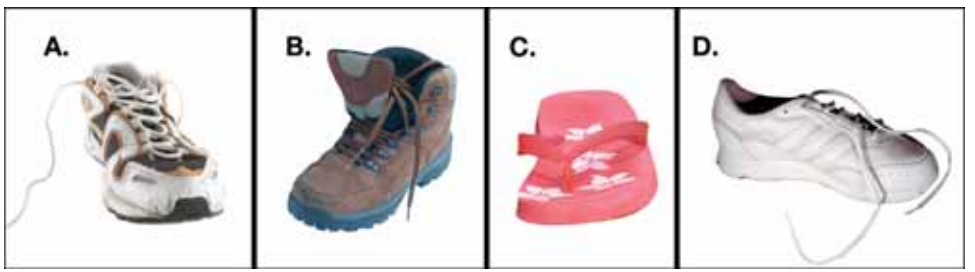
Darwin proposed that natural selection is the process for evolution. Today, it is still the most thorough explanation of how evolution occurs. The process of natural selection may be summarized in the steps below.

1. **Populations over-reproduce.** All organisms produce more offspring than can survive to adulthood and reproduce. This means that many of those offspring will die without reproducing. Survivors that are able to reproduce pass their traits on to their offspring.
2. **Individuals in a population vary.** There is random variation in traits among individuals in a population of a species. the variations each individual possesses happen by chance. Those variations are inherited.
3. **Favorable adaptations are selected.** The changing environment causes a selection of favorable traits (adaptations). Adaptations that fit well with the environment are passed on to offspring in greater numbers than adaptations that do not fit well.
4. **Favorable adaptations accumulate.** Favorable adaptations accumulate over many generations. This may lead to new species.



11.2 Section Review

1. On his journey, Darwin observed how different animal and plant species had adapted to function in their environments. Explain how each of the following items is best suited to its unique function.



2. Why did Darwin use selective breeding as evidence for evolution?
3. How did the work of geologists support Darwin's theories about evolution?
4. What is natural selection?
5. How did the work of Malthus help Darwin reach his conclusion about natural selection?
6. List three environmental variables that affect the size of a population.
7. A population of beetles eats only red flowers. Most of the beetles are red but a few of them are yellow. The red beetles are hidden from hungry, beetle-eating birds. The beetles eat up all of the red flowers and now there are only yellow flowers left. What would you expect to happen to the traits of the beetle population over time? What process would cause this to happen?

CHALLENGE

A challenge to Darwin's theory

Darwin's theory of evolution states that changes occur gradually and over many years.He used the fossil record to support his ideas. In the 1970s, American biologist Stephen Jay Gould (1941–2002) presented a challenge to Darwin's theory called *punctuated equilibrium*. He argued that a species can remain unchanged for millions of years. If a dramatic environmental event occurs, a species can undergo rapid changes in a short period of time. He also found evidence in the fossil record to support his idea.

1. What does Gould mean by a dramatic environmental event? List some of your ideas.
2. Do you agree or disagree with Gould's ideas? Explain your position and justify it with your knowledge about evolution.
3. Could Darwin's model for evolution and Gould's model both be correct? Explain your reasoning.

11.3 Natural Selection

Natural selection explains how a population changes in response to its environment. Those changes are called *adaptations*. Adaptations are inherited, therefore they must be carried on genes. Since Darwin developed his theory before Gregor Mendel's experiments, he knew nothing about genes. In this section, you will learn about the connection between natural selection and heredity.

Mutations

What causes genetic variation?

Since Darwin's time, there has been a growing body of knowledge about heredity. That knowledge explains many of Darwin's observations and supports the theory of evolution. For example, Darwin observed that individuals in a population show variation in their traits. Today, scientists know that variations in the population of a species are caused by random mutations in genes.

Random mutations in genes produce variations of traits in a population.

Mutations lead to alleles

Recall that alleles are different forms of a gene. A gene mutation leads to different alleles of that gene which in turn, leads to variations of a trait. Mutated alleles may cause favorable and unfavorable adaptations.

Favorable alleles are selected

Imagine a population of brown squirrels that has a single gene that determines fur color. A mutated allele causes white fur instead of brown fur. The squirrels with brown fur can hide from predators better than squirrels with white fur (Figure 11.12). Most of the squirrels that survive to reproduce are brown. Since brown fur is a favorable adaptation, the allele for brown fur is selected over the allele for white fur. What would happen to the frequency of the brown fur allele if the climate changed and the ground became covered in snow for most of each year?

STUDY SKILLS

Reviewing past topics will help you understand the concepts in this chapter. Below are topics and the page number in the text where you will find them. For each topic, go back and reread the page. Then, write down how that topic relates to what you are currently learning.

Species (definition) - page 40
Populations - page 56
Bacteria and evolution - page 137
Alleles - page 174
Mutations - page 198

Figure 11.12: *Squirrels with brown fur are better adapted than squirrels with white fur.*

The importance of genetic variation

Helpful mutations

You have learned that some mutations are harmful because they cause genetic disorders. Mutations may also be helpful because they contribute to genetic variation. **Genetic variation** refers to the variety of alleles in a population. Genetic variation is necessary for natural selection and ensures that a population has a better chance of survival should the environment change.

Changing environment

Because our fictional squirrel population carries an allele for white fur, it may have a better chance of surviving a change to a colder climate. The allele for white fur may be selected over the brown if the ground is covered in snow for most of each year. Over many generations, the frequency of the white fur allele may increase in the population while brown decreases.

Natural selection in action

Scientists have observed natural selection in species that produce new generations quickly. An example is pesticide resistance in the potato beetle. Farmers routinely spray pesticides to prevent this pest from destroying their crops. Each time they spray, a few of the beetles survive. The survivors carry a mutated allele that resists the pesticide. The survivors pass the resistant allele to their offspring. Because generations multiply quickly, it does not take long for a population of pesticide-resistant beetles to evolve (Figure 11.13).

VOCABULARY

genetic variation - the variety of alleles in a population.

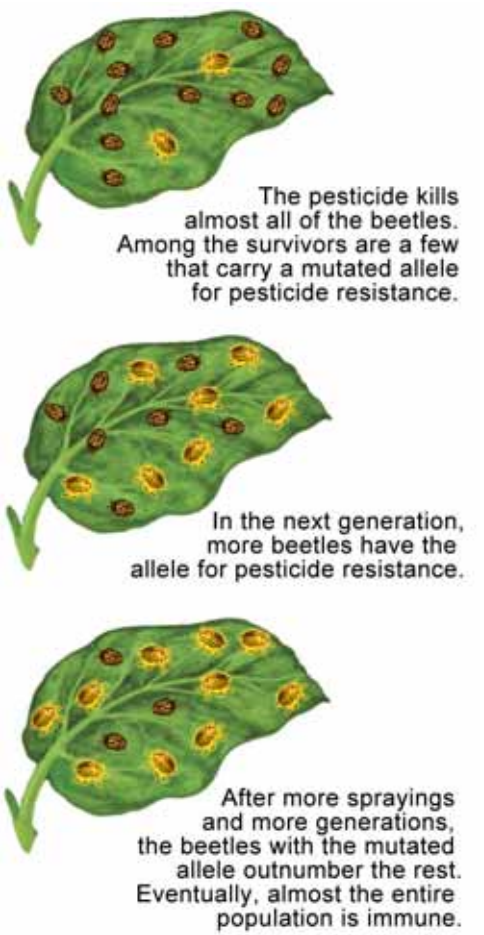


Figure 11.13: *How a population of potato beetles changes over time.*

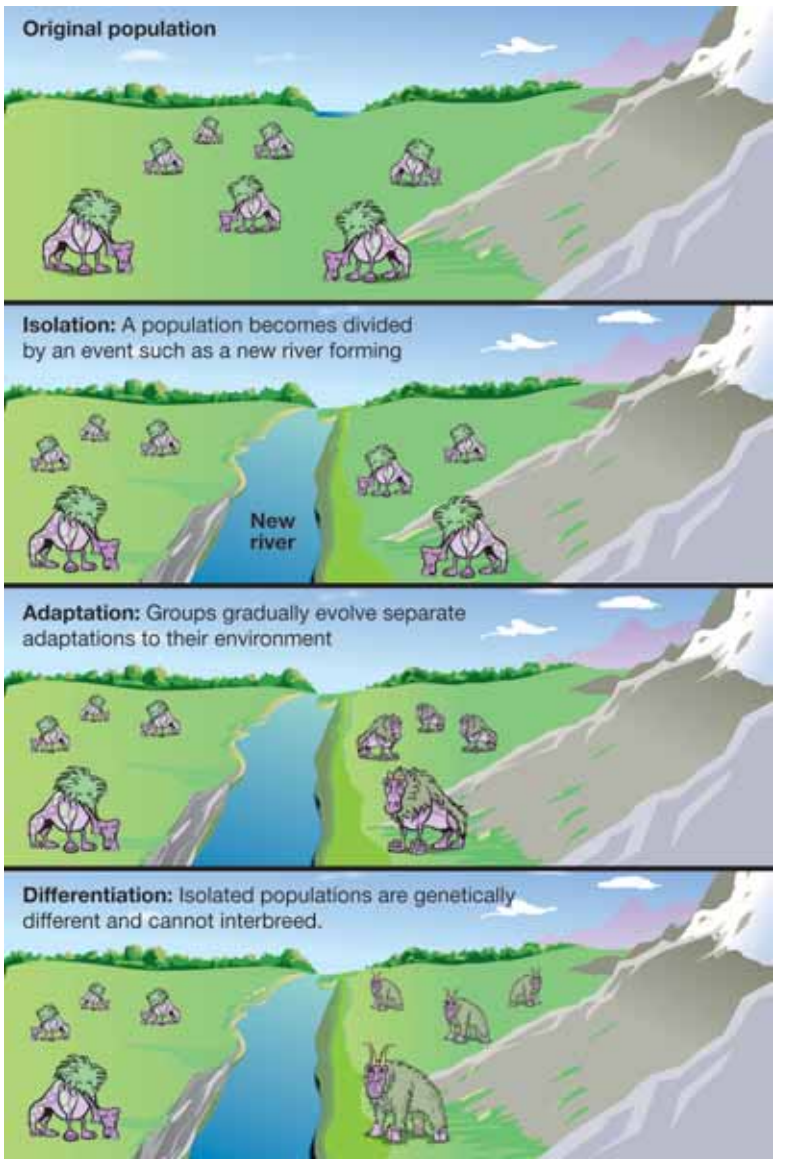
How a new species evolves

How does a new species evolve? Scientists theorize that natural selection leads to the formation of new species. Recall that a *species* is an isolated population of similar organisms that interbreed and produce fertile offspring. One way for a new species to evolve happens in three steps: *isolation*, *adaptation*, and *differentiation*.

Isolation *Isolation* happens when a population becomes divided by an event. Possible events include floods, volcanic eruptions, mountain formation, earthquakes, and storms. The original population becomes divided into smaller populations. Each population is physically and reproductively isolated from the others.

Adaptation *Adaptation* happens through natural selection. The event that causes isolation may also change the environment. As the environment changes, the population that lives there undergoes natural selection. Over time, each separated population may become adapted to their environment. If the environments are different, each population will have different adaptations.

Differentiation *Differentiation* happens when the isolated populations become so different that they can no longer interbreed, even if they could unite again. Over many generations, the isolated populations become genetically different from each other. Each population may have different allele frequencies. Random mutations in each population may create new alleles and thus new traits. As a result, one or more new species are formed.



Extinction of a species

What is extinction?

Extinction occurs when the environment changes and the adaptations of a species are no longer sufficient for its survival. Changes may include increased competition with other species, newly introduced predators, loss of habitat, and catastrophes. Based on the fossil record, scientists think most of the species that once lived on Earth are now extinct.

An example of extinction

The dodo bird is an example of how human impact may contribute to extinction. The dodo was first sighted around 1600 on Mauritius, an island in the Indian Ocean (Figure 11.14). It was a flightless bird with a stubby body and tiny wings (Figure 11.15). Scientists believe that the dodo evolved from a bird capable of flight. When an ancestor of the dodo landed on Mauritius, it found a habitat with plenty of food and no predators. It had no reason to fly and eventually evolved into a flightless bird.

The cause of the dodo's extinction

The dodo was extinct less than eighty years after its discovery. Some of the birds were eaten by the Dutch sailors who discovered them. Also, domestic pigs and cats destroyed their nests which were built on the ground. But the main cause of their extinction was the human destruction of their habitat.

The importance of genetic variation

One reason the dodo may have become extinct is the lack of genetic variation. As a species' population gets smaller, its genetic variation may decrease. Natural selection requires genetic variation. Therefore, a small population may be more susceptible to extinction than a large population if their environment changes. If genetic variation is not present, the population may not have enough favorable adaptations to survive changes in the environment. Scientists study extinctions like the dodo's in hope of preventing future extinctions.

Figure 11.14: *Mauritius is located off the coast of Madagascar.*

Figure 11.15: *The dodo was a flightless bird.*

11.3 Section Review

1. Why are mutations beneficial to the process of evolution?
2. Many species of animals carry an allele for albinism (lack of pigmentation). Albinos are usually pale or white in color. Explain why the allele for albinism is present at a lower frequency than the allele for having pigments. What conditions would be necessary for the albino allele to be more frequent?
3. Why is genetic variation necessary for natural selection to occur?
4. Construct a concept map that shows how a population of bacteria can develop resistance to antibiotics.
5. Describe how a new species evolves.
6. What is meant by the term *extinction*? List three causes of extinction.
7. Cheetahs are the largest of the small cats. The cheetah population once covered all of Africa and Asia. Now cheetahs are an endangered species. Loss of habitat, commercial farming, and development are major causes of its decline. Today, there are fewer than 12,000 cheetahs left on the planet. Explain, using your knowledge of natural selection, why it may be difficult to stop the decline of the cheetah population.

VOCABULARY

From previous page:

extinction - occurs when the environment changes and the adaptations of a species are no longer sufficient for its survival.

CHALLENGE

A cactus is a plant that lives in very hot and dry habitats. The spines of a cactus are modified leaves. The stem of a cactus is thickened and stores water. Explain how cactus leaves and stems may have changed over time through the process of natural selection.

ECOLOGY CONNECTION

Chameleons of the Sea

All animals try to blend into their surroundings - even us humans - but some are nearly perfect at it. Or should that read "nearly invisible?" What animal do you think is the best at blending in? If you guessed the chameleon, you're close. That reptile can change the color of its skin to match its surroundings. Yet no animal compares to the octopus and its relative the squid when it comes to disguises.

Most animals blend into their surroundings in order to protect themselves. But predators also want to blend in - so that they can surprise their prey. Many animals, like the octopus and squid, need to remain unseen because they are both predator and prey.

The octopus and squid can change color almost instantly, far faster than a chameleon. Indeed, they have been called "the chameleons of the sea." Their ability to change their body color, shape, and texture is quite a complicated process. They can create an amazing variety of appearances. The way they blend into their surroundings is one of nature's most dramatic examples of how organisms can adapt to their environments.

Intelligent invertebrates

The octopus and squid are *cephalopods*. In ancient times, cephalopods were one of the dominant life forms in the planet's oceans. They are the most biologically advanced of the mollusks (which include snails, clams, and oysters), and are considered to be highly intelligent invertebrate animals.

Cephalopods have large brains and complex nervous systems. They are very sensitive to their environments and are able to adapt quickly to change. Their eyes are sophisticated and similar to the human eye, with a cornea, lens, and retina.

Remember that their ability to blend into their surroundings is an adaptation that also makes cephalopods excellent predators. On the other hand, they lack the protection of a hard shell, which makes them attractive as prey.

So what adaptations have the octopus and squid made to ensure their survival? The ability to blend into their surroundings is their primary defense. Their soft bodies allow them to squeeze into small burrows between rocks, and they also have chemical weapons they use as a defensive smokescreen. They can shoot a cloud of ink into the water, giving them time to escape a predator.

In a blink of its eye

So just how do cephalopods blend into the ocean background so well? Their advantage is a special skin cell called a chromatophore. There are hundreds of chromatophores in each square centimeter of a cephalopod's skin.

Each of those chromatophores has three bags that contain different colors of liquid pigment. The bags are squeezed or

expanded to change the color displayed by each cell. And each of those cells is controlled separately. The cephalopod's complex brain coordinates all this.

OAR/National Undersea Research Program (NURP)
North Carolina State University

Imagine how many subtle differences in color can be created in this way. The octopus or squid is capable of producing millions of patterns to match any background. And, amazingly, the cephalopod does all this instantaneously.

Survival strategies

Cephalopods still must use a variety of other strategies to adapt to their environments. For example, an octopus or squid can change its texture using muscles in the skin. They also use different body postures to sculpt themselves into their surroundings. So they may curl into a ball and change their skin texture and look like a rock - to predator or prey.

Cephalopods change their appearance in courtship, in acts of aggression, and to warn of danger. Squid will display a high-contrast zebra pattern when courting in order to discourage other males from mating with a certain female.

These chameleons of the sea have survived over eons because they adapted to their surroundings. Like every animal, their survival depends on escaping predators, finding food, and reproducing. Think of it: The cephalopod's complex ability to sometimes render itself nearly invisible has meant the species has not disappeared from the ocean.

Questions:

1. How do cephalopods differ from other mollusks?
2. What is "background resemblance"?
3. Why is it important for cephalopods to blend in?
4. What are chromatophores?

CHAPTER ACTIVITY

The Hunter and the Hunted

In this chapter, you learned about the process of natural selection. In this activity you will simulate how natural selection works in a population of mice. Imagine a population of mice that have variations in their fur color. They are hunted by a species of hawk that has pincher-like claws. You will work in groups of four. You and your classmates will play the role of the hawks. The materials and what they represent in the simulation are shown below.

Material	What it represents
Paper squares (30 black, 30 white, 30 white with black spots)	Population of mice
Sheet of newspaper	The environment for the mice
Forceps	Hawk's claw
Petri dish	Hawk's nest

You will also need a stopwatch or a watch with a second hand, pencils, and graph paper.

What you will do

1. Open your sheet of newspaper and place it on a flat surface such as a lab table. This will serve as the environment for your mice.
2. Place the petri dish on the other side of the table. This will be the nest.
3. Select one person from your group to act as a hawk. This person should stand by the nest.
4. The hawk should have a pair of forceps. These represent one of its claws. The hawk can only pick up the mice with the forceps.
5. Spread the mice on their environment evenly.
6. Have another student play the role of the timer.
7. The hawk now swoops over and has 1 minute to pick up as many mice as possible. The hawk may only pick up one mouse at a time. Then, the hawk must place it in the nest before flying back to pick up another. The goal is to pick up as many mice as possible in the time period.
8. When the time is up record the number of mice left in the environment in the data table below.
9. Repeat this procedure for each person in the lab group.
10. After all data is collected, construct a bar graph. Be sure to label the graph and its axes.

	Number of black mice left	Number of white mice left	Number of spotted mice left
Hawk 1			
Hawk 2			
Hawk 3			
Hawk 4			

Questions:

a. What variations are present in your mouse population?
b. Why is variation important to the survival of a population?
c. Make a bar graph of your data.
d. What happened to the mouse population after each trial?
e. Suppose the surviving population goes on to reproduce. What do you think the next generation will look like?
f. How might the mouse population change over many generations?
g. In this simulation, which variation is a favorable adaptation? Which variations are least favorable?
h. If the environment suddenly changed to white, which variation would be the most favorable?

Chapter 11 Assessment

Vocabulary

Select the correct term to complete the sentences.

evolution	vertebrates	fossil
ancestor	genetic variation	fossil record
adaptations	homologous structures	natural selection
	cladogram	

Section 11.1

1. Inherited from parent to offspring, _____ increase an organism's chance of survival in their environment.
2. Biologists use a _____ to illustrate evolutionary relationships between organisms and their ancestors.
3. _____ share common evolutionary origins, but can be functionally unalike.
4. Mammals, bony fish, and birds are just a few examples of _____, animals with backbones.
5. Typically found in sedimentary rock, remains of organisms called _____ offer clues into evolutionary history.
6. The location in which fossils appear in the sedimentary layers is used to piece together an evolutionary sequence of life on Earth called the _____.

Section 11.2

7. _____ is a process by which organisms with favorable traits survive and reproduce more successfully than those

Section 11.3

8. Greater _____ signifies a larger variety of alleles and therefore greater survivability of a species over time.

Concepts

Section 11.1

1. As environmental conditions change over time, which population will have a better chance of survival?
   a. A population with a high level of variation.
   b. A population with several very fit and genetically similar organisms.
   c. Organisms that mutate very rarely.
   d. A population that feeds exclusively on one type of food.
2. How would a mutation in a skin cell differ from a mutation within a sperm or egg cell in relation to the theory of evolution?
3. In trying to understand the evolutionary relationships between two species which of the following would NOT be helpful?
   a. DNA analysis shows nearly identical strings of DNA sequence within each genome.
   b. Both species live in the similar environments and feed the same food.
   c. Embryos of each species show distinct similarities.
   d. Comparative analysis of dental impressions shows similarities in number and structure of each tooth.
4. Which statement best describes adaptation:
   a. A lily suddenly mutates its tissues to store more water in a drought.
   b. Fish swim away from a sudden source of pollution.
   c. A beetle hatches in time of food shortage with a mutation that contains enzymes to digest a greater variety of food.
   d. Environmental factors are a cause of natural selection in which there are only favorable traits.

Section 11.2

5. After studying the beaks of finches, Darwin developed a theory of how adaptations evolved. Are there other ideas that led him to this theory? Explain.
6. The size of a white-footed mouse population is influenced by
   a. the availability of acorns, a main source of food.
   b. an increase in the owl population, a primary predator.
   c. an extremely dry summer leading to a severe drought.
   d. All of the above
7. Variation:
   a. is not random and occurs due an environmental change.
   b. describes only changes in the behavior of a species.
   c. is acquired throughout an organism's lifetime.
   d. happens by chance and is passed to offspring.

Section 11.3

8. Mutations:
   a. occur randomly and produce variation in a population.
   b. occur due to changes in the environment.
   c. change only the physical appearance of an organism and not its genotype.
   d. were explained by Darwin's analysis of Mendel's pea experiments.
9. Do changes in the environment CAUSE mutations or are they already present in gene pool of a population? Explain.
10. Give an example of how a random mutation in an organism could give it an environmental edge over other members of its species.
11. A pregnant jungle tree frog is released into a remote and isolated mountain community. Of the 2000+ eggs she lays only she a few hundred last a sudden freeze. How might this situation develop further to create a new species?
12. Which is not a cause of extinction:
    a. Sudden environmental changes occur
    b. Poor adaptations to the changing environment
    c. Too much variation in the gene pool
    d. Introduction of a foreign species increases competition

Math and Writing Skills

In earlier periods of history, people believed fossils were organisms that spontaneously sprouted from the ground but were unable to properly develop and come to the surface. How is this different from modern understanding of fossil formation? How is the fossil record used to understand Earth's evolutionary history?

Chapter Project

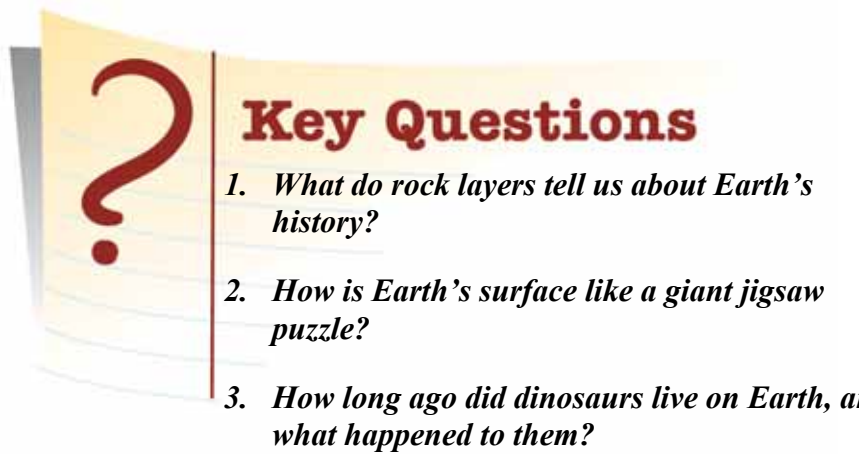
Endangered species

Extinct species are living things that have disappeared from Earth. The United States government has a protection program that places animals and plants on a special list if they are in danger of extinction. If a plant or animal makes the "endangered" or "threatened" list, funding is available for protecting it. The U.S. Fish and Wildlife Service maintains a list of endangered species. Find a list of animals that are listed as "endangered" in the United States. Choose a mammal, bird, reptile, amphibian, or fish from the list and create a large poster to teach others about this endangered species. On the poster, be sure to include the common and scientific name of the animal, interesting facts, a map with current locations marked, and list important things being done to protect this species. Your goal is to educate others about this endangered species.

Chapter 12

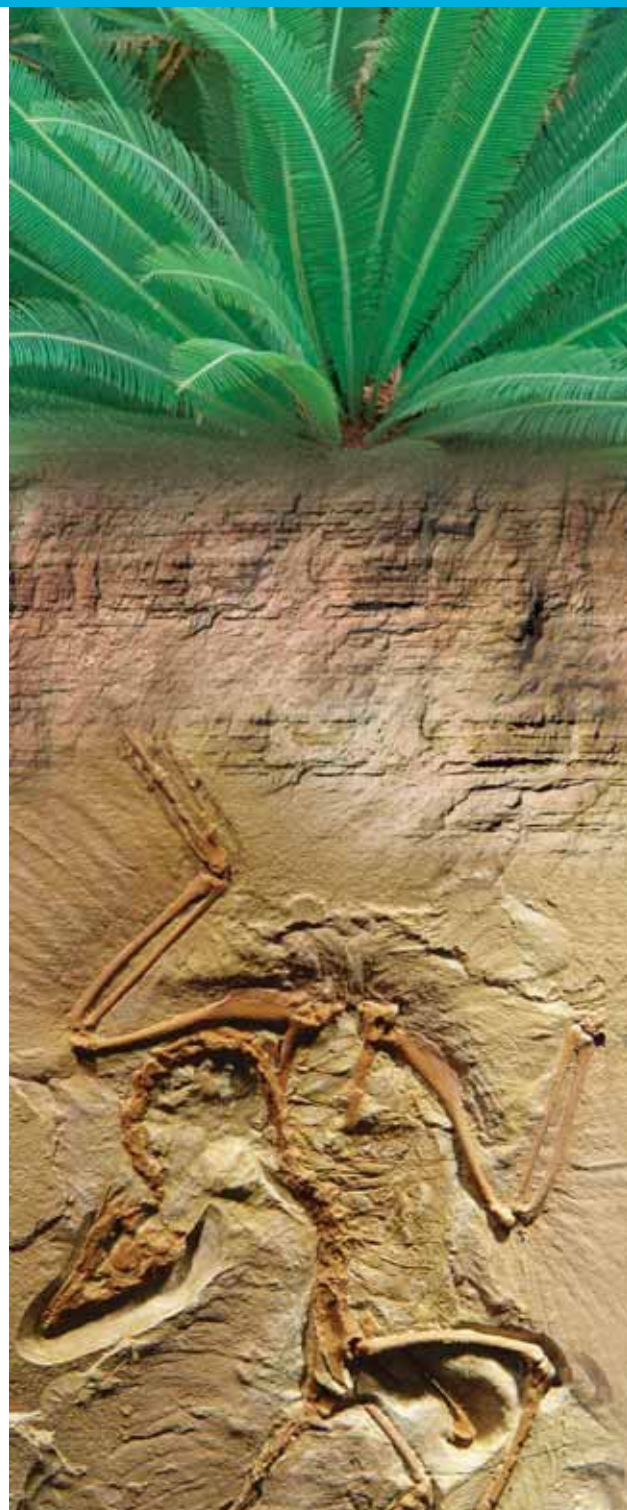
Earth and Life History

There was a time when Earth had a warm, tropical climate all over. Dinosaurs roamed Earth, and giant plants called cycads grew everywhere. Earth's land masses formed one giant continent. This might sound like science fiction, but it is actually a simple description of what geologists call the Mesozoic era in Earth's history. How do geologists know what Earth and its life forms were like millions of years ago? Explore this chapter to find out!



Key Questions

1. ***What do rock layers tell us about Earth's history?***
2. ***How is Earth's surface like a giant jigsaw puzzle?***
3. ***How long ago did dinosaurs live on Earth, and what happened to them?***



12.1 Evidence from Rocks

Earth's environment has been changing slowly since it was formed 4.6 billion years ago. These changes are the driving force behind evolution. **Geology** is the study of Earth's formation and structure. Geologists study rocks to find clues to Earth's formation. **Evidence from rocks and fossils allows us to understand the evolution of life on Earth.**

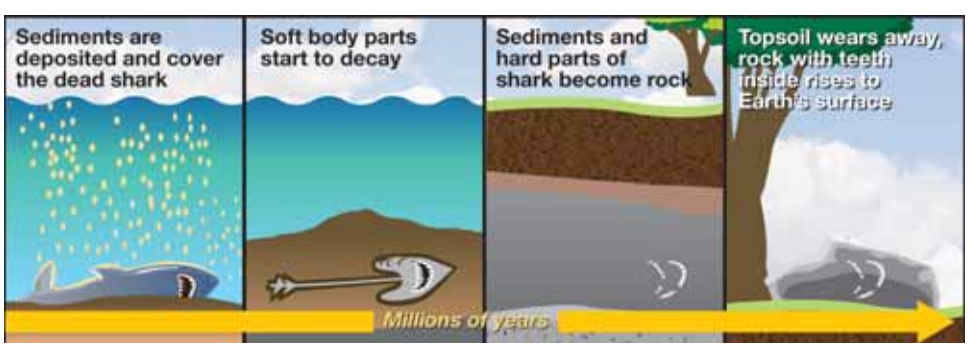
Fossil formation

Tonguestones and shark's teeth

In 1666, Nicholas Steno, a Danish anatomist, studied a shark's head and noticed that the shark's teeth resembled mysterious stones called "tonguestones" that were found inside of local rocks. At this time, people believed that tonguestones had either fallen from the moon, or that they grew inside the rocks. Steno theorized that tonguestones looked like shark's teeth because they actually *were* shark's teeth that had been buried and became fossils.

Fossil formation

Steno concluded that when a shark dies, sediments are deposited over its body. After a short time, the shark's soft parts decay, but the teeth do not. Over many years, layers of sediment cover the teeth. Over many more years, the layers of sediment are pressed together and become sedimentary rock. The shark's teeth become part of the rock. Steno's work led him to develop some important principles in geology, explained in this section.



VOCABULARY

geology - the study of Earth's formation and structure.

Figure 12.1: *This illustration is from Nicolas Steno's 1667 paper titled "The Head of a Shark Dissected."*

STUDY SKILLS

Make a concept map out of the following terms. The terms come from this chapter and Chapter 11.

evolution, adaptation, fossil, fossil record, natural selection, geology, rock, sedimentary rock, superposition, paleontologist, relative dating

The formation of sedimentary rock

The rock cycle

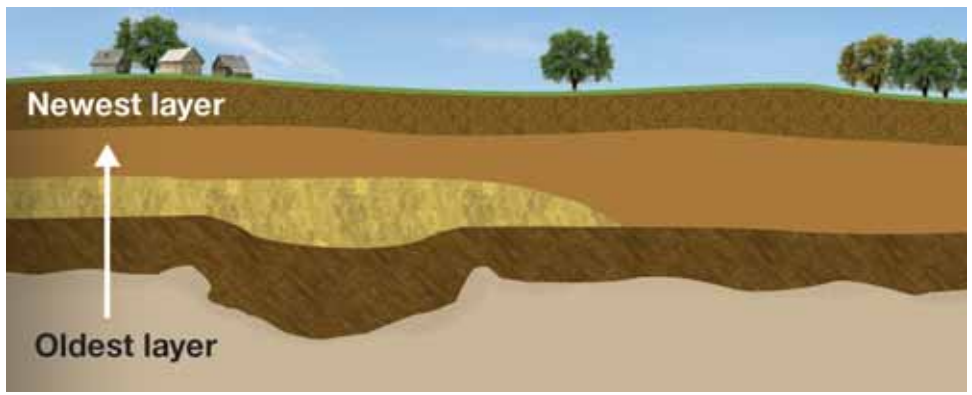
The **rock cycle** is the process of rock formation and recycling. Sedimentary rock formation is part of the rock cycle. (The other two types of rocks are *igneous* and *metamorphic*.) When rocks are unearthed and exposed to Earth's atmosphere, they are subject to weathering and erosion. This breaks rocks up into sediments.

Sedimentary rock layers form horizontally

Sediments are washed from the land and transported into bodies of water. They settle to the bottom because of gravity. Any change in the composition of material being deposited shows up as a distinct *horizontal* layer. Over time, those layers of sediment become layers of rock. Parts of organisms that do not decompose may become fossils within the layers (Figure 12.2).

Rock layers form from the bottom up

The relative age of each layer of sedimentary rock can be determined by applying an idea called superposition. **Superposition** states that the bottom layer of sedimentary rock is older than the layer on top because the bottom layer formed first. Stacking old newspapers in the order in which you received them illustrates superposition (Figure 12.3). The oldest newspaper will be on the bottom, and the newest on top.



VOCABULARY

rock cycle - the process of rock formation and recycling.

superposition - the principle that states that in layers of sedimentary rocks the lowest layers were the earliest to be deposited.

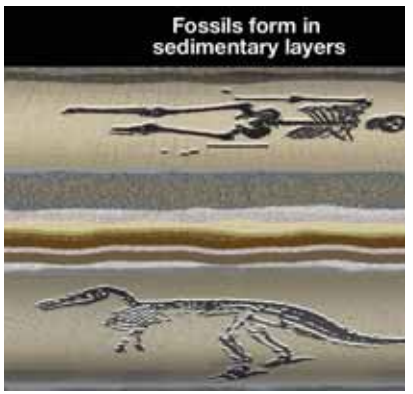


Figure 12.2: *Fossil formation.*

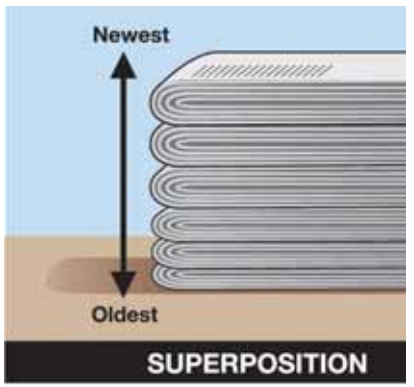


Figure 12.3: *A stack of newspapers illustrates superposition.*

Rock layers are bent or shifted by forces

Rock layers may bend and shift. Sometimes rock layers are found standing vertically, or tilted, or rolled into curves. Slow movements of Earth's crust create very powerful forces. Those forces can move and twist horizontal rock layers into different positions. The photo in Figure 12.4 shows what curved layers of sedimentary rock look like.

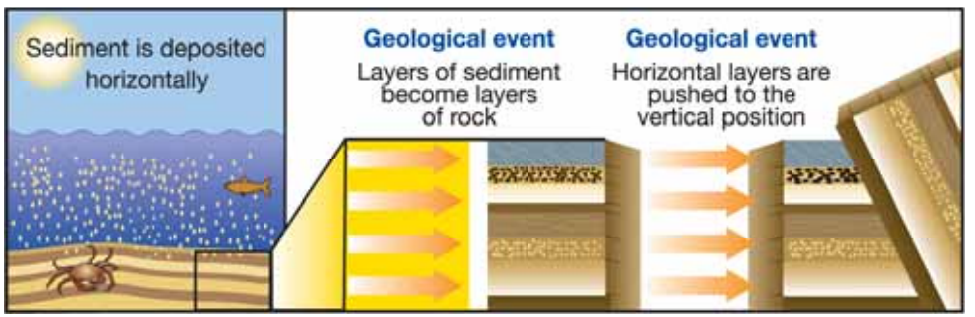
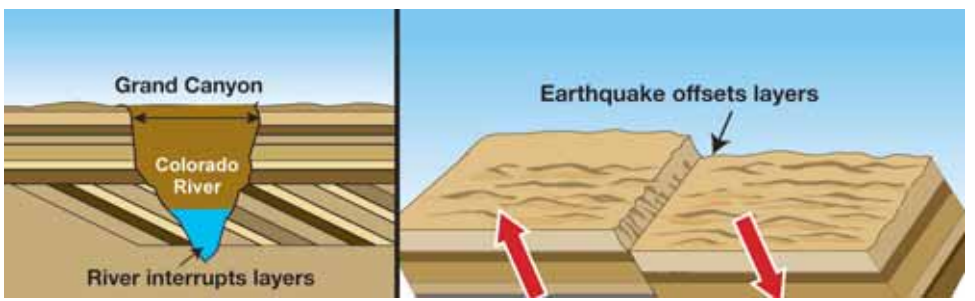


Figure 12.4: *Curved layers of sedimentary rock.*

Layers of rock are continuous

Horizontal layers of rock are continuous. When layers of sediment form, they extend in all directions. By comparing rock layers in the Grand Canyon, geologists have found that the layers on one side of the canyon more or less match up with the layers on the other side. A flowing river can interrupt layers or an earthquake can offset them. The Colorado River formed the gap that is now the Grand Canyon.



MY JOURNAL

Rock formations include mountains, boulders, cliffs, or anything made of rock that is too big for humans to move. Find a rock formation near your school or home. Sketch the formation and identify its features. Make a list of questions you would ask a geologist about the formation.

Relative dating

Relative dating

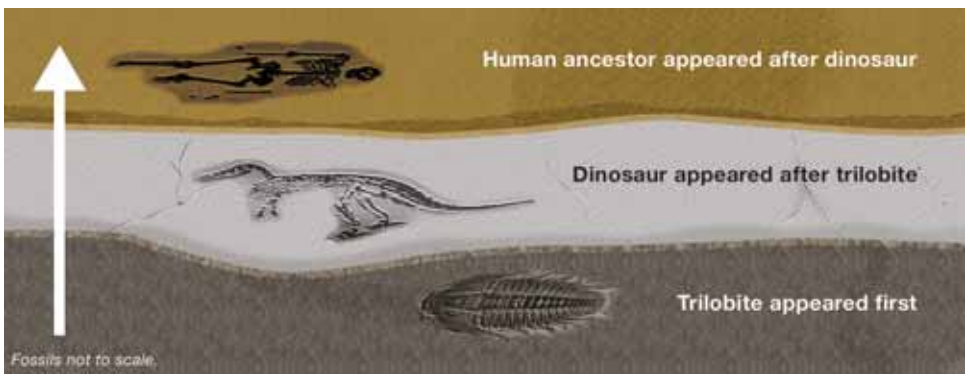
Steno's principles are used by geologists to determine the age of fossils and rocks in a process called relative dating. **Relative dating** is a method of sequencing events in the order they happened.

What is relative dating?

Figure 12.5 shows an example of relative dating. When you use relative dating, you are not trying to determine the exact age of an object. Instead, you use clues to sequence the order of events that occurred around it. Then you determine the age of the object *relative* to the other objects or events in the sequence. Can you list the three events shown in Figure 12.5 in order of occurrence?

Using relative dating to sequence fossils

Paleontologists use relative dating to determine the sequence of fossils in the order that each species existed. A **paleontologist** is a scientist who studies fossils. A cross section of sedimentary rock has many different layers. The oldest layers are found at the bottom and the newest at the top. Suppose fossils were found in the layers shown below. A paleontologist could sequence the organisms found according to their location in the layers. The organisms found in the top layers appeared after the organisms found in the layers below them.



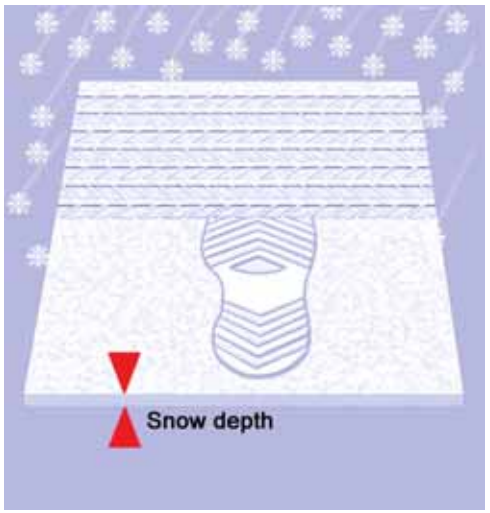


Figure 12.5: *This graphic illustrates three events: a footstep, a tire track, and snowfall. Which event happened first? Sequencing these events in the correct order is a form of relative dating.*

VOCABULARY

relative dating - a method of sequencing events in the order in which they happened.

paleontologist - a scientist who studies fossils.

More relative dating

Cross-cutting relationships

The idea of *cross-cutting relationships* states that a vein of rock that cuts across a rock's layers is younger than the layers. Figure 12.6 shows a rock formation with three layers and a cross-cutting vein. The rock layers formed first. The vein formed in a crack in the original rock. The bottom layer is the oldest part of the rock formation and the vein is the newest. The middle and top layers formed after the bottom layer but before the vein.

Inclusions

Sometimes rock pieces called *inclusions* are found inside another rock. During the formation of a rock with inclusions, sediments or melted rock surrounded the inclusion and then solidified. Therefore, the inclusions are older than the surrounding rock (Figure 12.6). A rock with inclusions is like a chocolate chip cookie. The chocolate chips (inclusions) are made first. Then they are added to the batter (melted rock or sediment) before being baked (hardened) into a cookie (rock).

Faunal succession

Faunal succession means that fossils can be used to identify the relative age of the layers of sedimentary rock (Figure 12.7). For example, dinosaur fossils are found in rock that is about 65 to 200 million years old because these animals lived that long ago. The fossils of modern human beings (*Homo sapiens*) are found in rock that is about 40,000 years old, but not in rock that is 65 to 251 million years old. And dinosaur fossils are not found in rock that is 40,000 years old. This means that human beings did not live at the same time as the dinosaurs. How might you learn which plants and animals *did* live at the same time as the dinosaurs?

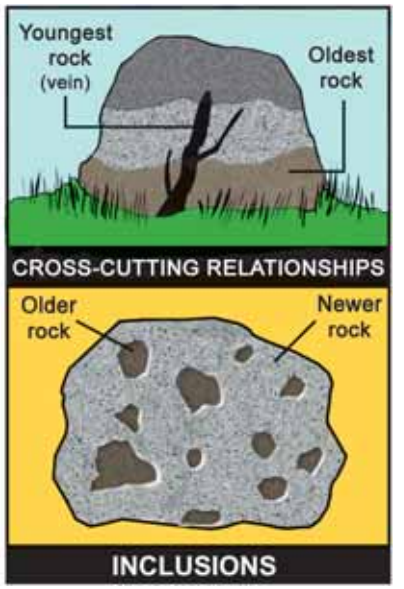
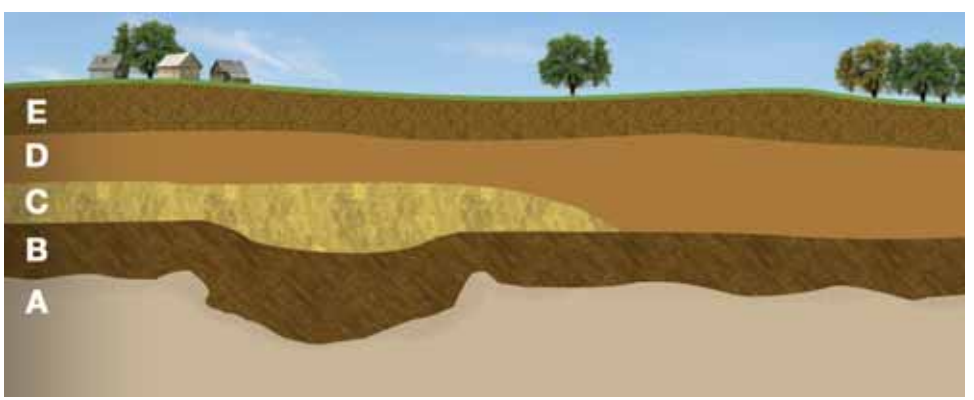


Figure 12.6: *Cross-cutting relationships and inclusions.*

Figure 12.7: *Faunal succession.*

12.1 Section Review

1. Who is Nicolas Steno? What ideas did he come up with that have contributed to modern geology?
2. A river cuts through a canyon and exposes the rock layers. How would the rock layers on either side of the canyon compare? Explain your reasoning.
3. What idea is represented in Figure 12.8? Which fossil is the oldest? Which is the newest? How can you tell?
4. True or False: Superposition states that rock layers near the surface of Earth are more recent than rock layers further from the surface. Explain your reasoning.
5. Study the following picture. Which is the oldest layer of rock? Which layer is the newest?



6. The rock in Figure 12.9 has many features. Use what you know about relative dating to place the features in order of occurrence from oldest to newest.
7. What are inclusions? Which part of a chocolate chip cookie are similar to inclusions?

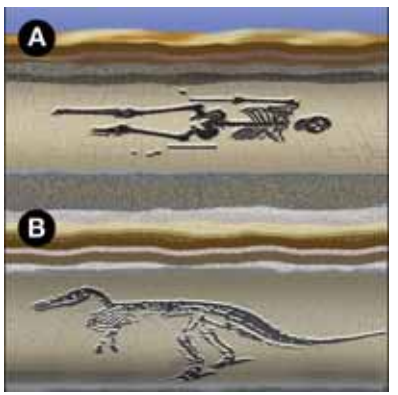


Figure 12.8: *Use the picture above to answer question 3.*

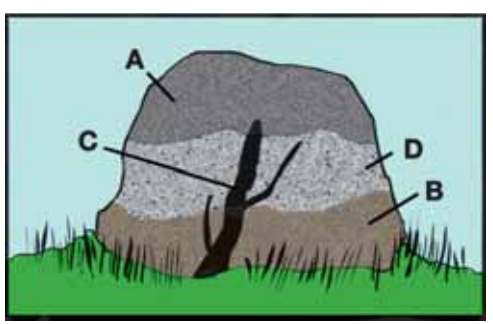


Figure 12.9: *Use the picture above to answer question 6.*

12.2 How Earth Changes

Geologists use an idea called uniformitarianism to piece together Earth's geologic history. **Uniformitarianism** refers to the use of features and process that are observable today, to interpret the ancient geologic record. For example, geologists have used the fossil record to determine how and why Earth's environments have been slowly changing over millions of years.

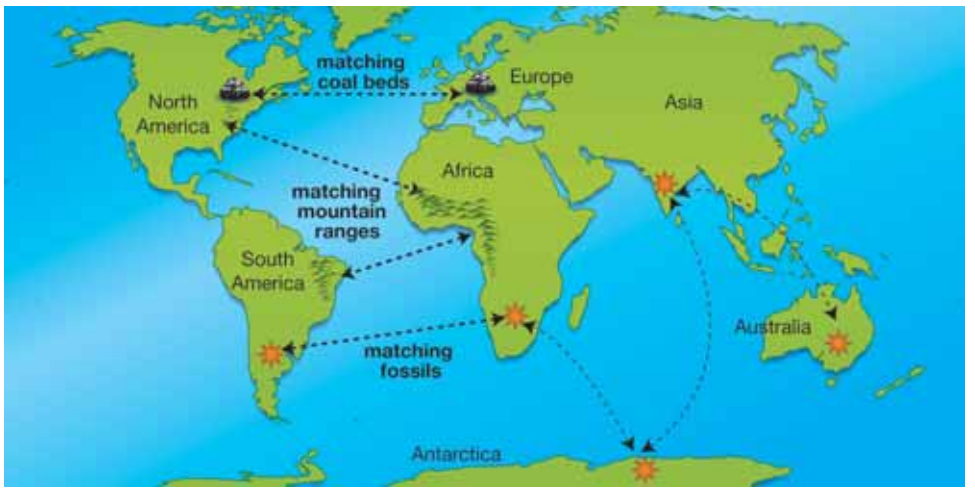
Pangaea

A supercontinent called Pangaea

In 1915, Alfred Wegener (1880–1930) theorized that the continents that we know today had been part of an earlier supercontinent. He called this great landmass **Pangaea**. According to his theory, Pangaea broke apart and the pieces drifted to their present places, becoming today's continents.

Evidence to support Wegener's theory

To support his theory, Wegener observed that fossils of plants and animals found on different continents were very similar. Also, there were matching geologic features on both sides of the Atlantic Ocean. Furthermore, the current shapes of the continents seemed to fit together like puzzle pieces (Figure 12.10).



VOCABULARY

uniformitarianism - using features and processes that are observable today to interpret the ancient geologic record.

Pangaea - an ancient supercontinent that broke apart to form today's continents.

Figure 12.10: *The continents on either side of the Atlantic Ocean fit together like puzzle pieces.*

Plate tectonics

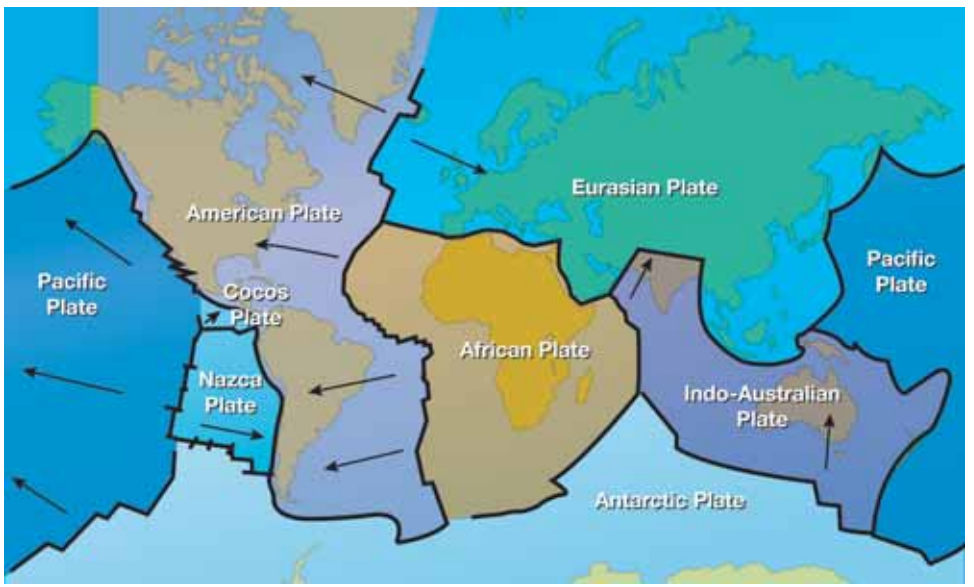
What is plate tectonics?

How the continents move is explained by a theory called **plate tectonics**. Earth's outer layers are called the *lithosphere*. The theory of plate tectonics, first stated in 1965, refers to the movement of giant pieces of the lithosphere called **lithospheric plates**. The movement of one plate causes the pulling or pushing of other plates, significantly affecting Earth's surface. There are seven large lithospheric plates and many smaller ones.

VOCABULARY

plate tectonics - a theory that describes how the continents move.

lithospheric plates - giant pieces of solid rock on Earth's surface.



Movement of tectonic plates

Forces beneath the lithosphere cause the plates to move. Some plates include continents (Figure 12.11). The continents move with their plates. The plates that include North America and Europe are moving apart at a rate of a little over 2 centimeters each year. By comparison, your fingernails grow at a rate of 2.5 centimeters a year. Though that rate may seem slow, it has produced enormous changes in Earth's surface over millions and millions of years.

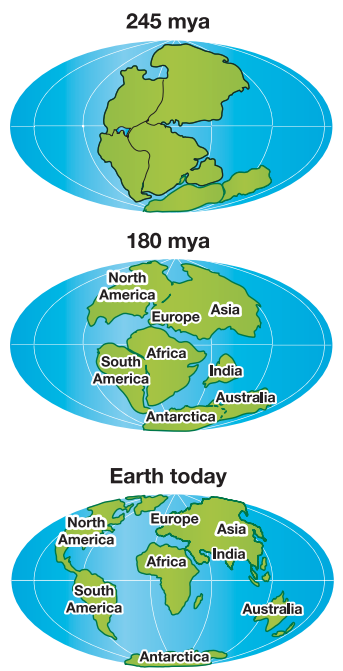
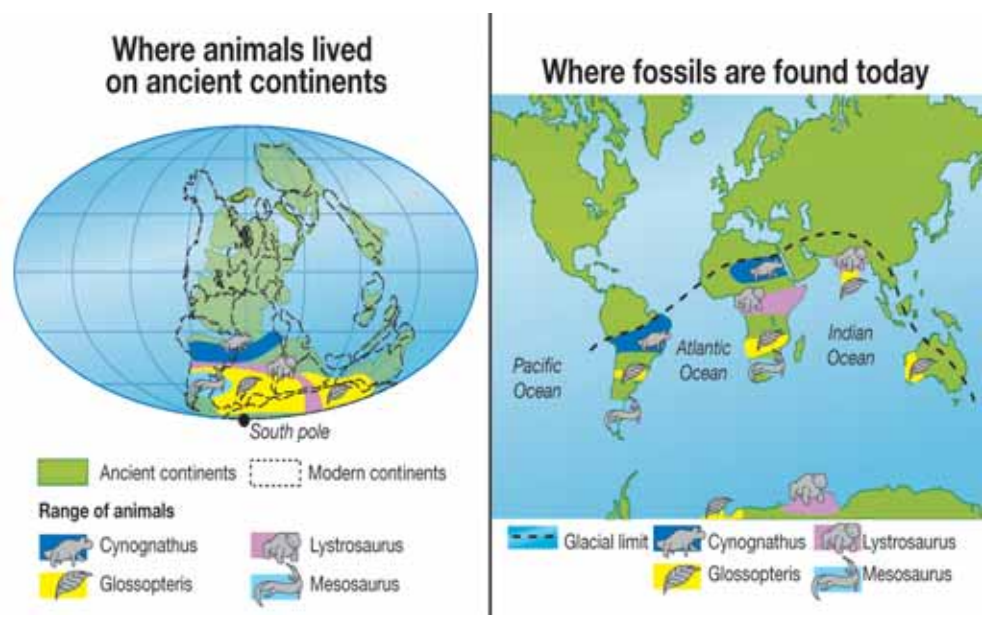


Figure 12.11: *The movement of tectonic plates causes the continents to move.*

Plate tectonics and fossil distribution

Fossil evidence for Pangaea The distribution of fossils provides evidence that the continents were once joined and have slowly separated over time. Fossils of the same species have been found on several different continents. If the continents had always been separated, we would not find these fossils on different continents.

Fossil distribution *Glossopteris*, an ancient plant species, was found on the continents of South America, Africa, India, and Australia (Figure 12.12). If the continents are reassembled into Pangaea, the distribution of glossopteris can be accounted for over a much smaller and connected geographic area. The distribution of other fossils can also be accounted for using the same method of analysis.



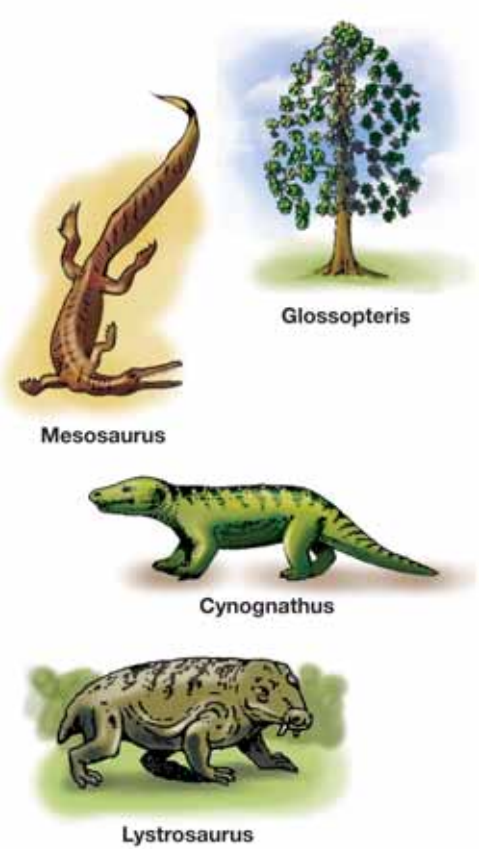


Figure 12.12: *Glossopteris was a woody, seed-bearing shrub or tree, 4–6 m in height. Glossopteris and the other fossil organisms shown have been found on different continents.*

Plate tectonics and evolution

Plate tectonics results in the formation of new species

One result of plate tectonics is the geographic separation of populations. Separation of lithospheric plates separated the continents and divided populations. Collision of plates pushed up mountain ranges which also divided populations (Figure 12.13). Once populations became geographically separated they could no longer interbreed. The separated populations evolved different adaptations. Eventually, they became different species.

Organisms adapt to their environments

Because the movement of plates is slow, organisms usually have time to adapt to changes in the environment. That is why organisms alive today are well adapted. But in the same location where well-adapted organisms thrive, scientists have discovered fossils of organisms that could not adapt to the changes. Dinosaur and plant fossils have been found on the continent of Antarctica. Today, Antarctica is permanently frozen and supports only species that have adapted to the gradual change in climate—like penguins (Figure 12.14).

Using fossils to interpret changes in the environment

Scientists use fossils to interpret environmental changes brought about by plate tectonics. To do this, they apply the principle of uniformitarianism. For example, ancient animals that resembled clams probably lived in the same type of environment as modern clams. If clam fossils are found on a mountain top, scientists assume that the mountain top may have once been part of an environment that supported a clam population. Geologic processes resulted in changes in that environment and the extinction of the clam population in that location. The fossils were probably brought to the surface by the collision of lithospheric plates.

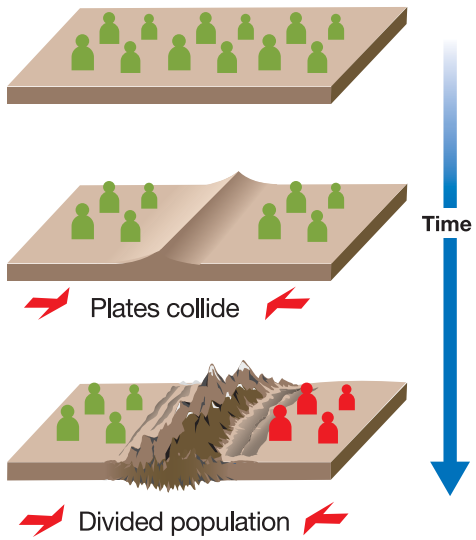
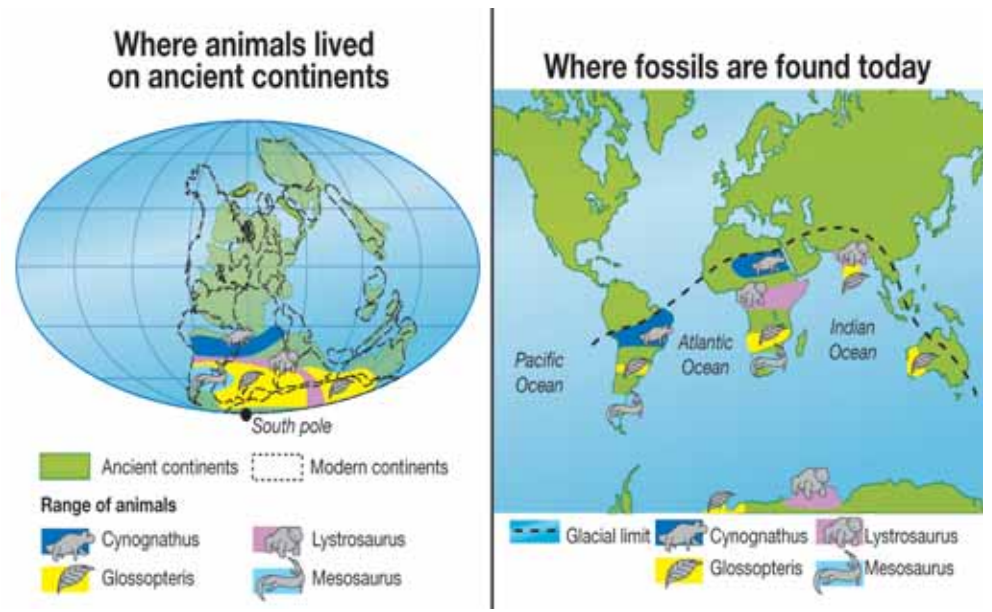


Figure 12.13: *Collision of plates may push up mountain ranges and divide populations.*

Figure 12.14: *A penguin.*

12.2 Section Review

1. How is Earth's surface like a giant jigsaw puzzle?
2. What was Pangaea? List three examples of evidence that Wegener used to support his idea of Pangaea.
3. Describe the theory of plate tectonics.
4. Write a paragraph describing the graphic below. Answer these questions in your paragraph.
   a. What does the left side of the graphic show?
   b. What does the right side of the graphic show?
   c. How does this graphic support the idea of plate tectonics?



5. How does plate tectonics contribute to the formation of new species?

MY JOURNAL

Imagine you are a penguin living in Antarctica. Write a short story describing a day in your life.

12.3 Life History

Scientists have developed a model of the history of life on Earth called the **geologic time scale** (Figure 12.15). It is based on studies of Earth's geology and the fossil record. Most of Earth's changes have occurred slowly, over millions of years. But occasionally, Earth's history has been interrupted by catastrophes such as massive volcanic eruptions or meteor impacts. These events had a significant effect in shaping Earth's surface and on the evolution of life. In this section you will read about the history of life on Earth as told by the fossil and geologic records.

The geologic time scale

Divisions of the geologic time scale

Paleontologists divide the geologic time scale into blocks of time called *eras* and *periods*. Eras are determined by the dominant life forms that were present at the time. Each era is divided into smaller blocks of time called periods. Periods are based on types of fossils found within each era.

Precambrian era

The Precambrian era lasted from Earth's formation 4.6 billion years ago until 542 million years ago (mya). The first prokaryotic cells appeared more than 3 billion years ago. Then, photosynthetic bacteria (cyanobacteria) evolved and began to add oxygen to Earth's atmosphere. Some of that oxygen reached Earth's upper atmosphere and formed the ozone layer. The ozone layer blocked harmful radiation from the sun. This allowed life to move out of the water and onto dry land. The first eukaryotic cells appeared in the Precambrian era, about 2 billion years after the first prokaryotic cells.

VOCABULARY

geologic time scale - a model of the history of life on Earth.

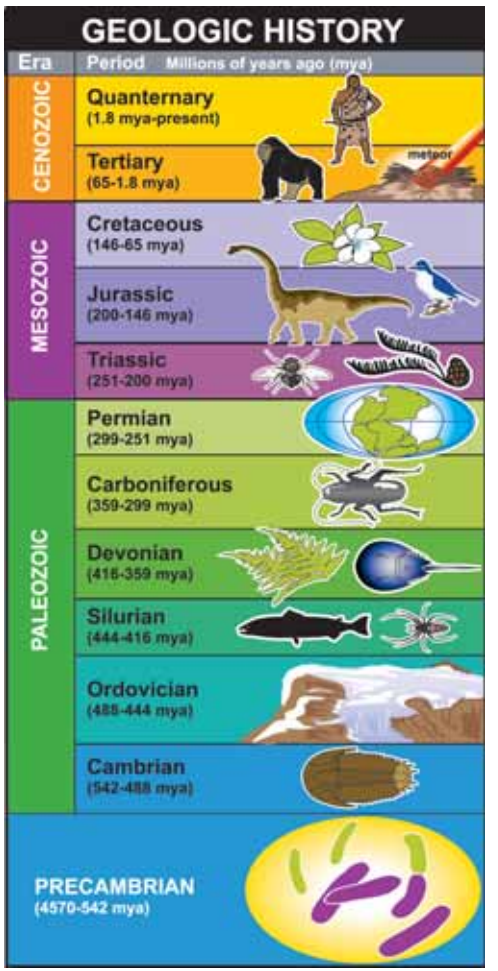


Figure 12.15: *The geologic time scale.*

Paleozoic era The Paleozoic era lasted from 542 to 251 mya. *Paleozoic* is a Greek word meaning "ancient life." Rocks dated from the Paleozoic era contain fossils of trilobites, snails, clams, and corals. Early in the era, many new, complex life forms developed, but glaciers covered the Earth in the Ordovician period, causing many of these new organisms to become extinct. In the Silurian period, fishes with backbones appeared. Next, plants and air-breathing animals began to populate the land. Toward the end of the Paleozoic era, much of the land was covered with forests of palm trees and giant ferns. Therapsids are a group of animals that dominated the land in the Permian period. Scientists believe that mammals evolved from therapsids.

Mesozoic era The Mesozoic era lasted from 251 to 65 mya. *Mesozoic* is a Greek word meaning "middle life." This era is often called the Age of Reptiles. Dinosaurs are the most well-known reptiles of the Mesozoic era and dominated Earth for about 150 million years (Figure 12.16). The Jurassic period was marked by the appearance of the first birds. Flowering plants evolved during the Cretaceous period. At the end of the Mesozoic era, 65 ya, dinosaurs and many other animal and plant species suddenly became extinct. Geologic evidence indicates that a giant meteor may have hit Earth. This may have been the cause of the extinctions.

Cenozoic era The Cenozoic era began 65 mya and is still going on. *Cenozoic* means "recent life." Fossils from the Cenozoic era are closest to Earth's surface, making them easier to find. Therefore, scientists have the most information about life in this era. The Cenozoic era is often called the Age of Mammals because many species of mammals appeared. Eohippus appeared in the Cenozoic era (Figure 12.17). The first human ancestors appeared about 4 million years ago. Modern humans appeared 40,000 years ago during the Quanternary period.

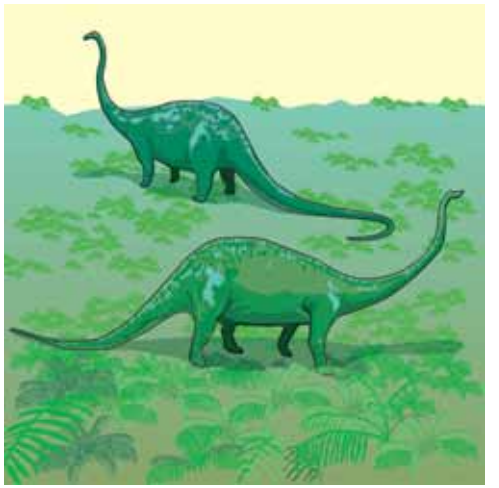


Figure 12.16: *Diplodocus is a dinosaur that lived in the Mesozoic era.*

Figure 12.17: *Eohippus appeared in the Cenozoic era.*

Mass extinctions

What are mass extinctions?

There have been at least five mass extinctions in which many types of plants and animals were wiped out. **Mass extinctions** are periods of large-scale extinction. They seem to be part of the evolutionary process because after each, new life forms emerge.

The greatest mass extinction

Scientists believe the greatest mass extinction was about 250 million years ago towards the end of the Paleozoic era. It is known as the Permian extinction, and it killed as many as 90 percent of all living things on Earth. Some scientists believe it was caused by an event such as a volcanic eruption or asteroid impact. That event sent particles of dust into the atmosphere and changed Earth's climate causing long- and short-term changes in the habitats of organisms living at that time. (Figure 12.18).

The most recent mass extinction

The Cretaceous-Tertiary extinction happened about 65 million years ago, ending the Mesozoic era. Many scientists believe a large asteroid hit Earth. The impact was so violent that once again, huge amounts of dust were thrown into the atmosphere. The sun was blocked out, possibly for years. Changes in climate and habitats caused the extinction of the dinosaurs. Afterwards, mammals became the dominant vertebrate life form on land.

A sixth mass extinction?

Today, some scientists think we are in the middle of a sixth mass extinction because many species have become extinct in the last few hundred years. This time, human impact may be the cause. But humans can also help prevent extinctions. The California condor is one example (Figure 12.19). A typical California condor has a 10-foot wingspan, making them the largest bird in North America. Government and private groups have created the California Condor Recovery Program. Because of the program, there are now almost 300 condors, over 100 of them in the wild in California, Baja California, and Arizona.

VOCABULARY

mass extinctions - periods of large-scale extinction.

Figure 12.18: *Scientists believe some mass extinctions were caused by an asteroid impact.*

Figure 12.19: *A California condor in flight.*

Absolute dating

What is absolute dating?

Relative dating provides information about the sequence of events in Earth's history. **Absolute dating** is a method of estimating the age of a fossil in *years*. Scientists use both absolute and relative dating to develop the geologic time scale. Absolute dating requires the use of a natural "clock." That clock is the *radioactive decay* of certain naturally-occurring elements like uranium and carbon.

What is radioactive decay?

Elements that undergo radioactive decay contain *unstable atoms*. All atoms are made of tiny particles held together by strong forces. Atoms of different elements contain different numbers of particles. Unstable atoms contain more particles than can be held together by the strong forces. They undergo radioactive decay by releasing some of those particles. In the process, they transform into different kinds of atoms. For example, when uranium atoms decay, one of the products is lead atoms (Figure 12.20).

What is half-life?

Half-life is the amount of time it takes for half of the unstable atoms in a sample to decay. Half-lives range from fractions of a second to billions of years. In a sample of uranium-238, it takes 4.5 billion years for half of the uranium atoms to transform into lead atoms. The half-life of carbon-14 is 5,730 years (Figure 12.20). One of the products of carbon-14 decay is nitrogen.

Using absolute dating

Scientists estimate the age of fossils by measuring the ratio of unstable to stable atoms in a sample of rock from a fossil. Earth's age is estimated by measuring the radioactive decay of uranium to lead. Scientists compared the amount of lead to uranium in a piece of uranium ore. With that measurement, the age of Earth was estimated to be about 4.6 billion years. The fossils of ancient bacteria, the first life forms, have been dated to be over 3 billion years old.

VOCABULARY

absolute dating - a method of estimating the age of a rock sample in years.

half-life - the amount of time it takes for half of the unstable atoms in a sample to decay.

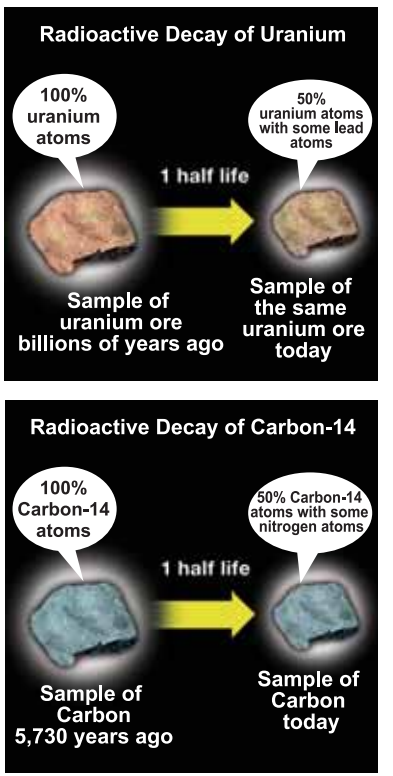


Figure 12.20: *The half-life of uranium-238 is 4.5 billion years. The half-life of carbon-14 is 5,730 years.*

12.3 Section Review

1. Explain how time is divided in the geologic time scale.
2. Match the organism or event to the time period in which it first appeared.
   a. dinosaur
   b. woolly mammoth
   c. archaebacteria
   d. human
   e. mass extinction of dinosaurs
   f. Pangaea
   g. plants
   h. fishes with backbones
3. What is a mass extinction?
4. How could a giant meteor impact change Earth's climate?
5. How have catastrophes contributed to the evolution of life on Earth?
6. Explain the difference between relative dating and absolute dating.
7. The age of a fossil is estimated to be about 280 million years old.
   a. Explain how scientists estimate the age, in years, of a fossil.
   b. To which era and period does the fossil belong? What are some organisms that lived during that time?

SOLVE IT!

1. A sample of rock contains 10 mg of carbon-14 atoms. The half-life of carbon-14 is 5,730 years. How many grams of carbon-14 will be in the sample after 11,460 years?
2. A sample of rock contains 4 mg of an unstable element. After 50 years, the sample contains 2 mg of the unstable element. What is the half-life of the element?

ARCHAEOLOGY CONNECTION

A Tiny Challenge to Human History

Imagine that an ancient band of humans had been found on a remote island. Imagine that these humans were only one meter tall - and that they hunted dwarf elephants that also lived on the island. Does that sound like the beginning of a science fiction movie? Well, this story is true.

In 2004, scientists made an amazing discovery. On the rugged, remote Pacific island of Flores, Indonesia, they found fossil bones of tiny humans. The scientists named this human *Homo floresiensis*, or Flores man. Adults of this ancient species were about as tall as today's 3-year-olds (who, like you, are *Homo sapiens*, or "wise man"). Flores man hunted dwarf elephants and other animals on the island. And the species disappeared about 13,000 years ago.

Archaeologists found stone tools made by these early humans. They know Flores man hunted, because burned bones have been found. Those bones show marks from the stone tools used by these small humans.

Small is the right size

The dwarf elephants were a type of stegodon. Stegodons are the largest of all the extinct elephants. They were 26 feet long and stood 13 feet high at the shoulder. But on Flores, they were small. Why? Often on an island there are few large predators. Food resources may be limited and large animals may run the risk of starvation. These evolutionary pressures can lead to small size, such as the dwarf stegodons. The same pressures may also have made Flores man small.

Earlier humans

It is not the small size of Flores man that is most fascinating. The remains are amazing because they are so young. The discovery has forced scientists to rethink the history of humans on Earth. It was believed that modern humans, *Homo sapiens*, had been the only humans on Earth for the last 30,000 years. Yet *H. floresiensis* was around 13,000 years ago.

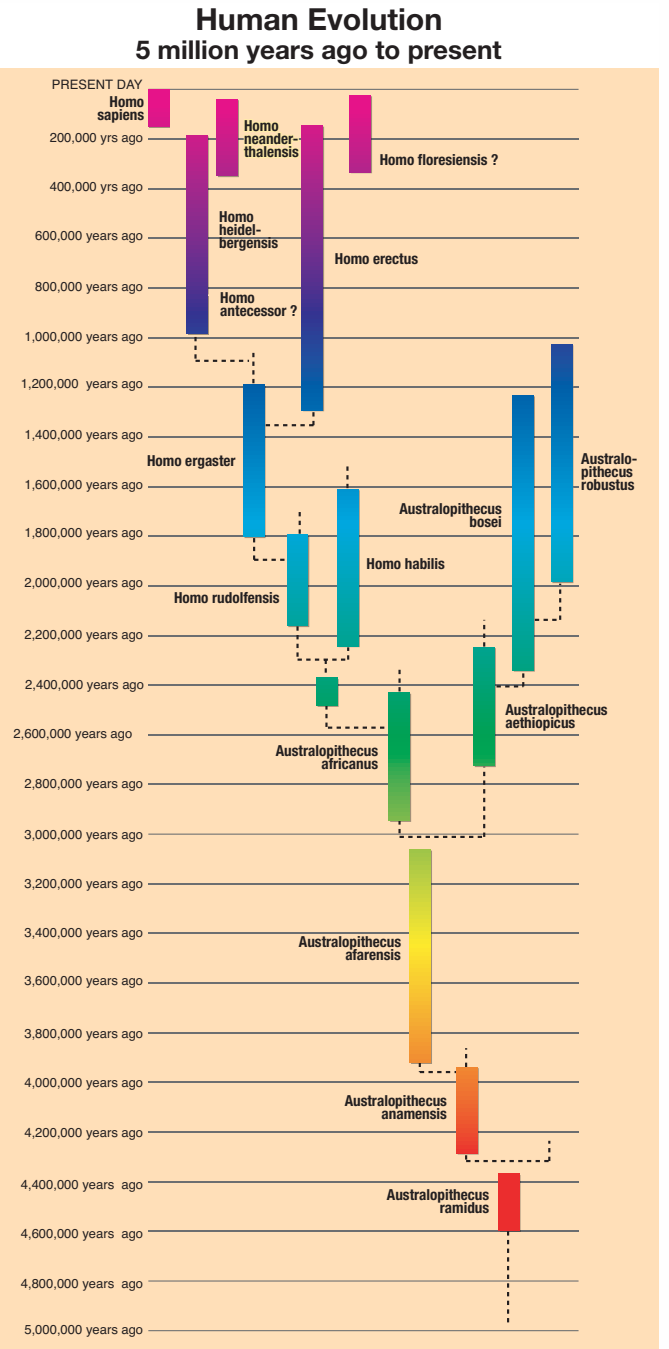
Scientists call the earliest humans *hominids*. One hominid was the ancestor of modern humans and Neanderthals. Primates are the order of mammals that includes humans, gorillas, chimpanzees, orangutans, and monkeys. Hominids and chimpanzees shared a common ancestor that lived about 6 million years ago. Long before that, about 65 million years ago, the earliest primates appeared. They lived in trees and were similar to the modern shrew, a tiny animal like a mouse, only smaller.

Scientists believe modern humans—that's us, *Homo sapiens*—first appeared about 195,000 years ago. At that time, another type of human, *Homo neanderthalensis*, also lived on Earth. The earliest Neanderthal fossils are 230,000 years old and were found in the Neanderthal, a valley in Germany. Neanderthals disappeared 30,000 years ago.

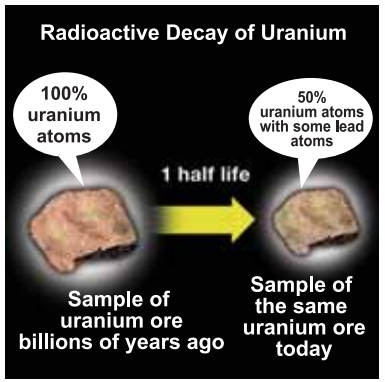
Now, Flores man makes it seem that yet another type of human was around for at least 17,000 more years. Archaeologists and anthropologists and many other scientists will study the Flores fossils. It may be years before they agree on where *H. floresiensis* should be placed on the human "family tree."

Questions:

1. How do archaeologists know that Flores man was a hunter?
2. Why might their home on an island have made Flores man small?
3. Why was the discovery of Flores man important? What effect did the discovery have on scientific understanding of human history?
4. How are modern humans and Neanderthals related?



CHAPTER ACTIVITY Radioactivity and Half-life



Scientists use absolute dating to estimate the age of a fossil in years. Absolute dating uses the decay of radioactive elements as a natural "clock." Uranium-238 decays naturally to lead-206 which is not radioactive. The time for half of the atoms in a sample of uranium-238 to perform this entire nuclear decay process takes about 4.5 billion years! In other words, the half-life of uranium-238 is 4.5 billion years. In this Investigation, you will simulate the radioactive decay of a fictional element.

What you will do

Your teacher has given you a can of pennies to represent the atoms of a sample of a fictional, radioactive element. To simulate the process of radioactive decay follow the steps below.

1. Make a data table in your notebook like the one shown at the left.
2. Shake your can of pennies and spill them out onto a tray or table.
3. Remove all pennies that are "heads" up and count them.
4. Record these as decayed atoms in your data table.
5. Put the rest of the pennies back into the can, shake them again.
6. Spill them out onto the tray or table, and again, remove and count the "heads."
7. Repeat this process until you have no more pennies left.
8. If necessary, add extra rows to your table.

Number of decayed atoms in each trial

sample number	number of decayed atoms	sample number	number of decayed atoms
1		8	
2		9	
3		10	
4		11	
5		12	
6		13	
7		14	

Questions

a. Graph your data for number of decayed atoms per sample vs. sample number. Sample number will be on the *x*-axis, and number of decayed atoms will be on the *y*-axis. Label the axes clearly. Be sure to provide a title for the graph. Be sure to use the entire graph in plotting your data.

b. Write a paragraph that describes what your graph looks like.

c. What part of this simulation represents the half-life of this new element? Explain your answer.

d. If the half-life of your element was 430 years and you had 2000 atoms of this element, how long would it take for the element to undergo complete radioactive decay to a stable isotope? What year would it be when the element finished decaying? Note: As you work through this problem, round the number of atoms left to a whole number. For example, round 62.5 to 63.

Chapter 12 Assessment

Vocabulary

Select the correct term to complete the sentences.

rock cycle	lithospheric plates	absolute dating
geologic time scale	paleontologists	pangaea
half-life	superposition	relative dating
geology	plate tectonics	uniformitarianism
mass extinctions		

Section 12.1

1. Understanding volcanoes, dinosaurs, earthquakes, rock cycles, and other Earth systems and the processes that act upon it is the study of _____.
2. Sedimentary, igneous, and metamorphic rocks are created, altered, and worn down in a process called the _____.
3. Estimating the age of fossils and rock layers from the arrangement of sedimentary layers is the principle of _____.
4. Before radioactive decay was understood, geologists were limited to _____ techniques to sequence geologic and prehistoric events.
5. Uncovering fossils in rock layers and conducting laboratory techniques that date specimens help _____ uncover the history of life on Earth.

Section 12.2

6. Using the present as keys to the past is consistent with the idea of _____.
7. Approximately 254 million years ago all major continents were fused into a massive landmass called _____.
8. _____ explains the changes and movement of lithospheric plates.
9. As _____ move slowly across the Earth's surface they sometimes collide and create huge mountain ranges.

Section 12.3

10. Earth's history is divided into eras and periods known as the _____.
11. Believed to have occurred at least five times in Earth's history, _____ seem to be a natural evolutionary process.
12. By comparing the amount of radioactive decay in a sample, _____ makes it possible to estimate the age of rock samples in years.
13. The _____ of radioactive isotope Potassium-40 is 1.3 billion years therefore it takes 1.3 billion years for half of its atoms to break down into argon-40.

Concepts

Section 12.1

1. The idea that sediments deposit and cover dead organisms in lakebeds, which eventually leads to fossilization, was introduced by
   a. Nicholas Steno
   b. Charles Darwin
   c. Alfred Wallace
   d. Alfred Wegener
2. Distinguish between the two terms: Superposition: Sedimentation
3. All of the following are used in relative dating except
   a. Superposition
   b. The fossil record
   c. Crosscutting and inclusions
   d. Radioactive Carbon-14 dating

4. Canyons and gorges are carved out of existing landmasses. The surrounding rock walls tell stories of the area's past history. What type of information can be revealed in canyon walls?

5. Describe in your own words the processes involved in the rock cycle.

6. Although sediments are deposited in even continuous layers, some sedimentary rocks exists in curved and interrupted forms. Explain two major reasons why this happens.

Section 12.2

7. The *coelacanth* is "living fossil" first caught off the coast of South Africa in 1939. Prior to this, it was believed to have lived 360 years ago and then suddenly become extinct approximately 70 million years ago. How can paleontologists use the coelacanth to understand life on Earth at the time of the dinosaurs?

8. How might the collision of two lithospheric plates contribute to the evolution of a species?

9. The movement of lithospheric plates helps explain all of the following except
   a. the distribution of fossils and living animals around the world.
   b. the occurrence of earthquakes and volcanic activity.
   c. the amount of solar radiation emitted from the sun.
   d. evidence of fossilized sea creatures found on high mountain ranges.

10. Australia is a unique continent with thriving marsupial populations like kangaroos. North America however has a thriving placental mammal population but only one known marsupial, the opossum. How might this be explained given what you know about plate tectonics?

11. The continents were once joined in a massive supercontinent called Pangaea and have slowly drifted over time. Which of the following statements does not support this idea?
   a. Fossils of the same species have been found on several different continents.
   b. Evidence from a meter impact broke apart the continent.
   c. Matching geological features such as mountain ranges and coal beds are distributed systematically across oceans.
   d. The shapes of today's continents fit together like a puzzle.

Section 12.3

12. Which of the following matches the geologic era with the correct historical event.
   a. Paleozoic- flowering plants and birds first appear.
   b. Cenozoic- evidence of the first human ancestors emerges.
   c. Mesozoic- fish with backbones appear.
   d. Precambrian- mammals became the dominant life form on land.

13. Why are the units of geologic eras not divided into equal time spans? What is the basis of division and how long did each era last? Provide an example.

14. After a mass extinction, species who survive
   a. Usually do not adapt to the new environmental conditions.
   b. Are usually only mammals.
   c. Frequently cannot survive and also become extinct.
   d. Often branch out into highly adapted species suited for the new environment.

15. Many theories exist about what caused the major mass extinctions throughout Earth's history. How might major changes in global temperature, sea level and atmospheric composition explain mass extinctions and the emergence of new life forms following such events?

16. Absolute dating
    a. Predicts the approximate age based upon position in sedimentary layers of rock.
    b. Can only be used to date animals and not other life such as plants and bacteria.
    c. Estimates the age of a fossil by measuring the decay of radioactive elements within the fossil.

Math and Writing Skills

1. Absolute dating using radioactive isotope Potassium-40 is used to date rocks millions of years old. The half life of Potassium-40 is 1.3 billion years. If sample of rock containing about 16g of radioactive Potassium-40 when it was formed now contains 4g of Potassium-40, how old is the rock?

2. What percentage of Carbon-14 will remain after 3 half lives?

3. If the amount of radioactive Carbon-14 left in a fossil indicates that the sample has decayed 85 half-lives, in what geologic time period did the organism live?

Chapter Project

Making a scaled timeline

A timeline is a visualization of a sequence of events. A scaled timeline is helpful when learning about historical events, because it gives you an idea of how much time it took for different events to occur. For example, how much time went by between the age of dinosaurs and when humans first appear in the fossil record? Reading the numbers of millions of years is one way to answer the question, but it is easier to visualize this amount of time if you can see it pictured on a relative time scale. For this project, you will construct your own scaled timeline of important events in the history of our changing Earth. You will need a roll of adding machine tape, colored pencils or markers, and a measuring tape. To make the timeline, follow these steps:

1. Measure out 20 feet of adding machine tape. Every inch equals 19 million years; every foot equals 230 million years
2. Using the scale described in step 1, place each event in the correct spot on the timeline. Use words and a sketch to represent each event on the timeline.
3. Use a lightly colored pencil to shade in the correct areas of the timeline that correspond to the Precambrian, Paleozoic, Mesozoic, and Cenozoic eras.
4. Stretch out the entire timeline and reflect on what this shows you about Earth's history.

Event	MYA
Human recorded history (5,000 yrs)	0.005
Earliest humans (Cro-Magnon)	0.1
Hominids (ancestors of humans)	3
Extinction of the Dinosaurs	66
First flowering plants	144
First mammals	200
First dinosaurs	230
Mass extinctions occurred	245
Forests that formed fossil fuels (coal and oil)	300
First vertebrates (fish)	400
Seedless land plants become common	400
First animals	600
First multicellular organisms	650
First eukaryotes	1500
Oldest fossils	3600
Formation of the earth	4600

Structure and Function in Living Things

Chapter 13 *The Diversity of Life*

Chapter 14 *Plants*

Chapter 15 *Animals*

TRY THIS AT HOME

Look at the illustration above. How many different species can you identify? Can you give their common names? What part of the world might you find these organisms?

Choose one of the organisms from the illustration and write about its habitat, adaptations, and life cycle.

Chapter 13

The Diversity of Life

Peter Rabbit is a storybook character that was created by Beatrix Potter, who lived in England from 1866 to 1943. Although best known for her children's book The Tale of Peter Rabbit, Beatrix Potter also spent part of her life studying a life form called lichens. You might have seen flat, textured, light green lichens growing on top of a rock or on a rotting log. Beatrix Potter theorized that a lichen is composed of a special relationship between two different life forms: an algae and a fungus. Decades later, scientists discovered that Potter was exactly right about her theory on lichens. Read this chapter to learn more about lichens and other members of Kingdom Protista and Kingdom Fungi.

Key Questions

1. ***What is a scientific name like Felis domesticus used for, and what does it mean?***
2. ***What living things are included in Kingdom Protista and Kingdom Fungi?***
3. ***What are algae and fungi, and how do they reproduce?***

13.1 Taxonomy and Systematics

In Chapter 2, you learned that all living things are classified into one of six kingdoms. Kingdoms are divided into smaller and smaller levels until you narrow an organism down to the level of species (Figure 13.1). In this section, you will learn how scientists classify organisms according to their characteristics and evolutionary relationships. This process is called *systematics*.

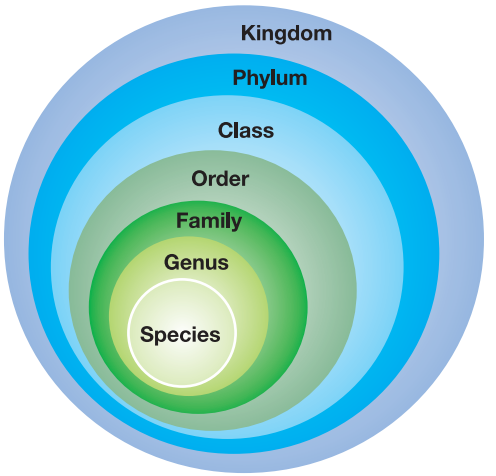
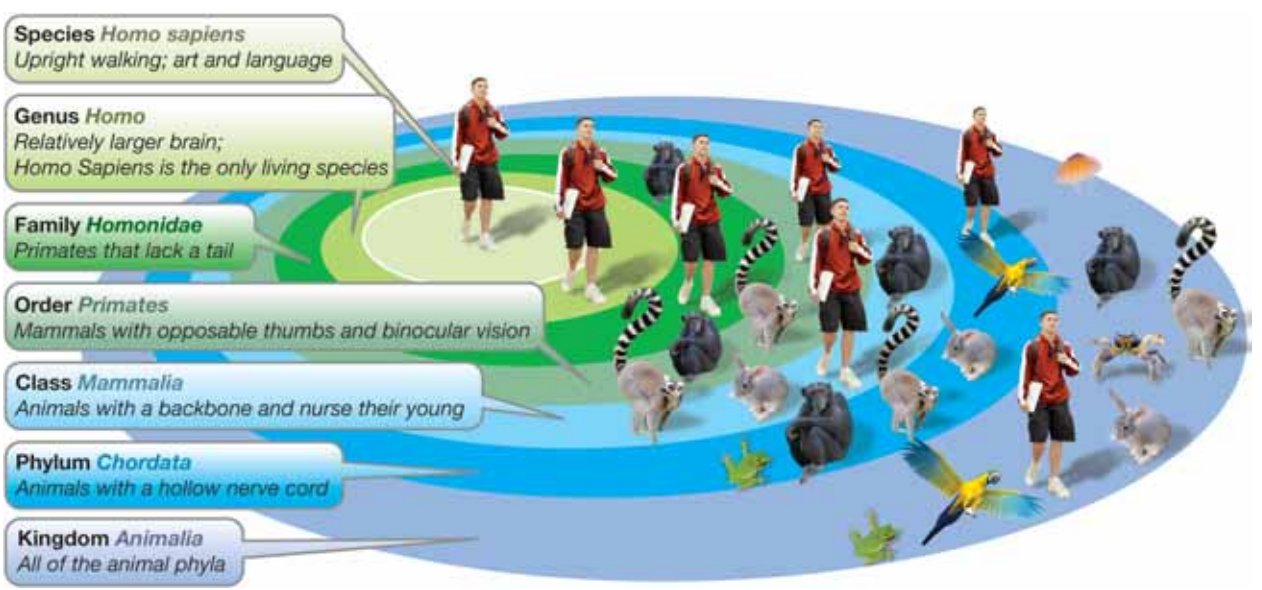


Figure 13.1: *The seven levels of classification of the Kingdom Animalia.*

Taxonomy revisited

Carolus Linnaeus A Swedish scientist and explorer named Carolus Linnaeus (1707–1778) developed a system of classification called *taxonomy* in the 1700s. Linnaeus classified living things according to their shared characteristics. He was able to study and classify over 7,000 species using his system. Recall that there are seven levels of classification. The diagram below shows how taxonomy is used to classify the human species.



STUDY SKILLS

A mnemonic to help you remember the levels of classification is:

King **P**hilip **C**ame **O**ver **F**rom **G**reater **S**cotland

Invent your own mnemonic for remembering the levels of classification for the Kingdom Animalia.

Scientific names

What is a scientific name?

Have you ever heard of an animal called a *Felis domesticus*? Sure you have, it's a house cat! When organisms are classified, scientists assign them a scientific name. A **scientific name** is the two-part, scientifically recognized name given to an organism, consisting of its genus and species. Scientific names are internationally recognized names given to organisms based on the system developed by Carolus Linnaeus.

Where do scientific names come from?

The first person to describe a new species gives it a scientific name. If the species belongs to an established genus, then the first part of the name is not new. If the organism cannot be placed into an existing genus, a new genus name must be given. Genus names are usually nouns. Species names are usually adjectives. There are many different sources for the species name including appearance, behavior, habitat, location where it was found, or the name of the person who discovered it.

The meaning of scientific names

You may have a difficult time understanding scientific names because they are usually in Latin or Greek. However, scientific names do have meanings. In our cat example (Figure 13.2), *Felis* is Latin for "cat" and *domesticus* is Latin for "domesticated." The scientific name is usually printed in italics, with the genus capitalized. A scientific name is incomplete without both the genus and species names.

The importance of scientific names

There are many different languages in the world. For example, a house cat is called a *gato* in Mexico. Different common names could cause confusion among scientists from around the world. Therefore, all scientists refer to each species by its scientific name. All known living things have a two-part scientific name. Do you know your scientific name? It's *Homo sapiens*!

VOCABULARY

scientific name - the two-part, scientifically recognized name given to an organism, consisting of its genus and species.

Figure 13.2: *The scientific name for the house cat.*

What is systematics?

Defining systematics

Darwin's theory of evolution led to the development of systematics. **Systematics** is the process of classifying living things according to evolutionary relationships. Systematics is based on shared, derived characteristics. *Derived* means that the characteristics evolved from a common ancestor.

Systematics and classification

Systematics is used to classify organisms and to show how they are related by evolution. For example, humans, chimpanzees, baboons, and lemurs are classified together in the order *primates*. Primates have binocular vision and opposable thumbs. *Binocular* refers to vision in which both eyes are used together. *Opposable* means the thumb can touch the tips of all of the other fingers. All four organisms are thought to have evolved from a common ancestor with similar characteristics.

Cladograms

The evolutionary development of primates can be shown on a simple *cladogram* (Figure 13.3). The characteristics listed along the right distinguish the levels above each *node* (the point where two branches meet). The nodes indicate a common ancestor between two groups. As you move up the diagram, organisms are separated into more specific groups. Following the diagram down to the root points to a common ancestor for all of the organisms.

DNA analysis

Today, scientists may use DNA analysis to classify living species. By comparing the DNA base sequences of different species, scientists can tell how closely related the species are. Then they can accurately classify them. For example, skunks were once thought to part of the weasel family which includes weasels, ferrets, and minks. All have a "musky" odor. By comparing their DNA though, scientists have determined that skunks are very different from other members of the weasel family and they have created a new family especially for skunks!

VOCABULARY

systematics - the process of classifying living things according to evolutionary relationships.

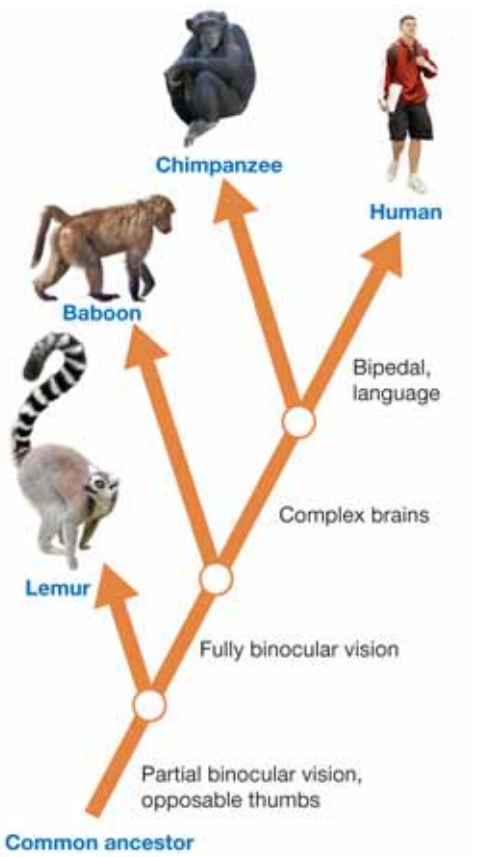
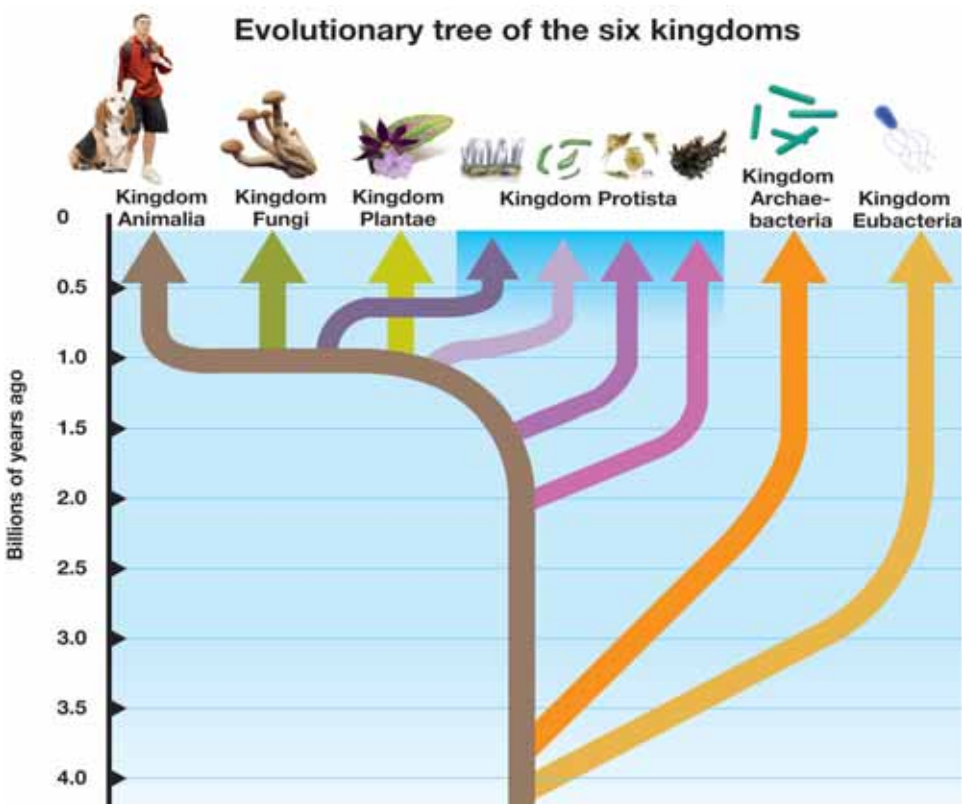


Figure 13.3: *A cladogram shows evolutionary relationships among different organisms.*

Evolution and the six kingdoms

An **evolutionary tree** is a diagram with many branches that shows evolutionary relationships among organisms, both living and extinct. The root of the diagram represents a common ancestor of all organisms. The point between each branch represents a common ancestor between branching groups. The diagram below is an evolutionary tree that shows the relationships among the six kingdoms. In a complete evolutionary tree, the levels of classification (phylum, class, order, etc.) would branch off from each kingdom all the way down to the species level.



VOCABULARY

evolutionary tree - a diagram with many branches that shows evolutionary relationships among organisms, both living and extinct.

STUDY SKILLS

In this unit, you will study the kingdoms that consist of multicellular organisms. The kingdoms and chapters where they will be studied are:

Kingdom Fungi - Chapter 13

Kingdom Plantae - Chapter 14

Kingdom Animalia - Chapter 15

Recall that you studied single-celled organisms in Chapter 7. These include the kingdoms of bacteria (Archaebacteria and Eubacteria) and protozoans—single-celled members of the Kingdom Protista).

Make a set of Kingdom Flashcards to aid in your studies. Place the kingdom on the front of the card. List the characteristics of the kingdom and some examples on the other side.

13.1 Section Review

1. Who was Carolus Linnaeus and what contribution did he make to the study of living things?
2. List the following terms in order of least-specific level to most-specific level.:

genus	order
kingdom	family
class	phylum
species	

3. Which of the following resembles a correctly written scientific name?
   a. *felis Domesticus*
   b. Felis
   c. Felis domesticus
   d. *Felis domesticus*
4. How are systematics and taxonomy similar? How are they different?
5. Use the cladogram in Figure 13.4 to answer the following questions.
   a. Which organisms have fur and nurse their young?
   b. Which organisms are air-breathing and live on land?
   c. Which organism is the most closely related to the mouse?
6. Study the diagram on page 265, then answer the questions below.
   a. Which evolved first, plants or fungi?
   b. Which group of organisms evolved just after bacteria?
   c. CHALLENGE! Why does Kingdom Protista have four branches?

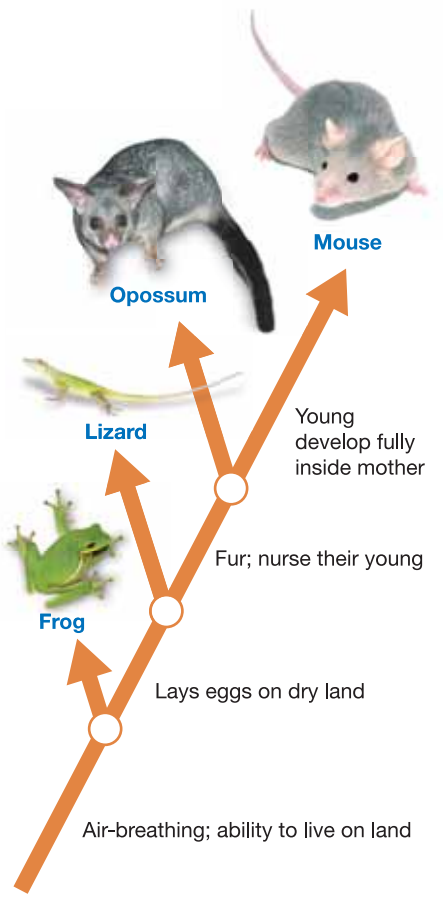


Figure 13.4: *Use this diagram to answer question 5.*

13.2 Algae and Fungi

In Chapter 7, you studied microscopic, single-celled organisms. These are the simplest organisms on Earth. In this unit, you will study the structure and function of *multicellular* organisms which are made of more than one cell. Plant-like algae are simple multicellular organisms. Algae can produce their own food and belong to the Kingdom Protista. The Kingdom Fungi consists of simple multicellular organisms that cannot produce their own food. In this section, you will learn about the structure and function of algae and fungi.

The evolution of sexual reproduction

An increase in the variety of life

Recall that the first prokaryotic cells appeared about 3 billion years ago. About 1 billion years ago, the first eukaryotic cells appeared. Then, rapid evolution produced the diverse life forms of protists, fungi, plants, and animals. What caused the rapid evolution that led to the diversity of life as we know it? The answer is that eukaryotic cells evolved the ability to reproduce sexually.

The importance of sexual reproduction

Prokaryotic cells reproduce asexually by splitting in two. Asexual reproduction does not allow for genetic variation unless a mutation occurs. Organisms that reproduce sexually produce more genetic variation among their offspring. You may recall that chromosomes become separated during meiosis and end up in different sex cells. During fertilization, the sex cells from each parent unite (Figure 13.5). These processes increase genetic variation. Genetic variation must be present for natural selection to occur. For that reason, once sexual reproduction evolved, new species began to evolve. This gave rise to multicellular organisms and eventually, the astounding diversity of life.

Sexual reproduction increases genetic variation and leads to new species.

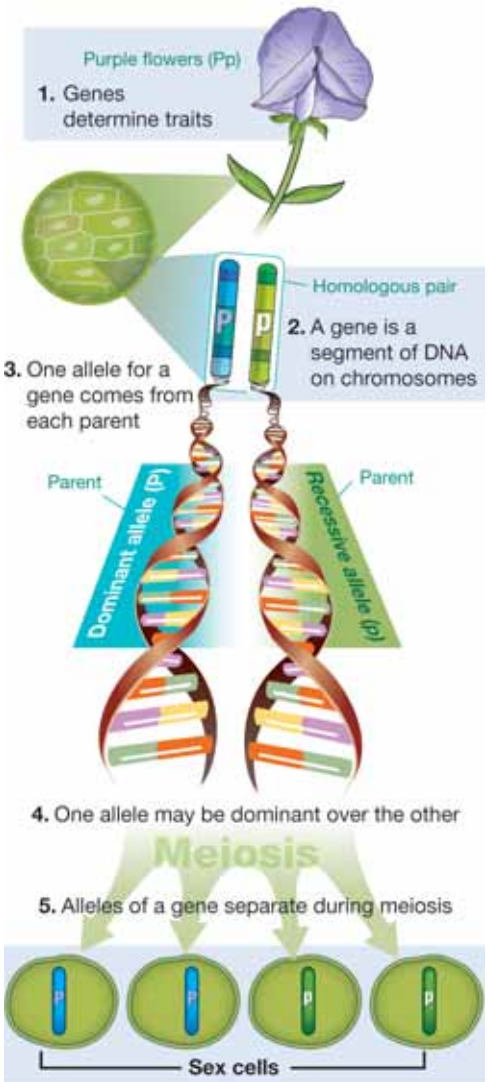


Figure 13.5: *The process of sexual reproduction increases genetic variation and leads to more new species.*

Algae

What are algae?

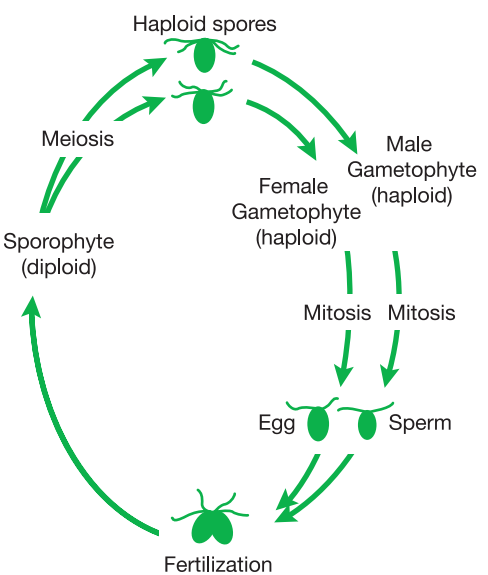
The Kingdom Protista, often called *protists*, contains many groups that evolved separately. For that reason, many scientists think that protists should be classified into several smaller kingdoms. **Algae** are photosynthetic protists that are plant-like in many ways. Scientists have classified about 30,000 species of algae in ocean and freshwater environments. These include single-celled species like diatoms and multicellular species like sea lettuce (*Ulva*) shown in Figure 13.6 and red algae.

Kelp structure and function

Kelp is a good example of multicellular algae. Figure 13.7 shows how kelp is adapted to life in regions where the tide washes in and out. The *holdfast* anchors it to the rock. The *air bladders* allow it to float. The *stipe* and *fronds* are flexible allowing it to bend with the waves. The presence of the brown pigment *fucoxanthin* allows the absorption of wavelengths of light that penetrate the water.

Sexual reproduction in algae

Some multicellular algae, such as *Ulva*, follow a pattern of reproduction called *alternation of generations*. Two forms of the algae alternate between diploid and haploid individuals. The haploid form, called a *gametophyte*, produces haploid sex cells. Sex cells unite to form a zygote. The zygote develops into the diploid form called a *sporophyte*. The sporophyte undergoes meiosis to form haploid spores that, in turn, form gametophytes.



VOCABULARY

algae - photosynthetic protists that are plant-like in many ways.

Figure 13.6: *Sea lettuce.*

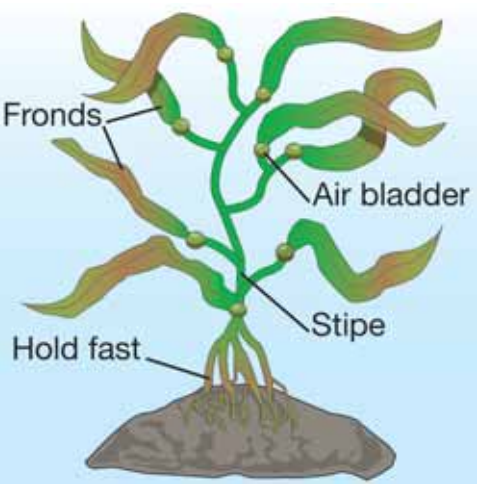


Figure 13.7: *The structures of kelp are adaptations to living in tidal areas.*

What are fungi?

Characteristics of fungi

Mushrooms, molds, and yeasts are examples of organisms in the Kingdom Fungi. Originally classified as plants, **fungi** (singular, *fungus*) do not make their own food. Nor do they have many animal-like characteristics. All fungi are made of eukaryotic cells that have cell walls made of *chitin*, a complex carbohydrate found in insects. Fungi range in form from a single-celled yeast to the multicellular honey mushroom that may reach the size of many football fields! Some types of fungi are shown in Figure 13.8.

How fungi get their food

Fungi do not eat their food as animals do. Instead, they release digestive enzymes into their surroundings. The enzymes break down organic material and the fungi absorb the nutrients directly into their cells. Some fungi get their food by digesting the dead remains of other organisms. Others are parasites that live on plants or animals, causing them harm. Athlete's foot, for example, is caused by a fungus.

Lichens

Some fungi live in symbiotic relationships with algae, bacteria, or plants. In those relationships, both the fungi and the other organism benefit. A good example is lichens. You may be familiar with lichens if you like to walk in the woods. Lichens are made of two organisms—a fungus, and a green algae or cyanobacteria. The algae carry out photosynthesis and provide the fungus with food. The fungus provides the algae with water and minerals it absorbs from the surface on which it lives.

VOCABULARY

fungi - organisms that make up the Kingdom Fungi, including yeasts, molds, and mushrooms, consisting of eukaryotic cells with cell walls made of chitin.

Figure 13.8: *Representatives of the Kingdom Fungi.*

Fungi structure and reproduction

Fungi structures

Figure 13.9 shows the structure of a typical fungus. All fungi are made up of thread-like filaments called **hyphae**. The cells that make up the hyphae sometimes contain two, three, or even more nuclei. In the fungi you are familiar with, the hyphae grow into whatever the fungus is feeding on—like a rotting log. The hyphae form a cottony mass of threads called a *mycelium*. The mycelium grows throughout the food source and releases digestive enzymes. The enzymes break down larger compounds into smaller molecules that can be absorbed into the cells of the fungus. Under the right conditions, part of the mycelium organizes and forms the fruiting body. The *fruiting body* is the part of a fungus that you would call a mushroom.

Asexual reproduction in fungi

Fungi can reproduce both sexually and asexually. Asexual reproduction occurs by the production of spores. A **spore** is a small, usually single-celled reproductive body that is capable of growing into a new organism. In a mushroom, spores are produced by the fruiting body within the gills (Figure 13.9). The spores are very light and are carried by the wind. If they land in suitable places, they grow into hyphae again. In another form of asexual reproduction, fragments of the hyphae can also grow into a new organism.

Sexual reproduction in fungi

To introduce genetic variation into the population, most fungi have a form of sexual reproduction. It involves two "mating types" of the organism. When the hyphae of opposite mating types meet, they fuse together. The nuclei of the mating types then fuse and immediately undergo meiosis. As a result, tiny haploid spores are formed.

VOCABULARY

hyphae - the thread-like filaments that make up a fungus.

spore - a small, usually single-celled reproductive body that is capable of growing into a new organism.

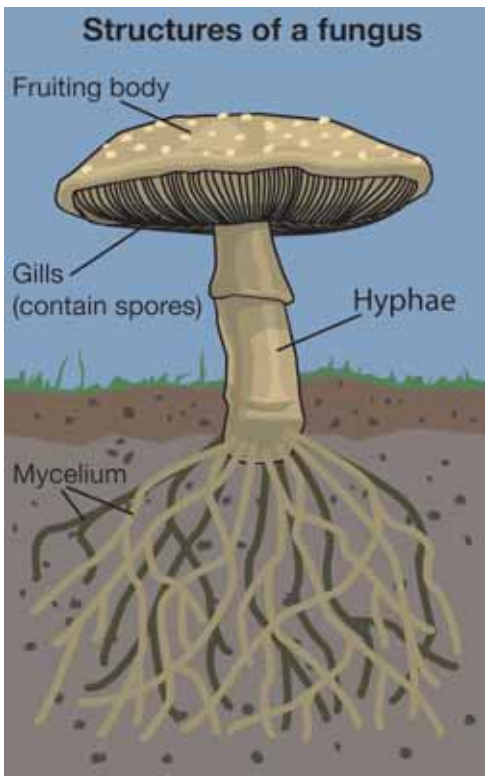


Figure 13.9: *The structures of a typical fungus.*

13.2 Section Review

1. Explain why the evolution of sexual reproduction led to the diversity of life on Earth.
2. Why do some scientists think the Kingdom Protista should be divided into several smaller kingdoms?
3. All of the following are characteristics of algae except:
   a. Algae have eukaryotic cells.
   b. Algae use the process of photosynthesis.
   c. Algae are single-celled and animal-like.
   d. Algae are multicellular and some are single-celled.
4. Describe how *Fucus* is adapted to living in tidal areas of the ocean.
5. Explain, using the terms *diploid* and *haploid*, what is meant by the term alternation of generations.
6. All of the following are characteristics of fungi except:
   a. Fungi are multicellular.
   b. Fungi have eukaryotic cells that contain chlorophyll.
   c. Fungi have cell walls made of chitin.
   d. Fungi are made up of filaments called hyphae.
7. Explain the function of each structure of a fungus:
   a. hyphae
   b. mycelium
   c. fruiting body
8. What is a spore? How do fungi reproduce using spores?

Many vocabulary terms from previous chapters were used in this chapter. In your journal, make a three-column table. In the first column write the words below. In the second column, write down the definition for each word from the chapter it was introduced. In the third column, write down how the term applies in this chapter.

Previous vocabulary terms:

asexual reproduction

sexual reproduction

meiosis

sex cells

genetic variation

haploid

diploid

symbiosis

parasite

ECOLOGY CONNECTION

Restoring Natural Ecosystems Is Not Easy

What if your bike got so damaged that you could no longer ride it? You would at least try to restore it to working condition. You might hope to do the same if you got a terrible haircut, or burned your fingers badly - you would try to restore them. People are trying to accomplish that with wetlands. These ecosystems have been damaged or destroyed and now we are trying to restore them.

Wetland ecosystems are always wet and near a water source. Water floods into the area and there is little or no drainage; water always remains. Freshwater wetlands are found at the edges of lakes and rivers. Saltwater wetlands are found in coastal areas on the oceans.

Wetlands usually have slow-moving or standing water. They also have soil. Wetlands are not true bodies of water, but are not considered dry land. For example, swamps and marshes are wetlands. In their natural state, wetlands serve crucial purposes, including:

- Reducing erosion.
- Protecting against floods.
- Improving water quality.
- Providing habitat for wildlife.

Wetlands reduce erosion by slowing water flow. When flowing water enters a wetland area, it meets resistance. This slows the flow. Slower water has less force and picks up and carries away less soil. Slower water also means a smaller volume of water at any one time. This means less flooding. Wetlands can act as a buffer between a water source and dry land.

Wetlands absorb sediments. In slow-moving water, sediments sink. So wetlands act as a filter, thereby improving the quality of the water.

Finally, wetlands provide homes and food for wildlife. Many species of plants, birds, amphibians, fish, and insects depend on wetland areas.

California's wetlands are almost gone

In California, more than 90 percent of the natural wetlands are gone from the coast. Inland wetlands also have been destroyed, with only patches remaining.

Those inland wetlands have been drained, some for farming, some to create landfills, some for mining. All of that has meant big changes for wetland ecosystems.

The San Francisco area once had many tidal wetlands, one of them on the southern part of San Francisco Bay. The water there is naturally salty, and since the 1860s, these wetlands were used to produce salt. The process involved making levees to block the tides. Ponds were formed and then were partially drained. This process was repeated over and over until finally the salt was concentrated and could be removed.

This salt-mining process had a big impact on local ecosystems.

We know now that even a small change in an environment can cause great harm. When the South Bay wetlands were turned into salt mines, the natural balance was upset. Animals that depended on the wetlands were threatened. Benefits to humans were lost, too, because the wetlands had helped to protect water quality and prevent flooding.

Restoration will take time

People became aware of these problems in the 1960s. Some people thought the salt mining should be stopped and the wetlands restored to their natural state. Others were against the idea. Finally, in 2002, the state announced a coastal restoration project for the San Francisco Bay Area.

But restoring an ecosystem is complicated business. The planning alone was expected to take five years, and the restoration between 10 and 30 years. At the end of the project, it is expected that water quality will be improved, endangered animals will find safe habitats, and commercial fishing will reap benefits, too.

A cautious approach

Just the same, some scientists advise caution. Levees will be removed when the wetlands are restored, which will allow tides to flow naturally. That will change the salt ponds that formed when the tides were blocked. The ponds will adjust to support a new ecological balance. The resulting ecosystem may not be purely "natural," but it supports many migrating birds.

Restoring natural ecosystems is complicated and difficult. Many things have to be considered. California's current plan is to restore some of the natural wetlands and preserve some of the salt ponds as they are.

When people try to reshape or control or repress natural forces, problems usually occur - some of them completely unexpected. For example, consider what has resulted from our putting out forest fires. Fires are a natural part of a forest's life cycle and, years ago, most of the fires were small. A portion of a forest would burn, but it would grow back over time. Often, fire would sweep through a forest, and many trees would survive.

Then people began to control the fires. With what unexpected result? There are more fires now and the fires are bigger. Uncontrolled fires used to clean out dry and dead plant material. Now, when people put fires out, that material does not get cleared away. It provides fuel for much hotter fires - which, in turn, can kill all the trees in a forest.

Like the restoration of wetlands, the problem of forest fire management will be solved only over a long time.

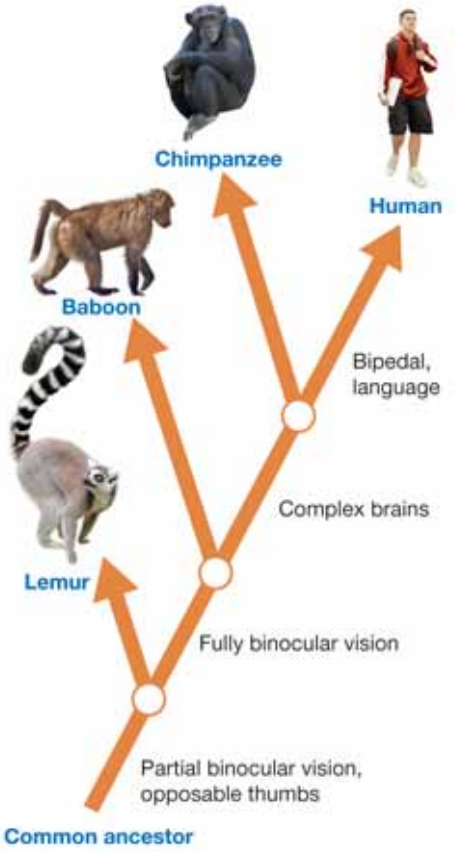
Questions:

1. What are some of the functions of natural wetlands?
2. Why have much of California's natural wetlands been lost?
3. What is one of the possible problems with restoring the San Francisco Bay Area wetlands?
4. What has resulted from decades of preventing natural forest fires?

CHAPTER ACTIVITY

How to Make a Simple Cladogram

A cladogram shows evolutionary relationships among groups of organisms. Shared characteristics are listed below each node (the point where two branches meet). Each node indicates a common ancestor from which different organisms branched. As you move up the diagram, organisms share fewer and fewer characteristics.



In this activity, you will use fruit to learn how to make a simple cladogram. Your cladogram will not show evolutionary relationships among the fruit. Instead, it will simply compare the observable characteristics of the fruit. For this activity, you will need a nectarine, kiwi, grapefruit, apple, lime or pictures of the fruit.

What you will do

1. Make tables like the ones shown to the right in your notebook.
2. Examine the fruit. Next to each characteristic in Table 1, list the fruit or fruits to which it applies.

Table 1: Fruit characteristics

Characteristic	Fruits to which it applies
has a skin	
smooth skin - not fuzzy	
segments inside	
green skin	
multiple or no seeds inside	

3. Now fill in Table 2 below:

Table 2: Fruit data

Fruit	Number of times it appears in Table 1
kiwi	
nectarine	
grapefruit	
lime	
apple	

4. Use the characteristics in Table 1 and the values in Table 2 to help you draw a cladogram for the fruit. Each fruit can only be used once in your cladogram.

Applying your knowledge

a. Which fruit has all of the characteristics? Which fruit has only one characteristic?

b. Give examples of three other characteristics that could have been used for your cladogram. Would your cladogram look different if other characteristics were chosen?

c. Draw a cladogram using the following organisms: *paramecium*, *algae*, *mushroom*, *redwood tree*, and *cat*. You may need to review previous chapters of this text for more information.

Chapter 13 Assessment

Vocabulary

Select the correct term to complete the sentences.

algae	spore	fungi
scientific name	systematics	hyphae
evolutionary tree		

Section 13.1

1. _____ is used to classify organisms and to show how they are related by evolution.
2. Carolus Linnaeus developed the system of using an organism's _____, or Genus species, to avoid confusion in communication.
3. A diagram that shows evolutionary relationships among living and extinct organisms is called (an) _____.

Section 13.2

4. Asexual reproduction in fungus occurs by the production of _____.
5. _____ are photosynthetic protists that share many characteristics with plants.
6. Mushrooms, molds, and yeast are all examples of _____.
7. _____ are threadlike filaments that absorb nutrients from whatever the fungus is feeding on.

Concepts

Section 13.1

1. If two organisms belong to the same family, what other taxonomic levels must those two organisms also share?
2. Which two of these organisms are most closely related?
   a. Buteo jamaicanensis
   b. Lagopus lagopus
   c. Buteo lagopus
   d. Laterallus jamaicensis
3. Sometimes scientific names are given for the scientist that discovered the organism. Name four other sources for scientific names.
4. List three reasons that you can tell that *Ursus maritimus* is a scientific name.
5. Explain how DNA analysis has changed the classification of skunks.
6. What is found at the root of an evolutionary tree?

Section 13.2

7. Which type of reproduction leads to greater genetic diversity: sexual reproduction or asexual reproduction? Why?
8. Describe how algae are similar to plants.
9. True or false: The pattern of reproduction called alteration of generations includes both sexual and asexual reproductive stages.
10. How would you classify a single celled, eukaryotic organism that performs photosynthesis and does not move?
11. The algae and the fungus that comprise lichen are an example of which of the three types of symbiosis?
    a. parasitism
    b. commensalism
    c. mutualism
12. Infer why gills (where the spores are produced) are located on the underside of the mushroom cap. Why do you think that fungi produce millions of spores?

Math and Writing Skills

Section 13.1

1. Use the greater than (>) or less than (<) symbol to complete these comparisons about taxonomic levels.
   a. genus _____ phylum
   b. class _____ family
   c. # of kingdoms _____ # of species
   d. # of orders _____ # of classes
   e. # of organisms in a phylum _____ # of organisms in a family
2. There are approximately 270 members of the order Carnivora, which includes a variety of organisms like bats, seals, cats, and bears. There are only 4 species of bears in the genus Ursus. What percent of the order Carnivora does the genus Ursus represent?
3. Common names often give misinformation about an organism like the names "koala bear", "jellyfish", and "horseshoe crab". Using these examples as well as your own examples and reasons, write a persuasive paragraph about the importance of using scientific names.

Section 13.2

4. Choose one type of algae. Describe a day in the life of the algae that you have chosen.
5. A family buys two loaves of bread at the grocery store on the same day. One loaf is served with dinner that night, while the other loaf stays in the refrigerator unopened. The remaining slices of the loaf served at dinner are put back in the refrigerator. A week later, one of the loaves of bread has mold growing on it. Which loaf is moldy - the dinner loaf or the unopened loaf? Explain your prediction.
6. A fairy toadstool ring is a type of underground fungus that produces mushrooms in a circle at the outer edge. This fungus got it's name because it appeared to many people that magical fairies made a ring of mushrooms overnight. A particular fairy toadstool ring grows in diameter by 3 meters each year. How many years old is this fairy toadstool ring if it has a diameter of 180 meters?
7. One giant puffball mushroom produces 7,000,000,000 spores, but for various reasons, only 25% survive. How many giant puffball spores will grow into new mushrooms at this survival rate?

Chapter Project

Studying yeast

Yeast is a member of Kingdom Fungi. *Saccharomyces cerevisiae*, called baker's yeast, is a fungi often used by cooks and bakers to make breads and other foods "rise". For this project, you will experiment with some baker's yeast and find out why it is such an important ingredient in bread recipes. You will need: 1 packet of active dry yeast; 1 cup very warm water; 2 tablespoons sugar; balloon; an empty water bottle. Follow the procedures:

1. Stretch out your balloon - blow it up several times and then put it aside.
2. Put the yeast, water, and sugar into the water bottle and swirl it around to dissolve the sugar and yeast.
3. Attach the balloon to the mouth of the bottle and set it aside.
4. Observe the balloon and find the answers to the questions.
5. Sketch the bottle/balloon to show what happened in your experiment
6. Do some research to find out what happened to the yeast, and write the explanation in your own words.
7. Explain why yeast is an important ingredient in a bread recipe. List at least two sources.

Chapter 14
Plants

What would it take for plants from Earth to survive in outer space? Travel and life in space is stressful to plants. There are extreme temperatures, drought conditions, radiation, and varying gravity, to name several issues. Scientists from North Carolina State University are looking deep in the ocean for help in redesigning plants for life in outer space. They are studying a microorganism that can grow in underwater sea volcanoes where temperatures exceed the boiling point of water. Scientists are trying to take a helpful gene from this microbe and insert it into a simple plant. Perhaps the adaptability of the microbe can be transferred to the plant, allowing it to grow and thrive in outer space. Read this chapter to learn more about plants. Perhaps in your lifetime, scientists will be growing plants in space!

Key Questions

1. ***What are some main characteristics that all plants have?***
2. ***Do all plants have seeds?***
3. ***How do plants manage to live just about anywhere, from the desert to the Arctic tundra?***

14.1 What Are Plants?

You have many reasons to be thankful for plants. Your breakfast came from plants. In fact, most of your food comes from plants or from animals that eat plants. The paper in this book contains wood pulp from plants. Some of the oxygen you breathe comes from plants. So the next time you see a plant, be sure to say thanks! In this section you will learn about the characteristics and types of plants.

Plant characteristics

Plants vary in size and shape

Plants come in all sizes, from the tiny duckweed which grows to only about 10 mm in length, to the giant redwood which grows to about 100 m in height. Plants also come in many different shapes like a feathery fern or a prickly cactus. Some examples of plants are shown in Figure 14.1.

Characteristics common to all plants

Despite their great diversity, all plants share the following characteristics:

- **Plants are producers and use photosynthesis to make food.** Most plants are green. This is because they contain the pigment chlorophyll. As you read in Chapter 6, chlorophyll absorbs certain wavelengths of light and uses that energy to make carbohydrate molecules.
- **Plants have eukaryotic cells with cell walls.** Plant cells have a true nucleus and are surrounded by a cell wall. The cell wall surrounds the cell membrane, protecting the plant and providing a rigid structure.
- **Plants have a cuticle.** A **cuticle** is a waxy layer that covers the parts of a plant that are exposed to air like leaves and stems. The cuticle is an adaptation for living on land that keeps plants from drying out.

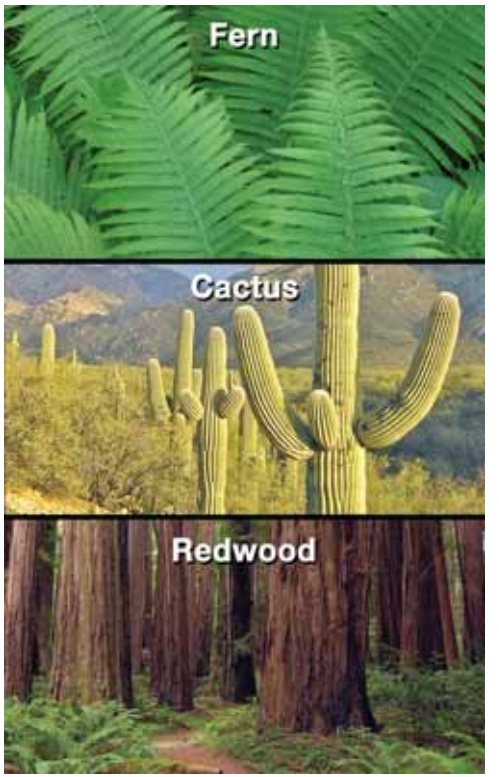


Figure 14.1: *Some representative plants.*

VOCABULARY

cuticle - a waxy layer that covers the parts of a plant that are exposed to air like leaves and stems.

Plant classification

Vascular and non-vascular plants

Classification in the Kingdom Plantae is based on the presence or absence of vascular tissues. **Vascular tissues** are made of cells organized into tube-like structures that transport water, minerals, and food throughout a plant.

Non-vascular plants

Non-vascular plants do not have any tissues to transport water and nutrients. Instead, they depend on the processes of diffusion and osmosis to supply their cells with nutrients. Because these processes are slow, non-vascular plants cannot grow very tall. Mosses and liverworts are examples of non-vascular plants.

Vascular plants

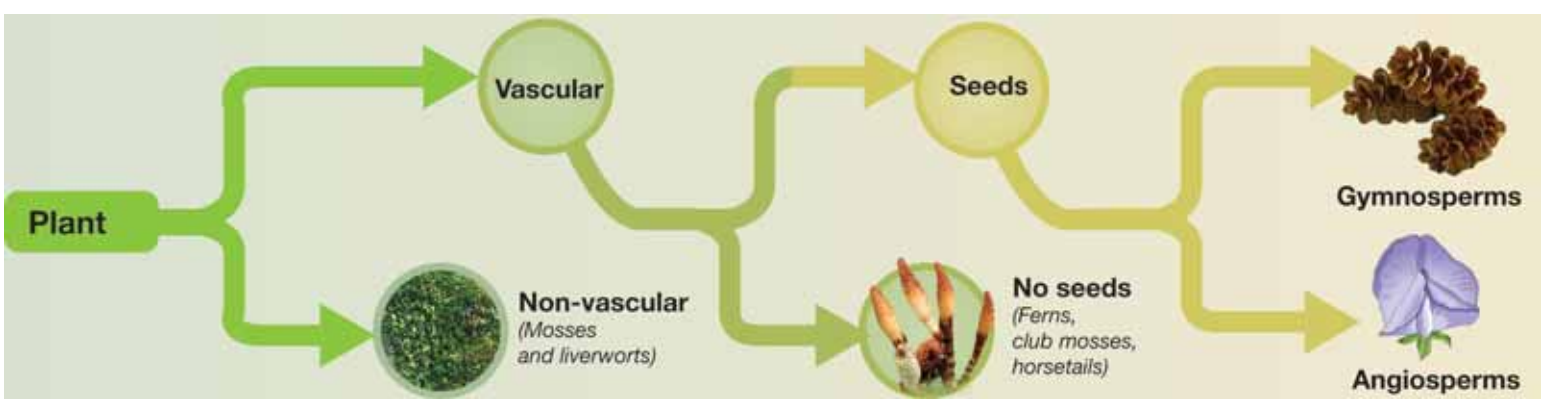
Vascular plants have tissues made of cells that transport water and nutrients throughout the plant. Like your veins and arteries, vascular tissues can transport materials over a distance. The evolution of vascular tissues is one of the adaptations that allowed plants to move onto land. **Vascular plants are divided into two groups—those that produce seeds and those that do not.** Plants that do not produce seeds include ferns, club mosses, and horsetails. Plants that produce seeds are divided into *gymnosperms* and *angiosperms,* which you'll learn more about later.

VOCABULARY

vascular tissues - cells organized into tube-like structures that transport water, minerals, and food throughout a plant.

non-vascular plants - do not have any tissues to transport water and nutrients.

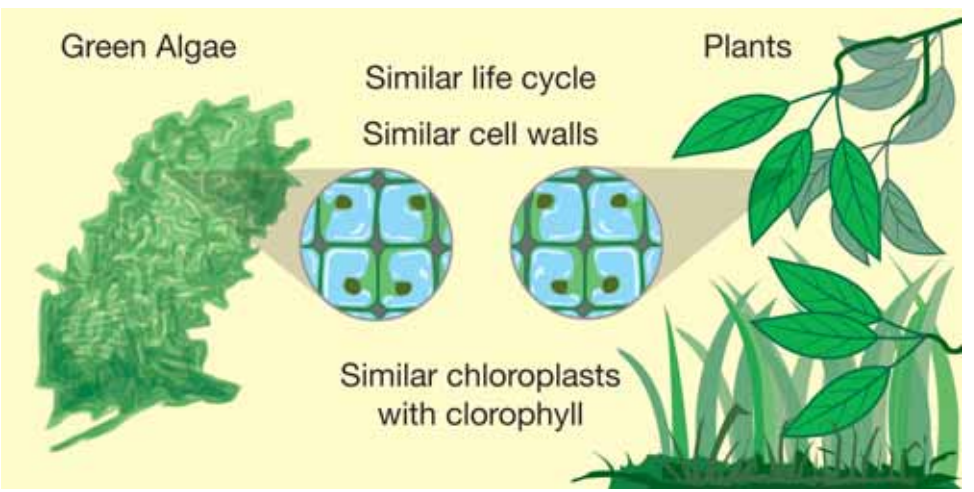
vascular plants - have tissues made of cells that transport water and nutrients throughout the plant.



Plant evolution

Plants and green algae

Because plants are similar in many ways to green algae, scientists think that both may have originated from an ancient species of green algae. Algae and green plants both have a life cycle that involves alternation of generations. Both contain the same type of chlorophyll and make the same type of starch. Also, both have similar cell walls.



A brief evolutionary history

The first ancestors of plants show up in the fossil record during the late Ordovician Period—about 450 million years ago. Plants started out living in water, an ideal environment that supported cells and transported nutrients. As Earth's environments changed, plants had to adapt to life on land. They evolved adaptations for support, protection, and to prevent them from drying out. They also evolved vascular tissues for transporting water and nutrients throughout their bodies. Figure 14.2 shows the evolutionary relationships among plant groups.

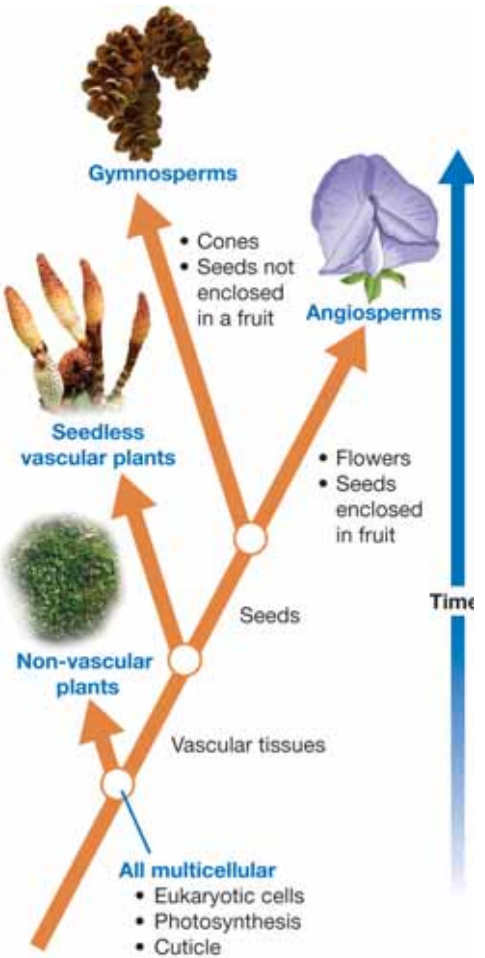


Figure 14.2: *A cladogram that shows evolutionary relationships among major plant groups.*

Non-vascular plants

Characteristics of non-vascular plants

The non-vascular plants include the mosses and liverworts. These are small, simple plants usually found in moist locations. Because they lack vascular tissues, each cell in the plant must absorb water and nutrients through osmosis and diffusion. Thus, mosses and liverworts do not grow very tall. Mosses and liverworts need water to carry the sperm to the eggs for fertilization. The life cycle of non-vascular plants shows an alternation of generations. It includes a *sporophyte* stage that produces spores and a *gametophyte* stage that produces sex cells.

Liverworts

You may have seen liverworts growing on wet rocks and soil in shady places (Figure 14.3). The sporophyte stage of a liverwort looks like a tiny palm tree. The body of the gametophyte stage is leafy and flattened. **Rhizoids** are root-like growths that extend from beneath the body and anchor the plant. They are not considered roots because they do not have vascular tissues.

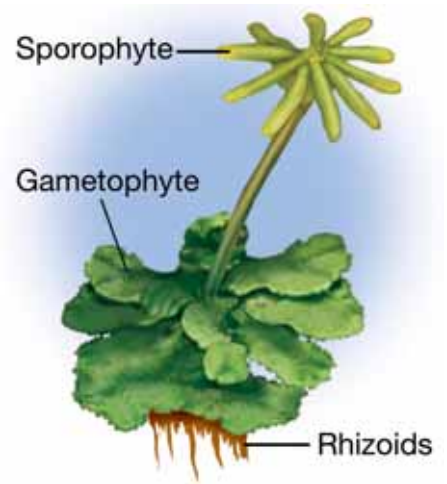


Figure 14.3: *Liverworts.*

VOCABULARY

rhizoids - root-like growths on mosses and liverworts that anchor the plant to a surface and do not have vascular tissues.

Mosses

Mosses usually grow together in large colonies and cover an area like a carpet (Figure 14.4). Each moss plant consists of a leafy stalk with rhizoids at the base to anchor the plant. The sporophyte stage of a moss has a *capsule* on top that contains the spores.

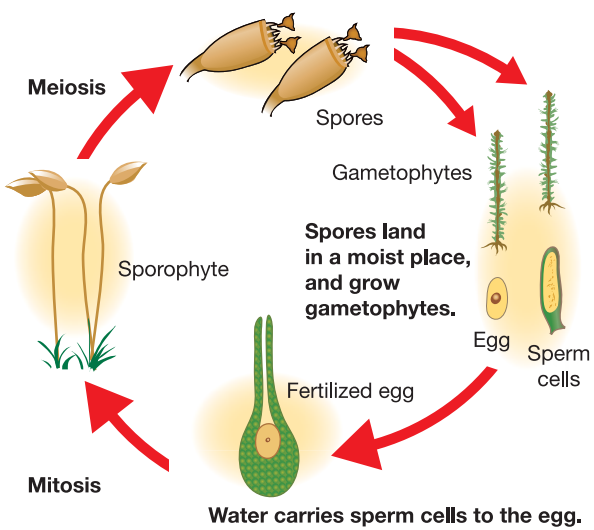


Figure 14.4: *A carpet of moss.*

Seedless vascular plants

What are seedless vascular plants?

The seedless vascular plants include ferns, club mosses, and horsetails (Figure 14.5). Because they have vascular tissues, these plants can grow taller than mosses and liverworts. A typical fern can reach heights of a meter or taller. Tropical tree ferns can reach a height of about 20 m. Ancestors of seedless vascular plants were even taller than their modern descendents. The first forests contained club mosses that grew to around 40 m tall! Modern club mosses are less than a meter tall.

Ferns

You can find ferns in tropical forests, temperate forests, and even in the Arctic. The form of a fern you will notice is the sporophyte. Figure 14.6 shows the structures of a fern. The leafy branch of the fern is called a *frond*. If you look underneath a fern frond, you may see small patches that contain the spores. Not every frond has spores under it. Ferns have an underground stem called a *rhizome* from which the fronds unfurl. Young fronds are tightly coiled and are called *fiddleheads*. The fern gametophyte is heart-shaped and about half the size of a pea. It has female parts that produce eggs and male parts that produce sperm. Like non-vascular plants, ferns need water to transport sperm cells to egg cells.

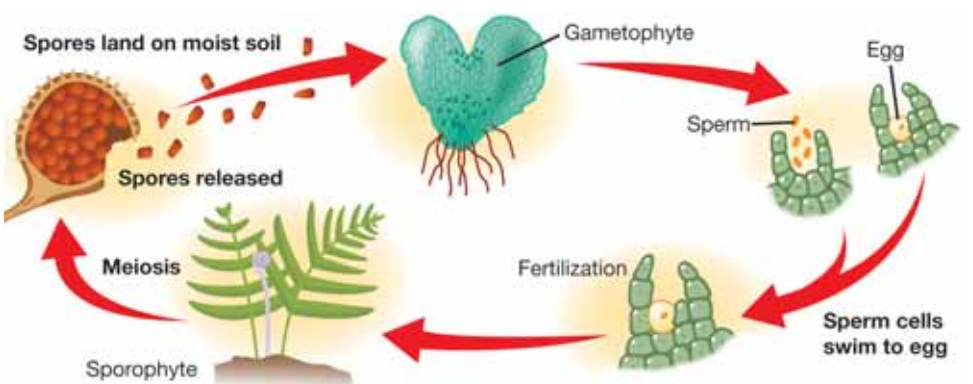


Figure 14.5: *Seedless vascular plants.*

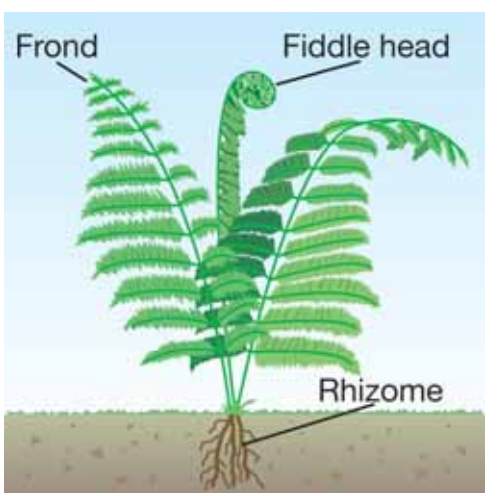


Figure 14.6: *The structures of a typical fern.*

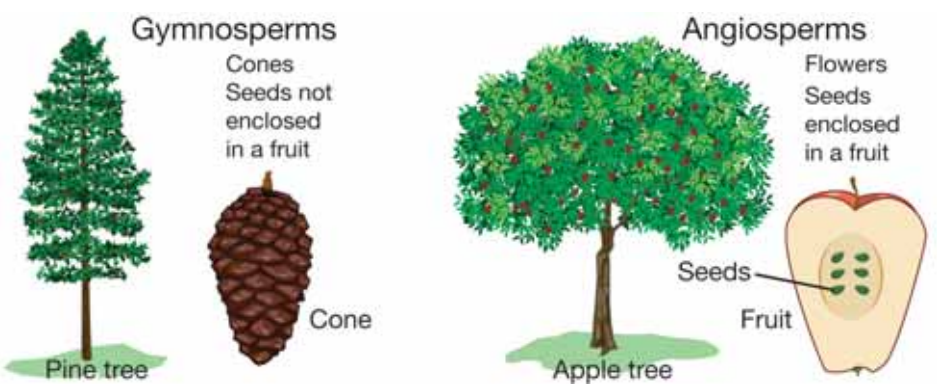
Vascular plants with seeds

What are seeds?

The types of plants you are probably most familiar with are trees, grasses, and flowers. These familiar plants are very different from mosses and ferns. They have the ability to produce *seeds*. A **seed** is a structure that contains a plant embryo and a supply of food inside a protective covering. A seed forms after fertilization and is made up of a plant embryo, stored food, and a tough covering. The three parts of a seed are shown in Figure 14.7.

Gymnosperms and angiosperms

Gymnosperms are a group of vascular plants whose seeds are not surrounded by a fruit. The seeds of many gymnosperms are housed in cones. Most gymnosperms are trees such as pine, fir, and spruce. **Angiosperms**, also known as flowering plants, produce seeds within a fruit. They are the most diverse of all plant groups and include fruit trees, roses, corn, grass, and oak trees.



Adaptations for life on land

Seed plants have many adaptations for living on land. Seeds are more resistant to drying out than spores. Unlike spores, seeds contain stored food to nourish the embryo and help it sprout and grow. Also, seed plants do not require water for reproduction. Recall that mosses and ferns need water for fertilization to occur. Finally, seed plants have well-developed vascular systems for transporting water and nutrients throughout their bodies.

VOCABULARY

seed - a structure that contains a plant embryo and a supply of food inside a protective covering.

gymnosperms - vascular, seed-producing plants whose seeds are not enclosed in a fruit.

angiosperms - vascular, seed-producing plants whose seeds are enclosed in a fruit.

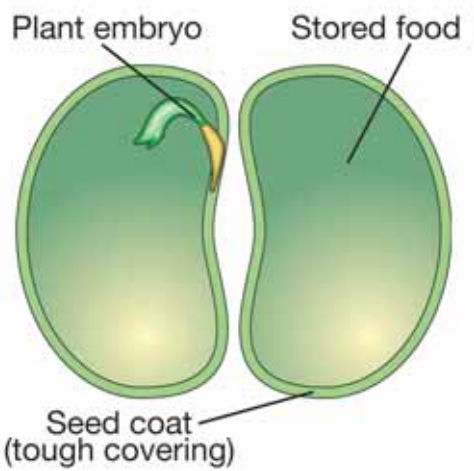


Figure 14.7: *The three parts of a seed.*

More about seed plants

Gymnosperms

Gymnosperms do not produce flowers and their seeds are not enclosed in a fruit. Gymnosperms include conifers, cycads, and gingkoes. A gymnosperm called the bristlecone pine is the oldest living organism on Earth (Figure 14.8). One bristlecone pine is believed to be almost 5,000 years old!

Conifers are a group of gymnosperms

The *conifers*, including pines and firs, are a group of gymnosperms that have cones. There are male and female cones on the same plant (Figure 14.9). Male cones produce male gametophytes called *pollen*. Pollen are dust-like particles that produce sperm. The female cone produces the eggs. Wind carries pollen to the female cone on the same or different plants. Sperm are released and fertilize the eggs. The seeds develop inside of the female cone.

Angiosperms

Angiosperms are flowering plants that produce seeds enclosed in a fruit. Angiosperms are divided into two classes—*monocots* and *dicots*. The two classes have different numbers of cotyledons in their seeds. A **cotyledon** is an embryonic leaf found inside of a seed. Monocots (*mono* = 1) have one cotyledon and dicots (*di* = two) have two. In monocots, bundles of vascular tissue are scattered while in dicots, the bundles form a ring.

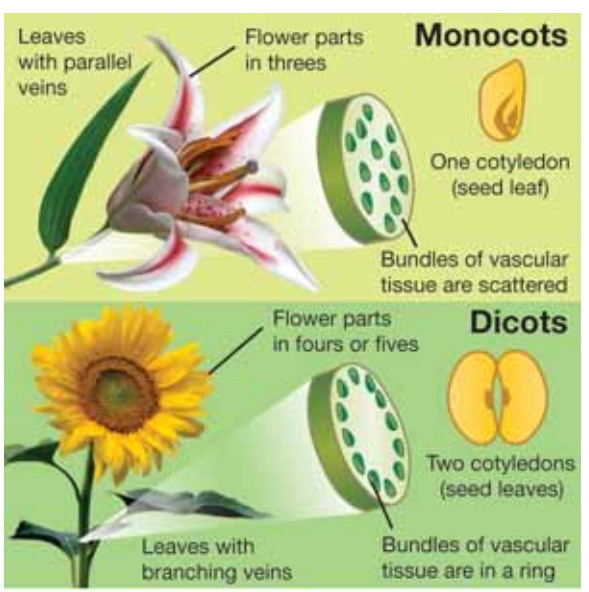


Figure 14.8: *The bristlecone pine is the oldest living thing on Earth.*

Figure 14.9: *Male and female cones on a pine tree.*

14.1 Section Review

1. All of the following are true of plants except:
   a. They have prokaryotic cells.
   b. They have a cell wall.
   c. They use photosynthesis to make their own food.
   d. They have a cuticle.
2. Define the following and give one example of each:
   a. non-vascular plant
   b. vascular plant
   c. seedless vascular plant
3. List two adaptations of plants for living on land.
4. What is the evidence that green plants evolved from green algae?
5. Why are some vascular plants tall while non-vascular plants are always short?
6. What are rhizoids? How are they similar and different than roots?
7. Which is true of the gametophyte generation of a fern?
   a. It produces spores which grow into a new plant.
   b. It produces sex cells.
   c. It is the dominant form of the plant you can see.
   d. It is diploid.
8. What are seeds?
9. List three reason why seed plants are more common than non-vascular or vascular plants with no seeds.
10. Give two examples of a gymnosperm and two examples of an angiosperm.

VOCABULARY

(from previous page)

cotyledon - an embryonic leaf found inside of a seed.

CHALLENGE

Plant cells have a cuticle while green algae do not. Explain why plant cells need a cuticle but algae do not.

MY JOURNAL

Although mosses and liverworts are small in size, they play an important role in the environment. Research mosses and liverworts to find out why they are important. Write a few paragraphs about their importance.

14.2 Roots, Stems, and Leaves

Death Valley, in California, is one of the hottest and driest places on Earth. It reaches temperatures well over 50 °C and the average yearly rainfall is less than 5 cm! Yet over 1,000 species of plants flourish there, such as the Joshua tree, shown at the left. Twenty-three of those species are found nowhere else in the world. Seed plants are found in all land environments from mountaintops to the Arctic tundra. How do plants manage to live just about anywhere? The best way to answer this question is to study their structure and function. In this section you will learn about the structure and function of roots, stems, and leaves.

The structure of a plant

Parts of a plant The body of a plant is made up of three distinct regions known as roots, stems, and leaves. *Roots* anchor the plant and take in water and nutrients. Together, all of a plant's roots make up the *root system*. *Stems* support the body of the plant and carry water and nutrients from the roots to other parts of the plant. *Leaves* are the organs of photosynthesis. Recall that photosynthesis is the process of using sunlight to make food. The stems and leaves of a plant make up the *shoot system*.

Vascular tissues Seed plants contain vascular tissues that carry water and nutrients from one end of the plant to the other. There are two types of vascular tissues. **Xylem** is a vascular tissue that carries water. **Phloem** is a vascular tissue that carries sugars and other foods throughout the plant. Figure 14.10 shows the parts and tissues of a plant.

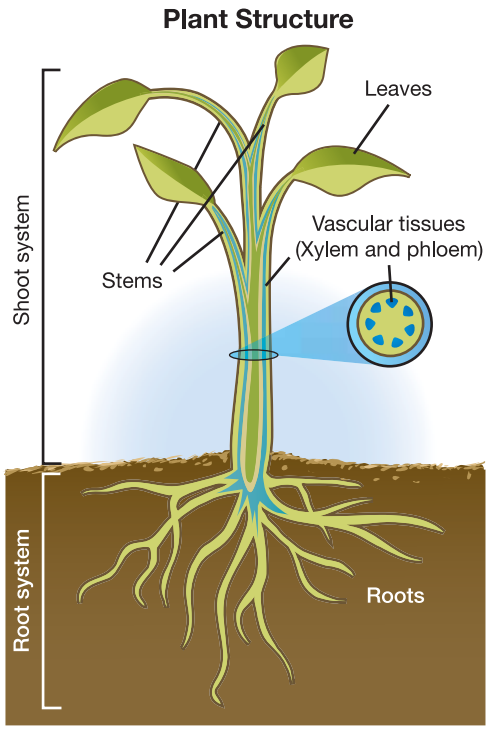


Figure 14.10: *The structure of a plant.*

VOCABULARY

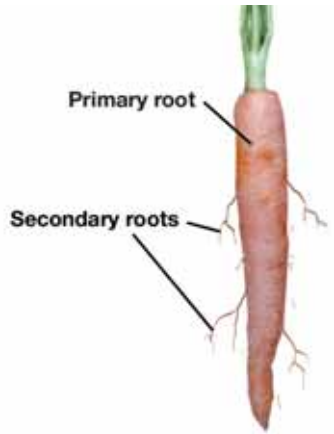
xylem - a vascular tissue that carries water throughout a plant.

phloem - a vascular tissue that carries sugars and other foods throughout a plant.

The root system

Functions of the root system

The main functions of the root system are to collect minerals and water from the soil and to anchor the plant. Roots also help support the part of the plant that is above ground. In addition, some roots store food produced from photosynthesis. The root system consists of a larger *primary root* and thinner *secondary roots* that branch off of the primary root. The photo (right) shows the root system of a carrot plant. The primary root of the carrot stores food.



Structure of roots

The layer of cells that covers the surface of roots is called the **epidermis**. Some epidermal cells grow outward into *root hairs*. Root hairs increase the surface area and maximize the amount of substances a plant can absorb. A plant's root system may contain billions of root hairs! Once absorbed, water and minerals diffuse through a layer of cells called the *cortex* and into the center of the root which contains the vascular tissues (xylem and phloem). The vascular tissues transport water and minerals to the rest of the plant. Figure 14.11 shows a cutaway and a cross section of a root.

Roots and osmosis

Plants use osmosis to take in water. When there is plenty of water in the soil, osmosis rapidly draws water into the root hairs. This happens because the concentration of water is greater on the outside of the root than on the inside. From there, water passes into the vascular tissues through osmosis. If the concentration of water is less outside the root than inside, the plant may lose water.

VOCABULARY

epidermis - the layer of cells that covers the surface of roots.

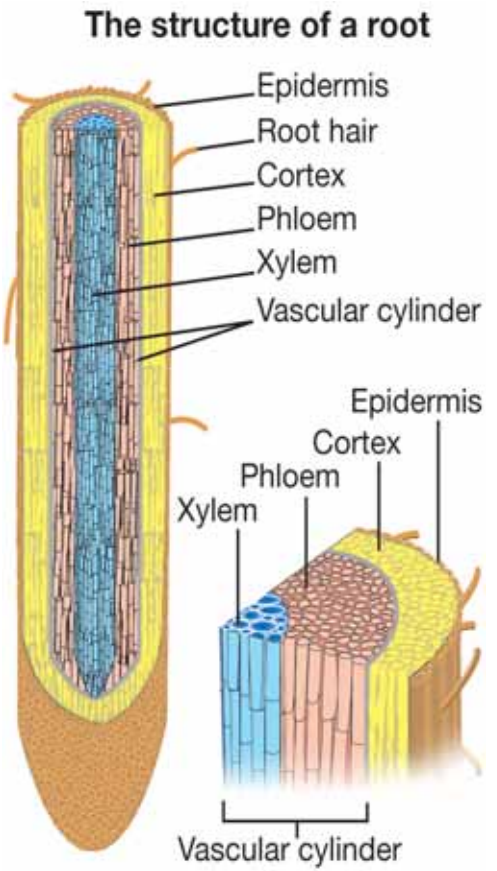


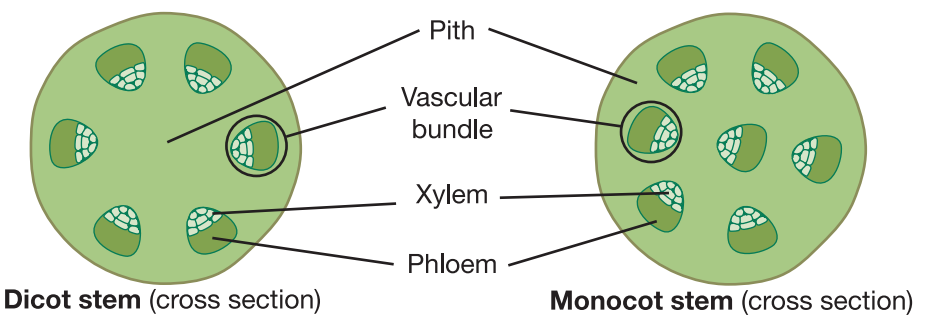
Figure 14.11: *The structure of a root.*

Stems

What are stems? Stems are part of the *shoot system* which also includes leaves and flowers. Flowers are discussed in Section 14.3. **Stems connect the roots that gather water and nutrients to the leaves that carry out photosynthesis.** Stems are usually located above ground, although some plants have underground stems. The white potato is an underground stem that stores starch. Stems come in many forms. The thickened stems of a cactus are adapted for storing water (Figure 14.12).

Figure 14.12: *The stems of a cactus are adapted for storing water.*

Stem structure Like roots, stems are covered in a layer of epidermal cells. They also contain vascular tissues. But those tissues are arranged differently in stems than they are in roots. In monocots, the bundles of xylem and phloem are scattered throughout the stem. In dicots and many gymnosperms, those bundles are arranged in a ring. The tissue inside the ring is called *pith*. The tissue outside the ring is called the *cortex*.



Types of stems Some plants have thin and flexible stems called *herbaceous stems*. Trees and shrubs have *woody stems* and produce a tough material called *wood*. At the beginning of the growing season, the plant produces thicker xylem cells. As fall approaches, the plant produces smaller xylem cells. When the growing season ends, the plant stops producing cells. This process produces the growth rings you see in a cross section of a tree trunk (Figure 14.13).

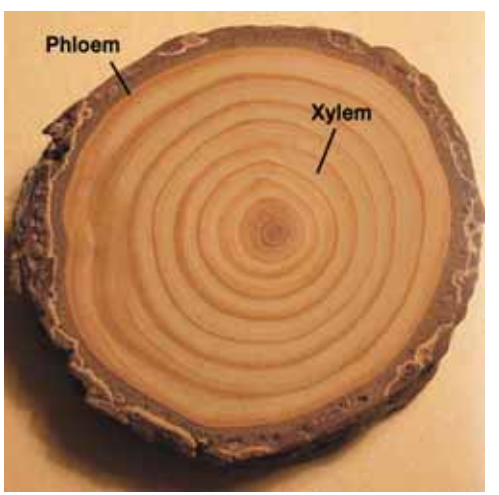


Figure 14.13: *The growth rings of a tree. Scientists analyze growth rings to study past weather patterns.*

Leaves

The function of leaves

The main function of leaves is to use sunlight to make food during the process of photosynthesis. Leaves take in carbon dioxide from the air and absorb sunlight. During photosynthesis, cells in leaves produce carbohydrates and oxygen. Oxygen is released into the air through the leaves. Carbohydrates are transported to other parts of the plant for later use.

The structure of a leaf

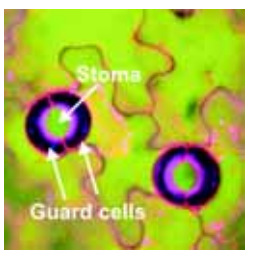
The structure of leaves is related to their function. Many leaves are broad and flat so they can absorb the maximum amount of sunlight. The diagram in Figure 14.14 shows a cutaway view of a leaf. As you can see, a leaf consists of many layers of tissue. The outer surface of the leaf is covered by the *cuticle* which protects the leaf. Next, is a single layer of cells called the *epidermis*. Light can easily pass through the epidermis and into the palisade and spongy layers where photosynthesis happens.

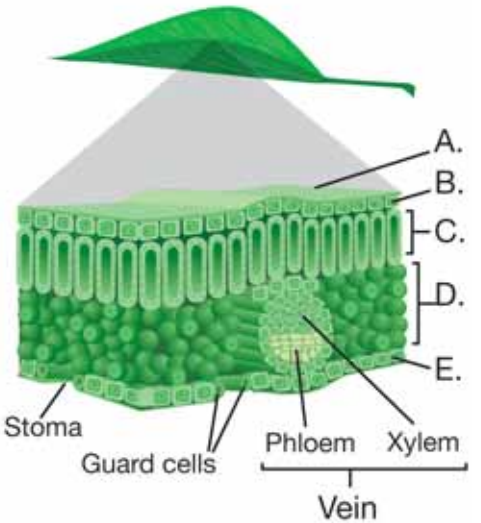
The palisade and spongy layers

The *palisade layer* is made up of elongated cells. Palisade cells contain many chloroplasts, the organelles where photosynthesis occurs. Cells in the *spongy layer* are spaced further apart. The air spaces between the cells allow carbon dioxide to diffuse throughout the leaf. The *veins* of the leaf contain xylem and phloem. Xylem carries water and minerals throughout the leaf. Phloem carries the carbohydrates made during photosynthesis to the rest of the plant.

Stomata

The *lower epidermis* contains tiny pores called stomata (singular, *stoma*). **Stomata** allow carbon dioxide to enter the leaf and oxygen and water vapor to exit. Each stoma is opened and closed by *guard cells*. The picture (right) shows two open stomata and their guard cells.





A. Cuticle

B. Upper epidermis

C. Palisade layer

D. Spongy layer

E. Lower epidermis

Figure 14.14: *A cutaway view of a leaf showing its structures.*

VOCABULARY

stomata - tiny pores that allow carbon dioxide to enter a leaf and oxygen and water vapor to exit.

Movement of fluids in plants

The vascular system of plants

The vascular tissues form a network of tubes that carries water and nutrients throughout the plant. The vascular system of a plant is a bit like your circulatory system which carries fluids throughout your body. But plants don't have a heart to pump fluids throughout their bodies. Water enters the plant through the roots by osmosis. But osmosis cannot push water throughout the rest of the plant. In vascular plants, xylem cells are joined to form continuous tubes. Water moves through the xylem by two forces—capillary action and transpiration (Figure 14.15).

Water moves through the xylem by capillary action and transpiration.

Capillary action

If a thin tube is placed in a cup of water, the water will rise up the tube in a process called *capillary action*. Water molecules are strongly attracted to each other and attracted to surfaces. Those attractive forces act together to pull water molecules up a thin tube—like the tubes formed by the xylem of a plant.

Transpiration

A stronger force is produced by a process known as transpiration. **Transpiration** is the loss of water through the stomata. When the stomata are open, the plant is able to obtain carbon dioxide for photosynthesis. Oxygen produced during photosynthesis exits through the open stomata, along with water vapor. As water exits the stomata, it draws more water out of the xylem. The strong attraction of water molecules to each other creates a pull of water molecules throughout the xylem, similar to a train engine pulling cars along. When the stomata are closed, transpiration stops. About 10 percent of the water vapor in Earth's atmosphere comes from plants through transpiration.

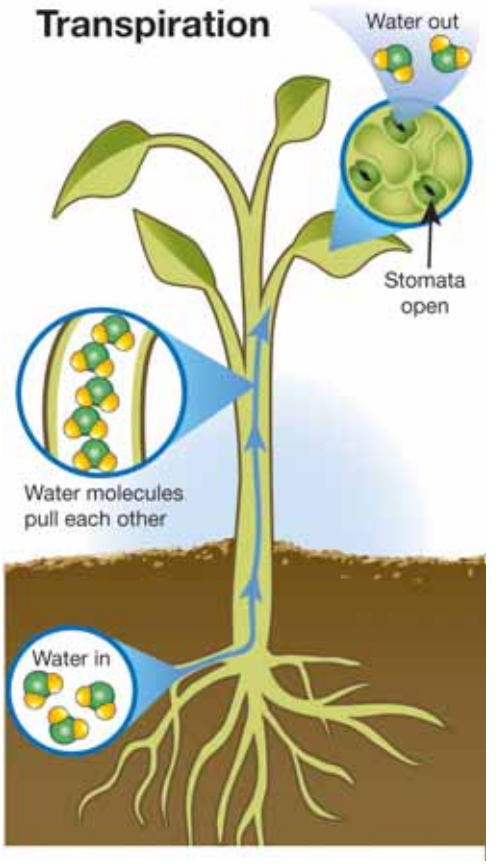


Figure 14.15: *Xylem tissues carry water from roots to leaves through capillary action and transpiration.*

VOCABULARY

transpiration - the loss of water through the stomata.

Plant responses

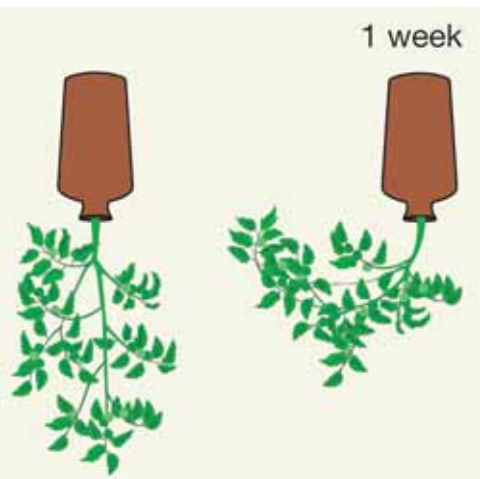
Stimulus and response

Have you ever gone from the dark to a brightly lit room? How does your body respond? First, you quickly squint your eyes. Then, your pupils get smaller to let less light pass in so you can stop squinting. Recall that a reaction to a *stimulus* (like light) is called a *response*. Responding to stimuli is a characteristic of all living things. So it shouldn't surprise you that plants also respond to stimuli.

VOCABULARY

tropism - growth in response to a stimulus.

Tropism



Plants respond to a stimulus by growing either away or toward the stimulus. Growth in response to a stimulus is called a **tropism**. In a positive tropism, a plant grows toward a stimulus. In a negative tropism, a plant grows away from a stimulus. Have you ever noticed that some houseplants appear to turn their leaves to face a window? A change in the growth of a plant due to light is called *phototropism*. When a plant grows toward a light source, the cells on one side of the stem grow longer than the cells on the other side (Figure 14.16). Plants also grow in response to gravity (*gravitropism*). If a plant is turned upside down, it will grow away from the pull of gravity and turn upward, as shown to the left.

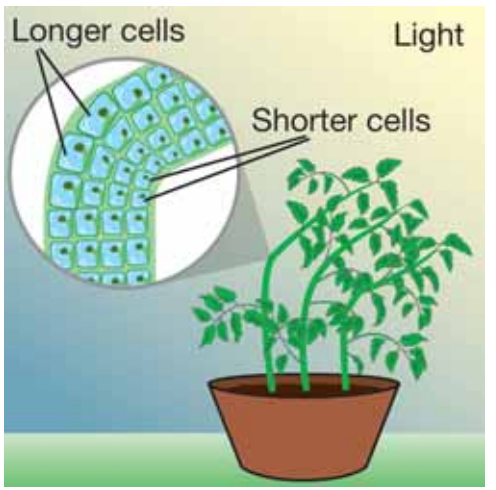


Figure 14.16: *Plant cells on one side of the stem grow longer than on the other side, causing the plant to grow towards a light source.*

Amount of daylight

Plants also grow in response to changes in seasons. As seasons change, so does the amount of light a plant is exposed to each day. In winter, there is less daylight than in summer. Changes in the amount of light each day is a stimulus to many plants. For example, some plants produce flowers in early Spring when the daylight is short. Other plants flower only in late summer when the daylight is long.

14.2 Section Review

1. Describe the major function of each region of a plant:
   a. roots
   b. stems
   c. leaves
2. What are the two major systems in a plant?
3. Explain the function of each vascular tissue:
   a. xylem
   b. phloem
4. What are root hairs? What is their function?
5. How are vascular tissues arranged in a monocot stem? A dicot stem?
6. Name the function of each leaf structure:
   a. stomata
   b. upper epidermis
   c. palisade layer
   d. spongy layer
   e. cuticle
   f. guard cells
7. Explain how transpiration pulls water throughout a plant.
8. Describe how a plant might respond to each situation:
   a. A potted plant is place in a window and receives light from only one direction.
   b. A plant is held in the position shown in Figure 14.17.

SOLVE IT!

For each situation below, tell whether water would move into the roots or out of the roots. Explain your reasoning for each answer.

1. Water is added to the soil of a potted plant that was dry.
2. Salt water is added to a potted plant.

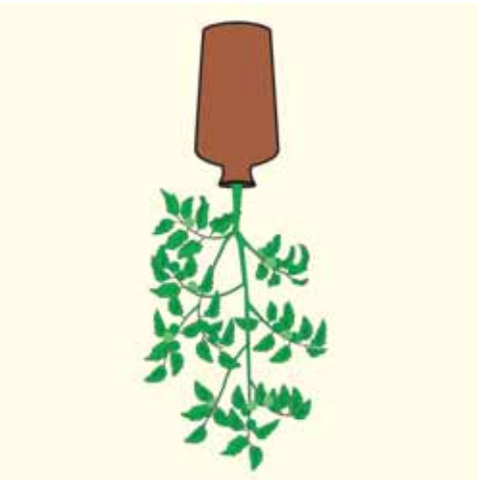


Figure 14.17: *Use this picture to answer question 8b.*

14.3 Reproduction in Flowering Plants

Normally, we associate flowers with a nice smell. But one type of flower, called a *carrion flower*, smells like rotting flesh (Figure 14.18). The smell of the carrion flower attracts flies. When flies crawl into the stinking flower looking for a meal, they brush up against the *anthers* of the flower which contain pollen. The flies fly out, carrying the pollen with them. When they land on another carrion flower, they brush up against the *stigma* and leave pollen behind! Flowers come in an amazing variety of smells, shapes, colors, and sizes. But they all have the same function—sexual reproduction. In this section, you will learn about reproduction in flowering plants.

Evolution of flowering plants

Angiosperms evolved from gymnosperms

It's hard to imagine a world without flowers. Angiosperms—the flowering plants, were the last of the seed plants to evolve. They appeared around 100 million years ago during the age of the dinosaurs and probably descended from a gymnosperm ancestor. Figure 14.19 is a photo of a *magnolia*, a primitive angiosperm. Can you see the resemblance of its fruit to the cone of a gymnosperm?

What are flowers?

A **flower** is the reproductive organ of angiosperms. Flowering plants reproduce by **pollination**, the transfer of pollen, containing sperm, to the female part of the flower. Since plants cannot move, they have evolved adaptations to ensure successful pollination. In many plants, the sperm from one plant must fertilize the egg of another plant. This ensures genetic variation. Over millions of years, a variety of flowers have evolved, many with unique adaptions for pollination. Some involve insects or birds while others involve wind, gravity, and other factors. Today, there are about 250 million species of flowering plants—more than any other group of plants.

Figure 14.18: *A carrion flower smells like rotting flesh. It even looks like flesh!*

VOCABULARY

flower - the reproductive organ of angiosperms.

pollination - the transfer of pollen, containing sperm, to the female part of the flower.

Figure 14.19: *The fruit of the magnolia resembles the cone of a gymnosperm.*

Flower structure and function

The function of flowers

Many flowers are beautiful and are used to celebrate important events. But as far as plants are concerned, flowers are used for one purpose: sexual reproduction. Figure 14.20 shows just a few types of flowers. Despite their diversity, most flowers have the parts shown in the diagram below.

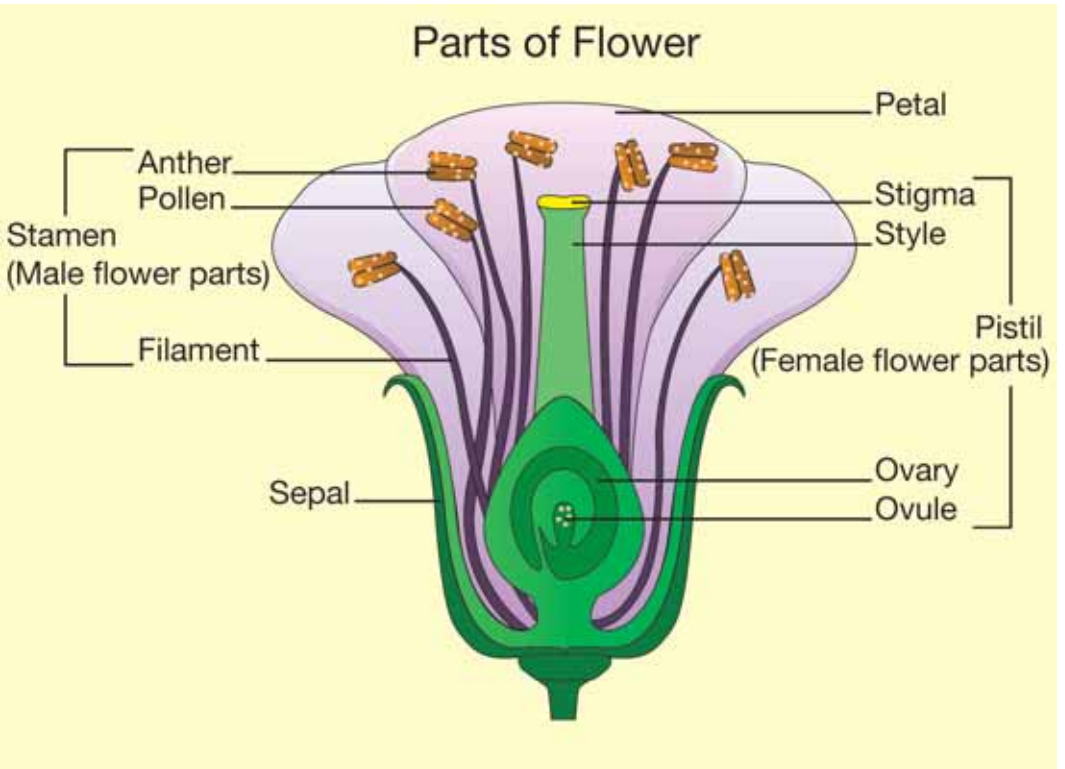


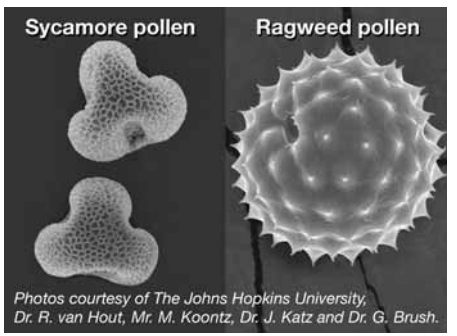
Figure 14.20: *A few types of flowers.*

Arrangement of flower parts

The flower parts are usually arranged in a ring around the female parts of the flower, called the pistil. *Sepals* make up the bottom ring of flower parts and are modified leaves. *Petals* are the colorful part of the flower (sepals are sometimes colorful too). Petals often help the plant reproduce by attracting insects or birds. The petals of the carrion flower are red and spotted and resemble rotting flesh!

Male flower parts

The male part of the flower is called the **stamen**. The stamen consists of the anther, pollen, and filament. The *filament* is a thin stalk that holds an anther. Each *anther* produces grains of pollen. **Pollen** is the reproductive spore that contains sperm cells. The picture (right) shows magnified pollen grains from sycamore and ragweed plants.



Female flower parts

The female part of the flower is called the **pistil**. The pistil consists of the stigma, style, ovary, and ovules (Figure 14.21). A flower may have one or more pistils. They are usually in the center of the flower. The tip of the pistil is called the stigma. The **stigma** attracts and holds grains of pollen. Stigmas are often sticky or feathery. Below the stigma is the *style*. The style connects the stigma to the ovary. The **ovary** is located at the base of the pistil and contains one or more ovules. Each **ovule** contains one egg cell. If fertilization occurs, each ovule develops into a seed and each ovary develops into a fruit.

If fertilization occurs, each ovule develops into a seed and each ovary develops into a fruit.

VOCABULARY

stamen - the male part of the flower.

pollen - the reproductive spore that contains sperm cells.

pistil - the female part of the flower.

stigma - part of the flower that attracts and holds pollen.

ovary - part of the flower that holds one or more ovules.

ovule - part of the flower that holds one egg cell.

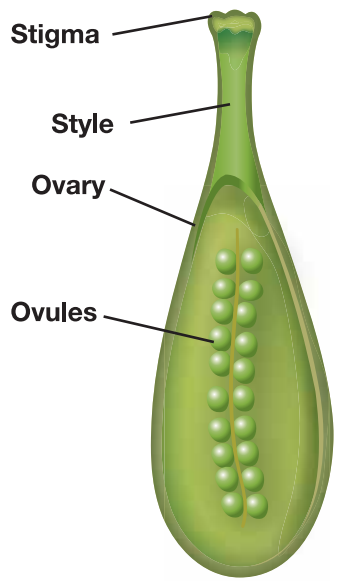


Figure 14.21: *A cross section of a pistil.*

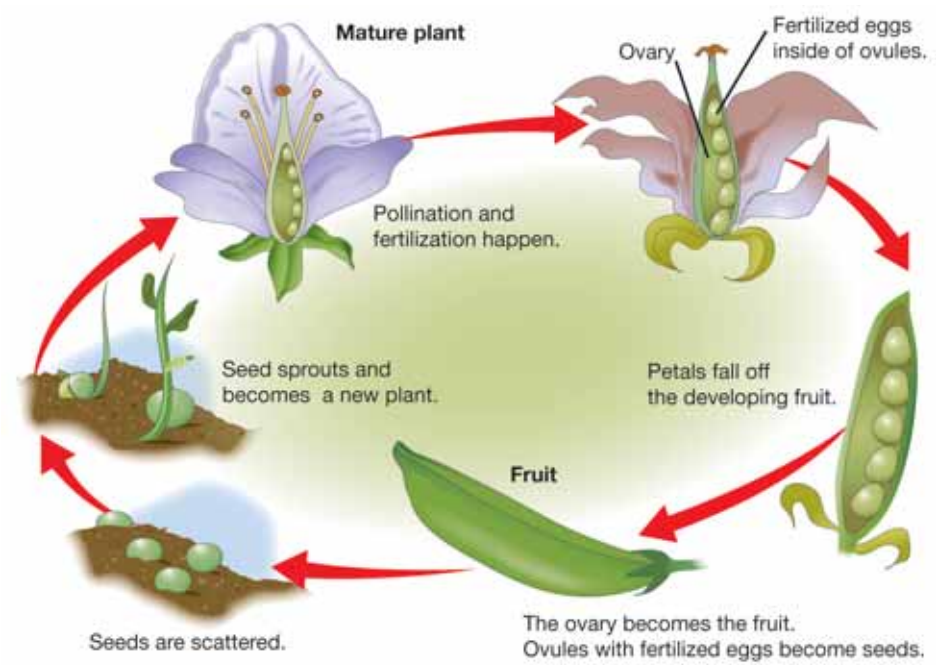
Reproduction in flowering plants

Fertilization

Fertilization in flowering plants happens through a process called pollination. Pollination occurs when pollen grains from the anther land on a stigma. After pollen grains land on the stigma, a *pollen tube* grows from the pollen grain, through the style, and into the ovary. Sperm cells inside the pollen grain travel down the pollen tube and into the ovary which contains the ovules. Fertilization occurs when one of the sperm cells fuses with the egg inside of an ovule (Figure 14.22).

Development of fruits and seeds

After fertilization occurs, each ovule develops into a seed. Each seed contains a tiny, undeveloped plant called an embryo. The ovary surrounding the ovules develops into a fruit that contains one or more seeds.



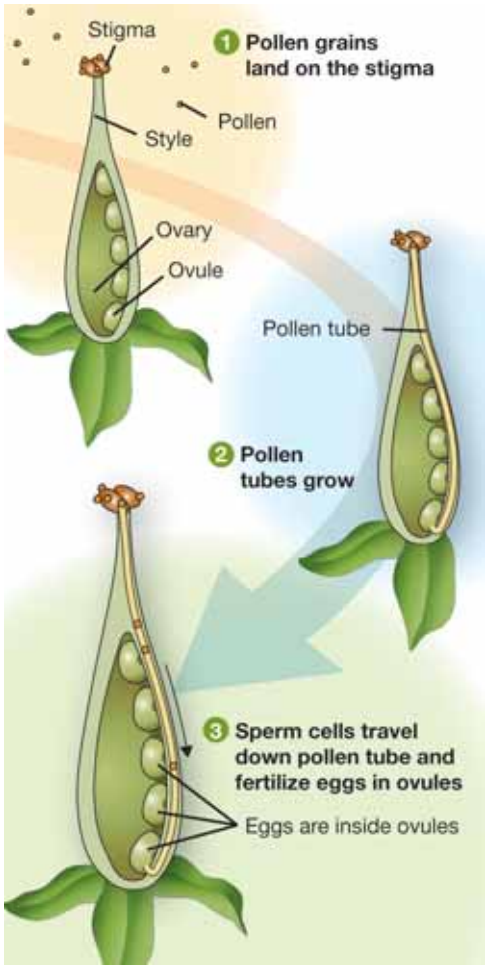


Figure 14.22: *Sperm cells travel from the pollen, through the pollen tube, and into the ovary where fertilization occurs.*

Fruits

What is a fruit?

Can you name a fruit? When you think of fruit, you may first think of oranges, grapes, and strawberries. But there are other examples you may not associate with being fruits. For example, a green bean is the fruit of the green bean plant. Figure 14.23 shows the fruit of a milkweed plant. A **fruit** is defined as a ripened ovary that contains angiosperm seeds. The ovary develops into a fruit at the same time the ovules develop into seeds. As the fruit develops, it swells and ripens. The function of a fruit is to hold and protect the seeds.

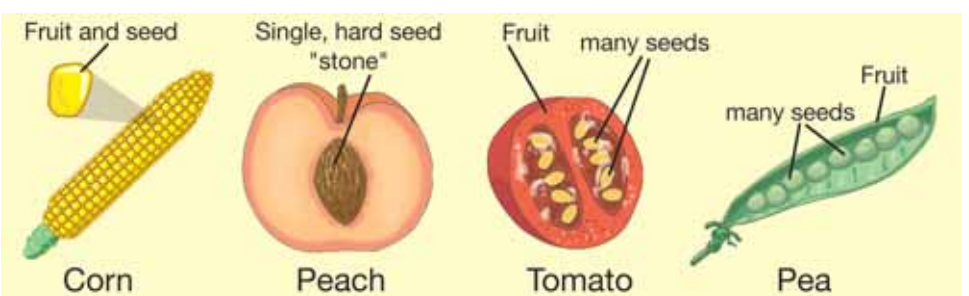
Figure 14.23: *The fruit of a milkweed plant.*

VOCABULARY

fruit - a ripened ovary that contains angiosperm seeds.

The amazing variety of fruits

The simplest fruits consist of a single seed enclosed in a single ovary. Grains like corn and wheat fit this description. In many grains, the ovary walls are so thin that they fuse with the seed. Each kernel of corn on a cob is actually an individual fruit! In nuts like acorns and chestnuts, the ovary hardens into a protective shell. In fruits like peaches and cherries, the fruits are soft and fleshy and contain a single, stony seed. Ovaries that contain many ovules produce a single fruit with many seeds. Grapes with seeds and tomatoes are examples. Legumes like beans and peas produce a fruit called a pod that contains many seeds. Most of the "fruit" of an apple is actually formed by the stem surrounding the ovary. If you slice an apple in half, you can see the boundary between the ovary wall and the stem (Figure 14.24).



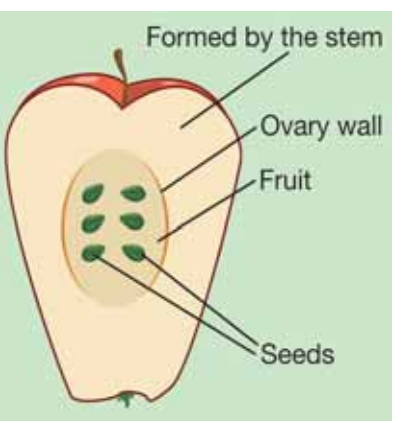


Figure 14.24: *The fruit of an apple begins in the core.*

Seeds and seed dispersal

Germination

Once the fruit and seeds are fully developed, the plant embryo inside of the seed goes into a *dormant* (inactive) state. Dormant seeds can often survive various harsh conditions like freezing temperatures and drought. Some seeds require extreme conditions to break their dormancy. Forest fires for example, burn the seed coats of some plant species and allow them to *germinate*. **Germination** is the process of a seed sprouting and its growth into a young plant (Figure 14.25).

Seed dispersal

Seed dispersal—the scattering of seeds, is an important part of a seed plant's life cycle. In order to germinate, a seed needs to be dropped into an environment with suitable conditions. Because plants cannot move, they depend on other forces to help seeds find the right conditions. These forces may include wind, water, or animals. **Fruits have evolved many ways to aid in seed dispersal.**

Examples of seed dispersal

Many seeds are dispersed directly into the air and rely on the wind to carry them. Maple trees have winged fruits that carry their seeds from the parent plant. Milkweed seeds have a tiny "umbrella" that allows them to drift over long distances. Coconuts are encased in a leathery fruit that floats over great distances on the ocean. Fruits like grapes, strawberries, and raspberries have sweet, fleshy fruits that are eaten by animals. The seeds pass, unharmed, through the animal's digestive system and are deposited in a new location.

VOCABULARY

germination - the process of a seed sprouting and its growth into a young plant.

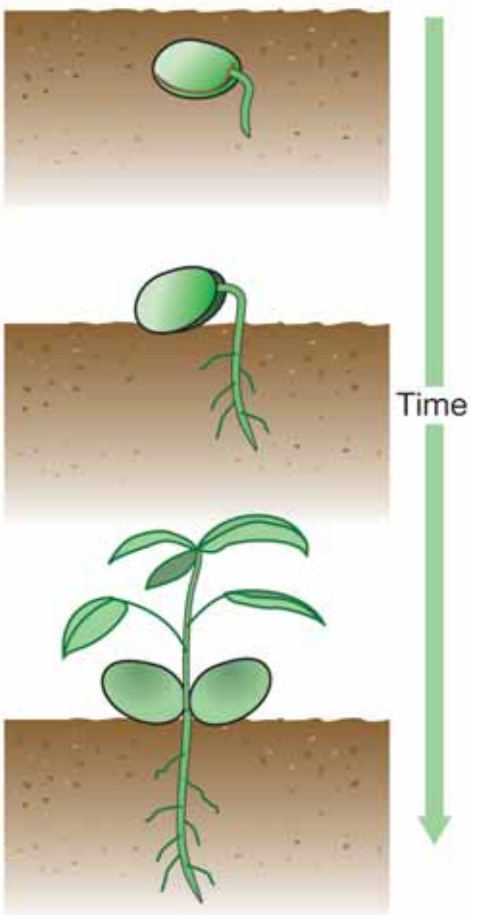


Figure 14.25: *The germination of a clover seed.*

14.3 Section Review

1. What is the main function of flowers?
2. How is a carrion flower adapted for pollination?
3. Match the structures below with their location on the diagram in Figure 14.26.

   stigma

   ovary

   ovule

   anther

   style

4. Name the function of each part in question 4.
5. List the steps to fertilization in flowering plants.
6. Why do seed plants need to evolve ways of dispersing their seeds?
7. Explain how each fruit is adapted to disperse seeds (wind, water, or animals).

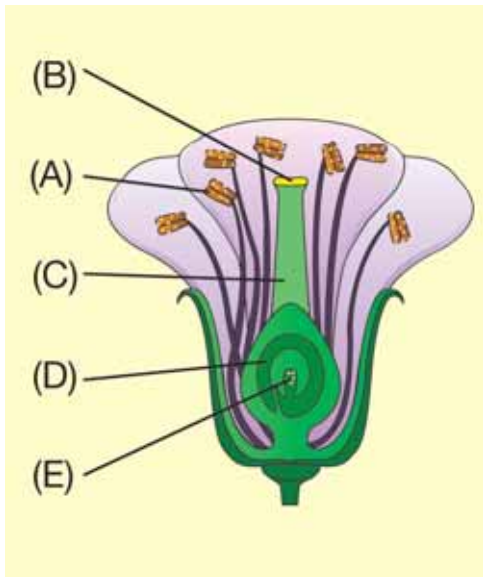
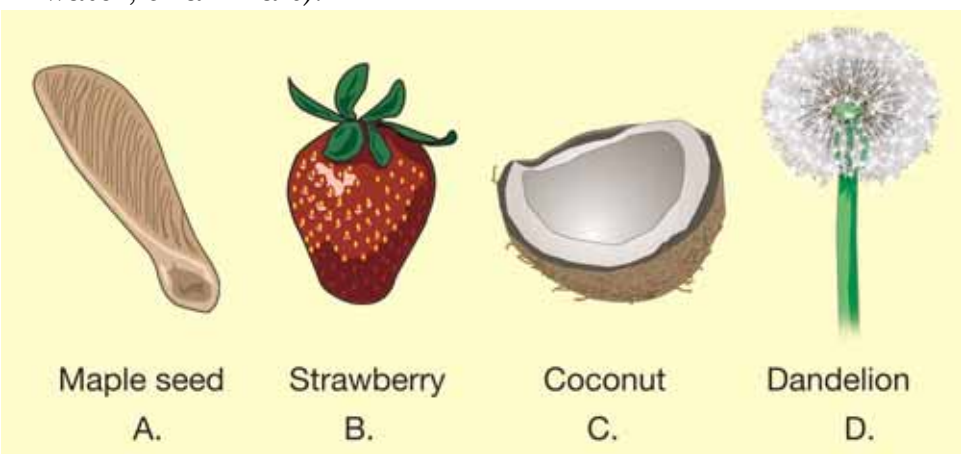


Figure 14.26: *Use the diagram to answer question 3.*



BIOLOGY CONNECTION

The Buds and the Bees

Lauren smiles as she dips her finger into the bucket of honey. She knows this golden liquid is deliciously sweet. Soon, it will be poured into jars and labeled and sold.

This is a common scene at Lauren's house because her father is an apiarist. That's another word for "beekeeper" (*apis* is Latin for bee), and there are an estimated 211,600 apiarists in the United States.

The honeybee colony

Honeybees are social insects that live in colonies. A typical colony will have one queen bee and thousands of worker bees and drones. The queen is the largest bee in the colony. Her job is to lay eggs, and a healthy queen can lay 3,000 eggs in one day. The workers are the smallest bees and there can be 50,000 of them in a colony. They, too, are females, and their jobs include collecting nectar and pollen, producing wax cells, making honey, tending the young, guarding the hive, and caring for the queen and the drones. Needless to say, they are the original "busy bees." Their age determines their job: Younger workers clean, build cells, and make honey; older workers gather nectar, pollen, and water. All worker bees defend the colony with their stingers. Most honeybees die shortly after they sting an intruder.

Male honeybees are called drones. They are larger than the workers and their job is to mate with the queen. There are usually only a few thousand drones in a colony. Drones do not have the body parts to collect nectar and pollen, nor do they have stingers.

The hive

Bee colonies make their homes in hives. Wild bees usually build their hives in trees. Beekeepers like Lauren's father build wooden hives for their bees. These wooden structures are usually boxlike, with removable frames lined up inside them. A single beehive can house an average of 50,000 bees.

The flower and pollination

Did you ever wonder why flowers are shaped and colored the way they are? A flower's color, scent, and structure are all important when it comes to attracting honeybees. Bees tend to like flowers that are blue, purple, and yellow. Bees have a strong sense of smell and are attracted to sweet-smelling flowers. Why is it important for bees to be attracted to flowers? It's a matter of "give and take": Honeybees gather the sweet nectar and pollen from the flowers - and as they flit from flower to flower, the bees pollinate the plants.

The transfer of pollen from one plant to another is called pollination. A large part of our diet comes from plants that have been pollinated by the honeybee. In fact, they are responsible for pollinating about 130 different agriculture crops such as fruits, berries, nuts, and vegetables. Large commercial farmers will rent colonies of honeybees to pollinate their crops.

They make honey in combs

How does the nectar of a flower become honey inside a honeycomb? The worker bees drink the nectar from the flowers and store it in honey sacs. Back at the hive, they transfer the honey into cells inside the wax combs. A cell is a hexagonal-shaped wax chamber used to store honey. All of these cells together make up the honeycomb. The workers must collect nectar from about 2 million flowers in order to produce about 1 pound of honey.

Beekeepers and their hives

Beekeepers like Lauren's father use smokers to calm their bees before opening the hive.

Honeybees have an alarm system that goes off when they smell smoke. They fear their hive is burning and they act to save the honey. They gorge themselves on honey and afterward are less likely to sting an intruder. The beekeepers can open the hive boxes and remove the individual frames. After careful inspection, the honey can be extracted from the comb and processed.

Questions:

1. What would happen to a honeybee colony if there were no worker bees?
2. Why are honeybees called "social insects"?
3. Explain the importance of honeybee pollination.
4. How do flowers and honeybees benefit each other?

CHAPTER ACTIVITY Design Your Own Pollinator

With the exception of plants that self-pollinate, all plants need pollinators. *Pollinators* like bees, birds, and butterflies, are responsible for carrying the pollen from one flower to another. Many flowering plants depend on pollinators to reproduce. As a result, many flowers have evolved certain adaptations to attract pollinators. Such adaptations increase a plants' chances reproduction. In this activity, you will create an imaginary flower with certain characteristics to attract and an imaginary pollinator that you will also design. For the activity, you will need drawing paper and colored pencils.

What you will do

1. Choose an organism to be the pollinator of your flower. You may choose a real organism or make up your own imaginary species.
2. Describe your pollinator. In neat writing, answer the following questions:

- What is your pollinator's (animal's) favorite food?
- What is your pollinator's (animal's) favorite shape?
- What is your pollinator's (animal's) favorite color?
- What is your pollinator's (animal's) favorite smell?

3. Draw and name your pollinator.
4. Label the part of pollinator's body that would pick up the pollen.
5. Using the qualities your pollinator likes, draw and name an imaginary flower that would attract your pollinator. Be creative!
6. Remember, the pollinator wants the food. Be sure to place the food in an area where the pollinator will be able to pick up the pollen while trying to get the food.
7. Label where the pollen is located on the flower.
8. Label where the pollen is deposited on the flower.
9. Be neat and creative!

Applying your knowledge

a. At the bottom of your picture, write a few paragraphs explaining the adaptations your pollinator has to the flower it pollinates.
b. Describe how the pollen is transferred from the pollinator to the flower. Use complete sentences and write neatly.
c. Describe the adaptations your flower has to the pollinator.

Chapter 14 Assessment

Vocabulary

Select the correct term to complete the sentences.

angiosperm	cotyledon	cuticle
germination	flower	fruit
ovary	gymnosperm	non-vascular plants
pistil	ovule	phloem
vascular plants	pollen	pollination
epidermis	seed	stamen
stigma	rhizoids	transpiration
tropism	stomata	vascular tissues
xylem		

Section 14.1

1. Angiosperms and gymnosperms are the two types of _____ that produce seeds.
2. The _____ is an important adaptation that allows plants to live on land without drying out.
3. Roots are more complex than _____ because they have vascular tissue.
4. All angiosperms either have one or two _____s inside their seeds.
5. Cells organized into tube like structures to transport water, minerals, and food make up _____.
6. Conifers, cycads, and ginkgoes are three groups of _____.
7. _____ usually grow in moist locations so that their cells can directly absorb water and nutrients through osmosis and diffusion.
8. The most diverse group of plants are the _____s, also known as flowering plants.
9. The three parts of a _____ are: a plant embryo, a food supply, and a protective covering.

Section 14.2

10. Carbon dioxide enters and oxygen and water vapor exit through the _____.
11. _____ produces 10% of the water vapor found in the Earth's atmosphere.
12. The way that plants respond to a stimuli, such as light or gravity, is called a _____.
13. Some of the cells of the _____ of roots grow out into root hairs to maximize the amount of substances that a plant can absorb.
14. The vascular tissue that carries water is called _____, while the vascular tissue that carries food is called _____.

Section 14.3

15. The _____ is the male part of the flower consisting of the anther, filament, and pollen.
16. Over time, _____s have developed amazing adaptations for _____.
17. _____ occurs when the seed sprouts and begins to develop into a whole new plant.
18. The _____ develops into the seed, while the _____ develops into the fruit.
19. _____ must be transferred from the anther to the _____ for pollination to occur.
20. The _____, which is the female part of the flower, is usually found in the center.
21. The function of the _____ is to hold and protect the seeds.

Concepts

Section 14.1

1. List three reasons why plants are important.
2. Identify two ways that plants are different from animals in terms of cell structure.
3. How are plants different from bacteria?
   a. Plants are eukaryotic, while bacteria are prokaryotic.
   b. Plants are multicellular, while bacteria are unicellular.
   c. Plants have a cell wall, while bacteria don't.
   d. both a and b
4. Why do cacti have a thick cuticle?
5. Would you expect a tall desert plant to be vascular or nonvascular? Explain your answer.
6. Why do seedless vascular plants still need to grow where it is moist if they have vascular tissue to move materials?
7. Explain what the difference is between each pair of terms:
   a. rhizoid, root
   b. spore, seed
   c. cone, fruit
   d. gametophyte, sporophyte
   e. vascular, non-vascular
   f. angiosperm, gymnosperm
   g. monocot, dicot
8. Match each plant with the group to which it belongs:

a. cycads	1. nonvascular plants
b. club mosses	2. gymnosperms
c. liverworts	3. seedless, vascular plants
d. grasses	4. angiosperms

Section 14.2

9. Draw and label your own example of a plant with these words: root system, roots, shoot system, stems. and leaves.
10. List five plants that you would put into a salad. Identify the part of the plant that you eat.
11. Desert plants often have shallow root systems that extend very far from the plant. Explain how this root adaptation is helpful.
12. What cell process do roots use to take in water?
    a. diffusion
    b. transpiration
    c. osmosis
    d. photosynthesis
13. Explain why rainforest plants often have large flat leaves, while desert plants usually have small, spiky leaves.
14. Why are the cuticle and epidermis transparent?
15. What part of the leaves are chloroplasts found in?
    a. spongy layer
    b. palisade layer
    c. cuticled
    d. epidermis
16. Would you expect plants to absorb more carbon dioxide during the day or at night? Why?
17. You look down on a plant growing in a shady area and notice something about the leaf arrangement. Each leave is spaced out so that it is not covering the leaf below it. Why is this a useful adaptation for the plant?
18. The two forces that move water through the xylem are _____ and _____.

Section 14.3

19. Why are flowers that are pollinated by the wind usually lacking bright, colorful petals? Why don't pine cones smell pretty? Explain how flowers and pine cones are specially adapted to fit their means of pollination.
20. Identify these flower parts as male or female: filament, ovule, pollen, ovary, anther, pistil, stigma, stamen, style.
21. In some flowers, the stamen extends beyond the petals. Is this helpful or harmful for the flower? Why?
22. Imperfect flowers have either male or female parts. Can these flowers self pollinate? From your understanding of genetics and angiosperm reproduction, is this arrangement advantageous? Explain your answer.
23. Ginkgoes have separate male and female plants. The fruit of ginkgo trees smells unpleasant. For this reason, only male trees are planted near houses. Explain why this practice makes sense.
24. Explain the advantage of dormancy for seeds.
25. What conditions would you predict are required for seed germination in most species of plants?
26. Explain how the seeds in the picture below are dispersed.

27. Describe what three challenges might be for a seedling that germinates right next to the parent plant.

Math and Writing Skills

Section 14.1

1. After science class one day, your friend tells you that he thinks plants are dumb. Write a persuasive paragraph to convince your friend that plants are really important in your daily life.
2. You are involved in writing a script for a new documentary about the challenges that plants face living on land. Choose a plant (moss, fern, gymnosperm, or angiosperm) and write an imaginary interview describing their adaptations for life out of water.
3. Your friend lives in Costa Rica and has a beautiful fern garden in her backyard. She is about to move to Arizona and is making plans for her garden at her new home. She is planning on trying another fern garden. What advice would you give your friend about her landscape plans?
4. Create a pie graph to show the comparative numbers of species of seedless vascular plants: 12,000 ferns, 1,000 club mosses, and 15 horsetails.
5. Which offers better protection for a seed - a cone or a fruit? Design an advertisement to show off the special features of your choice.
6. Monocots have petals in multiples of threes. Dicots have petals in multiples of fours and fives. Identify each of these flowers as monocot or dicot:
   a. 9 petals
   b. 16 petals
   c. 20 petals
   d. 21 petals

Section 14.2

7. Plants have adapted to all the diverse habitats of the Earth. Select three different habitats and describe the challenges that plants face there. Explain what special features that plants have for dealing with these challenges.
8. A tree trunk has a radius of 55 centimeters.
   a. What is the diameter?
   b. What is the circumference?
   c. If the tree grows at a rate of 10 mm a year, how old is the tree?
9. Design an experiment to show how water that is pulled in through the roots of plants is lost through the leaves.

Section 14.3

10. Many people don't realize that tomatoes are fruit. Now that you know the scientific definition of a fruit, make a list of ten other vegetables that may not be properly known as fruit.
11. Franny works in the produce department of a local grocery store. Her manager tells her to mark down all the fruit by 25% for an upcoming sale. She needs your help to determine which items are fruit. Calculate the new prices for the fruit in the chart below. Prices are listed per pound.

Butternut squash:	1.29	Potatoes:	0.40
Lettuce:	0.99	Onion:	0.20
Tomatoes:	2.99	Carrots:	0.25
Asparagus:	1.99	Green peppers:	2.99
Green beans:	1.19	Cabbage:	0.20
Cucumbers:	1.39	Spinach:	1.49
Oranges:	0.69	Bananas:	0.79

12. A seed package label claims that the seeds are 95% viable. If you plant 30 seeds, how many plants can you expect to grow?

Chapter Project

Carnivorous plants

Did you know that some plants can attract, capture, kill, and digest insects and other animal life? Carnivorous plants have been around for thousands of years. For this project you will choose a carnivorous plant and a method for sharing information about the plant with the rest of the class.

1. Choose one of these carnivorous plants

- Venus Fly Trap
- Cobra Lily
- Australian Pitcher Plant
- Tropical Pitcher Plant Vine
- Sundew

2. Choose a method for sharing information

- Tri-fold brochure
- Diorama that shows habitat, plant, and prey
- Working model of carnivorous plant

3. List four sources of information to accompany your project. Only two of the sources can be websites.
4. Make sure your project shows the following:
   a. Common name and scientific name of carnivorous plant
   b. Examples of plant's prey
   c. Explanation of plant's attraction, capture, and killing processes
   d. Information about plant's habitat

Chapter 15

Animals

Have you ever seen a living sea star (shown right)? Sea stars (group name Stelleroidea) are sometimes called starfish, though they are not real fish. But like fish, sea stars are animals. So is a tree frog, a dog, a luna moth, and a great blue heron (all shown right). You can probably name many other types of animals. What characteristics do all animals share? What characteristics do scientists use to place animals into different categories? Read this chapter to learn more about different groups of animals.

Key Questions

1. ***What do you have in common with a worm, sea star, frog, fish, and a bird?***
2. ***Why is a sponge an animal?***
3. ***Why is the sea squirt one of your distant cousins?***

15.1 What Is an Animal?

What do you have in common with a frog, a sponge, and a planarian (Figure 15.1)? If you guessed that you're all animals, you are right! Animals come in many shapes, forms, and sizes. Scientists estimate that there are between 1 and 2 million species of animals! Some, like whales and elephants, are bigger than a truck. Others, like dust mites, are microscopic. What are animals?

The Kingdom Animalia

Invertebrates and vertebrates

Scientists divide the Kingdom Animalia into two major groups: invertebrates and vertebrates. In Chapter 11 you learned that a *vertebrate* is an animal with a backbone. An **invertebrate** is an animal without a backbone. About 98 percent of all animals are invertebrates. This diverse group includes sponges, jellyfish, worms, insects, and mollusks. Only about two percent of all animals are vertebrates which belong to the *Phylum Chordata*. Vertebrates include fish, amphibians, reptiles, birds, and mammals. The table below shows the major animal phyla and their estimated number of living species.

Figure 15.1: *What do these organisms have in common?*

VOCABULARY

invertebrate - an animal without a backbone.

Phylum	Estimated number of species	Phylum	Estimated number of species	Phylum	Estimated number of species	Phylum	Estimated number of species	Phylum	Estimated number of species
Sponges	10,000	Flatworms	25,000	Mollusks	110,000	Arthropods	1,000,000	Vertebrates (Phylum chordata)	50,000
Cnidarians	9,500	Roundworms	80,000	Annelids	9,000	Echinoderms	6,000		

Characteristics of animals

What makes an animal?

Have you ever seen a hydra? If so, you probably used a microscope (Figure 15.2). Like you, a hydra is an animal. **All animals must perform certain functions to stay alive. These include response to the environment, feeding, digestion, respiration, transport of materials, and reproduction.** The process of evolution has produced great diversity in adaptations to these functions. Despite this diversity, most animals share all of the following characteristics.

Figure 15.2: *What do you have in common with a hydra?*

1. **Animals are multicellular and have eukaryotic cells.** Except for sponges, animal cells are arranged into tissues. Tissues are necessary to produce organs and organ systems. Tissues, organs, and organ systems are what enabled the evolution of organisms with large, multicellular bodies.

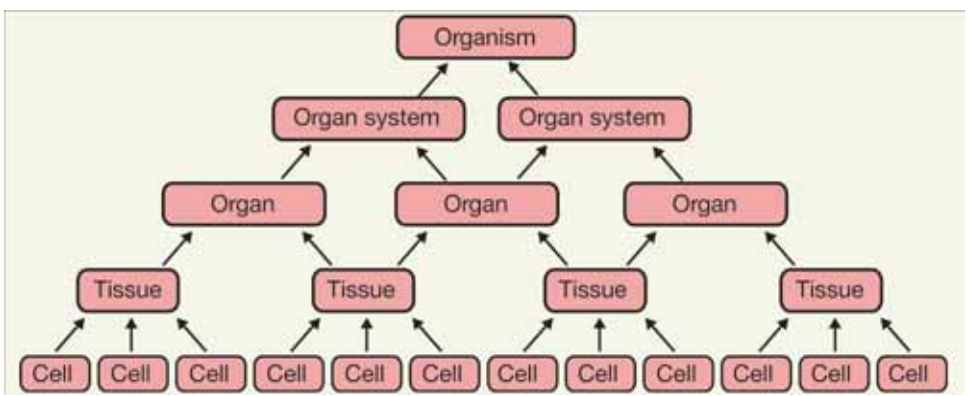
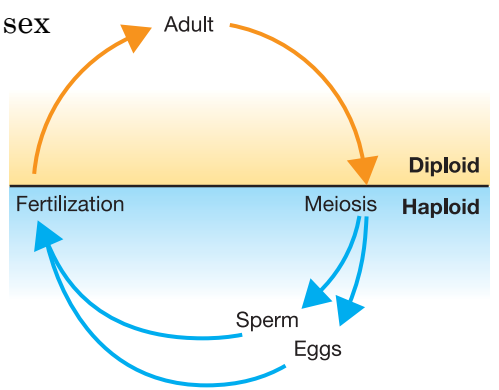


Figure 15.3: *Many animals have a skeleton. This lobster has an external skeleton.*

2. **Animal cells lack cell walls.** A *skeleton* supports the tissues of some animals. The skeleton may be internal or external (Figure 15.3). In some tissues, protein molecules found outside the cell membrane hold the cells together and provide support.

3. **Animals have a period of embryonic development.** Each animal starts out as a one-celled *zygote* (a fertilized egg) that divides into a multicellular *embryo*. Recall that an embryo is an organism in its earliest stage of development. During embryonic development, cells become specialized and tissues form. The growth of tissues, organs, and organ systems requires a period of embryonic development.
4. **Animals are consumers.** A consumer is an organism that eats other organisms. Animals cannot make their own food. To get energy and nutrients, they must eat other organisms or organic substances. This is a major characteristic that sets animals apart from plants.
5. **Animals can move.** Being a consumer often requires movement in order to capture prey. Most animals can move during at least some part of their life cycle.
6. **Most animals have muscle and nervous tissue.** **Muscle tissue** is made of muscle cells (Figure 15.4) and allows animals to move. **Nervous tissue** is made of nerve cells and enables coordinated movement and response to stimuli.
7. **Animals are diploid.** Their sex cells are haploid and are produced by meiosis. A basic animal life cycle is shown to the right.



VOCABULARY

muscle tissue - tissue made of muscle cells that allows animals to move.

nervous tissue - tissue made of nerve cells that enables coordinated movement and response to stimuli.

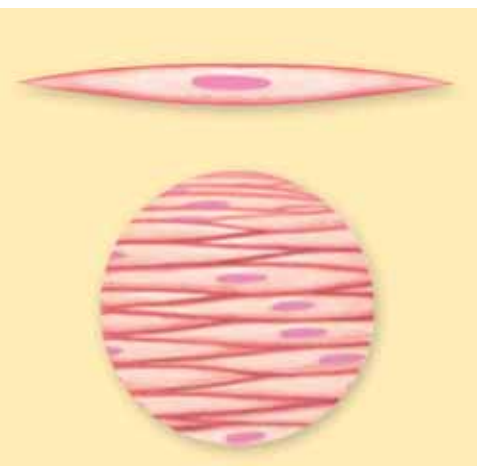
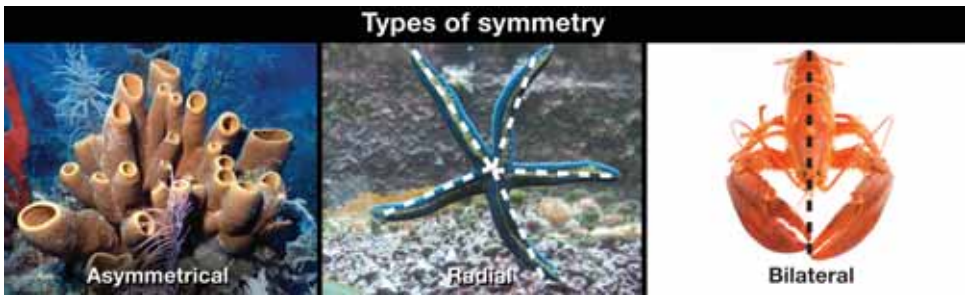


Figure 15.4: *Muscle tissue is made of muscle cells.*

Animal body plan and cavity

Symmetry

The body plan of an animal is called its *symmetry*. Animals that do not have symmetry, like sponges, are called **asymmetrical**. Some animals, like sea urchins, have radial symmetry. **Radial symmetry** means that the body parts are arranged in a circle around a central point. Other animals, like insects and all vertebrates, have bilateral symmetry. In **bilateral symmetry**, the body consists of two similar halves.



VOCABULARY

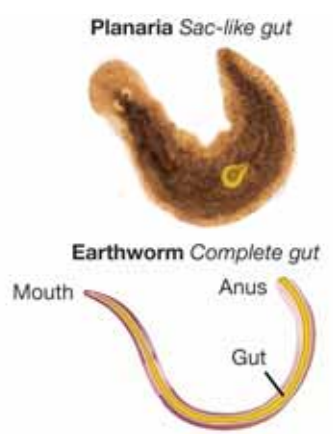
asymmetrical - organisms that do not have symmetry.

radial symmetry - a body plan in which the body parts are arranged in a circle around a central point.

bilateral symmetry - a body plan that consists of two similar halves.

The gut and body cavity

The *gut* is the digestive tract. It enables an animal to digest food outside of its cells. In animals without a gut (like sponges), food is digested inside of their cells. Simple animals have a *sac-like gut* with only one opening. More complex animals have a *complete gut* that runs from a mouth to an anus (shown right). Complex animals also have a *body cavity* that holds the gut and other organs. The body cavity provides an open space for organs to grow and function. The cross-section of an earthworm (Figure 15.5) reveals its body cavity.



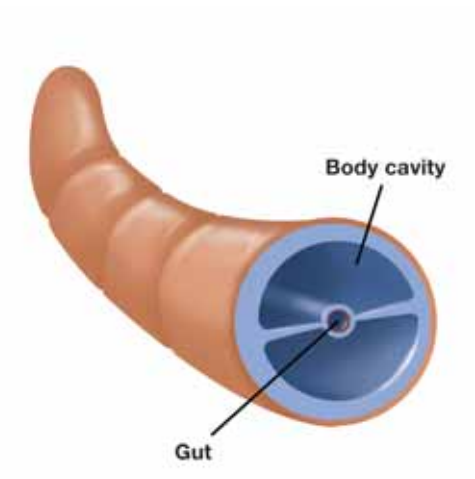


Figure 15.5: *A cross section of an earthworm reveals its body cavity.*

Organ systems

What is an organ system?

Recall that an organ system is a group of organs that work together to perform a function. The simplest animals do not have organ systems. **As animals evolved and became more complex, they developed organ systems to perform basic functions.** Some important organ systems are described below.

Support and movement

The **skeletal system** is a group of organs whose primary function is support. Some animals, like jellyfish and worms, do not have a skeletal system. Others, like lobsters, have *external skeletons* (Figure 15.6). All vertebrates have an *internal skeleton* that is made of organs called *bones*. The **muscular system** is a group of organs whose primary function is movement. In vertebrates, the skeletal and muscular systems work together to provide movement and support.

Circulation

Since animals are multicellular, they need to transport water and other materials to and from all of their cells. In simple animals, substances diffuse into cells from surrounding fluids and tissues. The *circulatory system* is a group of organs whose primary function is to transport materials to and from cells. Since all animals use cellular respiration, their cells need oxygen. Complex animals have a *respiratory system* that allows them to take in oxygen and release *carbon dioxide,* a waste product of cellular respiration.

Digestion

The **digestive system** is a group of organs whose primary function is to take in and digest food, and eliminate wastes. Simple animals do not have digestive systems. Others have simple cavities where food is digested by enzymes. Complex animals have complete digestive systems that run from mouth to anus.

VOCABULARY

skeletal system - a group of organs that provide support.

muscular system - a group of organs whose primary function is movement.

digestive system - a group of organs that take in and digest food, and eliminate wastes.

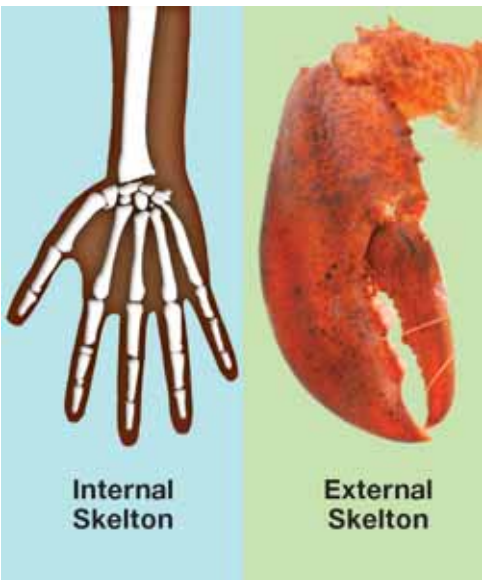


Figure 15.6: *You have an internal skeleton. A lobster has an external skeleton.*

Response To provide quick responses to stimuli, all animals except sponges have fibers called nerves. A **nerve** is a group of nerve cells whose function is to carry signals to control movements. Simple invertebrates have nerves arranged in fibers called *nerve cords* which run through their bodies. The **nervous system** is a group of organs and nerves that gather, interpret, and respond to information. The nervous system of an earthworm consists of a primitive *brain* and ganglia. *Ganglia* are bundles of nerves that control a body part. More complex animals have a nervous system with a brain stored in a well-formed *head*.

Reproduction All animals are capable of sexual reproduction. Some invertebrates are also capable of asexual reproduction. A planarian, for example, can be cut into several pieces, each of which grows into a complete worm (Figure 15.7). The new worms are genetically identical to the parent worm. Sexual reproduction involves exchange of genetic material which creates genetic variation. More complex animals have a **reproductive system** that functions in all reproductive processes. **Reproductive processes include production of sex cells and fertilization.** Some organisms, like earthworms, have both male and female reproductive systems on the same organism. Such an animal is called a **hermaphrodite**. More complex animals like vertebrates have separate male and female individuals.

VOCABULARY

nerve - a group of nerve cells whose function is to carry signals to control movements.

nervous system - a group of organs and nerves that gather, interpret, and respond to information.

reproductive system - a group of organs that function in all reproductive processes.

hermaphrodite - an individual organism that has both male and female reproductive parts.

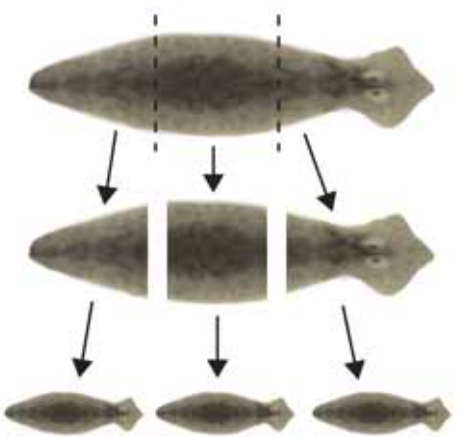


Figure 15.7: *A planarian can be cut into smaller pieces. Each piece develops into a new worm.*

15.1 Section Review

1. Classify each organism as either an invertebrate or a vertebrate:
   a. sponge
   b. turtle
   c. earthworm
   d. planarian
   e. human
2. All of the following are characteristics of animals except:
   a. are multicellular eukaryotes
   b. produce their own food
   c. are consumers
   d. have specialized tissues
3. How are cells, tissues, and organs related?
4. Name a characteristic that animals and plants share. Name a characteristic that distinguishes animals from plants.
5. Which type of symmetry does each object in Figure 15.8 have?
6. Match each organ system to its function.

Organ system	Function
1. circulatory system	a. response and control
2. reproductive system	b. take in and digest food
3. nervous system	c. movement
4. skeletal system	d. support
5. digestive system	e. transport materials
6. muscular system	f. production of sex cells and fertilization

SOLVE IT!

Make an Animal Kingdom pie chart. Use the information in the table on page 308. Convert the estimated number of species into percentages by dividing the number by the total number of animal species. Review pie charts on page 17.

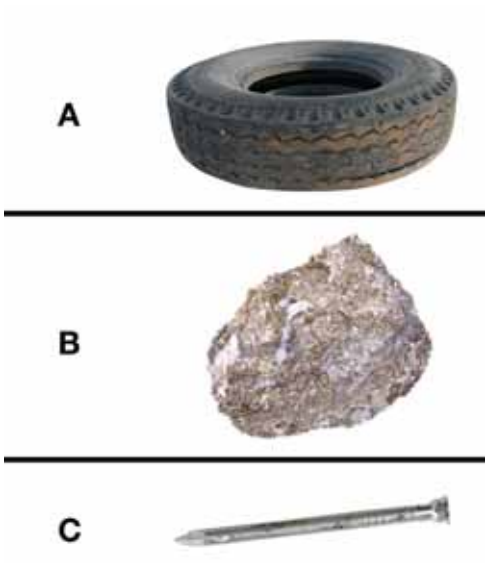


Figure 15.8: *Use this picture to answer question 5.*

15.2 Invertebrate Structure and Function

For centuries, sailors have written about giant, menacing sea monsters with long tentacles. These stories may have originated from sightings of the largest invertebrate—the giant squid. Giant squids can reach lengths of 15 meters and can swim at speeds of up to 30 km/hr! They have long, powerful tentacles that they use to grab their prey. They tear their prey apart with an enormous beak. Because they live in the deep ocean and are rarely seen, giant squids are still a mystery to scientists. Squids (Figure 15.9) are just one of a diverse group of organisms called invertebrates. In this section, you will learn about the structure and function of invertebrates.

Figure 15.9: *A squid.*

Sponges

Phylum Porifera

Sponges belong to the *Phylum Porifera* ("pore bearing.") They are asymmetrical and do not have a body cavity. **Sponges are different than other animals because they do not have organs or tissues.** Different sponges form different shapes, including tubes, fans, blobs, and barrels. Sponges range in size from only a few millimeters to 2 meters tall.

Feeding, reproduction, and habitat

Sponges do not move around. They feed by pulling water into the pores of their bodies and filtering out food particles. They have specialized cells that move water and collect and digest food. They reproduce asexually by a process called *budding*. In budding, a piece of a sponge breaks off and forms a new sponge. They also produce egg and sperm cells for sexual reproduction. Most sponges live in the ocean but there are a few freshwater species. Figure 15.10 shows a cross section of a sponge.

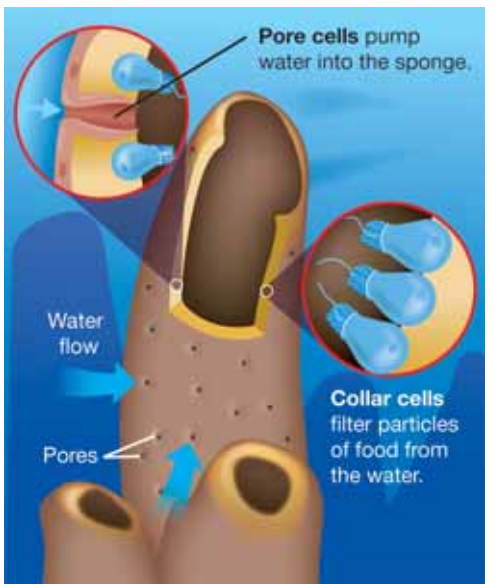


Figure 15.10: *A cross section of a simple sponge.*

Cnidarians and flatworms

Jellyfish are Cnidarians

The *Phylum Cnidaria* includes jellyfish, coral, sea anemones, and hydra. They have radial symmetry and do not have a body cavity. **Cnidarians have differentiated cells that are organized into two layers of tissues and nerves that form a network.** Cnidarians have a free-swimming form (called a *medusa*) and a stationary form (called a *polyp*). The jellyfish (shown right) is an example of the free-swimming form. Figure 15.11 shows a sea anemone, an example of the stationary form. The life cycle of most cnidarians includes both forms. All cnidarians live in water. They reproduce sexually and asexually.

Figure 15.11: *A sea anemone is an example of a cnidarian in the polyp form.*

Planarians are flatworms

Planarians belong to the *Phylum Platyhelminthes*—the flatworms. **Flatworms are the simplest animals having bilateral symmetry.** They have a sac-like gut but no body cavity. Figure 15.12 shows the anatomy of a planarian. Planarians secrete digestive enzymes onto their food and suck the food particles through an organ called a *pharynx*. They digest food in a *gastrovascular cavity*. Planarians have a primitive nervous system that consists of two *eyespots* connected to ganglia. Both are centralized in a head-like region. The ganglia act as a control center for sensory functions and movement. Planarians also have nerve cords that run down each side of their body, connected by other nerves. Planarians are hermaphrodites and reproduce both sexually and asexually.

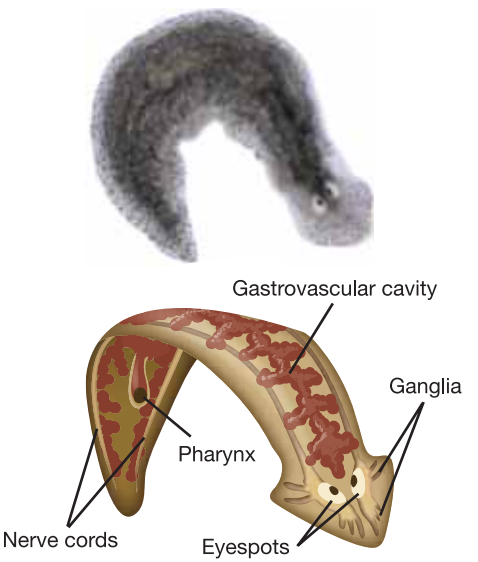
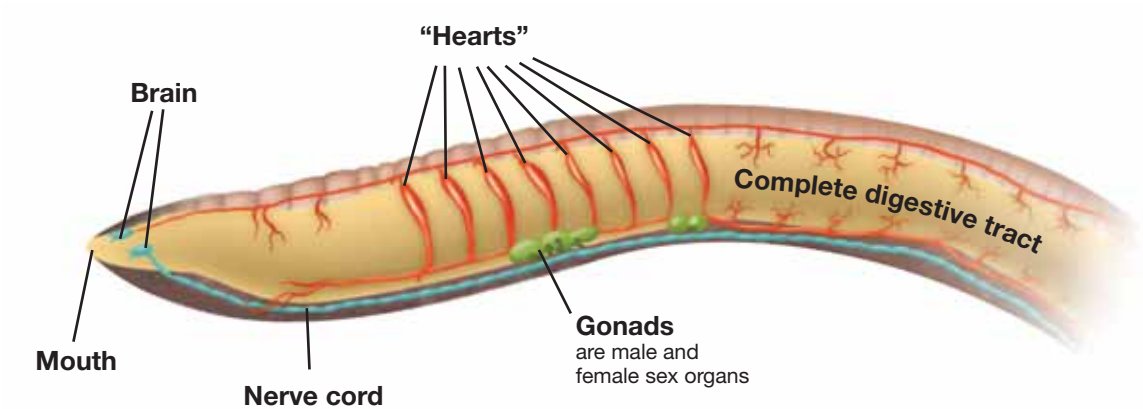


Figure 15.12: *The anatomy of a planarian.*

Roundworms and annelids

Roundworms Members of the *Phylum Nematoda* are called roundworms. Figure 15.13 shows a marine roundworm. **Roundworms are the simplest animals with a complete gut that runs from mouth to anus**. They have bilateral symmetry and a primitive body cavity. You may have never heard of roundworms but they play an important role in Earth's ecology. Billions of microscopic roundworms live in the soil. They eat bacteria and fungi and release compounds that help plants grow. Some scientists think that roundworms may be the most numerous animals on Earth! Roundworms reproduce asexually and sexually.

Annelids Earthworms belong to the *Phylum Annelida*—the annelids. **All annelids have bodies that are divided into individual segments.** Annelids have bilateral symmetry and a true body cavity. Earthworms are very important because they enrich the soil. They have a closed circulatory system with several heart-like structures that pump blood. Earthworms must mate to reproduce even though they are hermaphrodites. The anatomy of an earthworm is shown below.



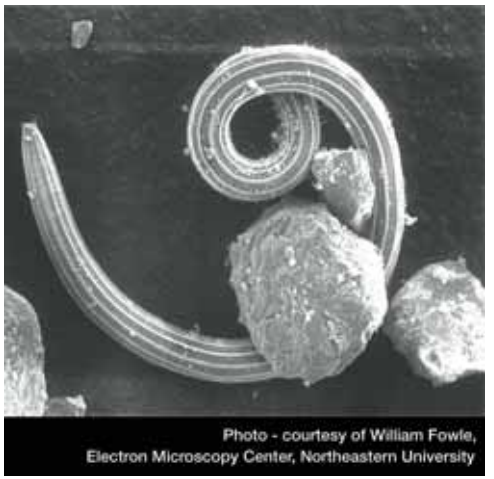


Figure 15.13: *A marine roundworm next to grains of sand. As you can tell, many roundworms are very small.*

STUDY SKILLS

Make phylum flashcards

Write the phylum name on one side of a 3 x 5 card. Write the major characteristics and examples on the other side of the card. You may also find pictures in magazines or the Internet and paste them onto the card. Do this for each animal phylum.

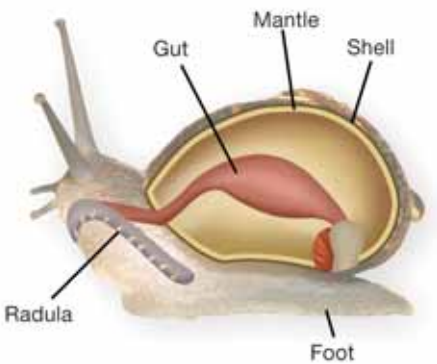
Mollusks

The Phylum Mollusca

Snails, clams, and squids are all members of the *Phylum Mollusca*—the mollusks (Figure 15.14). Mollusks are more advanced than roundworms but not as advanced as annelids. There is great diversity among mollusks, but each type of mollusk has a similar body plan. **Mollusks have bilateral symmetry and a true body cavity. The body of a mollusk typically has a *foot*, *gut*, *mantle*, and *shell*.**

The mollusk body

The *foot* is a soft, muscular structure that usually contains the *mouth*. The mouth may have a feeding structure called a *radula*. The *gut* is the mollusk's digestive tract. The *mantle* is a thin layer of tissue that surrounds part of the mollusk's body. Glands in the mantle secrete calcium carbonate, a compound that makes up the *shell*. Some mollusks do not have a shell but may have evolved from ancestors that had a shell.



Other organ systems and reproduction

Mollusks have a circulatory system with a simple heart. They also have a nervous system. Clams and their relatives have a simple nervous system with nerve cords and a few ganglia. Octopi and their relatives have a more advanced nervous system. They have a well-developed brain and eyes. They even have a sense of touch and taste. All mollusks reproduce sexually and have a life cycle that includes a stage called a larva. Some mollusks are hermaphrodites.

Figure 15.14: *Representative mollusks.*

Arthropods

What are arthropods?

The *Phylum Arthropoda* includes insects, spiders, and crustaceans (lobsters and crabs). **Arthropods have segmented bodies, jointed limbs, an exoskeleton, and well-developed organ systems.** They have bilateral symmetry and a true body cavity. Arthropods are the most successful animals on Earth. For each human, scientists estimate that there are over 200 million insects alone! Scientists believe that annelids and arthropods evolved from a common ancestor. The first arthropod was the *trilobite* (Figure 15.15). Trilobite fossils have been dated at about 400 million years old!

Figure 15.15: *A trilobite fossil.*

The insect body

Like annelids, insect bodies are segmented. In insects, some segments grow together to form three distinct regions: a *head*, a *thorax*, and an *abdomen*. Many segments contain specialized parts like wings, antennae, pinchers, and claws. Insects have a head with a well-developed brain. Most insects have *compound eyes* that are made of many identical light-sensing cells (right). They can see images, but not as well as you. Have you ever tried to sneak up on an insect? Even from behind, an insect can sense you are there, in part because they have antennae. *Antennae* are organs that respond to smell, touch, and taste. Figure 15.16 shows the external features of one insect, a cricket.

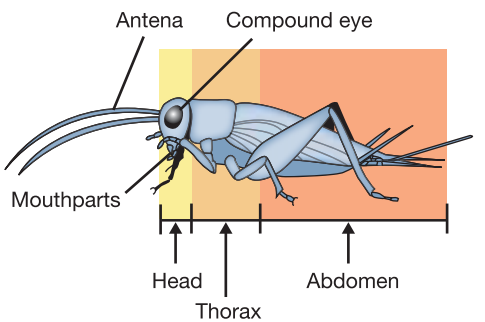


Figure 15.16: *The external features of a cricket.*

Life cycles

All arthropods reproduce sexually and most have separate male and female individuals. Many have a life cycle that involves a change in form called *metamorphosis*. For example, a moth starts off as a fertilized egg that hatches into a *larva* (the caterpillar). The larva transforms into a *pupa* (the cocoon). The adult moth eventually emerges from the pupa.

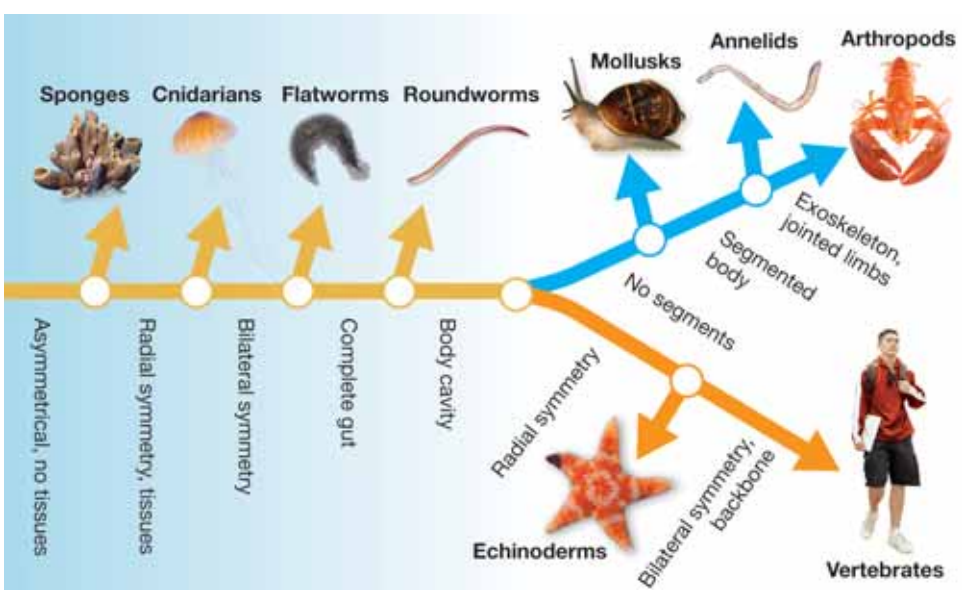
Echinoderms and a summary of the invertebrate phyla

What are echinoderms?

The *Phylum Echinodermata* (meaning "spiny skin") includes starfish, sea urchins, and sea cucumbers (Figure 15.17). **Echinoderms have radial symmetry, a body cavity, an internal skeleton, and spiny skin.** They also have an unusual feature called a water vascular system. The *water vascular system* is a network of fluid-filled canals connected to hundreds of tiny, tube-like feet. The water vascular system helps them move and capture food. Echinoderms do not have a head or a brain but they do have specialized nerve cells that provide senses of touch, taste, and smell. Some species have eyespots that can only detect light and dark. All echinoderms live in marine environments. They reproduce sexually and most have separate male and female individuals.

Summary: the evolution of animal phyla

The diagram below shows evolutionary relationships among the invertebrate phyla and vertebrates.



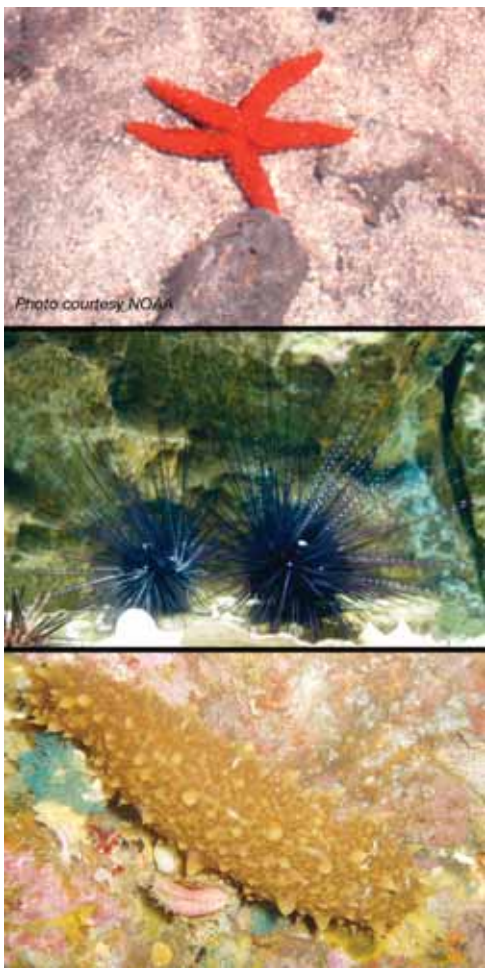


Figure 15.17: *Echinoderms include starfish (top), sea urchins (middle), and sea cucumbers (bottom).*

15.2 Section Review

1. Why do scientists classify sponges as animals?
2. Complete the table below. The first row is done for you.

Phylum	Symmetry	Body cavity	Example
Porifera	asymmetrical	none	sponges
Cnidaria			
Flatworm			
Roundworm			
Annelid			
Mollusk			
Arthropod			
Echinoderm			

3. Use the list of phyla in the table above to answer the following questions:
   a. Which phylum does not have tissues, organs, or nerves?
   b. Which phyla have a well-developed nervous system?
   c. Which phyla do not have a brain or head?
   d. Which phyla do not have an internal or external skeleton or shell?
   e. Which phylum has an exoskeleton?
   f. Which phyla have segmented bodies?
   g. Which phyla have a complete gut?
   h. Which phylum has a foot, mantle, and shell?
   i. Which phyla live only in water?

CHALLENGE

The diagram on the previous page shows evolutionary relationships among invertebrates and vertebrates. The trilobite shown below is a fossil organism. Propose where to place the trilobite on the diagram.

15.3 Vertebrate Structure and Function

Have you ever seen a sea squirt (Figure 15.18)? At first glance, they look similar to a sponge. Did you know that you are more closely related to a sea squirt than a squid? Humans and sea squirts are members of the *Phylum Chordata* (called *chordates*). All chordates have a structure called a notochord. A **notochord** is a flexible, rod-shaped structure found in the embryos of all chordates. Chordates also have a *hollow nerve cord*. The hollow nerve chord is fluid-filled and runs along the back of the organism. Sea squirt larvae have both of these characteristics. In this section, you will learn about *vertebrates*—the largest group of chordates.

Figure 15.18: *A sea squirt adult.*

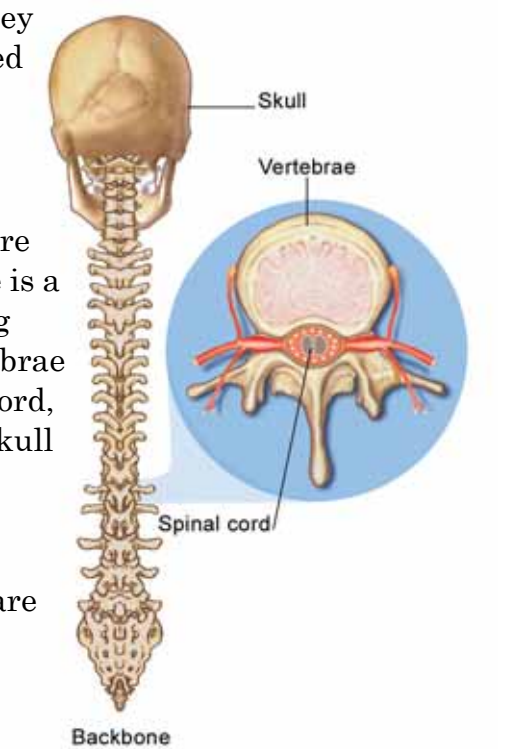
Characteristics of vertebrates

Vertebrates

Vertebrates include fish, amphibians, reptiles, birds, and mammals. They share the characteristics discussed below.

Vertebrates have a backbone and skull

All vertebrates have a *backbone* and a *skull*. The backbone and skull of a human are shown at the right. The backbone is a segmented column of interlocking bones called **vertebrae**. The vertebrae surround and protect the nerve cord, also called the *spinal cord*. The skull is made of cartilage or bone and protects the brain. *Cartilage* is a tough, elastic tissue found in the bodies of vertebrates. Your ears are made of cartilage. *Bone* is harder and denser than cartilage.



VOCABULARY

notochord - a flexible, rod-shaped structure found in the embryos of all chordates.

vertebrae - a set of interlocking bones that form the backbone of a vertebrate.

Internal skeleton

All vertebrates have an internal skeleton. **The skeleton provides support, protection, and a place for muscles to be attached.** The skeleton of all vertebrate embryos is made of cartilage. In most vertebrates, cartilage is replaced by bone as the organism grows and develops.

Bones and muscles work together

The bones and muscles of vertebrates work together to provide a structural framework for movement. Muscles are attached to bones by tendons. A *tendon* is band of tough, fibrous tissue that connects a muscle to part of a bone. Nerve signals cause muscle groups to contract (shorten) and relax which, in turn, causes bones to move.

Body cavity

All vertebrates have a body cavity that holds the organ systems. The body cavity of vertebrates has two regions (Figure 15.19). The *thoracic cavity* holds the heart and the lungs of air-breathing vertebrates. The *abdominal cavity* holds the digestive organs including the stomach, intestines, and liver.

Organ systems

Vertebrates have well-developed organ systems. The major organ systems are summarized in Table 15.1.

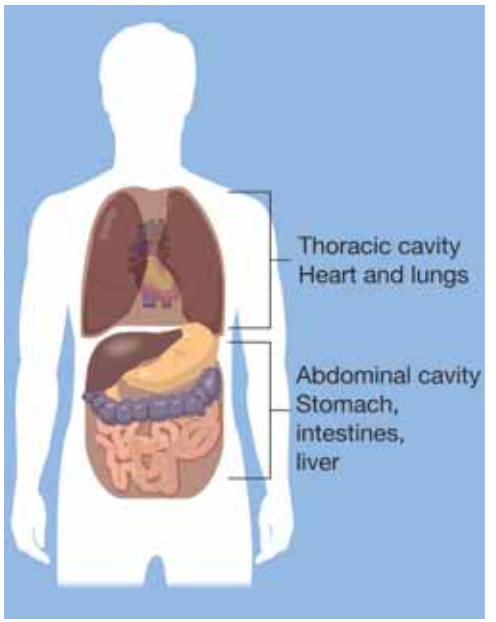


Figure 15.19: *The body cavity of a vertebrate.*

Table 15.1: Vertebrate organ systems, their functions, and major organs.

Organ system	Main function	Major organs
Integumentary	Barrier to external environment	Skin, scales, feathers, fur
Skeletal	Support and movement	Bones, cartilage
Muscular	Movement	Muscles, tendons
Digestive	Take in and digest food	Stomach, intestines, liver, pancreas
Respiratory	Exchange of oxygen and carbon dioxide	Lungs or gills
Circulatory	Transport materials to cells	Heart, blood vessels
Reproductive	Produce offspring	Testes, ovaries
Nervous	Response and movement	Brain, nerves
Urinary	Clean wastes from the blood	Kidneys
Endocrine	Regulate body functions	Glands that produce hormones

Vertebrate organs are made of four types of tissues

Four types of tissues

An *organ* is a group of tissues that function together. Vertebrate organs are made of four types of tissues: epithelial, connective, muscle, and nerve. Figure 15.20 shows some organs where each tissue is found.

Epithelial tissue

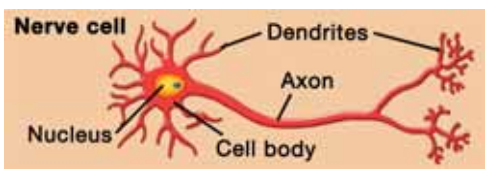
Epithelial tissue is made up of closely-packed cells in one or more layers. It forms the covering or lining of all internal and external body surfaces. Epithelial tissue protects the body and organs from dehydration, damage, and invasion by bacteria.

Connective tissue

Connective tissue provides strength, support, and protection to the soft parts of the body. The cells of connective tissue are embedded in a large amount of extracellular material. This material, secreted by the cells, is made up of protein fibers. Cartilage and bone are both made of connective tissue. Another type of connective tissue is the binding material for organs. Muscles are surrounded by a layer of connective tissue.

Nerve tissue

Nerve tissue transmits signals throughout the body. It is made of specialized cells called *neurons*. Each neuron (shown right) consists of a cell body which contains the nucleus, *dendrites*, and a single long fiber called the *axon*. The nerve signal, called an *impulse,* is conducted along the axon.



Muscle tissue

Three kinds of *muscle tissue* are found in vertebrates. *Skeletal muscle* is made of long fibers in bundles and causes bones to move. *Smooth muscle* lines the walls of organs and blood vessels. Contractions of smooth muscle help organs like the stomach and intestines to function. The heart is made of *cardiac muscle*.

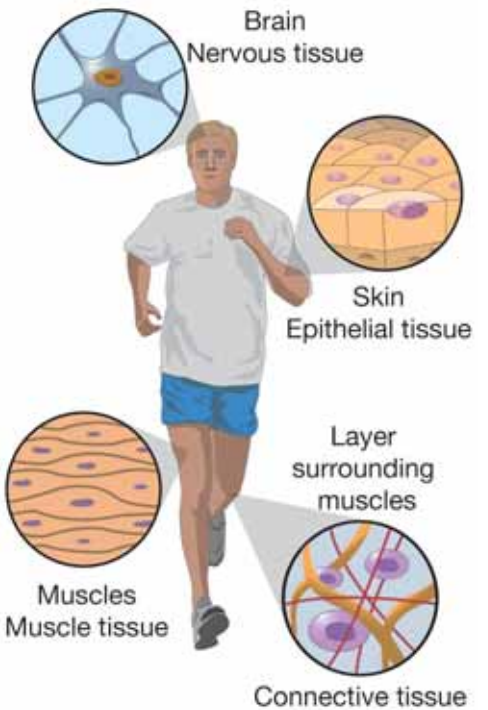


Figure 15.20: *The four types of tissues work together in the stomach.*

VOCABULARY

epithelial tissue - made up of closely packed cells in one or more layers. Lines the internal and external body surfaces.

connective tissue - provides strength, support, and protection to soft body parts.

Other characteristics of vertebrates

Temperature and chemical reactions

Most animals need to keep their bodies at a certain temperature. This is because the chemical reactions inside of their cells can operate only at temperatures that are neither too hot nor too cold.

Ectotherms

Animals that are not able to control their body temperature are called **ectotherms**. They are sometimes called *cold-blooded*. The body temperature of an ectotherm changes with the temperature of its environment. When it is cool, some ectotherms warm their bodies by basking in the sun (Figure 15.21). Nearly all fish, amphibians, and reptiles are ectotherms.

Endotherms

Birds and mammals are endotherms. **Endotherms** use the heat produced by the chemical reactions in their cells to maintain a constant body temperature. Endotherms are sometimes called *warm-blooded*. Because they are able to keep their body temperature warm, many endotherms are adapted to survive in cold climates.

Fertilization and development

Vertebrates reproduce sexually and have separate male and female individuals. Fertilization in vertebrates may occur externally or internally. In **external fertilization**, the female lays eggs and the male drops sperm onto them. Most fish and amphibians use external fertilization. In **internal fertilization**, the male deposits sperm inside of the female. In most reptiles and birds, the female lays eggs that contain the developing embryo. The eggs hatch and the young offspring emerge. In some cases, the eggs develop and hatch inside of the mother. In most mammals, the fertilized egg becomes an embryo that develops inside of the mother. Then, the mother gives birth to fully-developed offspring.

Figure 15.21: *A lizard basks in the sun to warm its body temperature.*

VOCABULARY

ectotherms - animals that are not able to control their body temperature.

endotherms - animals that use the heat produced by chemical reactions in their cells to maintain a constant body temperature.

external fertilization - the female lays eggs and the male deposits sperm on the eggs.

internal fertilization - the male deposits sperm inside of the female.

Fish

What are fish? **Fish are ectothermic, aquatic vertebrates with fins, gills, and a streamlined body**. They were the first vertebrates, and evolved about 500 million years ago. There are three classes of fish living today (Figure 15.22). *Jawless fish*, as the name suggests, do not have jaws. The lamprey is an example. *Cartilaginous fish*—the sharks and rays—have skeletons made of cartilage. They have fully-functional jaws and a backbone. *Bony fish* include all other living fish species. They have a bony skeleton.

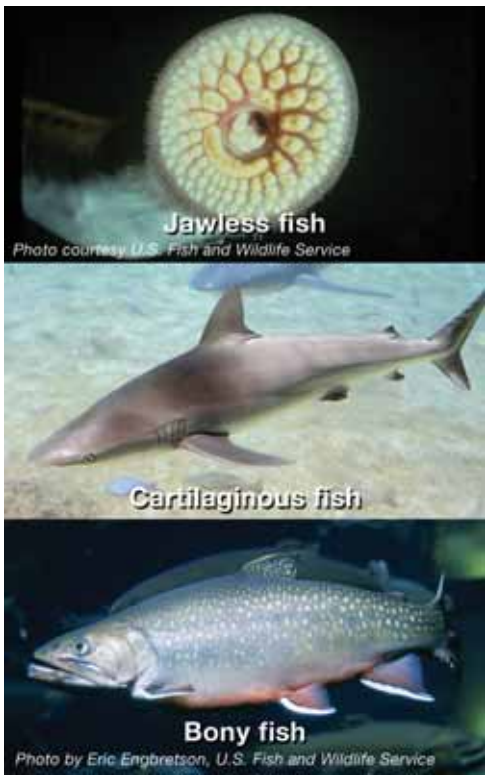
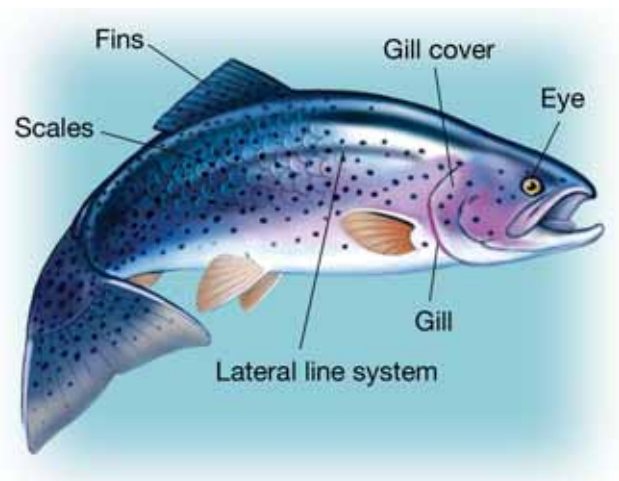


Figure 15.22: *The three classes of fish.*

Adaptations Fish have many adaptations for life in water. *Fins* are fanlike structures that help fish move, balance, steer, and stop. Fish have strong muscles attached to their backbones allowing them to move their bodies and increase their speed through the water. The bodies of many fish are covered with *scales* for protection. Most fish have a **lateral line system** that consists of rows of sense organs along each side. This system detects vibrations. To breathe, fish have **gills** that extract oxygen from the water and remove carbon dioxide from the blood.



Reproduction External fertilization is more common in fish species than internal fertilization. Usually, the eggs hatch outside of the mother's body but in some species, the eggs develop and hatch inside of the mother, who gives birth to live offspring.

VOCABULARY

lateral line system - rows of sense organs along each side of a fish that detect vibrations.

gills - organs that extract oxygen from water and remove carbon dioxide from the blood.

Amphibians

What are amphibians?

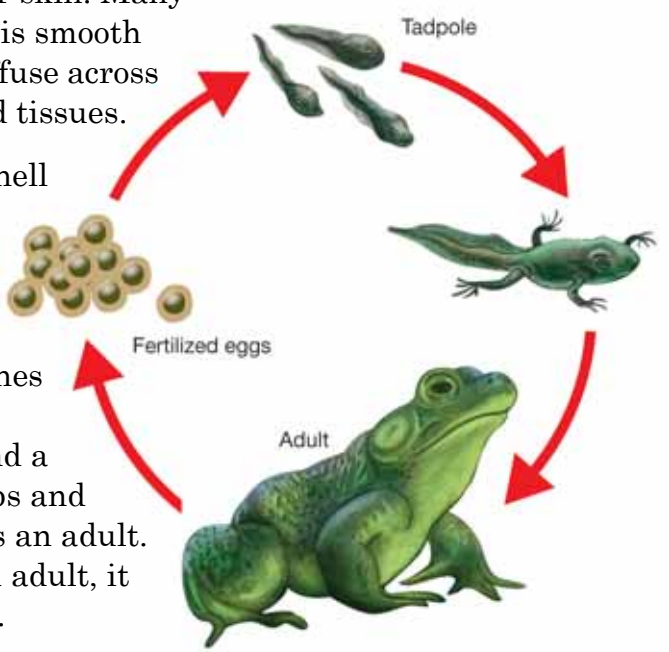
Amphibians are ectothermic, smooth-skinned vertebrates, such as frogs and salamanders, that usually hatch as an aquatic larva with gills. Scientists think the first amphibians evolved from an ancestor of the lungfish (Figure 15.23). Lungfish have lungs like most amphibians. A **lung** is a sac-like organ that takes oxygen from the air and transfers it to the blood. Lungfish have limb-like fins that help them to scuttle across mud on the shore. The fins of the ancient lungfish evolved to become strong enough to support their body weight on land. Eventually, amphibians that could live on land most of the time evolved.

Adaptations

Many amphibians are adapted to live part of their lives on land. Many live in damp habitats and some live in the water. Amphibians breathe by taking oxygen into their lungs. But many also absorb oxygen through their skin. Many amphibians have thin skin that is smooth and moist. Oxygen can easily diffuse across the skin and into their blood and tissues.

Reproduction and life cycle

Amphibian eggs do not have a shell and are usually laid in the water. In frogs, fertilization is external while salamanders have internal fertilization. The amphibian embryo usually hatches in the water as a larva called a *tadpole*. The tadpole has gills and a tail. Eventually, it develops limbs and lungs, loses its tail, and becomes an adult. Once the amphibian becomes an adult, it can live part of the time on land.



VOCABULARY

lung - a sac-like organ that takes oxygen from the air and transfers it to the blood.

Figure 15.23: *A lungfish.*

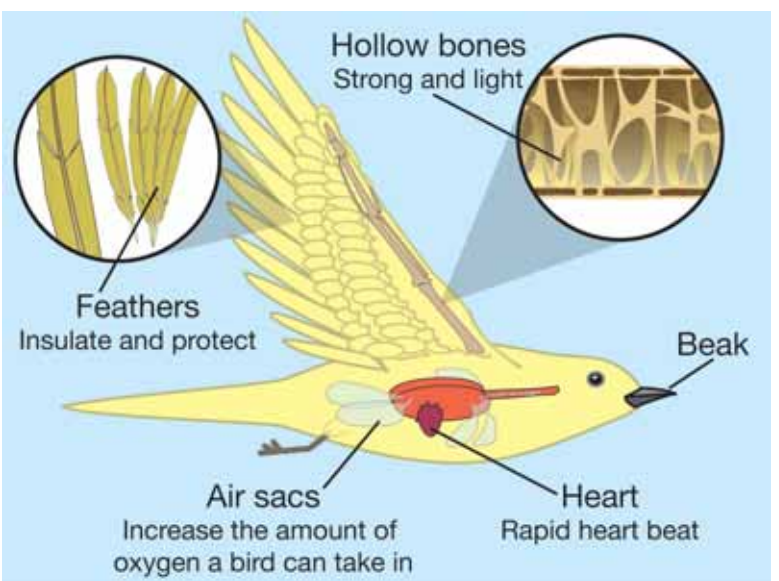
Reptiles and birds

Reptile characteristics

Reptiles are ectothermic, egg-laying vertebrates, that have an external covering of scales and breathe with lungs. Examples of reptiles are lizards, snakes, turtles, crocodiles, and dinosaurs (now extinct). Reptiles are adapted for life on land, although some, like crocodiles, live in water. The most important adaptation for life on land was the amniotic egg. An **amniotic egg** is surrounded by a shell that protects it from drying out. The parts of an amniotic egg are shown in Figure 15.24. Amniotic eggs are fertilized inside of the female. A shell then forms around the egg and it is laid on land. The embryo develops into a tiny reptile. Unlike amphibians, reptiles do not have a larval stage.

Bird characteristics

Birds are endothermic, egg-laying vertebrates with forelimbs modified to form wings. Like reptiles, birds have amniotic eggs. However, bird eggs have a harder shell than the leathery shells of reptile eggs. Also, birds use their body heat to keep their eggs warm until they hatch. This process is called *brooding*. Unlike reptiles, birds are endothermic and some species can tolerate the cold polar regions. Birds have beaks instead of jaws. They also have many adaptations for flight such as feathers, wings, hollow bones, and air sacs. The structures of a bird and their functions are shown to the left.



VOCABULARY

amniotic egg - an egg that is surrounded by a shell to prevent it from drying out.

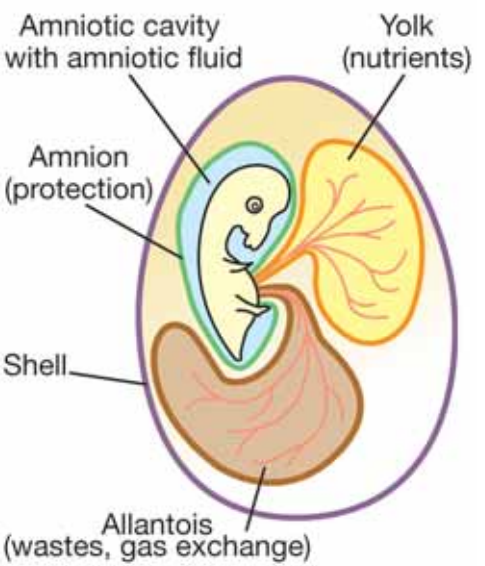


Figure 15.24: *The structure of the amniotic egg.*

Mammals

What is a mammal?

Mammals are endothermic vertebrates that have mammary glands. **Mammary glands** are organs that produce a nutritious fluid called milk. Most mammals are covered with hair or fur and have specialized teeth that help them to cut or chew their food. Mammals have highly-developed nervous systems and large brains. As a result, many mammal species have evolved intelligence and resourcefulness. Figure 15.25 show some examples of mammals.

Reproduction

Mammals have internal fertilization and most give birth to developed young. An exception is the duck-billed platypus which lays eggs! Most mammals are *placental mammals*. In placental mammals, embryos develop inside the mother in an organ called a *uterus*. An attachment to the uterus called a **placenta** supplies food and oxygen from the mother's blood to the developing embryo. The *gestation period* is the time it takes for an embryo to develop and varies among mammals. In humans, the gestation period is around nine months. Despite differences in development, all young mammals are fed milk from their mother's mammary glands.

Evolution of mammals

Mammals evolved from a now-extinct group of reptiles called **therapsids** (shown to the right). The earliest true mammals appeared over 200 million years ago. Since that time, mammals have evolved to live in different habitats. Modern mammals include animals that live on land and in water. The largest mammal—the blue whale—can grow to be over 30 meters long! The smallest mammal—the bumblebee bat—is only about 3 centimeters long and weighs about 2 grams!

VOCABULARY

mammary glands - organs that produce a nutritious fluid called milk.

placenta - an attachment to the uterus that supplies food and oxygen from the mother's blood to the embryo.

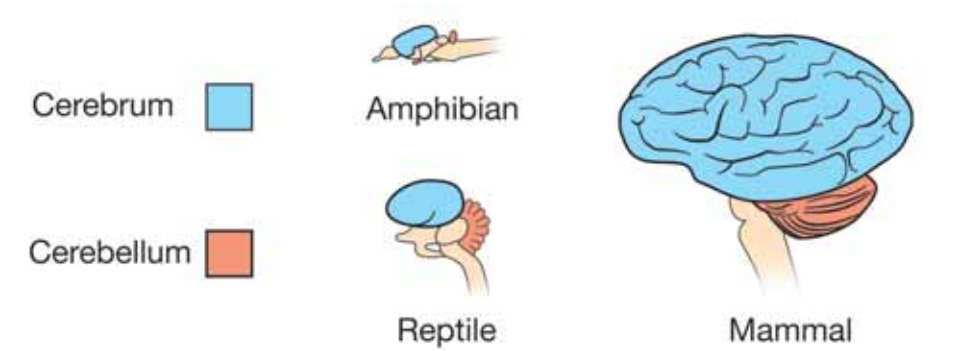
therapsids - an extinct group of reptiles from which mammals evolved.

Figure 15.25: *Some mammals.*

The mammalian brain and eye

The central nervous system

The brain of a mammal is more developed than that of other vertebrates. One difference is that mammals have a larger cerebrum and cerebellum, as shown below. The *cerebrum* is the part of the brain where most thinking takes place. The *cerebellum* coordinates movement and balance. Their well-developed brains allow mammals to think, learn, and quickly respond to changes in their environment.



The mammalian eye

Vision is an important way mammals perceive their environment. Figure 15.26 shows the structures of the mammalian eye. The *lens* is a transparent structure that, along with the **cornea**, refracts and focuses light. The *pupil* is a hole in the iris that controls the amount of light entering the eye. The *iris* is the pigmented part of the eye. A ring of tiny *ciliary muscles* connects the lens to the inner surface of the iris. Ciliary muscles contract to change the shape of the lens. The **retina** is a thin layer of cells in the back of the eye that converts light into nerve signals. Those signals are transmitted to the brain by the **optic nerve**. The *sclera* is the protective outer layer that gives the eye its shape. The *chroroid* provides oxygen and nutrients to the retina. The eye is filled with a jelly-like substance called *vitreous* and *aqueous humor*. *External muscles* control eye movement and help focus images.

VOCABULARY

cornea - part of the eye that, along with the lens, refracts and focuses light.

retina - a thin layer of cells in the back of the eye that converts light into nerve signals.

optic nerve - a nerve that transmits signals from the eye to the brain.

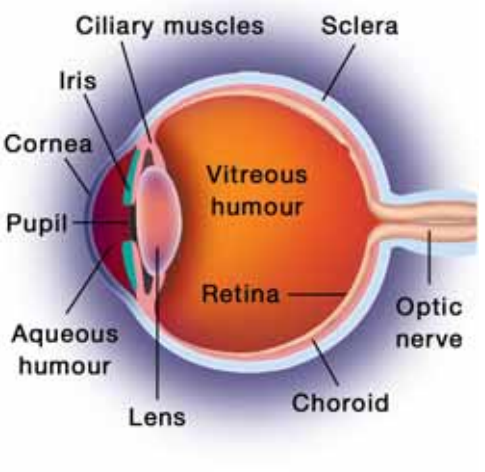


Figure 15.26: *The mammalian eye.*

15.3 Section Review

1. What are the similarities between a sea squirt and a fish? What are the differences?
2. Name the main function of each organ system.
   a. respiratory
   b. excretory
   c. integumentary
   d. circulatory
3. Name one organ from each system in question 2.
4. List the four types of tissues that make up vertebrate organs and explain their functions.
5. Name the three types of muscle tissue and where each is found in the body.
6. Tell whether each organism is an ectotherm or an endotherm.
   a. cat
   b. frog
   c. turtle
   d. swan
7. Match the organisms to their place on the cladogram in Figure 15.27. Explain your reasoning for each.
8. Name the function of each structure of the mammalian eye.
   a. lens
   b. cornea
   c. sclera
   d. pupil
   e. retina

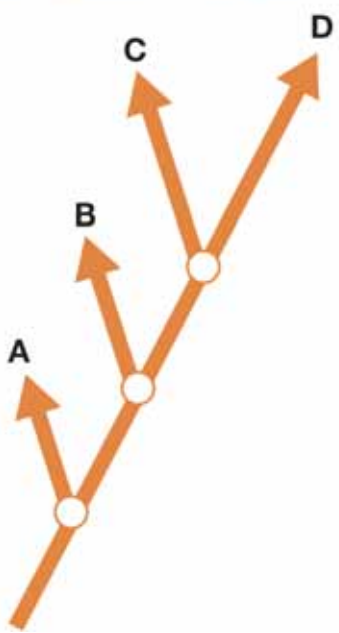


Figure 15.27: *Use the diagram above to answer question 7.*

RESEARCH CONNECTION

Snails vs. Crabs: An Undersea Arms Race

Wedged in the rocky hollow of a coral reef, a red-spotted crab, *Carpilius maculatus,* reaches out with its hefty right claw and grabs an unsuspecting snail from the ocean floor. Snip! The crab's claw clamps down on the shell's thick lip, producing a hairline crack.

The snail withdraws deep into its knobby shell, safely out of the crab's reach. Unable to cut the shell open, the hungry crab tries another tactic: squeezing the shell with crushing force until at last it gives way with a loud pop. The snail's armor shatters into tiny pieces. The crab, having won this round of battle, enjoys her feast.

An embedded observer

Witnessing this struggle off the coast of Guam is Dr. Geerat (Gary) Vermeij, a marine biologist. Earlier, Dr. Vermeij studied how snail shells differ around the world. He noted that some differences in shells can't be explained simply by environmental conditions. Tropical shells from Guam and Jamaica, for example, have evolved differently despite their similar climates. Now he is ready to test a new hypothesis. He thinks that some variations in shells may be linked to the different types of predators faced by snails in different areas.

Testing the hypothesis

Dr. Vermeij, who has been blind since age three, holds lightly to an assistant's elbow. Together they wade in the shallow water along Guam's seashore until they reach a coral reef. Then Dr. Vermeij uses his hands to explore the habitat, gathering live snails, empty shells, and several species of crabs including *Carpilius maculatus*. These are carried back to salt water aquariums in a marine lab.

The snails are measured, numbered, and placed in a tank. Each crab gets its own aquarium with rocks for shelter. The crabs are given snails of various sizes and shapes for prey.

Throughout the summer, Dr. Vermeij and his assistants kept careful records of the outcome of each crab and snail encounter. They learned which features help the snails withstand attacks and which features make them likely to become crab lunch.

Although his observations showed that crabs crush snails, this didn't yet prove that predators influence the size and shapes of shells in the wild. Dr. Vermeij still needed to know if shell breakage is a frequent cause of death for snails in Guam and other tropical environments.

Attitude adjustment

Dr. Vermeij went back to the reef, this time collecting hundreds of empty shells. Back in the lab, he turned each one over in his hands. He searched for holes or cracks like the ones made by his captive crabs. He found that more than 50 percent of these shells had telltale signs of predator breakage.

Dr. Vermeij also took note of scars on the shells. When he was a child collecting shells, he hated finding these raised, jagged lines intruding on a shell's smooth surface. Now he learned to recognize these scars as sites of *unsuccessful* attacks. The scars were like arrows pointing to strong defensive features.The scars provided evidence that the snail's predators sometimes fail. When predators fail, the snail's defensive traits can be passed down to the next generation. This is how stronger defenses evolve.

Hermit crab helpers

Next, Dr. Vermeij wanted to compare the ability of Guam snails to resist predator breakage with the ability of other tropical snails.

Dr. Vermeij traveled to Jamaica to sample shells there. He found that less than 25 percent of Jamaican shells showed signs of breakage by predators. He took a bunch of empty Jamaican shells back to Guam. He wanted to see how successful Guam's crabs would be at breaking these shells.

There was one problem. Crabs don't go around breaking empty shells. They're looking for food.

Dr. Vermeij realized that luckily, crabs aren't very picky eaters. So he collected a bunch of hermit crabs from Guam and offered them new housing in Jamaican shells. Then he put these shells in tanks holding Guam's *Carpilius* crabs.

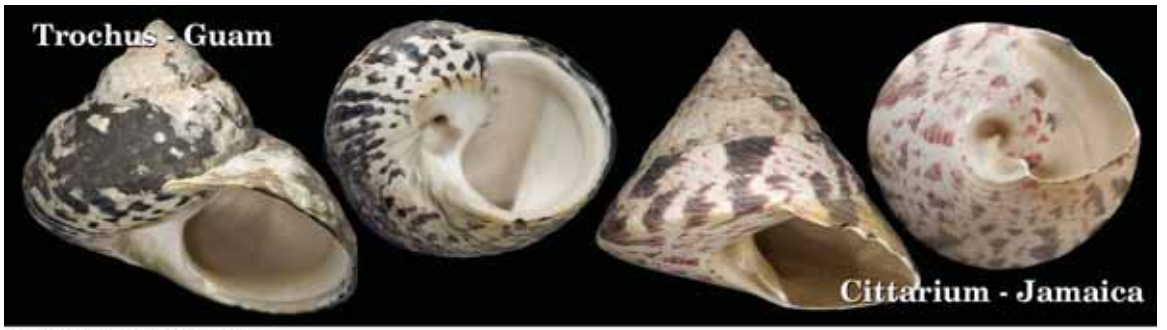


Photo - courtesy of Mary Graziose

Most of these Jamaican shells couldn't stand up to the predators from Guam. They offered larger openings, a thinner outer lip, and a groove on the underside that provided a nice place for a crab to grip. Similar snails from Guam had evolved much better defenses.

The crushing power of crabs

Why then, were Jamaican snails so much less likely to die from breakage by predators? Dr. Vermeij suspected that perhaps Jamaican crabs were less powerful.

To test this idea, Dr. Vermeij figured out a way to calculate the mechanical advantage of a crab claw's moveable finger based on its size and shape. He measured hundreds of crab specimens in the Smithsonian collection. He found that the two species of *Carpilius* found around Guam had thicker, more powerful claws than the single Jamaican species. Other types of crabs showed similar patterns.

The evidence was mounting. Where stronger crabs inhabit the waters, snails develop more elaborate structures to defend themselves. Where crabs are less of a threat, snails are not as well fortified.

Dr. Vermeij shared his research in several journal articles. After further study of predator-prey patterns in fossils, Dr. Vermeij wrote a book called *Evolution and Escalation: An Ecological History of Life*. He is now considered one of the world's leading experts on mollusks, both ancient and modern.

Questions:

1. What question was Dr. Vermeij trying to answer in Guam?
2. Dr. Vermeij has said that if you want to be a scientist, some of the qualities you need are boundless curiosity, a willingness to risk being wrong sometimes, creative thinking, and a passion for doing the hard work. How does Dr. Vermeij demonstrate each of these qualities?
3. Dr. Vermeij said that scarred and broken shells became "mines of information." What did he learn from them?

CHAPTER ACTIVITY Making an Evolutionary Tree

You have learned how evolutionary relationships among living organisms and their ancestors can be displayed on a branching diagram called an evolutionary tree. In this activity, you will create an evolutionary tree showing evolutionary relationships among vertebrates and their ancestors.

For this activity you will need a large sheet of newsprint or poster board, markers, pencils, glue, and magazine pictures of the following animals: shark, trout, frog, lizard, snake, turtle, crocodile, bird, kangaroo, mouse, and human.

What you will do

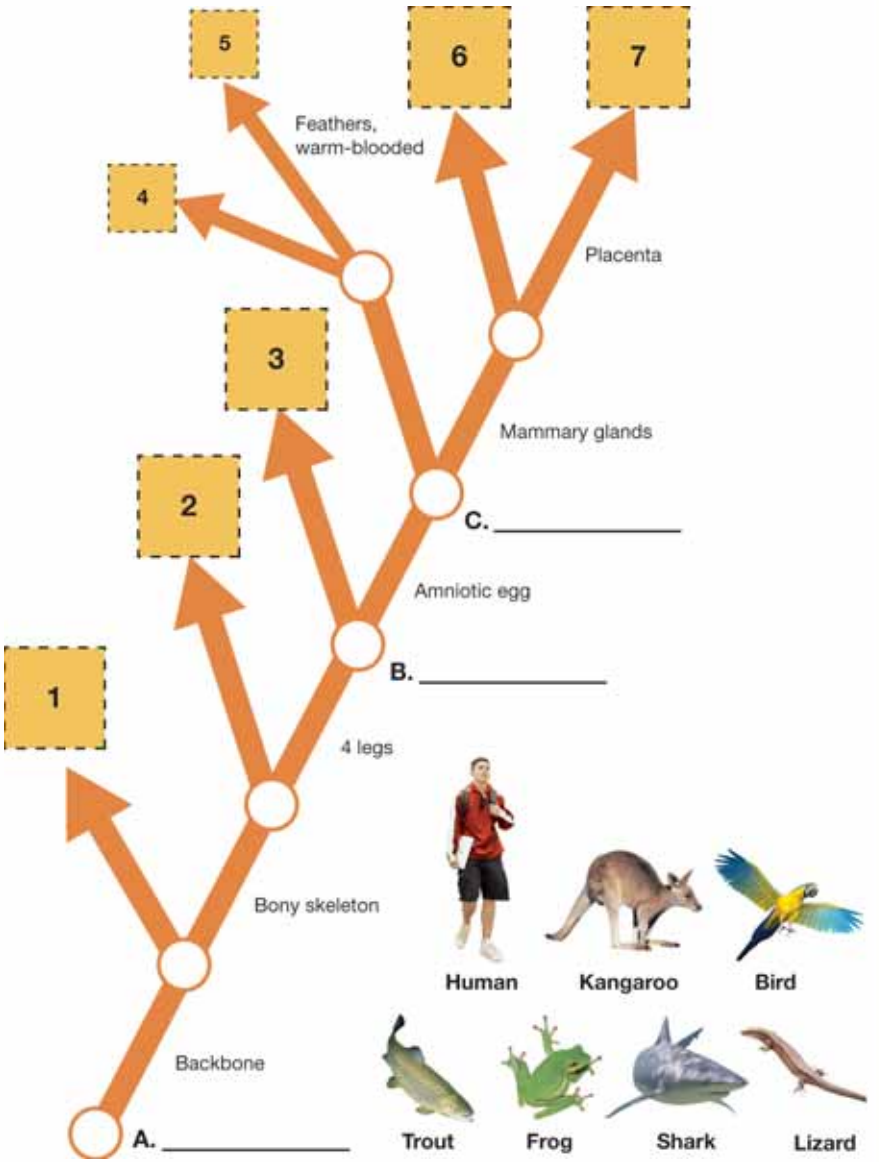
1. Use the diagram to the right as a template for your evolutionary tree.
2. Use the information in the diagram to place the organisms listed above at the correct numbers on the diagram.
3. Draw your tree on newsprint or poster board. Use a pencil first, then use markers to add color.
4. Find pictures of the different vertebrates in magazines or using the Internet. Cut out your pictures and glue them on your tree.
5. Answer the questions below and present your evolutionary tree to your class for discussion.

Applying your knowledge

a. Mammals evolved from an extinct group of organisms called therapsids. Where would therapsids be placed on your diagram (node A, B, or C)?

b. Early reptiles gave rise to all vertebrates except for fish and amphibians. Where would early reptiles be placed on your diagram (node A, B, or C)?

c. Sea squirts are chordates but do not have a backbone. Where would sea squirts be placed on your diagram (node A, B, or C)?



Chapter 15 Assessment

Vocabulary

Select the correct term to complete the sentences.

amniotic egg	circulatory system	ectotherm
bilateral symmetry	connective tissue	endotherm
external fertilization	cornea	epithelial tissue
hermaphrodite	digestive system	gills
lateral line system	internal fertilization	muscle tissue
muscular system	lung	nervous system
notochord	mammary glands	nervous tissue
optic nerve	placenta	pupil
retina	therapsids	radial symmetry
skeletal system	invertebrate	vertebrae

Section 15.1

1. One characteristic of animals is that they have tissues like _____ for movement and _____ for response.
2. Jellyfish, clams, and grasshoppers are _____ - animals without backbones.
3. Earthworms are _____ because they have both male and female reproductive parts.
4. The _____ provides support, while the _____ allows for movement.
5. Animals that are organized around a central point have _____, while animals that have two similar halves have _____.
6. The _____ of an animal helps to get nutrients and energy from food that the _____ then transports around the body along with oxygen and wastes.
7. The brain, spinal cord, and nerves make up the _____ of a human.

Section 15.3

8. Parts of the mammalian eye include: _____, _____, _____, and _____.
9. Most fish, amphibians, and reptiles are _____s, whereas birds and mammals are _____s.
10. All members of Phylum Chordata have a _____ - a flexible rod-shaped structure found in embryos.
11. Vertebrate organs are made of four types of tissues: muscle tissue for movement, nerve tissue for transmission of signals, _____ for support and protection of soft areas, and _____ for a protective outside layer.
12. The _____ is the most important adaptation for life on land since it keeps the embryo from drying out.
13. The backbone is made up of a set of joining bones called _____.
14. The male drops sperm onto eggs that the female has already laid in _____, whereas the male deposits the sperm inside the female in _____.
15. Mammals evolved from a now extinct group of reptiles called the _____.
16. Mammals feed their young with _____, which are organs that produce milk.
17. Fish have _____ for getting oxygen from water and amphibians have _____s for getting oxygen from the air.
18. The developing embryo of most mammals gets food and oxygen through the _____ that attaches it to the mother's uterus.
19. Most fish have a _____ for sensing vibrations.

Concepts

Section 15.1

1. What are the two major groups of animals? Describe each group and give an example.
2. Describe seven major characteristics of animals.
3. What are the three types of symmetry? Describe each type and give an example.
4. Describe the range of types of guts in animals from the most simple to the most complex.
5. List an organ that belongs to each of these organ systems:
   a. skeletal
   b. muscular
   c. digestive
   d. circulatory
   e. respiratory
   f. nervous
   g. reproductive
6. What organ systems help you to do these activities: run, do your homework, eat lunch, and watch television?
7. What is the advantage of having more than one type of reproduction for simple animals?

Section 15.2

8. Why is a sponge considered an animal?
9. How is a jellyfish more complex than a sponge?
10. What are the three types of worms? Which is the most simple? Which is the most complex?
11. What do a snail and a clam have in common?
12. Draw and label a mollusk body.
13. Why do you think there are more fossils of mollusks than worms?
14. What are two advantages and one disadvantage of having an exoskeleton?
15. Why is it advantageous for a butterfly larva and an adult butterfly to rely on different sources of food? What would happen if they both ate the same food?
16. If sea stars get stuck on the beach out of the water, they cannot make their way back to the ocean. Explain why not.

Section 15.3

17. Which of these is not a characteristic of vertebrates?
    a. a backbone and a skull
    b. an internal skeleton
    c. radial symmetry
    d. well developed organ systems
18. Match each of these tissue types to the correct description.

a. epithelial	1. three types including smooth, muscle, and cardiac
b. connective	2. transmits signals
c. nerve	3. provides strength, support, and protection
d. muscle	4. protects from dehydration, damage, and invasion from bacteria

19. Do you believe that an endothermic or an ectothermic animal would be more active on a cold night? Why?
20. Why do the largest reptiles live where it is warm year round?
21. Predict if ectothermic animals perspire. Explain your guess.
22. Why does external fertilization require water?
23. What are the five classes of vertebrates? Describe their major characteristics and give an example for each.
24. What are the three classes of fish? Which is most simple? Which is most complex?
25. Do you think gills have a lot of blood vessels? Why or why not?
26. If female fish lay thousands of eggs, why is the water not overcrowded with fish?
27. How are amphibians dependent on water?
28. How are birds' eggs more protected than the eggs of reptiles, amphibians, and fish?
29. Both birds and bats fly. Explain two major differences between these two types of animals.
30. Explain the difference between these pairs of terms:
    a. endoskeleton, exoskeleton
    b. gills, lung
    c. ectotherm, endotherm
    d. internal fertilization, external fertilization
    e. vertebrate, invertebrate
    f. radial symmetry, bilateral symmetry

Math and Writing Skills

Section 15.1

1. Make a wanted poster for animals that describes the key features of this kingdom.
2. Write help wanted advertisements for three of the organ systems found in animals. Describe what the important functions of the system are in your ad.
3. Write a creative story that includes the major organ systems discussed in this chapter.
4. Pretend that you are an animal that either has bilateral or radial symmetry. Write a persuasive paragraph that explains why your particular type of symmetry is advantageous.
5. Surveys show that the most popular pets in the United States today are (in order): cats, dogs, parakeets, small rodents (rabbits, gerbils, hamsters), and fish. Take a survey in your class to find out what pets your fellow classmates own. Create a graph to display your results.
6. The largest mammal (and animal overall) is the blue whale, which can be 110 feet long. The largest insect is a stick insect, which can measure 15 inches. How many stick insects would it take to equal the length of one blue whale?

Section 15.2

7. Write a news story about the discovery of a giant squid on a local beach. Include features of the squid and other mollusks in your story.
8. Some sponges live on the shells of crabs. Write a conversation that might occur between the sponge and the crab thanking each other for their help. Explain the advantages of this relationship for both the sponge and the crab in your script.

9. One particular sponge can filter water at the rate of 22.4 L / day. How much water does this sponge filter in one hour?
10. There are 150,000 species of mollusks. If 27% of mollusks are gastropods, what is the combined total number of species of bivalves and cephalopods?
11. You can figure out the temperature in summer by listening to cricket chirps. Count the chirps you hear in 15 seconds. Add 39 to the number of chirps to find the temperature in Fahrenheit within a few degrees. What would the temperature outside be if you counted 44 chirps in 30 seconds?
12. Compare and contrast two major phyla of invertebrates in terms of: symmetry, body structure, nutrition, locomotion, and reproduction.
13. Choose one major phyla of invertebrates to create a descriptive acrostic for its common name.
14. Design your own invertebrate. Draw a picture of your creation and answer these questions in a paragraph. What will it be called? What phyla would it belong to? What does it look like? How big will it be? What type of habitat does it live in? Describe what and how it eats. How does this invertebrate move? What are the predators of this new invertebrate? Describe how it defends itself.

Section 15.3

15. If there are 45 species of jawless fish, 275 species of cartilaginous fish, and 25,000 species of bony fish, how many total species of fish are there? What percent of the total number of fish does each class represent?
16. Write a guidebook that will help a tadpole adjust to life on land.
17. There are fewer species of amphibians than any other vertebrate group. Why do you believe that this is true? Explain your reasoning.
18. Your friend just got a job at the pet store. He is having trouble distinguishing the salamanders from the lizards. Give your friend advice about how to easily tell the difference between these two types of animals.
19. A frog might lay between 500 to 5,000 eggs at one time. A turtle could lay 100 eggs at a time. Explain these numbers in terms of fertilization and chance of survival.
20. Choose three different habitats and describe the types of birds that live there.
21. Explain the features of mammals that allow them to live successfully in colder environments than reptiles.
22. Pick two familiar vertebrates and describe their adaptations for getting food.
23. A box turtle lives five times as long as a gorilla. A gorilla lives twice as long as a giraffe. A giraffe lives twice as long as a rabbit. A rabbit lives five times as long as an opossum, which only lives for one year. How long do the other animals usually live for?
24. Nearly a quarter of all mammals can fly! 985 species of bats make up 23.1% of all known mammal species. Use this number to estimate the total number of mammal species scientists have discovered.

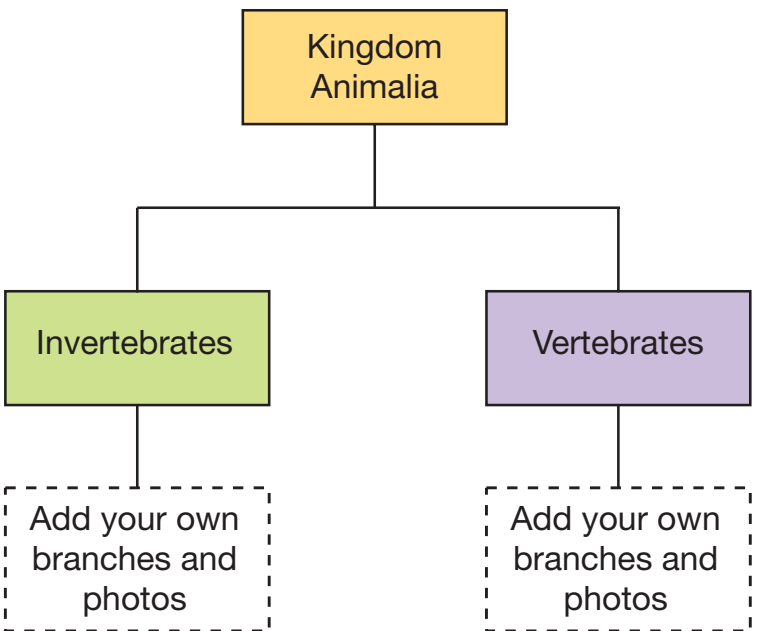
Chapter Project

Branching diagram poster

Biologists use a classification system to show how members of the animal kingdom are alike and different. Below is a list of animal category names. Sort the names and create a branching diagram poster that shows how the categories are related to one another. Start your poster with Kingdom Animalia at the top, and divide this into vertebrates and invertebrates. As you place each category name on your poster, find a picture or illustration of a representative member of the category from a magazine or the Internet, and include that picture on your poster. You may also make sketches.

Category names (in no particular order - you must decide how to place them on your poster!)

1. Phylum Platyhelminthes (flatworms)
2. Phylum Porifera (sponges)
3. Phylum Mollusca
4. Phylum Chordata
5. Phylum Arthropoda
6. Phylum Cnidaria
7. Reptiles
8. Birds
9. Phylum Annelida
10. Mammals
11. Phylum Nematoda (roundworms)
12. Fish
13. Amphibians
14. Phylum Echinodermata
15. Sea squirts



The Human Body

Chapter 16 *Human Body Systems*

Chapter 17 *Structure and Movement*

Chapter 18 *Vision and Hearing*

TRY THIS AT HOME

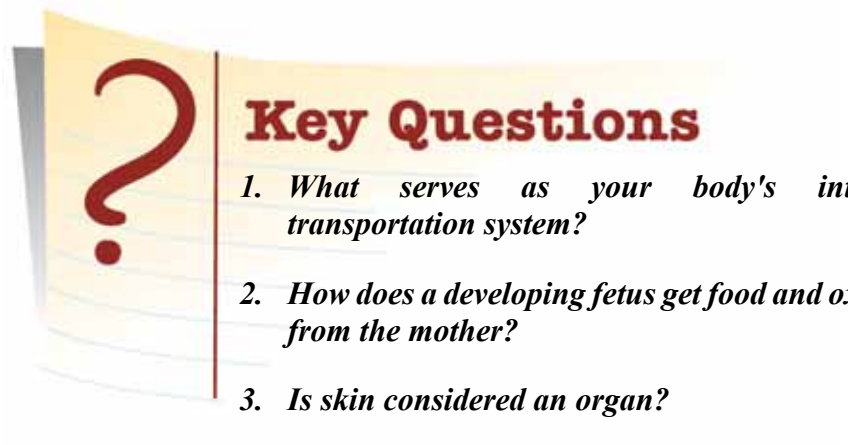
A good place to measure your pulse is the artery on the thumb-side of the wrist. Touch this area lightly with the index finger of your opposite hand until you feel your heartbeat. Count the amount of heartbeats for 15 seconds and multiply by four - this will give you your pulse rate.

Measure the pulse of other people in your household. Try to answer some of these questions: Does pulse vary with age? Does it vary with time of day (morning, afternoon, bedtime)? What happens to your pulse after you walk up stairs? Do girls have lower, higher, or the same pulse rates than boys?

Chapter 16

Human Body Systems

The human body is a busy place! Even when you are sitting down and reading a book, your body's organ systems are actively carrying out their jobs. Your heart beats an average of 70 times each minute, pumping blood to all parts of your body. Your lungs repeatedly take in and expel air. Your skin is constantly shedding dead cells and growing new ones. Your digestive system is working on the last meal you ate. Even when you sleep, your body's systems are at work. Read this chapter to learn all about how circulation, respiration, reproduction, digestion, and other systems work in the human body.



Key Questions

1. ***What serves as your body's internal transportation system?***
2. ***How does a developing fetus get food and oxygen from the mother?***
3. ***Is skin considered an organ?***

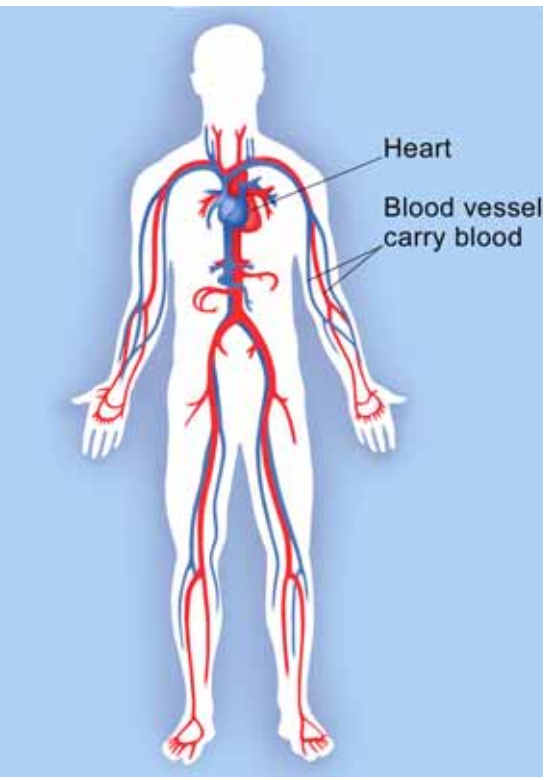
16.1 Circulation and Respiration

You're an animal! To be more specific, you're a mammal. Mammals have complex organ systems. These include skeletal, muscular, digestive, urinary, integumentary, nervous, reproductive, and endocrine systems. **All of your organ systems function because of the contributions of organs, tissues, and cells.** We will begin our study of the human body with the *circulatory* and *respiratory* systems.

The circulatory system

What is the circulatory system?

Your body is made of trillions of cells. Each cell needs oxygen and nutrients. As your cells carry out their functions, they need to get rid of wastes like carbon dioxide. How do substances move to and from your cells? Your body has a transportation system. The **circulatory system** transports blood throughout the body, delivers essential substances to cells, and removes wastes. It is sometimes called the *cardiovascular system*. The circulatory system consists of the *heart*, *blood vessels*, and *blood*.



STUDY SKILLS

Table 15.1 on page 323 gives information about the major organ systems. Use the table to make a set of flash cards. Write the name of a body system on one side of each card. Write its function and major organs on the other side of the card. Use the cards to remember the function and organs of each system.

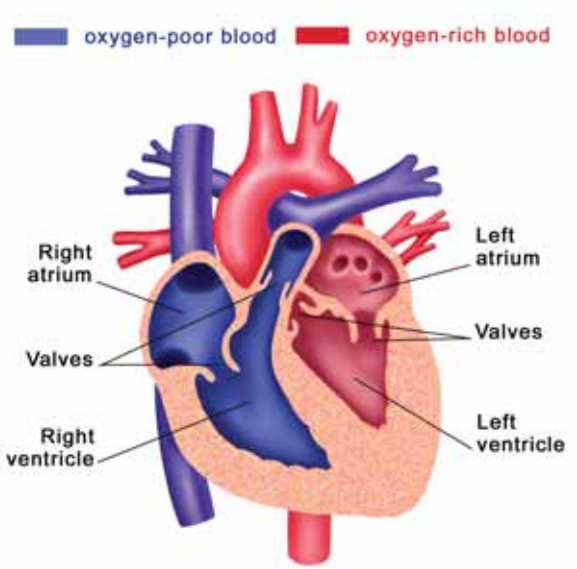
VOCABULARY

circulatory system - the body system that circulates blood throughout the body and delivers essential substances to cells and removes wastes.

The heart

Structure of the heart

What pumps over two million liters of blood per year and weighs only 300 grams? Your heart, of course! The *heart* is a hollow organ found in the middle of your chest. It is made mostly of *cardiac muscle tissue*. The heart *contracts* to pump blood throughout the body. A *contraction* happens when muscle tissue shortens. The right and left sides of the heart have separate functions. The right side of the heart collects oxygen-poor blood from the body and pumps it to the lungs where it picks up oxygen and releases carbon dioxide. The left side of the heart then collects oxygen-rich blood from the lungs and pumps it to the body so that every cell in the body has the oxygen it needs.



Blood flow through the heart

The heart has four chambers (Figure 16.1). Each chamber has a one-way valve at its exit. A **valve** is a flap of tissue that prevents the backflow of blood. When each chamber contracts, the valve at its exit opens. When a chamber relaxes, the valve closes so that blood does not flow backwards. The heart contracts (or beats) in two stages. This causes the *lub-dub* sound you hear. In the first stage the atria contract together. This pumps blood to the ventricles. In the second stage, the ventricles contract together. This pumps blood out of the heart. Then the heart muscle relaxes before the next heartbeat. This allows blood to flow into the atria again.

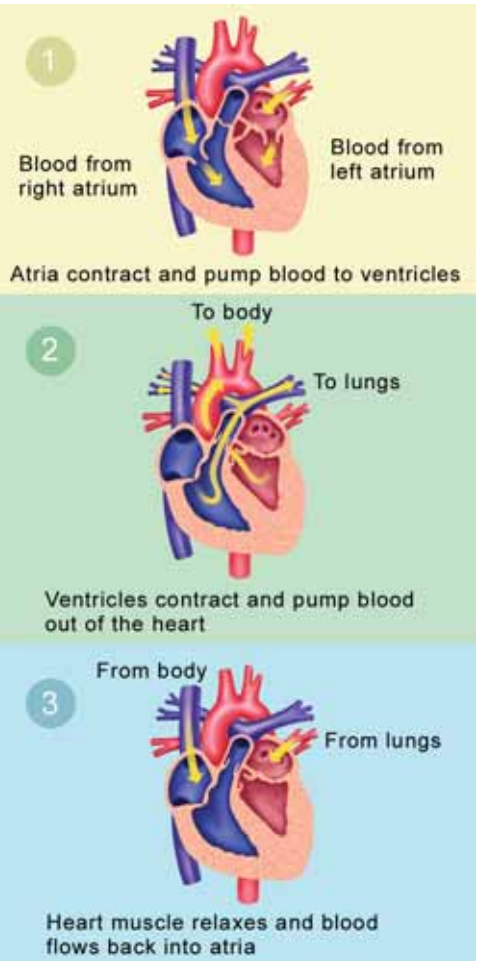


Figure 16.1: *The heart is a muscle that consists of four chambers and a valve between each chamber.*

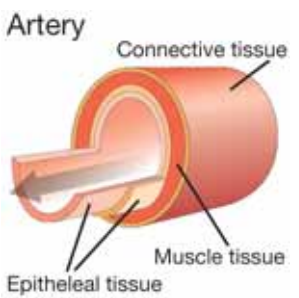
VOCABULARY

valve - a flap of tissue that prevents the backflow of blood.

Blood vessels

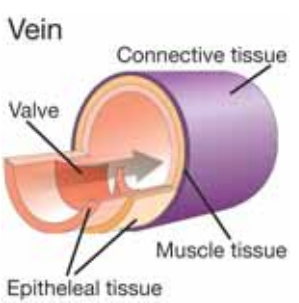
Blood vessels are organs that carry the blood throughout your body. There are three types of blood vessels: arteries, capillaries, and veins. Figure 16.2 shows the structure of these blood vessels.

Arteries **Arteries are blood vessels that carry blood from the heart.** With the exception of the pulmonary artery, they carry oxygen-rich blood. Each time the heart contracts, blood is pumped out at high pressure. Arteries are made of three layers of tissues that help them withstand that pressure. The lining is epithelial tissue. Next is a thick layer of smooth muscle that helps the artery withstand high pressure. The outer layer is made of elastic connective tissue that allows the artery to expand under pressure.



Capillaries **Capillaries are the smallest blood vessels where the exchange of materials with cells takes place.** Capillary walls are only one cell thick and may be so narrow that blood cells must pass through in single file. They form a net-like structure throughout your tissues. Oxygen and other materials diffuse through capillary walls into the tissues and then into cells.

Veins **Veins are blood vessels that carry blood toward the heart.** With the exception of the pulmonary veins, they carry oxygen-poor blood. Like arteries, veins have three tissue layers. But veins have thinner walls because they do not receive blood directly from the heart. The largest veins have one-way valves to keep blood flowing toward the heart.



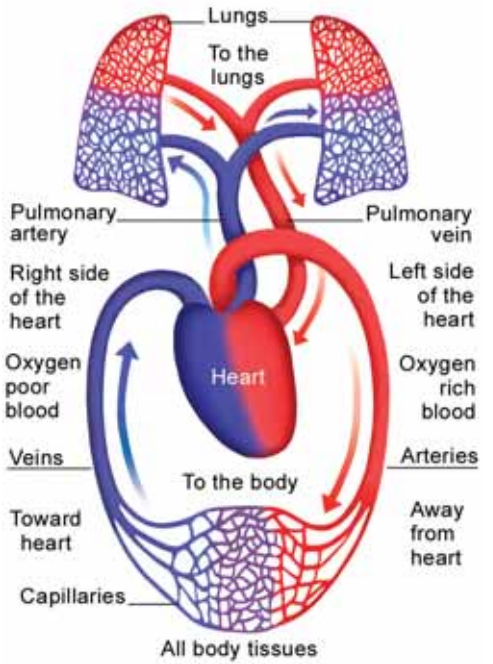


Figure 16.2: *The blood vessel system.*

VOCABULARY

arteries - blood vessels that carry blood away from the heart.

capillaries - the smallest blood vessels where the exchange of materials with cells takes place.

veins - blood vessels that carry blood toward the heart.

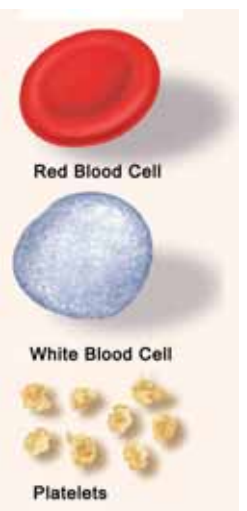
Blood

The function of blood

You have about 5 liters of blood in your body. **Blood** is a circulating connective tissue. It is made of a fluid called plasma, two types of cells (red blood cells and white blood cells), and particles called platelets. The main function of blood is to supply oxygen and nutrients to tissues and to remove waste products like carbon dioxide. Blood also transports hormones, enzymes, and immune cells between tissues and organs. Any interruption in the flow of blood can cause death in a matter of minutes. Interruptions in blood flow may be caused by a heart attack, stroke, or blood clots.

Plasma

About 55 percent of your blood is plasma. **Plasma** is the fluid part of the blood that contains water, dissolved nutrients, sugars, and proteins. Floating in the plasma are red blood cells, white blood cells and platelets.



Red blood cells

About 45 percent of your blood is made of red blood cells. **Red blood cells** transport oxygen to your cells. Red blood cells are red because of a pigment called hemoglobin. Hemoglobin grabs onto the oxygen molecules you inhale and carries them to your cells.

White blood cells and platelets

White blood cells and platelets make up a tiny fraction of your blood. **White blood cells** are part of your *immune system*. They help fight infections by destroying invaders like bacteria and viruses. Some white blood cells engulf invaders. Others produce antibodies that destroy invaders. *Platelets* are particles that prevent blood loss. When you cut or scrape your skin, platelets clump together in the damaged area and form a "plug."

VOCABULARY

blood - a circulating connective tissue made of plasma, cells, and platelets.

plasma - the fluid part of blood.

red blood cells - carry oxygen to cells.

white blood cells - immune cells that destroy invaders.

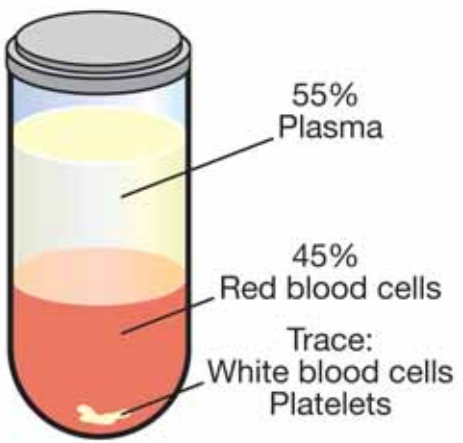


Figure 16.3: *The components of blood.*

Blood pressure

Heart contractions and blood pressure

Did you know that your blood circulates through about 90,000 kilometers of blood vessels in your body? Each heart beat pushes about 90 milliliters of oxygenated blood from the heart into the *aorta*, the body's largest blood vessel. From there, the blood flows to smaller arteries and then capillaries. Eventually, it transfers its oxygen to body cells and returns back to the heart through the veins. Contractions of the heart generate *blood pressure*. The rhythmic change in blood pressure is called a *pulse*. Blood pressure keeps the blood flowing in the right direction. Valves prevent backflow of blood.

Heart contractions generate blood pressure.

What is blood pressure?

Blood pressure is a measure of the force of blood pushing against the walls of the arteries. It is measured in *millimeters of mercury* (mm Hg). A pressure of 100 mm Hg means the pressure is great enough to push a narrow column of mercury 100 mm high. Normal blood pressure is 120/80 mm Hg. The top number is called the systolic pressure. *Systolic pressure* is the maximum force exerted against artery walls each time the heart contracts. The lower number is called diastolic pressure. *Diastolic pressure* is the force exerted on the arteries when the heart relaxes (Figure 16.4).

How to measure blood pressure

A *sphygmomanometer* is used to measure blood pressure. The cuff is pumped up with air to restrict blood flow in the arm. As the pressure in the cuff is released, blood starts flowing again. You can hear the flow in a stethoscope. The number at which blood starts flowing is the measure of the systolic pressure. Pressure in the cuff continues to release. The point at which no sound is heard indicates the pressure in the system when the heart is relaxed—the diastolic reading.

VOCABULARY

blood pressure - a measure of the force of the blood pushing against the walls of the arteries.

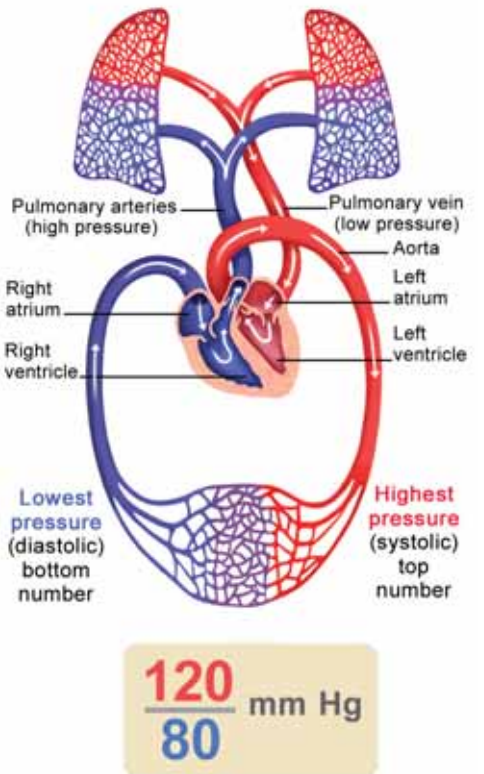


Figure 16.4: *Systolic and diastolic blood pressure.*

The respiratory system

Breathing and respiration

Do you ever notice your breathing? Probably not. Your breathing happens even when you don't think about it. When you breathe, you take in oxygen gas from the air and exhale carbon dioxide gas and water vapor. Your cells use the oxygen for cellular respiration and produce carbon dioxide and water. **Respiration** is the entire process by which the body exchanges and uses gases. Respiration is made possible by the respiratory system. The **respiratory system** consists of the lungs, and passageways that lead to the lungs.

VOCABULARY

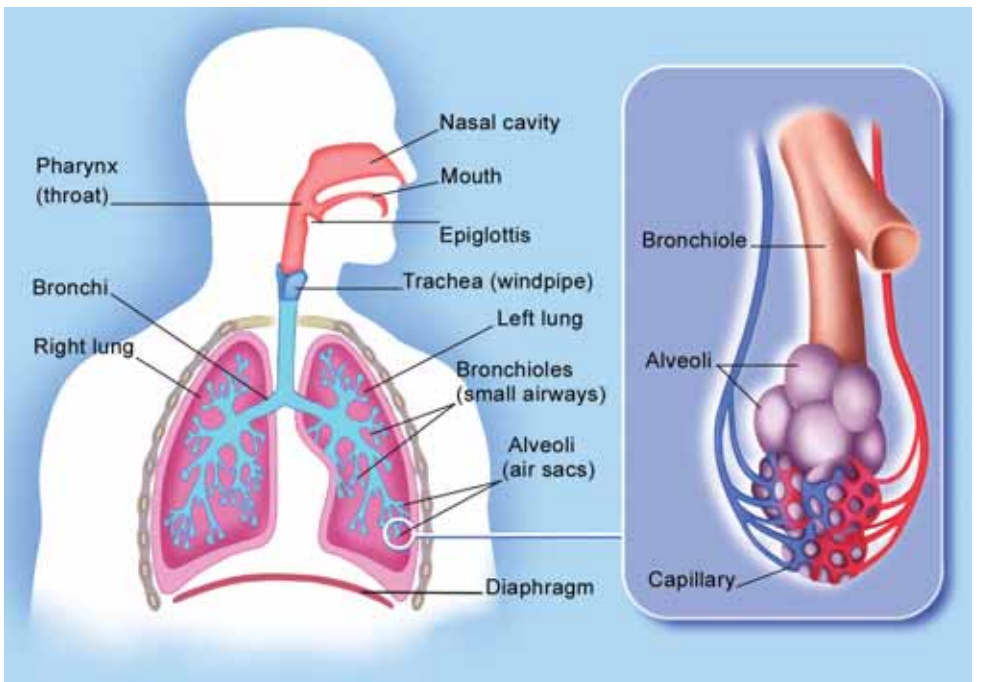
respiration - the entire process by which the body takes in oxygen and gets rid of carbon dioxide and water.

respiratory system - the body system consisting of the lungs, and passageways that lead to the lungs.

alveoli - tiny, sac-like structures of the lungs that are surrounded by capillaries where gas exchange takes place.

Structure and function of the respiratory system

The diagram to the right shows the organs of the respiratory system. When you breathe, air is inhaled through your *nose* and *mouth*. From there, it flows through the pharynx, or throat. The *pharynx* branches into two tubes. The esophagus leads to your stomach. The *larynx*, leads to your lungs. The larynx also contains your voice box. Next, air flows into the trachea, or windpipe. The *trachea* splits into two tubes called *bronchi*. One bronchus (singular) goes to each lung. Each bronchus branches into thousands of tiny tubes called *bronchioles*. Bronchioles end in tiny sacs called alveoli. Each of your lungs contains thousands of alveoli. **Alveoli** are sac-like structures surrounded by capillaries where the exchange of gases takes place. The *diaphragm* is a sheet of muscle that helps draw air into the lungs.



Putting it all together: tracing blood flow

Failure of any part can affect the entire system

Your circulatory and respiratory systems work together to ensure that every cell in your body has the oxygen it needs to perform cellular respiration. **The failure of any part can affect the entire system.** For example, a person may die from a heart attack (failure of the heart). Smoking may lead to inefficient gas exchange in the lungs and cause cardiovascular disease. Blockage of blood vessels may lead to inefficient gas exchange in the brain and cause a stroke. To understand the system, we can trace the flow of blood, starting at the heart. Follow the numbers in Figure 16.5 as you read the following paragraph.

Tracing blood through the system

All blood enters the right side of the heart through two veins. The *superior vena cava* carries oxygen-poor blood from the upper body parts. The *inferior vena cava* carries oxygen-poor blood from the lower body parts (**1**). When the right atrium contracts, the blood goes through a valve and into the right ventricle (**2**). When the right ventricle contracts, blood is pumped through a valve and into the *pulmonary artery* (**3**). From there, blood flows into the lungs where it picks up oxygen (**4**). The now oxygen-rich blood is carried back to the left atrium through the *pulmonary veins* (**5**). When the left atrium contracts, blood goes through a valve into the left ventricle (**6**). When the left ventricle contracts, blood is pumped through a valve and into the *aorta* (**7**). The aorta branches into arteries that lead to upper and lower parts of the body (**8**). Those arteries branch into smaller and smaller arteries and into capillaries (**9**). In the capillaries, blood cells release their oxygen which diffuses into tissues. Carbon dioxide and water are picked up from the body cells. The now oxygen-poor blood flows through the capillaries and into small veins (**10**). Smaller veins lead to larger veins and eventually to the superior and inferior vena cava. This is where the cycle begins again.

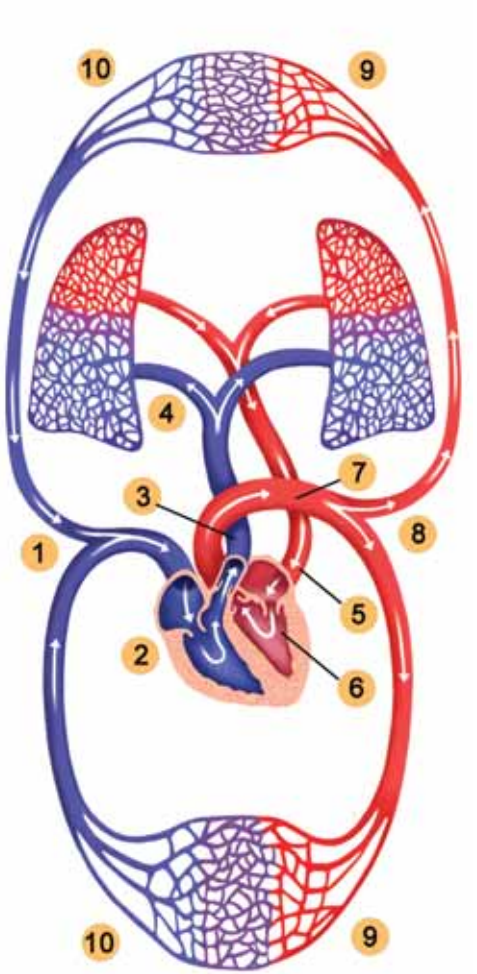


Figure 16.5: *The numbers in the diagram correspond to the numbers in the text to the left. Follow the numbers as you read the text.*

16.1 Section Review

1. What are the organs of the circulatory system?
2. What is the function of the right side of the heart? What is the function of the left side of the heart?
3. What is a valve? What is the function of a valve?
4. What causes the *lub-dub* sound of your heartbeat?
5. Match each component of the circulatory system with its function:

Organ system	Function
1. blood	a. pump blood
2. arteries	b. carry oxygen
3. red blood cells	c. prevent blood loss
4. capillaries	d. carry oxygen-poor blood to the heart
5. heart	e. transport gases and nutrients
6. veins	f. protect the body from invaders
7. white blood cells	g. carry oxygen-rich blood to the body
8. platelets	h. carry gases and nutrients into tissues

6. Why do the wall of arteries need to be thicker than the walls of veins?
7. Describe the structure of the lungs. Use the words bronchi, bronchioles, alveoli, and capillaries in your description.
8. Explain why each event could cause damage to your body:
   a. heart attack
   b. smoking
   c. stroke

Draw a flow chart that traces a drop of blood through your body. Use the following terms in your flow chart:

right ventricle

left ventricle

right atrium

left atrium

capillaries

arteries

veins

superior and inferior vena cava

aorta

pulmonary artery

pulmonary veins

lungs

oxygen-rich blood

oxygen-poor blood

16.2 Human Reproduction

Like most animals, humans reproduce sexually. As you have read, you started out as a single, fertilized egg called a zygote. The egg came from your mother and the sperm came from your father. In this section, you will learn about the process of human reproduction.

VOCABULARY

testes - produce sperm and testosterone.

hormone - a chemical that regulates body functions.

semen - a mixture of sperm and fluid that is ejaculated during sexual intercourse.

The male reproductive system

The components of the male reproductive system

Figure 16.6 shows the organs of the male reproductive system. **The male reproductive system produces sperm and transfers it to the female reproductive system.** The **testes** produce sperm and the male hormone, *testosterone*. A **hormone** is a chemical that regulates body functions. Testosterone regulates the development of male traits and the production of sperm (male sex cells). The testes are stored in the external *scrotum*. The scrotum is about 3°C cooler than body temperature (37°C). The cooler temperature allows sperm to develop. Sperm are produced in tightly-coiled tubes inside of the testes called *seminiferous tubules*. The *epididymis* temporarily stores mature sperm cells. Each sperm cell has a flagellum (shown left).

The path of sperm

A tube called the *vas deferans* passes from each epididymis into the body. The *prostate gland* produces some of the fluid that mixes with sperm as it travels through the vas deferans. The mixture of sperm and fluid is called **semen**. During sexual arousal, millions of sperm travel from the vas deferans, down the urethra, and are ejaculated out of the penis. *Ejaculation* is the abrupt discharge of semen. The *urethra* is a tube that runs through the penis. The penis is the organ that transfers sperm into the female's body.

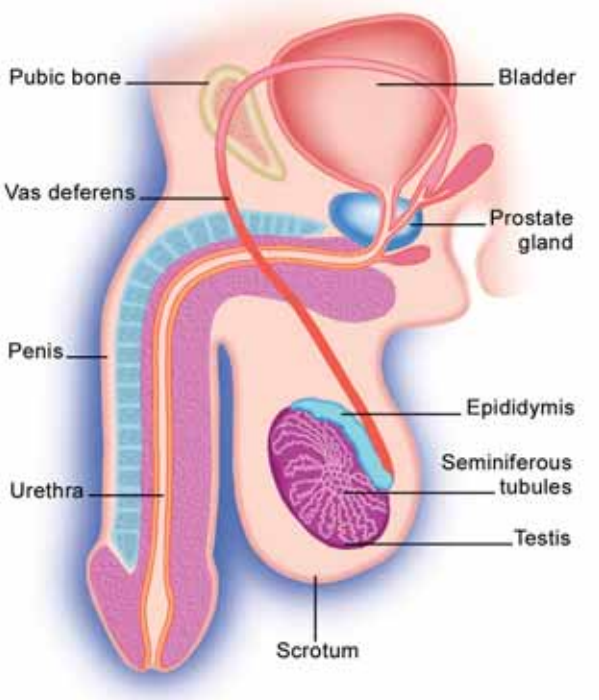


Figure 16.6: *The male reproductive system.*

The female reproductive system

The components of the female reproductive system

Figure 16.7 shows the female reproductive system. **The female reproductive system produces eggs, ensures development of fertilized eggs, and gives birth.** The ovaries are about the size of a large olive. **Ovaries** produce the eggs, also called *oocytes*. Ovaries also produce the female hormones *estrogen* and *progesterone*. The female hormones regulate the production and release of eggs and regulate the development of female traits. The *vagina* is the passageway that receives sperm during sexual intercourse.

Ovulation

Puberty is the time of life when male and female sex organs become mature. A woman has an estimated 300 to 400 thousand eggs contained within her ovaries at the time of puberty. At puberty, a woman begins to ovulate. **Ovulation** is the release of a mature egg from the ovary. An egg matures in a structure of the ovary called a **follicle**. During ovulation, a mature follicle ruptures through the ovary wall. Once released, the egg travels down one of the fallopian tubes that lead to the uterus. The **uterus** is the organ where a baby grows and develops.

The menstrual cycle

Each month starting at puberty, the tissue lining the uterus thickens to prepare for pregnancy. If fertilization occurs, the zygote moves down the fallopian tube and embeds in the thickened tissue. If fertilization does not occur, the egg deteriorates. Then, the tissue layer, along with the deteriorated egg, is discharged through the vagina. This process is called *menstruation* and lasts for about 5 days. After menstruation, the tissue lining the uterus thickens again. Ovulation occurs about two weeks into the cycle. The entire process is called the *menstrual cycle*. It repeats each month from puberty until late middle age.

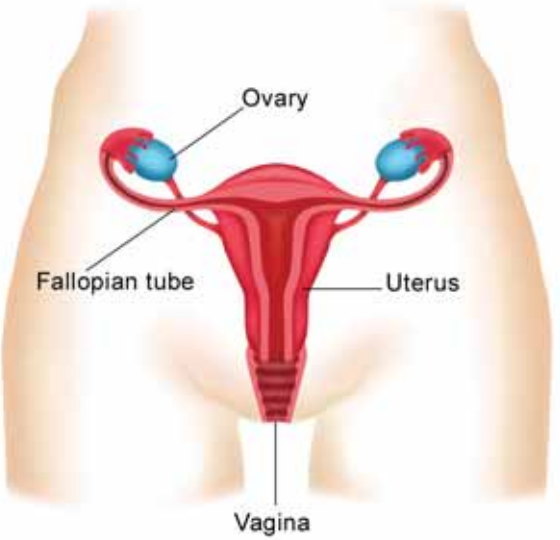


Figure 16.7: *The female reproductive system.*

VOCABULARY

ovaries - female organs that produce eggs and female hormones.

ovulation - the release of a mature egg from the ovary.

follicle - a structure of the ovary where an egg matures.

uterus - the organ where a baby grows and develops.

Fertilization and pregnancy

The start of the human reproductive process

The human reproductive process begins when a man ejaculates sperm into a woman's vagina during sexual intercourse. Some sperm may exit the penis before ejaculation occurs. Thus, sexual activity that does not involve ejaculation could also lead to the release of sperm into the vagina, fertilization, and pregnancy.

What happens during fertilization

Figure 16.8 shows the process that occurs from fertilization to pregnancy. Once inside the vagina, many sperm die because of the acidic environment. Surviving sperm use their flagella to swim through the uterus and up the fallopian tube. When they reach the egg, the sperm surround it. They release an enzyme that breaks down the proteins in the egg's outer covering. As soon as a single sperm gets through that covering, a reaction occurs that keeps any other sperm from entering. The membrane of the egg then fuses with the sperm. Next, the sperm's flagellum and mitochondria break down. At that point, the sperm is only a nucleus. This explains why all mitochondrial DNA is inherited from the mother, as you read in Chapter 10. When the sperm and egg nuclei fuse, fertilization is complete.

Implantation

The fertilized egg then begins a 5 day journey down the fallopian tube toward the uterus. During the journey, the zygote undergoes many mitotic divisions. By the time it reaches the uterus, it is an embryo that looks like a tiny ball of cells. The next step is called implantation. In **implantation**, the tiny embryo becomes embedded in the lining of the mother's uterus. Implantation is successful only about 30 percent of the time. Once the embryo is implanted, *pregnancy* begins. One of the first signs of pregnancy is that a woman's regular menstrual cycle stops. A pregnant woman may give birth to a baby between 38 and 42 weeks later which is the gestation period for humans.

VOCABULARY

implantation - the process in which an embryo becomes embedded in the lining of the uterus.

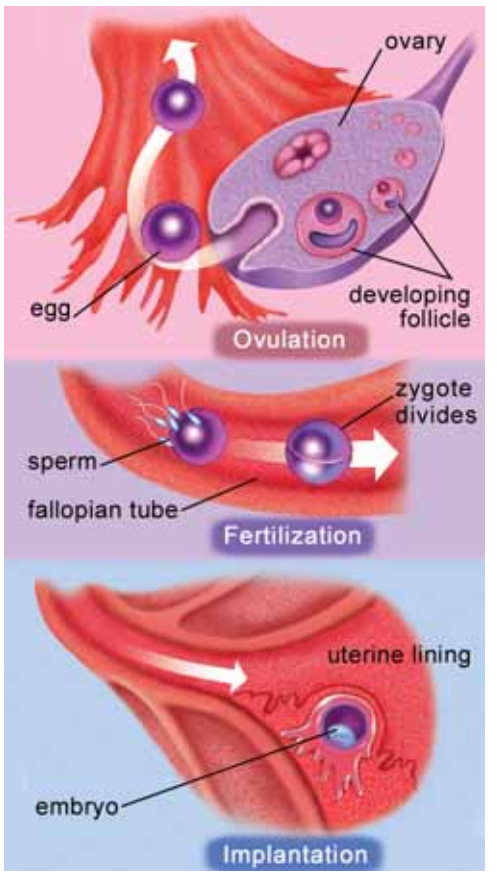


Figure 16.8: *From fertilization to implantation.*

Development and birth

The placenta and umbilical cord

Once the embryo is implanted in the uterus, the placenta begins to grow. Recall that the *placenta* supplies food and oxygen from the mother's blood to the developing embryo. It contains a network of blood vessels that links the embryo to the mother. By the fourth week of pregnancy, the embryo is about 2 millimeters long. It is surrounded by a thin, protective membrane called the *amnion*. Inside the amnion and surrounding the embryo, is *amniotic fluid* that protects the embryo from shocks. The **umbilical cord** has also formed. It contains arteries and veins that connect the embryo to the placenta. It enters the embryo's body at the *umbilicus*, or naval.

The developing fetus

At the eighth week, the embryo has developed enough to be called a **fetus**. A human fetus develops from the end of the eighth week of pregnancy (when the major structures have formed), until birth. Figure 16.9 shows a fetus and the structures that connect it to the mother. The blood of the mother and fetus do not mix together. Oxygen and nutrients pass from the mother's blood to the fetus through the placenta and umbilical cord. Waste products like carbon dioxide pass from the fetus to the mother's blood for removal. Most drugs and alcohol can easily pass through the placenta and into the fetus, as well as many infectious viruses such as the human immunodeficiency virus (HIV).

Labor and birth

After 38 to 42 weeks, the fetus is ready to live outside of the mother. The mother goes through a series of contractions called *labor*. The fetus is pushed, headfirst, through her vagina. The baby is still connected to the placenta by the umbilical cord. When the doctor ties and cuts the umbilical cord, *birth* is complete. The mother continues with labor until the placenta is pushed out of her body.

VOCABULARY

umbilical cord - contains arteries and veins that connect the embryo to the placenta.

fetus - an embryo that has developed for 8 weeks and has formed the major structures.

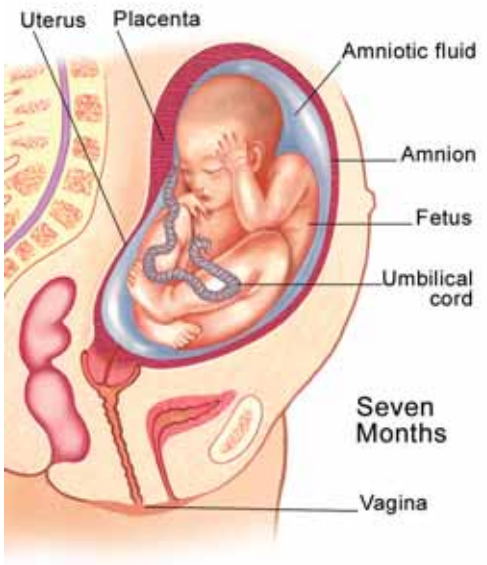


Figure 16.9: *The structures surrounding the fetus.*

16.2 Section Review

1. Match the parts of the male reproductive system listed below, to the letters on the diagram in Figure 16.10.
   urethra, *epididymis*, *testes*, *penis*, *vas deferans*, *scrotum*, *seminiferous tubules*
2. What is a hormone? Name the male hormone and the female hormones.
3. Match the parts of the female reproductive system listed below to the letters on the diagram in Figure 16.11.
   uterus, *ovary*, *fallopian tube*, *vagina*
4. Match each structure to its function.

Structure	Function
1. testes	a. links the mother to the embryo
2. ovaries	b. connects the fetus to the placenta
3. follicle	c. produces fluid that makes up semen
4. prostate gland	d. produces sperm
5. uterus	e. organ where the baby grows and develops
6. placenta	f. contains a developing egg
7. umbilical cord	g. produces eggs

5. Describe the sequence of events that occurs during fertilization.
6. What is implantation? Why is it a necessary step to pregnancy?
7. Why are materials exchanged between mother and fetus through the placenta?
8. Why do doctors advise women to not drink alcohol during pregnancy?

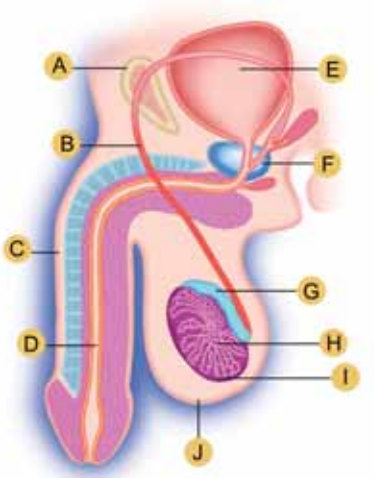


Figure 16.10: *Match the terms in question 1 to the letters in the diagram.*

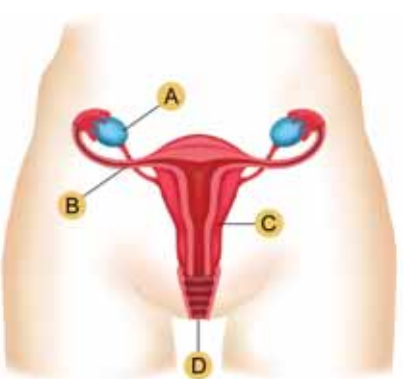


Figure 16.11: *Match the terms in question 3 to the letters in the diagram.*

16.3 Other Organ Systems

Why do you sweat? Why do you sometimes feel hungry? Why does your heart beat faster and you breathe heavier when you exercise? These are examples of how your organs work together to maintain a stable internal environment. Recall that this process is called homeostasis. In this section, you will learn about some of your other organ systems and their role in homeostasis.

The integumentary system

The function of the integumentary system

What is your body's largest organ? It's your skin and it's part of the integumentary system which also includes your hair and nails. The **integumentary system** has several functions described below.

- Your skin is a barrier between your underlying tissues and the outside environment. Skin is the first line of defense for blocking moisture and invaders like bacteria.
- Skin contains sweat glands that help regulate your body temperature. **Sweat glands** work by producing a salty fluid called *sweat* that flows to the surface of your skin when you are hot. As sweat evaporates, it cools your skin.
- Skin contains nerve endings that allow you to sense your environment through touch.

Anatomy of the skin

Figure 16.12 shows a cross section of the skin. The *epidermis* is the thin, outer layer that you see. The *dermis* lies underneath and is made of connective tissue and protein fibers. It contains the *sweat glands* and *nerve endings*. It also contains *oil glands* that produce oils to waterproof your skin. *Hair follicles* produce the hair on your skin. *Muscle fibers* attached to the hair follicles cause hair to stand up. This action helps regulate temperature. Hair also filters out dust particles from your nose and eyes. The *subcutaneous fat layer* functions as insulation for your body.

VOCABULARY

integumentary system - the body system consisting of the skin, hair, and nails that protects the underlying tissues.

sweat glands - glands in the skin that produce sweat to regulate body temperature.

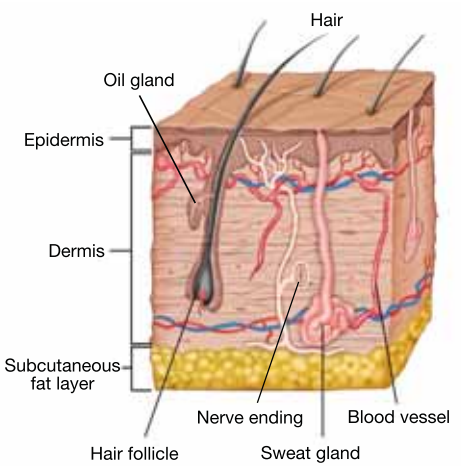


Figure 16.12: *A cross-section of the skin.*

The endocrine system

What is the endocrine system?

The **endocrine system** consists of a group of glands that produce hormones and release them into the blood. The endocrine system controls a variety of important functions such as cell processes, reproduction, and response to stress. The **pituitary gland** is often called the "master gland" because the hormones it releases regulate the release of hormones by other glands. Figure 16.13 shows the locations of endocrine glands and their functions.

VOCABULARY

endocrine system - a group of glands that produce hormones and release them into the blood.

pancreas - a gland that produces insulin and digestive enzymes.

adrenal glands - produce epinephrine, a hormone that prepares the body for stress.

The adrenal gland

Some glands affect many organs at once. The **adrenal glands** produce a hormone called *epinephrine*. Epinephrine prepares several of your organs for stress. When you get scared, it speeds up your heart rate, increases your breathing, and makes more blood sugar available for energy. This prepares your body to either run away from danger or fight for survival. It is called the *fight or flight response*.

Some glands function as part of other organ systems

Some glands also function as part of other organ systems. The **pancreas** releases *insulin*, a hormone that regulates the amount of sugar (glucose) in your blood. It is also part of the digestive system because it produces enzymes that digest proteins, carbohydrates, and fats. The endocrine function of testes and ovaries is to produce male and female sex hormones (testosterone in males, progesterone and estrogen in females). Their reproductive function is to produce sex cells.

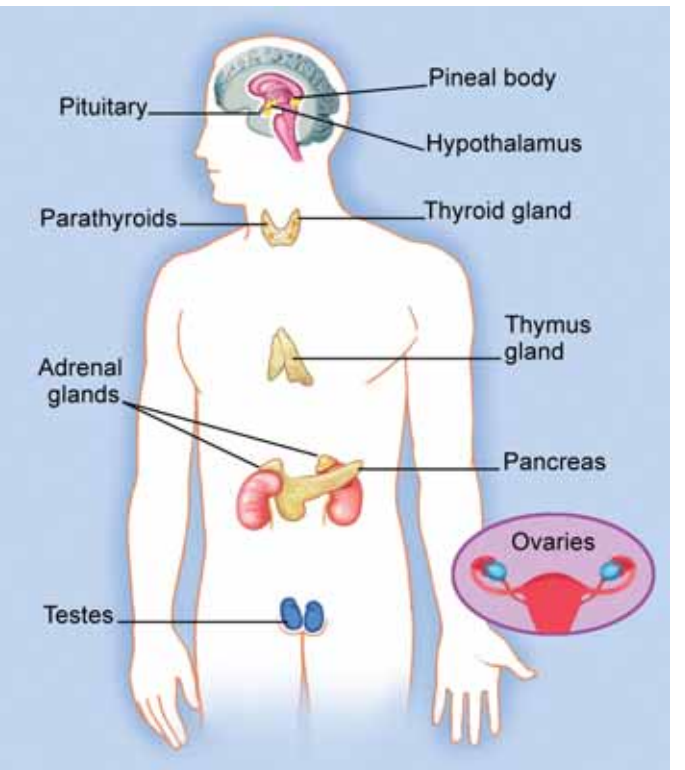


Figure 16.13: *The endocrine system.*

Feedback control systems

What are feedback control systems?

Sophia was hot so she turned on the air conditioner. The thermostat was set to 70°F. After awhile, the air conditioner turned off automatically when the room temperature reached the thermostat setting. A thermostat is a *feedback control* that sends a message to the air conditioner to turn off when a pre-set temperature is reached. Similarly, your body has **feedback control systems** that turn your endocrine glands on or off. These systems control the levels of hormones in your blood.

VOCABULARY

feedback control systems - systems that control the levels of endocrine hormones in the blood.

An example of a feedback control system

Recall that your cells need glucose for cellular respiration. A feedback control system maintains your blood glucose levels. The system involves your pancreas, which produces insulin, and your liver, which stores glucose. When you eat something, glucose from the food is absorbed by your small intestine and enters your blood. When blood glucose rises above normal levels, your pancreas releases insulin into your blood. Insulin tells your liver to take glucose from the blood and store it for future use. When glucose levels return to normal your pancreas stops producing insulin (Figure 16.14).

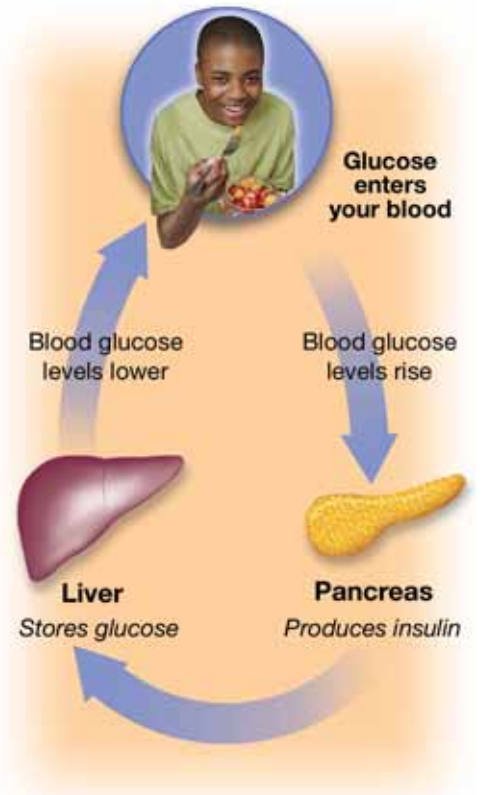


Figure 16.14: *A feedback control system for blood glucose.*

Diabetes mellitus

Sometimes, a feedback control system does not work properly. This may cause problems for other body systems. A person whose pancreas cannot make enough insulin has a condition called *diabetes mellitus*. That person must monitor blood glucose levels and may need injections of insulin to keep blood glucose levels normal. Chronic high blood glucose levels may cause damage to the eyes, kidneys, nerves, heart and blood vessels.

Digestive and excretory systems

What is the digestive system?

The *digestive system* is a group of organs that takes in and digests food, and eliminates solid wastes. You need a digestive system because the food you eat is in large pieces and your cells need molecules for cell processes. Your digestive system breaks food into smaller pieces and then uses enzymes to break those pieces down into molecules. Those molecules are absorbed by the small intestine and enter your blood where they are transported to different parts of your body. The digestive system is basically a long, twisting tube that runs from the mouth to the anus. Most of the digestive organs (like the *stomach* and *intestines*) are tube-like and contain the food as it makes its way through the body. Other organs (like the *liver* and *pancreas*) produce or store digestive chemicals. Figure 16.15 shows the organs of the digestive system.

What is the excretory system?

Your body gets rid of solid wastes through the digestive system. But it must also get rid of chemical wastes that are produced by chemical reactions in your cells. The **excretory system** is a group of organs that *excrete* chemical wastes. These include water, carbon dioxide, salts, and *urea*—a by product of protein reactions. The excretory system includes the kidneys, liver, lungs, and skin. The liver has functions in many organ systems. In the excretory system, it breaks down waste compounds into urea. Urea, along with excess water and salts, is filtered out by your *kidneys*. The liquid produced by your kidneys is called urine. Urine is stored in your bladder—until it gets too full. You can guess what happens next. Sweat glands in your skin also excrete excess water, salts, and urea. Carbon dioxide is excreted through the lungs.

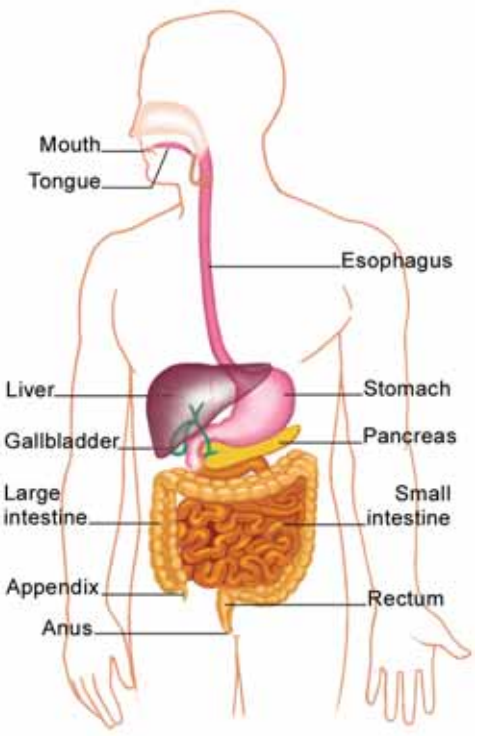


Figure 16.15: *The organs of the digestive system.*

VOCABULARY

excretory system - a group of organs that excrete chemical wastes.

16.3 Section Review

1. Name three functions of skin.
2. How does the skin contribute to homeostasis?
3. What is the endocrine system?
4. Match each endocrine gland to the hormone it produces:

Gland	Hormone
1. testes	a. epinephrine
2. ovaries	b. testosterone
3. pancreas	c. progesterone
4. adrenal glands	d. insulin

5. Why is the pituitary gland called the "master gland?"
6. Name two organs found in the digestive system.
7. Name two organs found in the excretory system.
8. What is a feedback control system and why is it important for endocrine gland function?
9. The excretory system gets rid of chemical wastes. Name a process that produces each chemical waste:
   a. urea
   b. carbon dioxide
10. Each organ below functions in more than one organ system. For each organ below: (1)name two organ systems for which it has functions; and (2)name its function in each system.
    a. sweat glands
    b. lungs
    c. liver
    d. pancreas

CHALLENGE

Use the following terms to create a concept map:

circulatory system
endocrine system
digestive system
heart
blood vessels
blood
hormones
insulin
pancreas
diabetes mellitus
feedback control system
glucose
liver

HEALTH CONNECTION

Effects of Smoking on Reproduction

According to the March of Dimes, an organization that works to improve the health of babies, an estimated 20 percent of women in the United States smoke, many of them while they are pregnant. Cigarette smoking is linked to the development of heart disease, cancer, and many respiratory conditions. It can be harmful to the fetus as it develops in the womb and to the baby at birth, leading to premature birth, low birthweight, and respiratory disorders. Smoking also can affect a women's reproductive health before pregnancy. Studies show that smoking may reduce a women's ability to become pregnant.

Toxic smoke

There are over 4,000 chemicals in cigarette smoke. Carbon monoxide and nicotine are two that are known to be harmful to a fetus. When a pregnant woman smokes, these chemicals pass through her blood stream into the placenta, the tissue that provides oxygen and nutrients to the fetus. Carbon monoxide and nicotine cause the vessels that supply blood to the fetus to narrow, thus preventing enough food and oxygen from reaching the developing baby.

Mothers and babies at risk

Women who smoke during pregnancy are at risk for having premature and low birthweight babies (a low birthweight is under 5½ pounds). These babies may be small because of poor growth before birth and/or early delivery (nine months being full term). In 2002, 12.2 percent of babies born to American women who smoked were of low birthweight. Meanwhile, only 7.5 percent of babies born to nonsmoking women were of low birthweight. Pregnant women who are regularly exposed to secondhand smoke also are at risk for having premature and low birthweight babies. And these babies then are at risk for serious health problems.

Children born to mothers who smoked during the pregnancy may have more colds, earaches, and respiratory problems than children born to nonsmoking mothers. Sudden Infant Death Syndrome (SIDS) is another risk for infants whose mothers smoked while pregnant. SIDS is the sudden and unexplained death of an infant under a year old. Studies show that babies whose mothers smoked while pregnant are up to three times more likely to die of SIDS than babies born to nonsmokers.

Smoking affects future generations

Women who smoke while pregnant risk health problems not only in their children, but also in their grandchildren. This means that smoking's harmful effects can reach two generations of a family. Researchers call this the "grandma effect." Scientists have found that when a pregnant woman smokes, her future grandchildren may have double the risk of developing asthma. Asthma is a respiratory disorder that causes wheezing, coughing, and tightness in the chest. This may happen to a child whose mother did not smoke during the pregnancy but whose grandmother smoked while pregnant.

How does this grandma effect happen? Some scientists believe that chemicals in cigarette smoke may change the DNA in a female fetus's eggs. DNA is the molecule that stores all of a person's genetic information. Eggs are the

female sex cells that are produced in a fetus while she is in the womb. It is thought the chemicals in smoke may change the genes that program the fetus's immune system. These altered genes may then trigger the development of asthma.

Efforts to reduce smoking

There are many organizations working to reduce the number of smokers in the United States. The March of Dimes supports research on the risks of smoking during pregnancy and provides information to pregnant women and their doctors. The Centers for Disease Control (CDC) also provides educational resources about the risks of smoking, with its aim being that, by 2010, less than 1 percent of pregnant women will be smoking.

Questions:

1. What impact do the toxic substances in cigarette smoke have on the development of a fetus?
2. What complications may occur in women who smoke both before they are pregnant and during their pregnancy?
3. List several smoking risks that may occur in developing fetuses and in newborns.
4. What is the "grandma effect"? What impact can a woman's smoking have on her grandchildren?

CHAPTER ACTIVITY Build a Lung Model

Animals need oxygen to survive. Land animals get oxygen from the air they breathe. The respiratory system consists of the airways, lungs, and muscles that work together to let air in and out of the body. In this activity you will build a model of a single lung and see for yourself how breathing really works.

For this activity, your group will need:

- 1 empty water bottle (the kind with the pull-top cap)
- 2 balloons (good-sized helium party balloons)
- duct tape
- scissors

What you will do

1. Poke a hole in the bottom of the empty bottle and use the scissors to carefully cut a small nickel-sized hole in the bottom of the bottle. (use caution - the bottom plastic is thick.)
2. Cut the neck off of one of the balloons and stretch the balloon over the entire bottom of the bottle. Secure with duct tape.
3. Unscrew the pull-top and pop up the opening so the cap is in the "open" position.
4. Slide the second balloon over the popped-out part of the cap and rest the cap on top of the bottle upside-down, with the balloon hanging into the bottle.
5. To operate your lung model, gently pull down on the middle of the balloon that is covering the bottom of the bottle. Watch what happens to the "lung" inside the bottle.

Applying your knowledge

1. Make a sketch of your lung model and label the parts of the model that represent the:
   a. diaphragm
   b. chest cavity
   c. lung
   d. airway
2. Use several sentences to explain why air enters the model lung when you pull down on the balloon that covers the bottom of the bottle.
3. Use several sentences to explain how breathing works in the human respiratory system.
4. How many times do you breathe in one minute? Work with a partner to determine your average number of breaths per minute and record your data. Compare your results with classmates. What is the class average for breaths per minute?
5. Research a lung disease. Some examples are: pneumonia, asthma, emphysema, chronic bronchitis, lung cancer. Use the internet and library for your research. Find answers to the following questions:

- What part of the respiratory system is affected?
- What are the symptoms?
- What are possible causes?
- What treatments are necessary?

Chapter 16 Assessment

Vocabulary

Select the correct term to complete the sentences.

capillaries	respiration	feedback control system
red blood cell	alveoli	umbilical cord
blood pressure	ovaries	endocrine system
arteries	testes	pancreas
valve	hormones	sweat glands
veins	follicle	fetus
plasma	semen	adrenal glands
circulatory system	implantation	respiratory system
white blood cell	ovulation	integumentary system
blood	uterus	

Section 16.1

1. Made up of the heart, blood vessels and blood, the _____ transports substances to and from the cells.
2. The failure of a heart _____ to properly close could cause the blood to flow backwards in the vessels.
3. _____ carry blood away from the heart.
4. The network of small blood vessels that allow oxygen and other substances to flow into tissues are _____.
5. Thin walled vessels that return blood to the heart are _____.
6. Made of specialized cells, plasma and platelets, _____ transports nutrients, wastes and other substances throughout the body.
7. Red and white blood cells are suspended in a fluid called _____.
8. A blood cell containing the oxygen carrying molecule hemoglobin is a _____.
9. A blood cell that helps fight infections is a _____.
10. _____ is a measure in mm Hg of the force that blood exerts on the walls of blood vessels.
11. An organism exchanges of oxygen, carbon dioxide and water with the environment through the process of _____.
12. The _____ consists of the lungs and their associated passages.
13. Sac-like structures within the lung that allow gas exchange are _____.

Section 16.2

14. Production of sperm and testosterone take place in the _____.
15. _____ such as testosterone help regulate body functions.
16. _____ is formed of sperm and fluid from the prostrate gland.
17. Organs that produce eggs and female sex hormones are the _____.
18. Beginning at puberty, females release mature eggs from the ovary in a process called _____.
19. Developing eggs mature in _____ of the ovary.
20. Development and growth an embryo happens in the _____.
21. After the fertilized egg travels down the fallopian tube, the process of _____ must take place in order for pregnancy to continue.
22. The placenta supplies nutrients and oxygen to the embryo via the _____.
23. After the eighth week of pregnancy, the _____ has all the major structures of an adult.

Section 16.3

24. The skin, nails and hair are major components of the _____.

25. Without ____, the body would be unable to regulate body temperature.
26. The _____ is made up of glands that secrete regulatory hormones.
27. The _____ aids in digestion and blood sugar regulation.
28. The _____ produce epinephrine, which triggers a fight or flight response to stress.
29. Without our complex _____, the body could not control the effects of hormonal secretions from endocrine glands.

Concepts

Section 16.1

1. A lack of energy is a symptom seen in some types of blood disorders. Which component of the blood is most likely the cause and why?
2. Which statement correctly describes blood pressure?
   a. Accidental loss of blood would increase systolic pressure.
   b. Sphygmomanometers measure pressure exerted on the walls of blood vessels returning to the heart.
   c. A blood pressure reading of 110/73 mm Hg signifies that the force exerted on arterial walls during the relaxation of the heart can push a column of mercury 73 mm high.
   d. Vessels returning to the heart have thicker walls to accommodate higher blood pressures.
3. Accidentally, surgeons reverse the aorta and pulmonary arteries of a heart transplant patient. Now the right ventricle pumps blood out through the aorta and the left ventricle is connected to the pulmonary artery. How would this change blood flow? Why would this need to be corrected quickly?
4. Outline the path an oxygen molecule would take as it traveled from the outside environment to your tissues.
5. Which of the following is true?
   a. Blood moves most quickly in the capillaries.
   b. Heart valves force blood through the heart
   c. More than half of your blood is made of red blood cells.
   d. Large veins have one-way valves to channel blood back towards the heart.
6. Lung tissue damage caused by smoking can lead to the slowing of blood from the heart to the lungs. Which structure is most likely weakened by the increased pressure caused by the backup?
   a. Right ventricle
   b. Aorta
   c. Left ventricle
   d. Pulmonary artery

Section 16.2

7. Which of the following correctly traces the path of sperm out of a man's body.
   a. Vas deferens-prostrate gland seminiferous tubules, urethra
   b. Seminiferous tubules-epididymis-vas deferens-urethra
   c. Seminiferous tubules-vas deferens-epididymis-urethra
   d. Epididymis-seminiferous tubules-vas deferens-urethra
8. The levels of which of the following would not be analyzed in the case of a couple not being able to conceive children?
   a. Testosterone
   b. Estrogen and progesterone
   c. Sperm production
   d. Epinephrine

9. Fraternal twins are the result of two eggs being fertilized by separate sperm. Outline the series of events that happen within a woman that would lead to a fraternal twin pregnancy.
10. How does the fetus receive nourishment during development?
11. Which of the following is true about drug and alcohol consumption during pregnancy?
    a. Drug and alcohol use is not a risk because the maternal blood and fetal blood do not mix.
    b. Only drugs can pass through the placenta to the fetus.
    c. Organ and tissue damage can result as both drugs and alcohol pass easily through the placental lining to the fetus.
    d. Alcohol is dangerous to the fetus only if the mother drinks beyond her legal limits.

Section 16.3

12. Third degree burns involve the deeper dermal layers of the skin. Why are these more dangerous than first degree burns involving only the epidermal layers?
13. Describe how sweat glands regulate homeostasis in the body.
14. In a person with diabetes mellitus, the level of which hormone would fail to increase in the blood after eating a chocolate bar?
    a. epinephrine
    b. insulin
    c. testosterone
    d. progesterone
15. Of the following, which would have the most widespread effects if damaged?
    a. Pituitary gland
    b. Testes
    c. Adrenal gland
    d. Pancreas
16. How are the organs of the excretory system different from those of the digestive system?
17. Of the following, which does not have a role in the production or excretion of urea?
    a. Liver
    b. Bladder
    c. Kidney
    d. Stomach

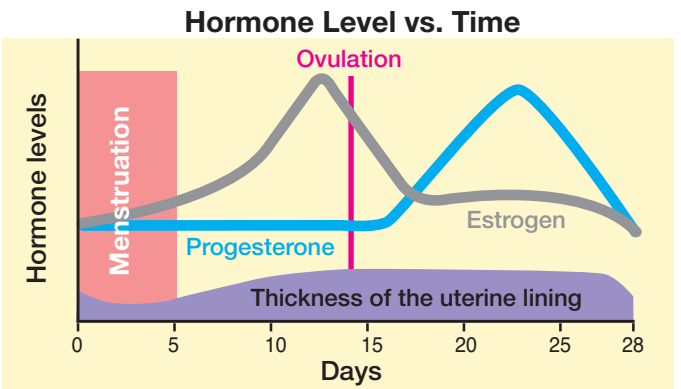
Math and Writing Skills

Section 16.1

1. The average male American lifespan is 72 years. Assuming the average resting heart rate for a male is 72 beats per minute, calculate the number of times the heart of an average male will beat over his lifetime.
2. The average amount of blood a person has is 5 liters. If 55% of that blood is plasma, how many liters of plasma does the average person contain?
3. Write a short story that describes the journey of a red blood cell through the human circulatory system.

Section 16.2

4. The graph below shows the hormone levels in a woman's blood during her menstrual cycle. Examine the graph and then answer the questions below.



   a. Which hormone controls the thickening of the uterine lining?
   b. Which hormone controls ovulation?
   c. What happens when the levels of both hormones decline?

Section 16.3

5. Make a line graph that shows the levels of insulin and glucose in your blood before and after eating a candy bar. Plot time on the *x*-axis and insulin/glucose level on the *y*-axis. You do not need to worry about the numerical values of the variables. Just estimate what the curve of each line would look like.

Chapter Project

Placental Health

It is important for a pregnant woman to maintain a healthy lifestyle, since oxygen and nutrients pass from her blood to the fetus through the placenta and umbilical cord. For this project you will create a tri-fold brochure that teaches the importance of the placenta and umbilical cord. Make a brochure that could be displayed in the waiting room of a doctor's office. Make your brochure creative and informative so people will want to read it. You need to list four sources of information on the very back of your brochure. Only two of the sources can be websites. Things to include in your brochure:

1. Labeled sketch that shows fetus, placenta, and umbilical cord in the uterus.
2. List of behaviors or choices that result in harmful substances reaching the fetus through the placenta.
3. List of diseases that can be transferred from the mother to the fetus through the placenta.
4. "Do's and Don'ts" to maintain a healthy pregnancy.
5. Places to go for more information (4 sources; only 2 websites).

Chapter 17

Support and Movement

Why are skeletons often used to scare people on Halloween? Many people associate a skeleton with a dead person, but your skeletal system is quite alive and it is an extremely important body system. Why is your skeleton so important? You probably know that your bones provide support and structure for your body. Did you also know that your bones and muscles protect your vital organs, and allow you to move? Did you know that bones produce blood cells and store important minerals that your body needs? Your jaw, neck, arms, feet, and other skeletal/muscle partners work like simple machines to accomplish daily tasks. After reading this chapter, you will see that the human systems of support and movement can do more than scare people on Halloween!

Key Questions

1. ***Why are bones so important to the human body, and how many are there?***
2. ***How do muscles move bones?***
3. ***Why is the human body like a machine?***

17.1 Bones and Muscles

Like a machine, your body consists of many parts that move. Those parts are your bones and muscles. Muscles are attached to bones by tendons. Muscles and bones work in coordination with your nervous system to move your body on demand. In this section you will learn about the structure and function of bones and muscles and how they work together.

The skeletal system

Growth of the skeletal system

The *skeletal system* is the name given to the collection of bones in your body. A baby's body has about 300 bones at birth. These eventually fuse (grow together) to form the 206 bones in an adult. Much of a baby's skeleton is made of cartilage. As you grow, most of the cartilage grows and is slowly replaced by bone with help from calcium. By the time you are 25, growth is complete. Then, your bones will have reached their final size.

Functions of the skeletal system

The skeletal system serves many important functions including:

- It protects the vital organs such as the brain, heart, and lungs.
- It gives your body shape and form.
- It allows for movement.
- It produces blood cells and stores minerals.

How the skeleton is divided

The human skeleton is divided into two parts. The **axial skeleton** consists of bones that form the *axis* of the body. It supports and protects many organs and includes the skull, vertebral column, ribs, and sternum. The **appendicular skeleton** includes the bones of the limbs and the *girdles*. The *pectoral girdle* forms your shoulders and anchors your arms. The *pelvic girdle* forms your hips and anchors your legs. The diagram on the next page shows the major bones of your body.

VOCABULARY

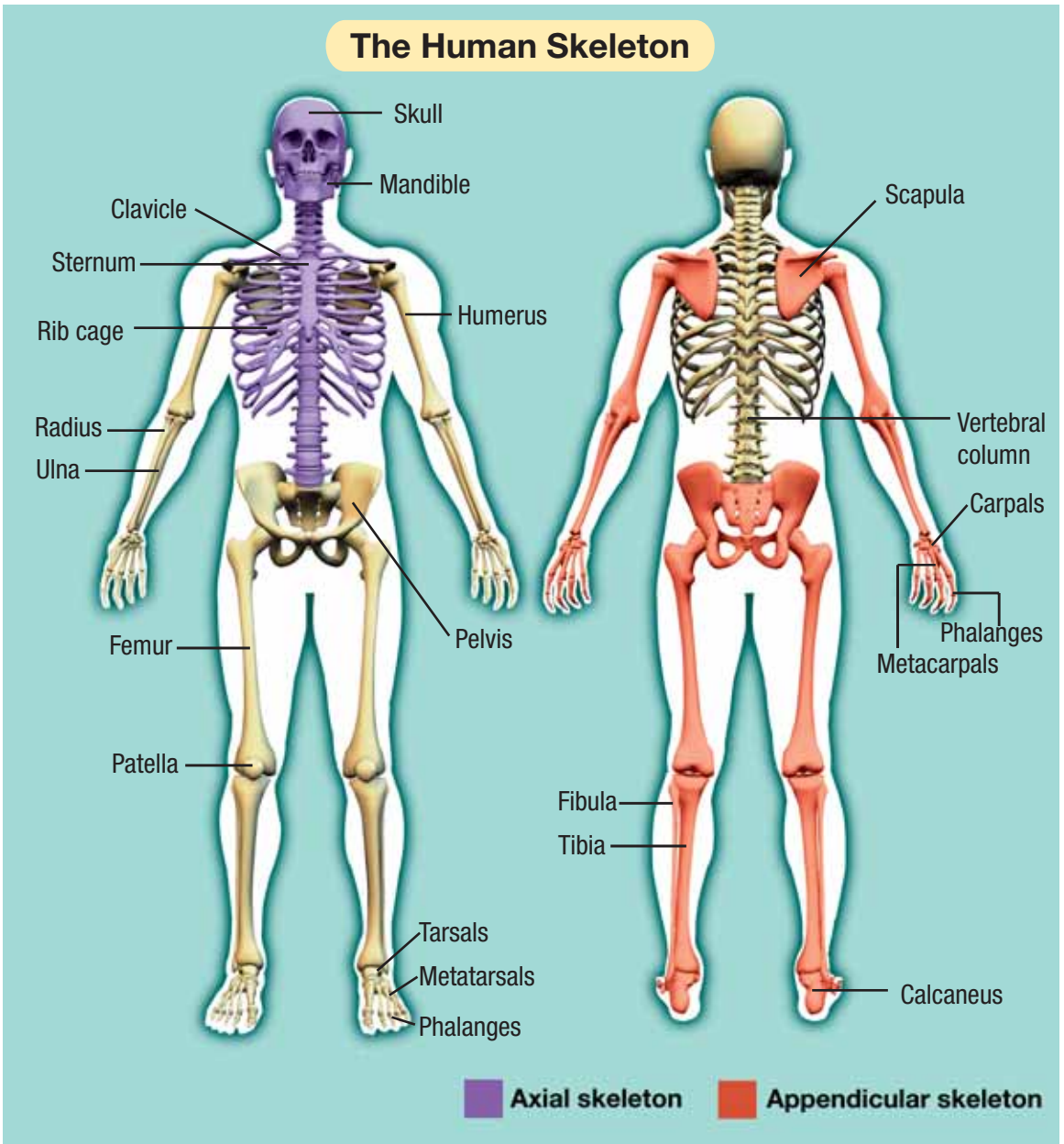
axial skeleton - forms the axis of the body and includes the skull, vertebral column, ribs, and sternum.

appendicular skeleton - the bones of the limbs, including the bones of the pectoral and pelvic girdles.

STUDY SKILLS

Learning your bones

The human skeleton is shown on the next page. Study the diagram and find the location of the bones of your own body. Learn the names of the major bones on the diagram. Then, try to identify the bones on a model skeleton without looking at the names on the diagram.



Your bones

Here are the common names for some of your bones

Mandible - jaw bone

Sternum - breast bone

Scapula - shoulder blade

Humerus - upper arm

Radius/ulna - forearm

Femur - thigh

Tibia - shin bone

Phalanges - fingers and toes

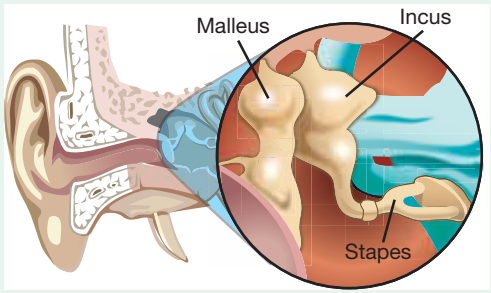
Pelvis - hip

Patella - knee cap

Calcaneus - heel

What are the smallest bones in your body?

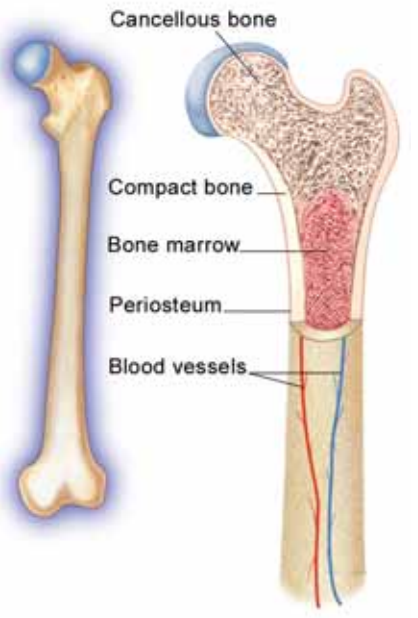
The bones of your inner ear!



What is bone?

The structure of bone

If you've ever seen a real skeleton in a museum, you might think that all bones are dead. But the bones that make up your skeleton are living organs. Bones are made of many layers of connective tissue and minerals produced by living cells. Almost every bone in your body has a similar structure:



- The outer surface of bone is called the periosteum. The **periosteum** is a thin membrane that contains blood vessels to nourish the bone and nerves.
- The next layer is called compact bone. **Compact bone** provides most of the strength and support. It is the smooth, hard part you see when you look at a skeleton. Tiny canals within compact bone contain blood vessels (Figure 17.1).
- Within the compact bone are many layers of cancellous bone. **Cancellous bone** has many open spaces like a sponge. Cancellous bone is not quite as hard as compact bone, but it is still very strong.
- In many bones (like the femur), the cancellous bone protects the innermost part of the bone called bone marrow. **Bone marrow** is a thick, jelly-like layer that makes blood cells or stores fat. *Red bone marrow* produces red blood cells. *Yellow bone marrow* stores fat.

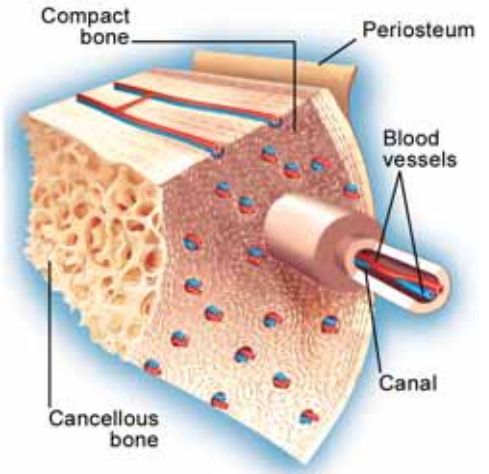


Figure 17.1: *A cross section of the femur—longest bone in your body.*

VOCABULARY

periosteum - the outer surface of a bone that contains blood vessels and nerves.

compact bone - the layer of bone that provides most of its strength.

cancellous bone - the layers of bone that have many open spaces like a sponge.

bone marrow - a thick, jelly-like layer of bone that makes blood cells or stores fat.

Joints

Fixed and moving joints

The place where two bones meet is called a **joint**. Some joints are fixed while others move. Your skull has some fixed joints called sutures. *Sutures* close up the bones of the skull. Moving joints are the ones that let you twist, bend, and move different parts of your body. Figure 17.2 shows the types of moving joints.

Hinge joints

One type of moving joint is called a **hinge joint**. Your elbows and knees each have hinge joints. They allow you to bend and then straighten your arms and legs. These joints are like the hinges on a door. Just as most doors can only open one way, you can only bend your arms and legs in one direction. You also have many smaller hinge joints in your fingers and toes.

Ball and socket and sliding joints

Another important type of moving joint is the **ball and socket joint**. You can find these joints at your shoulders and hips. They are made up of the round end of one bone fitting into a small cup-like area of another bone. Ball and socket joints allow movement in every direction. *Sliding joints* allow bones in your hand to glide over one another and provide flexibility.

Where bones meet

Bones are held together at the joints by ligaments. **Ligaments** are strong elastic bands of connective tissue. When bones move, there is friction. Cartilage helps cushion the areas where bones meet. Have you ever seen someone lubricate a door hinge to stop it from squeaking? Your joints have their own lubricating fluid called *synovial fluid*. This fluid helps them move freely.

VOCABULARY

joint - the place where two bones meet.

hinge joint - joints that allow one-way movement.

ball and socket joint - joints that allow movement in all directions.

ligament - a strong elastic band of connective tissue.

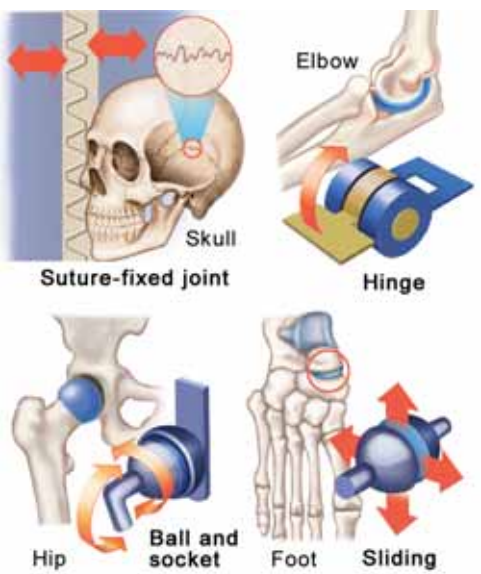


Figure 17.2: *Three types of moving joints.*

The muscular system

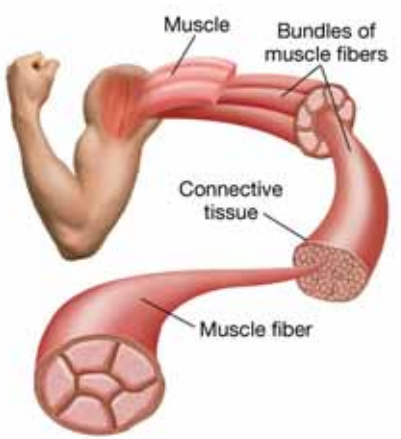
What is the muscular system?

The **muscular system** consists of skeletal muscles and tendons. *Skeletal muscles* are made of skeletal muscle tissue. Recall that the other two types of muscle tissue are cardiac muscle and smooth muscle. A **tendon** is a strand of tough connective tissue that attaches a skeletal muscle to a bone. The major function of the muscular system is to move bones. It also provides support and protection for your organs. Figure 17.3 shows some human body muscles.

Muscle action

The beating of your heart and movement of your digestive tract are both examples of involuntary muscle action. *Involuntary* means you do not control the movement. Most of the time, skeletal muscles are involved in voluntary muscle movement. *Voluntary* means that you can control it. When you lift an object, it is voluntary. You can voluntarily blink your eyes. However, sometimes blinking your eyes is involuntary.

Skeletal muscle tissue



Skeletal muscle tissue is made up of thousands of cylindrical muscle fibers often running the entire length of the muscle. Bundles of fibers are bound together by connective tissue. Blood vessels and nerves run through the connective tissue. Muscle fibers contain long muscle cells each with thousands of mitochondria for energy. During a muscle contraction, a complex reaction causes muscle fibers to shorten. When the muscle relaxes, muscle fibers return to their original position.

VOCABULARY

muscular system - a body system that consists of skeletal muscles and tendons.

tendon - a strand of tough connective tissue that attaches a skeletal muscle to a bone.

Figure 17.3: *Some human muscles.*

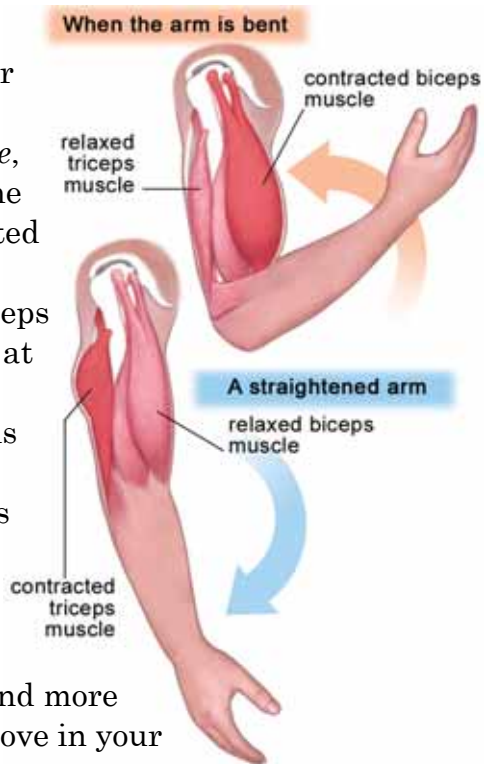
Movement

Muscles work in pairs

Muscles usually work in pairs called flexors and extensors. If a muscle bends part of your body, it is called a **flexor**. If a muscle straightens part of your body, it is called an **extensor**. Flexor and extensor pairs are found across many of your joints. These pairs provide almost all the movement of your skeleton.

An example of muscle movement

An example of a flexor and extensor working together is found in your arm. The flexor is the *biceps muscle*, located at the front of your arm. The extensor is the *triceps muscle*, located at the back of your arm. When the biceps muscle is contracted, the triceps muscle is relaxed. Your arm bends at the elbow joint and raises your forearm. When the triceps muscle is contracted the biceps muscle is relaxed. Now, your arm straightens out.



Exercise

Muscles require movement and exercise to remain strong. Muscles actually become stronger, larger, and more efficient with more exercise. You move in your every day activities. This is sufficient to maintain your muscle strength. *Resistance exercise* requires muscles to overcome resistance (weight). This increases muscle size and strength. *Aerobic exercise* like running, swimming laps, and cycling strengthens the heart and increases the endurance of skeletal muscle.

VOCABULARY

flexor - a muscle that bends part of your body.

extensor - a muscle that straightens part of your body.

Figure 17.4: *Resistance and aerobic exercises.*

17.1 Section Review

1. Match the names of the bones below to letters in the diagram (Figure 17.5).
   - humerus
   - femur
   - pelvic bone
   - vertebral column
   - sternum
   - ulna
2. Tell whether each bone in question 1 is part of the appendicular skeleton or axial skeleton.
3. Match each layer of bone to its function.

Organ system	Function
1. red marrow	a. provides most of the strength and support
2. periosteum	b. produces red blood cells
3. cancellous bone	c. stores fat
4. yellow marrow	d. contains blood vessels and nerves
5. compact bone	e. contains many open spaces like a sponge

4. Name a place on your body that has each type of joint:
   a. hinge joint
   b. ball and socket joint
   c. sliding joint
5. In the pair of muscles below, which is the extensor? Which is the flexor?
   a. triceps
   b. biceps

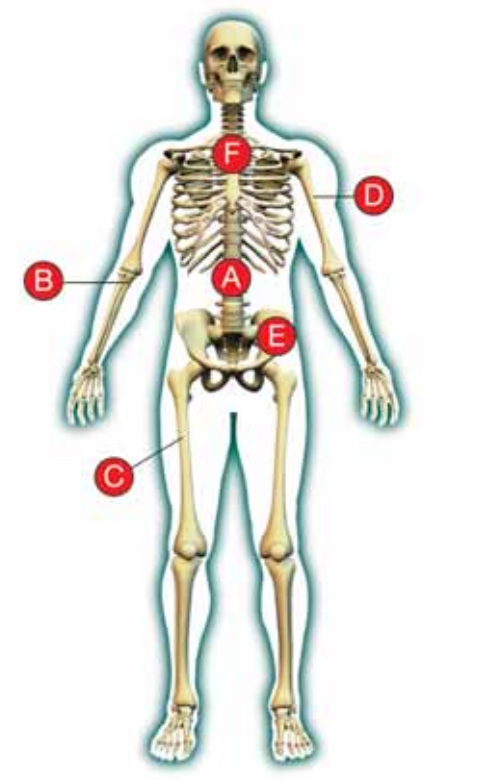


Figure 17.5: *Use this diagram to answer question 1.*

17.2 The Human Body as a Machine

You may have heard the human body described as a machine. In fact, it is. Your bones and muscles work as *levers* to perform everything from chewing to throwing a ball. The lever is an example of a *simple machine*. In this section, you will learn how simple machines work. You will also learn how certain parts of the human body work as levers. First, you need to know a little about the concept of *force*.

Forces

What is a force? A **force** is a push or pull, or any action that has the ability to change motion. Forces are created in many different ways. For example, your biceps muscle creates a force when you raise your arm. Earth's gravity creates forces that pull on everything around you. On a windy day, the movement of air creates forces.

Measuring force Weight is a measure of the force exerted by gravity. Weight is therefore a measure of force. The *pound* is the English unit of force. The *newton* (N) is the SI unit of force. A force of one newton is the exact amount of force needed to cause a mass of one kilogram to increase in speed (accelerate) by one meter per second each second (Figure 17.6). The newton is a smaller unit of force than the pound. One pound of force equals 4.448 newtons. How much would a 100-pound person weigh in newtons? Remember that 1 pound = 4.448 newtons. Therefore, a 100-pound person weighs 444.8 newtons.

VOCABULARY

force - a push or a pull, or any action that has the ability to change motion.

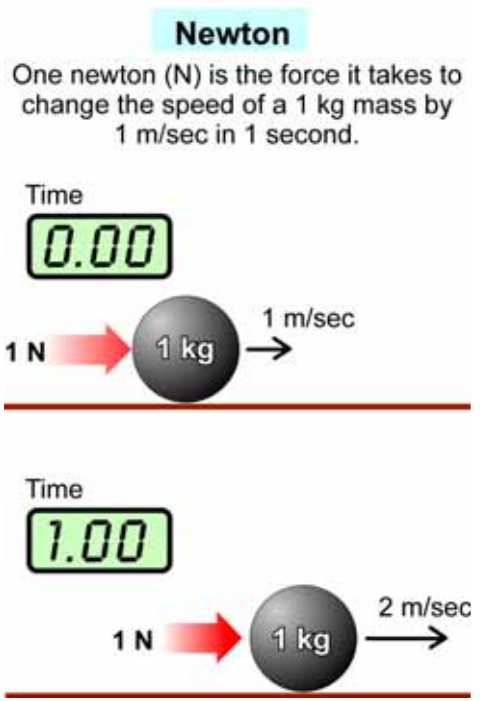
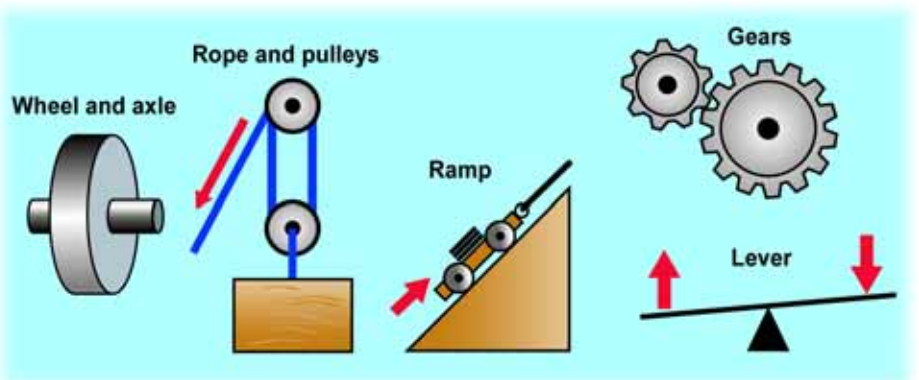


Figure 17.6: *The definition of a newton.*

Simple machines

The beginning of technology

A *simple machine* is an unpowered mechanical device, such as a lever. Some other simple machines are a wheel and axle, ropes and pulleys, gears, and a ramp.



Input force and output force

Simple machines are often used to lift heavy loads. A lever allows you to move a rock that weighs 10 times as much as you do (or more). You can think of simple machines in terms of an *input force* and an *output force*. With a lever, the **input force** (also called the *effort*) is the force you apply. The **output force** is the force exerted on the *load* you are lifting (Figure 17.7).

ropes and pulleys

A simple machine can create an output force large enough to lift a heavy load with a smaller input force. In ropes and pulleys, the input force is what you apply to the rope. The output force is what gets applied to the load you are trying to lift. One person could lift an elephant with a properly designed set of ropes and pulleys (Figure 17.8)!

VOCABULARY

input force - the force applied by a lever (also called the effort).

output force - the force exerted on the load.

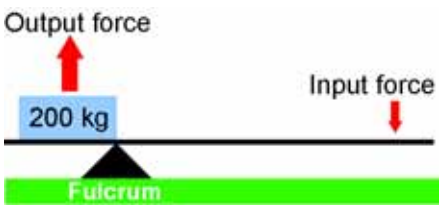


Figure 17.7: *Forces in a lever.*

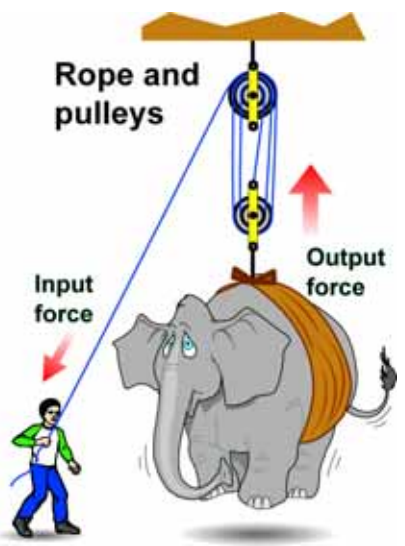


Figure 17.8: *Forces in a set of ropes and pulleys.*

Levers and mechanical advantage

Examples of levers

A lever can be made by balancing a board on a log (Figure 4.7). Pushing down on one end of the board lifts a load on the other end of the board. The downward force you apply is the input force. The upward force the board exerts on the load is the output force. Other examples of levers include: pliers, a wheelbarrow, and the human biceps and forearm.

Parts of the lever

All levers include a stiff structure (the lever) that rotates around a fixed point called the **fulcrum**. The side of the lever where the input force is applied is called the input arm. The output arm is the end of the lever that moves the rock or lifts the heavy weight. Levers are useful because you can arrange the fulcrum and the input and output arms to adapt to the task you need to perform.

The ability of a lever to perform a task depends on its mechanical advantage. **Mechanical advantage** is the ratio of output force produced by a simple machine to the applied input force. The higher the output force in relation to the input force, the greater the mechanical advantage. You can calculate mechanical advantage by dividing the output force, in newtons, by the input force, in newtons as shown in the formula below:

MECHANICAL ADVANTAGE

$$\text{Mechanical advantage} \rightarrow MA = \frac{F_o}{F_i}$$

F_o ← Output force (N)

F_i ← Input force (N)

VOCABULARY

fulcrum - the fixed point where a lever rotates.

mechanical advantage - the ratio of output force produced by a simple machine to the applied input force.

SOLVE IT!

Suppose the output force of a machine is 10N and the input force is 5N. What is the mechanical advantage of the lever? Using the formula, you get:

$$MA = \frac{\text{output force (N)}}{\text{input force (N)}} = \frac{10\,\text{N}}{5\,\text{N}} = 2$$

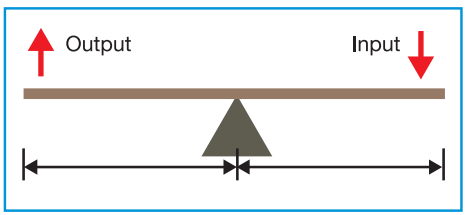
Calculate the mechanical advantage for each lever:

1. Output force = 25N
   Input force = 5N
2. Output force = 10N
   Input force = 2N
3. Output force = 5N
   Input force = 10N

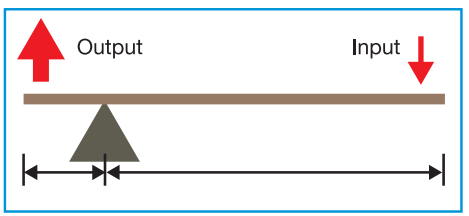
Mechanical advantage and length of input and output arms

Lever arm length and mechanical advantage

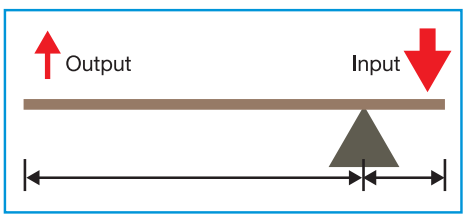
The input force that is applied to a lever and the output force are related to the lengths of the input and output arms. When the input and output arms are the same length (because the fulcrum is in the middle of the lever), the input and output forces are the same. The input and output forces are different if the fulcrum is not in the center of the lever. The side of the lever with the longer arm has the smaller force.



Output arm = Input arm
Output force = Input force
Mechanical advantage = 1



Output arm < Input arm
Output force > Input force
Mechanical advantage > 1



Output arm > Input arm
Output force < Input force
Mechanical advantage < 1

< Means less than > Means greater than

Varying the length of the arms

For some levers, the output arm is longer than the input arm and the output force is less than the required input force. Levers designed this way achieve a wide range of motion on the output side. For example, a broom is a lever used to sweep floors (Figure 17.9).

SOLVE IT!

The mechanical advantage of a lever can be calculated if you know the lengths of the input and output arms using this formula:

$$MA = \frac{\text{length of input arm}}{\text{length of output arm}}$$

Use the formula above to calculate the mechanical advantage of a lever with an input arm that is 40 cm long and an output arm that is 60 cm long.

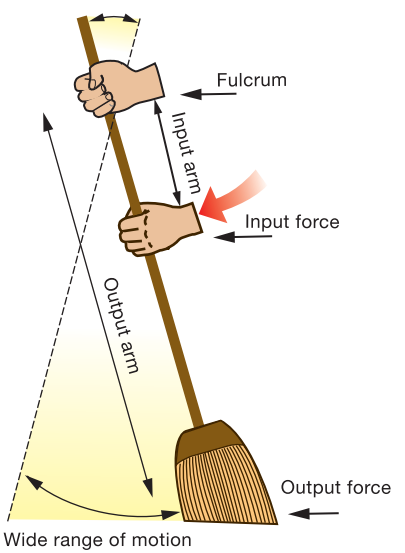


Figure 17.9: *A broom has a mechanical advantage of less than 1.*

The three classes of levers

The three types of levers

There are three types of levers, as shown in Figure 17.10. They are classified by the locations of the input and output forces relative to the fulcrum.

First-class levers

First-class levers always have the fulcrum between the input force and the output force. If the input arm of a first-class lever is larger than the output arm, you can produce a large output force relative to the input force. Sometimes the input arm of a first-class lever is shorter than the output arm. In this case, the output force is less than the input force. The advantage of a lever designed this way is that work done by the lever can be done faster—a small amount of motion of the input arm translates into a huge motion made by the output arm. The mechanical advantage of a first-class lever can be greater than one or less than one. Examples of first-class levers include pliers and see-saws.

Second-class levers

Second-class levers always have the output force between the fulcrum and the input force. Therefore, the input arm will always be longer than the output arm in second-class levers. What does this mean in terms of mechanical advantage? It means that mechanical advantage will always be greater than one. Second-class levers always multiply force. Wheelbarrows are second-class levers.

Third-class levers

Third-class levers always have the input force between the fulcrum and the output force. This means that the output arm is always longer than the input arm and mechanical advantage is less than one. If mechanical advantage is less than one, then you can never multiply force by using a third-class lever. Third-class levers do result in a wide range of motion that is important in moving your arms or sweeping large areas when you use a broom.

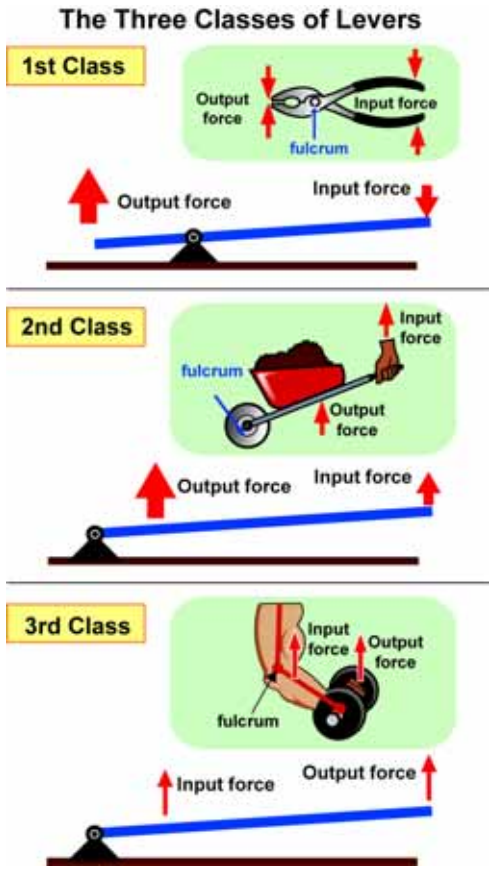


Figure 17.10: *Examples of three kinds of levers.*

Levers in the human body

In the human body, all bones act as levers and each joint can serve as a fulcrum.

The neck Stop reading for a moment. Relax your neck so that your head drops slowly forward. The head is a heavy object—about 4.5 kilograms. Your head drops forward when you relax your neck because your head and neck work like a first-class lever (Figure 17.11). The fulcrum is at the top of the neck. The muscles in the neck provide an input force that allows you to raise your head. When you relax these muscles, gravity causes your head to fall forward.

The jaw Think about how your jaw works when you bite into an apple. When biting, your jaw works as a third-class lever. The input force (applied by your jaw muscles) occurs between the fulcrum (the joint where your jaw bone connects to your skull) and the output force which is applied to the apple.

The arms Your forearms work as third-class levers (see Figure 17.10 on the previous page). As you have learned, third-class levers require more input force than output force. However, the gain in third-class levers is range of motion. The range of motion of your arms is very important in that it makes it possible to reach, pick up objects, and lift them. Often, we are doing tasks that don't require a lot of output force. For example, when you turn a page of this book, you need range of motion to move the page, but you don't need a lot of force!

Feet When you stand on your toes, the feet act as second-class levers (Figure 17.12). Your toes are the fulcrum. The input force is provided by your calf muscles. The output force is the weight of your foot being lifted.

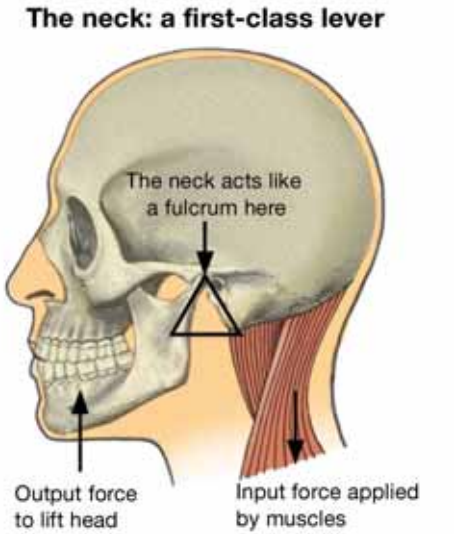


Figure 17.11: *The neck is an example of a first-class lever.*

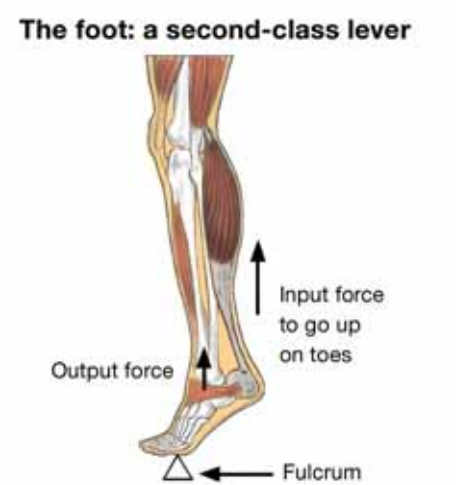
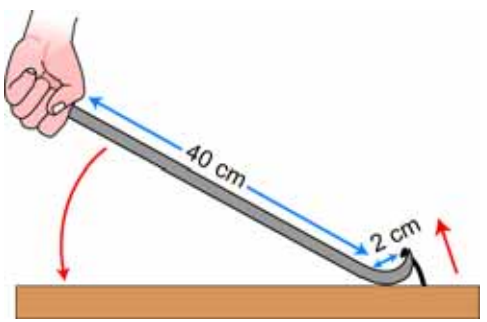


Figure 17.12: *The foot is an example of a second-class lever.*

17.2 Section Review

1. What is a force? Name two units used to measure forces.
2. How much does a 5 pound bag of flour weigh in newtons?
3. What is a simple machine? List three examples.
4. For the simple machine below: (a) Which is the output force? (b) Which is the input force? (c) Calculate the mechanical advantage.



5. Calculate the mechanical advantage for each lever:
   a. A lever has an input force of 15 N and an output force of 60 N.
   b. A lever has an input arm that is 35 cm and an output arm that is 7 cm.
   c. A lever has an output force of 5 N and an input force of 50 N.
6. The picture in Figure 17.13 shows the location of levers in the human body. For each lever in the diagram:
   a. Tell whether it is a first-class, second-class, or third-class lever.
   b. Tell whether the mechanical advantage is greater than, less than, or equal to 1.

CHALLENGE

Solve each challenging problem below.

1. A lever has a mechanical advantage of 2. Its output force is 100N. What is the input force of the lever?
2. A lever has an input arm that is 25 cm long. If it has a mechanical advantage of 5, what is the length of its output arm?
3. The total length of a lever is 100 cm. If the fulcrum is placed 75 cm from the edge of the output arm, what is its mechanical advantage?

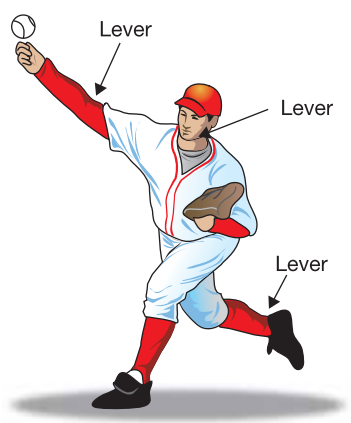
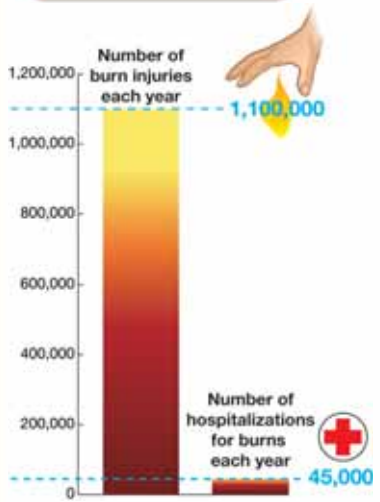


Figure 17.13: *Use the diagram to answer question 6.*

HEALTH CONNECTION

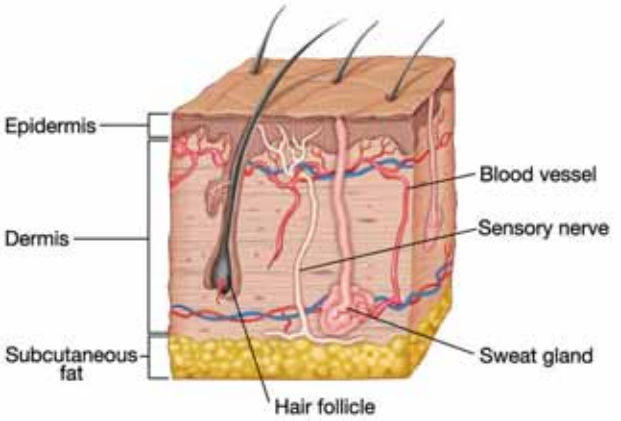
Skin Grafts for Burn Victims



According to the American Burn Association, there are 1.1 million burn injuries in the United States each year. About 45,000 Americans need to be hospitalized because of serious burns. Some 50 years ago, there were fewer than 10 hospitals in the country that specialized in treating burns. Today, there are +about 200 special burn care centers. There are many types of burns, including those caused by fire, heat, chemicals, electricity, sunlight, and nuclear radiation.

Layers of the skin

The skin is the largest organ of the human body. It has several functions: to serve as a protective barrier against infection, to help keep our bodies at the correct temperature, and to provide us our sense of touch.



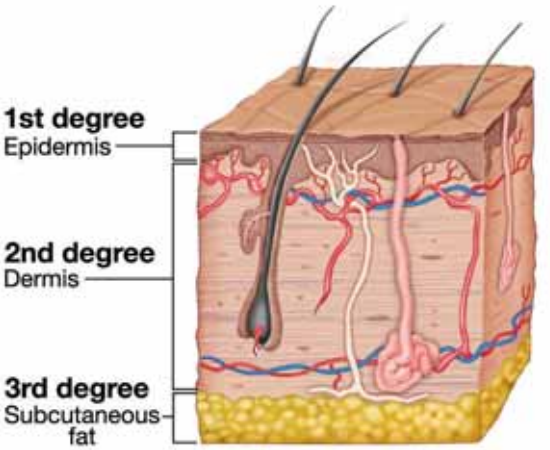
There are three main layers of the skin: epidermis, dermis, and subcutaneous fat. The epidermis is the outer layer of skin that you see. The body constantly adds new cells to this layer because 30,000-40,000 dead cells flake off the surface of your skin every minute. The epidermis also contains a substance called melanin, which gives skin its color.

The dermis is the tough and stretchy layer of skin that lies below the epidermis. The dermis contains nerve endings, blood vessels, oil glands, and sweat glands.

The bottom layer of skin is called the subcutaneous layer. It mostly contains fat to help your body stay warm. The subcutaneous layer also provides a cushion to protect your body from injury.

Degrees of burns

The degree of a burn is determined by how deeply it penetrates the skin. Burn wounds are classified into three depths. A first-degree burn is a minor burn that affects only the epidermis - a sunburn, for instance. Symptoms include redness, swelling, pain, and peeling skin. A second-degree burn is deeper and causes more damage to the skin. Blisters occur with second-degree burns and there is damage to the dermis. A third-degree burn is the most severe type of burn. It damages all the layers of skin and can sometimes expose muscle or bone. Healing from third-degree burns is slow and may result in much scarring.



Sources of skin grafts

Patients with severe burns are often treated with skin grafts. Surgeons who are specially trained in treating burn victims perform these procedures.

Skin grafts may involve taking healthy skin from an unburned part of the patient's body and placing it on the damaged area. This procedure is also called autografting, "auto-" referring to the graft being from the same individual.

Sometimes patients with large burns do not have enough undamaged skin for autografting, so skin is taken from a human donor. This is called an allograft, "allo-" referring to the donor being of the same species but different genetically.

However, skin from human donors is not always available, either. Sometimes skin from an animal donor (such as a pig) is used. This is called a xenograft, "xeno-" referring to the donor being of another species. The problem with donated skin is the risk of infection; the body's immune system often rejects the donated skin.

A system that helps burn victims to heal is the Integraâ Dermal Regeneration Template. This is not a replacement for skin, because it is not made from living cells. It provides a protective covering so that a patient's own cells can grow. These cells arrange themselves into a layer similar to a normal, healthy dermis.

Scientists are trying to develop a true artificial skin. It would work like normal skin and could be used to treat large burn areas. Scientists hope to create cells that will grow hair follicles and sweat glands, and so look and feel more like normal skin. Much research is still to be done but scientists hope artificial skin will become available in the near future.

New procedures for skin replacement

In 1987, a procedure for permanent skin replacement was developed involving creating large amounts of skin in the laboratory using skin cells from the burn victim. The body is less likely to reject this skin because it is made from the patient's own cells. This laboratory-created skin does not look or function like normal skin. Its color may be different from the patient's, and it does not contain hair follicles or pores for sweating.

Questions:

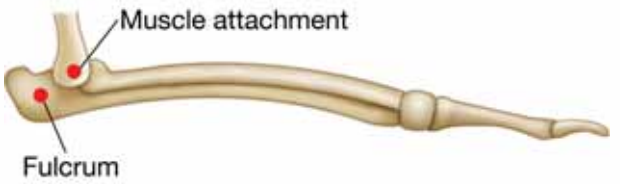
1. What are the different causes of burns?
2. What are the three layers of the skin and what do they contain?
3. What are the different degrees of burns and which layers of the skin do they affect?
4. What types of skin grafts are available to burn patients?

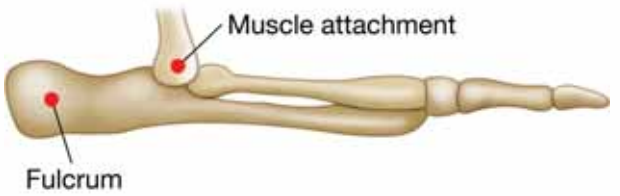
CHAPTER ACTIVITY Leg levers - Digger or Runner?

Some animals do a lot of running, while others spend a lot of their time digging. The way the leg lever is put together for each of these animals is different. In this activity you will find the mechanical advantage of two leg bones and decide which one is from a digger and which is from a runner. For this activity, you will need graph paper with 0.5 cm boxes, a pencil, and a calculator.

What you will do

1. Place a piece of graph paper over the leg bone sketches shown to the right. Trace both leg bones without moving or lifting the paper until all the tracing is done. Begin with the left side of each bone so it starts on one of the graph box lines. This will make it easier to count boxes in the next steps.
2. There are two important measurements to make when comparing the leg levers. One measurement is the distance from the fulcrum to the point of muscle attachment, and the other is from the fulcrum to the opposite end of the bone. Count how many boxes there are from the fulcrum to the muscle attachment point and label this on each sketch. This is the *input distance*.
3. Count how many boxes there are from the fulcrum to the right side of the lever and label this on each sketch. This is the *output distance*.
4. To find the mechanical advantage of each leg bone, divide the *input distance* by the *output distance*. Your number will be less than one.
5. Record the mechanical advantage for each leg bone beside the sketch. There is no unit label for mechanical advantage, because it is a ratio or comparison of measurements.





Applying your knowledge

The leg bone with the higher mechanical advantage can generate more force. The leg bone with the lower mechanical advantage can move quickly.

a. Now that you know the mechanical advantage of each leg bone, which leg bone belongs to the digger? Explain your answer.
b. Which leg bone belongs to the runner? Explain your answer.
c. Levers can be set up in three different ways, depending on where the fulcrum is in comparison to the input and output sides of the lever. Use your textbook to review the three types of levers. What class of lever is represented by the digger and runner leg bones? Explain your answer.
d. Use everyday items like popsicle sticks, fasteners, and rubber bands to model a runner leg lever and a digger leg lever. You may use any materials you wish, but the goal is to make a model that you can use to demonstrate the difference in how the two leg bones generate force and speed.

Chapter 17 Assessment

Vocabulary

Select the correct term to complete the sentences.

appendicular skeleton	bone marrow	extensor
axial skeleton	cancellous bone	flexor
ball and socket joint	compact bone	force
input force	hinge joint	fulcrum
ligament	muscular system	joint
mechanical advantage	tendon	periosteum
output force		

Section 17.1

1. Two muscles usually work together: the _____, which bends the body part, and the _____, which straightens the body part out.
2. Inside the layers of bone, _____ makes blood cells or stores fat.
3. Skull, vertebral column, ribs and sternum make up the _____, while the bones of limbs and girdles make up the _____.
4. The primary function of the _____ is movement.
5. _____ more spongy and not quite as strong as _____.
6. The two types of _____s are fixed and moving.
7. The _____ is a thin membrane that has blood vessels to nourish the bone and nerves.
8. The knee is an example of a _____, whereas the shoulder is an example of a _____.
9. The strand of tough connective tissues that attaches a skeletal muscle to a bone is called a _____.
10. _____ hold bones together at joints.

Section 17.2

11. The fixed point where a lever rotates in called the _____.
12. The _____ is calculated by dividing the output force by the input force.
13. Scientists use the Newton to express _____.
14. A simple machine can be used to create a large _____ with a small _____.

Concepts

Section 17.1

1. Explain why a human has more bones as a baby than as an adult.
2. What are the four major functions of the skeletal system?
3. Name and describe the two parts of the skeletal system.
4. Circle the correct answers to complete the following statement.
   The (pectoral, pelvic) girdle forms the shoulders, while the (pectoral, pelvic) girdle forms the hips.
5. Draw and label a cross section of bone.
6. Predict what might happen to a person that has a disease of the periosteum.
7. Your skull is made up of 22 bones. All but one of the joints is fixed. What is the one movable joint of the skull?
8. Describe the three types of moving joints.
9. Compare and contrast ligaments and tendons.
10. When a person suffers from arthritis, their cartilage is damaged. Why does this make movement painful?

11. Label these muscle movements are voluntary or involuntary: movement of the digestive tract, blinking of the eye, beating of the heart, raising the forearm.
12. Muscle fibers contain thousands of _____ for energy.
    a. endoplasmic reticulum
    b. lysosomes
    c. ribosomes
    d. mitochondria
13. The quadriceps muscle is on the front of the thigh. The hamstring muscle is on the back of the thigh. Explain what happens to the leg when each of these muscles contracts and relaxes.
14. Describe the two types of exercise. Give an example of each.

Section 17.2

15. Give three examples of different forces.
16. Look around your house and school for everyday examples of simple machines. List at least five that you find.
17. What is the difference between input force and output force?
18. Draw and label a lever with these terms: fulcrum, input force, output force.
19. Which of these is not a lever?
    a. pliers
    b. wheelbarrow
    c. ramp
    d. human biceps and forearm
20. Circle the correct answers to complete the statement. The side of the lever that is (longer, shorter) has the (smaller, greater) force.
21. What is the advantage of having a longer output arm than input arm?
22. How are levers classified?
23. Name and describe the three types of levers.
24. Identify each of the following levers as first, second, or third class:
    a. seesaw
    b. wheelbarrow
    c. tweezers
25. Match these descriptions to the correct type of lever:

a. 1st class	1. load - effort - fulcrum
b. 2nd class	2. load - fulcrum - effort
c. 3rd class	3. fulcrum - load - effort

26. Circle the correct answers to complete the statement. In the human body, (bones, joints) act as levers and (bones, joints) can serve as fulcrums.
27. Pick a lever in the human body to describe. Name the class of the lever and identify the fulcrum.

Math and Writing Skills

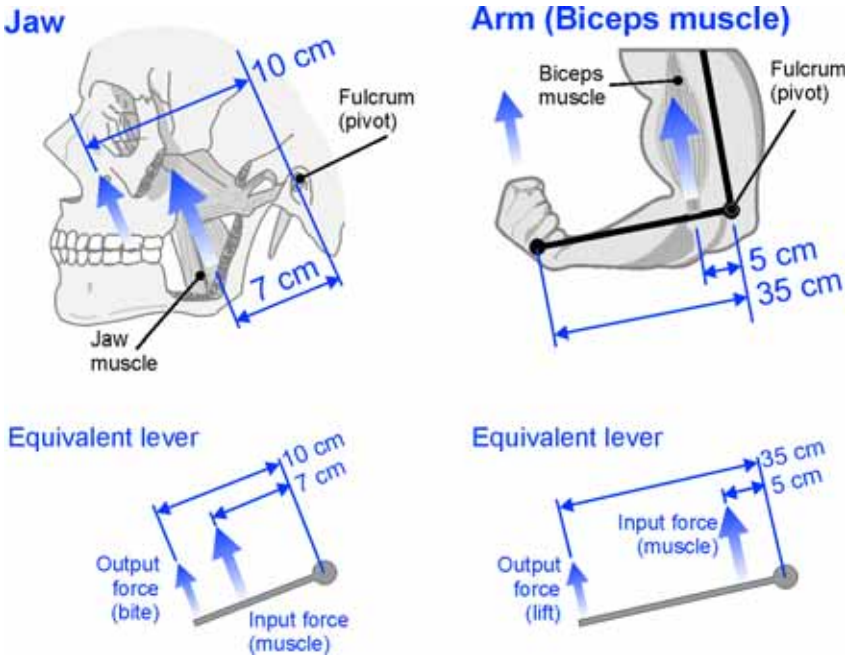
Section 17.1

1. Your friend tells you that bones are non-living things. Is your friend correct? Explain.
2. Write a persuasive paragraph about the importance of calcium to bone development.
3. Since cancellous bone is spongy, it weighs less than compact bone. Predict how an organism's overall body weight would be affected if all bones were made up of only compact bone. How might this be a challenge?

4. Bones are comprised of: 30% living tissue, cells, and blood vessels; 45% mineral deposits; and 25% water. Create a pie graph to show the make up of bones.
5. A male adult's height is 3.84 times the length of his thigh bone. If a male's thigh bone is 18.2 inches long, how is his overall height?
6. Design a robot that will fold the laundry. Make a sketch of your idea and label the types of joints necessary to perform this task.
7. How would your life be different if your involuntary muscles were voluntary? Write about a typical day at school if all your muscles were voluntary.
8. Muscles only pull - they can never push. Explain how it is possible for the human body to push something if this statement is true.
9. Make a poster to show how exercise is important for muscles.
10. your brother is crazy about lifting weights! Try and convince him to include aerobic exercise in his workout routine.
11. While you were training for track season, you reduced your resting heart rate from 82 to 67 beats per minute through daily exercise. How many contractions have you saved your heart each day?

Section 17.2

12. Tim weighs 800.64 newtons. How many pounds does he weigh?
13. Write a short story with as many examples of simple machines as you can. Create a separate answer key so that you can have a classmate try to find the examples.
14. Explain how rowing a boat is an example of a lever. Be sure to identify the location of the input force, output force, and fulcrum.
15. Your jaw works as a lever when you bite an apple. Your arm also works as a lever, as do many of the bones in your body. Using the diagrams below, answer the following questions by analyzing the changes in force and distance.



a. Using the distances shown, calculate and compare the mechanical advantage of the jaw and arm. Which is larger?
b. Suppose the jaw and biceps muscles produce equal input forces of 800N. Calculate and compare the output forces in biting (jaw) and lifting (arm). Which is larger?
c. Suppose you need an output force of 500N. Calculate and compare the input forces of the jaw and biceps muscles required to produce 500 N of output force. Explain how your calculation relates to the relative size of the two muscles.

16. A car gets stuck in the mud. The driver is using a lever to try to get out. If the driver applies an input force of 500 N and the mechanical advantage is 5, what is the output force?
17. Fill in these comparison statements with <, >, or =.
    a. If the mechanical advantage equals 1, the output force _____ the input force.
    b. If the output arm is less than the input force, the mechanical advantage _____ 1.
    c. If the mechanical advantage is less than 1, the output force is _____ the input force.
18. If the mechanical advantage of a lever is 12 N and the length of the input arm is 48 cm, what is the length of the output arm?
19. You just got a job at your local home improvement store! Your first assignment is to give a presentation on the three types of levers. Write an informative description of the types of levers and how they can be used to help with home improvement projects.
20. Write an article for the sports section of a newspaper about a recent sporting event of your choice. Include at least five examples of joints as levers in your article.

Chapter Project

Human Body Presentation

The human body's skeletal and muscular systems are complex and interesting, and for this project, you will choose a topic from the list below to learn more about these systems. Choose a topic, research it, and decide on a way to present your findings. You may decide to write a report, create a poster, build a model, write a poem or song, or put together a short book about what you have learned.

Choose a topic:

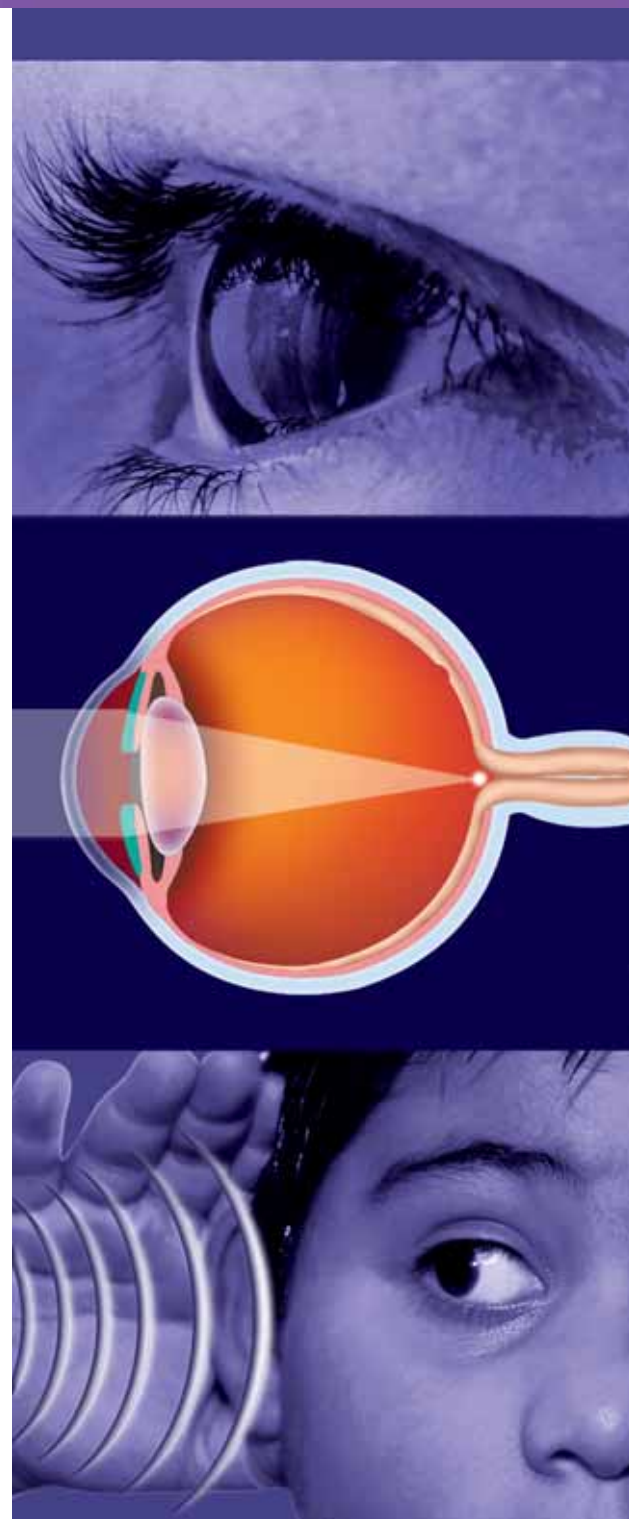
- Where did the funny bone get its name, and why does it hurt so much when you hit it?
- What actually makes that sound when you crack your knuckles?
- What does it mean to "pull a muscle", and what should you do to care for this type of injury?
- What is a major disease that can harm that skeletal or muscular system?
- How do X-rays work?
- How do doctors categorize different types of bone fractures?

1. Research your topic and take notes on what you learn. You must use four different sources of information, with no more than two of them being websites. Be sure to list your sources!
2. Create a product, such as a report, mini-storybook, model, poster, or something else of your choice to share what you've learned with your classmates.

Chapter 18

Vision and Hearing

Although small, your eyes and ears are amazingly important and complex organs. Do you know how your eyes and ears work? Scientists have learned enough about these organs to begin creating artificial eye and ear parts that might restore vision and hearing to some people who have lost their ability to see or hear. To do this, scientists and engineers must know a lot about light and sound waves, as well as how the brain works. Study this chapter to learn all about light and sound waves, the brain, and even how different optical systems work in addition to the structure and function of eyes and ears.



Key Questions

1. ***What are the components of your nervous system?***
2. ***How do telescopes and human eyes work?***
3. ***How does the human ear work, and why can you tell one voice from another, even when both say the same word?***

18.1 The Nervous System

Which body system allows you to see and hear? Which body system keeps your other systems working properly? You are right if you guessed your nervous system. In this section, you will learn about the components of the nervous system and how signals are transmitted in your body.

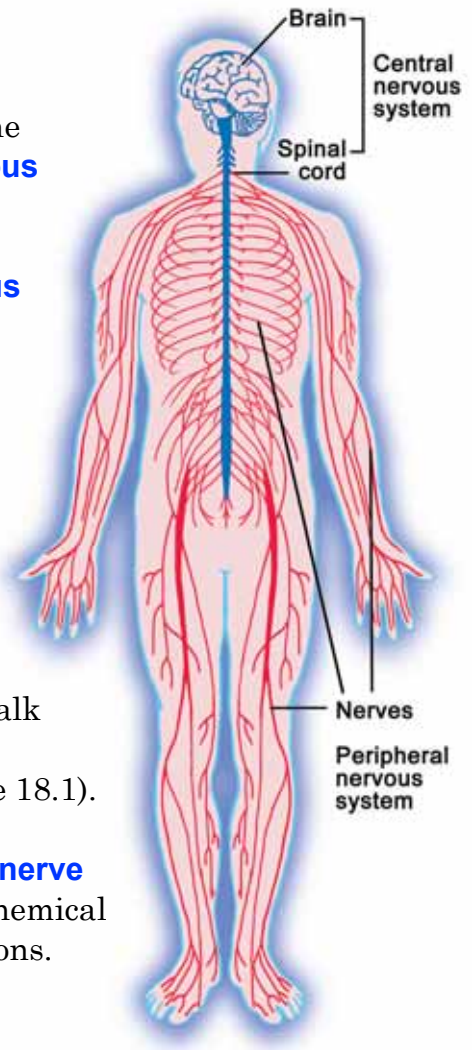
Parts of the human nervous system

Central and peripheral nervous systems

There are two major divisions of the nervous system. The **central nervous system** is your body's command center. It includes the brain and spinal cord. The **peripheral nervous system** consists of nerves that connect all areas of the body to the central nervous system. You can think of the peripheral nervous system as the "information highway" of your nervous system.

Neurons and nerve impulses

Your nervous system is made of hundreds of billions of specialized cells called neurons. A neuron has three parts: the cell body, a long stalk called the axon, and finger-like projections called dendrites (Figure 18.1). Neurons send signals called nerve impulses throughout your body. A **nerve impulse** is wave of electrical and chemical activity transmitted between neurons.



VOCABULARY

central nervous system - the control center of the body that includes the brain and spinal cord.

peripheral nervous system - consists of nerves that connect all areas of the body to the central nervous system.

nerve impulse - a wave of electrical activity transmitted between neurons.

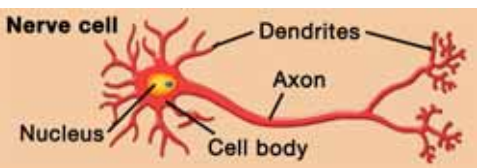


Figure 18.1: *The parts of a neuron.*

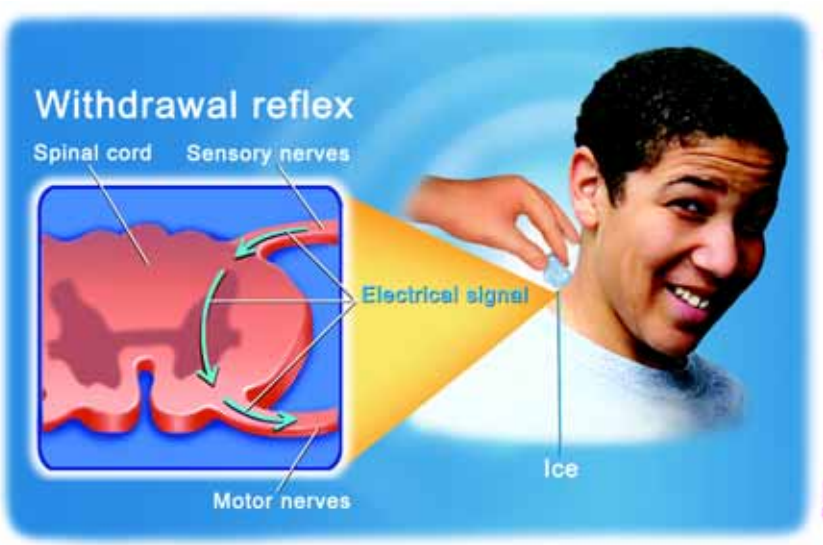
How your body responds to a stimulus

The withdrawal reflex

Imagine you're relaxing on the couch, watching your favorite television show. Someone sneaks up behind you and touches the back of your neck with a wet, frosty ice cube. Before you even have a chance to think "who did that?" your body springs into action. The ice cube triggers an automatic response called a **withdrawal reflex** that happens without a conscious decision on your part.

Sensory and motor nerves

A withdrawal reflex happens because nerve impulses are sent through the nerves in your body. When an ice cube touches the back of your neck, **sensory nerves** in your skin send nerve impulses through wire-like nerve fibers to your spinal cord. In the spinal cord, the nerve impulse is transferred to motor nerves. **Motor nerves** control muscle contractions. Impulses from your motor nerves cause the muscles in your neck and back to contract, jerking your body away from the ice cube. All of this happens in a split second!



VOCABULARY

withdrawal reflex - an involuntary response to an outside stimulus.

sensory nerves - nerves that receive sensory stimuli, such as how something feels.

motor nerves - nerves that transmit signals to skeletal muscle, causing movement.

MY JOURNAL

A withdrawal reflex happens automatically. A stimulus like cold or hot can trigger this response. Write a reflection about a time you experienced a withdrawal reflex. What caused the withdrawal reflex (the stimulus)? How did your body respond? How did you react afterwards?

How a nerve impulse works

Electrical and chemical signals

A withdrawal reflex starts when sensory nerves in your skin receive a stimulus from outside the body. That stimulus starts a nerve impulse along the cell membrane. When a neuron is at rest, the inside of the cell membrane is electrically negative compared with the outside. Figure 18.2 illustrates how a nerve impulse works.

1. The stimulus causes the cell membrane to open channels that let positively-charged particles into the cell. The inside of the cell becomes positively charged compared with the outside.
2. Other channels open and let positively-charged particles out of the cell. As they leave, the inside of the cell membrane once again becomes negatively-charged compared with the outside.
3. The nerve impulse travels down the axon like dominoes falling. When the impulse reaches the end of the axon, chemicals are released and picked up by a neighboring neuron, causing the nerve impulse to continue.

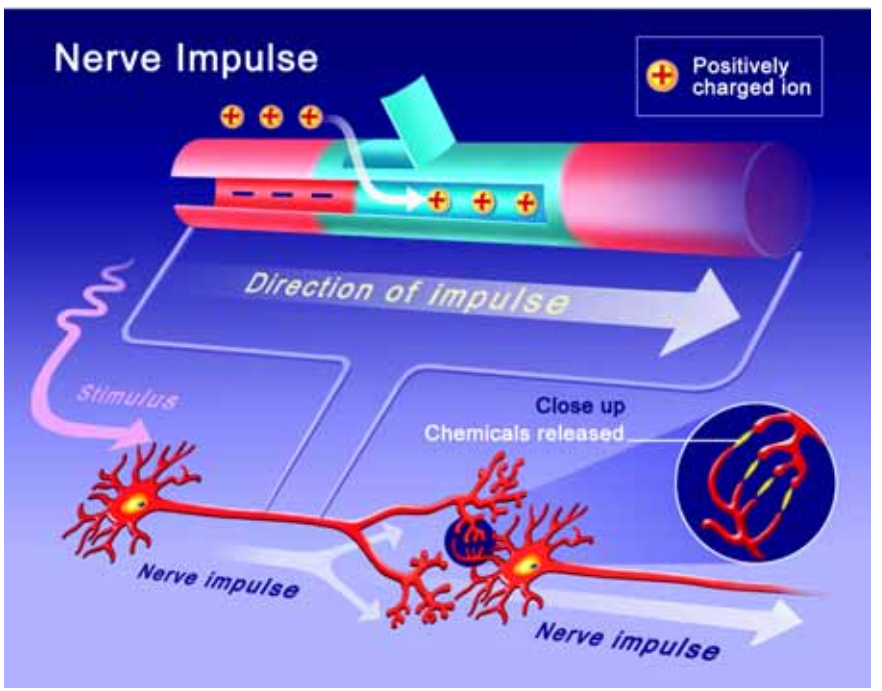


Figure 18.2: *A nerve impulse is a combination of electrical and chemical signals.*

Non-stop nerve impulses

Each second, your body fires off about five trillion nerve impulses. **Your emotions, decisions, and physical actions all happen through nerve impulses traveling through neurons in your brain, spinal cord and nerves.** A single neuron can have up to ten thousand dendrites connecting to other neurons. It is estimated that just one cubic millimeter of brain tissue contains a billion connections between cells!

The brain

What is the brain?

The brain is the processing and control center of your nervous system. The brain and spinal cord are made of tissues called gray and white matter. *Gray matter* is mostly made up of the cell bodies of neurons. *White matter* is mostly made up of the axons coming from those cell bodies. In general, grey matter makes up the parts of the brain responsible for information processing. White matter is responsible for transmitting nerve impulses.

The brain has three parts

The three parts of the brain are the cerebrum, the cerebellum, and the medulla (Figure 18.3). These parts are all connected but each part has its own function.

The cerebrum

The largest part of your brain is the dome-shaped cerebrum. The **cerebrum** controls voluntary movements and the senses (touch, taste, smell, vision, hearing). It also allows you to think, talk, solve problems, and imagine. The cerebrum is divided into two halves called hemispheres. The right hemisphere controls the left side of the body and the left hemisphere controls the right side of your body! But both sides are involved in most activities.

The cerebellum

The **cerebellum** provides feedback on the position of the body in space. It receives sensory information and sends nerve impulses to different skeletal muscles to keep you balanced. The cerebellum is located underneath the back of your cerebrum.

The medulla

The **medulla** is the part of the brain that controls your spinal cord. It also controls your involuntary breathing, heart rate, blood pressure, and some other involuntary activities. It receives sensory input from the heart and blood vessels and sends nerve impulses back to those organs to control their function. The medulla is located underneath the cerebrum and in front of the cerebellum.

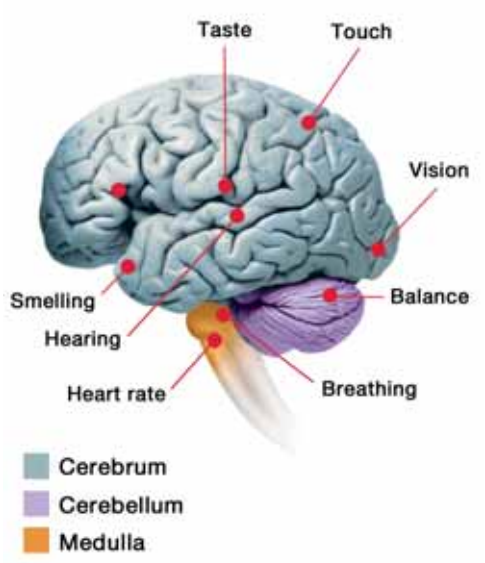


Figure 18.3: *The three parts of the brain and some of their functions.*

VOCABULARY

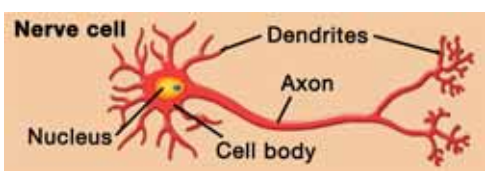
cerebrum - the part of the brain that controls voluntary movements, the senses, and thought.

cerebellum - the part of the brain that keeps the body in balance.

medulla - the part of the brain that controls the spinal cord and many involuntary activities like breathing and heart rate.

18.1 Section Review

1. Define each category of the nervous system:
   a. central nervous system
   b. peripheral nervous system
2. Explain how a nerve impulse is both electrical and chemical.
3. Classify each as voluntary, involuntary, or both. If the action can be both, explain how.
   a. the beating of your heart muscle
   b. breathing
   c. raising your arm
   d. lifting a rock
   e. blinking your eyes
   f. movement of muscles in your digestive system
4. The diagram below shows a neuron. Name the function of each of its parts.



5. The brain and spinal cord are made of two tissues. Name those tissues and explain their function.
6. Match each brain structure to one of its functions.

Structure	Function
1. medulla	a. controls involuntary breathing
2. cerebrum	b. detects the position of the body in space
3. cerebellum	c. controls imagination

CHALLENGE

Measuring how fast someone responds to what they see

1. Hold a ruler near the end (highest number) and let it hang down.
2. Have a partner put their hand at the bottom of the ruler and ready to grab it. They should not be touching the ruler.
3. Tell your partner that you will drop the ruler sometime within the next 5 seconds. They should catch the ruler as fast as they can after it is dropped.
4. Record the place on the ruler where they catch it, in cm.
5. Test the same person 3 to 5 times. Vary the time of dropping the ruler within the 5 second "drop-zone" so the other person cannot guess when you will drop the ruler.
6. Design an experiment to test one of the following questions:

- Does the amount of light affect response?
- Who responds faster, girls or boys?
- Does age affect response?

18.2 Vision

In Chapter 4, you learned how a microscope uses light to form magnified images. The human eye also uses light to form images. Every time you see something, light is involved. In complete darkness, you cannot see anything! In this section, you will explore how human vision works.

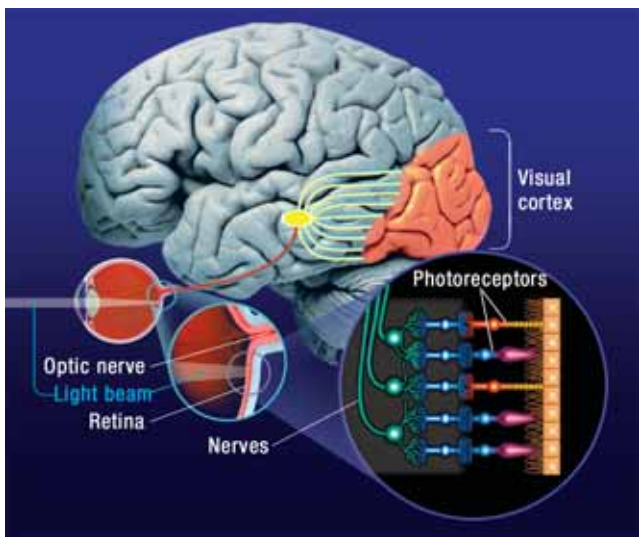
The human eye

You see the world by reflected light

Figure 18.4 shows what happens when you see this page. Light rays in the room reflect off the page and into your eyes. The reflected light carries information that allows your brain to form an image of the page. If you were in a room with no light, you would not be able to see this page because it does not give off its own light. You see many objects because they reflect light

How the eye works

The *eye* is the sensory organ used for vision. You learned about the mammalian eye in Chapter 15. The structures of the human eye are similar to the eyes of other mammals.



Light passes through the cornea and enters the eye through the pupil. It passes through the lens and is refracted to a focal point on the retina.

The retina contains light-sensitive cells called photoreceptors. **Photoreceptors** convert light into nerve impulses that travel through the **optic nerve** to the visual cortex of the brain. The *visual cortex* interprets the light as an image.

STUDY SKILLS

Review Section 4.3 to refresh your memory about light. Write down the following terms and their meanings: **light ray, reflection, refraction, lens, focal point, focal length.**

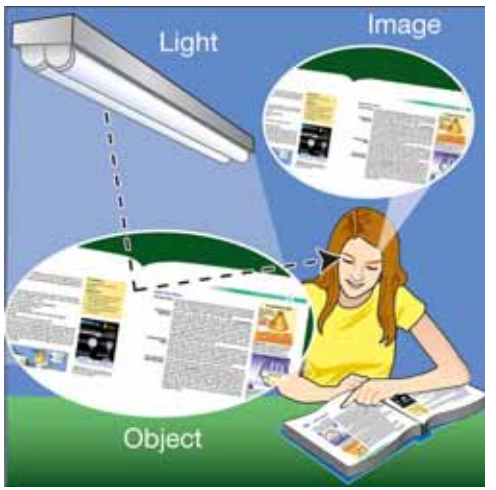


Figure 18.4: *What happens when you see this page.*

VOCABULARY

photoreceptors - light-sensitive cells of the retina that convert light into nerve impulses.

optic nerve - a nerve that carries nerve impulses from the eyes to the brain.

Seeing an image

How does light enter the eye?

Light enters the eye through the pupil. The **pupil** is an opening created by the *iris*, the pigmented part of the eye. A ring of muscles causes the iris to open or close to change the size of the pupil. When there is a lot of light, the iris closes and pupil gets smaller. When the light is dim, the iris opens up and the pupil gets larger (Figure 18.5).

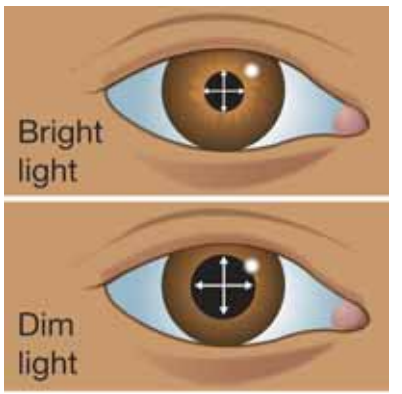
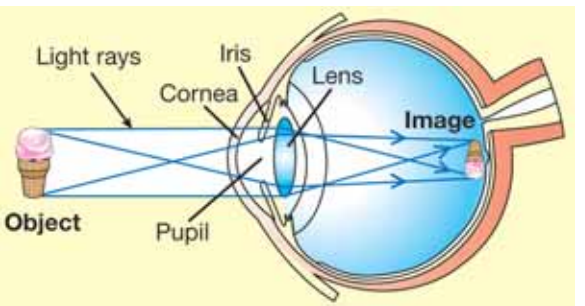


Figure 18.5: *The pupil of the eye gets smaller in bright light and larger in dim light.*

The lens forms an image

An **image** is a picture of an object formed where light rays meet. In Chapter 4 you learned that a convex lens refracts light rays to a focal point. The lens in your eye refracts light rays to a focal point on the retina called the fovea. The *fovea* is the spot on the retina where the image forms. Since the lens in your eye is a single lens, the image formed on the retina is actually upside down! Your brain interprets the image as right-side up so you don't notice.



Focusing

The lens in your eye has a feature that makes it different from the lenses you use in a science lab. The lens in your eye is flexible. Small muscles around the edge cause the lens to stretch and change its shape. When the lens changes its shape, so does the focal length. This allows you to focus on objects close by and also on objects further away (Figure 18.6). The *cornea* is the transparent front part of the eye that covers the iris and pupil. The cornea works with the lens to refract light and helps the eye to focus. But unlike the lens, the curvature of the cornea is fixed.

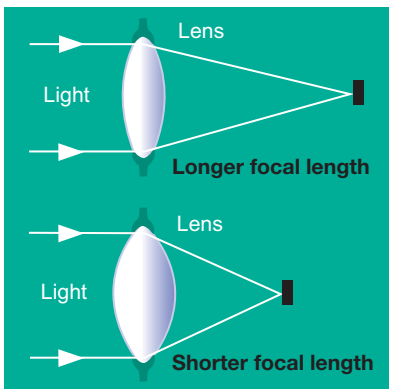


Figure 18.6: *The lens of your eye can change shape to change its focal length.*

VOCABULARY

pupil - the hole in the eye through which light enters.

image - a picture of an object formed where light rays meet.

How the human eye sees color

How we see color

In Chapter 6, you learned that **light is part of a range of waves called the electromagnetic spectrum. *Color* is how we perceive the energy of light**. All of the colors of visible light have different energies. Red light has the lowest energy and violet light has the highest energy. As you move through the spectrum of visible light from red to violet, the energy of the light increases (Figure 18.7).

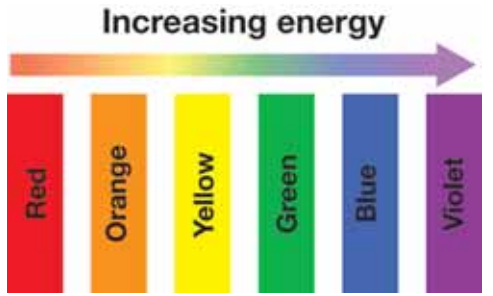


Figure 18.7: *Color is how we perceive the energy of light.*

Cone cells respond to color

Our eyes have two types of photoreceptors: cone cells and rod cells. **Cone cells** respond to color (Figure 18.8) and there are three types. One type responds best to red light. Another type responds best to green light and the last type responds best to blue light. We see a wide range of colors depending on how each kind of cone cell is stimulated. For example, we see white light when all three types of cones (red, green, blue) are equally stimulated.

Rod cells respond to light intensity

Rod cells respond only to differences in light intensity, and not to color (Figure 18.8). Rod cells detect black, white, and shades of gray. However, rod cells are more sensitive than cone cells especially at low light levels. At night, colors seem washed out because there is not enough light for cone cells to work. When the light level is very dim, you see "black and white" images transmitted from your rod cells.

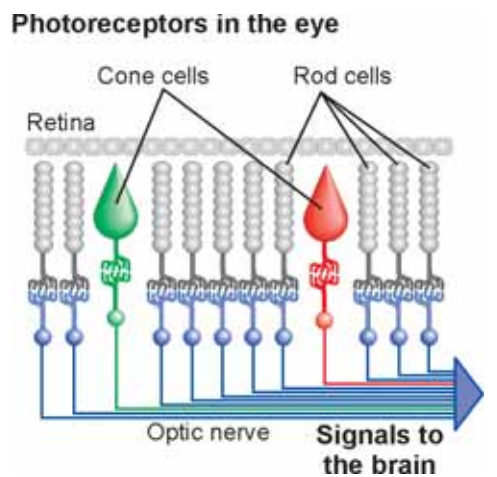


Figure 18.8: *Cone cells and rod cells.*

How rod and cone cells work together

An average human eye contains about 130 million rod cells and 7 million cone cells. Each one contributes a "dot" to the total image assembled by your brain. The brain evaluates all 137 million "dots" about 15 times each second. The cone cells are concentrated near the center of the retina, making color vision best at the center of the eye's field of view. Each cone cell "colors" the signals from the surrounding rod cells.

VOCABULARY

cone cells - photoreceptors that respond to color

rod cells - photoreceptors that respond to light intensity.

How color is perceived

The additive color process

Our eyes work according to an *additive color process* — three photoreceptors (red, green, and blue) in the eye operate together so that we see millions of different colors. The color you "see" depends on how much energy is received by each of the three different types of cone cells. The brain thinks "green" when there is a strong signal from the green cone cells but no signal from the blue or red cone cells (Figure 18.9).

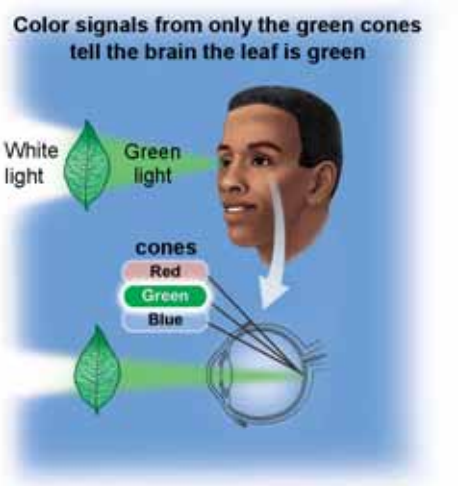
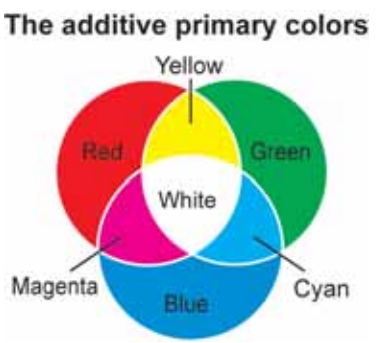


Figure 18.9: *If the brain gets a signal from only the green cone, we see green.*

How we perceive color

We perceive different colors as a combination of percentages of the three additive primary colors: red, green, and blue. For example, we see yellow when the brain gets an equally strong signal from both the red and the green cone cells at the same time. Whether the light is actually yellow, or a combination of red and green, the cones respond the same way and we perceive yellow. If the red signal is stronger than the green signal we see orange (Figure 18.10). If all three cones send an equal signal to the brain, we interpret the light we see as white.



Two ways to see a color

The human eye can see any color by adding different percentages of the three additive primary colors. Mixing red and green light is one way the eye sees the color yellow or orange, for example. Keep in mind that you perceive these colors even though the light itself is still red and green. You can also see pure yellow light or orange light that is not a mixture of red and green. For example, sodium street lights produce pure yellow light, not a mixture of yellow and green.

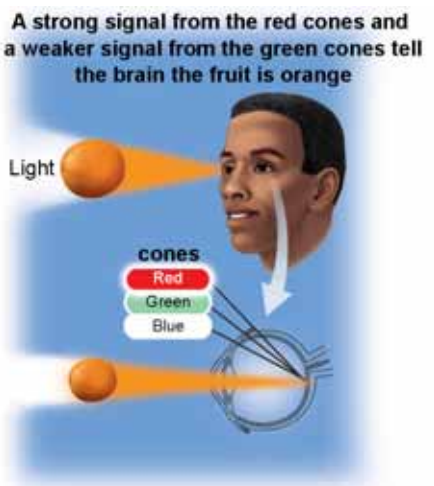


Figure 18.10: *If there is a strong red signal and a weak green signal, we see orange.*

Color blindness

Not everyone sees color the same way

You may be surprised to learn that all people do not see color the same way. A condition called color blindness affects about 8 percent of males and 0.4 percent of females. This means that about one out of every 13 men has color blindness and about one out of every 250 women has color blindness.

Color blindness is inherited

Although color blindness can be caused by eye disease, it is most often an inherited condition. More males than females have color blindness because of how the genes that determine our sex are inherited. Males have a X and a Y chromosome; females have two X chromosomes. The color blindness alleles are on the X chromosome which males receive only from their mothers; they receive the Y chromosome from their fathers. Because females receive two X chromosomes, they have two chances to inherit the alleles for normal color vision.

What is color blindness?

People who are color blind have trouble seeing certain colors. The most common condition is red-green color blindness (Figure 18.11). People with this type of color blindness have trouble seeing reds and greens. Less common is blue-green color blindness. Complete color blindness means that the person can only see shades of gray. Fortunately, this condition is rare.

Living with color blindness

It is easy to lead a normal life with color blindness. Having color blindness just means that an individual must look for ways to adapt to situations where color is involved. For example, color is extremely important when driving because traffic lights and street signs are color-coded. Fortunately, in most states, the traffic lights are vertical and the colors are in the same position—red on top, yellow in the center, and green on the bottom.

Figure 18.11: *This graphic illustrates how red-green color blindness affects seeing a traffic light. The top of the graphic shows what the traffic light looks like with normal color vision. The middle and bottom graphic show what a traffic light looks like with two of the common forms of color blindness.*

18.2 Section Review

1. Match the parts of the eye to their functions:

Structure	Function
1. iris	a. hole through which light enters
2. cornea	b. opens or closes to change the pupil
3. lens	c. respond to light intensity
4. retina	d. convert light into nerve impulses
5. photoreceptors	e. refracts light and can change shape
6. optic nerve	f. refracts light and helps the lens focus
7. rod cells	g. respond to color
8. pupil	h. sends nerve impulses to the brain
9. cone cells	h. inner surface where light rays land

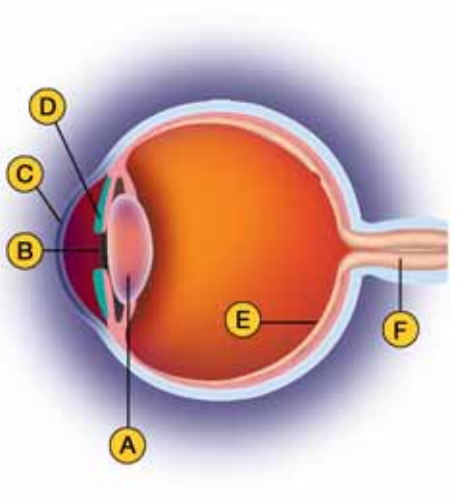


Figure 18.12: *Use the diagram above to answer question 2.*

2. Match the structures in question 1 to the letters on the diagram in Figure 18.12.
3. Fill in the table below:

Colors of light mixed	Color you see
red + green	
red + blue	
green + blue	
red + green + blue	

4. What is color blindness? Why is it more common in males than in females?

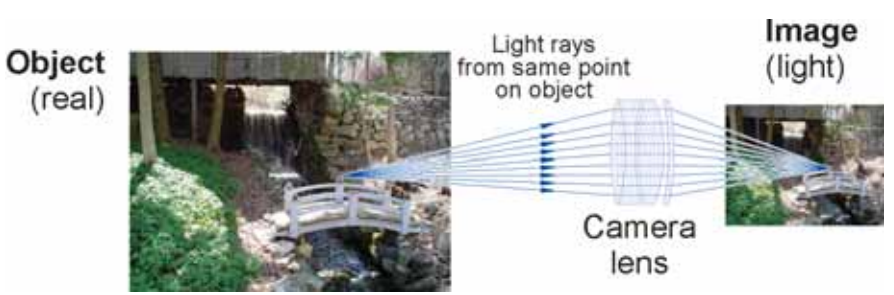
18.3 Optics

Optics is the study of how light behaves. It is helpful to think about optics in terms of *objects* and *images*. Objects are real physical things that give off or reflect light rays. Images are "pictures" of objects that are formed in space where light rays meet. Images are formed by our eyes, and by mirrors, lenses, prisms, and other optical devices (Figure 18.13). Images are not objects you can touch; they are just illusions created by organizing light collected from objects. You learned how lenses refract light in Chapter 4. In this section, you will learn about how lenses and mirrors create images.

Images

How images are created

Each point on an object gives off light rays in all directions. That is why you can see an object from different directions. Images are created by collecting many light rays from each point on an object and bringing them back together again in a single point (the *focal point*). For example, a camera works by collecting the rays from an object so they form an image on the film. In the diagram below many rays from a part of the bridge railing are focused to a single point by the camera lens, forming the image of that part of the railing. A camera captures some but not all of the light rays. This is why a photograph only shows one side of an object — you can't turn a photograph over and see the back of any object!



STUDY SKILLS

Review the following terms from Section 4.3:

lens, convex lens, concave lens, microscope

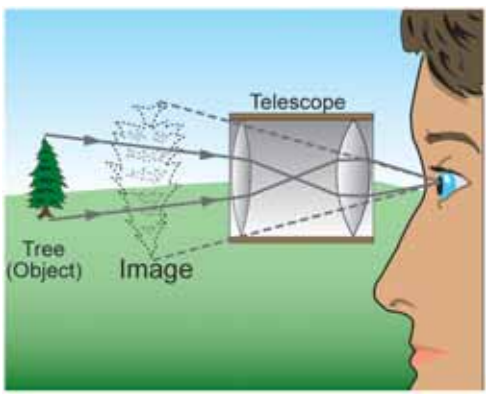


Figure 18.13: *You see the tree because light from the tree reaches your eye. The image of the tree in a telescope is not the real tree, but instead is a different way of organizing light from the tree. A telescope organizes the light so that the tree appears bigger but also upside down!*

VOCABULARY

optics - the study of how light behaves.

Virtual and real images

Seeing your reflection

If you stand in front of a flat mirror, your image appears the same distance behind the mirror as you are in front of the mirror (Figure 18.14). If you move back the image seems to move back too. If you raise your left hand, the hand on the left side of the image is raised. How does this happen?

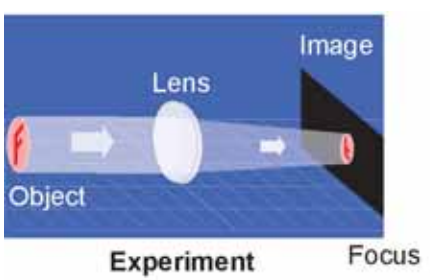
Figure 18.14: *An image in a flat mirror.*

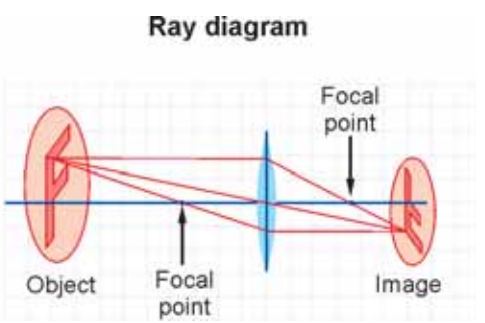
Virtual images

The image in a mirror is called a virtual image. In a **virtual image**, light rays do not *actually* come together to a focal point to form the image. They only *appear* to come together. The virtual image in a flat mirror is created by your eyes and brain. Your brain "sees" where you would be if the light rays reaching your eye had come in a single straight line. Because the light rays do not actually meet, a virtual image cannot be projected onto a screen or on film. Virtual images are illusions created by your eye and brain.

A converging lens forms a real image

A convex lens can form a real image (diagram below). In a **real image**, light from a single point on an object comes back together at a single point in another place to make an image. The place where light comes back together again is called the *focus*. The focus is where you see the image clearly. Real images can be projected onto a screen or film as shown below.





VOCABULARY

virtual image - an image where light rays do not actually come together to form the image.

real image - light from a single point on an object comes back together at a single point in another place to make an image.

Optical systems

What is an optical system?

Optical systems are built from lenses, mirrors, and prisms. Optical systems do two things. First, an optical system collects light rays. Second, the system changes the light rays to form an image. A camera is an optical system that collects light to *record* an image. Your eye is also an optical system. A photocopy machine is another optical system. The more light an optical system collects, the brighter the image it can form.

A pinhole camera

A pinhole camera is a simple optical system (Figure 18.15). You can make a pinhole camera by poking a pinhole through a box. No image forms on the front of the box because rays from many points of the object reach the same point on the box. An image does form inside the box, however. The image inside the box forms because light rays that reach a point on the box surface are restricted by the pinhole to come from only a pinhole-sized point on the object.

A lens makes the image brighter

The image formed by a pinhole is very dim because the pinhole is small and does not allow much light to come through. The image formed by a lens is brighter because a lens is larger and collects more light (Figure 18.15). Each point on the image is formed by a cone of light collected by the lens. With a pinhole, the cone is much smaller and therefore the image has a much lower light intensity.

Larger lenses make brighter images

The larger the lens, the brighter the image. This is because a larger lens collects more light rays. Compared to smaller lenses, larger lenses can make good images with less light. That is why inexpensive cameras with small lenses need a flash to take pictures indoors. The small lens does not capture enough light by itself.

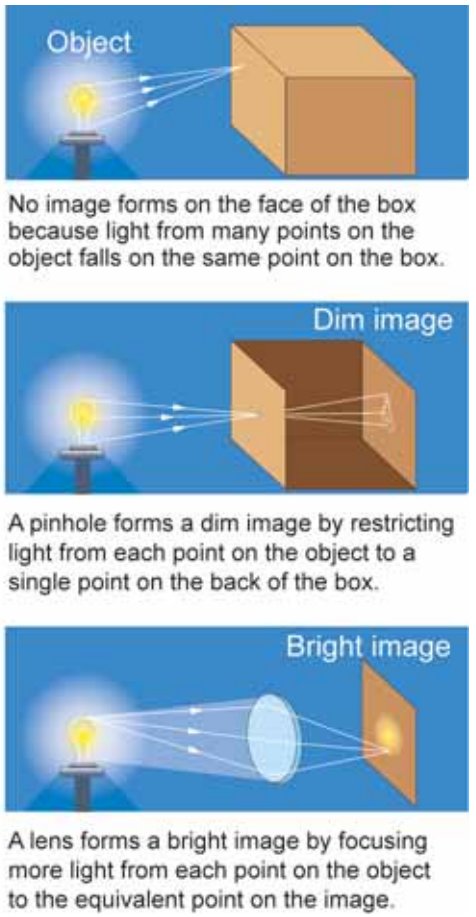


Figure 18.15: *The images formed by a pinhole camera and a lens are different in brightness because different amounts of light are collected to form each point in the image.*

How telescopes work

Lenses can form virtual images

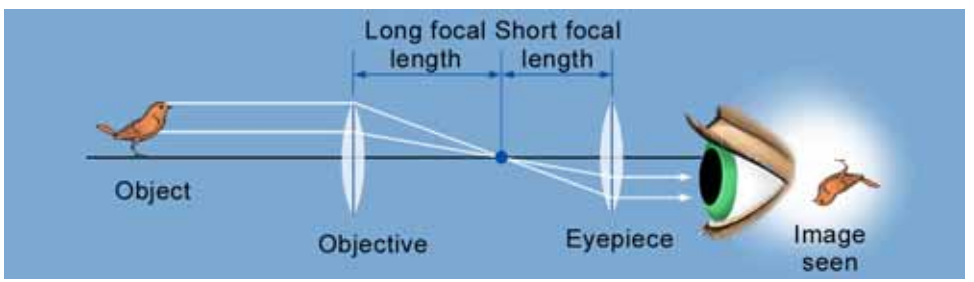
In addition to real images, lenses can also form virtual images. For example, a convex lens used as a magnifying glass creates an image that is virtual and larger than life (magnified). Light is refracted by the lens so that it appears to come from a much larger object (Figure 18.16).

A magnifying glass

A magnifying glass is a single convex lens. A magnified virtual image forms when you look at an object that is *closer* than one focal length from the lens. If the object is farther than one focal length you see a real image that is smaller than actual size (and upside down). The focal-length limit is why magnifying glasses should be held fairly close to the objects you are looking at.

The refracting telescope

To get higher magnification, microscopes and telescopes use more than one lens. A *refracting telescope* has two convex lenses with different focal lengths. The lens with the shorter focal length is nearer to the eye.



Reflecting telescope

Because large lenses are nearly impossible to make, most modern telescopes use a concave mirror instead of one lens. The diagram shows a reflecting telescope, much like the one used by the Hubble Space Telescope and almost all astronomical observatories (Figure 18.17).

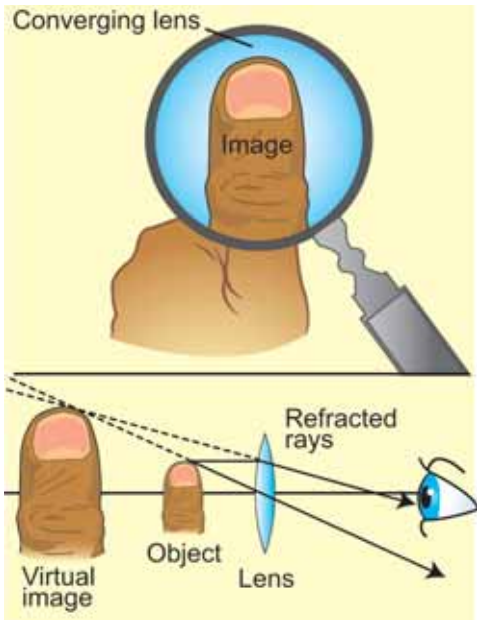


Figure 18.16: *A magnifying glass forms a virtual image that is larger and appears behind the lens.*

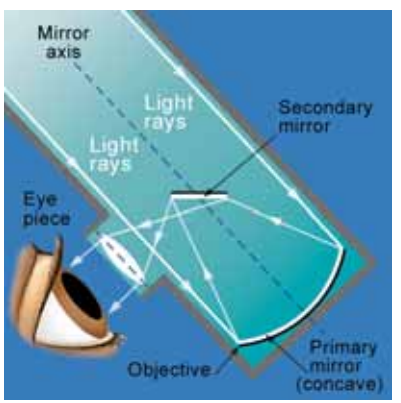
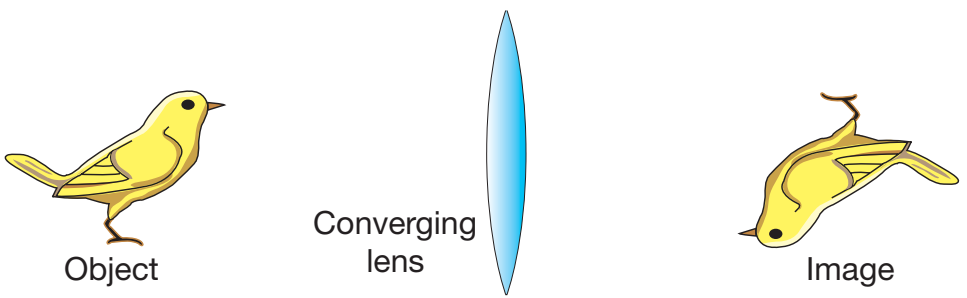


Figure 18.17: *The light rays in a reflecting telescope.*

18.3 Section Review

1. If an object is 1 foot away from a mirror, how far behind the mirror surface does the image appear to be? Is this image a real or virtual image?
2. What is the difference between a real and virtual image?
3. Mirrors and lenses both produce images your eyes can see. How are mirrors and lenses similar? How are they different?
4. Copy the diagram below on your paper. Using a ruler, draw the path of the light rays from the object to the image in the diagram below.



5. Is the image in the diagram above a virtual image or a real image? Explain your answer.
6. Why do ambulances often have the letters for "AMBULANCE" reversed on the front of the vehicle?
7. Why do some optical systems use more than one lens?
8. Explain how a lens can form both virtual and real images.
9. Is the image of the brine shrimp in Figure 18.18 a virtual image or a real image? Explain your answer.

STUDY SKILLS

Make a concept map using the following terms:

lens
refraction
reflection
light ray
optical system
eye
camera
telescope
virtual image
real image
mirror
convex lens
concave lens

Figure 18.18: *Use this picture to answer question 9.*

18.4 Hearing

Like light, sound is a wave. A **wave** is a vibration that transfers energy from place to place. Your eyes can detect light waves. You cannot see sound waves with your eyes. Instead, you "see" them with your ears! In this section, you will learn about sound and how the ear detects it.

VOCABULARY

wave - a vibration that transfers energy from place to place.

frequency - the number of vibrations per second.

What is sound?

Sound is a wave

Sound waves are *pressure waves* with alternating high and low pressure regions. A sound wave is created when something vibrates—like a speaker playing music. If you touch the surface of the speaker, you can feel the vibrations that create a sound wave. Those vibrations transfer energy to the surrounding air molecules.

How a sound wave is created

Air molecules are spread very far apart and are in constant, random motion (Figure 18.19). When they are pushed by the vibrations, it creates a layer of higher pressure (Figure 18.20). That layer pushes on the next layer, which pushes on the next layer, and so on. The result is a traveling vibration of pressure—a sound wave. The molecules in a sound wave are compressed in the direction that the wave travels.

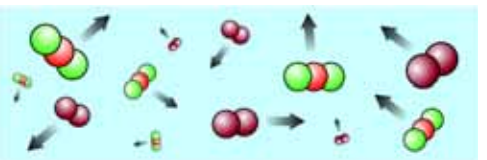


Figure 18.19: *Air is made of molecules in constant, random motion.*

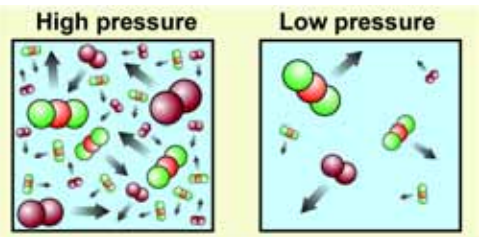
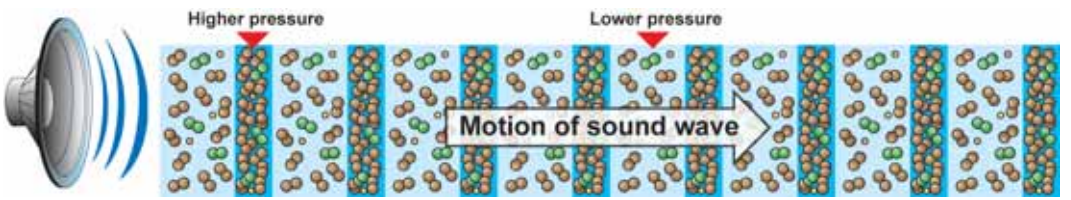


Figure 18.20: *At the same temperature, higher pressure contains more molecules per unit of volume than lower pressure.*



Frequency

The **frequency** of a sound wave is the number of vibrations per second. Wave frequency is measured in *hertz* (Hz). A wave with a frequency of 1 hertz vibrates at one vibration per second.

Properties of sound

Pitch

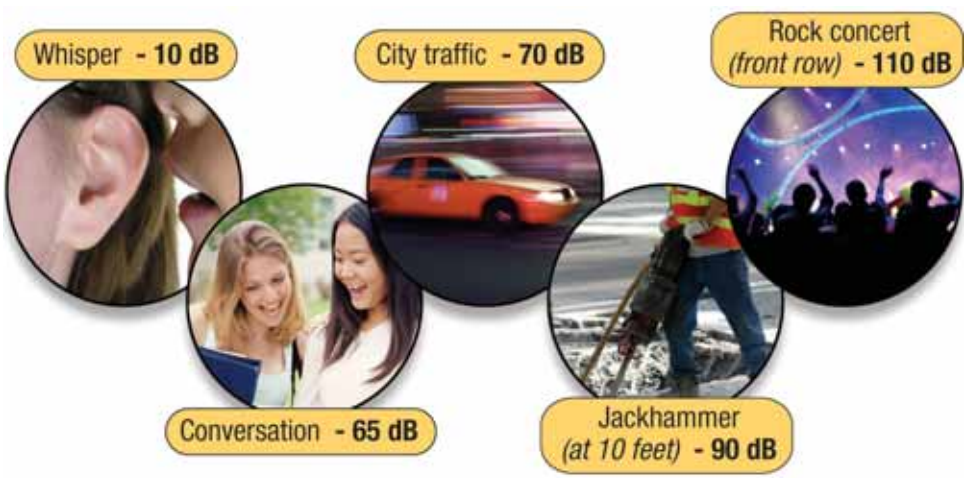
The **pitch** of a sound is how we hear and interpret its frequency. A low-frequency sound has a low pitch, like the rumble of a big truck or a bass guitar. A high-frequency sound has a high pitch, like the scream of a whistle or siren. The range of frequencies humans can hear varies from about 20 hertz to 20,000 hertz.

VOCABULARY

pitch - how humans hear and interpret the frequency of sounds.

Loudness

The *loudness* of a sound is measured in decibels (dB). The *decibel* is unit used to express relative differences in the loudness of sounds. The *decibel scale* compares the loudness of sounds. Most sounds fall between zero and 100 on the decibel scale. The diagram below compares the loudness of some sounds on the decibel scale.



frequency spectrum

Why is it easy to recognize one person's voice from another, even when people are saying the same word? The reason is that voices have different mixtures of frequencies. A *frequency spectrum* is a graph showing the different frequencies present in a sound. Loudness is on the vertical axis and frequency is on the horizontal axis. Figure 18.21 shows the frequencies of the voices for three individuals saying "hello."

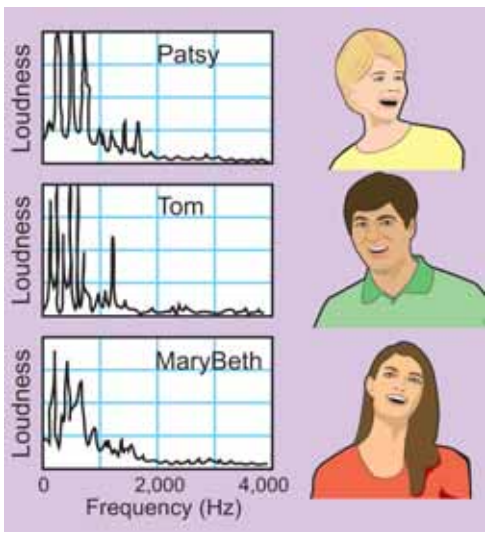
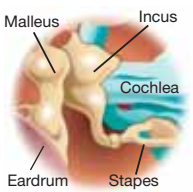


Figure 18.21: *The frequencies in three people's voices as they say the word "hello."*

How the ear works

The outer ear The parts of the ear are shown in Figure 18.22. The *outer ear* helps collect sound waves and directs them into the middle ear. Some mammals can move their outer ears to detect the direction of sound. You must turn your head. The outer ear funnels sound waves into the ear canal which leads to the middle ear.

The middle ear The *middle ear* is an air-filled cavity that consists of the eardrum and three tiny, interconnected bones: the *maleus*, *incus*, and *stapes* (shown left). The *eardrum* is a tightly stretched membrane that vibrates as the sound wave reaches it. The eardrum vibrates at the same frequency of the sound wave. Being connected to the maleus, the movements of the eardrum set the maleus, incus, and stapes into motion at the same frequency of the sound wave.



The inner ear The stapes is connected to the cochlea of the inner ear. The inner ear has two important functions: providing our sense of hearing and our sense of balance. The three semicircular canals near the cochlea are also filled with fluid. Fluid moving in each of the three canals tells the brain whether the body is moving left-right, up-down, or forward-backward. The **cochlea** is a tiny fluid-filled cavity in the inner ear that contains nerve endings essential to hearing.

The cochlea The stapes vibrates against the cochlea. Fluid in the spiral of the cochlea vibrates and creates waves that travel up the spiral. The spiral channel starts out large and gets narrower near the end. The nerves near the beginning respond to lower-frequency sound. The nerves at the small end of the channel respond to higher-frequency sound. Neurons in the cochlea convert the waves into nerve impulses and send them to an area of the brain that interprets sound.

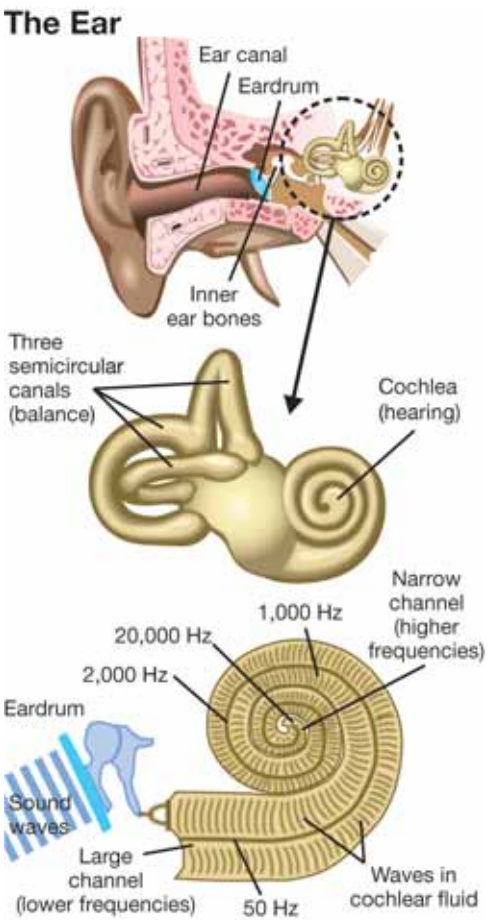


Figure 18.22: *The parts of the human ear.*

VOCABULARY

cochlea - a spiral-shaped, fluid-filled cavity of the inner ear that contains nerve endings essential to hearing.

18.4 Section Review

1. What is a wave? Why is sound a wave?
2. Explain why sound waves are described as pressure waves.
3. Two containers of equal volume are stored at the same temperature. Container A contains air under higher pressure than the air in container B. Which container has more molecules of air?
4. What is the frequency of a wave? What is the unit of frequency?
5. Which has a higher pitch, a bass guitar or a screaming voice?
6. What is a decibel? How are decibels used?
7. Based on experience, arrange the following sounds from lowest to highest on the decibel scale:
   a. a library
   b. a school band concert
   c. a barking dog from 10 feet away
   d. a whisper
8. Match each structure of the ear to its function:

Structure	Function
1. stapes	a. converts sound waves to vibrations
2. cochlea	b. transfers vibrations from ear drum
3. outer ear	c. vibrates against the cochlea
4. ear drum	d. gathers sound waves
5. maleus	e. directs sound waves to the ear drum
6. semi-circular canals	f. help you stay in balance
7. ear canal	g. contains a fluid that vibrates

SOLVE IT!

Light waves have very small wavelengths that are measured in nanometers. A nanometer is one-billionth of a meter. The wavelength of sound waves is measured in meters. The frequency of a wave is inversely related to its wavelength. Answer the questions below:

1. Which have higher frequencies, light waves or sound waves?
2. Arrange the following frequencies from longest to shortest wavelength: 500 Hz, 10 Hz, 20,000 Hz, 55 Hz.

PHYSICS CONNECTION

Keeping Things in Focus

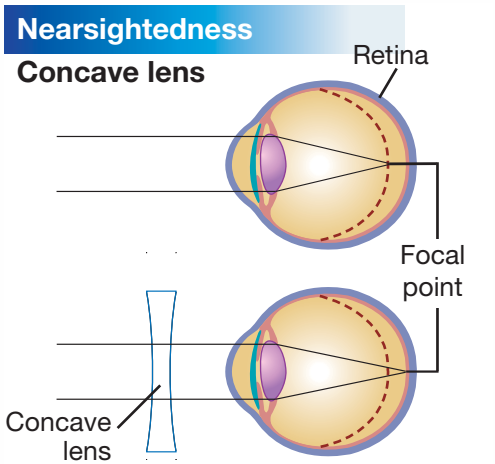
So gradually that you might not have noticed, you find you have trouble reading numbers or writing on the classroom chalkboard. Or a friend points to a sign down the hall, but you cannot quite make out what it says. What is happening? Maybe you are becoming nearsighted.

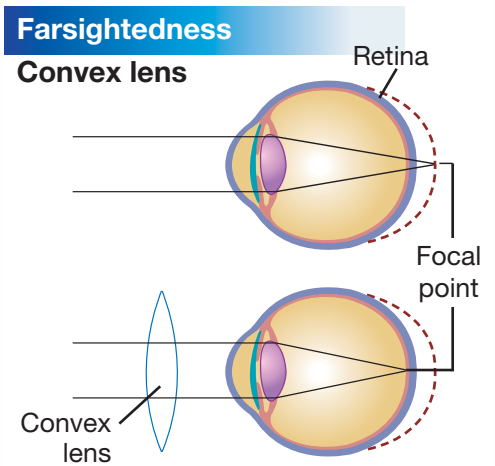
Nearsightedness is common, affecting one in four people, and most often developing during school age and adolescence. If you are nearsighted, objects near you are clear, but objects at some distance are blurry. This occurs when light rays entering the eye are focused imperfectly, either because the eyeball is too long or because the cornea bulges. In the normal eye, light rays passing through the cornea and lens are focused perfectly, reaching the retina and creating clear images.

Science has made it easy to correct nearsightedness with glasses or contact lenses. The lenses may have to be changed a few times as a child grows, but nearsightedness usually stabilizes in a person's early twenties.

Vision is an amazing process. Light reflects off objects all around us. When we look at an object, reflected light enters our eyes. That light is focused and hits the retina, the innermost layer of the eye, the light-sensing area at the back of the eye. In the retina, light energy is converted to electrical impulses that our brains interpret as vision.

When vision is normal, the light image is in focus when it hits the retina. In the eyes of a nearsighted person, the image focal point is in front of the retina. The image is out of focus by the time it reaches the retina. The brain sees a fuzzy image. Corrective lenses change the focal point of the image so that it is in focus when it reaches the retina. Wearing glasses or contacts, nearsighted people can see as clearly as people with normal vision.





Looking at farsightedness

You have almost certainly seen someone - your teacher, a parent or grandparent - reach for their glasses to read the fine print on something. If a person

has trouble focusing on objects that are close, that person is farsighted. Many people become farsighted later in life. The eye shortens, changing the focal point of light entering the eye. The light entering the eye is focused behind the retina. Farsighted people have difficulty clearly seeing objects that are close; they look fuzzy or blurry. This is the opposite of what people who are nearsighted experience, when they are unable to focus clearly on objects in a distance.

Both conditions can be remedied with corrective lenses. With a nearsighted person, a concave lens, or a lens that curves inward, bends the light so that the focal point is in front of the lens. When the image reaches the retina, it will be in focus. With someone who is farsighted, a convex lens, or a lens that curves outward, bends the light so that the focal point is behind the lens. Here, too, when the image reaches the retina, it will be in focus.

Reading the "E"

Dr. F. Todd Perzy, an optometrist, uses a variety of tests to examine people's eyes. One of the most common tests is reading an eye chart. With the lights dimmed, the patient focuses on a large target, like the "E" on the chart. The doctor shines a light into the patient's eyes and flips lenses in a machine positioned in front of each eye. Depending on how the light reflects from the patient's eyes, Dr. Perzy can start to determine the necessary corrective measures.

An eye doctor, be it an optometrist or an ophthalmologist, also checks the overall health of the eye. He shines light into the patient's eye and examines each part from front to back.

Advances in vision correction

Glasses and contact lenses are no longer the only way to correct vision. Today, LASIK (an acronym for laser-assisted in situ keratomileusis) is the most popular. This eye surgery reduces or eliminates the need for glasses in people who are nearsighted or farsighted. Since 1995, approximately 3 million Americans have had some type of laser eye surgery. But even with the advancements in laser surgery, more than half the people in the United States still wear some type of corrective lens.

Questions:

1. Explain what happens to images in the eye when a person is farsighted.
2. Explain what happens to images in the eye when a person is nearsighted.
3. What is the difference between a concave lens and a convex lens?

CHAPTER ACTIVITY Human Ear Model

Ears are truly amazing organs. The ear picks up mechanical sound waves (vibrating air molecules) and translates the vibrations into signals that the brain can understand. In this activity you will build a model of the ear. Then, you will figure out how the model works. Finally, you will relate the parts of your model to the parts of a human ear.

To build your model, you will need:

- 2 plastic cups
- 1 empty potato stick can
- 1 balloon
- 1 index card
- 1 small lightweight ball (Styrofoam or hollow plastic)
- 1 party noisemaker

What you will do

1. Carefully cut off the bottom of the potato stick can so the can is open at both ends.
2. Cut off the neck of the balloon and stretch it over one end of the can; secure with tape. Make sure the balloon is stretched as tightly as possible.
3. Cut a strip of index card that is 0.5 cm wide.
4. Tape one end of the index card strip to the balloon-covered end of the can
5. Tape the other end of the index card strip to the lightweight ball.
6. Tape the entire can/balloon/paper/ball assembly to an upside-down cup.
7. Fill the second cup with water and place it under the ball so the ball floats on top of the water.
8. To operate your ear model, insert the noisemaker into the can from the open end so that it is very close to the balloon covering, but not touching it or any part of the can. Without moving any part of the model, blow into the noisemaker and watch what happens to the floating ball.

Applying your knowledge

a. What causes the floating ball to move?
b. Make a sketch of your ear model and label the parts of the model that represent the: outer ear, eardrum middle ear bones, inner ear/cochlea.
c. Do Internet or library research on three different causes of hearing loss.
d. Do Internet or library research on new devices called cochlear implants that allow hearing impaired people to hear sounds for the first time. How do the implants work?

Chapter 18 Assessment

Vocabulary

Select the correct term to complete the sentences.

central nervous system	cerebellum	image
cone cells	cerebrum	medulla
frequency	cochlea	motor nerves
nerve impulse	optic nerve	optics
peripheral nervous system	photoreceptors	pitch
pupil	real image	
rod cells	sensory nerves	virtual image
wave	withdrawal reflex	

Section 18.1

1. The three parts of the brain are: the _____, which controls involuntary actions; the _____, which controls voluntary movements and the senses; and the _____, which provides feedback on the position of the body.
2. A wave of chemical and electrical activity transmitted between neurons is called a _____.
3. _____ send nerve impulses through wire-like nerve fibers to the spinal cord, while _____ control muscle contractions.
4. An example of a _____ is when someone pulls their hand back from a hot plate.
5. The two divisions of the nervous system are the _____, which is the command center, and the _____, which is the "information highway."

Section 18.2

6. The iris opens and closes to change the size of the _____ depending on the amount of light available.
7. The _____ carries nerve impulses from the eyes to the brain.
8. _____ are photoreceptors that respond to color, while _____ are photoreceptors that respond to light intensity.
9. Even though the _____ formed in the retina is upside down, your brain interprets it as right side up.
10. The retina contains light sensitive cells called _____.

Section 18.3

11. A mirror creates a _____, whereas a converging lens can create a _____.
12. The study of how light behaves is called _____.

Section 18.4

13. _____ is measured in Hertz (Hz).
14. The _____ is how humans hear and interpret the frequency of sounds.
15. Your ear detects sound _____.
16. Neurons in the _____ convert waves into nerve impulses and send them to the brain.

Concepts

Section 18.1

1. Which division of the nervous system includes these parts?
   a. brain
   b. nerves throughout the body
   c. spinal cord
2. What are the three parts of a neuron?
3. Which of these is not a withdrawal reflex?
   a. pulling hand back from a hot pan on the stove
   b. taking foot out of cold pool water
   c. shivering on a cold day at the bus stop
   d. none of the above

4. What is the difference between sensory and motor neurons?
5. Put the following events of a withdrawal reflex in the correct order:
   a. inside of the cell membrane becomes positively charged
   b. sensory nerves in skin receive stimuli
   c. inside of the cell membrane becomes negatively charged again compared to the outside
   d. chemicals are released to pass on the nerve impulse to the neighboring neuron
   e. impulse travels down the axon to the end
   f. other channels open to let out positively charged particles
   g. stimulus causes cell membrane to open channels to let in positively charged particles
6. Certain drugs inhibit the release of chemicals from the axons of nerve cells. How may these drugs affect the transmission of nerve impulses?
7. Identify the correct part of the brain for each description:
   a. largest part
   b. controls the spinal cord
   c. keeps body balanced
   d. located under the back half of the cerebrum
   e. divided into two halves called hemisphere
   f. located in front of the cerebellum
   g. controls voluntary movement
   h. receives input from the heart and blood vessels
   i. controls the senses
8. Infer which part of the brain is responsible for coughing and sneezing. Explain your choice.
9. What symptoms might indicate that a person's cerebrum has been injured?
10. Explain why injuries to the medulla are often fatal.
11. A stroke results from a clot in the brain that typically results in paralysis. If a person was unable to move their left arm and left leg after a stroke, predict which side of the brain the clot most likely occurred in. Explain your prediction.

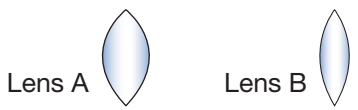
Section 18.2

12. How is light critical to vision?
13. Explain how light travels through the eye.
14. What happens to the iris and the pupil in these situations?
   a. a person leaves the movie theater on a sunny afternoon
   b. a person goes inside after soccer practice on a sunny morning
   c. the light is turned on when a person is napping in a dark room
15. How does your eye focus on objects?
16. Which color has the most energy? Which color has the least energy?
17. What are the two types of photoreceptors? Describe their functions.
18. Which works better in dim light - rods or cones? Explain.
19. Why is color vision best at the center of the field of view?
20. What is the additive color process?
21. Which of these is not a primary color?
   a. white
   b. green
   c. blue
   d. red

22. Explain how the design of traffic lights helps people with color blindness.

Section 18.3

23. Which of the following terms relates to optics?
    a. image
    b. focal point
    c. light rays
    d. all of the above
24. Explain how a camera captures an image.
25. Of the lenses shown to the right, which has the shorter focal length?



26. What is an optical system? Describe their two functions.
27. Why does a lens give a brighter image than the hole in a pinhole camera?
28. What are the two types of telescopes? Explain the difference.

Section 18.4

29. How are sound and light similar? How are they different?
30. Describe how sound is created.
31. What are two properties of sound? Describe each property.
32. How can you recognize different people's voices?
33. Why is being able to move their ears a helpful adaptation for some mammals?
34. Explain why a person should never stick a sharp object in their ear.
35. Why can an infection in the inner ear cause a person to lose their balance?

Math and Writing Skills

Section 18.1

1. Write a short story that has three examples of withdrawal reflexes. Do not mark your examples so that a classmate may try to identify the examples in your story.
2. The average human brain weighs 1.3 kilograms. If 1 kilogram is equivalent to 2.21 pounds, how many pounds does the average human brain weigh?
3. A nerve impulse can travel at the speed of 120 kilometers per second. Electricity can travel at 300,000 kilometers per second. How many times faster do electric impulses travel than nerve impulses?

Section 18.2

4. In the average eye, 130 million of the photoreceptors in the eye are rod cells, while 7 million of the photoreceptors are cone cells. What percent of photoreceptors are rod cells? What percent are cone cells?
5. If the brain evaluates all 137 million dots created by photoreceptors every fifteen seconds, how many times does the brain scan all the dots in a minute? In an hour? In a day?

Section 18.3

6. Look around your house and school to find examples of how optics affect your daily life. Write a paragraph describing the ways that optics impact you each day.
7. Write a short story that includes at least five examples of real and virtual images. Do not indicate your examples in the story so that a classmate can try to identify your examples as real or virtual images.
8. Choose an optical system to describe in detail including how it works.

Section 18.4

9. Write short play that explains how a sound wave travels through the ear. Include how the sound wave affects the different parts of the ear.
10. Imagine that you are a town representative that is in charge of setting local noise level laws. Propose what you believe would be a reasonable maximum decibel limit. Explain your proposal.
11. A noise creates 10,000 vibrations in 2 seconds. What is the frequency of this sound in Hertz?
12. The speed of sound is 340.29 m/s. The speed of light is 299,792,458 m/s. Given these speeds, how much faster is light than sound? How does this explain why you see lightening before you hear thunder?

Chapter Project

Color models

Our eyes work according to an *additive color process*. Three photoreceptors (red, green, and blue) in the eye operate together so that we see millions of different colors. Color printers work according to a *subtractive color process*. Three different pigments or inks (cyan, magenta, and yellow) combine to make millions of different colors. In this project, you will combine cyan, magenta, and yellow clay or paint to produce the colors red, blue, and green. You will need:

- Polymer clay or tempera paint in the colors cyan, magenta, and yellow
- One sheet of construction paper or poster board
- Paintbrush and water (if using paint)
- Ruler and pencil

1. Create a blank color chart on your construction paper or poster board like the one below. DO NOT write the words in the boxes.

magenta	Mix magenta and cyan, with more magenta than cyan	Mix equal parts of magenta and cyan	Mix cyan and magenta, with more cyan than magenta	cyan
yellow	Mix yellow and magenta, with more yellow than magenta	Mix equal parts of yellow and magenta	Mix yellow and magenta, with more magenta than yellow	magenta
cyan	Mix cyan and yellow, with more cyan than yellow	Mix equal parts of cyan and yellow	Mix cyan and yellow, with more yellow than cyan	yellow

2. On the boxes of the table that contain a color name, paint that box with the pure color of paint or fill the box with that color clay by pressing the clay firmly onto the paper.
3. In the other boxes of each row, create a mixture according to the instructions in each box and paint or press the clay into the appropriate box.
4. When you look at the middle boxes, you should see one that is red, one that is blue, and one that is green. If you do not see these colors, you will have to experiment with different ratios of one color to another to achieve the pure red, blue, and green. If your magenta is more intense than your cyan, for example, you might not be able to mix equal parts to achieve a sharp blue color. Mix your paint on a different piece of paper before you use it to paint your final boxes. If you are using clay, work the colors together well to achieve your final colors before you press it onto the final grid.
5. On the back of your color chart, write a paragraph that summarizes what you have learned about the subtractive color process by doing this project.

Glossary

A glossary is an alphabetical list of important words found in the sections in this book. Use this glossary just as you would use a dictionary: to find out the meaning of unfamiliar words. This glossary gives the meaning that applies to the words as they are used in the sections of this book. As with any subject, science has its own vocabulary. The study of science is more meaningful if you know the language of science.

A

absolute dating – a method of estimating the age of a rock sample in years.

active transport – a process that allows molecules to move across the cell membrane from lower to higher concentrations.

adaptation – an inherited trait that helps an organism survive.

adrenal glands – produce epinephrine, a hormone that prepares the body for stress.

aerobic bacteria – bacteria that use oxygen for cellular respiration.

algae – photosynthetic protists that are plant-like in many ways.

alleles – different forms of a gene.

alveoli – tiny, sac-like structures of the lungs that are surrounded by capillaries where gas exchange takes place.

amniotic egg – an egg that is surrounded by a shell to prevent it from drying out.

amoebas – a group of protozoans that move by means of pseudopods.

anaerobic bacteria – bacteria that do not require oxygen to survive.

ancestor – an organism from which others have descended.

angiosperms – vascular, seed-producing plants whose seeds are enclosed in a fruit.

antibodies – proteins that bind to viruses and prevent them from infecting cells.

appendicular skeleton – the bones of the limbs, including the bones of the pectoral and pelvic girdles.

area – a measurement of how much surface something has.

arteries – blood vessels that carry blood away from the heart.

asexual reproduction – a type of reproduction that requires only one parent.

asymmetrical – organisms that do not have symmetry.

atom – the smallest particle of an element that keeps the chemical identity of that element.

ATP – a molecule that stores and transfers energy within the cells.

axial skeleton – forms the axis of the body and includes the skull, vertebral column, ribs, and sternum.

B

bacteria – organisms that consist of a single, prokaryotic cell.

ball and socket joint – joints that allow movement in all directions.

base sequence – the order of base pairs along a gene.

bilateral symmetry – a body plan that consists of two similar halves.

biology – the study of life.

blood – a circulating connective tissue made of plasma, cells, and platelets.

blood pressure – a measure of the force of the blood pushing against the walls of the arteries.

bone marrow – a thick, jelly-like layer of bone that makes blood cells or stores fat.

C

cancellous bone – the layers of bone that have many open spaces like a sponge.

capillaries – the smallest blood vessels where the exchange of materials with cells takes place.

carbohydrates – energy-rich compounds such as sugars and starches made from carbon, hydrogen, and oxygen.

cell – the smallest unit of a living thing.

cell cycle – the period of time from the beginning of one cell division to the beginning of the next.

cell differentiation – the process of cell specialization.

cell division – the process of one cell dividing into two daughter cells.

cell membrane – a separating barrier that controls movement of materials into and out of the cell.

cell theory – a theory that explains the relationship between cells and living things.

cell wall – the outer layer of a plant cell that is made from cellulose and makes plant cells rigid.

cellular respiration – the process in which the chemical bonds of energy-rich molecules are converted into a form of energy that cells can use.

central nervous system – the control center of the body that includes the brain and spinal cord.

cerebellum – the part of the brain that keeps the body in balance.

cerebrum – the part of the brain that controls voluntary movements, the senses, and thought.

chemical reaction – a process that rearranges the atoms of one or more substances into one or more new substances.

chlorophyll – the main pigment used in photosynthesis that absorbs blue and red light and reflects green light.

chloroplast – an organelle that converts light energy into chemical energy in the form of molecules.

chromosome – a structure made of DNA and protein in the nucleus of a eukaryotic cell.

ciliates – a group of protozoans that move by waving tiny, hair-like organelles called cilia.

circulatory system – the body system that circulates blood throughout the body and delivers essential substances to cells and removes wastes.

cladogram – a tree-like diagram that displays evolutionary relationships among living species and their ancestors.

cochlea – a spiral-shaped, fluid-filled cavity of the inner ear that contains nerve endings essential to hearing.

codominance – when an organism that has both alleles of a gene displays both phenotypes at the same time.

color – how we perceive the energy of light.

community – all of the organisms that interact in a given area.

compact bone – the layer of bone that provides most of its strength.

competition – when organisms in a community vie for the same food supply.

compound – a substance that contains two or more different elements that are chemically joined.

cone cells – photoreceptors that respond to color.

connective tissue – provides strength, support, and protection to soft body parts.

control variable – the variables you keep the same in an experiment.

cornea – part of the eye that, along with the lens, refracts and focuses light.

cotyledon – an embryonic leaf found inside of a seed.

cross-pollination – when the pollen from one plant is used to fertilize another plant.

cuticle – a waxy layer that covers the parts of a plant that are exposed to air like leaves and stems.

cytokinesis – the process where the cytoplasm and its organelles divide into two daughter cells.

cytoplasm – a fluid mixture that contains the organelles and the compounds the cell needs.

cytoskeleton – a series of protein fibers inside of a cell that give structure and shape to the cell.

D

dependent variable – the variable that you believe is influenced by the independent variable.

diffusion – the movement of molecules from areas of greater concentration to areas of lesser concentration.

digestive system – a group of organs that take in and digest food, and eliminate wastes.

diploid – a double set of chromosomes.

direct relationship – a relationship in which one variable increases with an increase in another variable.

DNA fingerprinting – the process of producing an image of patterns from someone's DNA.

DNA replication – the process of a DNA molecule making a copy of itself.

dominant allele – the form of a gene that, when present, covers up the appearance of the recessive allele.

E

ecosystem – a group of living things and their surroundings.

ectotherms – animals that are not able to control their body temperature.

element – the simplest form of matter.

embryo – an organism in its earliest stage of development.

endocrine system – a group of glands that produce hormones and release them into the blood.

endoplasmic reticulum – an organelle that transports proteins inside of the cell.

endotherms – animals that use the heat produced by chemical reactions in their cells to maintain a constant body temperature.

energy – the ability to cause change or do work.

epidermis – the layer of cells that covers the surface of roots.

epithelial tissue – made up of closely packed cells in one or more layers. Lines the internal and external body surfaces.

eukaryotic cell – a cell that has a nucleus and membrane-covered organelles.

evolution – the process of how organisms acquire adaptations over time.

evolutionary tree – a diagram with many branches that shows evolutionary relationships among organisms, both living and extinct.

excretory system – a group of organs that excrete chemical wastes.

experiment – a controlled test to determine if a hypothesis is supported or refuted.

experimental variable – the variable you change in an experiment.

extensor – a muscle that straightens part of your body.

external fertilization – the female lays eggs and the male deposits sperm on the eggs.

extinction – occurs when the environment changes and the adaptations of a species are no longer sufficient for its survival.

F

feedback control systems – systems that control the levels of endocrine hormones in the blood.

fertilization – the union of egg and sperm.

fetus – an embryo that has developed for 8 weeks and has formed the major structures.

flagellates – a group of protozoans that do not have organelles for movement and are parasites.

flexor – a muscle that bends part of your body.

flower – the reproductive organ of angiosperms.

focal length – the distance from the center of the lens to the focal point.

focal point – a point where light rays meet.

follicle – a structure of the ovary where an egg matures.

food chain – shows how each organism in a community gets its food.

force – a push or a pull, or any action that has the ability to change motion.

fossil – a remnant or trace of an organism from the past, such as a skeleton or leaf imprint, embedded and preserved in Earth's crust.

fossil record – a historical sequence of life on Earth based on the sequence of fossils.

frequency – the number of vibrations per second.

fruit – a ripened ovary that contains angiosperm seeds.

fulcrum – the fixed point where a lever rotates.

fungi – organisms that make up the Kingdom Fungi, including yeasts, molds, and mushrooms, consisting of eukaryotic cells with cell walls made of chitin.

G

gene – a unit that determines traits.

genetic disorder – an abnormal condition that an organism inherits.

genetic engineering – the process of transferring genes from one organism into the DNA of another organism.

genetic variation – the variety of alleles in a population.

genetics – the study of heredity.

genome – the total amount of hereditary material in a single cell of an organism.

genotype – the alleles of a gene an organism contains.

geologic time scale – a model of the history of life on Earth.

geology – the study of Earth's formation and structure.

germination – the process of a seed sprouting and its growth into a young plant.

gills – organs that extract oxygen from water and remove carbon dioxide from the blood.

Golgi body – an organelle that receives proteins, packages them, and distributes them.

graph – a visual way to represent data.

growth – an increase in mass.

growth rate – the change in size of a population over time.

gymnosperms – vascular, seed-producing plants whose seeds are not enclosed in a fruit.

H

habitat – a place where an organism lives.

half-life – the amount of time it takes for half of the unstable atoms in a sample to decay.

haploid – a half set of chromosomes.

heredity – a set of traits an organism receives from its parents.

hermaphrodite – an individual organism that has both male and female reproductive parts.

hinge joint – joints that allow one-way movement.

homeostasis – the process of maintaining a life-supporting internal environment.

homologous structures – body structures that have a common origin but do not necessarily perform the same function.

hormone – a chemical that regulates body functions.

host cell – a cell that is, or becomes, infected with a virus.

hyphae – the thread-like filaments that make up a fungus.

hypothesis – a possible explanation that can be tested with an experiment.

I

image – a picture of an object formed where light rays meet.

immune system – a system that protects an organism from unfamiliar objects like viruses.

implantation – the process in which an embryo becomes embedded in the lining of the uterus.

incident ray – the light ray that strikes a surface.

incomplete dominance – when the phenotype of the two alleles blend.

independent variable – a variable that you believe might influence another variable.

input force – the force applied by a level (also called the effort).

integumentary system – the body system consisting of the skin, hair, and nails that protects the underlying tissues.

internal fertilization – the male deposits sperm inside of the female.

interphase – the stage of the cell cycle that occurs between cell divisions.

inverse relationship – a relationship in which one variable decreases when another variable increases.

invertebrate – an animal without a backbone.

J

joint – the place where two bones meet.

L

lateral line system – rows of sense organs along each side of a fish that detect vibrations.

length – a measurement of distance.

lens – an object designed to refract light in a specific way.

ligament – a strong elastic band of connective tissue.

light ray – an imaginary line that represents a thin beam of light.

lipids – energy-rich compounds such as fats, oils, and waxes made from carbon, hydrogen, and oxygen.

lithospheric plates – giant pieces of solid rock on Earth's surface.

lung – a sac-like organ that takes oxygen fro the air and transfers it to the blood.

lysosome – an organelle that contains enzymes that break things down to be reused by the cell.

M

mammary glands – organs that produce a nutritious fluid called milk.

mass – a measure of the amount of matter that makes up something.

mass extinctions – periods of large-scale extinction.

matter – anything that has mass and takes up space.

measurement – a value that tells the amount of something.

mechanical advantage – the ratio of output force produced by a simple machine to the applied input force.

medulla – the part of the brain that controls the spinal cord and many involuntary activities like breathing and heart rate.

meiosis – cell division that produces sex cells with half the number of chromosomes.

microscope – magnifies objects so you can see their features.

mitochondria – an organelle that produces much of the energy a cell needs to carry out its functions.

mitochondrial DNA – DNA that is found in the mitochondria of a cell.

mitosis – the process of cell division where the nucleus divides into two nuclei.

molecule – a group of two or more atoms joined together chemically.

motor nerves – nerves that transmit signals to skeletal muscle, causing movement.

muscle tissue – tissue made of muscle cells that allows animals to move.

muscular system – a body system that consists of skeletal muscles and tendons.

muscular system – a group of organs whose primary function is movement.

mutation – a change in the hereditary material of an organism.

N

natural selection – the process by which organisms with favorable adaptations survive and reproduce at a higher rate than organisms with less-favorable adaptations.

nerve – a group of nerve cells whose function is to carry signals to control movements.

nerve impulse – a wave of electrical activity transmitted between neurons.

nervous system – a group of organs and nerves that gather, interpret, and respond to information.

nervous tissue – tissue made of nerve cells that enables coordinated movement and response to stimuli.

non-vascular plants – do not have any tissues to transport water and nutrients.

notochord – a flexible, rod-shaped structure found in the embryos of all chordates.

nucleic acids – molecules that contain information needed for making proteins.

O

optic nerve – a nerve that carries nerve impulses from the eyes to the brain.

optic nerve – a nerve that transmits signals from the eye to the brain.

optics – the study of how light behaves.

organ – a group of tissues that works together to carry out a set of functions.

organ system – a group of organs that works together to perform a set of functions.

organelle – a structure inside of a cell that helps it perform its functions.

organism – an individual form of life.

osmosis – the diffusion of water across the cell membrane.

output force – the force exerted on the load.

ovary – (1) part of the flower that holds one or more ovules; (2) female organs that produce eggs and female hormones.

ovulation – the release of a mature egg from the ovary.

ovule – part of the flower that holds one egg cell.

P

paleontologist – a scientist who studies fossils.

pancreas – a gland that produces insulin and digestive enzymes.

Pangaea – an ancient supercontinent that broke apart to form today's continents.

parasite – an organism that lives in or on a host organism and causes it harm.

periosteum – the outer surface of a bone that contains blood vessels and nerves.

peripheral nervous system – consists of nerves that connect all areas of the body to the central nervous system.

phenotype – the form of a trait that an organism displays.

phloem – a vascular tissue that carries sugars and other foods throughout a plant.

photoreceptors – light-sensitive cells of the retina that convert light into nerve impulses.

photosynthesis – a process where plants use the energy of sunlight to produce carbohydrates.

photosynthetic bacteria – bacteria that produce their own food through photosynthesis.

pigment – a molecule that absorbs some colors of light and reflects others.

pistil – the female part of the flower.

pitch – how humans hear and interpret the frequency of sounds.

placenta – an attachment to the uterus that supplies food and oxygen from the mother's blood to the embryo.

plasma – the fluid part of blood.

plate tectonics – a theory that describes how the continents move.

pollen – the reproductive spore that contains sperm cells.

pollination – the transfer of pollen, containing sperm, to the female part of the flower.

pollutant – a variable that causes harm to an organism.

polygenic traits – traits that are determined by more than one gene.

population – a group of individuals of the same species living in a given area.

probability – the mathematical chance that an event will occur.

prokaryotic cell – a cell that does not have a nucleus or membrane-covered organelles.

protein synthesis – the production of proteins in the cell.

proteins – complex molecules made from smaller molecules called amino acids.

protozoan – a single-celled eukaryote that has some animal-like characteristics.

punnett square – shows all of the possible combinations of alleles from the parents.

pupil – the hole in the eye through which light enters.

R

radial symmetry – a body plan in which the body parts are arranged in a circle around a central point.

real image – light from a single point on an object comes back together at a single point in another place to make an image.

recessive allele – the form of a gene that is hidden when the dominant allele is present.

red blood cells – carry oxygen to cells.

reflected ray – the light ray that bounces off a surface.

reflection – occurs when light bounces off a surface.

refraction – the bending of light as it crosses a boundary between two different transparent materials.

relative dating – a method of sequencing events in the order in which they happened.

respiration – the entire process by which the body takes in oxygen and gets rid of carbon dioxide and water.

respiratory system – the body system consisting of the lungs, and passageways that lead to the lungs.

reproduction – the formation of new organisms of the same species.

reproductive system – a group of organs that function in all reproductive processes.

response – how an organism reacts to a stimulus.

retina – a thin layer of cells in the back of the eye that converts light into nerve signals.

rhizoids – root-like growths on mosses and liverworts that anchor the plant to a surface and do not have vascular tissues.

ribosomes – an organelle that makes proteins.

rock cycle – the process of rock formation and recycling.

rod cells – photoreceptors that respond to light intensity.

S

scientific method – a process used by scientists to find the answers to questions.

scientific name – the two-part, scientifically recognized name given to an organism, consisting of its genus and species.

seed – a structure that contains a plant embryo and a supply of food inside a protective covering.

selective breeding – the process of selecting organisms with desired traits to serve as parents for the next generation.

semen – a mixture of sperm and fluid that is ejaculated during sexual intercourse.

sensory nerves – nerves that receive sensory stimuli, such as how something feels.

sex cells – special cells that contain half the number of chromosomes as body cells.

sexual reproduction – a type of reproduction that involves special cells called sex cells.

skeletal system – a group of organs that provide support.

solution – a mixture of two or more substances that are evenly distributed at the molecular level.

species – a group of similar organisms that can produce offspring.

spore – a small, usually single-celled reproductive body that is capable of growing into a new organism.

stamen – the male part of the flower.

stigma – part of the flower that attracts and holds pollen.

stimulus – something that causes a response.

stomata – tiny pores that allow carbon dioxide to enter a leaf and oxygen and water vapor to exit.

superposition – the principle that states that in layers of sedimentary rocks the lowest layers were the earliest to be deposited.

sweat glands – glands in the skin that produce sweat to regulate body temperature.

symbiosis – an interaction where two species live together for a long time.

system – a group of objects, effects, and variables that are related.

systematics – the process of classifying living things according to evolutionary relationships.

T

taxonomy – the process of identifying and classifying living things.

temperature – a measure of how hot or cold something is.

tendon – a strand of tough connective tissue that attaches a skeletal muscle to a bone.

testes – produce sperm and testosterone.

theory – an explanation of how a process or event is thought to occur.

therapsids – an extinct group of reptiles from which mammals evolved.

tissue – a group of specialized cells that performs a particular function.

trait – a characteristic that an organism can pass on to its offspring.

transpiration – the loss of water through the stomata.

tropism – growth in response to a stimulus.

true-breeding plant – a plant that will always produce offspring with the same form of a trait when it self-pollinates.

U

umbilical cord – contains arteries and veins that connect the embryo to the placenta.

uniformitarianism – using features and processes that are observable today to interpret the ancient geologic record.

unit – a fixed amount of something.

uterus – the organ where a baby grows and develops.

V

vaccine – a preparation of virus particles that, when injected into the body, causes the immune system to produce antibodies.

vacuole – an organelle that stores food, water, and other materials needed by the cell.

valve – a flap of tissue that prevents the backflow of blood.

variable – a factor that affects how a system works.

vascular plants – have tissues made of cells that transport water and nutrients throughout the plant.

vascular tissues – cells organized into tube-like structures that transport water, minerals, and food throughout a plant.

veins – blood vessels that carry blood toward the heart.

vertebrate – a set of interlocking bones that form the backbone of a vertebrate.

vertebrates – animals with a backbone.

virtual image – an image where light rays do not actually come together to form the image.

virus – a tiny, nonliving particle made up of genetic material and protein.

volume – a measurement of the amount of space something occupies.

W

wave – a vibration that transfers energy from place to place.

white blood cells – immune cells that destroy invaders.

withdrawal reflex – an involuntary response to an outside stimulus.

X

xylem – a vascular tissue that carries water throughout a plant.

Z

zygote – a fertilized egg.

Index

The index gives the page numbers where you can find a word, definition, information about a topic or a large category. You can use the index when you are studying and need to find information quickly. The index is a good place to look up a vocabulary word to get more information about the meaning of a word.

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California Standards

These pages provide you with the standards that are taught in this book and are required learning for the state of California.

STANDARD SET 1. Cell Biology		Completed
1. All living organisms are composed of cells, from just one to many trillions, whose details usually are visible only through a microscope. As a basis for understanding this concept:	1.a. Students know cells function similarly in all living organisms.	☐
	1.b. Students know the characteristics that distinguish plant cells from animal cells, including chloroplasts and cell walls.	☐
	1.c. Students know the nucleus is the repository for genetic information in plant and animal cells.	☐
	1.d. Students know that mitochondria liberate energy for the work that cells do and that chloroplasts capture sunlight energy for photosynthesis.	☐
	1.e. Students know cells divide to increase their numbers through a process of mitosis, which results in two daughter cells with identical sets of chromosomes.	☐
	1.f. Students know that as multi cellular organisms develop, their cells differentiate.	☐

STANDARD SET 2. Genetics		
2. A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences. As a basis for understanding this concept:	2.a. Students know the differences between the life cycles and reproduction methods of sexual and asexual organisms.	☐
	2.b. Students know sexual reproduction produces offspring that inherit half their genes from each parent.	☐
	2.c. Students know an inherited trait can be determined by one or more genes.	☐
	2.d. Students know plant and animal cells contain many thousands of different genes and typically have two copies of every gene. The two copies (or alleles) of the gene may or may not be identical, and one may be dominant in determining the phenotype while the other is recessive.	☐
	2.e. Students know DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.	☐

STANDARD SET 3. Evolution		Completed
3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. As a basis for understanding this concept:	3.a. Students know both genetic variation and environmental factors are causes of evolution and diversity of organisms.	☐
	3.b. Students know the reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution.	☐
	3.c. Students know how independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.	☐
	3.d. Students know how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.	☐
	3.e. Students know that extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient for its survival.	☐

STANDARD SET 4. Earth and Life History		
4. Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept:	4.a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.	☐
	4.b. Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.	☐
	4.c. Students know that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.	☐
	4.d. Students know that evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old and that life on this planet has existed for more than 3 billion years.	☐
	4.e. Students know fossils provide evidence of how life and environmental conditions have changed.	☐
	4.f. Students know how movements of Earth's continental and oceanic plates through time, with associated changes in climate and geographic connections, have affected the past and present distribution of organisms.	☐
	4.g. Students know how to explain significant developments and extinctions of plant and animal life on the geologic time scale.	☐

STANDARD SET 5. Structure and Function in Living Systems		Completed
5. The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. As a basis for understanding this concept:	5.a. Students know plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.	☐
	5.b. Students know organ systems function because of the contributions of individual organs, tissues, and cells. The failure of any part can affect the entire system.	☐
	5.c. Students know how bones and muscles work together to provide a structural framework for movement.	☐
	5.d. Students know how the reproductive organs of the human female and male generate eggs and sperm and how sexual activity may lead to fertilization and pregnancy.	☐
	5.e. Students know the function of the umbilicus and placenta during pregnancy.	☐
	5.f. Students know the structures and processes by which flowering plants generate pollen, ovules, seeds, and fruit.	☐
	5.g. Students know how to relate the structures of the eye and ear to their functions.	☐

STANDARD SET 6: Physical Principles in Living Systems		
6. Physical principles underlie biological structures and functions. As a basis for understanding this concept:	6.a. Students know visible light is a small band within a very broad electromagnetic spectrum.	☐
	6.b. Students know that for an object to be seen, light emitted by or scattered from it must be detected by the eye.	☐
	6.c. Students know light travels in straight lines if the medium it travels through does not change.	☐
	6.d. Students know how simple lenses are used in a magnifying glass, the eye, a camera, a telescope, and a microscope.	☐
	6.e. Students know that white light is a mixture of many wavelengths (colors) and that retinal cells react differently to different wavelengths.	☐
	6.f. Students know light can be reflected, refracted, transmitted, and absorbed by matter.	☐
	6.g. Students know the angle of reflection of a light beam is equal to the angle of incidence.	☐
	6.h. Students know how to compare joints in the body (wrist, shoulder, thigh) with structures used in machines and simple devices (hinge, ball-and-socket, and sliding joints).	☐
	6.i. Students know how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system.	☐
	6.j. Students know that contractions of the heart generate blood pressure and that heart valves prevent backflow of blood in the circulatory system.	☐

STANDARD SET 7. Investigation and Experimentation		Completed
7. 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 three strands, students should develop their own questions and perform investigations. Students will:	7.a. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.	☐
	7.b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.	☐
	7.c. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.	☐
	7.d. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure)	☐
	7.e. Communicate the steps and results from an investigation in written reports and oral presentations.	☐