Animals

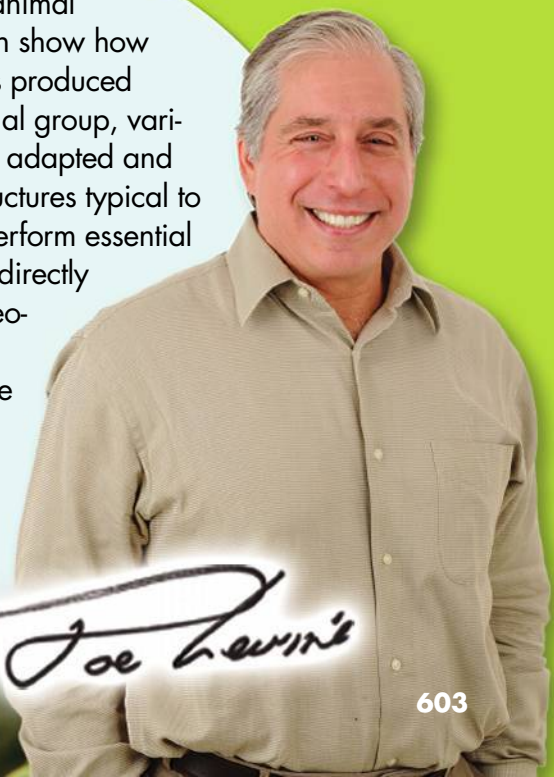
UNIT 7

Chapters

INTRODUCE the Big ideas

- **Unity and Diversity of Life**
- **Evolution**
- **Structure and Function**

"Studies of animal structure and function show how evolutionary change has produced life's diversity. In each animal group, various 'body-part tool kits' have adapted and changed over time to form structures typical to each group. Those structures perform essential functions, most of which help—directly or indirectly—to maintain homeostasis. The body-part tool kits are shaped by genetics whose shared elements can be traced back over time and throughout the animal kingdom."



Joe Levine

25 Introduction to Animals

Big idea

Unity and Diversity of Life

Q: What characteristics and traits define animals?

BIOLOGY.com Search Chapter 25 GO • Flash Cards

INSIDE:

Though they look very different, the hundreds of animal species that make up or live near a coral reef share characteristics common to all animals.

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

SLIME DAY AT THE BEACH

It was a warm October day in Boston when people started calling beach offices, aquariums, and even 9-1-1. Beaches near Boston were coated with a layer of jellylike ooze. People were confused and worried. Some thought there had been an oil spill. However, police and firefighters found that the ooze was not oil.

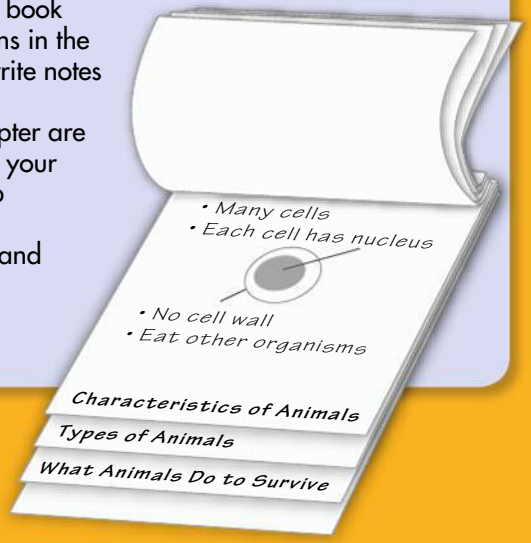
More slimy masses kept washing up on the beach. When people looked more closely, they saw that the slime was made of small, individual creatures. Each creature was transparent and the size of a fingernail. What were they?

Read for Mystery Clues As you read this chapter, look for clues to help you find out what the slime was.

FOUNDATIONS for Learning

You can use a layered book to review the main ideas in this chapter. Make a layered book by stapling pieces of paper together. Your book should have visible tabs, as in the diagram below. Write the name of the first lesson on the front page of your book. Write the main topics from the lesson on the tabs that are showing. Write notes for each main topic on the part of each paper that is not showing. Use both words and pictures in your notes.

Make another layered book for Lesson 2. Make a third layered book using the key questions in the chapter, but do not write notes in this third book yet. At the end of the chapter are two activities that use your layered books to help answer the question: What characteristics and traits define animals?



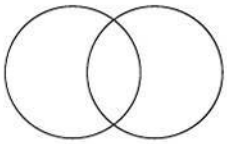
25.1 What Is an Animal?

Key Questions

- ***What characteristics do all animals share?***
- ***What characteristics distinguish invertebrates and chordates?***
- ***What essential functions must animals perform to survive?***

BUILD Understanding

Venn Diagram Use a Venn diagram to show the similarities and differences between invertebrates and chordates.



Invertebrates Chordates

In Your Workbook Go to your workbook to learn more about making a Venn diagram. Complete the Venn diagram started for you.

For more on the diversity of animals, go to the Visual Guide.
pp. DOL 30–DOL 64

Characteristics of Animals

A bald eagle circles a salt marsh looking for prey. Suddenly, it dives and captures a fish. At the bottom of the marsh, worms burrow beneath rocks. In the air above the marsh, mosquitoes buzz. The eagle, fish, worms, and mosquitoes are all animals. All members of the animal kingdom share certain characteristics. Animals are heterotrophs, organisms that get energy by eating other organisms. Animals are multicellular, or have bodies composed of many cells. Animal cells are eukaryotic—each cell has a nucleus. Animal cells do not have cell walls.

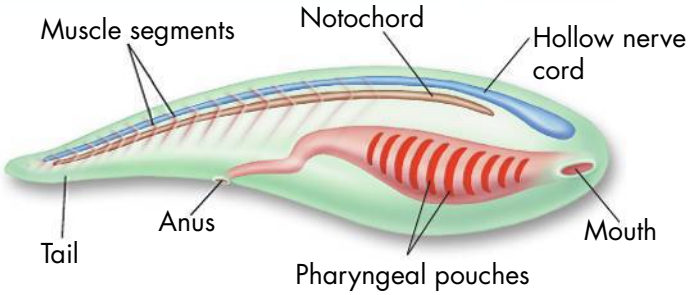
Key Question What characteristics do all animals share?
Animals are multicellular heterotrophs that get energy by eating other organisms. Animals have eukaryotic cells that do not have cell walls.

Types of Animals

The animal kingdom is a large and diverse group. Animals can be classified into two main groups: invertebrates and chordates.

Invertebrates More than 95 percent of all animals can be lumped into a catch-all grouping called **invertebrates.** That term is used to describe animals that do not have a backbone. Invertebrates include sea stars, jellyfishes, worms, snails, and insects. They range in size from dust mites to giant squids that are more than 14 meters long. "Invertebrates" are not a proper clade according to evolutionary classification. Scientists classify invertebrates into 33 different phyla.

Chordates Fewer than 5 percent of animal species are **chordates** (KAWR dayts). Chordates are members of the phylum Chordata. All chordates have four characteristics that are present during at least one stage of life. Chordates have a hollow nerve cord that runs along the back (or dorsal) part of the body. They also have a **notochord** that is located below the nerve cord. A notochord is a long supporting rod that runs through the body just below the nerve cord. Most chordates only have a notochord when they are embryos.



Characteristics of Chordates All chordates have a hollow nerve cord, a notochord, pharyngeal pouches, and a tail that extends past the anus. Some chordates have all these traits as adults. Other chordates only have some of these traits as embryos.

All chordates have a tail that extends past the anus. (The anus is the opening where wastes leave the body.) The tail disappears in some chordates as the embryo develops. All chordates also have **pharyngeal** (fuh RIN jee ul) **pouches.** Pharyngeal pouches are paired structures in the throat region. In some chordates, such as fishes, slits develop that connect pharyngeal pouches to the outside of the body. Pharyngeal pouches may develop into gills. Gills are structures that are used for gas exchange.

Phylum Chordata includes some odd aquatic animals known as nonvertebrate chordates. These chordates do not have a backbone. Most chordates develop a backbone, or vertebral column. Chordates with backbones are called **vertebrates.** Vertebrates include fishes, amphibians, reptiles, birds, and mammals.

Key Question What characteristics distinguish invertebrates and chordates?
Invertebrates lack a backbone. Chordates have all four of the following during at least one stage of life: a dorsal, hollow nerve cord; a notochord; a tail that extends past the anus; and pharyngeal pouches.

What Animals Do to Survive

Animals come in an amazing variety of body shapes, sizes, and colors. No matter what they look like, all animals must perform certain basic functions to stay alive. In addition, all animals must reproduce. Like all organisms, animals must keep their internal environments stable. They do this in three ways:
1. Animals gather and respond to information.
2. They take in and distribute oxygen and nutrients to cells.
3. They collect and get rid of carbon dioxide and other wastes.

Over time, members of different animal phyla have evolved very different body structures to perform the functions that keep them alive. You will study these structures in more detail in Chapters 27 and 28.

BUILD Vocabulary

invertebrate
an animal that lacks a backbone, or vertebral column

chordate
an animal that has, for at least one stage of its life, a dorsal, hollow nerve cord; a notochord; a tail that extends beyond the anus; and pharyngeal pouches

notochord
a long supporting rod that runs through a chordate's body just below the nerve cord

pharyngeal pouch
one of a pair of structures in the throat region of a chordate

vertebrate
an animal that has a backbone

PREFIXES
The prefix *in-* means "not." An invertebrate does *not* have a backbone. A vertebrate does have a backbone.

BUILD Vocabulary

feedback inhibition
a process in which a stimulus produces a response that opposes the original stimulus; also called negative feedback

WORD ORIGINS

The word *inhibition* comes from the Latin word *inhibitionem*, which means "a restraining." To restrain something means to hold it back.

Maintaining Homeostasis All organisms must keep their internal environments stable. This process is known as maintaining homeostasis. Maintaining homeostasis is the most important function of all animal body systems.

Homeostasis is often maintained by feedback inhibition. **Feedback inhibition,** or negative feedback, is a system in which the result of a process helps to limit the process itself. The heating system in a house uses feedback inhibition. If the rooms are too cold, the thermostat turns on the heat. When the rooms get warm enough, the thermostat turns off the heat. Your body's thermostat works in a similar way. If you get too cold, you shiver. Shivering causes your muscles to generate heat. If you get too hot, you sweat. Sweating helps you to lose heat.

Gathering and Responding to Information Animals use many body systems to gather and respond to information in their environment. In many animals, the nervous system gathers information. Specialized cells called receptors sense light, sound, chemicals, and touch. Information from the receptors travels to other nerve cells, which determine how to respond. Some invertebrates have a loose network of nerve cells with no real center. Other invertebrates and most chordates have large numbers of nerve cells concentrated in a brain.

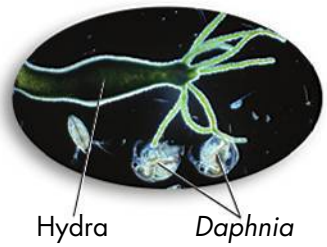
INQUIRY into Scientific Thinking

GUIDED INQUIRY

How Hydra Feed

The hydra is a small aquatic invertebrate that is related to jellyfish and sea anemones. The hydra has a tubelike body with long, thin tentacles at the top. *Daphnia* are also small aquatic invertebrates. They are related to shrimp and crabs. Each *Daphnia* has a round body and an eyespot. In this lab, you will investigate how hydra feed on *Daphnia*.

1. Your teacher will provide you with hydra and *Daphnia*. Using a dropper pipette, gently place one hydra onto a well slide.
2. Let the hydra adjust to its surroundings for 5 to 10 minutes.
3. Using your dropper, add one *Daphnia* to the slide.
4. Observe the hydra under the microscope.



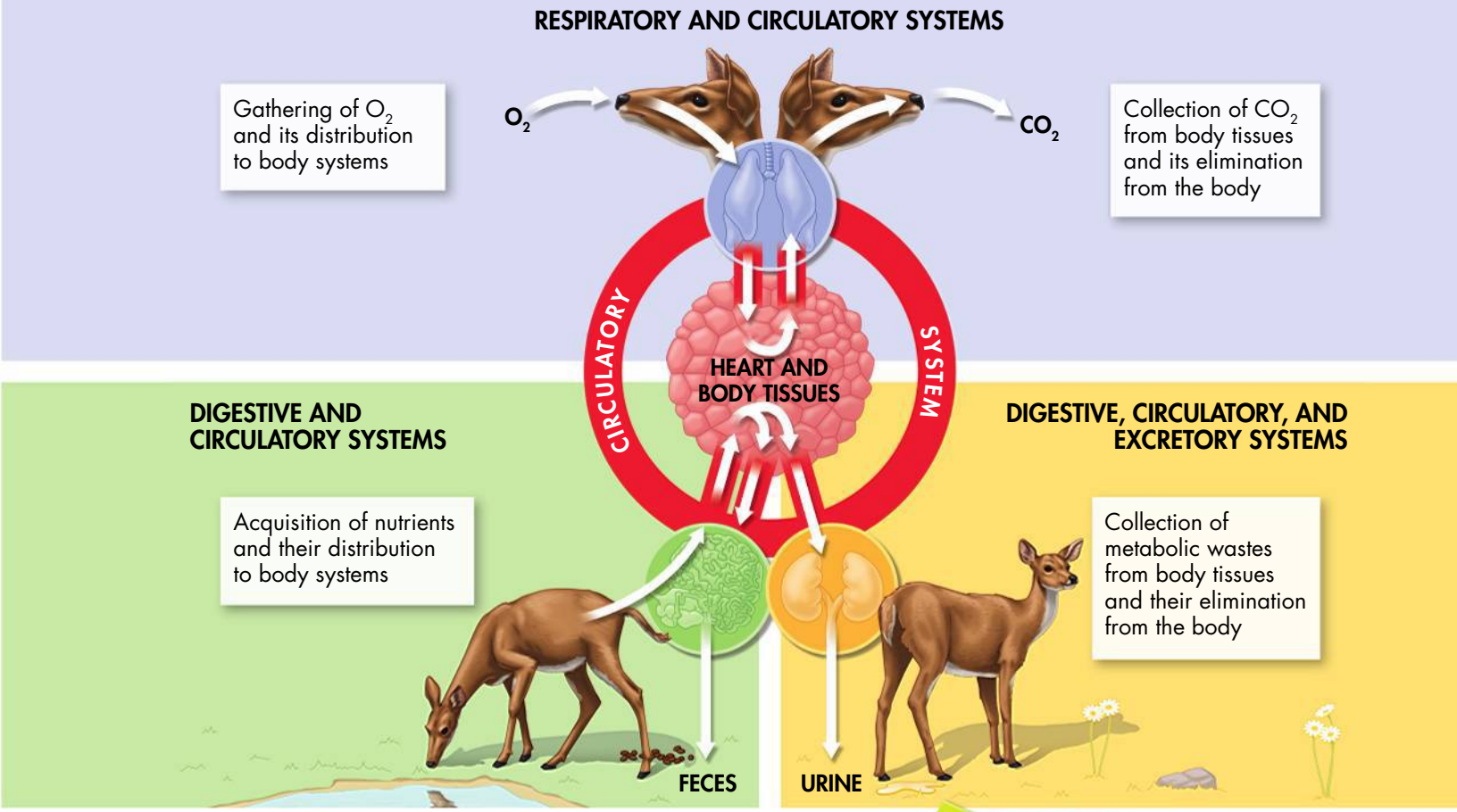
Analyze and Conclude

1. Observe What happens when the *Daphnia* is added to the same slide as the hydra?

2. Draw Conclusions How do the hydra's tentacles help it to maintain homeostasis?

3. Quick Write What else would you like to learn about how the hydra survives in its environment? Write down two new questions.

In Your Workbook Get more help for this activity in your workbook.



Animals often respond to the information they have processed by moving around. The nervous system causes muscles to become shorter. When muscles become shorter, they can move the animal's supporting structure, called a skeleton. Skeletons vary from phylum to phylum. Invertebrates like earthworms have flexible skeletons. Insects and other invertebrates have skeletons outside their bodies. Vertebrates have skeletons inside their bodies that are made of bones.

Getting and Delivering Oxygen and Nutrients All animals must breathe to obtain oxygen. Small animals that live in wet places can "breathe" by allowing oxygen to diffuse across their skin. Larger animals use gills, lungs, or air passages to breathe.

All animals must eat to get nutrients. Many animals have digestive systems that break down food into nutrients. Then the body must deliver the oxygen and nutrients to its cells. Many animals use a circulatory system to carry oxygen and nutrients around the body. The circulatory system works together with the respiratory and digestive systems to keep an animal alive.

Collecting and Removing CO_2 and Other Wastes The activity of animal cells produces waste products. Some of these waste products contain nitrogen, often in the form of ammonia. Both carbon dioxide and ammonia are poisonous. In high concentrations, these substances can destroy cells. Therefore, the body must get rid of these wastes.

BUILD Connections

MOVING MATERIALS IN, AROUND, AND OUT OF THE BODY

The structures of an animal's respiratory, digestive, and excretory systems must work together with the structures of the animal's circulatory system.

Many animals use respiratory systems that get rid of carbon dioxide. Most animals have an excretory system that gets rid of wastes like ammonia. An excretory system is an organ system that concentrates or processes nitrogen-containing wastes. Some animals can get rid of nitrogen-containing wastes right away. Other animals have to store them before getting rid of them. Before waste products can be removed from the body, they have to be collected from the cells. Some sort of circulatory system is needed to collect wastes. The circulatory system brings carbon dioxide to the respiratory system. It also brings nitrogen-containing wastes to the excretory system.

Reproduction Like many vertebrates, this pygmy marsupial frog is caring for her young while they develop. Unlike most animals, she is carrying her eggs on her back!

Reproducing Most animals reproduce sexually. Sexual reproduction helps create and maintain genetic diversity. Genetic diversity allows a species to evolve as the environment changes. Many invertebrates and a few vertebrates can also reproduce asexually. Asexual reproduction usually produces offspring that are exactly the same as the parent. Asexual reproduction allows animals to increase their numbers quickly. However, it does not increase genetic diversity.

Key Question What essential functions must animals perform to survive?

Animals must maintain homeostasis by gathering and responding to information, getting and delivering oxygen and nutrients, and collecting and removing carbon dioxide and other wastes. They must also reproduce.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. All _____ have a hollow nerve cord during at least one stage of life.

2. Fishes, amphibians, reptiles, birds, and mammals are all chordates that are also _____.

Critical Thinking

3. Compare and Contrast What is the defining characteristic of invertebrates? What are four characteristics of chordates?

4. Relate Name two waste products that are produced by an animal's cells. Why must these waste products be eliminated from an animal's body?

5. Write to Learn Answer the first clue of the mystery. Think about the characteristics of invertebrates and chordates. Which type of animal would have a stiff rod running along its tail?

MYSTERY CLUE

Scientists verified that the organisms were young animals that had a stiff rod running along the tail. What does this suggest about the slimy critters? (Hint: See p. 607.)

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25.2 Animal Body Plans and Evolution

Features of Body Plans

Why does a worm look so different from a fish? Why do butterflies have wings while dolphins have flippers? Body structures in animals that are alive today were shaped by millions of years of evolution. Each animal phylum has its own combination of body structures called a body plan. The eight main features of animal body plans are described below.

Levels of Organization As the first cells of most animals develop, they differentiate (or change) into specialized cells. These specialized cells are organized into tissues. Tissues combine during development to form organs. Organs work together to make up organ systems. Organ systems carry out complex functions for the body.

Body Symmetry The bodies of most animals show some kind of symmetry. Some animals have body parts that extend outward from the center. This type of symmetry is called **radial symmetry.** Radially symmetric animals can be sliced, like a pie, by imaginary planes beginning at the center. Some radially symmetric animals can be divided into an even number of "slices." Others, like sea stars, contain an odd number of radially symmetric parts.

Many animals have **bilateral symmetry.** In bilateral symmetry, a single imaginary plane divides the body into left and right sides that look the same. Animals with bilateral symmetry have a front (anterior) end and a back (posterior) end. Animals with bilateral symmetry also have an upper (dorsal) side and a lower (ventral) side. Your back is on your dorsal side. Your belly is on your ventral side.

Animals with radial symmetry have body parts that extend out from a central point. Animals with bilateral symmetry have distinct front (anterior) and back (posterior) ends and have right and left sides.

Key Questions

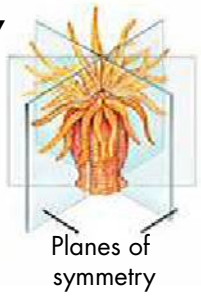
- ***What are some features of animal body plans?***
- ***How are animal phyla defined?***

BUILD Understanding

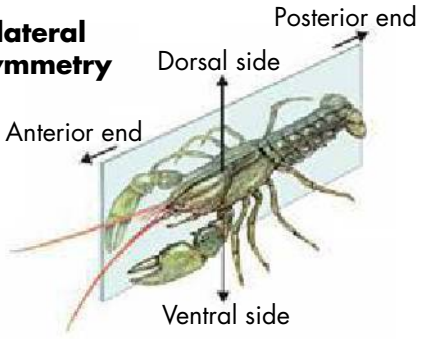
Concept Map You can use concept maps to show how ideas or concepts connect. As you read the lesson, draw a concept map showing the different features of animal body plans and the different types of each feature.

In Your Workbook Refer to your workbook to review the features of different body plans.

Radial Symmetry



Bilateral Symmetry



Body Symmetry Animals with radial symmetry have body parts that come out from a central point. Animals with bilateral symmetry have distinct front and back ends and left and right sides.

BUILD Vocabulary

radial symmetry
a body plan in which body parts repeat around the center of the body

bilateral symmetry
a body plan in which a single imaginary line can divide the body into left and right sides that are mirror images of each other

endoderm
the innermost germ layer; develops into the linings of the digestive tract and much of the respiratory system

mesoderm
the middle germ layer; develops into muscles and much of the circulatory, reproductive, and excretory systems

ectoderm
the outermost germ layer; produces sense organs, nerves, and the outer layer of skin

coelom
a body cavity lined with mesoderm

pseudocoelom
a body cavity that is only partially lined with mesoderm

PREFIXES

You can use the prefixes for each word that describes a germ layer to remember where the germ layer is located in the embryo. The prefix *endo-* means "within." The prefix *meso-* means "middle." The prefix *ecto-* means "outside."

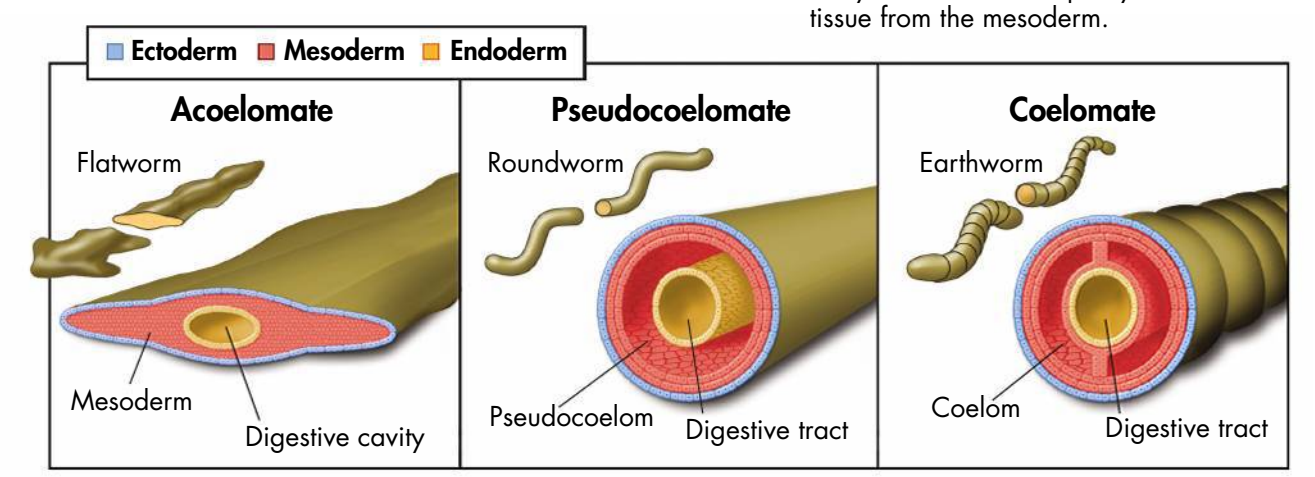
Differentiation of Germ Layers As fertilized eggs develop, the cells of most animals differentiate, or change, into three layers called germ layers. The **endoderm** is the inside germ layer. Its cells develop into the linings of the digestive system and most of the respiratory system. The **mesoderm** is the middle germ layer. Its cells develop into muscles and most of the circulatory, reproductive, and excretory systems. The **ectoderm** is the outer germ layer. Its cells develop into organs of the nervous system and the skin.

Formation of Body Cavity Most animals have some kind of body cavity. A body cavity is a space that is filled with fluid. A body cavity holds the organs and gives them space to grow. Your stomach and intestines are located in your body cavity. Many animals have a true **coelom** (SEE lum). A coelom is a body cavity that is completely lined with tissue that develops from the mesoderm. Some invertebrates have a **pseudocoelom** (soo doh SEE lum), which is only partly lined with tissue from the mesoderm. Other invertebrates, called acoelomates, do not have a body cavity at all.

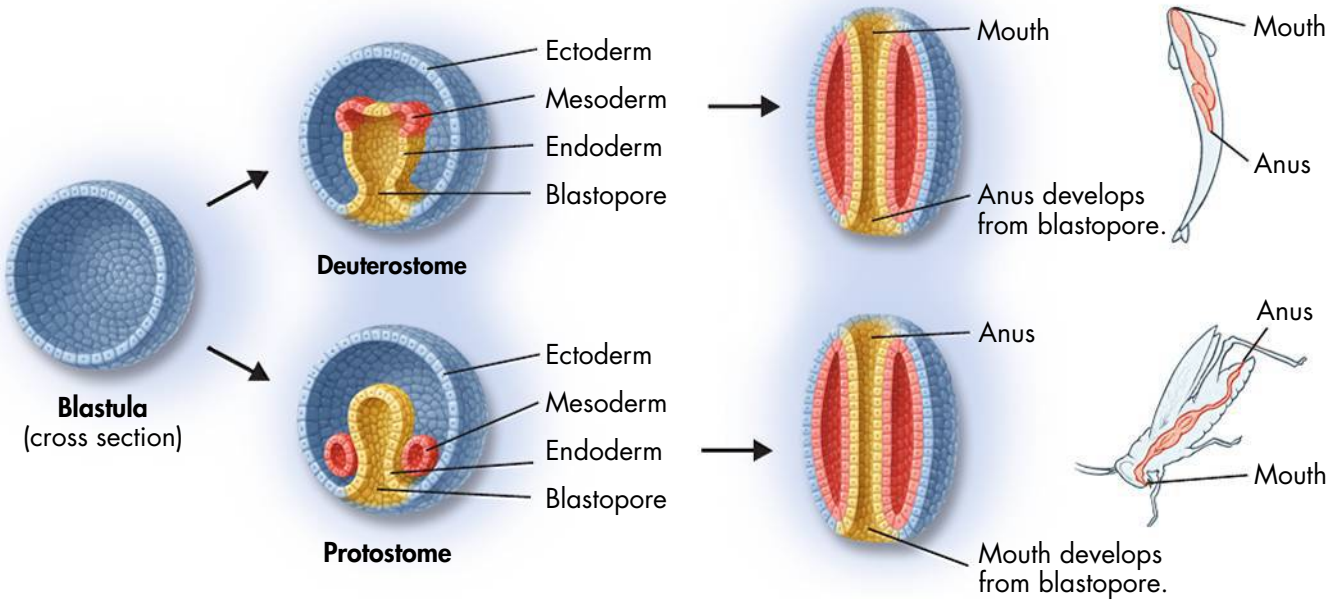
Patterns of Embryo Development Every animal that reproduces sexually begins life as a fertilized egg, or **zygote** (ZY goht). As the zygote begins to develop, it develops into an embryo. As the embryo develops, it forms a hollow ball of cells called a **blastula** (BLAS tyoo luh). The blastula looks like an inflated balloon. As the blastula continues to develop, it folds in on itself. Imagine holding a partly inflated balloon in your hand and pushing your thumbs toward the center. This folding inward forms a tube down the middle of the blastula. This tube becomes a digestive tract. In a digestive tract, food enters through one opening, called the mouth. Wastes leave through another opening, called the anus.

The first opening that forms as the blastula folds is called a blastopore. This opening can become either the mouth or the anus, depending on the animal.

Body Cavities Acoelomates do not have a coelom between their body wall and digestive cavity. Pseudocoelomates have body cavities that are partly lined with tissue from the mesoderm.



Blastopore Formation A hollow ball of cells called a blastula forms during the early development of an animal embryo. An opening called a blastopore forms in this ball. In deuterostomes, such as fishes, the blastopore forms an anus. In protostomes, such as grasshoppers, the blastopore forms a mouth.



▶ ***Protostomes*** In phyla that are **protostomes** (PROH tuh stohms), the blastopore becomes the mouth. In protostomes, the anus forms from a second opening that develops at the opposite end of the tube. Most invertebrates are protostomes.

▶ ***Deuterostomes*** In **deuterostomes** (DOO tur uh stohms), the blastopore becomes the anus. The mouth is formed from the second opening that develops in the tube. Chordates and echinoderms are deuterostomes.

Segmentation: Repeating Parts As many animals that have bilateral symmetry develop, their bodies become divided into segments. Segments are body parts that are repeated. Worms, insects, and vertebrates usually have at least some parts that repeat on each side of the body. Bilateral symmetry and segmentation are often found together.

Cephalization: Getting a Head Animals with bilateral symmetry usually also have **cephalization** (sef uh lih ZAY shun). Cephalization is the concentration of sense organs and nerve cells at the front end of an animal. Cephalization often creates a head. Arthropods and vertebrates both show cephalization.

The heads of arthropods and vertebrates form when different body segments combine during embryo development. As the segments grow together, sense organs (such as eyes) and nerve cells become concentrated in the head. Animals with heads usually move in a "head-first" direction. Moving head first allows their sense organs to come into contact with new parts of their environment first.

BUILD Vocabulary

zygote a fertilized egg

blastula a hollow ball of cells that develops when a zygote undergoes a series of cell divisions

protostome an animal whose mouth is formed from the blastopore

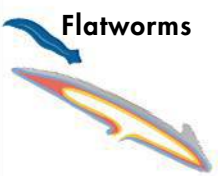
deuterostome an animal in which the blastopore becomes an anus, and the mouth is formed from the second opening that develops

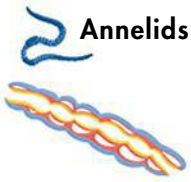
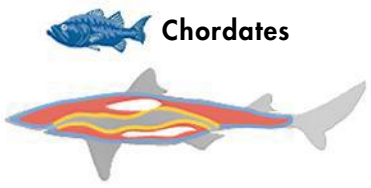
cephalization the concentration of sense organs and nerve cells at the anterior end of an animal

PREFIXES

The prefix *proto-* comes from a Greek word meaning "first." This can help you to remember that the blastopore becomes a mouth (the "first" opening of the digestive system) in a protostome.

Body Plans The different features of body plans are shown for nine animal phyla below. The body plans of modern animals suggest that invertebrates and chordates evolved from a common ancestor.

Ectoderm Mesoderm Endoderm	Sponges	Cnidarians	Arthropods	Roundworms	Flatworms
					
Levels of Organization	Specialized cells	Specialized cells, tissues	Specialized cells, tissues, organs	Specialized cells, tissues, organs	Specialized cells, tissues, organs
Body Symmetry	Absent	Radial	Bilateral	Bilateral	Bilateral
Germ Layers	Absent	Two	Three	Three	Three
Body Cavity	–	Acoelom	True coelom	Pseudocoelom	Acoelom
Embryological Development	–	–	Protostome	Protostome	Protostome
Segmentation	Absent	Absent	Present	Absent	Absent
Cephalization	Absent	Absent	Present	Present	Present

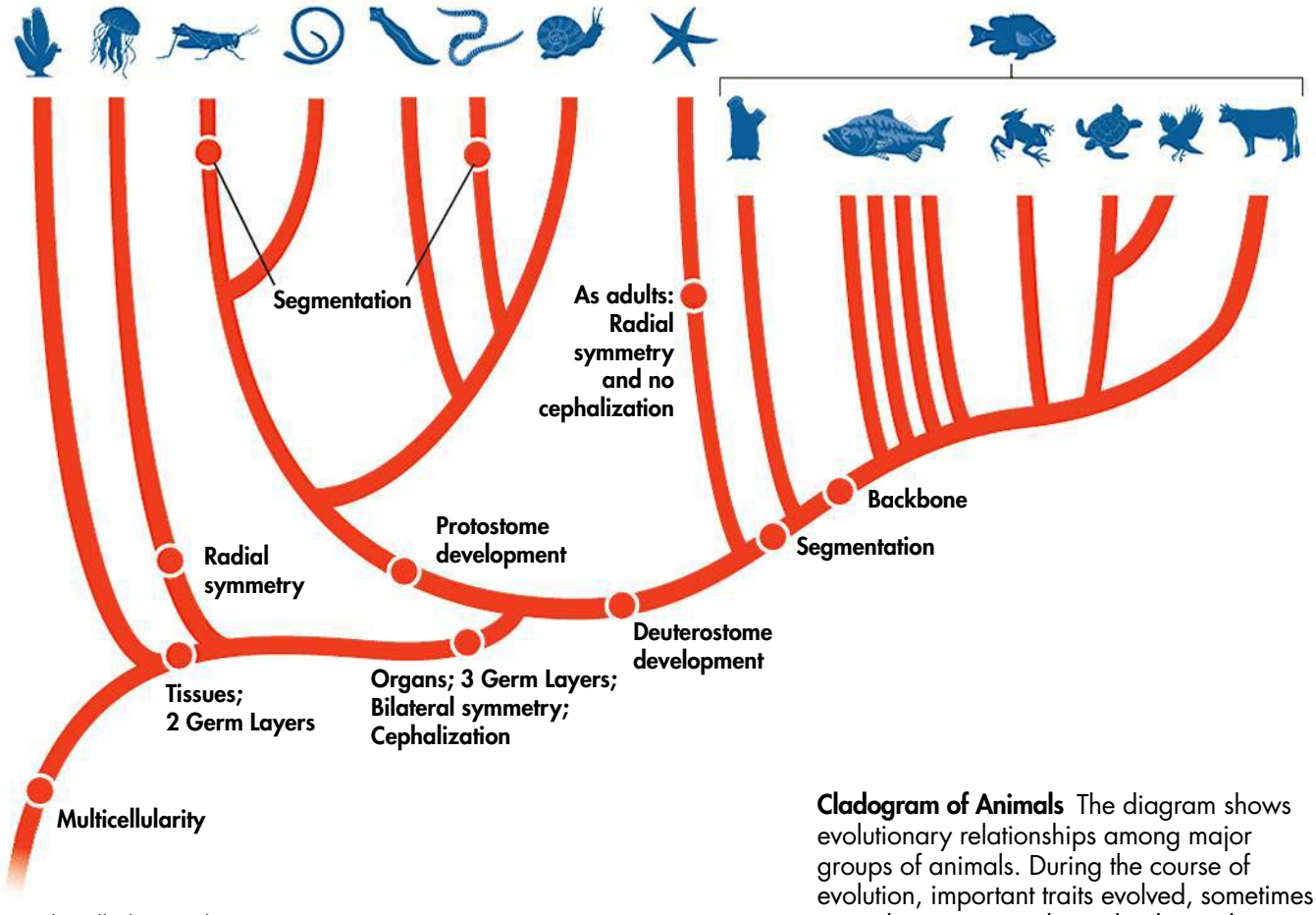
Ectoderm Mesoderm Endoderm	Annelids	Mollusks	Echinoderms	Chordates
				
Levels of Organization	Specialized cells, tissues, organs	Specialized cells, tissues, organs	Specialized cells, tissues, organs	Specialized cells, tissues, organs
Body Symmetry	Bilateral	Bilateral	Radial (as adults)	Bilateral
Germ Layers	Three	Three	Three	Three
Body Cavity	True coelom	True coelom	True coelom	True coelom
Embryological Development	Protostome	Protostome	Deuterostome	Deuterostome
Segmentation	Present	Absent	Absent	Present
Cephalization	Present	Present	Absent (as adults)	Present

Limb Formation: Legs, Flippers, and Wings Animals that have bilateral symmetry and segmentation usually have appendages on both sides of the body. Appendages can be bristles, legs, or other types of limbs. Dragonfly and bird wings, spider legs, dolphin flippers, and monkey arms are all appendages. Different kinds of appendages have evolved several times, and have been lost several times, in various animal groups.

Key Question What are some features of animal body plans?
Features of animal body plans include levels of organization, body symmetry, differentiation of germ layers, formation of body cavities, patterns of embryo development, segmentation, cephalization, and limb formation.

The Cladogram of Animals

The features of animal body plans and other evidence provide information for building a cladogram, or phylogenetic tree, of animals. The cladogram below shows our current understanding of the relationships among animal phyla. Animal phyla are usually defined by their adult body plans and patterns of embryo development. For example, the phylum Arthropoda is defined by a body plan that includes bilateral symmetry, segmentation, cephalization, an external skeleton, and jointed legs. Every phylum has its own combination of ancient traits from ancestors and new traits that are found only in that phylum.



Cladogram of Animals The diagram shows evolutionary relationships among major groups of animals. During the course of evolution, important traits evolved, sometimes more than once, as shown by the circles.

Limb Variations Birds have evolved front limbs specialized as wings. Frogs have evolved four legs.

Differences Between Phyla The cladogram shows the sequence in which important body plan features evolved. You may think that a cladogram shows "improvements" from one phylum to the next. This notion is not correct. The body systems of vertebrates are not better than the body systems of invertebrates. Any system found in a living animal is good enough to allow the animal to survive and reproduce.

Changes Within Phyla Different groups within each phylum show different variations on basic body plans. For example, land vertebrates usually have four limbs. Many of these animals, such as squirrels and frogs, walk or hop on four limbs that we call legs. In birds, the front limbs have evolved into wings. In monkeys, the front limbs have evolved into arms. And through evolution, snakes have lost all of their limbs!

Evolutionary Experiments You can think of each phylum's body plan as an evolutionary "experiment." The first version of each major body plan appeared millions of years ago. Each body plan has changed as phylum members adapted to changing environments. If those changes enabled phylum members to survive and reproduce, the phylum still exists. If the body plan did not meet the changing challenges, groups in the phylum, or the entire phylum, have become extinct.

Key Question How are animal phyla defined?
Animal phyla are usually defined by their adult body plans and their patterns of embryo development.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. A vertebrate has _____ symmetry, which means that it has right and left sides that are mirror images of each other.
2. The middle germ layer is called the _____.
3. A body cavity that is only partly lined with tissue from the mesoderm is a _____.

Critical Thinking

4. **Relate Cause and Effect** What will happen to a phylum over time if its body plan does not allow its members to survive and reproduce?

5. **Write to Learn** Answer the second clue of the mystery. Write your answer in paragraph form. Use the terms *segmentation*, *deuterostomes*, and *pharyngeal pouches* in your paragraph.

MYSTERY CLUE

The mystery creatures are deuterostomes. Their larvae have bilateral symmetry, a dorsal hollow nerve cord, and pharyngeal pouches—but no backbone. Where on the cladogram do they belong? (Hint: See p. 615.)

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Pre-Lab: Comparing Invertebrate Body Plans

Problem What characteristics can be used to classify invertebrates?

Materials compound microscope; prepared slides of cnidarian, roundworm, and earthworm cross sections; red, blue, and yellow colored pencils

Lab Manual Chapter 25 Lab

Skills Focus Observe, Classify, Compare and Contrast

Connect to the Big idea All members of Kingdom Animalia share a set of characteristics that define them as animals. However, the diversity within the kingdom is vast. For example, some animals have a backbone, but many do not. Some animals have radial symmetry, but many do not. In this lab, you will use preserved cross sections to compare the body plans of three invertebrates. You will pay particular attention to germ layers and body cavities.

BIOLOGY.com Search Chapter 25 GO

Visit Chapter 25 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Learn how scientists determine that an organism is an animal as the Untamed Science crew visits a research facility on Coconut Island.

Art in Motion View an animation that shows the differences in early development in protostomes and deuterostomes.

Art Review Review your understanding of body symmetry with this drag-and-drop activity.

Background Questions

a. Review Describe three characteristics that all animals share.

b. Review What are the three germ layers, and what structures do they give rise to?

c. Explain What is the function of a body cavity?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. Compare and Contrast Which two features of animal body plans will you be comparing in this lab?

2. Apply Concepts Where will you look for tissue that formed from the ectoderm layer?

3. Infer Is a hydra smaller than, larger than, or about the same size as an earthworm? Base your answer on the procedure in this lab.

25 CHAPTER Summary

25.1 What Is an Animal?

- Animals are members of the kingdom Animalia. Animals are hetertrophs that get nutrients and energy by eating other organisms. Animals have multicellular bodies made of eukaryotic cells that do not have cell walls.
- Invertebrates include all animals that lack a backbone.
- All chordates show four characteristics during at least one stage of life: a hollow nerve cord down the back, a notochord, a tail that extends past the anus, and pharyngeal pouches.
- Like all organisms, animals must maintain homeostasis. They do this by gathering and responding to information, obtaining and distributing oxygen and nutrients, and collecting and eliminating carbon dioxide and other wastes. Animals also reproduce.

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invertebrate (p. 606)
chordate (p. 606)
notochord (p. 606)
pharyngeal pouch (p. 607)
vertebrate (p. 607)
feedback inhibition (p. 608)

25.2 Animal Body Plans and Evolution

- Features of animal body plans include levels of organization, body symmetry, differentiation of germ layers, formation of body cavities, patterns of embryo development, segmentation, cephalization, and limb formation.
- Animal phyla are usually defined according to adult body plans and patterns of embryo development.

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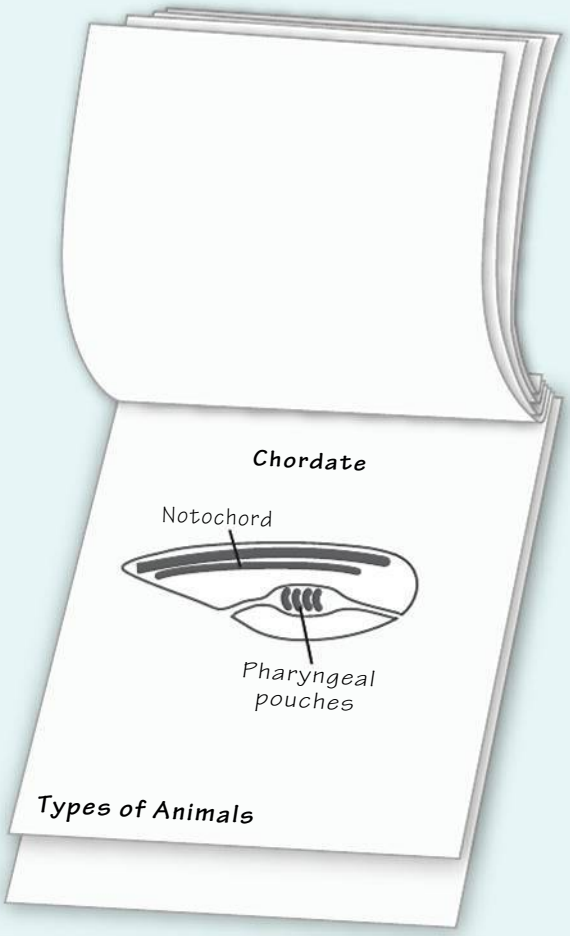
radial symmetry (p. 611)
bilateral symmetry (p. 611)
endoderm (p. 612)
mesoderm (p. 612)
ectoderm (p. 612)
coelom (p. 612)
pseudocoelom (p. 612)
zygote (p. 612)
blastula (p. 612)
protostome (p. 613)
deuterostome (p. 613)
cephalization (p. 613)

Foundations for Learning Wrap-Up

Use the layered books you made when you started the chapter to help you to organize your thoughts about which characteristics define animals.

Activity 1 Get together in a group of three. Take out one of the layered books that summarizes the main topics in Lesson 1 or 2. Read aloud one of the main topics listed on the tabs of the book. Discuss the things that you should remember about that topic. Look inside the layered book to see if you have remembered all the important concepts.

Activity 2 Stay in your group of three. Take out all of the layered books that contain the key questions from the chapter. Work together to write notes and draw diagrams that answer each question. Do this without looking at your textbook.



25 CHECK Understanding

Assess the Big idea Unity and Diversity of Life

Write an answer to the question below:

Q: What characteristics and traits define animals?

Constructed Response

Write an answer to each of the numbered questions below. The answer to each numbered question should be one or two paragraphs long. To help you begin, read the **Hints** below the questions.

1. **If you were presented with a small, living organism, how would you try to determine whether or not it was an animal?**

   Hint Remember the characteristics of organisms that belong to the animal kingdom.

2. **Animals need oxygen and nutrients in order to survive. How do animal systems work together to get oxygen and nutrients to the animal's cells?**

   Hint Review the Respiratory and Circulatory Systems diagram that shows how materials move in, around, and out of the body.

   Hint Think about which systems get oxygen and food into the body. Which system delivers oxygen and nutrients to cells?

3. **How have cephalization and segmentation led to the great diversity of animals?**

   Hint Remember how segmentation allowed the development of cephalization.

   Hint Refer to the chart of Body Plans and to the Cladogram of Animals to find examples of animals for your answer.

solve the CHAPTER MYSTERY

SLIME DAY AT THE BEACH

Although most people had never seen creatures like these before, biologists had no trouble identifying them. The slimy creatures were salps—descendants of the most ancient members of phylum Chordata. Salps belong to a group of chordates called tunicates. As adults, most tunicates live attached to rocks or the sea floor. Salps are different. The adults are free-swimming. They pump water in through their mouths and out the other end. This ability allows them to feed and move themselves through the water at the same time. Salps are usually found in tropical seas. They can be carried north by the Gulf Stream and are sometimes washed onto beaches by storms.

1. **Compare and Contrast** How are salps different from jellyfish?

UntamedScience™ **Never Stop Exploring Your World.**

Discovering what the slime was is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

25 CHECK Understanding

25.1 What Is an Animal?

Understand Key Concepts

1. Which of the following is a characteristic of all chordates but is not found in invertebrates?
   - **a.** a notochord
   - **b.** four legs
   - **c.** a circulatory system
   - **d.** a skeleton
2. Most animals reproduce
   - **a.** sexually by producing diploid gametes.
   - **b.** asexually by cloning.
   - **c.** sexually by producing haploid gametes.
   - **d.** asexually by fusion.

Think Critically

3. **Classify** What characteristic distinguishes vertebrates from nonvertebrate chordates?
4. **Compare and Contrast** How does the way vertebrates gets rid of carbon dioxide differ from the way they get rid of ammonia?

25.2 Animal Body Plans and Evolution

Understand Key Concepts

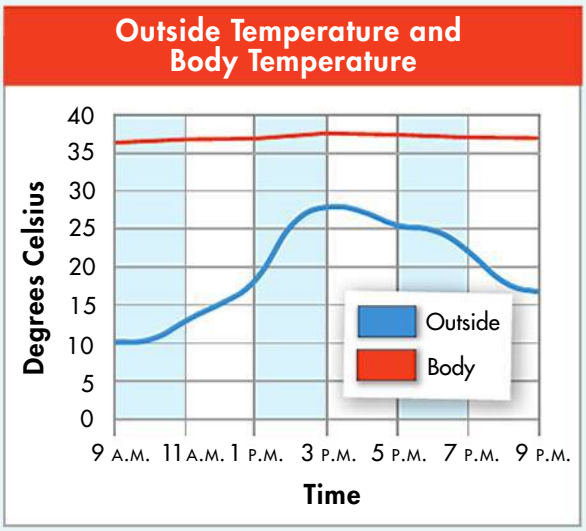
5. Cnidarians and echinoderms have symmetry that extends from a central point. This type of symmetry is called
   - **a.** radial.
   - **b.** bilateral.
   - **c.** circular.
   - **d.** dorsal.
6. An animal whose mouth is formed from the blastopore is a(n)
   - **a.** deuterostome.
   - **b.** endoderm.
   - **c.** protostome.
   - **d.** mesoderm.
7. List the three germ layers.
8. Name two body plan characteristics that are shared by all arthropods and chordates.

Think Critically

9. **Sequence** List the following developments in the order of their appearance during evolution: tissues, deuterostome development, multicellularity, segmentation.
10. **Apply Concepts** Explain how bilateral symmetry was an important development in the evolution of animals.
11. **Infer** Why is it inaccurate to state that the cladogram of animals shows the improvements in body plans that have occurred over time?

Connecting Concepts

Use the graph to answer questions 12–14.



12. **Interpret Graphs** At what time of day is the body temperature closest to that of the outside environment?
13. **Draw Conclusions** What is the relationship between human body temperature and the temperature of the environment?
14. **Infer** How do you explain the shape of the graph for human body temperature?

Standardized Test Prep

Multiple Choice

1. Which of the following is a type of tissue that arises in most animals during development?
A endoderm **C** ectoderm
B mesoderm **D** all of the above

2. Which of the following is NOT a characteristic of animals?
A the ability to make their own food
B the ability to move
C eukaryotic cells
D cells that lack cell walls

3. A hollow ball of cells formed after the zygote undergoes division is called a
A coelom. **C** deuterostome.
B protostome. **D** blastula.

4. Which trend did NOT occur during invertebrate evolution?
A specialization of cells
B development of a notochord
C bilateral symmetry
D cephalization

5. What is a function of the excretory system?
A to supply cells with oxygen and nutrients
B to rid the body of metabolic wastes
C to gather information from the environment
D to break down food

6. Animals often respond to information processed by their nervous system by moving around, using their
A circulatory system.
B excretory system.
C musculoskeletal system.
D digestive system.

7. The concentration of nerve tissue and organs in one end of the body is called
A cephalization.
B segmentation.
C body symmetry.
D nerve nets.

Questions 8 and 9

A biology student has two samples of earthworms in soil, as shown below. The student knows that, because the worms' body temperature changes with the environment, the worms in Sample A have a higher body temperature than those in Sample B. The student uses a stereomicroscope to count the number of heartbeats per minute for three worms from each sample.

Sample A: At temperature of worms' soil environment

Sample B: In ice water

8. Look at the student's two samples. What can you conclude?
A Sample A is the control.
B Sample B is the control.
C Either sample can serve as a control.
D This is not a controlled experiment.

9. The student finds that the worms from Sample A have a faster heart rate than the worms from Sample B. What hypothesis might you form based on this observation?
A The worms in Sample A are healthier than the worms in Sample B.
B A decrease in body temperature corresponds to an increase in heart rate.
C There is no relationship between body temperature and heart rate.
D A decrease in body temperature corresponds to a decrease in heart rate.

Open-Ended Response

10. What characteristics distinguish invertebrates from nonvertebrate chordates?

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10
See Lesson	25.2	25.1	25.2	25.2	25.1	25.1	25.2	25.1	25.1	25.1

26 Animal Evolution and Diversity

Big idea

Evolution

Q: How have animals descended from earlier forms through the process of evolution?

This skeleton of a gopher snake gives clues about how it is related to other vertebrates.

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INSIDE:

- **26.1 Invertebrate Evolution and Diversity**
- **26.2 Chordate Evolution and Diversity**
- **26.3 Primate Evolution**

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

FOSSIL QUEST

To Josh and Pedro, fossil hunting sounded like a great summer trip. But where should they go? Their parents said they must stay within the United States. Josh wanted to search for the very first animals. Pedro wanted to look for the ancestors of birds. Where could they find these fossils? Were any good sites close enough to keep their parents from worrying?

They realized that they needed to know when the animals they were searching for lived. Then, they needed to figure out where they could find rocks of the right ages. As you read this chapter, look for clues to the geologic time periods when the first animals and birds lived. Also look for clues about where the boys might find their fossils. Then, solve the mystery.

Read for Mystery Clues As you read this chapter, look for clues to help you discover where Josh and Pedro's "Fossil Quest" will take them. Then, solve the mystery at the end of the chapter.

FOUNDATIONS for Learning

Cladograms show the relationships among living things. Before you read the chapter, get three sheets of blank paper and three index cards. As you read each lesson, copy each cladogram from the book onto a sheet of paper. Then choose three animals mentioned in the chapter. Draw a picture of each animal and describe it. At the end of the chapter are two activities that use the cards and sheets of paper. They will help you answer the question: How have animals descended from earlier forms through the process of evolution?

26.1 Invertebrate Evolution and Diversity

Key Questions

When did the first animals evolve?

What does the cladogram of invertebrates illustrate?

BUILD Understanding

Preview Visuals Before you read, preview the cladogram of invertebrates on p. 626. Write down any questions you have about it. As you read, write answers to your questions.

In Your Workbook Go to your workbook to learn more about how to preview visuals. Complete the Preview Visuals activity for Lesson 26.1.

For more on the diversity of animals, go to the Visual Guide.
pp. DOL 30–64

Origins of the Invertebrates

The origins of the first animals are a great mystery. Fossils show that a huge number of animals first appeared between 530 and 515 million years ago. This period is called the "Cambrian Explosion." How did so many kinds of animals evolve so quickly? What simpler forms did they come from?

The first living things were single celled. For 3 billion years, all living things were single celled. Multicellular animals may have evolved from ancestors like choanoflagellates (koh AN uh FLAJ uh layts). These single-celled eukaryotes sometimes grow in groups. In many ways they are like sponges, the simplest animals.

Traces of Early Animals The first animals were tiny and had soft bodies. Soft bodies do not form fossils as well as hard body parts. Some early fossils come from sponges and animals like jellyfish. Scientists have also found trace fossils of tracks and burrows made by animals long ago. Such clues show that the first animals may have begun evolving 600 million years ago.

The Ediacaran Animals Some of the most exciting fossils of animals that lived before the Cambrian Period come from the Ediacara Hills of Australia. These strange fossils are about 565 to about 544 million years old. They show animals with body plans that are different from those of anything alive today. These animals had little cell or tissue specialization, and no organization into a front and back end. Some may have had algae living within their bodies. Others were segmented and had bilateral symmetry. Some seem to be related to jellyfishes and worms. Many were flat and lived on the bottom of shallow seas.

Fossil Clues Tiny fossils such as this 565-million-year-old embryo are rare and valuable finds (SEM 100×).

The Cambrian Explosion The Cambrian Period began about 542 million years ago. Many fossils of animals from this time can be found in China and Canada. These fossils show that over a period of 10 to 15 million years, animals evolved complex body plans. They had specialized cells, tissues, and organs. Many had body symmetry, segmentation, and a front end and a back end. Many had **appendages,** or parts such as legs or antennae that come out from the body. Some Cambrian animals had shells, skeletons, and other hard body parts. Animals with hard body parts are more likely to leave fossils than animals with soft bodies.

A number of Cambrian fossils are ancient members of modern invertebrate phyla. For example, *Marrella*, shown below, was an arthropod. Other Cambrian fossils come from strange groups that are now extinct. By the end of the Cambrian Period, all the basic animal body plans had evolved. Later evolutionary changes would form the structures of the animals we know today.

Modern Invertebrate Diversity Today, invertebrates are the most common animals on Earth. They live in nearly every ecosystem and are part of nearly every food web. There are far more invertebrates than so-called "higher animals," such as reptiles and mammals.

Key Question When did the first animals evolve?
Fossil evidence shows that the first animals began evolving long before the Cambrian Explosion.

Cladogram of Invertebrates

How are the groups of invertebrates related? On the top of the next page is a cladogram of invertebrates. It shows how scientists think that the major groups of living invertebrates are related to each other. It also shows the order in which some important features came about. Many of these features, such as tissues, first came about in the Cambrian animals.

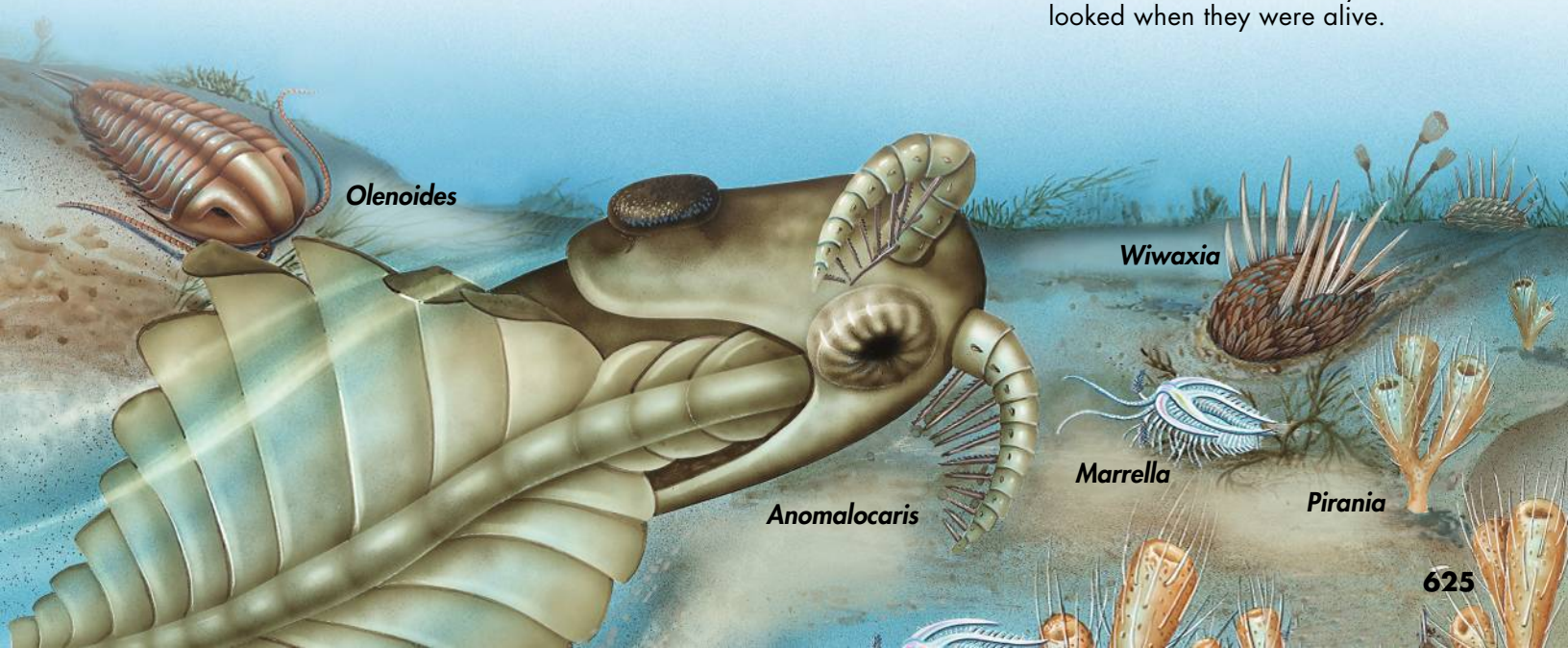
BUILD Vocabulary

appendage
a structure, such as a leg or antenna, that extends from the body wall

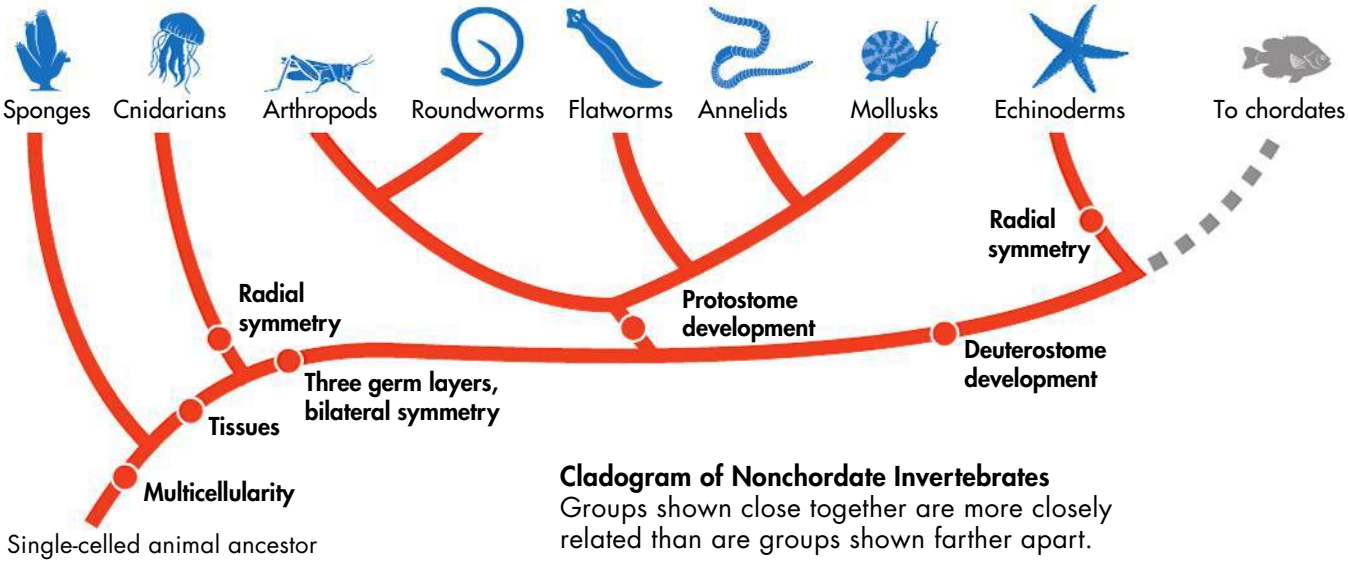
larva
the immature stage of an organism

MULTIPLE MEANINGS

The word *append* means to "attach" or "add on." In everyday speech, an appendage is something that is added onto or attached to something larger. In biology, an appendage is a small part that is attached to a larger body.



Cambrian Animals The Burgess Shale in Canada contains fossils of animals from the Cambrian Period. This picture shows how some of those animals may have looked when they were alive.



Cladogram of Nonchordate Invertebrates
Groups shown close together are more closely related than are groups shown farther apart.

Key Question What does the cladogram of invertebrates illustrate? **The cladogram shows current hypotheses about the evolutionary relationships of major groups of modern invertebrates. It also shows the order in which some important features evolved.**

▶ ***Sponges*** Sponges are members of the phylum Porifera (por IHF er uh). These animals have pores, or tiny openings, all over their bodies. With few specialized cells, sponges are some of the simplest animals. But like all animals, sponges are multicellular heterotrophs that do not have cell walls. p. DOL 31

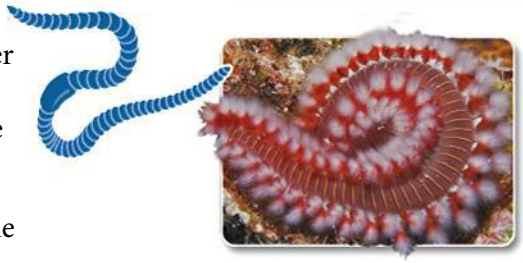
▶ ***Cnidarians*** Jellyfishes, sea fans, sea anemones, hydras, and corals are in the phylum Cnidaria (ny DAYR ee uh). Cnidarians live in water. They have soft bodies, specialized tissues, and radial symmetry. They are carnivores that use rings of stinging tentacles around their mouths to capture prey. Some cnidarians live alone. Others live in groups called colonies. pp. DOL 32–33

▶ ***Arthropods*** Spiders, centipedes, insects, and crabs are members of the phylum Arthropoda (ahr THRAHP oh duh). Arthropods have bodies that are divided into segments and covered in a hard outer skeleton, or exoskeleton. Their appendages have joints. They also have cephalization. They live in oceans, fresh water, on land, and in the air. More than a million species have been identified. That is more than three times the number of all other animal species on Earth! pp. DOL 34–37

▶ ***Nematodes (Roundworms)*** Members of the phylum Nematoda are roundworms. They are unsegmented worms with bodies that have a pseudocoelom, a body space with tissue that loosely holds organs in place. Their digestive tracts have two openings—a mouth and an anus. Some live in soil or water. Others are parasites that live in plants or animals. p. DOL 38

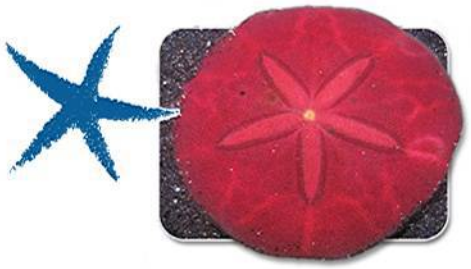
▶ ***Flatworms*** Flatworms are in the phylum Platyhelminthes (plat ih hel MIN theez). These soft, unsegmented worms have tissues and organ systems. They have bilateral symmetry and cephalization. They do not have coeloms. Most of these worms are only a few millimeters thick. p. DOL 39

▶ ***Annelids*** Earthworms are members of the phylum Annelida (un NEL ih duh). So are leeches and some other worms that live in the ocean. Annelids have segmented bodies that look like stacks of little rings. They also have coeloms. pp. DOL 40–41



▶ ***Mollusks*** Snails, slugs, clams, and octopi belong to the phylum Mollusca. Most mollusks have soft bodies with an inner or outer shell. They have coeloms and complex organ systems. The **larva** (plural: larvae), or young stage, of a mollusk is called a trochophore (TRAHK oh fawr). Trochophores can swim through the water. (Many annelids also have trochophore larvae. These similar larvae show that annelids and mollusks are closely related.) pp. DOL 42–43

▶ ***Echinoderms*** Sea stars, sea urchins, and sand dollars are in the phylum Echinodermata (ee KY noh durm aht uh). Most adult echinoderms have five-part radial symmetry. Echinoderms have a spiny skin stretched over a hard inner skeleton. They also have a water vascular system—a group of water-filled tubes that end in tube feet. They use their tube feet for walking and for holding food. Like chordates, echinoderms are deuterostomes. pp. DOL 44–45



CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The young stage of some animals is called a _____.

2. Legs, arms, and antennae are kinds of _____.

Critical Thinking

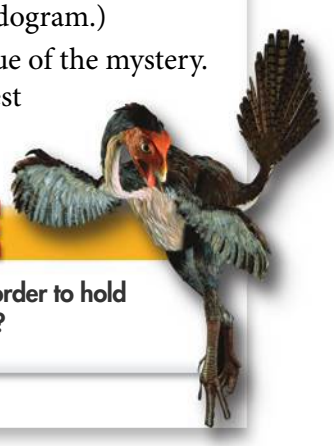
3. Describe What was the Cambrian Explosion?

4. Relate Cause and Effect Why is it rare to find fossils of animals from before the Cambrian Period? What about these animals makes it rare for them to form fossils?

5. Interpret Diagrams Look at the cladogram of invertebrates. Which group is more closely related to echinoderms: mollusks or chordates? How can you tell?

6. Sequence Which feature of echinoderm ancestors evolved first—radial symmetry or deuterostome development? (**Hint:** Study the cladogram.)

7. Write to Learn Answer the first clue of the mystery. In your answer, tell when the earliest known animals are thought to have lived.



MYSTERY CLUE

How old would rocks need to be in order to hold fossils of the earliest known animals? (Hint: See p. 624.)

BIOLOGY.com Search Lesson 26.1 GO • Lesson Assessment

26.2 Chordate Evolution and Diversity

Key Questions

What are the most ancient chordates?

What can we learn by studying the cladogram of chordates?

BUILD Understanding

Venn Diagram Create a Venn diagram that shows how nonvertebrate chordates and vertebrates are alike and different.

In Your Workbook Go to your workbook to learn more about making a Venn diagram. Complete the Venn diagram for Lesson 26.2.

Origins of the Chordates

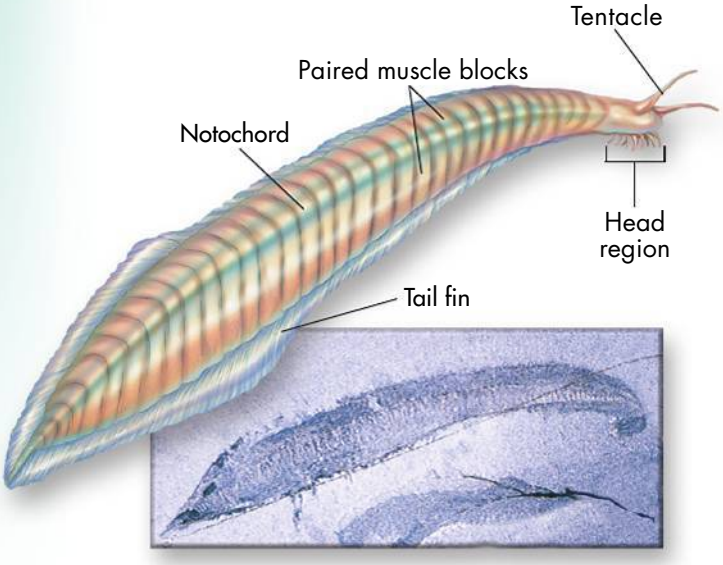
Chordates are the animals we know best. Why? For one thing, they are large and easy to see. Some we keep as pets. Others we eat. Where did they all come from? What were the first chordates like?

The Earliest Chordates Studies of embryos suggest that the earliest chordates were related to the ancestors of echinoderms. The oldest known fossil of a chordate is *Pikaia* (pih KAY uh). When *Pikaia* was first found, scientists thought it was a worm. But it had a notochord and blocks of muscles that formed a pattern like that of simple modern chordates.

Another fossil called *Myllokunmingia* (MY loh kuhn min jee uh) is the earliest known vertebrate. It had muscles that form a pattern. It also had traces of fins and gills, and a head with sense organs. Its skull and skeleton were likely made of cartilage. **Cartilage** is a strong connective tissue that is softer than bone. It holds up many parts of a vertebrate's body. (Cartilage gives your ears their shape.)

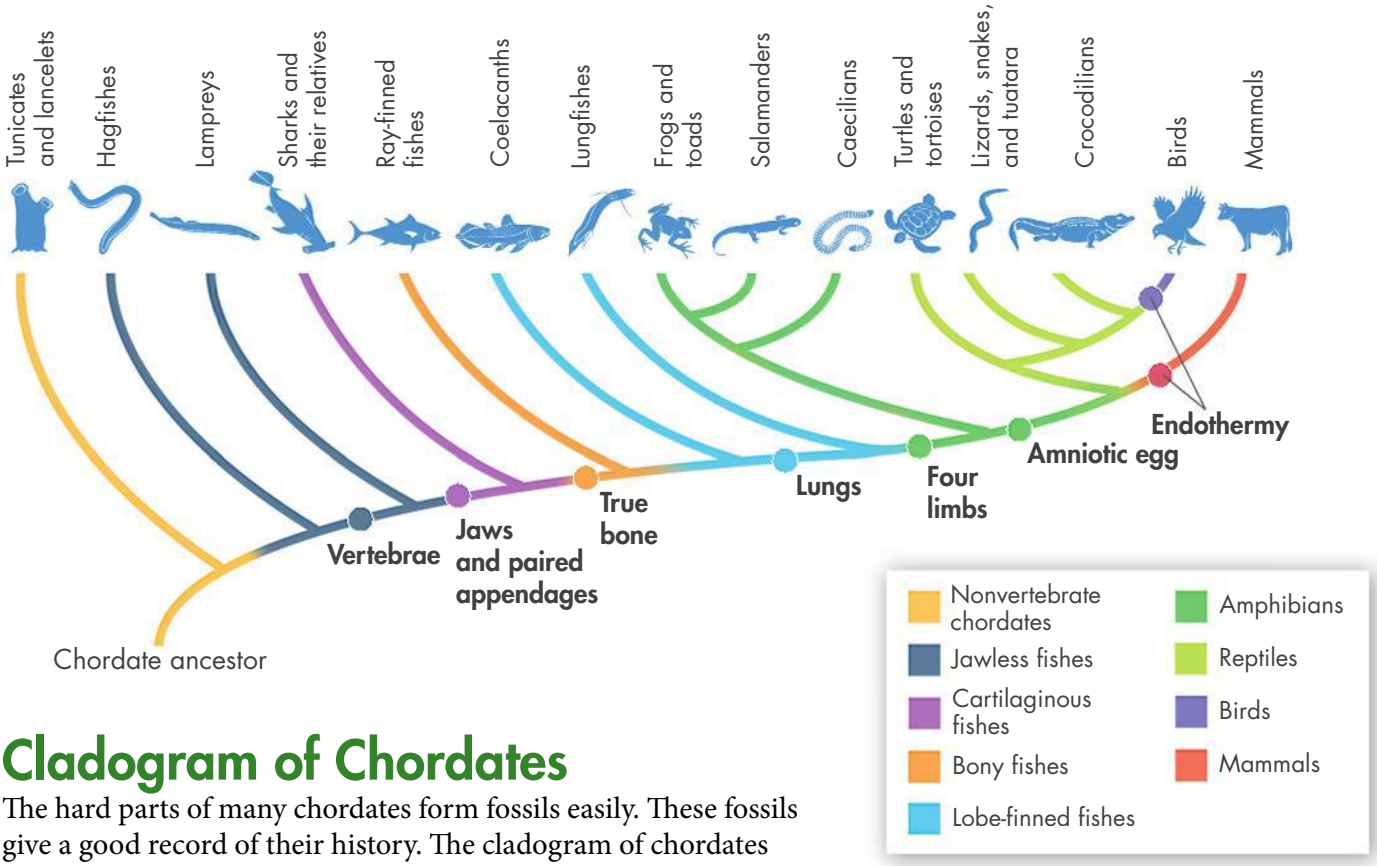
Modern Chordate Diversity Today there are six groups of chordates. These are the nonvertebrate chordates and the five groups of vertebrates—fishes, amphibians, reptiles, birds, and mammals. Of these, fishes are the largest group. Today's chordate species are only a small part of the total number that have ever lived on Earth. pp. DOL 46–64

Key Question What are the most ancient chordates? **Studies of embryos show that the most ancient chordates were related to the ancestors of echinoderms.**



***Pikaia*, an Early Chordate**
Pikaia is the oldest known chordate.

Cladogram of Chordates Chordates include both vertebrates and nonvertebrates. All of the groups shown on the cladogram share a common invertebrate ancestor. The circles show the evolution of some important adaptations.



Cladogram of Chordates

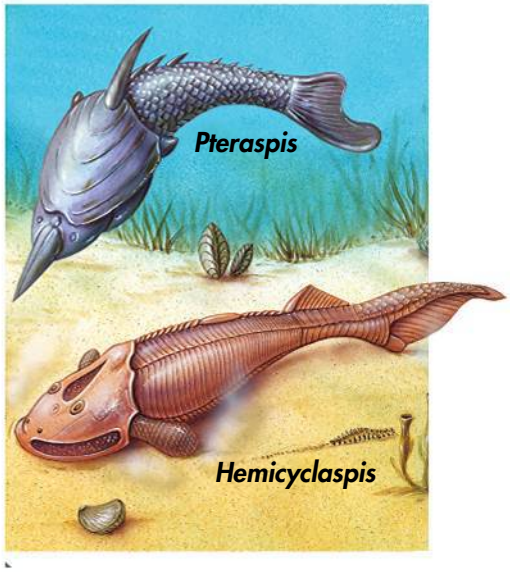
The hard parts of many chordates form fossils easily. These fossils give a good record of their history. The cladogram of chordates above shows how scientists think the different groups are related. It also shows when features, such as jaws and limbs, came about.

Nonvertebrate Chordates Two groups of chordates do not have backbones. These nonvertebrate chordates are the tunicates and lancelets. Fossils show that their ancestors branched off from vertebrates more than 550 million years ago. Adult tunicates look more like sponges than humans. They do not have a notochord or a tail. But their larvae have all the key features of chordates. Lancelets look like small eels. They live on the sandy ocean bottom. pp. DOL 46–47

Jawless Fishes The earliest fishes evolved during the late Cambrian Period, about 510 million years ago. These odd-looking animals did not have true jaws or teeth. Their skeletons were made of cartilage. In the Devonian Period, jawless fishes ruled the seas. For this reason, this time is called the Age of Fishes. Some armored jawless fishes, such as those shown at right, became extinct about 360 million years ago. Other kinds of jawless fishes gave rise to modern jawless fishes: lampreys and hagfishes. p. DOL 49

Neither lampreys nor hagfishes have backbones. However, they do have notochords. As larvae, lampreys filter their food from water. As adults, they are parasites. Hagfishes look like big pink worms. They make slime, which helps them slip away from enemies. They can even tie their own bodies into knots!

Jawless Fishes of the Devonian These armored fishes did not have jaws. Their paired fins helped them swim.



Jaws *Dunkleosteus* lived 360 million years ago. Its jaws were so powerful that it could have bitten a modern shark in half!

Sharks and Their Relatives Other early fishes evolved a very useful adaptation for feeding: jaws. Jaws hold teeth and muscles. These parts make it possible to bite and chew.

Early fishes also evolved two pairs of fins, one pair toward the front of the body and one pair toward the back. Paired fins help fishes control their body movements. Tail fins and powerful muscles let them swim quickly.

These adaptations gave rise to the adaptive radiation of the Chondrichthyes (kahn DRIK theez): the sharks, rays, and skates. These animals have skeletons made of cartilage. Some, such as the great white shark, eat meat. Others, such as the manta ray, eat plankton. p. DOL 50

Bony Fishes Another group of early fishes evolved skeletons made of bone. This adaptation set in motion the adaptive radiation of the class Osteichthyes (ahs tee IK theez), which includes the bony fishes. p. DOL 51

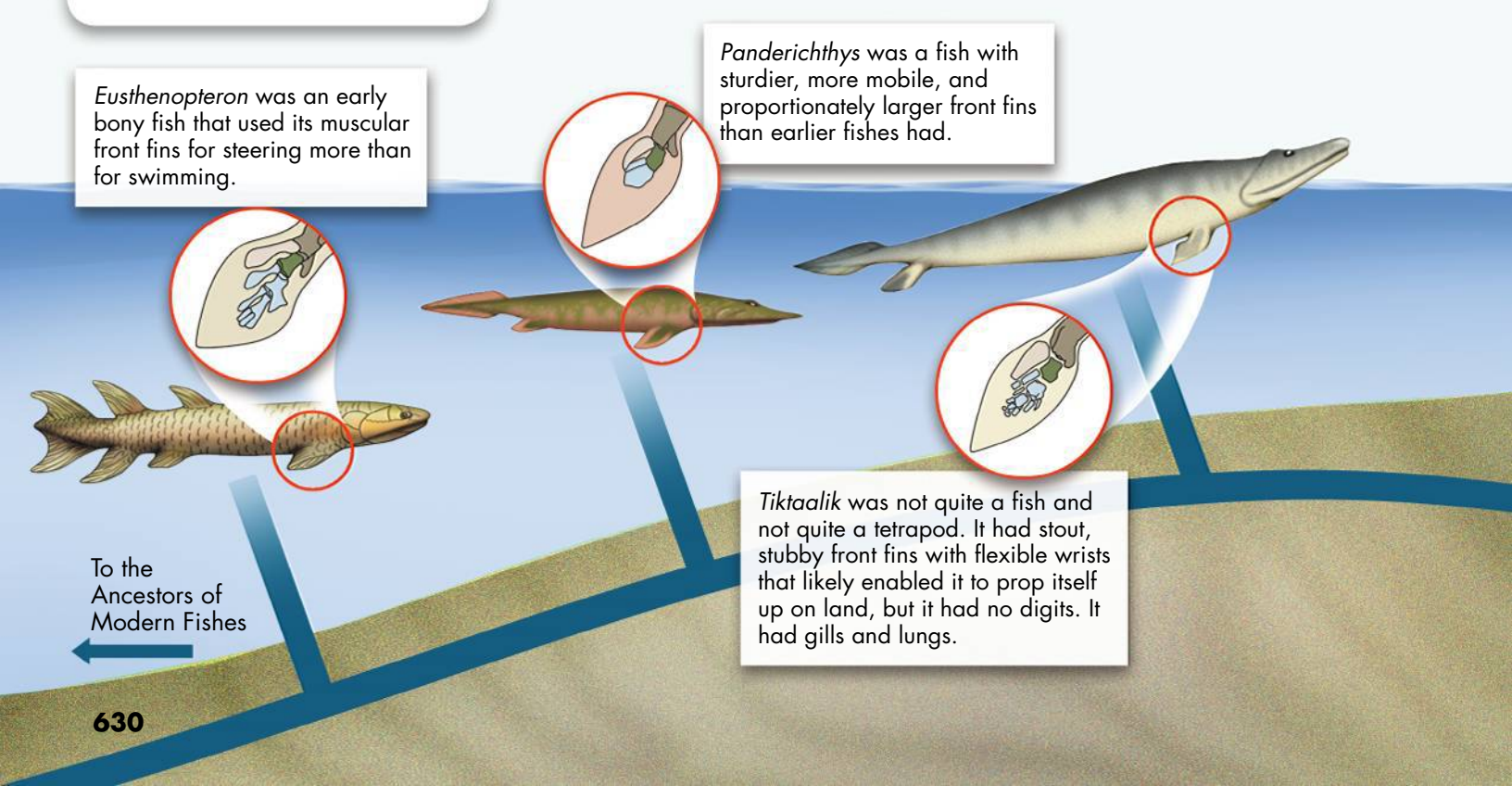
▶ ***Ray-Finned Fishes*** Most fishes you know of, such as eels, catfish, and goldfish, are ray-finned fishes. Ray-finned fishes have skeletons made of bone. The name "ray-finned" describes the thin bones that hold up the skin in their fins. Most bony fishes also have fins, scales, and gills.

▶ ***Lobe-Finned Fishes*** Another group of bony fishes are the lobe-finned fishes. They evolved larger bones that support thick, fleshy fins. Modern lobe-finned fishes include lungfishes and coelacanths (SEE luh kanths). One ancient group of lobe-finned fishes gave rise to the four-limbed vertebrates, or **tetrapods.**

BUILD Connections

FROM FINS TO FEET

The feet of tetrapods evolved from the fins of ancient bony fish. This cladogram shows some animals in this line of evolution. All of the animals in the art are extinct.



Amphibians Frogs and toads are amphibians. The word *amphibian* means "double life." As larvae, these animals live in water. As adults, they can live on land. Most adults have lungs and can breathe air. But most amphibians need water to reproduce. Amphibians have moist skin. They do not have scales or claws. pp. DOL 52–53

▶ ***The "Fishapod"*** Adaptations for life on land evolved slowly, over millions of years. Some groups of lobe-finned fishes evolved sturdy fins. Over time, some of these appendages evolved features that looked like the limbs of tetrapods. Many fossils, discovered over many years, document these changes. Recently, scientists have discovered several fossils that show clearly how lobed fins evolved into front and hind limbs. One such fossil is *Tiktaalik*. This animal had a mix of fish and tetrapod features in many of its body parts. It had gills and could swim underwater. It also had lungs and could crawl on land. Many call it a "fishapod"—part fish, part tetrapod. It shows a clear middle stage between fishes and tetrapods.

▶ ***Adaptations to Life on Land*** To live on land, animals need more than legs. Early amphibians also evolved ways to breathe air and to protect themselves from drying out. With these adaptations, amphibians became the main vertebrates of the warm and wet Carboniferous Period, which lasted from 359 to 300 million years ago.

Their success did not last. Climate changes caused many swamps to dry up. Most amphibians became extinct by the end of the Permian Period, about 250 million years ago. Today, only three orders of amphibians survive—frogs and toads, salamanders, and caecilians (see SIL ee unz).

BUILD Vocabulary

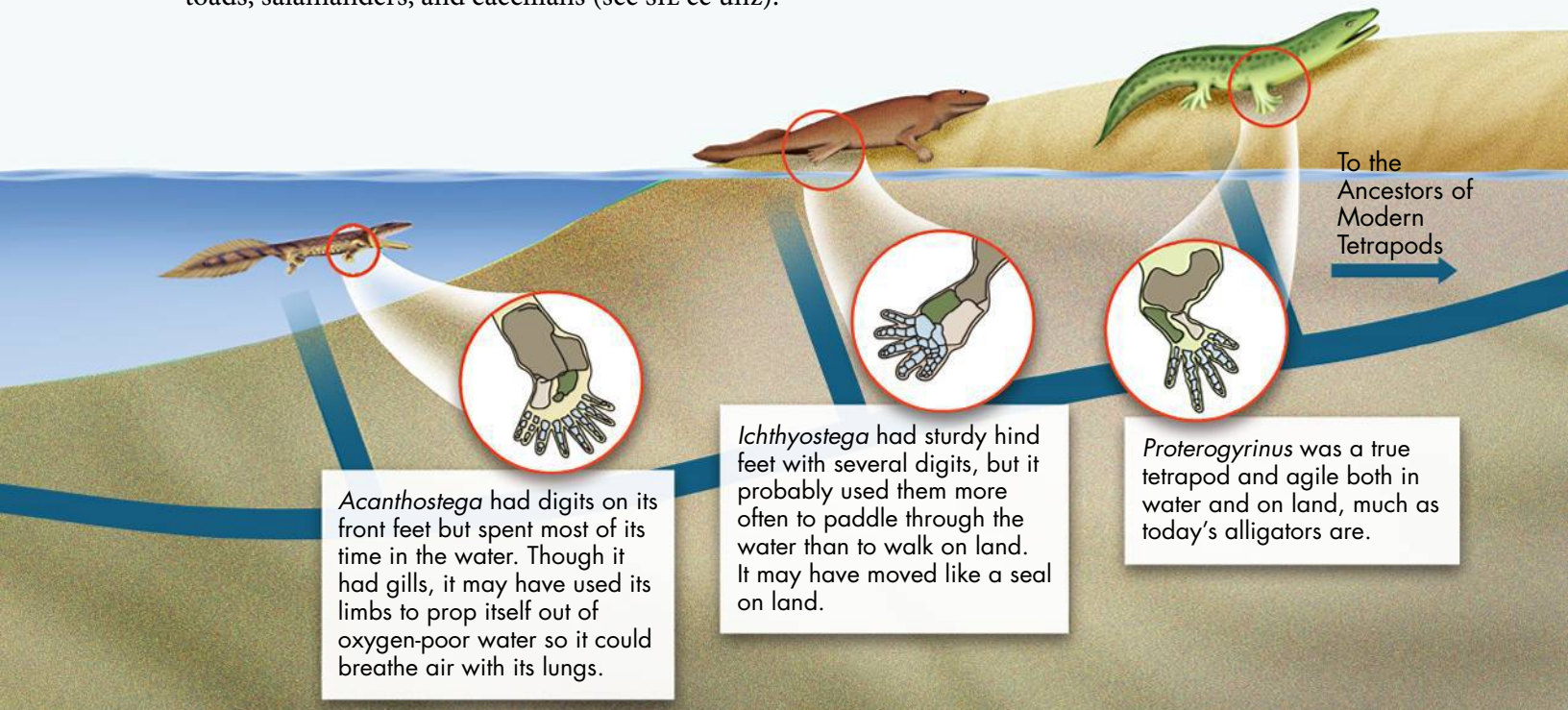
cartilage
a type of connective tissue that supports the body and is softer and more flexible than bone

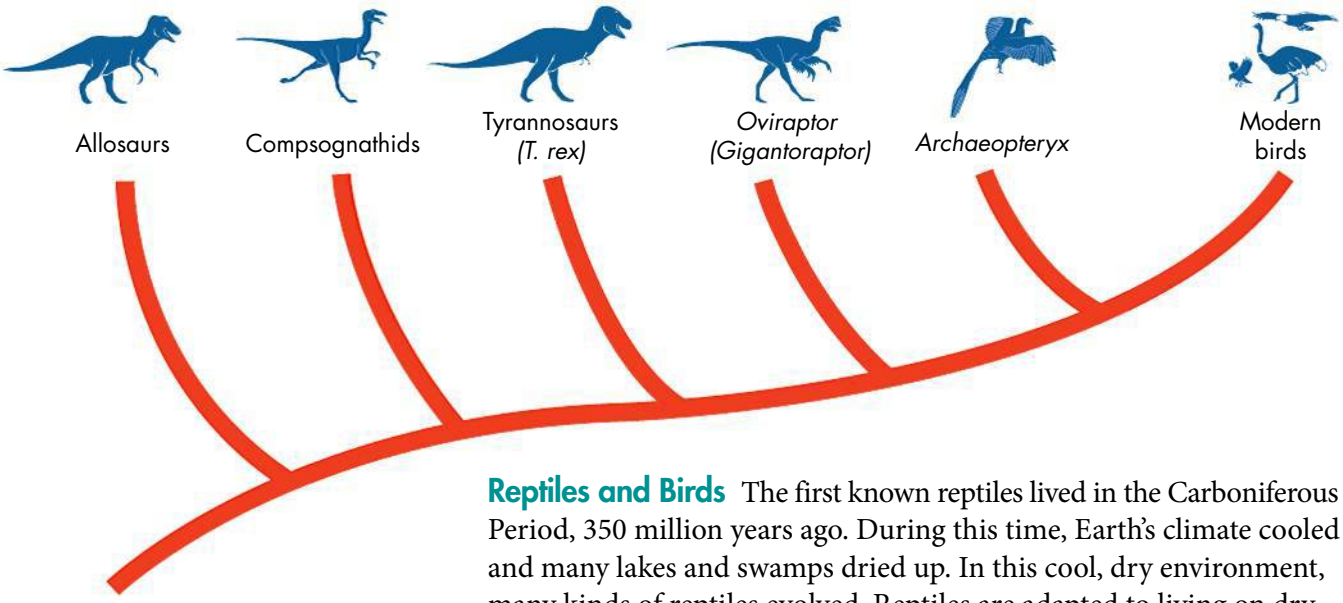
tetrapod
a vertebrate with four limbs

WORD ORIGINS

The word *tetrapod* comes from the Greek words *tetra*, meaning "four," and *pod*, meaning "foot."

***Tiktaalik*, the Fishapod** This 375-million-year-old fossil of *Tiktaalik* was found in Canada. Like a fish, it had gills. Like a tetrapod, it had lungs and fins with wrist bones.





Evolution of Birds and Reptiles The cladogram shows current hypotheses about the relationship between living and extinct reptiles. None of the groups shown are direct ancestors of modern reptiles or modern birds.

Reptiles and Birds The first known reptiles lived in the Carboniferous Period, 350 million years ago. During this time, Earth's climate cooled and many lakes and swamps dried up. In this cool, dry environment, many kinds of reptiles evolved. Reptiles are adapted to living on dry land. They have scaly skin, well-formed lungs, and strong legs. Their eggs have shells and membranes that keep them from drying out. There are four groups of reptiles living today: lizards and snakes, crocodiles, turtles and tortoises, and the tuatara. pp. DOL 54–55

▶ ***Dinosaurs*** During the Triassic and Jurassic periods reptiles called dinosaurs lived all over the world. Some were small. Others were enormous. Some ate leafy plants. Others were carnivorous. Some dinosaurs even had feathers. The first birdlike fossils to be discovered came from the end of the Jurassic Period, about 150 million years ago. Fossils show that one group of feathered dinosaurs included the ancestors of modern birds.

INQUIRY into Scientific Thinking

Feather Evolution

The information in the table shows the kinds of feathers that were found in some groups of dinosaurs that lived before birds.

Group (listed alphabetically)	Feather Status
Allosaurs	None
Archaeopteryx	Flight feathers
Compsognathids	Hairlike feathers
Oviraptors	True feathers
Tyrannosaurs	Branched feathers

Analyze and Conclude

1. **Organize Data** Copy the cladogram of the Evolution of Reptiles and Birds into your notebook. Then review the information about drawing cladograms in Chapter 18.

2. **Infer** Draw circles on the cladogram to show when different kinds of feathers evolved.

3. **Draw Conclusions** Which type of feathers would you expect modern birds to have?

In Your Workbook Get more help for this activity in your workbook.

▶ ***Mass Extinction*** At the end of the Cretaceous Period, about 66 million years ago, a mass extinction took place. Scientists hypothesize that it was caused by natural disasters, including volcanic eruptions and a fall in sea level. A huge asteroid smashing into Earth probably caused forest fires and dust clouds. After these events, dinosaurs and many other living things became extinct.

▶ ***Birds*** Modern birds make up the class Aves. Birds can keep their bodies warm when it is cold. Birds have feathers and strong, yet light bones. Their two legs are covered with scales and their front limbs are wings. pp. DOL 56–59

Mammals Members of the class Mammalia are mammals. They can be as small as mice or as large as whales. Mammals are covered in hair. They also breathe air, have four-chambered hearts, and are able to keep warm in cold weather. The mothers feed their young with milk from their mammary glands. Most mammals bear live young that have developed in the mother's body. pp. DOL 60–64

Mammals first evolved during the late Triassic Period, about 220 million years ago. They were very small and looked like tree shrews. While dinosaurs ruled, mammals were small. They were active mostly at night. After the great dinosaur extinction, about 65 million years ago, mammals began to get bigger and live in many different places. The Cenozoic Era is also called the Age of Mammals.

Key Question What can we learn by studying the cladogram of chordates? **The cladogram of chordates shows how chordate groups are related and the points at which different features evolved.**

***Archaeopteryx*, an Early Bird** This fossil comes from the late Jurassic Period, about 150 million years ago. *Archaeopteryx* (ahr kee AHP tur iks) was a small, running dinosaur that had feathers. The drawing shows how *Archaeopteryx* may have looked.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. _____ is a strong, flexible tissue that supports chordate muscles and body parts.
2. Animals that have four appendages are called _____.

Critical Thinking

3. **Review** Name the group of animals whose ancestors were related to the earliest chordates.
4. **Compare and Contrast** What are two ways that bony fishes differ from ancient jawless fishes?
5. **Compare and Contrast** How do nonvertebrate chordates differ from other chordates?
6. **Relate Cause and Effect** How could the climate changes of the Permian Period have caused many kinds of amphibians to become extinct?
7. **Write to Learn** Answer the second clue of the mystery.

MYSTERY CLUE

How old would rocks need to be in order to contain fossils of the ancestors of birds? (Hint: See p. 632.)

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26.3 Primate Evolution

Key Questions

- ***What characteristics do all primates share?***
- ***What are the major evolutionary groups of primates?***
- ***What adaptations enabled later hominines to walk upright?***
- ***What is the current scientific thinking about the genus* Homo?**

BUILD Understanding

T-Chart Before you read Lesson 3, make a T-chart that lists the main topics (green headings) in the left column. As you read, write details for each topic in the right column.

In Your Workbook Go to your workbook to learn more about making a T-chart.

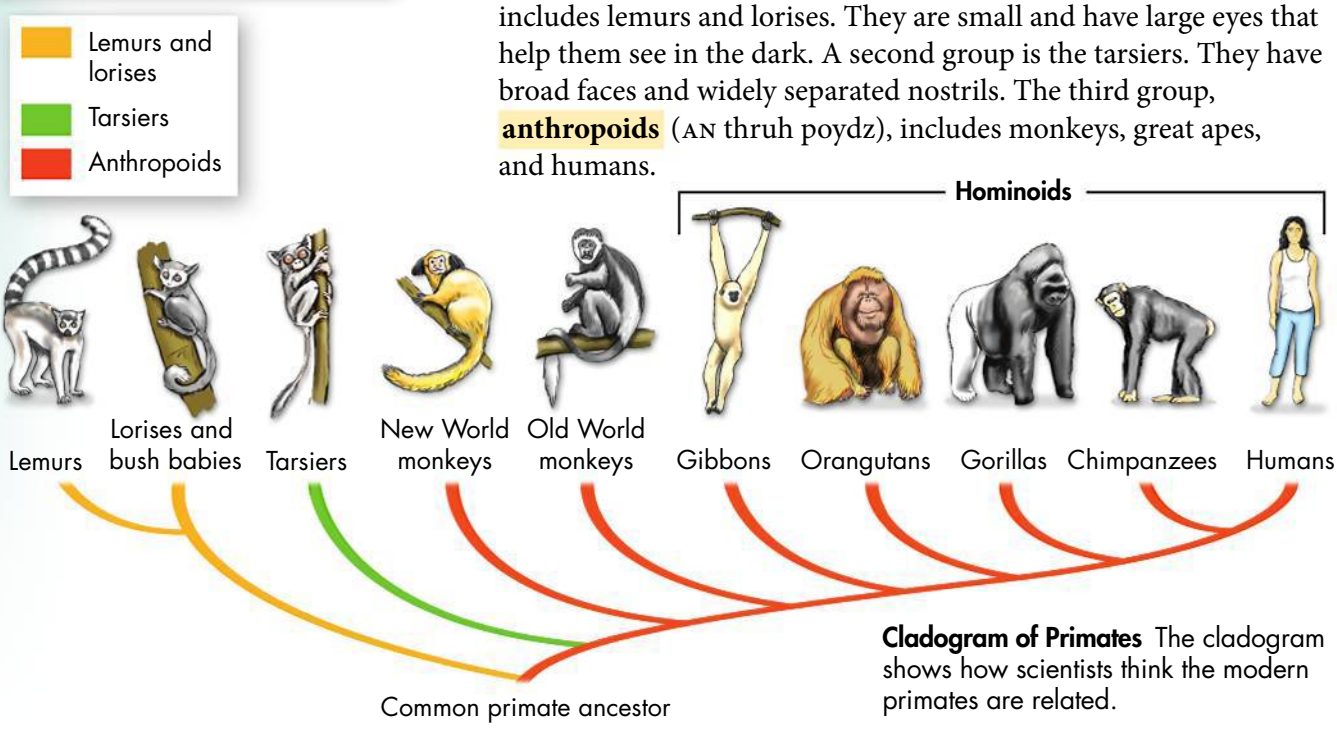
What Is a Primate?

Lemurs, monkeys, great apes, and humans are primates. All primates have evolved adaptations useful for life in trees. Primates have long fingers and toes that can curl around things and hold them tightly. Most primates have thumbs and big toes that can open and close against the other fingers like a hinge. All of us have nails instead of claws, and arms that can rotate at the shoulder. Primates also have a strong collar bone (clavicle) that helps tree-dwelling species to swing from branch to branch. Eyes on the front of our faces give us **binocular vision,** the ability to combine what we see with two eyes into one image that has depth. Finally, all primates have a well-developed cerebrum, or "thinking" part of the brain. p. DOL 64

Key Question What characteristics do all primates share?
Primates have long fingers and toes, nails, arms that rotate at the shoulder, strong clavicles, binocular vision, and large cerebrums.

Evolution of Primates

The ancestors of modern primates lived more than 65 million years ago. Today there are three major groups of primates. One group includes lemurs and lorises. They are small and have large eyes that help them see in the dark. A second group is the tarsiers. They have broad faces and widely separated nostrils. The third group, **anthropoids** (AN thruh poydz), includes monkeys, great apes, and humans.



Cladogram of Primates The cladogram shows how scientists think the modern primates are related.

When the continents separated 45 million years ago, anthropoids were split into two groups. New World monkeys live in Central and South America and they have prehensile tails. A **prehensile tail** can wrap around a branch and hold on like an extra hand.

The other group of anthropoids are the Old World monkeys and great apes. They live in Africa and Asia. Old World monkeys climb trees. But they do not have prehensile tails. Great apes include gibbons, orangutans, gorillas, chimpanzees, and humans. Great apes are also called hominoids.

Key Question What are the major evolutionary groups of primates? **The three major groups of primates are the lemurs and lorises, the tarsiers, and the anthropoids.**

BUILD Vocabulary

binocular vision the ability to merge visual images from both eyes, giving depth perception and a three-dimensional view of the world

anthropoid the primate group made up of monkeys, apes, and humans

prehensile tail a long tail that can coil tightly around a branch

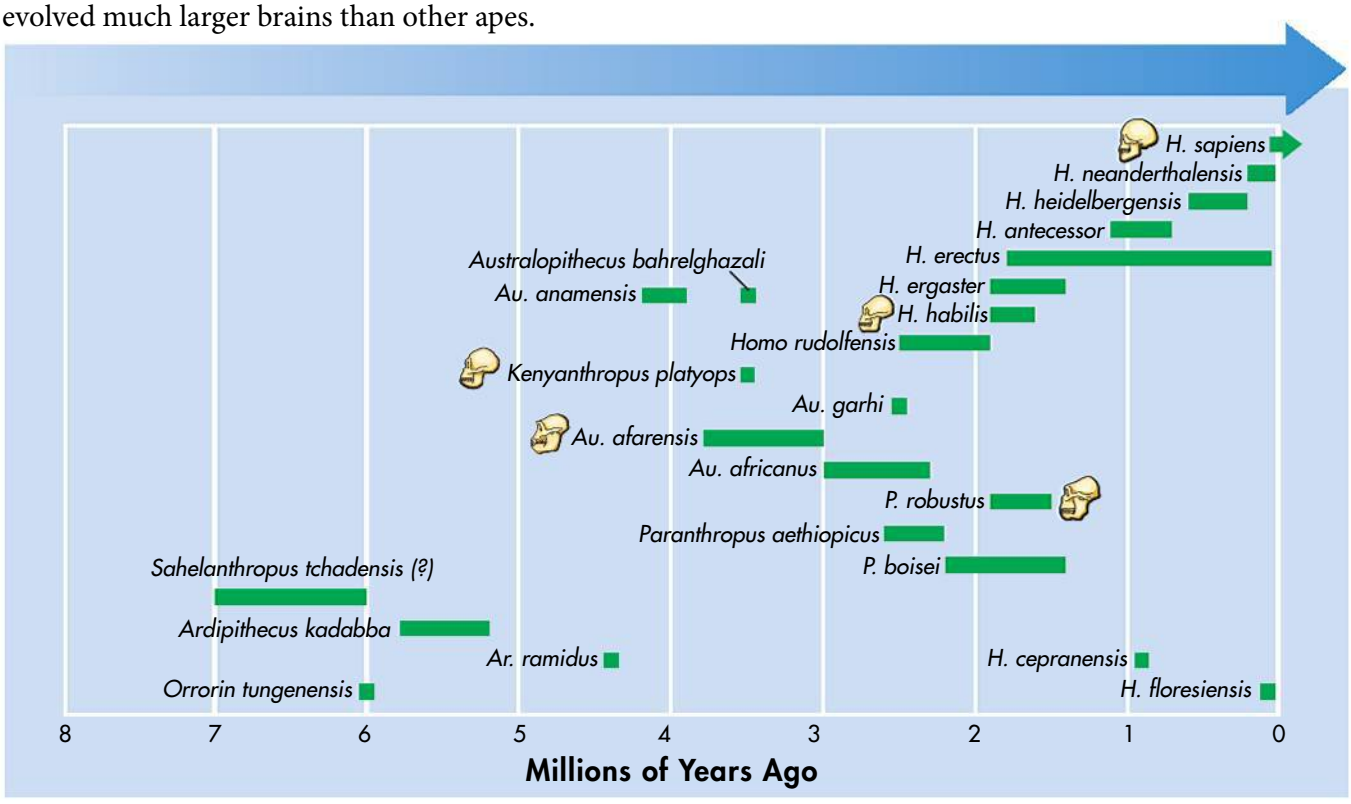
opposable thumb a thumb that allows the hand to grasp objects and use tools

Hominine Evolution

The study of human ancestors and other primates shows that chimpanzees are our closest living relatives. Recent fossil discoveries show that the evolutionary lines that led to humans split from the lines that led to chimpanzees around 6 or 7 million years ago. DNA studies agree with fossil evidence about the time these lines split.

All hominoids in the line that led to humans are called hominines. The fossils of early hominines show changes in the slope of the skull, neck, spine, hip bones, and leg bones. These changes in shape let later species walk upright. Animals that walk on two feet are said to be bipedal. Standing and walking upright left the hands free for using tools. Each hand had an **opposable thumb** that could touch the tips of the fingers. This thumb made it easier to use tools. Hominines also evolved much larger brains than other apes.

Time Line This time line shows hominine fossils and the time range during which each species probably lived. These time ranges may change as paleontologists gather new data. Right now, there are several different hypotheses about how these species are related. That's why we present these data as a time line, rather than as a cladogram.



Lucy "Lucy" is the nickname of a fossil of *A. afarensis* that was discovered in Ethiopia. Lucy's skeleton was not complete. The bones that were found are dark blue.

Hominine Relationships Researchers have found fossils of at least 20 species of hominines. All these species are relatives of modern humans. But not all of them are human ancestors. What's the difference? Think of your family. Your relatives may include aunts, uncles, cousins, parents, grandparents, and great grandparents. But only your parents, grandparents, and great grandparents are your ancestors.

It isn't easy to figure out which hominines are human ancestors and which are just distant relatives. It is now clear that there have been several hominine adaptive radiations. Each of these radiations produced several species. These species are shown in the time line on p. 635. From fossils alone, it is hard to tell how some of these species are related to each other and to humans.

Fossils of Hominines Fossils tell how early hominines looked and lived. *Australopithecus afarensis* lived from about 4 million to 2.5 million years ago. A skeleton of *A. afarensis* called "Lucy" stood about 1 meter tall. One set of trace fossils is thought to be of *Australopithecus* footprints. These footprints show that the ability to walk upright evolved long before large brains.

Key Question What adaptations enabled later hominine species to walk upright? **The skull, neck, spine, hip bones, and leg bones of early hominines changed shape in ways that let later species walk upright.**

The Road to Modern Humans

About 2 million years ago in Africa, a new group of hominines arose. Scientists classify these species in the genus *Homo*. One set of fossils was found with tools made of stone and bone. It was named *Homo habilis* (HAB ih lus), which means "handy man." Another species, *Homo ergaster*, was larger than *H. habilis*. It had a bigger brain and a nose that was more like that of modern humans.

Out of Africa Fossils show that relatives and ancestors of modern humans left Africa in waves. (Skull symbols show where bones were found.)

Out of Africa—But When and Who? In time, some members of the genus *Homo* moved from Africa to other parts of the world. Where and when did our species, *Homo sapiens*, evolve? One hypothesis says that modern humans evolved in several different parts of the world at the same time. Another hypothesis says that modern humans evolved in Africa about 200,000 years ago. Then they moved out of Africa. Soon they took the place of other hominines that already lived elsewhere. DNA from living humans strongly supports the second hypothesis: *Homo sapiens* came out of Africa.

Modern Humans At least three other *Homo* species lived at the same time as early humans. The two most important were *Homo neanderthalensis* and *Homo sapiens*. Neanderthals began living in Europe and western Asia about 200,000 years ago. They lived in Europe until about 24,000 years ago. Neanderthals were very good hunters, made stone tools, and used fire. They lived in social groups and buried their dead with simple rituals.

Homo sapiens arrived in the Middle East from Africa about 100,000 years ago. About 50,000 years ago, they began making and using tools from stone and bones. They also painted on cave walls. They buried their dead with elaborate rituals.

Neanderthals and *Homo sapiens* lived side by side in the Middle East for about 50,000 years and in Europe for several thousand years. How and why did Neanderthals disappear? Did they inbreed with *Homo sapiens*? No one knows for sure. We do know this: For the last 24,000 years, *Homo sapiens* has been Earth's only hominine. Our species is the only surviving member of a clade that was once large and diverse.

Key Question What is the current scientific thinking about the genus *Homo*? **Many species of *Homo* lived before *Homo sapiens* appeared. At least three other *Homo* species lived at the same time as early humans.**

Cro-Magnon Art This ancient cave painting from France shows that Cro-Magnons were skilled artists.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. _____ lets primates combine the images from two eyes into a single image.
2. A(n) _____ can wrap around a branch and hold on like a hand.

Critical Thinking

3. **Relate Cause and Effect** How was walking upright important to the evolution of hominines?
4. **Compare and Contrast** What is one way in which Neanderthals differed from *Homo sapiens*?
5. **Write to Learn** Describe the two hypotheses that explain how *Homo sapiens* spread throughout the world. How are these two hypotheses alike? How are they different?

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Pre-Lab: Investigating Hominoid Fossils

Problem What can a comparison of skulls and hands reveal about the evolution of humans?

Materials metric ruler, protractor

Lab Manual Chapter 26 Lab

Skills Focus Measure, Analyze Data, Compare and Contrast

Connect to the Big idea To learn about the evolution of humans, scientists study both close relatives and possible ancestors. Fossils of possible ancestors are rare, and complete skeletons are even rarer. Yet, scientists have gained valuable information from those fossils that have been found. In this lab, you will make measurements that a paleontologist might make after finding a fossil. Then, you will use your data to make inferences about human evolution.

Background Questions

a. **Review** What are hominoids, and what are hominines?

b. **Explain** Use the examples of chimpanzees and humans to explain the difference between evolutionary relatives and ancestors.

c. **Compare and Contrast** What is the difference between the locomotion of humans and the locomotion of chimpanzees?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Use Models** What will you use instead of actual skulls and hands to make your measurements?

2. **Interpret Visuals** The bony cavities in a skull that protect the eyes are called orbits, or eye sockets. On the skulls, what does line AC measure? What does line BC measure?

3. **Use Analogies** Shoe sizes such as 9A and 11E (or 9 narrow and 11 extra-wide) are an example of an index. What two measurements are being compared in a shoe index?

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Visit Chapter 26 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Join the Untamed Science crew as they talk with insect experts to better understand why there are more than a million insects.

Art Review Review your understanding of different hominoids.

InterActive Art Build a cladogram of invertebrates.

26 CHAPTER Summary

26.1 Invertebrate Evolution and Diversity

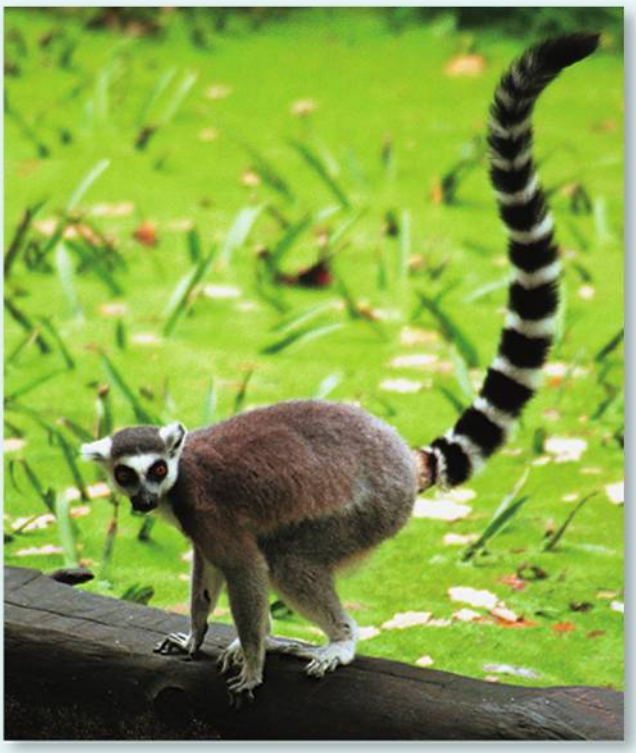
- Fossil evidence shows that the first animals began evolving long before the Cambrian Explosion.
- The cladogram of invertebrates shows current hypotheses about the evolutionary relationships of major groups of modern invertebrates. It also shows the order in which some important features evolved.

appendage (p. 625)
larva (p. 627)

26.2 Chordate Evolution and Diversity

- Studies of embryos show that the most ancient chordates were related to the ancestors of echinoderms.
- The cladogram of chordates shows how chordate groups are related and the points at which different features evolved.

cartilage (p. 628)
tetrapod (p. 630)



26.3 Primate Evolution

- Primates are mammals that have long fingers and toes, nails, arms that rotate at the shoulder, strong clavicles, binocular vision, and large cerebrums.
- The three major groups of primates are lemurs and lorises, tarsiers, and the anthropoids.
- The skull, neck, spine, hip bones, and leg bones of early hominines changed shape in ways that let later species walk upright.
- Many species of *Homo* lived before *Homo sapiens* appeared. At least three other *Homo* species lived at the same time as early humans.

binocular vision (p. 634)
anthropoid (p. 634)
prehensile tail (p. 635)
opposable thumb (p. 635)

26 CHECK Understanding

Assess the Big idea Evolution

Write an answer to the question below.
Q: How have animals descended from earlier forms through the process of evolution?

Constructed Response

Write an answer to each of the questions below. The answer to each question should be one or two paragraphs. To help you begin, read the **Hints** below the questions.

1. **Analyze Concepts** What can you tell about the ancestors of different groups of animals by looking at a cladogram?

   Hint Cladograms show evolutionary relationships.

   Hint Cladograms show when features evolved.

2. **Relate Cause and Effect** Life on Earth began in water. What are some of the ways that animals evolved to live on land?

   Hint Tetrapods can move on land, while fish cannot.

   Hint Breathing air requires different body parts than breathing underwater.

3. **Infer** When scientists find hominine fossils, they measure their size and decide their age. Why is it important for scientists to know the age as well as the size of these hominine bones?

   Hint Bone size helps scientists know how animals walked.

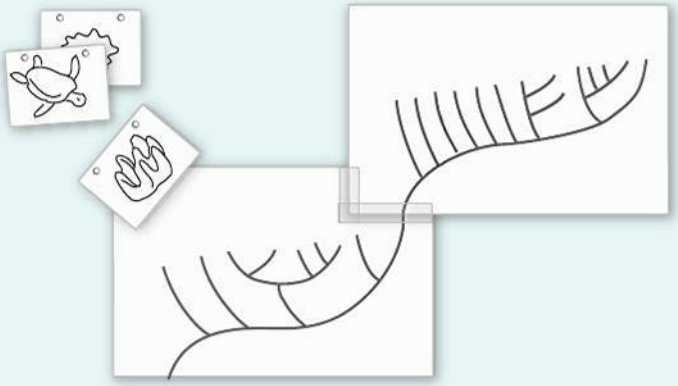
Foundations for Learning Wrap-Up

Use the three cladograms and the animal index cards you prepared while you read the chapter to help review what you learned. They will help you understand how different groups of animals are related.

Activity 1 Compare your three cladograms. Find the places where they overlap with one another. For example, the right end of the cladogram of invertebrates has a symbol that represents all chordates. The cladogram of chordates starts with an invertebrate ancestor. Attach these two cladograms where they overlap.

Next, attach the cladogram of primates where it overlaps with the cladogram of chordates. Then draw lines to connect the three cladograms.

You have now made a much larger cladogram. It shows details for only one group of chordates. Imagine how big your cladogram would be if it showed all the animals!



Activity 2 Study three index cards that each describe an animal in detail. Find where they belong in your large cladogram. Attach each one to the cladogram at the point where it belongs. Extend any lines that should connect with one another. Use the cladogram to find out how closely related your three animals are. Are they found within the same smaller cladogram? How closely related are they to humans? To a single-celled ancestor?

26.1 Invertebrate Evolution and Diversity

Understand Key Concepts

1. The ancestors of many modern animal phyla first appeared during the
   a. Burgess Period. **c.** Precambrian Era.
   b. Cambrian Period. **d.** Ediacaran Period.

2. Which of the following groups has species that live in water, on land, and in the air?
   a. arthropods **c.** mollusks
   b. annelids **d.** echinoderms

Test-Taking Tip

Think of examples to help you eliminate answer choices. For question 2, think of what adaptations are needed to survive in the different places. Then think of examples of each of the different groups of animals. Earthworms and other kinds of worms are annelids. Worms do not have wings, so they cannot live in the air.

3. What evidence indicates that annelids and mollusks are closely related?

Think Critically

4. **Infer** Most cnidarians do not swim. To catch prey, they let water currents carry the prey to them. How is this behavior related to special structures they have?

5. **Compare and Contrast** How is the structure of echinoderms different from that of arthropods?

26.2 Chordate Evolution and Diversity

Understand Key Concepts

6. Which adaptation is NOT characteristic of reptiles?
   a. scaly skin **c.** lungs
   b. shelled egg **d.** gills

7. What feature separates birds from other groups of living animals?
   a. feathers **c.** warm bodies
   b. two legs **d.** wings

8. Dinosaurs became extinct at the end of the
   a. Triassic Period.
   b. Cretaceous Period.
   c. Carboniferous Period.
   d. Permian Period.

9. What adaptation lets birds live in places that are colder than those in which most reptiles live?

10. Which two major groups of fishes that still survive today evolved from the early jawed fishes?

Think Critically

11. **Infer** What structures of nonvertebrate chordates make these animals seem more closely related to vertebrates than to other groups of animals?

26.3 Primate Evolution

Understand Key Concepts

12. Anthropoids include monkeys and
   a. lemurs. **c.** tarsiers.
   b. lorises. **d.** humans.

13. Which of the following is characteristic of primates, but not of other mammals?
   a. body hair
   b. rotation at the shoulder joint
   c. notochord
   d. ability to control body temperature

14. The first hominines evolved about
   a. 30,000 years ago.
   b. 100,000 years ago.
   c. 6 to 7 million years ago.
   d. 120 million years ago.

15. What features do hominines have? Give an example of a hominine.

26 CHECK Understanding

Think Critically

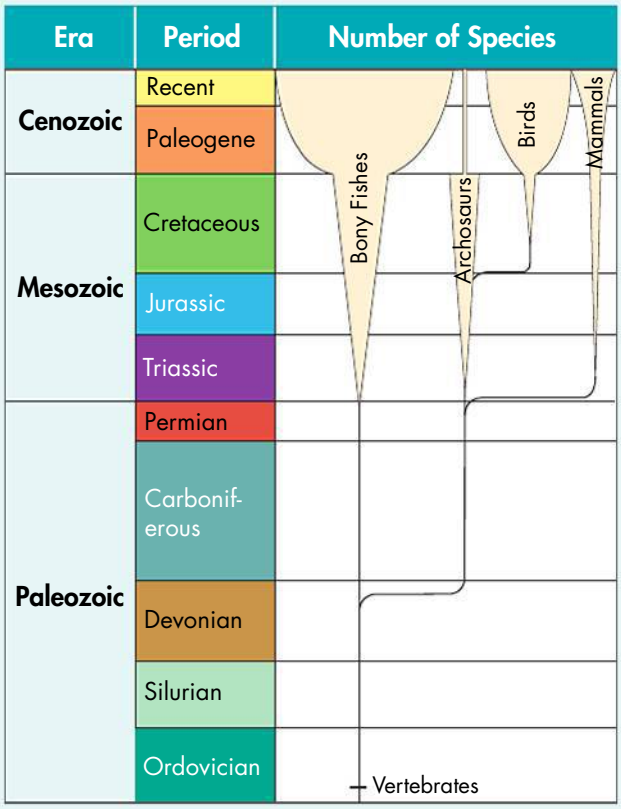
16. Apply Concepts How are binocular vision and opposable thumbs useful to a primate?

Connecting the Concepts

Use Science Graphics

The chart below shows the relative number of species in four groups of vertebrates over time. The places where the shapes are thick show that there were many species at that time. The places where they are thin show that there were few. Use the chart to answer questions 17–19.

17. Interpret Visuals During which period did amphibians first evolve?



18. Compare and Contrast How is this kind of diagram similar to a traditional cladogram? What additional information can be learned from it?

19. Interpret Visuals Which of the groups shown has the greatest number of species today?

solve the CHAPTER MYSTERY

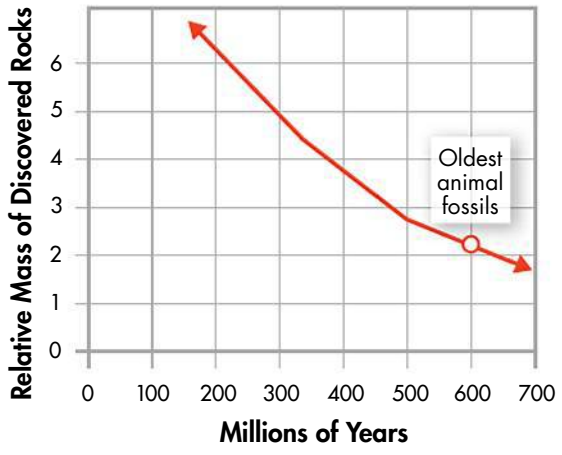
FOSSIL QUEST?

Josh would have a hard time finding rocks old enough to show traces of the first animals. Such fossils would be about 600 million years old. Most of these rocks have been destroyed by geological activity. Most sites are in China and Australia. None are in the United States.

Pedro found better news. Reptiles related to bird ancestors lived during the Cretaceous Period. There are a number of places where fossils of that age have been found. One such place is the Green River area in Utah. Because both boys like dinosaurs, they joined a field trip for teens to the Green River to search for bird ancestors.

1. Infer The earliest known animals lived during the Proterozoic Eon, while the ancestors of birds lived during the Cretaceous Period. Why is it so much harder to find fossils of the earliest known animals than it is to find fossils of the ancestors of birds? (*Hint:* See the graph below.)

Ages of Discovered Rocks



UntamedScience Finding the solution to the mystery is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

Standardized Test Prep

Multiple Choice

1. Which of the following is NOT a mollusk?
A leech **C** clam
B squid **D** snail

2. Which of the following invertebrates have segmented bodies?
A flatworms **C** cnidarians
B roundworms **D** annelids

3. All animals have some form of body symmetry EXCEPT
A sponges. **C** worms.
B jellyfishes. **D** arthropods.

4. Which of the following groups can be classified as nonvertebrate chordates?
A sponges
B tunicates
C fishes
D all of the above

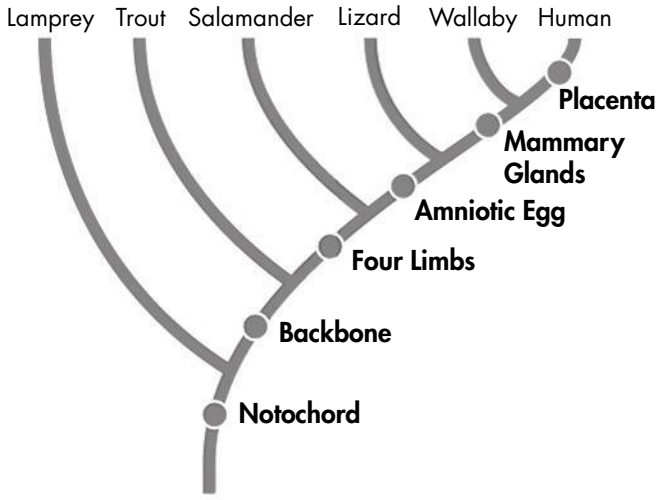
5. Many scientists think that birds evolved from
A mammal-like reptiles.
B amphibians.
C mammals.
D dinosaurs.

6. Which of the following is NOT a characteristic of reptiles?
A scaly skin **C** lungs
B eggs with shells **D** mammary glands

7. Which of the following are hominoids?
A all mammals **C** humans only
B all primates **D** all great apes

8. When did the first true mammals appear?
A Cretaceous Period
B Triassic Period
C Cenozoic Era
D Carboniferous Period

Questions 9–11 Refer to the following cladogram.



9. Which characteristic is shared by humans, wallabies, and trout?
A placenta **C** four limbs
B notochord **D** mammary glands

10. Which animals have the closest evolutionary relationship, as shown by the cladogram?
A humans and wallabies
B humans and lizards
C humans and lampreys
D humans and trout

11. A valid conclusion from this cladogram is that
A salamanders, trout, and lampreys all have a backbone.
B four limbs appeared in vertebrate evolution before the notochord appeared.
C humans and lampreys share a common ancestor.
D mammary glands appeared in vertebrate evolution after the placenta appeared.

Open-Ended Response

12. What is the difference between a hominoid and a hominine?

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10	11	12
See Lesson	26.1	26.1	26.1	26.2	26.2	26.2	26.3	26.2	26.2	26.2	26.2	26.3

27 Animal Systems I

Big idea

Structure and Function

Q: How do the structures of animals allow them to take in essential materials and get rid of wastes?

BIOLOGY.com Search Chapter 27 GO • Flash Cards

INSIDE:

Red-billed oxpeckers are carnivores that have a mutualistic relationship with zebras. The birds eat ticks and insects that are parasites on the zebras. This action frees the zebras of these parasites.

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

(NEAR) DEATH BY SALT WATER

It started as an adventure. Some college buddies tried their own version of a "survivor" experience. During summer vacation, the college friends were dropped on a small, tropical island. They had few supplies. They would be picked up in a few days.

The island was hot and dry. It had no fresh water. Some members of the group drank coconut milk when they were thirsty. One group member hated coconuts. He drank salt water to get his fluids. At first, he was fine. Then, he became sick and weak. He was dizzy, had headaches, and could not concentrate. His friends began to panic. What was happening? As you read the chapter, look for clues to explain why their friend became so ill. Then, solve the mystery.

FOUNDATIONS for Learning

Take a piece of paper and make a Z-fold, as shown below. Write the key questions for the first lesson of the chapter on the left panel of the fold. Predict the answers to these questions on the middle panel of the fold. Leave the right panel blank for now. Make three more Z-fold pages for the other three lessons of the chapter. Write the key questions and predict the answers for each of these lessons. At the end of the chapter are two activities that use the Z-fold charts to help answer the question: How do the structures of animals allow them to take in essential materials and get rid of wastes?

27.1 Feeding and Digestion

Key Questions

- ***How do animals get food?***
- ***How does digestion occur in animals?***
- ***How are mouthparts adapted for different diets?***

BUILD Understanding

Two-Column Table Before you read, look at the green headings in the lesson. As you read, make notes about the ideas developed in each heading.

In Your Workbook Refer to your workbook for suggestions about how to use a two-column chart to organize your notes.

Obtaining Food

All animals are heterotrophs that get their energy by eating food. Animals feed in many different ways. Tiny insects dine on blood. Bison feed on grasses. And giant blue whales feed on tiny plankton floating in the ocean. In fact, adaptations for feeding are a large part of what makes animals so interesting.

Filter Feeders Filter feeders eat by straining algae and tiny animals from water. Most filter feeders have gills or other structures that act like nets. Many invertebrate filter feeders, such as sponges, spend most of their lives in a single place. Vertebrate filter feeders, such as blue whales, usually feed while swimming.

Detritivores Detritivores eat bits of decaying plants and animals. They also eat bacteria and algae that live on decaying material. Many worms and crustaceans are detritivores.

Carnivores Carnivores eat other animals. Sharks and wolves are carnivores that use their sharp teeth to catch prey.

Herbivores Herbivores eat plants or parts of plants. Some herbivores can eat leaves. Others eat seeds or fruits.

Parasites Parasites live on or in another organism. They feed on the blood or tissues of their host. Many parasites cause disease.

Mutualists Some animals have mutualistic relationships that help both partners. For example, many coral animals have algae living in their tissues. The algae carry out photosynthesis, which is the corals' main source of energy. In addition, the algae recycle nutrients and help the corals make their calcium carbonate skeletons. The algae, in turn, get nutrients from the corals' wastes. The algae are also protected from algae eaters.

Key Question How do animals get food?

Some animals filter food out of water. Others feed on decaying material, other animals, or plants. Parasites feed on the tissues of living organisms.

Processing Food

Getting food is just the first step. Next, food must be broken down, or digested. Then food can be absorbed, giving energy and nutrients to cells throughout the body.

Intracellular Digestion Sponges and many other simple animals digest food inside specialized cells. Nutrients move from the specialized cells to other body cells by diffusion. This digestive process is called **intracellular digestion.**

Extracellular Digestion Most complex animals rely on extracellular digestion. In **extracellular digestion,** food is broken down outside of cells in a digestive system.

▶ ***Gastrovascular Cavities*** Some invertebrates have a space in their bodies that is surrounded by tissues that carry out digestion and circulation. This space is called a **gastrovascular cavity.** Gastrovascular cavities have a single opening. Animals that have a gastrovascular cavity obtain food and get rid of wastes through the same opening. Some cells lining the cavity secrete enzymes that digest food. Other cells surround food and digest it in vacuoles. Nutrients are then absorbed and carried to the rest of the body.

BUILD Vocabulary

intracellular digestion
a type of digestion in which food is digested inside specialized cells that pass nutrients to other cells by diffusion

extracellular digestion
a type of digestion in which food is broken down outside the cells in a digestive system and is then absorbed

gastrovascular cavity
a digestive chamber with a single opening

PREFIXES

The prefix *intra-* means "on the inside, within." The prefix *extra-* means "outside of." Intracellular digestion takes place *inside* of cells and extracellular digestion takes place *outside* of cells.

Obtaining Food The orca, sea slug, barnacles, and cleaner shrimp get their food in different ways.

Carnivore – Orca

Herbivore – Sea Slug

Filter Feeders – Barnacles

Detritivore – Cleaner Shrimp

BUILD Vocabulary

digestive tract
a tube that begins at the mouth and ends at the anus

rumen
a stomach chamber in cows and related animals in which bacteria digest cellulose

ACADEMIC WORDS

In biology, the word *tract* means "a system of organs and tissues that work together to perform one function." The *digestive tract* is a tube with organs such as a stomach and intestines that work together to break down food.

▶ ***Digestive Tracts*** Many invertebrates and all vertebrates digest food in a tube called a **digestive tract,** or gut. A digestive tract has two openings. Food moves through in one direction. Food enters through the mouth. Wastes leave through the anus.

Digestive tracts often have specialized structures that carry out different tasks as food passes through. Mouthparts such as teeth may cut or smash food into smaller pieces. Birds have a special organ called a gizzard that grinds food into smaller pieces. In many animals, the mouth secretes enzymes that start the process of chemical digestion. The stomach and intestines also secrete digestive enzymes. The intestines absorb nutrients that are released by digestion.

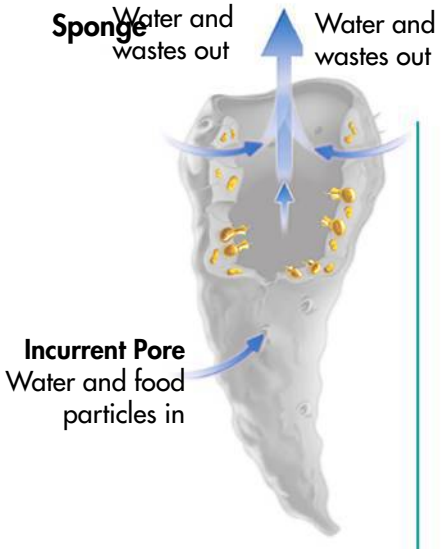
▶ ***Solid Waste Disposal*** Some materials in food cannot be digested. Organisms expel solid wastes called feces through either the single digestive opening or the anus.

Specialized Digestive Tracts Carnivorous invertebrates and vertebrates have short digestive tracts. These digestive tracts produce fast-acting enzymes. These enzymes are able to break down most animal tissues.

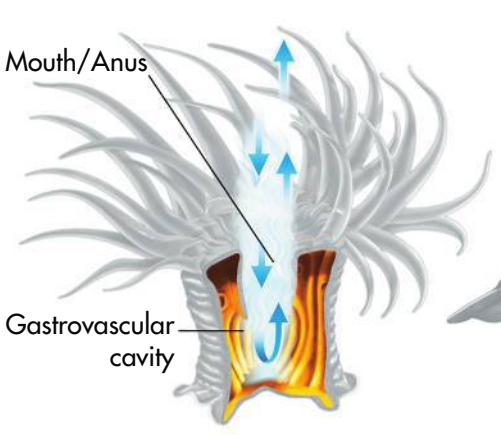
Plant tissues are more difficult to digest. No animal produces digestive enzymes that can break down the cellulose in plant tissue. Some herbivores have very long intestines that hold bacteria that are able to digest cellulose. Other herbivores have specialized pouches that hold mutualistic bacteria. For example, cows have a pouchlike extension of their esophagus called a **rumen.** Bacteria in the rumen digest cellulose. The food then moves back into the cow's mouth. The cow chews the food a second time, then swallows it again. This process is called "chewing the cud."

Key Question How does digestion occur in animals?
Some invertebrates, such as sponges, break down food using intracellular digestion. Most invertebrates and all vertebrates break down food using extracellular digestion.

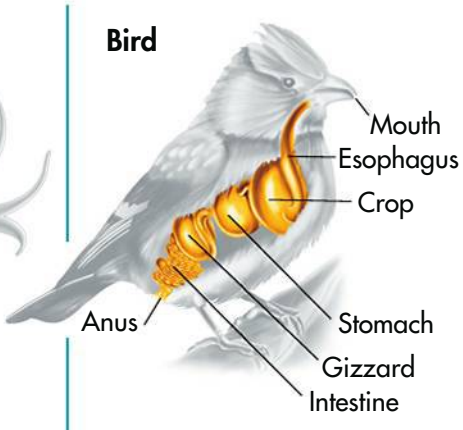
Digesting Food Animals have different digestive structures with different functions.



Sponge The sponge has one digestive opening and uses intracellular digestion.



Cnidarian The cnidarian has a gastrovascular cavity and uses extracellular digestion.



Bird The bird has a digestive tract and uses extracellular digestion.

Specializations for Diets

Animals with specialized diets have evolved specialized mouthparts that help them to grab and digest food.

For example, mammals that are carnivores have sharp teeth that help them grab and hold prey. These teeth can also slice meat. The jaws of these carnivores move up and down to chop meat into small pieces.

Herbivores have mouthparts that grind leaves. The front teeth and lips of mammalian herbivores can grab and tear. The jaws of these herbivores move from side to side to grind leaves.

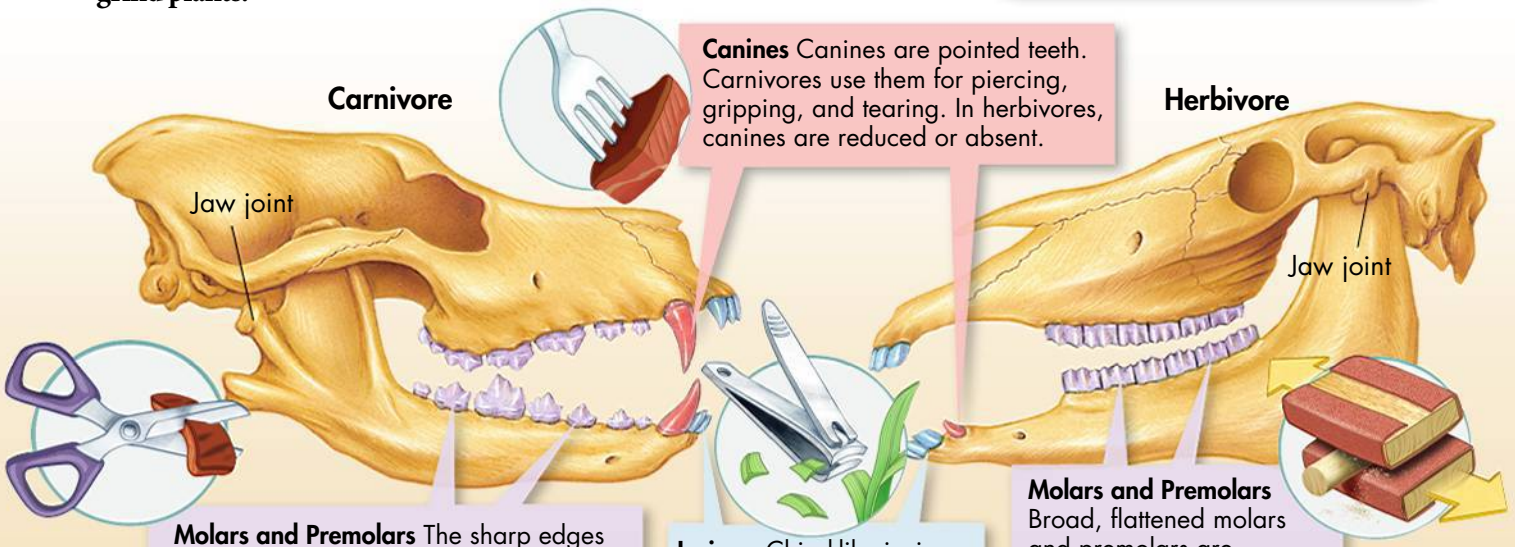
Key Question How are mouthparts adapted for different diets?

Carnivores usually have sharp mouthparts that can capture food, hold it, and cut it into pieces. Herbivores usually have mouthparts that can grind plants.

BUILD Connections

SPECIALIZED TEETH

The jaws and teeth of mammals are well adapted to their diets. How are mammal teeth like objects that you have around the house?



CHECK Understanding

Use the highlighted words from the lesson to complete each sentence correctly.

1. A digestive chamber that has a single opening is called a _____.
2. All vertebrates digest food in a tube called a _____.
3. The process by which food is broken down inside specialized cells is _____.

Critical Thinking

4. **Classify** Identify the following animals as a filter feeder, detritivore, parasite, or carnivore: a hawk that eats mice; a lobster that feeds on dead fish; a tick that feeds on a dog's blood; a blue whale that eats plankton.
5. **Compare and Contrast** How do the mouthparts of a leaf-eater differ from those of a meat-eater?
6. **Write to Learn** Describe how a cow digests food. Include the words *cellulose*, *rumen*, and *cud*.

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27.2 Respiration

Key Questions

- ***What characteristics do the respiratory structures of all animals share?***
- ***How do aquatic animals breathe?***
- ***What respiratory structures enable land animals to breathe?***

BUILD Understanding

Concept Map As you read the lesson, create a concept map that shows the characteristics of the lungs of vertebrates.

In Your Workbook Refer to your workbook for suggestions about how to use a concept map to organize your notes.

BUILD Vocabulary

gill a feathery structure specialized for the exchange of gases with water

lung an organ used for respiration; a place where gases are exchanged between the blood and inhaled air

MULTIPLE MEANINGS

The word *respiration* has two different meanings. At the level of an organism, respiration is the exchange of oxygen and carbon dioxide with the air. At the level of a cell, respiration is the process by which food molecules are broken down to release energy. Because cellular respiration requires oxygen, the two processes are related.

Gas Exchange

In respiration, all animal cells take in oxygen and give off carbon dioxide. Animals must get this oxygen from their environment. In other words, all animals need to "breathe." Humans can drown because our lungs cannot take oxygen from water. Fishes have the opposite problem. Their gills cannot use oxygen from the air.

Living cells cannot actively pump oxygen and carbon dioxide across membranes. Instead, animals have respiratory structures that allow these gases to move in and out by passive diffusion.

Gas Diffusion and Membranes Gases diffuse from an area of higher concentration to an area of lower concentration. Gases diffuse best across a thin, moist membrane that is selectively permeable. The amount of diffusion that can take place increases as the surface area of a membrane increases.

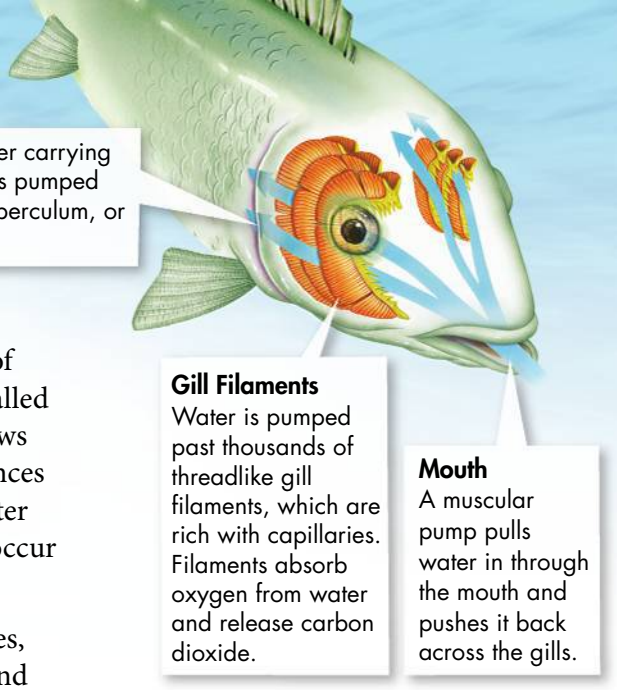
Requirements for Respiration Respiratory structures contain a moist membrane with a large surface area. Only certain gases, such as oxygen and carbon dioxide, can move across this membrane. Respiratory structures also maintain different concentrations of carbon dioxide and oxygen on either side of the membrane. These different concentrations promote diffusion of those gases.

Key Question What characteristics do the respiratory structures of all animals share?

Respiratory structures provide a large surface area of moist, selectively permeable membrane. The membrane keeps a difference in the relative concentrations of oxygen and carbon dioxide on either side of it. This difference in concentration helps diffusion take place.

Respiration in Aquatic Animals

Animals such as flatworms and amphibians have thin-walled bodies that are wet. Oxygen and carbon dioxide can diffuse through the body coverings of these animals. Larger, active animals cannot rely on respiration through the skin alone. Many aquatic invertebrates and most aquatic chordates exchange gases through gills.



Respiration With Gills Fish respire with gills. As water passes over the gills, oxygen enters the capillaries and carbon dioxide exits.

Gills are feathery structures that expose a large surface area of membrane to water. Inside gills are many tiny blood vessels called capillaries. Animals pump water across their gills as blood flows inside. Pumping water over the gills helps to maintain differences between the oxygen and carbon dioxide concentrations in water and blood. When concentrations are different, diffusion can occur between the capillaries and water.

Reptiles that live in water and aquatic mammals such as whales, breathe with lungs. **Lungs** are organs that exchange oxygen and carbon dioxide between blood and air. Animals that breathe with lungs inhale air at the surface and hold their breath underwater.

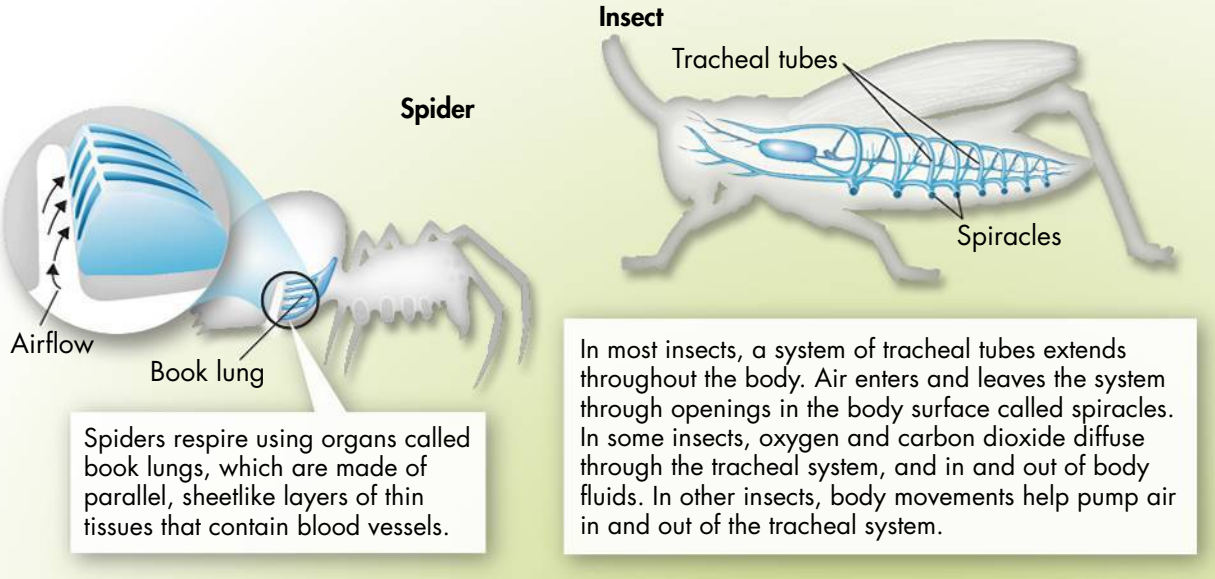
Key Question How do aquatic animals breathe?
Most aquatic animals breathe through their skin or with gills. Aquatic reptiles and mammals breathe with lungs and must hold their breath underwater.

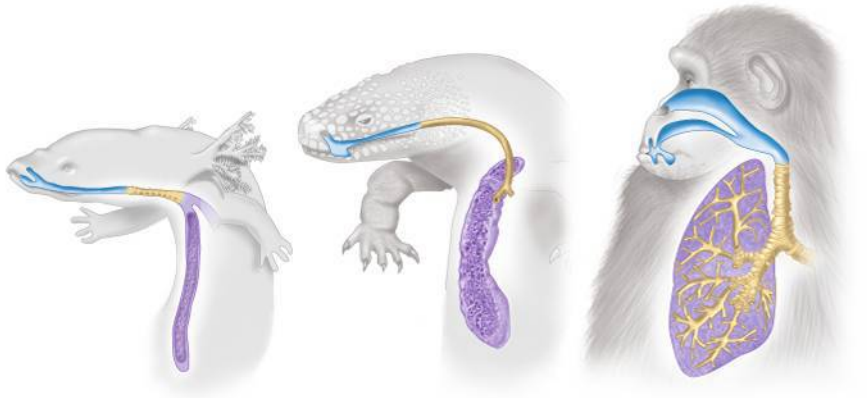
Respiration in Land Animals

Animals that live on land face a challenge that aquatic animals do not. Land animals must keep their respiratory membranes moist in dry conditions.

Respiration in Land Invertebrates Invertebrates that live on land have a wide variety of respiratory structures. Some land animals, such as earthworms, can respire across their skin as long as it stays moist. Land snails respire by using a mantle cavity, which is lined with moist tissue and blood vessels. Insects and spiders have very complex structures, as shown in the art.

Respiratory Structures of Land Invertebrates Invertebrates that live on land have a wide variety of respiratory structures that help their membranes stay moist, even in dry conditions.





Lungs Vertebrates that live on land breathe with lungs. Lungs with a larger surface area can take in more oxygen and release more carbon dioxide.

Lung Structure in Vertebrates

All land vertebrates breathe with lungs. Inhaling brings oxygen-rich air into the lungs. Oxygen diffuses into the blood through capillaries in the lungs. Carbon dioxide diffuses out of the blood and is exhaled.

▶ ***Amphibian, Reptilian, and Mammalian Lungs*** The internal surface area of lungs increases from amphibians to reptiles to mammals. The lung of an amphibian is like a sac with ridges. The lung of a reptile is small but often divided into chambers. A mammalian lung is large with many branches. Bubblelike structures called **alveoli** (al VEE uh ly; singular: alveolus) fill the lungs of mammals. These structures provide a large surface area for gas exchange. In the lungs of mammals and most other vertebrates, air moves in and out through the same passage. For this reason, some stale air is trapped in the lungs.

▶ ***Bird Lungs*** Air flows through bird lungs in one direction. One-way air flow is more efficient than the in-and-out air flow of mammals. Stale air does not get trapped. One-way flow allows birds to get enough oxygen to power their flight muscles.

Key Question What respiratory structures enable land animals to breathe? **Land animals breathe by using structures such as the skin, mantle cavities, book lungs, tracheal tubes, and lungs.**

BUILD Vocabulary

alveolus
a tiny air sac at the end of the bronchiole in the lungs that provides surface area for gas exchange to occur

WORD ORIGINS

The Latin word *alveolus* means "small cavity." A cavity is a hollow space. The *alveoli* in the lungs are air sacs that are small and hollow.

CHECK Understanding

Use the highlighted words from the lesson to complete each sentence correctly.

1. The feathery structures that allow fish to obtain oxygen from water are _____.
2. The tiny air sacs in lungs where gas exchange occurs are called _____.

Critical Thinking

3. **Explain** How are the respiratory structures of all animals similar?
4. **Apply Concepts** Explain why it is important that respiratory surfaces remain moist.
5. **Review** Which groups of aquatic animals breathe with gills? With lungs?
6. **Compare and Contrast** Compare the structures that land invertebrates and land vertebrates use to breathe.
7. **Write to Learn** Describe the events that occur when a mammal breathes in and out. Include the path of air through its lungs.

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27.3 Circulation

Open and Closed Circulatory Systems

How do animals get oxygen and nutrients to their cells? How do their cells get rid of carbon dioxide and other wastes? In small aquatic animals that are only a few cells thick, materials move by diffusion. But most animals move these materials in blood. Usually one or more hearts pump blood through a circulatory system. A **heart** is a hollow, muscular organ that pumps blood.

Open Circulatory Systems Arthropods and most mollusks have **open circulatory systems.** In an open circulatory system, blood is only partly contained in blood vessels. The vessels empty into a system of sinuses, or spongy holes. There, blood is in direct contact with body tissues. Blood collects in another set of sinuses. Eventually it flows back to the heart.

Closed Circulatory Systems Larger invertebrates and all vertebrates have **closed circulatory systems.** In a closed circulatory system, blood moves entirely within blood vessels. Nutrients and oxygen reach body tissues by diffusing across the walls of tiny blood vessels called capillaries. Blood that is completely contained in vessels can be pumped under high pressure. Thus, a closed circulatory system is more efficient than an open circulatory system.

Key Question How do open and closed circulatory systems compare? **In an open circulatory system, blood is only partly contained within blood vessels. In a closed circulatory system, blood is completely contained in blood vessels.**

Key Questions

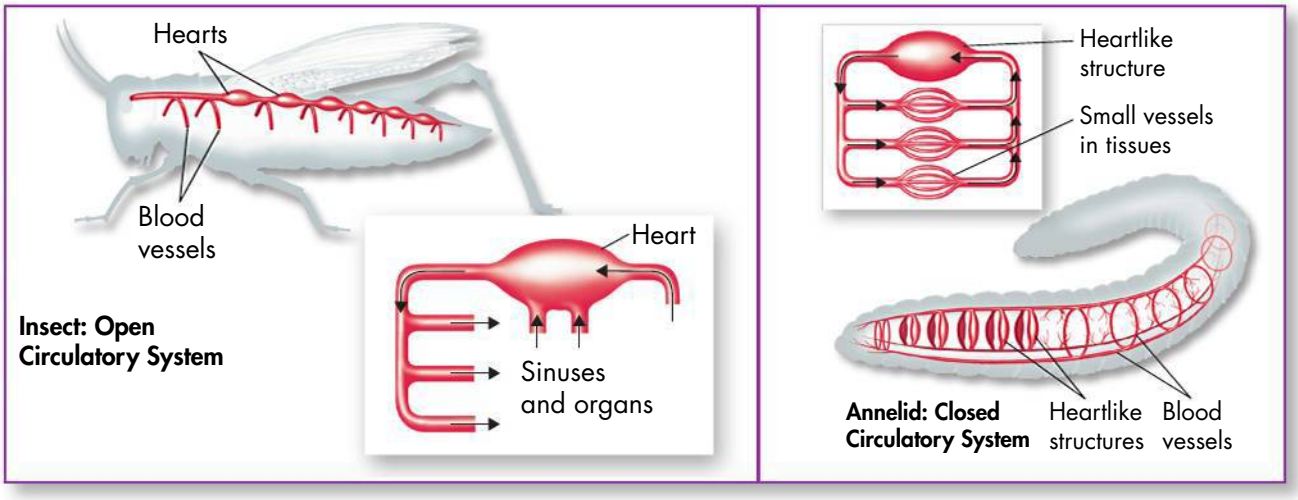
How do open and closed circulatory systems compare?

How do the patterns of circulation in vertebrates compare?

BUILD Understanding

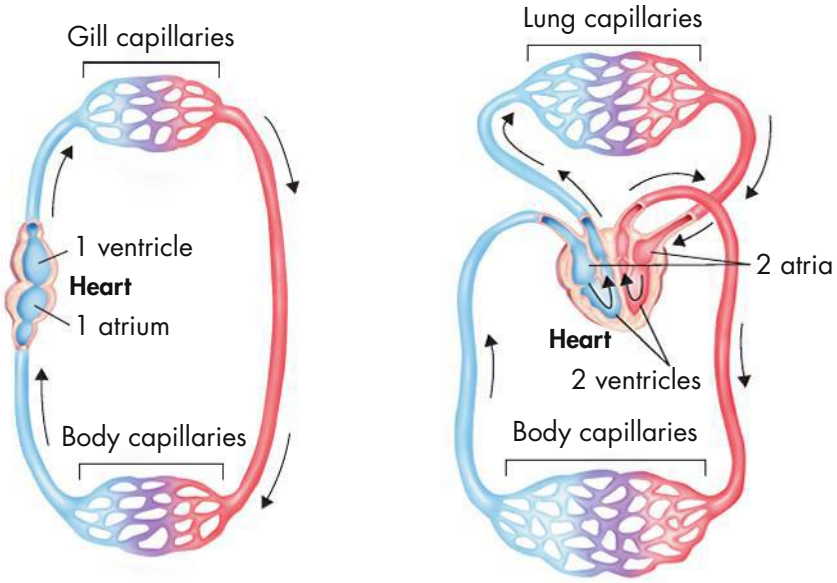
Cycle Diagram As you read, draw a cycle diagram showing how blood moves through a closed, two-loop circulatory system. Use five steps in your diagram.

In Your Workbook Refer to your workbook to see how to make a cycle diagram.



Open and Closed Circulatory Systems A grasshopper has an open circulatory system. Blood leaves vessels and moves through sinuses before returning to the heart. Earthworms have closed circulatory systems. Blood stays in the vessels of a closed circulatory system.

Single- and Double-Loop Circulation Most vertebrates that use gills for respiration have a single-loop circulatory system. Most vertebrates that use lungs have a double-loop circulatory system. (In diagrams of animals' circulatory systems, blood vessels carrying oxygen-rich blood are red. Blood vessels carrying oxygen-poor blood are blue.)



Single- and Double-Loop Circulation

As vertebrates evolved, they developed more complex circulatory systems. These systems move materials to and from body tissues very efficiently.

Single-Loop Circulation Most vertebrates with gills have a single-loop circulatory system. A single pump forces blood around the body in one direction. In fishes, the heart has two chambers. The **atrium** (plural: atria) is the chamber that receives blood that is about to enter the ventricle. The **ventricle** is the chamber that pumps blood out of the heart and to the gills. In the gills, blood picks up oxygen and releases carbon dioxide. It then travels to the rest of the body, delivering oxygen to the body's cells. By the time blood returns to the atrium, it has become oxygen-poor.

Double-Loop Circulation As larger and more active land vertebrates evolved, the capillary networks in both their lungs and body tissues became larger. A single pump would not have been strong enough to pump blood through these larger systems. In reptiles, birds, and mammals, a double-loop, two-pump circulatory system evolved. Each loop is powered by one side of the heart.

In the first loop, one side of the heart forces oxygen-poor blood from the heart to the lungs. In the lungs, blood picks up oxygen and drops off carbon dioxide. Oxygen-rich blood then returns to the heart. In the second loop, the other side of the heart forces oxygen-rich blood to the rest of the body. Oxygen-poor blood returns to the heart. Then, the cycle begins again.

Key Question How do the patterns of circulation in vertebrates compare? **Most vertebrates that use gills for respiration have a single-loop, one-pump circulatory system. Most vertebrates that use lungs have a double-loop, two-pump circulatory system.**

BUILD Vocabulary

heart a hollow muscular organ that pumps blood throughout the body

open circulatory system a type of circulatory system in which blood is only partly contained within a system of blood vessels as it travels through the body

closed circulatory system a type of circulatory system in which blood circulates entirely within blood vessels that extend throughout the body

atrium an upper chamber of the heart that receives blood that is about to enter the ventricle

ventricle a lower chamber of the heart that pumps blood out of the heart

WORD ORIGINS

The word *circulatory* comes from the Latin word *circulare,* which means "to form a circle." In a circulatory system, blood circles around the body.

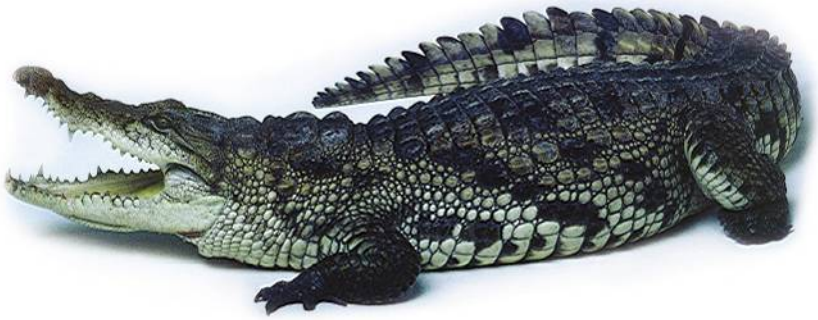
Evolution of the Four-Chambered Heart A four-chambered heart is actually two separate pumps working next to each other. Where did the second pump come from? During the evolution of vertebrates, partitions arose that divided the original two chambers into four chambers. This separated oxygen-rich blood from oxygen-poor blood. You can get an idea of how the four chambers evolved by looking at the hearts of modern vertebrates.

Amphibian hearts usually have three chambers: two atria and one ventricle. The left atrium gets oxygen-rich blood from the lungs. The right atrium gets oxygen-poor blood from the body. Blood from both atria flows into the ventricle. The shape of the ventricle helps direct the movement of blood. Most oxygen-poor blood goes to the lungs. Most oxygen-rich blood goes to the rest of the body. But there is some mixing of oxygen-rich and oxygen-poor blood.

Reptilian hearts usually have three chambers. Their ventricles are usually divided a little more than those of typical amphibians. This partial division allows less mixing of oxygen-rich and oxygen-poor blood.

Mammals have a four-chambered heart. The right atrium gets oxygen-poor blood from the body. The right ventricle pushes that blood to the lungs. The left atrium gets oxygen-rich blood from the lungs. The left ventricle pushes oxygen-rich blood out to the rest of the body. Oxygen-rich and oxygen-poor blood cannot mix.

Reptilian Heart Under the armor-like hide of this crocodile lies a heart with two atria and one ventricle.



CHECK Understanding

Use the highlighted words from the lesson to complete each sentence correctly.

1. The upper chamber of the heart that receives blood that is about to enter the ventricle is called the _____.
2. In a(n) _____, blood empties into sinuses before returning to the heart.
3. The chamber of the heart that pumps blood out of the heart to the rest of the body is the _____.

Critical Thinking

4. **Compare and Contrast** Compare the structure of an open circulatory system to that of a closed circulatory system.
5. **Relate Cause and Effect** How does having a closed circulatory system benefit a large, active animal?
6. **Review** What are two different patterns of circulation found in vertebrates?
7. **Write to Learn** Answer the question in the mystery clue. What happens when you drink a thick liquid through a straw? Is it harder or easier than drinking water through a straw?

MYSTERY CLUE

Human blood is only about a third as salty as seawater. It needs to circulate through very small capillaries. What might happen if the water content of a person's blood were to drop too low? (Hint: See p. 654.)

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27.4 Excretion

Key Questions

- ***How do animals manage toxic nitrogen-containing waste?***
- ***How do aquatic animals eliminate wastes?***
- ***How do land animals remove wastes while conserving water?***

BUILD Understanding

Preview Visuals Write a question you have about the figure called Excretion in Aquatic Animals. As you read the lesson, try to answer your question.

In Your Workbook Refer to your workbook to see how previewing visuals can help you to understand the ideas in this lesson.

BUILD Vocabulary

excretion the process by which nitrogen-containing wastes are eliminated from the body

kidney an organ of excretion that separates wastes and extra water from the blood

PREFIXES

The prefix *ex-* means "out of, from." *Excretion* helps to get wastes "out" of the body.

The Ammonia Problem

So far in this chapter, you have learned how animals get rid of carbon dioxide. But cells also produce other wastes. What are those wastes? And how do animals get rid of them?

When cells break down proteins, they create a nitrogen-containing waste called ammonia. Ammonia is a problem, because it is poisonous! Animals get rid of ammonia by the process of **excretion.** Some small animals that live in water get rid of ammonia by allowing it to diffuse out of their body. Big animals and smaller ones that live in dry places have excretory systems that process and remove ammonia.

Storing Nitrogen-Containing Wastes Animals that cannot get rid of ammonia right away have evolved ways to store nitrogen-containing wastes. Ammonia is too toxic, or poisonous, to store. Many animals convert ammonia into compounds that are less toxic. Insects, reptiles, and birds change ammonia into a sticky white compound called uric acid. Uric acid is much less toxic than ammonia and does not dissolve easily in water. Mammals and some amphibians convert ammonia to urea. Like uric acid, urea is less toxic than ammonia. Unlike uric acid, urea easily dissolves in water.

Maintaining Water Balance Excretory systems help keep the correct balance of water in blood and body tissues. Some systems get rid of water when they get rid of nitrogen-containing wastes. Other systems get rid of nitrogen-containing wastes but conserve water.

Many animals use **kidneys** to separate wastes and extra water from blood. Kidney cells cannot actively pump water across their membranes. Yet they need to separate water from wastes. Kidneys solve this problem by pumping ions to create areas with higher osmotic concentrations. Water moves passively into these areas by osmosis. So this process saves water, but it cannot get rid of extra salt.

Key Question How do animals manage toxic nitrogen-containing waste? **Animals either get rid of ammonia quickly or convert it to other nitrogen-containing compounds that are less toxic.**

Excretion in Aquatic Animals

Most aquatic animals allow ammonia to diffuse out of their bodies. The surrounding water carries the ammonia away. But aquatic animals must still keep the right amount of water in their bodies. Animals have different challenges in fresh water and salt water.

Freshwater Animals Most freshwater animals have body fluids that are saltier than the water they live in. This higher concentration of salt causes water to move into their bodies and salts to diffuse out. Flatworms have cells called flame cells that remove extra water. Amphibians and freshwater fishes get rid of extra water by making lots of watery urine. Freshwater fishes also pump salt in through their gills.

Saltwater Animals Invertebrates that live is salt water usually have less of a problem with water balance than freshwater invertebrates. That is because the water concentration in their bodies is similar to that of the seawater around them. In contrast, the bodies of fishes are usually less salty than seawater. They tend to lose water to their surroundings. These fishes get rid of salt across their gills. Their kidneys conserve water by producing small amounts of concentrated urine.

Key Question How do aquatic animals eliminate wastes?

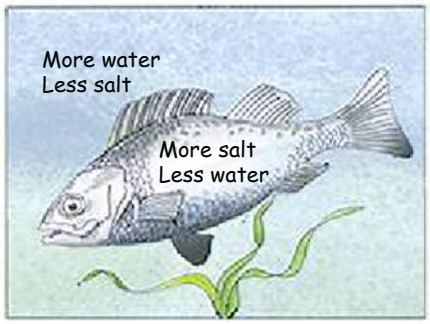
Aquatic animals generally allow ammonia to diffuse out of their bodies into the surrounding water.

BUILD Connections

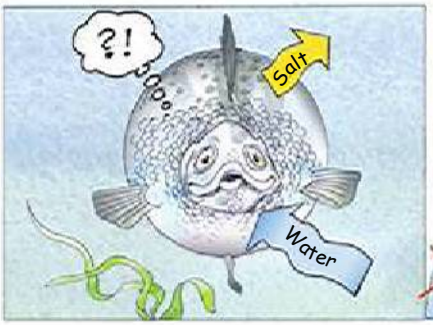
EXCRETION IN AQUATIC ANIMALS

All animals must get rid of toxic ammonia and still keep the right amount of water in their bodies. Freshwater and saltwater fish do this in different ways.

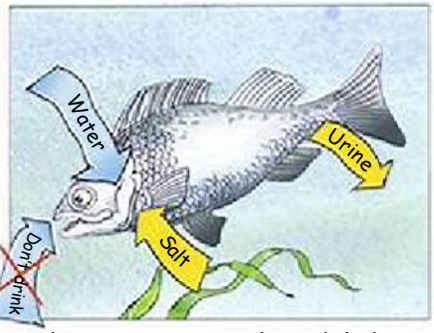
Fresh Water



The bodies of freshwater animals, such as fishes, contain a higher concentration of salt than the water they live in.



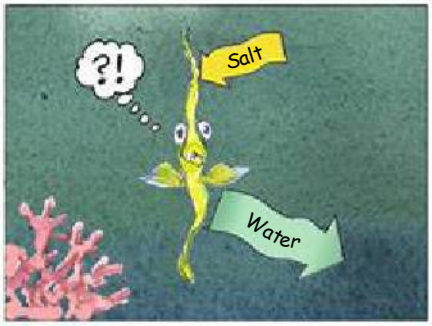
So water moves into their bodies by osmosis, mostly across the gills. Salt diffuses out. If they didn't excrete water, they'd look like water balloons with eyes!



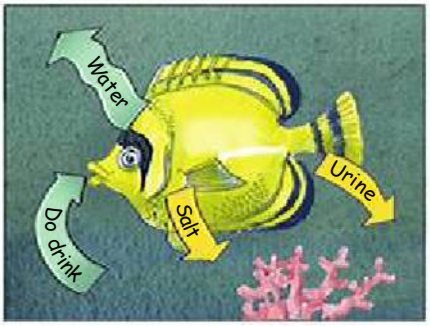
So they excrete water through kidneys that produce lots of watery urine. They don't drink, and they actively pump salt in across their gills.

Salt Water

The bodies of saltwater animals, such as fishes, contain a lower concentration of salt than the water they live in.



So they lose water through osmosis, and salt diffuses in. If they didn't conserve water and eliminate salt, they'd shrivel up like dead leaves.



So they conserve water by producing very little concentrated urine. They drink, and they actively pump salt out across their gills.

INQUIRY into Scientific Thinking

Water and Nitrogen Excretion

In this lab, you will investigate the differences between uric acid and urea.

1. Label one test tube Urea and the other Uric Acid. Place 2 grams of urea in the one labeled Urea. Place 2 grams of uric acid in the one labeled Uric Acid.
2. Add 15 mL of water to each test tube. Stopper and shake the test tubes for 3 minutes.
3. Observe each test tube. Record your observations.

Analyze and Conclude

1. Observe Which substance—urea or uric acid—is less soluble in water? Explain.

2. Infer Birds and reptiles excrete nitrogen-containing wastes in the form of uric acid. How does this adaptation help these animals to survive on land?

In Your Workbook Get more help for this activity in your workbook.

Excretion in Land Animals

Land animals also face challenges. In dry air, animals can lose large amounts of water through their respiratory membranes. And even though water may be scarce, they must use water to get rid of nitrogen-containing wastes. Land animals have evolved excretory systems that help conserve water.

Land Invertebrates Some invertebrates that live on land, such as earthworms and snails, produce urine in nephridia. **Nephridia** (singular: nephridium) are tubelike excretory structures that filter body fluid. Body fluid enters the nephridia through openings. The fluid becomes more concentrated as it moves along the tubes. Urine then leaves the body through excretory pores.

Insects and spiders convert ammonia into uric acid. Uric acid and other nitrogen-containing wastes are absorbed from body fluids by **Malpighian tubules.** These structures concentrate wastes and add them to digestive wastes moving through the gut. The uric acid and wastes form a thick paste that leaves the body through the anus. This paste does not contain much water, so this process reduces water loss.

Land Vertebrates In vertebrates, kidneys get rid of most nitrogen-containing wastes. Mammals and land-living amphibians convert ammonia to urea. Urea is excreted in urine. Most reptiles and birds convert ammonia to uric acid. This uric acid passes through ducts into a structure that also receives digestive wastes. The walls of this structure absorb most of the water from the wastes. The animal then excretes a thick, white paste that you would recognize as "bird droppings."

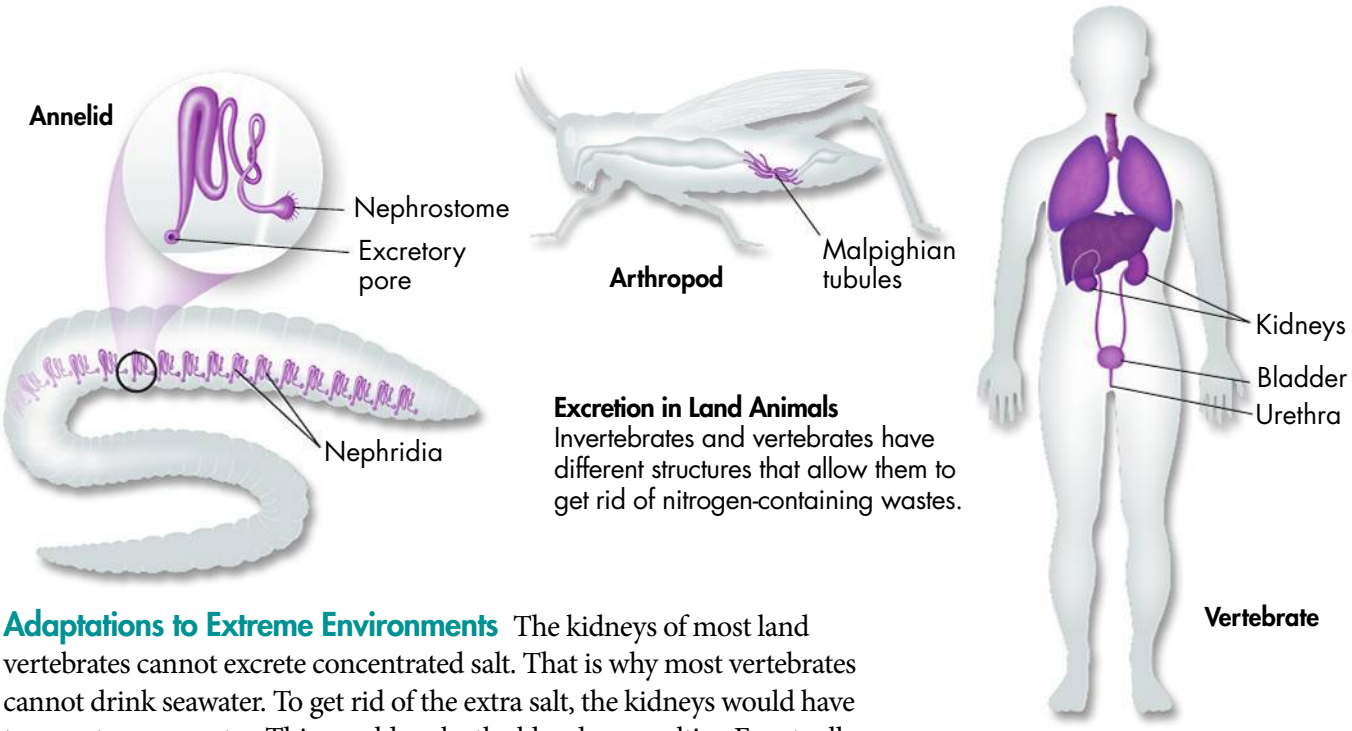
BUILD Vocabulary

nephridium
an excretory structure of earthworms and other annelids that filters body fluid

Malpighian tubule
a structure in most terrestrial arthropods that concentrates uric acid and adds it to digestive wastes

WORD ORIGINS

The word *nephridium* comes from the Greek word, *nephros*, which means "kidney." A nephridium is a structure in invertebrates that functions like a vertebrate kidney.



Excretion in Land Animals Invertebrates and vertebrates have different structures that allow them to get rid of nitrogen-containing wastes.

Adaptations to Extreme Environments The kidneys of most land vertebrates cannot excrete concentrated salt. That is why most vertebrates cannot drink seawater. To get rid of the extra salt, the kidneys would have to excrete more water. This would make the blood even saltier. Eventually cells would become so dry that the animal would die.

Many animals that live where fresh water is not available have adaptations that conserve water and get rid of extra salt. Some marine reptiles and birds have glands in their heads that excrete salt solutions. Kangaroo rats that live in the American southwest have remarkably efficient kidneys. They produce urine that is 25 times more concentrated than their blood!

Key Question How do land animals remove wastes while conserving water? **Land animals have different specialized structures that allow them to get rid of nitrogen-containing compounds while also conserving water.**

CHECK Understanding

Use the highlighted words from the lesson to complete each sentence correctly.

1. In a spider, waste fluid becomes concentrated inside _____.
2. Land vertebrates have organs called _____ that separate wastes and extra water from the blood.
3. Excretory structures in earthworms that create urine are called _____.

Critical Thinking

4. **Review** Why does ammonia create a problem for all animals?
5. **Compare and Contrast** How do the different water-balance needs of freshwater animals and saltwater animals explain the different ways that they excrete nitrogen-containing waste?
6. **Write to Learn** Answer the question in the mystery clue below. Think about what happens when there is extra salt in the blood.

MYSTERY CLUE

Humans have kidneys that have evolved to conserve salt, not to get rid of it. How could this have posed a problem for the sick "survivor"? (Hint: See above.)

BIOLOGY.com Search Lesson 27.4 GO • Lesson Assessment

Pre-Lab: Anatomy of a Squid

Problem What structures does a squid use to obtain nutrients and eliminate wastes?

Materials squid, dissecting tray, hand lens, forceps, dissecting scissors, dissecting pins, dissecting probe

Lab Manual Chapter 27 Lab

Skills Focus Observe, Infer, Sequence, Draw Conclusions

Connect to the Big idea All animals obtain their food by eating other organisms. All animals need a way to digest the food, and most animals need a way to circulate the absorbed nutrients to all the cells in the body. Animals also need to absorb oxygen from their environment for cellular respiration. Finally, animals need to rid their bodies of wastes.

The ways that animals meet these needs vary greatly. Often, different habitats require different structures. For example, an animal that must obtain its oxygen from air will not have the same respiratory structures as an animal that must obtain its oxygen from water. In this lab, you will dissect a squid and observe parts of several body systems.

Background Questions

a. **Compare and Contrast** How are a gastrovascular cavity and a digestive tract different?

b. **Review** What process takes place in all respiratory structures?

c. **Compare and Contrast** What is the difference between an open and a closed circulatory system?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Interpret Visuals** What structure can you use to distinguish the ventral side of a squid from the dorsal side?

2. **Infer** Why is it important to lift the mantle while cutting it?

3. **Predict** What do you expect the gills to look like, and why?

BIOLOGY.com Search Chapter 27 GO

Visit Chapter 27 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Trek carefully with the Untamed Science crew as they get up close and personal with bears to learn about their adaptations.

Art in Motion What happens when fresh- and saltwater fishes excrete water or salt? Find out by watching this animation.

Art Review Review your knowledge of the different types of respiratory systems with this activity.

InterActive Art See how single- and double-loop circulation systems compare.

Visual Analogy Compare the structure and function of the types of teeth with common objects.

27 CHAPTER Summary

27.1 Feeding and Digestion

- Most filter feeders have gills or other structures that strain algae and small animals from water. Detritivores eat decaying material. Carnivores eat other animals. Herbivores eat plants or parts of plants. Parasites feed on the blood or tissues of their host. Sometimes two types of animals have a relationship that helps both of them.
- Some invertebrates break down food through intracellular digestion. Most invertebrates and all vertebrates use extracellular digestion.
- Carnivores usually have sharp mouthparts that can capture food, hold it, and cut it into pieces. Herbivores usually have mouthparts that can grind plant material.

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intracellular digestion (p. 647)
extracellular digestion (p. 647)
gastrovascular cavity (p. 647)
digestive tract (p. 648)
rumen (p. 648)

27.2 Respiration

- Respiratory structures provide a large surface area of moist, selectively permeable membrane. The membrane keeps a difference in the relative concentration of oxygen and carbon dioxide on either side of it. This difference in concentration allows diffusion to take place.
- Most aquatic animals breathe through their skin or with gills. Aquatic reptiles and mammals breathe with lungs and must hold their breath underwater.
- Invertebrates that live on land have a variety of different respiratory structures, including skin, mantle cavities, book lungs, and tracheal tubes. All vertebrates that live on land—reptiles, birds, mammals, and land-living amphibians—breathe with lungs.

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gill (p. 651)
lung (p. 651)
alveolus (p. 652)

27.3 Circulation

- In an open circulatory system, blood is only partly contained within blood vessels. In a closed circulatory system, blood circulates entirely within blood vessels.
- Most vertebrates with gills have a single-loop circulatory system with a single pump. This pump forces blood through a single-loop circulatory system. Most vertebrates with lungs have a double-loop, two-pump circulatory system.

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heart (p. 653)
open circulatory system (p. 653)
closed circulatory system (p. 653)
atrium (p. 654)
ventricle (p. 654)

27.4 Excretion

- Animals either get rid of ammonia quickly or convert it to other nitrogen-containing compounds that are less toxic.
- Aquatic animals generally allow ammonia to diffuse out of their bodies into the surrounding water.
- Some land invertebrates, including earthworms and snails, produce urine in nephridia. Insects and spiders convert ammonia to uric acid. Mammals and land amphibians convert ammonia to urea, which is excreted in urine. Most reptiles and birds convert ammonia into uric acid.

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excretion (p. 656)
kidney (p. 656)
nephridium (p. 658)
Malpighian tubule (p. 658)

27 CHECK Understanding

Assess the Big idea Structure and Function

Write an answer to the question below:
Q: How do the structures of animals allow them to take in essential materials and get rid of wastes?

Constructed Response

Write an answer to each of the numbered questions below. The answer to each numbered question should be one or two paragraphs long. To help you begin, read the **Hints** below the questions.

1. **How is a digestive tract a more efficient structure for taking in and processing food than a gastrovascular cavity?**

   Hint A gastrovascular cavity has one opening. A digestive tract has two openings, and food moves in one direction.

   Hint A digestive tract may have specialized organs, such as a stomach and intestines.

2. **Do you think large, active vertebrates would have been likely to succeed without the evolution of closed circulatory systems? Explain your reasoning.**

   Hint Blood that is completely contained within blood vessels can be pumped under greater pressure. Therefore, it can travel a greater distance.

   Hint To move quickly, muscles need a large supply of oxygen.

3. **All animals need to control the amount of water within their bodies. They also need to get rid of nitrogen-containing wastes. Compare the way that earthworms and insects are able to control these functions.**

   Hint Excretion usually requires water. Earthworms and insects have different kinds of structures that help conserve water.

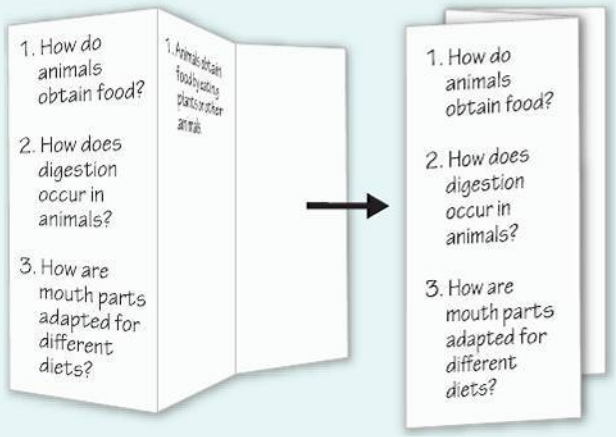
   Hint Review the art of excretory systems on page 659 as you plan your answer.

Foundations for Learning Wrap-Up

Use the Z-fold charts you made when you started the chapter to help you to organize your thoughts about how animals get food and get rid of wastes.

Activity 1 Get together in a group of three. Exchange the Z-fold charts for Lesson 1 with the members of your group. Look at the predicted answers for each key question. Discuss what is right about each answer and what might be missing. Do the same thing for the other lessons of the chapter.

Activity 2 Fold the Z-fold for Lesson 1 so that the predictions on the middle panel are hidden. Turn the Z-fold over. Write the answers for each of the key questions on the back of the Z-fold. Compare your predictions to the answers that you wrote after reading the chapter. Do the same thing for the other lessons of the chapter.



27.1 Feeding and Digestion

Understand Key Concepts

1. Animals that get food by eating decaying bits of plant and animal material are called
   a. herbivores. **c.** detritivores.
   b. carnivores. **d.** filter feeders.

Test-Taking Tip

When you are answering multiple-choice questions, be sure to read all the choices before you choose an answer. One choice may seem right. However, when you read the other choices, you may find that another choice is more correct. For example, consider question 1. Herbivores eat plants, so at first you might think that the answer is **a**. But the question asks about decaying bits of plants, so the correct answer is **c**.

2. Which animal below relies primarily on intracellular digestion?
   a. sponge **c.** dragonfly
   b. clam **d.** earthworm

3. Compare the processes of intracellular and extracellular digestion.

Think Critically

4. **Infer** The skull of a mammal has no sharp canine teeth. The large teeth toward the back of the jaw are very flat. What did this mammal eat?

27.2 Respiration

Understand Key Concepts

5. Most terrestrial insects breathe using a network of structures called
   a. gills. **c.** book gills.
   b. tracheal tubes. **d.** book lungs.

6. For the exchange of carbon dioxide and oxygen, an animal's respiratory surfaces must be
   a. cold. **c.** hot.
   b. dry. **d.** moist.

7. Most fishes exchange gases by pumping water
   a. over their gills. **c.** over their atria.
   b. through their lungs. **d.** through their alveoli.

8. With what respiratory structures do aquatic reptiles and mammals breathe? Why are these structures inconvenient when these animals swim underwater?

Think Critically

9. **Infer** Snails that live on land have a respiratory structure called a mantle cavity. The mantle cavity is often covered with mucus. What might the function of the mucus be?

27.3 Circulation

Understand Key Concepts

10. Most arthropods have
    a. no circulatory system.
    b. an open circulatory system.
    c. a closed circulatory system.
    d. skin gills.

11. In a closed circulatory system, blood
    a. comes in direct contact with tissues.
    b. empties into sinuses.
    c. does not transport oxygen.
    d. remains within blood vessels.

12. Most vertebrates that have gills have a(n)
    a. double-loop circulatory system.
    b. accessory lung.
    c. single-loop circulatory system.
    d. four-chambered heart.

13. Describe the circulatory system of a mammal. Is it open or closed? State the number of loops and the number of heart chambers in the system.

Think Critically

14. **Compare and Contrast** What is the major structural difference between vertebrates that have single-loop circulatory systems and those that have double-loop systems?

27 CHECK Understanding

27.4 Excretion

Understand Key Concepts

15. The amount of salt and water in the body fluids of mammals is controlled by the

a. lungs. **c.** intestine.

b. kidneys. **d.** heart.

16. The elimination of nitrogen-containing wastes by the body is called

a. excretion. **c.** respiration.

b. circulation. **d.** digestion.

17. Why do most animals convert ammonia to urea or uric acid?

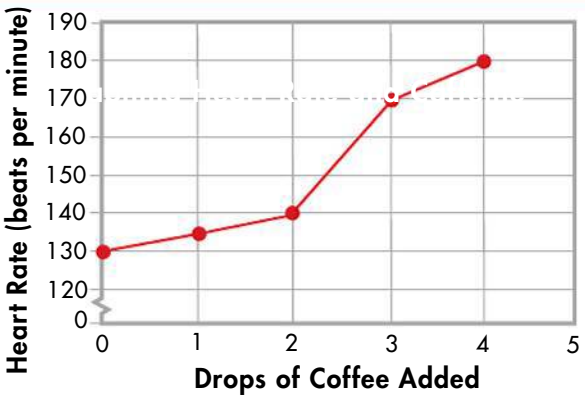
Think Critically

18. **Apply Concepts** Uric acid requires less water to excrete than urea does. How is the production of uric acid an advantage to animals that live on land?

Connecting Concepts

A student conducts an experiment to measure the effect of caffeine on the heart rate of a small pond-water animal called Daphnia. *The results are shown in the graph.*

***Daphnia* Heart Rate and Caffeine**



19. **Interpret Graphs** Describe the effect that caffeine has on the heart rate of *Daphnia*.

20. **Predict** What would be the effect of five or more drops of coffee on the heart rate of *Daphnia*?

solve the CHAPTER MYSTERY

(NEAR) DEATH BY SALT WATER

Luckily, the group that was supposed to pick up the friends came earlier than planned. They took the sick man to the hospital. He was diagnosed with severe dehydration. The doctors gave him water and fluids through an intravenous drip. If he had gone much longer without treatment, he would have died. What had happened? Why didn't his friends have the same problem?

As sailors have known for centuries, humans cannot drink salt water. But why?

Seawater is saltier than human blood and body fluids. Drinking seawater loads the body with extra salt. Human kidneys cannot make urine with salt concentrations high enough to get rid of the salt. The kidneys are then forced to excrete too much water in urine, which lowers the amount of water in blood. The blood becomes thick and cannot pass through capillaries. Cells and tissues begin to dry out. This dehydration can cause fatal kidney failure and heat stroke.

1. **Compare and Contrast** The other group members who did not drink seawater experienced water stress as well. What was going on in their circulatory and excretory systems? Why wasn't their water stress as serious as the water stress experienced by their friend?

2. **Propose a Solution** If you were marooned on an island that had no fresh water, what would be your plan for getting some?

UntamedScience™ Finding out what happened to the college student who drank salt water is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

Standardized Test Prep

Multiple Choice

1. Animals that live on an animal and feed on its body tissues are called
A parasites. **C** herbivores.
B carnivores. **D** detritivores.

2. Examining the teeth of an animal can give information about whether it
A practices intracellular or extracellular digestion.
B is a filter feeder or a detritivore.
C is a nutritional symbiont.
D is a herbivore or a carnivore.

3. Movement of oxygen and carbon dioxide across a respiratory surface requires
A that the respiratory surface be moist.
B active transport by the cells of the respiratory surface.
C alveoli.
D an equal concentration of both gases on both sides of the membrane.

4. In an open circulatory system, blood
A is confined to blood vessels at all times.
B circulates around body tissues.
C exchanges gases with lung alveoli.
D is not required for exchanging gases with body cells.

5. In chordates with four-chambered hearts, there is
A only one loop in the circulatory system.
B mixing of oxygen-rich and oxygen-poor blood.
C partial partition of the ventricle.
D no mixing of oxygen-rich and oxygen-poor blood.

6. Most reptiles excrete wastes in the form of
A urea. **C** uric acid.
B ammonia. **D** toxins.

7. What is a function of the excretory system?
A to supply cells with oxygen and nutrients
B to rid the body of metabolic wastes
C to exchange oxygen and carbon dioxide with the environment
D to break down food

Questions 8–9

A biology student is investigating the relationship between cricket chirping and air temperature. She catches a cricket and places it in a jar. She leaves the jar outside, and each day she counts the number of chirps during a 15-second period. At the same time, she records the outside temperature near the cricket. Her data for a 5-day period are shown below.

Temperature and Cricket Chirping

Day	Number of Chirps in 15 Seconds	Outside Temperature (°C)
Monday	31	23
Tuesday	20	16
Wednesday	12	11
Thursday	29	21
Friday	25	19

8. At which of the following temperatures would a cricket be most likely to chirp 9 times in 15 seconds?
A 10°C **C** 0°C
B 18°C **D** 25°C

9. What can the student conclude from this experiment?
A Crickets cannot chirp more than 31 times in 15 seconds.
B The number of times a cricket chirps decreases when the temperature decreases.
C The number of times a cricket chirps increases when the temperature decreases.
D There is no relationship between the number of times a cricket chirps and temperature.

Open-Ended Response

10. Which types of vertebrates have double-loop circulation and which types have single-loop circulation?

If You Have Trouble With . . .

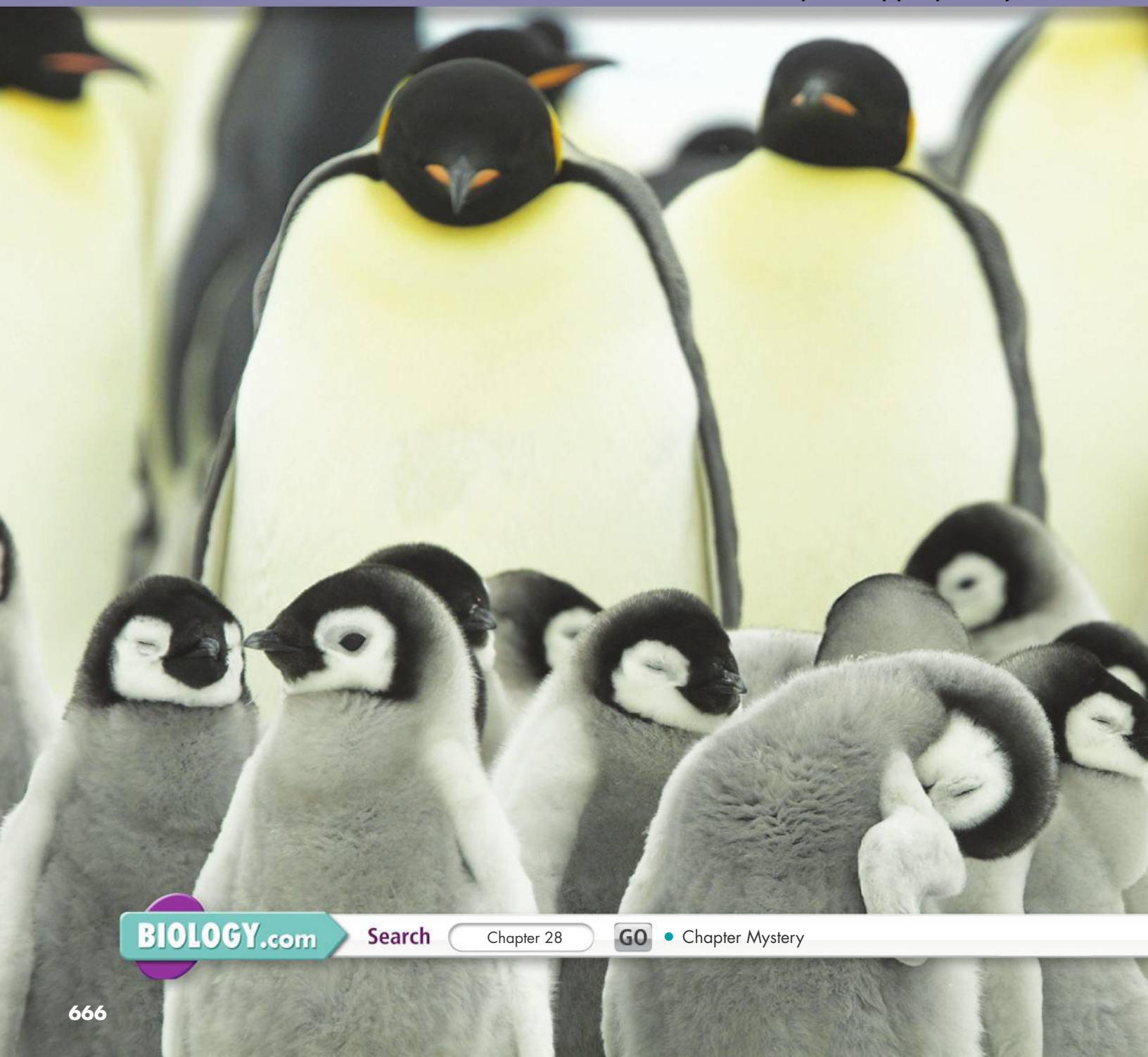
Question	1	2	3	4	5	6	7	8	9	10
See Lesson	27.1	27.1	27.2	27.3	27.3	27.4	27.4	27.3	27.3	27.3

28 Animal Systems II

Big idea

Structure and Function

Q: How do the body systems of animals allow them to collect information about their environments and respond appropriately?



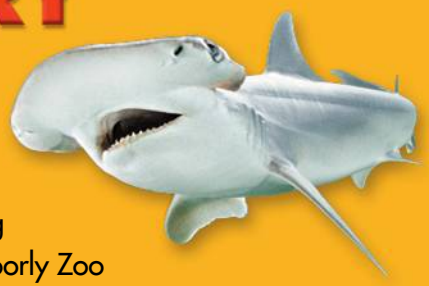
BIOLOGY.com Search Chapter 28 GO • Chapter Mystery

INSIDE:

Thick down feathers keep these young penguins warm. They share their warmth by huddling close together.

- Untamed Science Video
- Flash Card

CHAPTER MYSTERY



SHE'S JUST LIKE HER MOTHER!

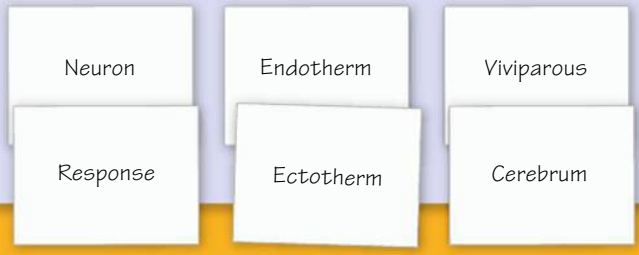
In 2001, a surprising thing happened at the Henry Doorly Zoo in Omaha, Nebraska. A bonnethead shark gave birth to a female baby bonnethead. Workers at the zoo were shocked. For three years, there had been only three bonnethead sharks in the tank where the baby was born. All of these sharks were female.

Some female sharks are able to store sperm for later fertilization. Does this explain how the shark got pregnant?

Read for Mystery Clues As you read the chapter, look for clues that help explain how the baby bonnethead's mother got pregnant. Also, think about how sharks usually reproduce. Think about how that process affects genetic material in the offspring. Then, solve the mystery.

FOUNDATIONS for Learning

Science uses many vocabulary words. These words can help you to understand basic science concepts. Before you read the chapter, write down the vocabulary words on index cards. As you read, write the definitions on the back of the cards. At the end of the chapter are two activities that use these cards to help you to answer the question: How do the body systems of animals allow the animals to collect information about their environments and respond appropriately?



28.1 Response

Key Questions

- ***How do animals respond to events around them?***
- ***What are the trends in nervous system evolution?***
- ***What are some types of sensory systems in animals?***

BUILD Understanding

Preview Visuals Previewing visuals helps you prepare to read and understand the text. Before you read, preview the visual of neural circuits. Take note of any questions you have about it. As you read, try to answer your questions.

In Your Workbook Refer to your workbook for suggestions about how to use a T chart to organize your notes about the visuals in this lesson.

How Animals Respond

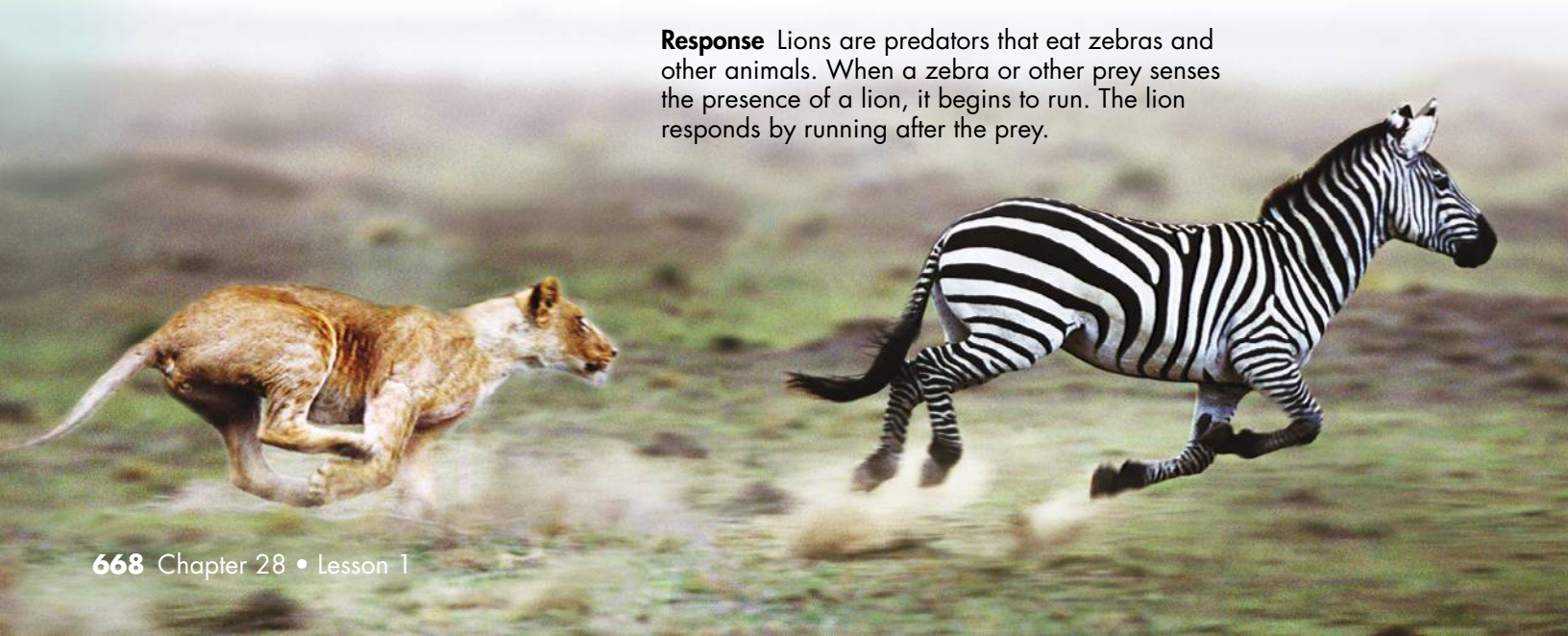
Imagine that you are at a favorite place, such as a beach. The sun feels warm on your face. You hear the waves crashing on the shore. You smell salt air. Now think about how your body experiences the place. Your senses gather information about how it looks, sounds, or smells. Your nervous system organizes this information. Your brain decides how to respond to it.

All animals experience and respond to their environments. Sometimes animals need to catch food. Other times, they need to escape from predators. Most animals have specialized nervous systems that allow them to respond to their environments. Nervous systems are made of specialized nerve cells, called **neurons.** Neurons work together to receive and organize information. Then, they "decide" how to respond.

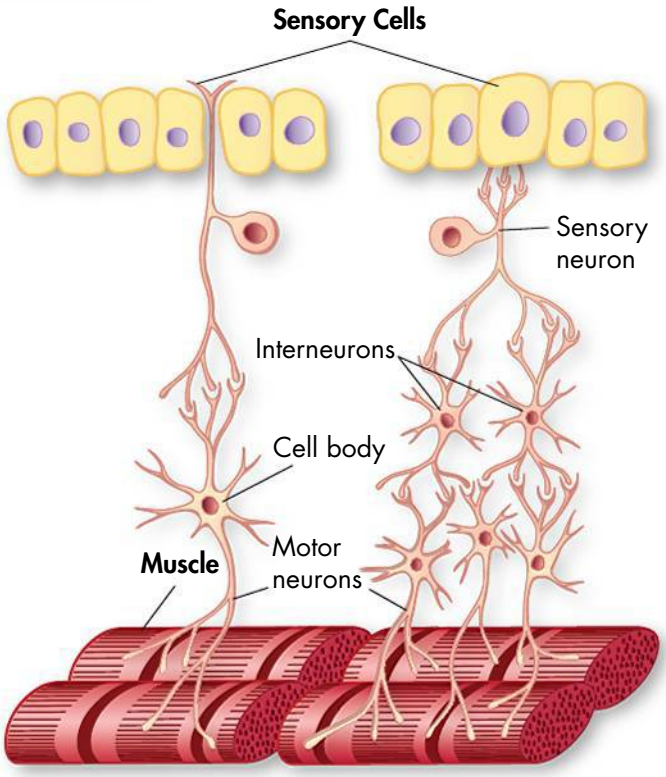
Detecting Stimuli

Information in the environment that causes an organism to react is called a **stimulus** (plural: stimuli). Chemicals, light, heat, and sounds can all be stimuli.

Specialized cells called **sensory neurons** are able to sense stimuli. Each type of sensory neuron responds to a particular stimulus. For example, sensory neurons in the ear sense sounds. Like humans, many other animals also respond to light, taste, sound, odor, temperature, gravity, and pressure. Some animals also have sensory cells that humans do not have. For example, some animals can sense weak electric currents or Earth's magnetic field.



Response Lions are predators that eat zebras and other animals. When a zebra or other prey senses the presence of a lion, it begins to run. The lion responds by running after the prey.



Neural Circuits In simple neural circuits, sensory neurons connect to motor neurons and allow fast but simple responses (left). In more complex neural circuits, interneurons and specialized sensory cells connect sensory neurons to motor neurons (right). Complex neural circuits allow a more complex response.

Processing Information When sensory neurons sense a stimulus, they pass information about the stimulus to other nerve cells. **Interneurons** receive information from sensory neurons and usually pass the information to other neurons. Interneurons process information and determine how an animal responds to stimuli.

The number of interneurons an animal has can determine how flexible and complex an animal's behavior can be. Some invertebrates, such as cnidarians and worms, have very few interneurons. These animals only have simple responses to stimuli. They may swim toward light or toward a chemical stimulus that signals food. They may move away from a stimulus that signals danger.

Vertebrates have more complex nervous systems with larger numbers of interneurons. The vertebrate brain is made of many interneurons, which is why the behaviors of vertebrates can be more complex than the behaviors of most invertebrates.

Responding A specific reaction to a stimulus is called a **response.** Waking up when you hear an alarm is a response. So is licking your lips when you smell good food.

Many body systems work together to allow an animal to respond to a stimulus. The nervous system directs the response to a stimulus. However, the response is usually carried out by cells and tissues that are not nerve cells. A lion's decision to chase prey is carried out by muscle cells that produce movement. Nerve cells called **motor neurons** carry "directions" from interneurons to muscle cells. Other responses to environmental conditions may be carried out by other body systems, such as the respiratory or circulatory systems.

Key Question How do animals respond to events around them? **An animal's body system—including the nervous system and the muscular system—work together to respond to a stimulus.**

BUILD Vocabulary

neuron a nerve cell; specialized for carrying messages throughout the nervous system

stimulus a signal to which an organism responds

sensory neuron a type of nerve cell that receives information from sensory receptors and sends signals to the central nervous system

interneuron a type of neuron that processes information and may send information to motor neurons

PREFIXES

The prefix *inter-* means "between or among." The word *internet* means that information is shared among all connected computers. Interneurons share information between neurons.

Trends in Nervous System Evolution

Nervous systems vary greatly across the animal kingdom. Some are relatively simple. Others are complex. Nervous systems also differ in the amount of specialization and cephalization.

BUILD Vocabulary

response a specific reaction to a stimulus

motor neuron a type of nerve cell that carries directions from interneurons to either muscle cells or glands

ganglion a group of interneurons

cerebrum a part of the brain responsible for voluntary activities of the body; the "thinking" region of the brain

cerebellum a part of the brain that coordinates movement and controls balance

WORD ORIGINS

The Latin word for "brain" is *cerebrum*. The words *cerebrum* and *cerebellum* come from this Latin word. Both the cerebrum and cerebellum are parts of the brain.

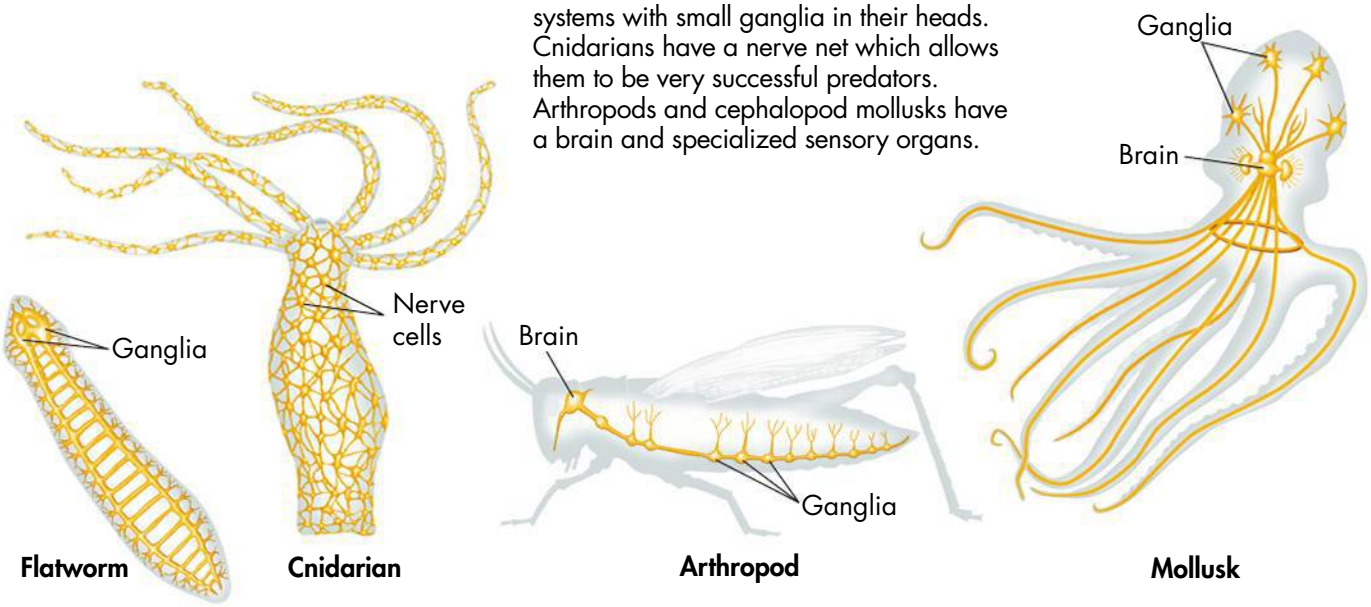
Invertebrates Invertebrate nervous systems range from simple collections of cells to complex systems with many interneurons.

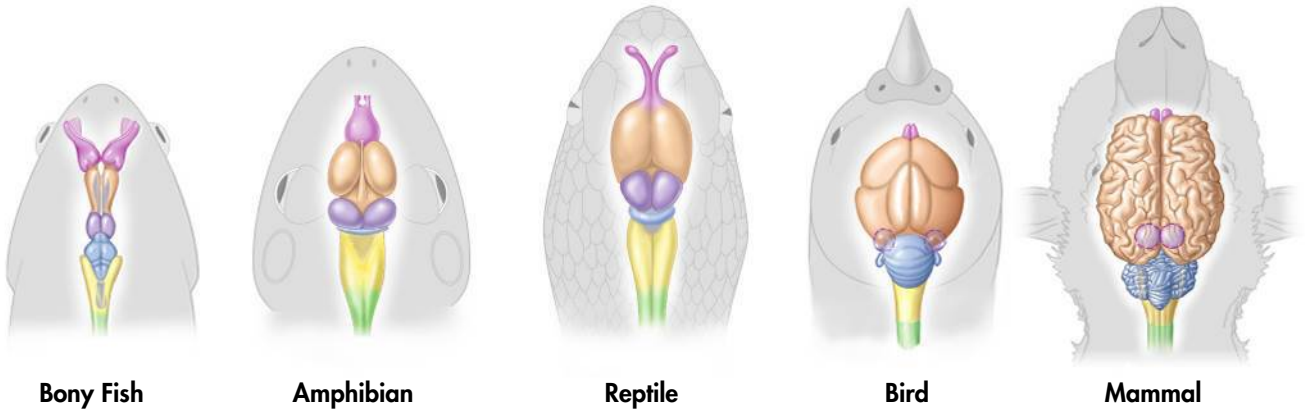
▶ ***Nerve Nets, Nerve Cords, and Ganglia*** Cnidarians, such as jellyfishes, have simple nervous systems called nerve nets. In a nerve net, neurons are connected in a netlike arrangement. Neurons in a nerve net have few specializations. In radially symmetric invertebrates, such as sea stars, some interneurons are grouped together into nerves or nerve cords. These nerves form a ring around the animal's mouth and stretch out along its arms. In still other invertebrates, a number of neurons are grouped together into **ganglia** (singular: ganglion). Interneurons connect with each other in ganglia.

▶ ***"Heads"*** Animals that have bilateral symmetry often show cephalization. Cephalization (sef uh lih ZAY shun) is the concentration of sensory neurons and interneurons into a "head." Certain flatworms and roundworms have some cephalization. Cephalopod mollusks, such as octopi and squid, have more developed cephalization. So do many arthropods. In these animals, interneurons form ganglia throughout the body. The largest ganglia, called cerebral ganglia, are found in the head.

▶ ***Brains*** In some species of invertebrates, cerebral ganglia are organized into a brain. The brains of some cephalopods, such as octopi, allow complex behaviors and learning.

Invertebrate Nervous Systems Invertebrate nervous systems have different amounts of cephalization and specialization. Flatworms have centralized nervous systems with small ganglia in their heads. Cnidarians have a nerve net which allows them to be very successful predators. Arthropods and cephalopod mollusks have a brain and specialized sensory organs.





Vertebrate Brains The cerebrum and cerebellum increase in size from fishes to mammals. The cerebrum is the "thinking" region. In fishes, amphibians, and reptiles, the cerebrum is relatively small. In birds and mammals, the cerebrum is much larger and may contain folds that increase its surface area. The cerebrum is especially large in primates. The cerebellum is also highly developed in birds and mammals.

Chordates

Chordates have complex nervous systems. Nonvertebrate chordates have no heads as adults. However, they still have cerebral ganglia. All vertebrates, on the other hand, have brains. Vertebrate brains are formed from many interneurons that are connected to each other. These interneurons are also connected with sensory neurons and with motor neurons in the head and the rest of the body.

▶ ***Parts of the Vertebrate Brain*** The cerebrum, cerebellum, medulla oblongata, optic lobes, and olfactory bulbs are all parts of the vertebrate brain. The **cerebrum** (SEHR uh brum) is the "thinking" part of the brain. The cerebrum receives sensory information and signals the body to respond. The cerebrum is also involved in learning, memory, and conscious thought. The **cerebellum** (sehr uh BEL um) controls balance and helps to coordinate body movement. The medulla oblongata (mih DUH luh ahb lahn GAHT uh) controls the way that many organs work. Optic lobes help an animal to see. Olfactory bulbs help an animal to smell. Vertebrate brains are connected to the rest of the body by a spinal cord. The spinal cord is a thick collection of nerves that is surrounded by the spine.

▶ ***Vertebrate Brain Evolution*** As vertebrates evolved, their brains became larger and more complex. Vertebrate brains increase in size and complexity from fishes, through amphibians and reptiles, to birds and mammals.

Key Question What are the trends in nervous system evolution?
Invertebrate nervous systems range from simple collections of nerve cells to complex systems that include ganglia and brains. All vertebrate nervous systems include brains. As vertebrates evolved, their brains became larger and more complex.

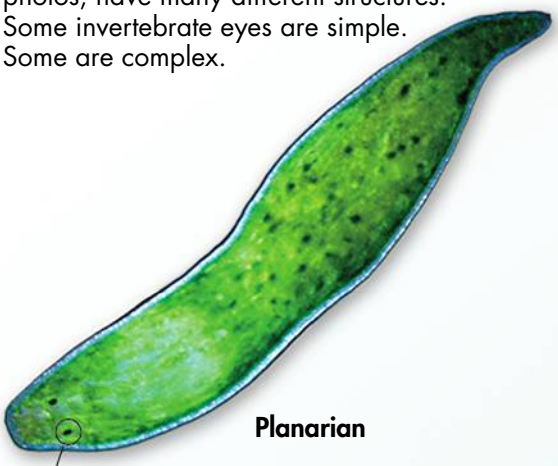
Not Such a Bird Brain The brains of chickadees are very complex. The part responsible for remembering locations gets bigger when the bird stores food in the fall. When winter comes, the tiny bird is able to find hundreds of storage places. In spring, the bird's brain returns to normal size.

Sensory Systems

Animals that have complex nervous systems usually have well-developed sensory systems. Sensory systems in animals range from individual sensory neurons to sense organs.

Invertebrate Sense Organs Many invertebrates have sense organs that can sense light, sound, vibrations, movement, body position, and chemicals in air or water. Invertebrate sense organs range from simple to complex. Flatworms have simple eyespots that sense light. Invertebrates with more cephalization have specialized sensory tissues and complex sense organs. Some cephalopods and arthropods have complex eyes that sense motion and color. Complex eyes can also form images.

Invertebrate Eyes Invertebrate sense organs, such as the eyes shown in these photos, have many different structures. Some invertebrate eyes are simple. Some are complex.



Planarian

Eyespot: Some animals have eyespots, which are groups of cells that can detect changes in the amount of light (LM 50×).

Scallop

Simple Eye: The 40–60 simple eyes of a scallop do not form images. They do, however, detect movement well enough to enable the scallop to escape its predators.

Mosquito

Compound Eye: The compound eyes of arthropods are made up of many lenses that detect minute changes in movement and color but produce less-detailed images than human eyes do.

Squid

Complex Eye: Octopi and squid have eyes as complex as fishes and humans, though their structures differ.

Chordate Sense Organs Nonvertebrate chordates do not have many specialized sense organs. For example, lancelets have a cerebral ganglion with a pair of eyespots that can see light.

Most vertebrates have highly specialized sense organs. Many vertebrates have very sensitive organs of taste, hearing, and smell. Sense organs in some sharks are so sensitive that they can detect 1 drop of blood in 100 liters of water! Many fishes, amphibians, reptiles, birds, and mammals have color vision that is as good as, or better than, the color vision of humans.

All mammal ears have the same basic parts. However, there are big differences in each animal's hearing range. Bats and dolphins can hear sounds at very high frequencies. Elephants can hear sounds at very low frequencies.

Certain fishes can sense weak electric currents in water. Sharks use their "electric sense" to find their way around the oceans. Other species use electric currents to find prey in dark water. Some fishes use electric pulses to communicate with one another. Earth has a magnetic field that some animals can sense. Many birds use this magnetic field to find their way during migration.

Key Question What are some types of sensory systems in animals? **Sensory systems in animals range from individual sensory neurons to sense organs such as eyes or ears. Many vertebrates also have specialized sense organs that are sensitive to tastes, odors, vibrations, or electrical currents.**

Animal	Hearing Range (Hz)
Tree frog	50–4000
Canary	250–8000
Dog	67–45,000
Bat	2000–110,000
Human	30–23,000
Elephant	16–12,000
Bottlenose dolphin	75–150,000

Vertebrate Hearing Many vertebrates can hear sounds that humans cannot hear. Would you expect to be able to hear the highest pitch that a dog can hear? Explain.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. Information in the environment that causes an animal to react is called a _____.
2. Specialized cells called _____ help an animal to detect stimuli.
3. In invertebrates, interneurons are grouped together into structures called _____.
4. The _____ is the "thinking" region of the brain.

Critical Thinking

5. **Explain** What is the job of a motor neuron?
6. **Compare and Contrast** Describe the degree of cephalization shown by cnidarians, flatworms, octopi, and vertebrates.
7. **Infer** What is the general relationship between how complex an animal's nervous system is and how complex its sensory system is?
8. **Write to Learn** The compound eyes of insects sense movement better than they see details. How might sensing movement be more important to an insect than seeing details?

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28.2 Movement and Support

Key Questions

- ***What are the three types of skeletons?***
- ***How do muscles allow movement?***

BUILD Understanding

Compare/Contrast Table As you read this lesson, create a table comparing and contrasting the three types of skeletons.

In Your Workbook Refer to your workbook to learn how to organize your ideas using a compare/contrast table.

Types of Skeletons

How does a salmon swim through the water and then leap into the air? How does a worm burrow into the ground? Animals move in many different ways. Yet, their body structures work in similar ways.

Skeletal Support To move efficiently, all animals must do two things. First, they must create a force. Then, they must use that force to push or pull themselves around. Stiff body parts help an animal move. Legs push against the ground. Wings push against the air. Body parts are made stiff and strong by skeletal systems.

▶ ***Hydrostatic Skeletons*** Some invertebrates, such as cnidarians and earthworms, have hydrostatic skeletons. **Hydrostatic skeletons** are fluid-filled body segments that work together with body cells that contract. A hydra has a hydrostatic skeleton. When a hydra closes its mouth, the cells that circle around its body tighten. This tightening allows the animal to get longer and reach out with its tentacles to grab prey. When the hydra opens its mouth, water flows out. Cells in its body wall contract, causing the hydra to become shorter.

Hydrostatic Skeleton Hydras have hydrostatic skeletons. When a hydra closes its mouth, water that is trapped in its body causes it to get longer. When it opens its mouth, water is released and the hydra becomes shorter.

▶ ***Exoskeletons*** Many arthropods and mollusks have exoskeletons. An **exoskeleton** is a hard covering on the outside of an animal's body. Arthropods have exoskeletons made of a complex carbohydrate called chitin (KY tin). Most mollusks have exoskeletons that are shells made of calcium carbonate.

Exoskeletons have many advantages. Exoskeletons provide coverings that prevent the animals from drying out. They also provide protection from predators.

Exoskeletons also have disadvantages. When an arthropod needs to increase in size, it must break out of its old exoskeleton and grow a new one. This process is called **molting.** Exoskeletons are also relatively heavy. As an arthropod gets larger, its exoskeleton makes up a larger and larger portion of its body weight. This is one reason that some science fiction monsters could never exist. The legs of an elephant-size spider would break under the spider's weight!

▶ ***Endoskeletons*** Echinoderms and vertebrates have endoskeletons. An **endoskeleton** is a hard support system inside the body. Sea stars and other echinoderms have an endoskeleton composed of hard plates made of calcium. Sharks and some other fishes have endoskeletons made of cartilage. Other vertebrates have skeletons made of cartilage and bone.

Endoskeletons allow vertebrates to swim, fly, burrow, walk, crawl, or leap. All of these endoskeletons provide strong, lightweight support. Because endoskeletons are light in relation to the bodies that they support, vertebrates can grow very large.

Endoskeletons have some advantages and disadvantages over exoskeletons. Because an endoskeleton does not surround the body, it cannot protect the animal as an exoskeleton can. However, an endoskeleton can grow as an animal grows. Animals that have endoskeletons do not molt.

Joints Arthropods and vertebrates can move because their skeletons are divided into parts connected by joints. **Joints** are places where parts of a skeleton are held together in ways that allow the parts to move. In vertebrates, bones are connected to each other at joints by strong connective tissues called **ligaments.** Most joints are formed by a combination of ligaments, cartilage, and joint fluid. Joint fluid helps the bones to move without rubbing against each other.

Key Question What are the three types of skeletons? **The three main skeletal systems in animals are hydrostatic skeletons, exoskeletons, and endoskeletons.**

BUILD Vocabulary

hydrostatic skeleton
a skeleton made of fluid-filled body segments that work with cells that contract to allow the animal to move

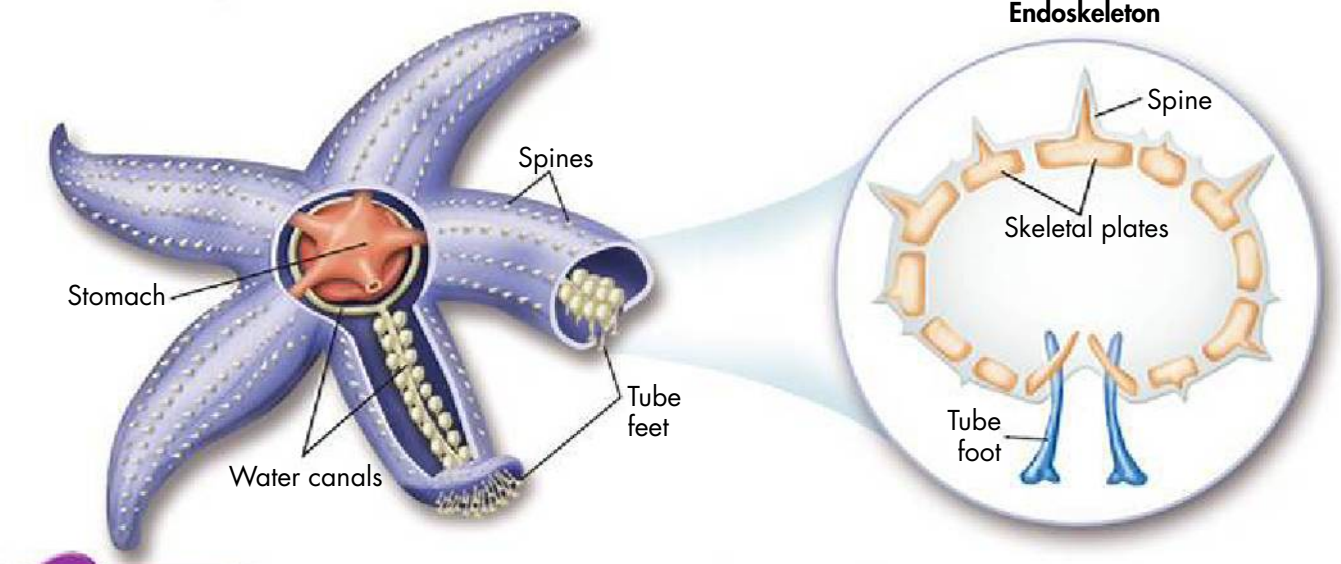
exoskeleton
an external skeleton; a tough outer covering that protects and supports the bodies of many invertebrates

molting
the process of shedding an exoskeleton and growing a new one

endoskeleton
an internal skeleton; a structural support system within the body of an animal

PREFIXES

The prefix *exo-* means "outside." The prefix *endo-* means "within." And *exoskeleton* is outside of the body. An *endoskeleton* is inside, or within, the body.



Endoskeleton Endoskeletons are structural support systems that are inside of the body. Some invertebrates, such as the sea star, have endoskeletons composed of hard plates made of calcium.

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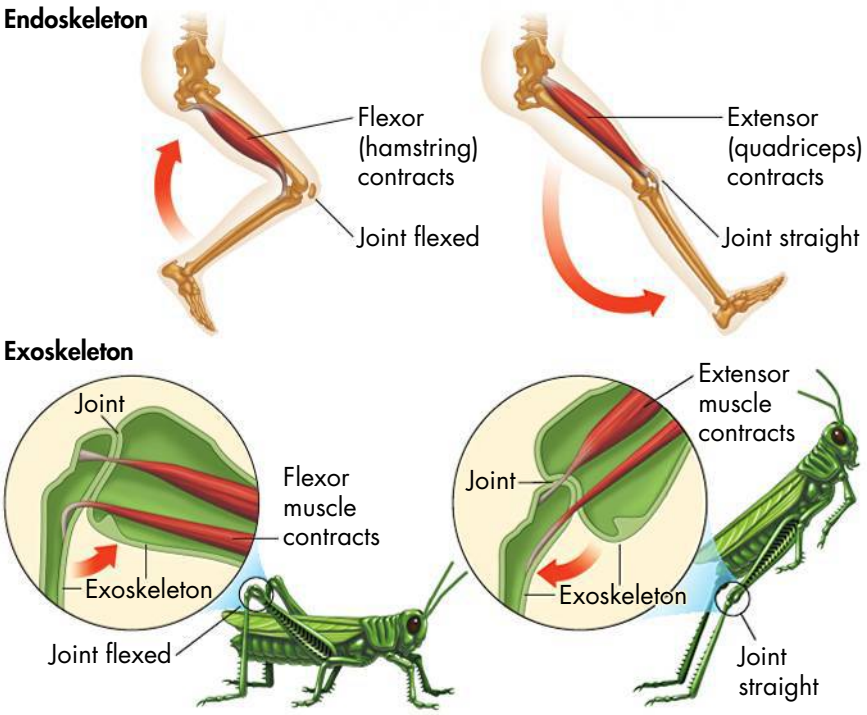
Muscles and Joints These diagrams show how muscles work with both a vertebrate endoskeleton and an invertebrate exoskeleton to bend and straighten joints.



Muscles and Movement

Muscles are tissues that provide the force for movement. Muscles produce force when they contract, or get shorter. Muscles are attached to bone around the joints by tough connective tissue called **tendons.** Tendons pull on bones when muscles contract.

Opposite Muscle Groups

Muscles do not produce force as they relax, or get longer. Muscles can only pull; they cannot push. If muscles only pull in one direction, how do they allow animal bodies to move in many different directions? Usually, muscles work together in pairs or groups that pull parts of the skeleton in opposite directions.

In arthropods, muscles are attached to the inside of the exoskeleton. In vertebrates, muscles are attached around the outside of bones. In both cases, muscle pairs or groups attach across joints. When one muscle group contracts, the joint bends. When the opposite group contracts, the joint straightens.

Vertebrate Muscular and Skeletal Systems

Amazing combinations of bones, muscle groups, and joints have evolved in vertebrates. In many fishes and snakes, muscles are arranged in blocks on opposite sides of the backbone. These muscle blocks contract in waves down the body. This allows the body to move back and forth. In many amphibians and reptiles, the limbs stick out sideways from the body. Sideways motions of the backbone move these limbs forward and backward. In most mammals, the limbs extend straight down from their bodies. Opposite muscle groups allow these limbs to bend.

BUILD Vocabulary

joint
the place where one bone attaches to another bone

ligament
a tough connective tissue that holds bones together in a joint

tendon
a tough connective tissue that connects skeletal muscles to bones

WORD ORIGINS

The word *ligament* comes from the Latin word *ligamentum*, which means "band, tie, or ligature." You can think of a *ligament* as a "band" of connective tissue that "ties" muscles to bones.

Muscular and Skeletal Systems of Vertebrates A wide variety of bones, muscle groups, and joints have evolved in vertebrates. Differently shaped bones and muscles form limbs that are adapted for jumping (frog), flying through the air (hawk), and holding objects (raccoon).

The shapes and positions of bones, muscles, and joints in vertebrates relate to the functions that they perform. Limbs that allow animals to run or jump have very different shapes than limbs that allow animals to fly, swim, or hold objects. Scientists can understand how extinct vertebrates moved by studying the joints of fossil bones and the places where tendons and ligaments once attached to bones.

Key Question How do muscles allow movement? **Muscles work together in pairs or groups that are attached to different parts of a supporting skeleton.**

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The hard covering on the outside of an arthropod is called a(n) _____.
2. The _____ of a sea star is composed of hard plates that are made of calcium.
3. Bands of connective tissue that connect bones at joints are called _____.
4. Bands of connective tissue that connect muscles to bones are called _____.

Critical Thinking

5. **Review** What is a hydrostatic skeleton?
6. **Compare and Contrast** How are exoskeletons and endoskeletons different from each other?
7. **Review** Which two body systems work together to allow animals to move?
8. **Review** What characteristics are common in the skeletons of all vertebrates?
9. **Write to Learn** Suppose that you found a vertebrate fossil and brought it to an expert. The expert showed you that the joint structure of the fossil was similar to the joint structure of a modern squirrel. Infer the kinds of movements for which the animal had been adapted. Explain your inferences in a paragraph.

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28.3 Reproduction

Key Questions

- ***How do asexual and sexual reproduction in animals compare?***
- ***How do internal and external fertilization differ?***
- ***Where do embryos develop?***
- ***How are terrestrial vertebrates adapted to reproduction on land?***

BUILD Understanding

Concept Map As you read lesson 28.3, use concept maps to show how ideas or concepts connect. Use circles to show the most important parts of the concept. Connect the circles with lines.

In Your Workbook Refer to your workbook for suggestions about how to use a concept map to organize the main ideas in this lesson.

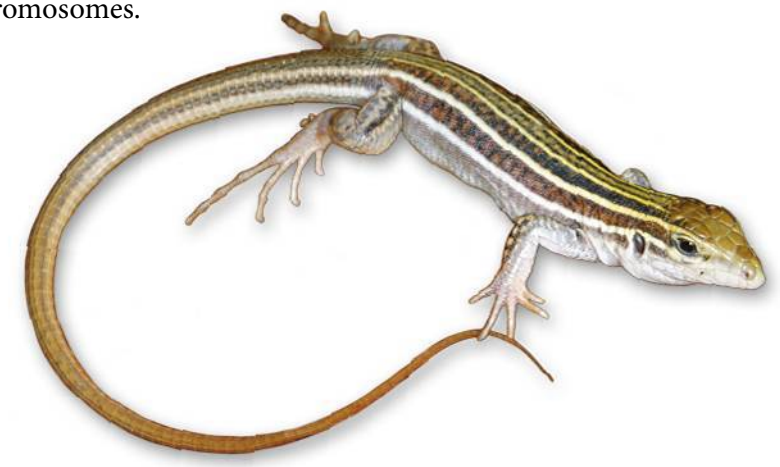
Asexual and Sexual Reproduction

Sexual reproduction can be dangerous. Just ask a male praying mantis, who may be eaten by his mate. Or ask a female deer, who carries young while trying to avoid predators. If sexual reproduction is dangerous, why do most animals engage in it? What are the advantages of sexual reproduction over asexual reproduction?

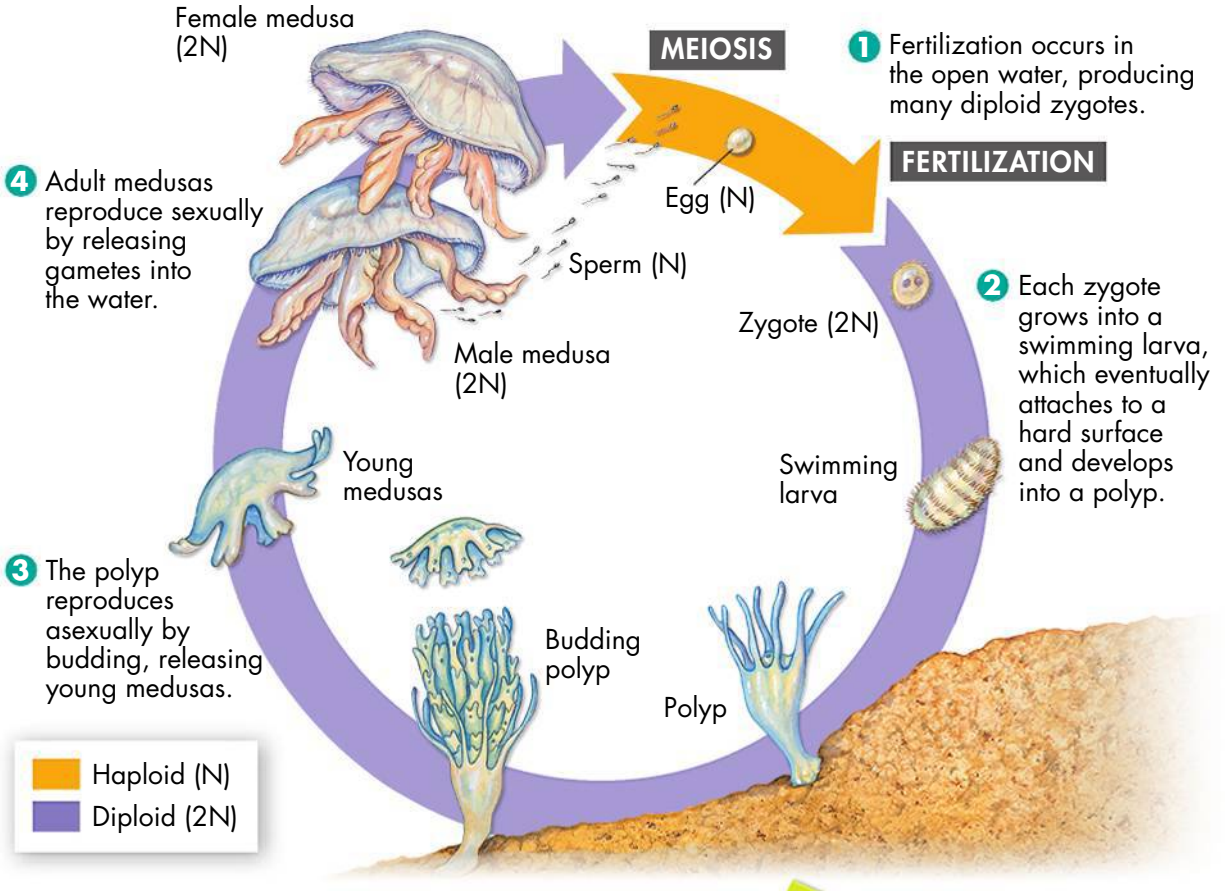
Asexual Reproduction Many invertebrates and a few chordates can reproduce asexually. Animals reproduce asexually in many ways. Some cnidarians divide in two. Some animals reproduce through budding, which produces new individuals from the parent's body wall. Females of some species produce eggs that develop without being fertilized, in a process called parthenogenesis (pahr thuh noh JEN uh sis). Parthenogenesis occurs in some invertebrates, but it is rare in vertebrates.

Asexual reproduction has advantages and disadvantages. Since it requires only one parent, individuals can reproduce quickly. However, since individuals carry DNA from only one parent, offspring have less genetic diversity than individuals that are produced sexually. A population with very little genetic diversity may not be able to adapt if the environment changes.

Sexual Reproduction Sexual reproduction involves meiosis, which produces reproductive cells called gametes. Gametes have half the number of chromosomes found in body cells. Male animals produce small gametes, called sperm, which swim. Females produce larger gametes, called eggs, which do not swim. When an egg and sperm join during fertilization, they produce a zygote that contains a full set of chromosomes.



Parthenogenesis Some whiptail lizard species reproduce only by parthenogenesis.



Sexual reproduction increases genetic diversity in a population by creating individuals with new combinations of genes. Populations with greater genetic diversity are better able to adapt to changing environmental conditions.

In most animals that reproduce sexually, individuals are either male or female. But some species of worms, mollusks, and fishes are hermaphrodites (hur MAF roh dytes). Hermaphrodites can be both male and female at the same time, or they can change from one sex to the other.

Key Question How do asexual and sexual reproduction in animals compare?

In asexual reproduction, one parent produces offspring. In sexual reproduction, gametes from two parents combine to produce offspring. Sexual reproduction increases genetic diversity in a population.

Reproductive Cycles Many invertebrates have life cycles that alternate between sexual and asexual reproduction. For example, many cnidarians alternate between two body forms: polyps and medusas (muh DOO suhs). In jellyfish, polyps produce medusas asexually by budding. The medusas reproduce sexually by releasing eggs and sperm into the water. A fertilized egg grows into a larva that swims freely. The larva may attach to a hard surface and develop into a polyp.

BUILD Connections

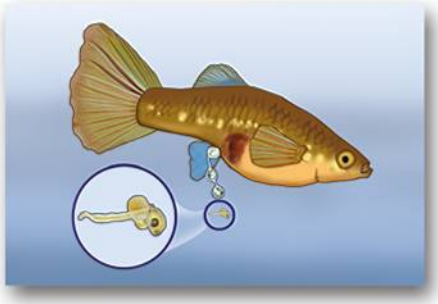
ALTERNATING REPRODUCTIVE CYCLES

The reproductive cycle of this jellyfish alternates between sexual and asexual reproduction. Medusas can reproduce sexually when a female releases eggs and a male releases sperm. Fertilization forms a zygote that grows into a larva. The larva develops into a polyp. The polyp reproduces asexually by budding. This budding forms a new medusa.

External Fertilization One type of external fertilization is spawning. During spawning, females release eggs and males release sperm at the same time.

Embryo Development Embryos may develop inside or outside the body of a parent.

Robin - Oviparous



Guppy - Ovoviviparous

Horse - Viviparous

Internal and External Fertilization

Sperm fertilize eggs during sexual reproduction. Fertilization may take place either outside or inside the body of the female.

External Fertilization Animals that live in water often have external fertilization. External fertilization takes place outside the body of the female. Many invertebrates, such as corals, worms, and mollusks, have external fertilization. These animals release large numbers of eggs and sperm into the water at the same time. Chordates with external fertilization include the nonvertebrate chordates and many fishes and amphibians. They may spawn (release eggs and sperm) in pairs or in small groups.

Internal Fertilization Many aquatic animals and nearly all land animals reproduce by internal fertilization. Internal fertilization takes place inside the body of the female. In some animals, sperm is released into the environment and is later taken in by the female. In other animals, the male has an organ that deposits sperm inside the female.

Key Question How do internal and external fertilization differ? **In external fertilization, eggs are fertilized outside the body of the female. In internal fertilization, eggs are fertilized inside the body of the female.**

Development and Growth

When a fertilized egg starts to divide, it becomes an embryo. The care and protection given to developing embryos varies widely.

Where Embryos Develop Embryos develop either inside or outside the body of a parent.

▶ ***Oviparous Species*** In **oviparous** (oh VIP uh rus) species, embryos develop in eggs outside of the parents' bodies. Most invertebrates, many fishes and amphibians, most reptiles, all birds, and a few mammals are oviparous.

▶ ***Ovoviviparous Species*** In **ovoviviparous** (oh voh vy VIP uh rus) species, embryos develop in eggs inside their mother's body. The young rely on the yolk sac of their eggs for food. Young hatch inside the mother or outside right after the eggs leave her body. Some fishes, including some sharks, are ovoviviparous.

▶ ***Viviparous Species*** In **viviparous** (vy VIP uh rus) species, embryos get nutrients from their mother's body during development. Some insects, sharks, bony fishes, amphibians, and reptiles are viviparous. Most mammals are viviparous.

Key Question Where do embryos develop?
Embryos develop either inside or outside the mother's body.

How Young Develop Most newborn mammals and newly hatched birds and reptiles look like small adults. In other groups of animals, young look very different from adults. As many animals develop, they go through metamorphosis. **Metamorphosis** is a process that causes many changes in the shape and form of a developing animal.

▶ ***Aquatic Invertebrates*** Many aquatic invertebrates have a larval stage that looks nothing like the adult animal. These larvae may float in open water before taking their adult form. Some groups, such as cnidarians, have a single larval stage. Other groups, such as crustaceans, go through several larval stages before becoming adults.

▶ ***Terrestrial Invertebrates*** Insects may go through incomplete or complete metamorphosis. Grasshoppers go through incomplete metamorphosis. In this process, immature forms called **nymphs** (nimfs) look like small adults. However, nymphs do not have adult structures such as wings or reproductive organs. These structures develop as the nymphs molt.

Butterflies go through complete metamorphosis. The larva eats, molts, and grows. After a final molt, it becomes a **pupa** (PYOO puh; plural: pupae). Body changes occur during the pupal stage. The adult that emerges is completely different from the larva.

Metamorphosis in arthropods is controlled by hormones. High levels of a juvenile hormone keep an insect in its larval stage during complete metamorphosis. When hormone levels decrease, the larva becomes a pupa. When hormone production stops, the pupa emerges as an adult.

▶ ***Amphibians*** Amphibians also go through metamorphosis that is controlled by hormones. This metamorphosis changes larvae that live in water into adults that live on land.

BUILD Vocabulary

oviparous
a species in which embryos develop in eggs outside the parent's body

ovoviviparous
a species in which the embryos develop within the mother's body but depend entirely on the yolk sac of their eggs

viviparous
animals that bear live young that are nourished directly by the mother as they develop

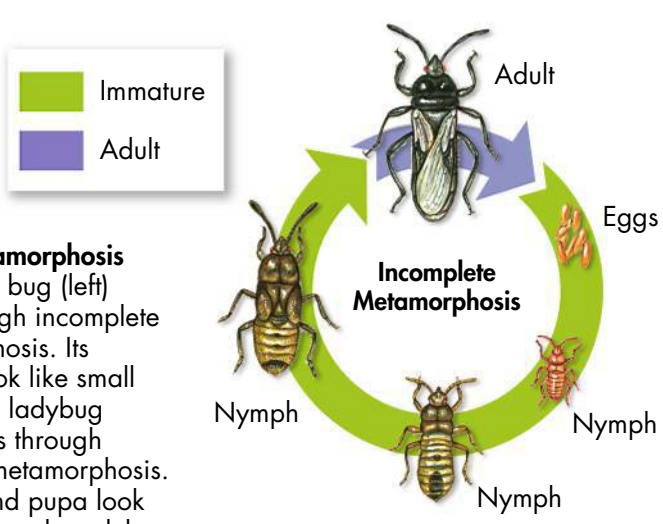
metamorphosis
a process of changes in shape and form of a larva into an adult

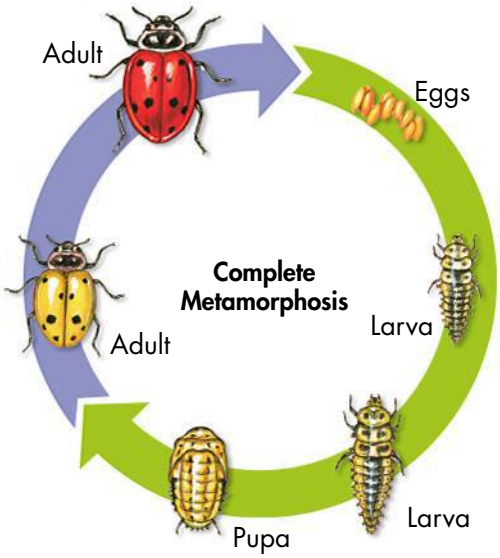
nymph
an immature form of an animal that looks like the adult form but does not have functional sexual organs

pupa
a stage of complete metamorphosis in which the larva develops into an adult

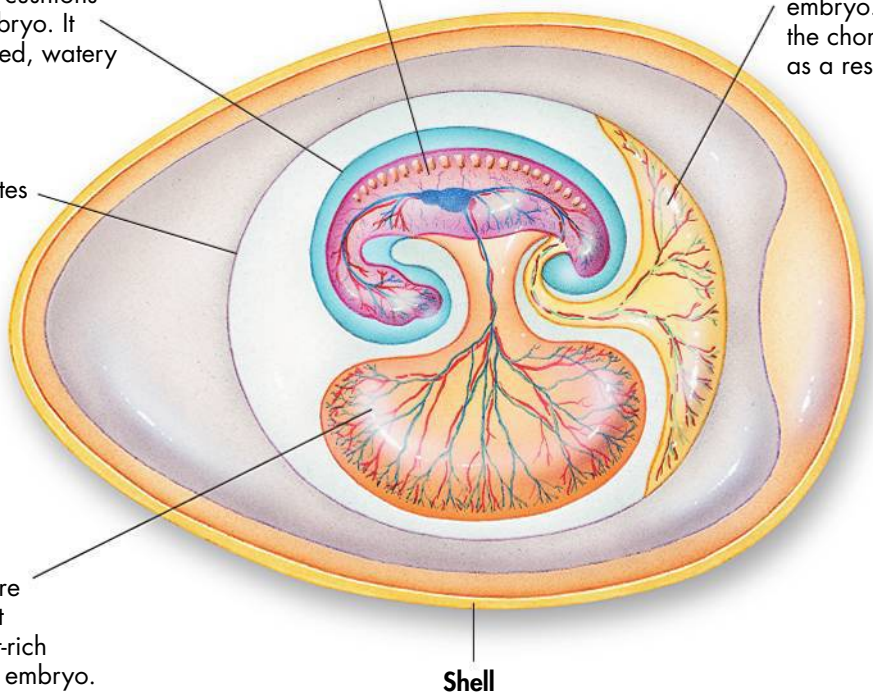
PREFIXES

The prefix *vivi-* comes from a Latin word meaning "alive." The prefix *ovi-* comes from a Latin word meaning "egg." A *viviparous* species is "born alive." An *oviparous* species hatches from an egg. An *ovoviviparous* species develops in an egg inside the mother but may hatch inside the mother to be "born alive."





Insect Metamorphosis The chinch bug (left) goes through incomplete metamorphosis. Its nymphs look like small adults. The ladybug (right) goes through complete metamorphosis. Its larva and pupa look different from the adult.



Amniotic Egg An amniotic egg contains four membranes and an outer shell. Although the egg is waterproof, it allows gases to pass through. The shell of a reptile egg is usually soft and leathery. The shell of a bird egg is usually hard and brittle.

Care of Offspring Some types of animals do not care for their young. Many aquatic invertebrates, fishes, and amphibians release many eggs and then leave. Some young are likely to survive, even though adults do not protect them.

Many animals do care for their young. Some amphibians carry developing young in their mouths, backs, or stomachs. Birds and mammals usually provide parental care. Species that provide long-term parental care usually give birth to fewer young than do species that give no parental care.

BUILD Vocabulary

amniotic egg an egg composed of shell and membranes that create a protected environment in which the embryo can develop out of water

mammary gland a gland in female mammals that produces milk to nourish the young

placenta a specialized organ in placental mammals through which respiratory gases, nutrients, and wastes are exchanged between the mother and developing young

WORD ORIGINS

The word *mammary* comes from the Latin word *mamma*, which means "breast." Mammary glands are found in a female mammal's breast.

Reproduction in Chordates

Chordate reproduction was first adapted for water. Most fishes and amphibians lay eggs that must develop in water. Many terrestrial chordates have eggs that protect the developing embryo on land.

The Amniotic Egg Reptiles, birds, and a few mammals lay amniotic eggs. An **amniotic** (am nee AH tik) **egg** contains four membranes and an outer shell. The amniotic egg is one of the most important vertebrate adaptations to life on land. It provides a protected environment where the embryo can develop without drying out.

Reproduction in Mammals All mammals nourish their young with milk produced by the mother's **mammary glands.** There are three groups of mammals—monotremes, marsupials, and placentals. Each has different adaptations for reproduction.

▶ ***Monotremes*** Like reptiles, monotremes lay soft-shelled, amniotic eggs. Like mammals, young monotremes are fed with milk. Female monotremes secrete milk through pores on the abdomen.

▶ ***Marsupials*** Marsupials are born at such an early stage of development that they are almost embryos. Young marsupials crawl across their mother's fur and attach to a nipple in her pouch, or marsupium (mahr soo pee um). The young remain in the marsupium until they can survive on their own.

▶ ***Placentals*** Placental mammals are named for the placenta. A **placenta** is a specialized organ that allows the exchange of nutrients, gases, and wastes between the young and the mother. The placenta allows the embryo to develop for a long time inside the mother. Placental mammals are born at an advanced stage of development.

Key Question How are terrestrial vertebrates adapted to reproduction on land? **Reptiles, birds, and some mammals have amniotic eggs in which an embryo can develop outside the mother without drying out. Most mammals bear live young and feed their young with mother's milk.**

Mammals Mammal groups include monotremes such as the echidna (top), marsupials such as the kangaroo (below), and placental mammals such as the harp seal (below left).

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. A species in which an embryo gets nutrients from the mother's body during development is called a(n) _____ species.
2. The process in which a developing animal changes in shape and form is _____.
3. Female mammals have _____ that produce milk to nourish their young.

Critical Thinking

4. **Review** Which type of reproduction results in the most genetic diversity?
5. **Review** Define the two types of fertilization.
6. **Compare and Contrast** What is the difference between a nymph and a larva?
7. **Interpret Visuals** In your own words, describe the functions of two of the membranes shown in the art of the amniotic egg.
8. **Write to Learn** Answer the first clue of the mystery. What kind of reproduction in vertebrates can produce offspring from only one parent?

MYSTERY CLUE

The females in the tank had not had contact with a male for three years. And female bonnetheads do not store sperm for longer than five months. So what happened? (Hint: See p. 678.)

BIOLOGY.com Search Lesson 28.3 GO • Lesson Assessment

28.4 Homeostasis

Key Questions

Why is the interdependence of body systems essential?

How do animals control their body temperature?

BUILD Understanding

Venn Diagram A Venn diagram is a useful tool for comparing two topics. Draw a Venn diagram to compare and contrast the ways that ectotherms and endotherms control body temperature.

In Your Workbook Refer to your workbook to learn how to fill in a Venn diagram.

Interrelationships of Body Systems

A herd of wildebeests moves across Africa's Serengeti Plain. The land is dusty and dry, so the herd is heading toward greener pastures. They move mechanically, so that their steps use as little energy as possible. Because they have not eaten in a long time, their bodies break down fat for energy. Their bodies also conserve water by producing very little urine. To survive the difficult journey, body systems work to keep internal conditions as constant as possible.

Recall that the word *homeostasis* is used to describe stable conditions inside the body. Homeostasis is necessary for an animal's survival. Animal cells must be supplied with glucose for energy. Cells must have enough water and be able to get rid of wastes. The cells of some animals must be kept at a constant temperature. Homeostasis must not fail, not even during dry conditions, extreme hunger, extreme heat, or extreme cold. If homeostasis fails, the animal could die.

All body systems work together to maintain homeostasis. Many body systems work closely with the circulatory system. After the respiratory system takes in oxygen, the circulatory system delivers the oxygen to cells. After the digestive system breaks food down into nutrients, the circulatory system delivers those nutrients to cells. The circulatory system collects wastes from body tissues. It then delivers these wastes to the lungs and kidneys of the excretory system.

The muscular and nervous systems work with other systems to maintain homeostasis. Muscles help to move food through the digestive system. The nervous system directs these muscle movements.

Interrelationships of Body Systems All body systems must work together to keep animals like these migrating wildebeests alive.

Fighting Disease The controlled environment inside an animal's body is a comfortable place for both body cells and unwanted invaders. Pathogens can use oxygen and nutrients in the body to grow and reproduce. If pathogens are not destroyed, they may cause disease by harming the function of one or more body systems. Most animals have an immune system that can recognize "self" and "other." Once the immune system identifies the "others" in the body, it can attack the invaders and restore homeostasis.

Chemical Controls All vertebrates and many invertebrates have an endocrine system that controls many body processes. **Endocrine glands** control body activities by releasing chemicals called hormones into the blood. Hormones are carried by the blood to the organs that they control. Some hormones control growth and development.

Mammals have hormones that control the way that the body stores energy. Other hormones control the amount of water in the body. Still others control the amount of calcium in bones.

Key Question Why is the interdependence of body systems essential? **All body systems work together to maintain homeostasis.**

Body Temperature Control

Control of body temperature is important for homeostasis. Many body functions are influenced by temperature. Muscles cannot work well if they are too cold or too hot. Cold muscles contract slowly, making an animal slow to react. Muscles that are too hot may get tired easily.

An animal must do three things to control body temperature. First, the animal must find a source of heat. Second, it must find a way to conserve heat when temperatures in the environment are too cold. Third, it must find a way to get rid of extra heat when temperatures in the environment are too hot. An animal is called an ectotherm or an endotherm, based on the way that it can control body temperature.

Ectotherms An **ectotherm** is an animal that usually depends on sources of heat outside of its body to control its body temperature. Invertebrates, fishes, and amphibians are ectotherms. So are most reptiles.

Ectotherms have low metabolic rates when resting, so their bodies do not create much heat. When these animals are active, their muscles can create heat. However, most ectotherms do not have much body insulation. Therefore, they quickly lose heat to the environment.

Most ectotherms control body temperature by absorbing heat from the environment or losing heat to the environment. For example, a lizard may lie in the sun on a cool morning to absorb heat. In the afternoon, the lizard may raise its body off of a hot surface—in a process called "stilting"—in order to lower its body temperature. Ectotherms often use underground burrows to escape from extreme temperatures. On hot, sunny days, they can use the burrow to cool off. On cold nights, they can use the same burrow to conserve their body heat.

BUILD Vocabulary

endocrine gland
a gland that releases its secretions (hormones) directly into the blood, which carries these secretions to other areas of the body

ectotherm
an animal whose body temperature is determined mainly by the temperature of its environment

endotherm
an animal whose body temperature is regulated, at least in part, using heat created within its body

WORD ORIGINS

The prefix *ecto-* comes from the Greek word *ektos*, which means "outside." The suffix *–therm* comes from the Greek word *thermos*, which means "hot." An ectotherm gets its heat from the outside. In other words, it cannot make heat within its own body.

Ectotherm The shovel-snouted lizard is an ectotherm that lives in the Namib Desert in Africa. This desert is one of the hottest places on Earth. The lizard controls its body temperature by stilting—raising its body off of the hot sand by performing a kind of push-up.

INQUIRY into Scientific Thinking

GUIDED INQUIRY

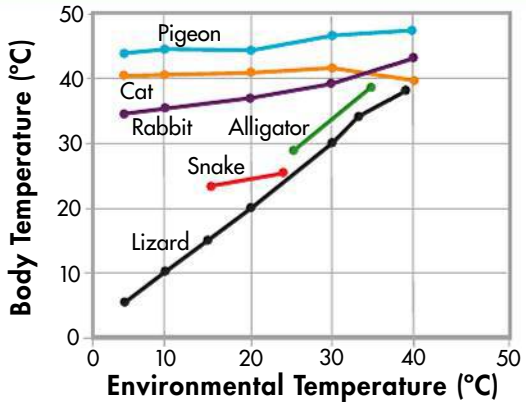
Comparing Ectotherms and Endotherms

An ectotherm is an animal that controls its body temperature mainly by using heat from outside its body. An endotherm is an animal that controls its body temperature mostly by using heat that is produced within its body. The graph shows the internal body temperatures maintained by several ectotherms and endotherms at different environmental temperatures.

1. Interpret Graphs Which animal has the highest body temperature when the environmental temperature is between 0°C and 10°C? Which has the lowest body temperature under these conditions?

2. Infer Which animals represented in the graph are ectotherms? Which are endotherms? Explain your answers.

Temperature Control in Chordates



3. Predict If these animals lived in your area, would you expect all of them to be equally active year-round? Why or why not?

In Your Workbook Get more help for this activity in your workbook.

Endotherm Many endotherms, such as this dingo, pant when they are very warm. Panting allows moisture in the mouth and respiratory tract to evaporate. This process helps to cool the blood.

Endotherms An **endotherm** is an animal whose body temperature is controlled, at least in part, by using heat that is produced by its own body. Endotherms have high metabolic rates that create heat, even when the animals are resting. All birds and mammals are endotherms.

Endotherms have different ways of conserving heat. Birds conserve body heat by fluffing out their feathers. Mammals use a combination of body fat and hair as insulation.

Endotherms have different ways of getting rid of extra heat. Some birds and most mammals get rid of heat by panting. When an animal pants, it breathes with its mouth open and its tongue sticking out. Heat flows out of the body as water evaporates from the mouth and tongue. Humans sweat to reduce their body temperature. As sweat evaporates, it removes heat from the skin. It also removes heat from the capillaries just below the surface of the skin. As warm blood flows into these cooled capillaries, the blood loses heat.

Comparing Ectotherms and Endotherms There are advantages and disadvantages to being an endotherm. Endotherms can move around on cool nights or in cold weather, because they create and conserve body heat. But it takes a lot of fuel to feed the high metabolic rate that makes heat. The amount of food that it takes to keep a single cow alive would be enough to feed ten cow-size lizards!

There are also advantages and disadvantages to being an ectotherm. It is more energy efficient to be an ectotherm in a warm environment. However, large ectotherms can get into trouble if it gets very cold at night or if the environment stays cold for long periods of time. It takes a long time for an animal to warm up in the sun after a cold night. That is one reason why most large lizards and amphibians can only live in tropical or subtropical areas.

Evolution of Temperature Control The first animals were ectotherms. When did endothermy evolve? Current evidence suggests that endothermy evolved at least twice in vertebrates. It evolved once in the line of ancient reptiles that led to birds. It evolved again in the line of ancient reptiles that led to mammals.

Key Question How do animals control their body temperature? **An ectotherm controls body temperature by exchanging heat with the environment. An endotherm controls body temperature by using heat made by its own body.**

Endotherm Insulation Birds such as this northern cardinal use feathers to stay warm. When a bird gets cold, its fluffy undercoat of down feathers stands up. Body heat becomes trapped in the air spaces between the feathers.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. Structures that release hormones into the blood are called _____.
2. An animal that controls its body temperature mainly by absorbing heat from its surroundings is a(n) _____.
3. An animal that controls its body temperature mainly by producing its own heat is called a(n) _____.

Critical Thinking

4. **Explain** Give an example of how multiple body systems work together to maintain homeostasis.
5. **Compare and Contrast** Why must an endotherm eat more food than an ectotherm of the same size?
6. **Form a Hypothesis** Birds and mammals live in both warm and cold areas. Most reptiles and amphibians live in relatively warm areas. Form a hypothesis that would explain this difference.
7. **Write to Learn** Think about what you do during an average day. Write a paragraph describing how your body maintains homeostasis during some of your activities.

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Pre-Lab: Comparing Bird and Mammal Bones

Problem Is the density of an animal's bones related to the way the animal moves?

Materials cross-sections of chicken, duck, and cow bones; hand lens; small chicken, duck, and cow bones; balance

Lab Manual Chapter 28 Lab

Skills Focus Form a Hypothesis, Design an Experiment, Measure

Connect to the Big idea In order to move, an animal must generate physical force and apply this force against the air, the water, or the ground. The force is generated by the contraction of muscles. In vertebrates, the muscles are attached to bones. The joints that connect bones bend or straighten when groups of muscles contract. There is a close link between the structure of an animal's skeletal and muscular systems and how the animal moves. In this lab, you will investigate whether there is a similar link between the density of bones and how an animal moves.

Background Questions

a. **Review** What type of skeleton do vertebrates have? List one advantage of this type of skeleton.

b. **Explain** Why are pairs of muscles or two different groups of muscles needed to bend and straighten a joint?

c. **Apply Concepts** Why do you think humans have only 4 bones in each arm and shoulder, but 27 bones in each wrist and hand? (**Hint:** Compare the movement of your arm and your hand when you button a shirt.)

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Compare and Contrast** Compare the type of data you will collect in Part A to the type of data you will collect in Part B.

2. **Predict** How might looking at cross sections of bones help you form a hypothesis about the relative density of the bones?

3. **Design an Experiment** Will you need to use samples with the same mass in Part B? Why or why not?

BIOLOGY.com Search Chapter 28 GO

Visit Chapter 28 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Join the Untamed Science crew as they interview experts to learn more about how the sex of offspring is determined in some animals.

Art in Motion Watch an animation that shows the motion of joints in both exoskeletons and endoskeletons.

Art Review Review your understanding of vertebrate brains.

InterActive Art Look at the structure and function of the water vascular system in a sea star.

28 CHAPTER Summary

28.1 Response

- When an animal responds to a stimulus, its body systems—including its nervous system and muscular system—work together to create a response.
- Animal nervous systems show different degrees of cephalization and specialization. Invertebrate nervous systems range from simple collections of nerve cells to complex systems that include ganglia and brains. All vertebrate nervous systems include brains. As vertebrates evolved, their brains became larger and more complex.
- Sensory systems in animals range from individual sensory neurons to sense organs, such as eyes and ears. Many vertebrates also have sense organs that are sensitive to tastes, odors, vibrations, or electrical currents.

neuron (p. 668)
stimulus (p. 668)
sensory neuron (p. 668)
interneuron (p. 669)
response (p. 669)
motor neuron (p. 669)
ganglion (p. 670)
cerebrum (p. 671)
cerebellum (p. 671)

28.2 Movement and Support

- Animals have three main kinds of skeletal systems: hydrostatic skeletons, exoskeletons, and endoskeletons.
- In many animals, muscles work together in pairs or groups that are attached to different parts of a supporting skeleton.

hydrostatic skeleton (p. 674)
exoskeleton (p. 674)
molting (p. 675)
endoskeleton (p. 675)
joint (p. 675)
ligament (p. 675)
tendon (p. 676)

28.3 Reproduction

- Asexual reproduction requires only one parent, so individuals may reproduce quickly. However, offspring that are produced asexually have less genetic diversity than do offspring that are produced sexually. Sexual reproduction increases genetic diversity in a population by creating individuals with new combinations of genes.
- In internal fertilization, eggs are fertilized inside the body of the egg-producing individual. In external fertilization, eggs are fertilized outside the body of the egg-producing individual.
- Animals may be oviparous, ovoviviparous, or viviparous.
- Reptiles, birds, and a few mammals have evolved amniotic eggs in which an embryo can develop without drying out. Different mammals reproduce and develop in different ways. However, all mammals feed their young with mother's milk.

oviparous (p. 680)
ovoviviparous (p. 680)
viviparous (p. 680)
metamorphosis (p. 681)
nymph (p. 681)
pupa (p. 681)
amniotic egg (p. 682)
mammary gland (p. 682)
placenta (p. 683)

28.4 Homeostasis

- All body systems work together to maintain homeostasis.
- Most reptiles, invertebrates, fishes, and amphibians are ectotherms. Most ectotherms control body temperature mainly by getting heat from the environment or losing heat to the environment. Birds and mammals are endotherms. Endotherms have high metabolic rates that create heat even when they are resting.

endocrine gland (p. 685)
ectotherm (p. 685)
endotherm (p. 686)

28 CHECK Understanding

Assess the Big idea Structure and Function

Write an answer to the question below:
Q: How do the body systems of animals allow them to collect information about their environments and respond appropriately?

Constructed Response

Write an answer to each of the numbered questions below. The answer to each numbered question should be one or two paragraphs long. To help you begin, read the **Hints** below the questions.

1. **How does a cat's nervous system sense and respond to a mouse?**

   Hint What kinds of sense organs do cats have that allow them to sense stimuli such as movements, sounds, and vibrations?

   Hint Think about how the neurons in a cat's nervous system work together to sense and respond to stimuli in the environment.

2. **The cat runs after the mouse to try to catch it. Describe how a cat is able to run.**

   Hint List the body systems that work together to allow an animal to move.

   Hint Look at the diagram that shows how muscles and joints work together.

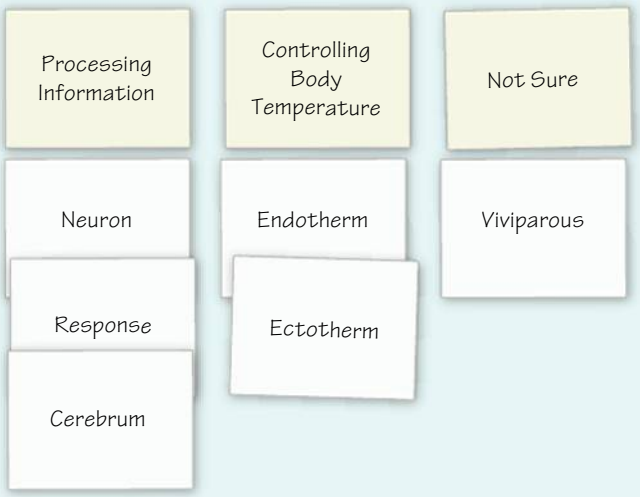
3. **A cat can spend time outside on a warm summer day and a cool summer night. How does the cat control its body temperature?**

   Hint Cats are endotherms.

Foundations for Learning Wrap-Up

Use the index cards that you have made to help you review the vocabulary in this chapter.

Activity 1 Take a stack of blank index cards. Write the main topics from this chapter on these cards. (Green headings are main topics.) Write Not Sure on one of the cards. Put the topic cards on a table. Arrange the vocabulary cards in groups under each topic. Put any cards that you are not sure about in the Not Sure category. Get together with a classmate and talk about how each word fits into its category. Help each other to put the Not Sure cards under the right topics.



Activity 2 You can play a game to review the vocabulary words in this chapter. Get together with three of your classmates and divide yourselves into two teams. Shuffle all of the vocabulary cards and deal them out, face down, to both teams.

Set a timer for 2 minutes. When the timer starts, draw one of your vocabulary cards. Say words or sentences that relate to this vocabulary word to try to get your partner to say the word. If you accidentally say the vocabulary word, throw that card into a discard pile, so you won't get credit for it.

After 2 minutes, let the other team try. Play the game until one team is out of cards. At that point, the team with the most completed cards wins.

28.1 Response

Understand Key Concepts

1. An animal's reaction to a stimulus is called a
   - **a.** response.
   - **b.** ganglion.
   - **c.** neuron.
   - **d.** trigger.
2. The simplest nervous systems are called
   - **a.** cephalopods.
   - **b.** motor neurons.
   - **c.** nerve nets.
   - **d.** sensory neurons.
3. What kinds of environmental stimuli are some animals able to sense that humans cannot sense?

Test-Taking Tip

Rephrase the Question When you read a question that you do not understand, try to put the question in your own words. If it is written as a statement, make it into a question. Using simpler words and changing the way a question is written may help you to figure out how to answer a hard question.

Think Critically

4. **Compare and Contrast** List the three major types of neurons and compare their roles.
5. **Apply Concepts** Suppose a pet dog is having trouble coordinating its movements. Why might a veterinarian X-ray the dog's brain?

28.2 Movement and Support

Understand Key Concepts

6. Which of the following animals uses a hydrostatic skeleton to move?
   - **a.** arthropod
   - **b.** sponge
   - **c.** fish
   - **d.** earthworm
7. Muscles generate force
   - **a.** only when they get longer.
   - **b.** only when they get shorter.
   - **c.** when they get longer or shorter.
   - **d.** all the time.
8. How do a fish's muscles work when the fish swims?

Think Critically

9. **Compare and Contrast** List one advantage and one disadvantage of exoskeletons and endoskeletons.
10. **Infer** The largest land animals are vertebrates. Why are insects unable to grow as large as vertebrates?

28.3 Reproduction

Understanding Key Concepts

11. A species that has eggs that develop outside the mother's body is
    - **a.** oviparous.
    - **b.** viviparous.
    - **c.** ovoviviparous.
    - **d.** nonviparous.
12. What organ in many female mammals allows the exchange of gases, nutrients, and wastes between the mother and the developing young?
    - **a.** marsupium
    - **b.** amniotic egg
    - **c.** mammary gland
    - **d.** placenta
13. How did the evolution of the amniotic egg allow many animals to live on land?

Think Critically

14. **Compare and Contrast** Describe the differences between a newborn placental mammal and a newborn marsupial.
15. **Predict** Why would you expect most species that use external fertilization to reproduce in water?

28 CHECK Understanding

28.4 Homeostasis

Understand Key Concepts

16. The control of the conditions inside an animal's body is called
- **a.** homeostasis.
- **b.** ectothermy.
- **c.** endothermy.
- **d.** reactivity.

17. The main source of heat for an ectotherm is
- **a.** its high rate of metabolism.
- **b.** the environment.
- **c.** its own body.
- **d.** its food.

18. What does the immune system do?

Think Critically

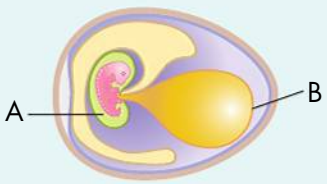
19. **Apply Concepts** What two body systems work together to deliver hormones to the organs that they affect? Describe how this interaction takes place.

20. **Apply Concepts** Describe how the circulatory system helps maintain stable conditions inside the body.

21. **Relate Cause and Effect** Identify two ways in which endotherms conserve body heat.

Connecting Concepts

Use the diagram to answer questions 22 and 23.



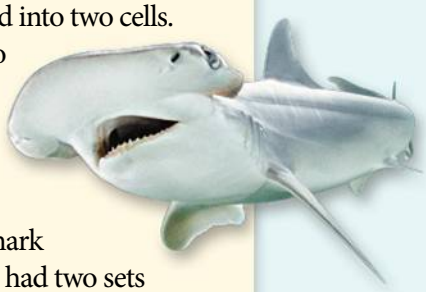
22. **Intrepret Visuals** What does the membrane labeled A do?

23. **Intrepret Visuals** What is membrane B? What does this membrane do?

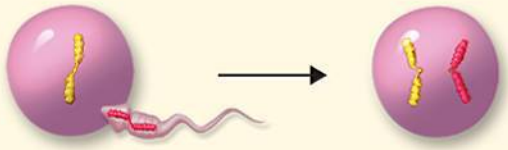
solve the CHAPTER MYSTERY

SHE'S JUST LIKE HER MOTHER!

The baby bonnethead had been created by automictic parthenogenesis. In this process, the mother's unfertilized egg divided into two cells. These two cells came together to form a zygote with two sets of chromosomes that were exactly the same. (See below.) The identical nature of the chromosomes made the baby shark homozygous for every trait. She had two sets of alleles that were exactly the same.



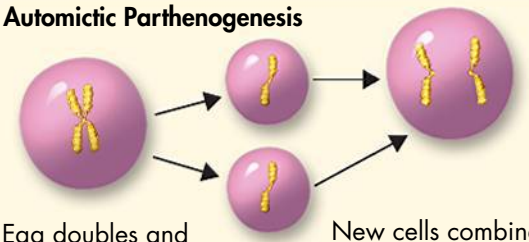
Normal Fertilization



Egg is fertilized with sperm.

Baby shark has one set of chromosomes from each parent.

Automictic Parthenogenesis



Egg doubles and divides its genetic material.

New cells combine. Baby shark has two sets of identical chromosomes, both from the mother.

1. **Apply Concepts** Explain why the baby shark was not a clone, or exact genetic copy, of its mother. (**Hint:** The mother was conceived by sexual reproduction.)

UntamedScience™ **Never Stop Exploring Your World.** Finding a solution to what happened in the shark tank is just the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

Standardized Test Prep

Multiple Choice

1. What part of a vertebrate's brain is the "thinking" region?
- **A** olfactory bulb
- **B** cerebellum
- **C** cerebrum
- **D** medulla oblongata

2. Neurons that receive and send information from and to other neurons are called
- **A** ganglia.
- **B** motor neurons.
- **C** sensory neurons.
- **D** interneurons.

3. The skeleton of a shark is composed primarily of
- **A** bone.
- **B** vertebrae.
- **C** cartilage.
- **D** tendons.

4. Joints between bones of the human skeleton are held together mostly by
- **A** tendons.
- **B** muscles.
- **C** ligaments.
- **D** skin.

5. In oviparous species, embryos
- **A** develop internally.
- **B** obtain nutrients directly from the mother's body.
- **C** obtain nutrients from the external environment.
- **D** develop outside of the body.

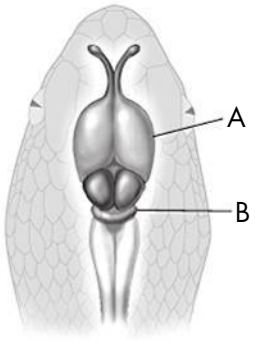
6. Most animals reproduce sexually by producing
- **A** buds.
- **B** clones.
- **C** haploid gametes.
- **D** diploid gametes.

7. Maintaining homeostasis in multicellular organisms requires
- **A** a properly functioning heart.
- **B** a nervous system.
- **C** hormones.
- **D** all body systems working together.

8. Which of the following are endothermic?
- **A** fish and amphibians
- **B** mammals and birds
- **C** reptiles and mammals
- **D** all vertebrates

Questions 9–10

Study the illustration of a reptile brain and answer questions 9 and 10.



9. What is the name of the structure labeled A?
- **A** cerebrum
- **B** optic lobe
- **C** cerebellum
- **D** olfactory bulb

10. What are some functions of the structure labeled B?
- **A** vision
- **B** control of internal organ functions
- **C** connection of the brain to the rest of the body
- **D** coordination of movement and control of balance

Open-Ended Response

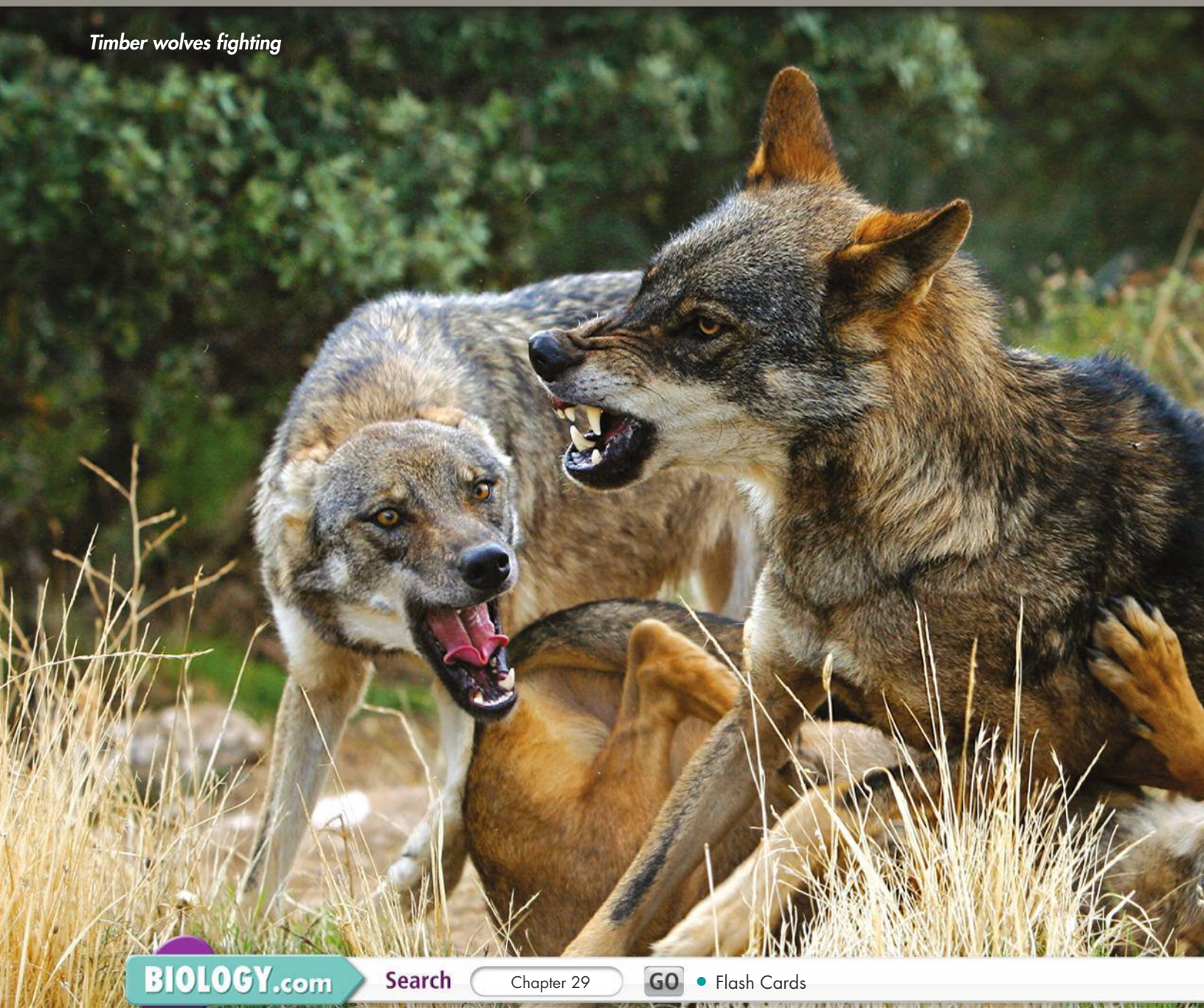
11. Why can't muscles function individually?

If You Have Trouble With . . .											
Question	1	2	3	4	5	6	7	8	9	10	11
See Lesson	28.1	28.1	28.2	28.2	28.3	28.3	28.4	28.4	28.1	28.1	28.2

29 Animal Behavior

Big idea **Evolution**

Q: How do animals interact with one another and their environments?



Timber wolves fighting

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INSIDE:

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

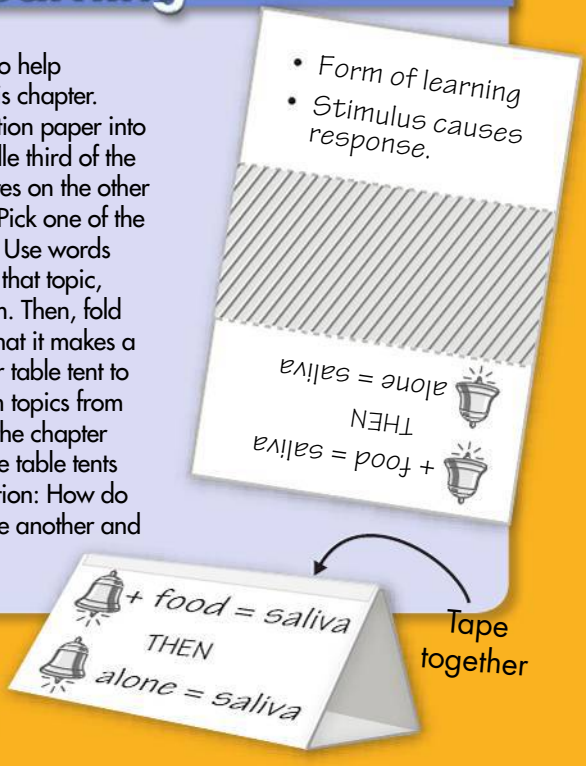
ELEPHANT CALLER ID?

It is a hot, dusty afternoon in Africa's Etosha National Park. A group of elephants walks toward a watering hole. They begin to drink and splash around. Suddenly, they freeze. One elephant places her trunk flat on the ground. The tip of her trunk points toward her feet. Soon, the elephants clump together, pushing their young calves into the center of the group. Some of the elephants place weight on the front of their feet. Most of them keep their ears flattened against their heads. The group moves slowly away from the watering hole.

Read for Mystery Clues People who are watching the elephants cannot see or hear anything that could have scared the group. What are these elephants doing and why? As you read this chapter, look for clues that explain the behavior of this elephant group. Then, solve the mystery.

FOUNDATIONS for Learning

You can use table tents to help organize the ideas in this chapter. Fold a piece of construction paper into thirds. Color in the middle third of the paper. You will write notes on the other two thirds of the paper. Pick one of the main topics in Lesson 1. Use words and pictures to illustrate that topic, as shown in the diagram. Then, fold and tape the paper so that it makes a table tent. Make another table tent to illustrate one of the main topics from Lesson 2. At the end of the chapter are two activities that use table tents to help answer the question: How do animals interact with one another and their environments?



29.1 Elements of Behavior

Key Questions

- ***How can behavior influence the evolution of animal species?***
- ***What is an innate behavior?***
- ***What are the major types of learning?***
- ***How do many complex behaviors arise?***

BUILD Understanding

Concept Map As you read, create a concept map to organize the information in this lesson.

In Your Workbook Go to your workbook to learn more about making a concept map.

Behavior and Evolution

A young boy eats lunch at a table outside of a Caribbean restaurant. In the bushes nearby, an iguana watches closely. The dangerous-looking iguana crawls closer. When the boy sees the lizard, he jumps out of his chair. But the iguana is not interested in the boy's toes. This lizard is a vegetarian. The iguana quickly eats the boy's French fries that have fallen to the ground.

What's so interesting about this scene? This species of iguana usually lives in trees. These iguanas are normally shy and do not come close to humans. However, this iguana has learned that getting close to humans can mean an easy meal!

The activity of the iguana is an example of behavior. **Behavior** is the way that an organism reacts to a stimulus in its environment. Recall that a stimulus is any information that causes an organism to react.

Some behaviors are simple. A dog turns its head when it hears a noise. Other behaviors are complex. For example, some animals wash their food before eating it. The way that an animal behaves often depends on an internal condition, such as hunger. If the iguana had not been hungry, he probably would have stayed away from the boy.

Most behaviors are necessary for survival. For example, animals must be able to find and catch food, choose a habitat, avoid predators, and find mates. Many behaviors are influenced by genes. If these behaviors help an animal survive and reproduce, they will be passed on to the next generation. Eventually helpful behaviors will spread throughout the population, or even the species. Thus, certain behaviors can evolve by natural selection, just like physical traits.

Key Question How can behavior influence the evolution of animal species? **If an inherited behavior allows an animal to survive and reproduce, the behavior can spread throughout the population.**

Innate Behavior

How does a spider know how to spin a web? How do chicks know how to beg for food? These animals are showing **innate behaviors,** or instincts. An animal performs an innate behavior even though it has no previous experience with the stimulus to which it is responding. Innate behaviors allow animals to survive without the need for experience. An animal's genes and its environment interact to cause innate behaviors.

One example of an innate behavior is a newborn mammal's ability to suck milk from its mother's body. This innate behavior is simple. Other innate behaviors, such as making a spider web, are complex.

Key Question What is an innate behavior? **An innate behavior is a behavior that an animal performs even though it has no previous experience with the stimulus to which it is responding.**

Learned Behavior

If all behaviors were innate, the behaviors would be hard or impossible for an animal to change during its lifetime. If that were the case, individual animals would have a hard time responding to changes in their environment. But when many animals experience something new, they are able to respond by changing their behavior. Making changes to behaviors based on experience is called **learning.**

Many animals have the ability to learn. Organisms with simple nervous systems, such as sea stars and most other invertebrates, learn only rarely. In a few invertebrates and many chordates, learning is common. Scientists have identified four main types of learning: habituation, classical conditioning, operant conditioning, and insight learning.

Habituation The simplest type of learning is habituation. **Habituation** happens when an animal stops responding to a repeating stimulus that does not harm or reward the animal. Imagine crows eating near a road. At first, passing cars cause the crows to fly away. Over time, they learn that the cars will not harm them. They stop flying away. The crows have become habituated to the cars. In other words, a stimulus (the cars) no longer causes a response (flight). An animal can save energy by ignoring a stimulus that does not affect its survival.

BUILD Vocabulary

behavior the way an organism reacts to changes in its internal condition or to stimuli in its environment

innate behavior a behavior that an animal performs without any previous experience with the stimulus to which it is responding

learning a change in behavior as a result of experience

habituation a type of learning in which an animal decreases or stops its response to a repetitive stimulus that neither rewards nor harms the animal

WORD ORIGINS

The word *innate* is from the Latin word *innatus*, which means "inborn." An innate behavior is a behavior that is strongly shaped by genes an animal is born with.

Habituation Crows by the side of a road fly away when a car passes. After many cars have passed without harming the crows, the birds become habituated to the cars. From then on, the crows do not fly away when cars pass them.

Operant Conditioning

1. A dog randomly brushes its tail against a bell hanging on a doorknob.

2. The owner responds by opening the door. The ring-the-bell, open-the-door sequence happens a few times.

3. The dog then learns to ring the bell when it wants to go out.

BUILD Vocabulary

classical conditioning
a type of learning that occurs when an animal makes a mental connection between a stimulus and some kind of reward or punishment

operant conditioning
a type of learning in which an animal learns to behave in a certain way through repeated practice, to receive a reward or avoid punishment

insight learning
a type of behavior in which an animal applies something it has already learned to a new situation, without a period of trial and error; also called reasoning

imprinting
a type of behavior based on early experience; once imprinting has occurred, the behavior cannot be changed

ACADEMIC VOCABULARY

The term *insight* means "a clear or deep understanding of a complex situation." In insight learning, an animal understands a new situation and then responds to it.

Classical Conditioning

In **classical conditioning,** an animal responds to a stimulus that has become linked to a positive or negative experience. The Russian scientist Ivan Pavlov first described classical conditioning around 1900. Pavlov noticed that dogs have an innate response to food—they salivate, or drool. Pavlov rang a bell every time he offered his dogs food. After a while, his dogs would salivate when they heard the bell, even when there was no food. Pavlov's experiment caused the dogs to salivate (a response) in reaction to a bell (stimulus) associated with food.

Operant Conditioning

Operant conditioning happens when an animal learns to behave in a certain way to get a reward or to avoid punishment. The American scientist B.F. Skinner first described operant conditioning in the 1940s. Skinner conducted experiments using a box that became known as a "Skinner box." A Skinner box has a lever inside. An animal that is put inside the box will accidentally push the lever at some point. When it pushes the lever, the animal receives food. After it is rewarded several times, the animal learns that it can get food by pushing the lever.

Operant conditioning is often called trial-and-error learning. After a random behavior produces a reward, the animal tries to get the reward again (a trial). Most trials result in errors (no reward). However, sometimes a trial will produce a reward.

Insight Learning

In **insight learning,** an animal applies something it has already learned to a new situation. The animal does not go through a period of trial and error. Insight learning is also called reasoning. Humans use insight learning to solve new problems. Insight learning is also common in some nonhuman primates. In one experiment, a hungry chimpanzee used insight learning to stack boxes in order to reach bananas overhead.

Key Question What are the major types of learning?
The four major types of learning are habituation, classical conditioning, operant conditioning, and insight learning.

Imprinting in the Wild
This sandhill crane chick has imprinted on its mother. Because it has imprinted on its mother, it will follow her in flight during migration.

Complex Behaviors

Many complex behaviors combine innate behavior with learning. One example of complex behavior is imprinting. In **imprinting,** an animal has an innate urge to follow the first moving object that it sees. But the animal is not born knowing what that object will look like. It must learn from experience what to follow. Once imprinting has occurred, the behavior becomes fixed.

Usually young birds such as the sandhill crane shown above imprint on their mothers. Imprinting on their mothers improves their chance of survival. A young crane that stays close to its mother is protected from predators. It also learns where to get food.

INQUIRY into Scientific Thinking

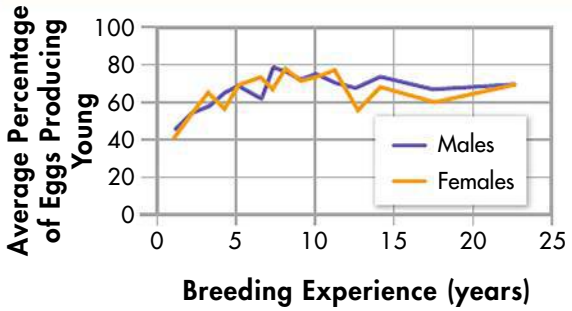
Caring for Young

Can experience help animals be better parents? The data in the table are from studies of a seabird, the short-tailed shearwater. Each pair produces only one egg a year. If that egg breaks or if the chick dies, the female bird does not lay another egg. The graph shows the percentage of eggs that develop into young birds, in relation to the age or breeding experience of the parents. This ratio is called reproductive success.

1. Interpret Tables What is the approximate success rate of a female shearwater with five years of breeding experience?

2. Compare and Contrast Are there obvious differences in reproductive success between male and female shearwaters?

Reproductive Success of Short-Tailed Shearwaters



3. Draw Conclusions Do older shearwaters have better reproductive success than younger birds have? Explain your answer.

4. Form a Hypothesis Do you think these birds learn to raise young more successfully over time?

In Your Workbook Get more help for this activity in your workbook.

Imprinting in Captivity Recently hatched cranes that are raised in captivity imprint on a red-headed bird puppet worn on the hand of a researcher. Later, that puppet is used to help introduce these birds to the wild.

Researchers use imprinting to help raise endangered cranes in captivity. The researchers create hand puppets that look like adult cranes. When they show these puppets to baby cranes, the baby cranes imprint on the puppets. After the cranes have grown up, researchers use the puppets to train the cranes where to fly during migration.

Imprinting does not always involve vision. Animals can imprint on sights, sounds, odors, or other cues. Newly hatched salmon imprint on the odor of the stream in which they have hatched. When they are young, the salmon swim out to sea. Years later, adult salmon use that odor to help them return to their home stream to lay eggs.

Key Question How do many complex behaviors arise?
Many complex behaviors combine innate behavior with learning.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. A behavior that an animal performs even though it has no previous experience with the stimulus to which it is responding is called a(n)_____.
2. An animal learns to behave in a certain way because it is given a reward. This type of learning is called _____.
3. An animal applies something that it has already learned to a new situation. This type of learning is called _____.

Critical Thinking

4. **Review** What is behavior?
5. **Review** Which aspect of imprinting is innate? Which aspect is learned?
6. **Write to Learn** Answer the first clue of the mystery.

MYSTERY CLUE

Elephants living elsewhere exhibit behaviors similar to those of the elephants at the watering hole. What does this suggest about the importance of these behaviors? (Hint: See p. 696.)

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29.2 Animals in Their Environments

Behavioral Cycles

As night falls on a coral reef, animals there act like city commuters during rush hour. Some species have "day jobs" feeding in bright light. They form "traffic jams" as they move into reef caves to rest for the night. Species that work the "night shift" come out to feed in the dark. At dawn, the cycle reverses.

Daily Cycles The behavior of animals in the coral reef is an example of a circadian rhythm. **Circadian** (sur KAY dee un) **rhythms** are behavioral cycles that happen daily. The human behavior of going to school during the day and sleeping at night is an example of a circadian rhythm.

Seasonal Cycles Other behavioral cycles are seasonal. In temperate and polar areas, many species are active during spring, summer, and fall. These species enter a sleeplike state, or dormancy, during winter. Some mammals enter a kind of dormancy called hibernation. Dormancy allows animals to survive periods when food and other resources are not available.

Migration is the seasonal movement of an animal from one environment to another. Many species of animals migrate, and many animals migrate over huge distances. Migration allows animals to take advantage of good environmental conditions. Many songbirds live in tropical regions when it is winter in temperate areas. When these birds fly north in the spring, they find lots of food. They also find space to raise young.

Key Question How do environmental changes affect animal behavior?
Many animals respond to the cycles in the environment with daily or seasonal cycles of behavior.

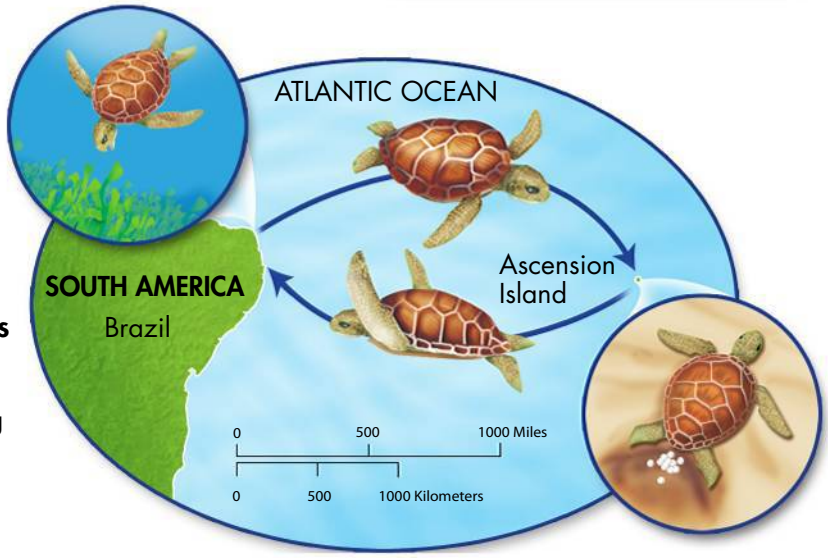
Key Questions

- ***How do environmental changes affect animal behavior?***
- ***How do social behaviors increase an animal's evolutionary fitness?***
- ***How do animals communicate with others in their environments?***

BUILD Understanding

KWL Chart Fill in a KWL chart as you read Lesson 29.2. In the first column, write down what you already know about the topic. In the second column, write what you want to find out. In the last column, write what you have learned after reading the lesson.

In Your Workbook Refer to your workbook for suggestions about how to use a KWL chart to organize your notes.



Seasonal Behavior of Green Sea Turtles
Each year, green sea turtles migrate back and forth between their feeding grounds on Brazil's coast and their nesting grounds on Ascension Island.

Territorial Behavior A bear marks its territory with its fur and scent.

BUILD Vocabulary

circadian rhythm a behavioral cycle that happens daily

migration seasonal behavior in which animals travel from one environment to another

territory a specific area occupied and protected by an animal or group of animals

aggression threatening behavior that one individual uses to show dominance over another individual

courtship a type of behavior in which two animals communicate in a way that leads to mating

society a group of closely related individuals of the same species that work together for the benefit of the group

communication the passing of information from one individual to another

WORD ORIGINS

The word *circadian* comes from two Latin words: *circa*, which means "about," and *diem*, which means "day." Circadian rhythms have a daily cycle.

Social Behavior

When animals interact with each other, they are performing social behaviors. Social behaviors help animals get food and other resources, compete for mates, and protect their offspring. Social behaviors include territoriality, aggression, courtship, and forming of societies.

Territoriality and Aggression Many animals behave in ways that keep other animals from using limited resources. Some animals live in a specific area, or **territory,** that they defend against competitors. Territories usually contain resources such as food, water, nesting sites, shelter, and potential mates. Animals often mark their territory with their fur or scent. If another animal comes into their territory, the "owner" chases it away. Animals may show aggression when defending their territories. **Aggression** is threatening behavior that is used to show the dominance, or greater power, of one animal over another.

Courtship An animal that reproduces sexually must find and mate with another member of its species. During **courtship** behavior, members of one sex (usually males) show that they are ready to mate. Members of the opposite sex (usually females) choose which individual they will accept. Animals may produce sounds, visual displays, or chemical signals to attract mates.

In some species, courtship involves rituals. Rituals are a series of behaviors that are always performed in the same way. Many rituals include signals and responses that continue until mating happens.

Animal Societies An animal **society** is a group of animals of the same species that live close to each other and work together. Societies can protect individuals from predators. They can also improve an animal's ability to find food, protect a territory, guard young, or fight off rivals. For example, African wild dogs hunt in packs. The females in the pack may take turns guarding all the pups, while other adults hunt for prey.

Members of a society are often closely related to one another. The help of relatives may improve the evolutionary fitness of an individual, because closely related individuals share many genes. Helping a relative increases the chance that the genes of an individual will be passed on to offspring.

Social insects, such as ants, bees, and wasps, have some of the most complex animal societies. In colonies of social insects each individual has a specific job. In ant colonies, all females except the queen are workers. The queen is the only female that reproduces. Male ants function only to fertilize the queen.

Key Question How do social behaviors increase an animal's evolutionary fitness?

Social behaviors can help animals claim or defend territories or resources, choose mates, and form social groups. These behaviors can increase an animal's evolutionary fitness.

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Communication

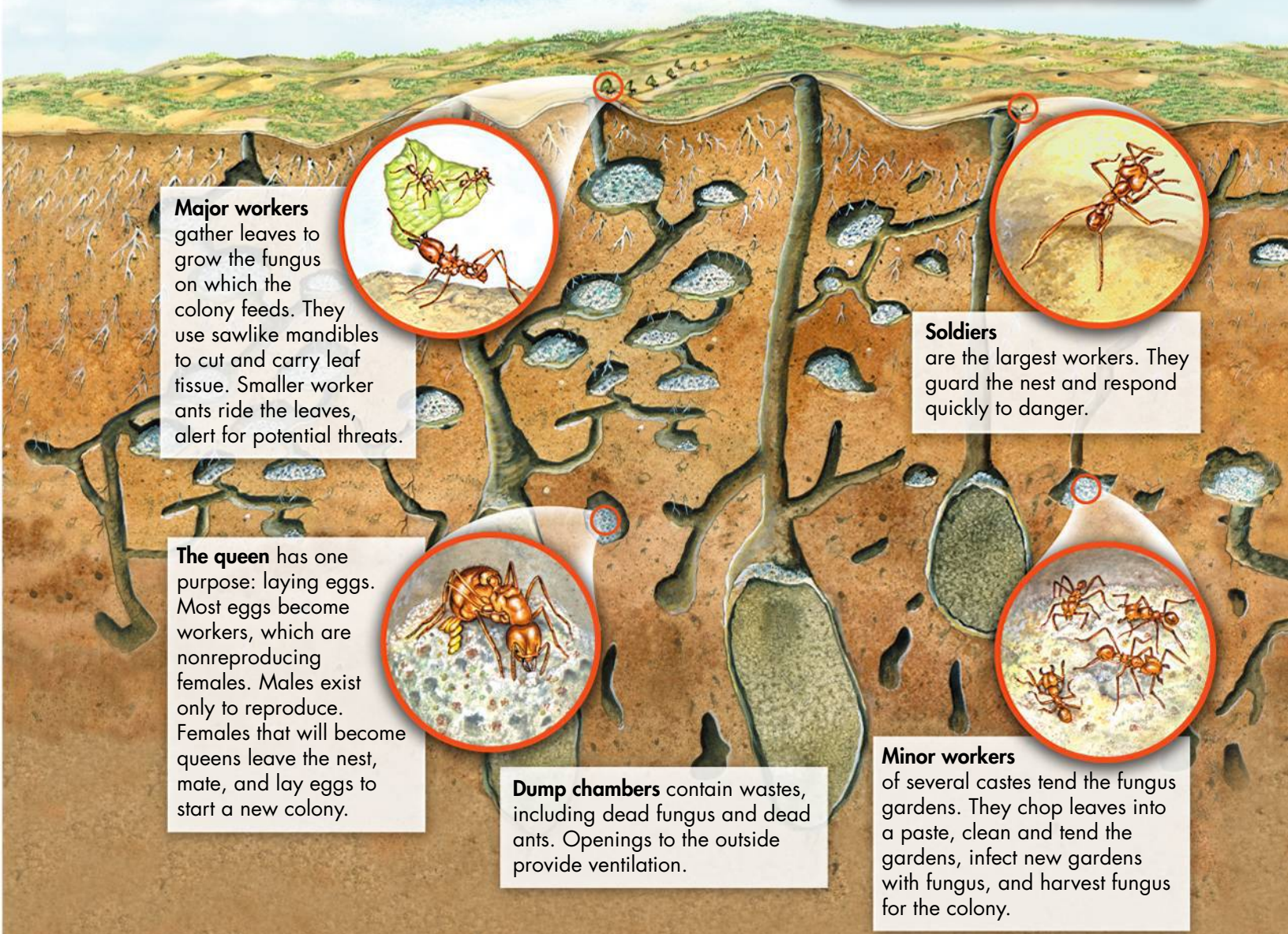
Social behavior involves more than one individual, so it requires communication. **Communication** is the passing of information from one individual to another. Animals may communicate using chemical, visual, or sound signals. Some species also use their own kind of language. The kinds of signals a species uses depend on the sense organs it has and the environment in which it lives.

Chemical Signals Animals with good senses of smell, such as insects, fishes, and mammals, can communicate with chemicals. Some animals, such as bees, ants, and lampreys, release chemicals called pheromones (FEHR uh mohnz). Pheromones can mark a territory or signal that an animal is ready to mate. Pheromones affect the behavior of other individuals of the same species.

BUILD Connections

AN ANT SOCIETY

In a leaf-cutter ant society, only a single queen reproduces. Different groups of ants within the colony perform other tasks.



Major workers gather leaves to grow the fungus on which the colony feeds. They use sawlike mandibles to cut and carry leaf tissue. Smaller worker ants ride the leaves, alert for potential threats.

Soldiers are the largest workers. They guard the nest and respond quickly to danger.

The queen has one purpose: laying eggs. Most eggs become workers, which are nonreproducing females. Males exist only to reproduce. Females that will become queens leave the nest, mate, and lay eggs to start a new colony.

Dump chambers contain wastes, including dead fungus and dead ants. Openings to the outside provide ventilation.

Minor workers of several castes tend the fungus gardens. They chop leaves into a paste, clean and tend the gardens, infect new gardens with fungus, and harvest fungus for the colony.

BUILD Vocabulary

language a system of communication that combines sounds, symbols, and movements according to a set of rules about sequence and meaning, such as grammar and syntax

Visual Signals Many animals have well-developed eyes that can sense shapes and colors. These animals often use visual signals to communicate. In many species, males use colorful displays to signal when they are ready to mate. Squids can change their color to send a variety of signals. Some animals, such as fireflies, even send signals using light that is made within their bodies.

Sound Signals Most animals with good senses of hearing and the ability to make noises can communicate using sound. Dolphins use sound signals to communicate in the ocean. Elephants make sounds with their feet and vocal cords that can be used to identify individuals. Elephants, and some other animals, can send messages that can be felt rather than heard.

Language **Language** is a complex system of communication that uses rules to combine sounds, symbols, and movements. Many animals, including elephants, primates, and dolphins, seem to have "words"—calls with specific meanings, such as "lions on the prowl." However, untrained animals do not seem to use a set of rules for communication like those in human language.

Key Question How do animals communicate with others in their environments? **Animals may use a variety of signals to communicate with one another. Some can also use language.**

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. Behavioral cycles that happen daily are called _____.
2. _____ is seasonal movement from one environment to another.
3. Many animals defend a _____, which is an area that contains resources.

Critical Thinking

4. **Review** Name two ways in which animal behavior is related to environmental cycles.
5. **Review** List three types of social behavior.
6. **Relate Cause and Effect** How does membership in a society increase the evolutionary fitness of its members?
7. **Write to Learn** Answer the mystery clue.

MYSTERY CLUE

When threatened by predators, adult elephants form a circle around young elephants. What may have caused this behavior in the elephants at the watering hole? (**Hint:** See p. 703.)

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Pre-Lab: Termite Tracks

Problem How can you determine the type of stimulus that triggers a particular response?

Materials petri dishes, paper, scissors, termites, small paintbrushes, forceps, ballpoint pens, rollerball pens, felt-tip pens

Lab Manual Chapter 29 Lab

Skills Focus Form a Hypothesis, Design an Experiment, Draw Conclusions

Connect to the Big idea Animals react to their environments as they search for food, avoid predators, and look for a mate. The survival of a species can depend on these behaviors. Some behaviors are inherited and evolve over time due to natural selection. Over many generations, behaviors that help animals survive spread through a population. Behaviors that are not adaptive become less common. In this lab, you will observe an inherited behavior of termites. Then you will design an experiment to determine the type of stimulus that triggers the behavior.

Background Questions

a. Review How is a behavior usually defined?

b. Explain How do innate behaviors, or instincts, help animals survive?

c. Infer You see an ant walk across the ground. A minute later, you see another ant walk in the same exact line. What type of communication do you think is taking place?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Control Variables** Why do you think the instructions ask you to draw a figure eight rather than a straight line?
2. **Draw Conclusions** How will you decide whether a termite has a positive reaction, a negative reaction, or no reaction to a stimulus?
3. **Predict** Read pages 703–704 of your textbook. Which of the signals described could be a stimulus for the termite in this lab? Explain your answer.

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Untamed Science Video See how the latest technologies help the explorers from Untamed Science track the movements of different animals.

Tutor Tube Instinct? Sorting out everyday and scientific behavior terms.

Art Review Identify animal communication strategies.

Art in Motion Watch social behavior in a population.

29 CHAPTER Summary

29.1 Elements of Behavior

- If an inherited behavior allows an animal to survive and reproduce, the behavior can spread through the population.
- An innate behavior is a behavior that an animal performs even though it has no previous experience with the stimulus to which it is responding. Innate behaviors are also called instincts.
- The four major types of learning are habituation, classical conditioning, operant conditioning, and insight learning.
- Many complex behaviors combine innate behavior with learning.

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behavior (p. 696)
innate behavior (p. 697)
learning (p. 697)
habituation (p. 697)
classical conditioning (p. 698)
operant conditioning (p. 698)
insight learning (p. 698)
imprinting (p. 699)

29.2 Animals in Their Environments

- Many animals respond to the cycles in the environment with daily or seasonal cycles of behavior.
- Social behaviors can help animals to find and protect food, guard young, avoid predators, and find mates. Since these behaviors can increase an animal's survival and reproduction, they can improve its evolutionary fitness.
- Animals may use a variety of signals to communicate with one another. Some animals can use language.

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circadian rhythm (p. 701)
migration (p. 701)
territory (p. 702)
aggression (p. 702)
courtship (p. 702)
society (p. 702)
communication (p. 703)
language (p. 704)

Assess the Big idea Evolution

Write an answer to the question below:

Q: How do animals interact with one another and their environments?

Constructed Response

Write an answer to each of the numbered questions below. The answer to each numbered question should be one or two paragraphs long. To help you begin, read the **Hints** below the questions.

1. **You are studying the behavior of a chimpanzee. You observe that the chimpanzee has learned how to use a key to open a box that contains food. How do you know whether the chimpanzee has learned this behavior using operant conditioning or insight learning?**

   Hint Look at the steps that show how a dog learns using operant conditioning on p. 698. Could a chimpanzee learn how to unlock a box using similar steps?

2. **Describe how the behaviors of animals in the northern United States help them survive when seasons change from fall to winter.**

   Hint What is the difference between the behavior of songbirds and the behavior of mammals when winter arrives?

3. **Some animals live in societies. What are the benefits of living in a group? What are the costs?**

   Hint Would resources be more available to an animal that lived in a group or less available?

29 CHECK Understanding

Foundations for Learning Wrap-Up

Use the table tents you made when you started the chapter to help you organize your thoughts about how animals interact with one another and with their environments.

Activity 1 Work together as a class. Write the seven main chapter topics on separate sheets of paper.

- Behavior and Evolution
- Innate Behavior
- Learned Behavior
- Complex Behaviors
- Behavioral Cycles
- Social Behavior
- Communication

Choose seven desks in the classroom. Put one of the sheets on each of the desks.

Have everyone place each of his or her table tents on the desk that matches its topic. Work together to make sure all the table tents are in the right place. Then, review each topic in small groups by looking at the table tents.

Activity 2 Divide up into pairs. Pick a topic from the chapter, but do not tell your partner what it is. Make a new table tent to illustrate that topic. Use mainly pictures on your table tent—just a few words. Be creative! Do not use the same pictures that are found in your textbook.

Tape the table tent together and give it to your partner. Have your partner guess what the table tent illustrates without looking at the textbook. Switch places and repeat the activity.

29.1 Elements of Behavior

Understand Key Concepts

1. The way an organism reacts to stimuli in its environment is called
   a. behavior. **c.** conditioning.
   b. learning. **d.** imprinting.

2. Animal behaviors can evolve through natural selection because
   a. what an animal learns is added to its genes.
   b. all behavior is completely the result of genes.
   c. all behavior is completely the result of environmental influences.
   d. genes that influence behaviors that increase fitness can increase in frequency from one generation to the next.

3. Which kind of behavior is shown below?

   a. insight learning **c.** classical conditioning
   b. imprinting **d.** operant conditioning

4. How can habituation contribute to an animal's survival?

Think Critically

5. **Infer** When a baby smiles, her mother picks her up and cuddles her. Over time, the baby smiles more and more often. Explain what type of learning the baby is showing.

Test-Taking Tip

Use Time Wisely When you are taking a test, answer all the questions you are sure about first. Put a mark next to the questions that you need to go back to. Skip any questions that you really cannot answer. Only go back to those questions if you have time.

29 CHECK Understanding

29.2 Animals in Their Environments

6. Each year, a bird called the redstart travels from its winter home in South America to its nesting area in New York. This behavior is called
   a. imprinting. **c.** migration.
   b. competition. **d.** courtship.

7. Which of the following is NOT social behavior?
   a. courtship **c.** hunting in a pack
   b. territoriality **d.** operant conditioning

8. Describe two ways in which social behavior can benefit an animal.

9. Explain how aggression and territorial behavior are related.

Think Critically

10. **Apply Concepts** Because a highway has been constructed through a forest, many of the animals that once lived there have had to move to a different wooded area. Is this migration? Explain.

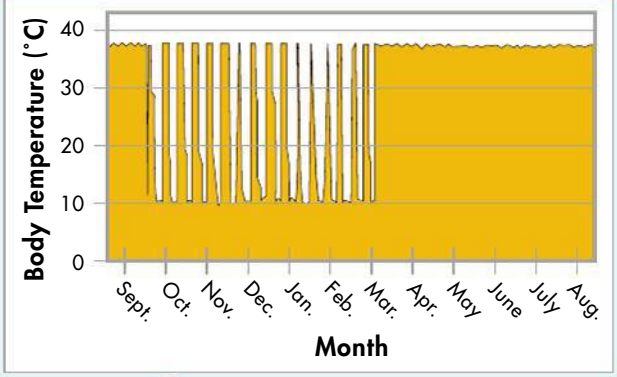
Connecting Concepts

In winter, some mammals enter into a state of dormancy. Dormancy is an energy-saving adaptation in which metabolism slows down, causing body temperature to become lower. The graph below tracks a ground squirrel's body temperature over the course of a year.

11. **Explain** Describe the pattern that you observe.

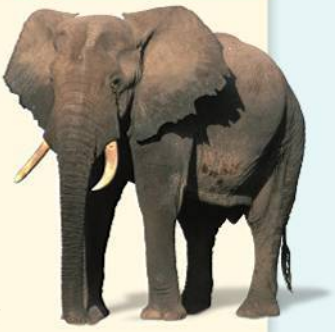
12. **Infer** What can you infer about the squirrel's behavior at different times of the year?

Body Temperature of a Ground Squirrel



solve the CHAPTER MYSTERY

ELEPHANT CALLER ID?



Elephants can communicate with loud calls and vibrations that can travel long distances. Elephants send these vibrations by drumming on the ground with their feet. They also make low rumbling calls that contain very low-frequency vibrations. The air vibrations can travel up to 16 kilometers. The ground vibrations can travel up to 32 kilometers.

Elephants sense these vibrations with specialized pads of fat in their feet. They can also detect the vibrations with receptor cells in their feet and trunks. By standing still and pressing their feet and trunks to the ground, they can sense the vibrations better. Some patterns of vibrations can identify individuals—like caller ID for elephants!

The vibrations contain greetings, locations of food, and warnings of danger. The elephants at the watering hole had sensed a message from another herd of elephants: "Warning! Lions!"

1. **Compare and Contrast** How do vibrations in the ground compare with sounds in the air as a way to communicate over long distances?

2. **Form a Hypothesis** Sometimes researchers play sounds and vibrations from elephant groups that live far from Etosha. The elephants at Etosha do not always respond. Why might this be the case?

3. **Connect to the Big Idea** How do elephants' responses to low-frequency vibrations in their environment affect their survival?

UntamedScience **Never Stop Exploring Your World.** Finding the solution to the Elephant Caller ID? mystery is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

Standardized Test Prep

Multiple Choice

1. A rat that learns to press a button to get food is exhibiting
A insight learning. **C** classical conditioning.
B operant conditioning. **D** habituation.

2. A dog that always salivates at the ringing of a bell is exhibiting
A insight learning. **C** classical conditioning.
B operant conditioning. **D** habituation.

3. A chimpanzee that stacks boxes in order to reach a banana hanging from the ceiling is showing
A insight learning. **C** classical conditioning.
B operant conditioning. **D** habituation.

4. A bird that stops responding to a repeated warning call when the call is not followed by an attack is showing
A insight learning. **C** classical conditioning.
B operant conditioning. **D** habituation.

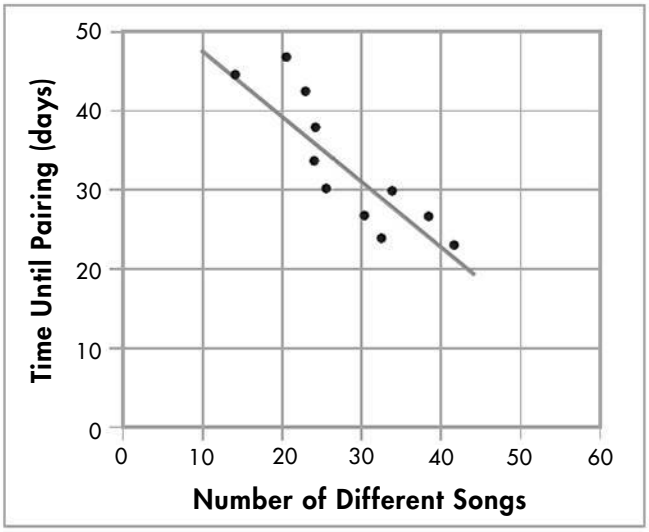
5. Which kind of behavior does NOT involve learning?
A habituation **C** imprinting
B trial and error **D** instinct

6. A male three-spined stickleback fish will attack male red-bellied sticklebacks and models of fishes that have a red underside. It will not attack males or models lacking a red underside. What can you conclude from the three-spined stickleback's behavior?
A The stimulus for an attack is a red underside.
B The stimulus for an attack is aggression.
C The stimulus for an attack is the presence of a fish with red fins.
D The stimulus for an attack is the presence of a fish model.

7. Which of the following is NOT an innate behavior?
A a dog looking for its food dish
B a baby mammal sucking milk
C a worm moving away from bright light
D a spider spinning a web

Questions 8–9

A researcher observed sedge warblers during breeding season. She charted the number of different songs a male bird sang compared to the time it took him to pair with a mate. The graph shows her data.



8. The researcher was trying to find out whether there is a correlation between
A the number of a male bird's songs and the number of offspring.
B the number of a male bird's songs and his attractiveness to females.
C a male's age and when he mates.
D a female's age and when she mates.

9. What can you conclude based on the graph?
A Males prefer females that do not sing.
B Females prefer males that do not sing.
C Males prefer females with a larger number of songs.
D Females prefer males with a larger number of songs.

Open-Ended Response

10. How does defending a specific territory benefit an animal?

If You Have Trouble With . . .										
Question	1	2	3	4	5	6	7	8	9	10
See Lesson	29.1	29.1	29.1	29.1	29.1	29.1	29.1	29.2	29.2	29.2

UNIT 7 Animals

Unit Project

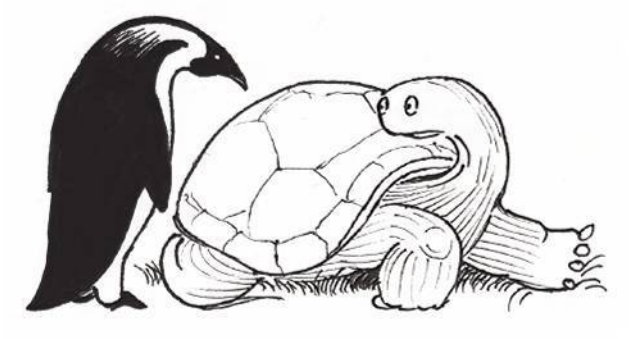
Zoo Exhibit

Have you ever been to the zoo? Going to the zoo is a great way to see and learn about living things from around the world. Imagine you work for a zoo in your local city and have been asked to set up a new exhibit entitled *The Diversity of Animals.*

Your Task Design an exhibit that highlights the different groups of animals in the animal kingdom and their characteristics.

Be sure to

- show the differences in shapes and forms of animals.
- show the similarities/differences in the ways in which groups of animals carry out basic life processes (circulation, respiration, excretion, movement, response, feeding).
- design the exhibit so that it is clear and engaging.



Reflection Questions

1. **Score your exhibit using the rubric below. What score did you give yourself?**
2. **What did you do well in this project?**
3. **What needs improvement?**
4. **What aspects of another group's exhibit did you like? Why?**

Assessment Rubric

Score	Scientific Content	Quality of Exhibit
4	Exhibit reveals a thorough understanding of animals and the ways they carry out life processes.	Exhibit is very organized, educational, and engaging to visitors.
3	Exhibit reveals an adequate understanding of animals and the ways they carry out life processes.	Exhibit is organized and clear, but it could be more engaging to visitors.
2	Exhibit reveals a limited understanding of animals and the ways they carry out life processes.	Exhibit needs improvement in clarity and organization. It is somewhat engaging.
1	Exhibit reveals significant misunderstandings about animals and the ways they carry out life processes.	Exhibit is very unclear and disorganized. It is not engaging.

The Human Body

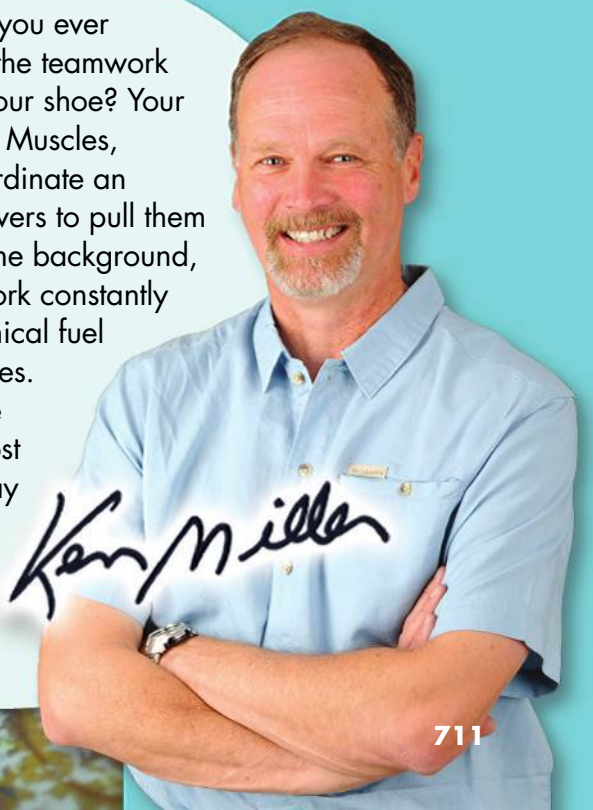
UNIT 8

Chapters

INTRODUCE the Big ideas

- **Homeostasis**
- **Structure and Function**

"Have you ever thought about the teamwork involved in tying your shoe? Your eyes locate the laces. Muscles, bones, and nerves coordinate an intricate series of maneuvers to pull them tight and tie the knot. In the background, lungs and bloodstream work constantly to bring oxygen and chemical fuel to those muscles and nerves. The body is an incredible machine, but what is most extraordinary is the way in which its systems and organs work together."



30 Digestive and Excretory Systems

Big idea

Homeostasis

Q: How are the materials that enter and leave your body related to the processes that maintain homeostasis?

Food sellers display their goods at a floating food market on Dal Lake in northern India.

BIOLOGY.com Search Chapter 30 GO • Flash Cards

INSIDE:

- 30.1 Organization of the Human Body
- 30.2 Food and Nutrition
- 30.3 The Digestive System
- 30.4 The Excretory System

• Untamed Science Video • Chapter Mystery

CHAPTER MYSTERY

THE TELLTALE SAMPLE

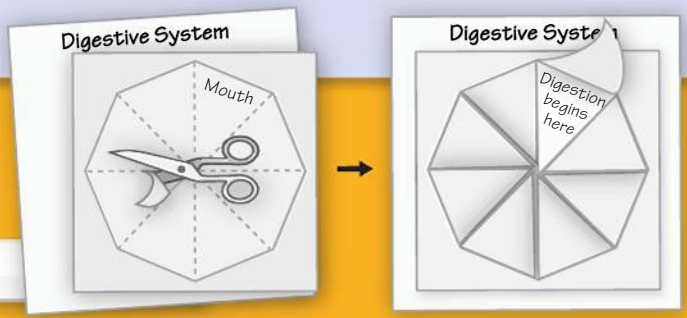
All players had to get a physical on the first day of football practice. "Please provide me with a urine sample," the doctor said. Each student was handed a plastic cup and sent to the restroom. The players had no idea how much could be learned from their urine.

Philip and Seth handed in their samples. They were told right away to go home and drink plenty of water before practice the next day. The next day, Andrew was told he might have diabetes and should see his doctor. Several days later, another player was dropped from the team. He had violated the school's well-known antidrug policy. How was all this information learned from a urine sample?

Read for Mystery Clues As you read this chapter, look for clues to help you predict what can be learned by examining what leaves your body. Then, solve the chapter mystery.

FOUNDATIONS for Learning

Think of organs as building blocks for an organ system. Before you read the chapter, make two layered pinwheels, one for the digestive system and one for the excretory system. Use two sheets of paper. Write the name of the system at the top of the first sheet. To make the tabs of the pinwheel, fold the second sheet in half twice. Then cut the paper diagonally and along each fold, as shown below. Tape the pinwheel to the first sheet of paper. As you read the chapter, write the name of an organ from the system on each tab. Then write the functions of the organ under the tab. At the end of the chapter are two activities that use the pinwheels to help answer the question: How are the materials that enter and leave your body related to the processes that maintain homeostasis?



30.1 Organization of the Human Body

Key Questions

- ***How is the human body organized?***
- ***What is homeostasis?***

BUILD Understanding

Previewing Visuals Study the Build Connections feature on p. 716. For each system, describe how it interacts with at least one other system.

In Your Workbook Go to your workbook for more about previewing visuals.

BUILD Vocabulary

epithelial tissue
a type of tissue that lines the interior and exterior body surfaces

connective tissue
a type of tissue that provides support for the body and connects its parts

nervous tissue
a type of tissue that transmits nerve impulses throughout the body

muscle tissue
a type of tissue that makes movements of the body possible

WORD ORIGINS

The word *tissue* comes from the Middle English word *tissu*, which means "rich fabric." A tissue is a "fabric" of cells that perform the same function.

Organization of the Body

How does a softball player field a ground ball? She uses her eyes and brain to figure out where to move. Her bones support her muscles as she moves. Her lungs absorb the oxygen her cells use during cellular respiration. Her brain monitors the ball and sends signals to guide her hand to catch it. An easy out, a routine play. How do all of these parts of the body work together to allow the softball player to field the ball?

Every cell in the human body works alone, yet also depends on the rest of the body. How can so many single cells and parts work together so efficiently? One way to answer this question is to study the organization of the human body.

Cells A cell is the basic unit of structure and function in living things. Remember that single cells in multicellular organisms are usually specialized. Bone cells, blood cells, muscle cells, and other types of cells each perform a specific function.

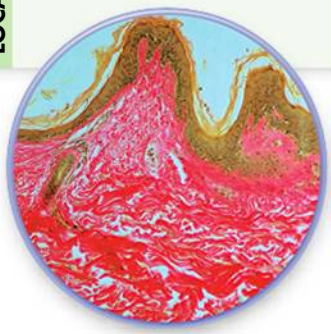
Tissues A group of cells that performs a single function is called a tissue. There are four basic types of tissue in the human body—epithelial, connective, nervous, and muscle.

▶ ***Epithelial Tissue*** The tissue that lines the interior and exterior surfaces of your body is **epithelial tissue.** Your skin and the lining of your stomach are examples of epithelial tissue.

▶ ***Connective Tissue*** The type of tissue that provides support for the body and connects its parts is called **connective tissue.** Fat cells, bone cells, and blood cells are types of connective tissue. Many connective tissues produce a protein called collagen. Collagen is a fiberlike protein that makes tissues strong and durable. Collagen helps the tissue keep its shape even when it is under pressure.

Types of Tissue The four major types of tissue are epithelial tissue, connective tissue, nervous tissue, and muscle tissue.

	Epithelial Tissue	Connective Tissue	Nervous Tissue	Muscle Tissue
FUNCTIONS	Protection, absorption, and excretion of materials	Binding of epithelial tissue to structures, support, and transport of substances	Receiving and transmitting nerve impulses	Voluntary and involuntary movements
LOCATIONS	Skin, lining of digestive system, certain glands	Under skin, surrounding organs, blood, bones	Brain, spinal cord, and nerves	Skeletal muscles, muscles surrounding digestive tract and blood vessels, the heart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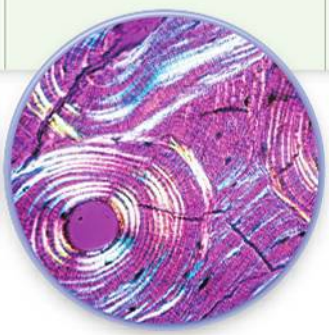
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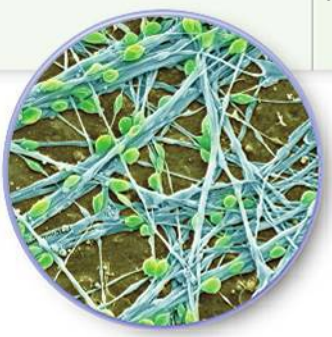
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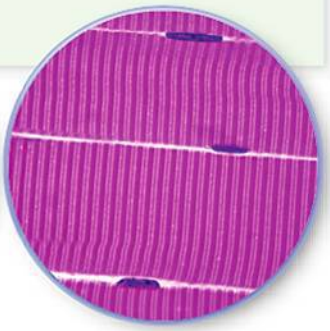
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▶ ***Nervous Tissue*** Nerve impulses are transmitted all over the body by **nervous tissue.** Neurons and glial cells are examples of nervous tissue. Neurons carry the nerve impulses, while glial cells surround and protect the neurons.

▶ ***Muscle Tissue*** Movements of the body are possible because of **muscle tissue.** Some muscles you can control, some you cannot control. For example, you can control the muscles in your arms and legs. But you cannot control the muscles in the pupils of your eyes.

Organs

An organ is a group of different types of tissue that work together. An organ may perform a single function or a group of related functions. Your eye is an organ that has all four types of tissues. All four tissues work together to enable us to see.

Organ System

A group of different organs that perform closely related functions is called an organ system. The brain and spinal cord are organs of the nervous system. The organ systems work together to keep the body stable. The organ systems are shown on the next page.

Key Question How is the human body organized?

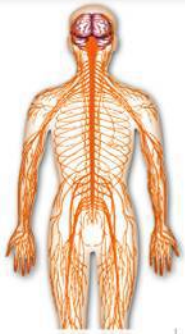
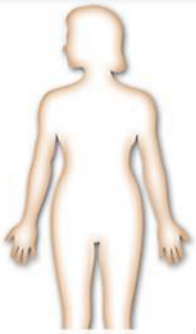
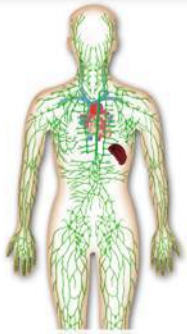
The human body is organized into four levels: cells, tissues, organs, and organ systems.

BUILD Connections

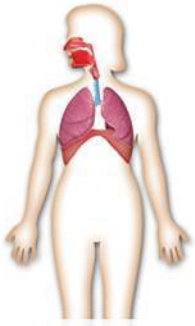
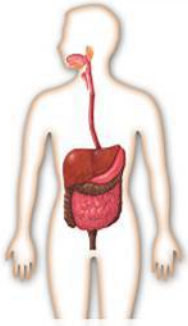
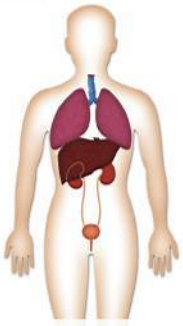
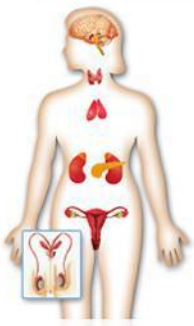
HUMAN BODY SYSTEMS

Each organ system shown here has a different set of functions. However, they all work together to maintain homeostasis in the body.

In Your Workbook
Go to your workbook for an exercise about the functions of body systems.


	Nervous System	Integumentary System	Immune/ Lymphatic Systems	Muscular System	Circulatory System	Skeletal System
STRUCTURES	Brain, spinal cord, nerves	Skin, hair, nails, sweat and oil glands	White blood cells, thymus, spleen, lymph nodes, lymph vessels	Skeletal muscle, smooth muscle, cardiac muscle	Heart, blood vessels, blood	Bones, cartilage, ligaments, tendons
FUNCTIONS	Recognizes and coordinates the body's response to changes in its internal and external environments	Guards against infection, injury, and ultraviolet radiation from the sun; helps to regulate body temperature	Helps protect the body from disease; collects fluid lost from blood vessels and returns it to the circulatory system	Works with skeletal system to produce voluntary movement; helps to circulate blood and move food through the digestive system	Transports oxygen, nutrients, and hormones to cells; fights infection; removes cell wastes; helps to regulate body temperature	Supports the body; protects internal organs; allows movement; stores mineral reserves; contains cells that produce blood cells


	Respiratory System	Digestive System	Excretory System	Endocrine System	Reproductive System
STRUCTURES	Nose, pharynx, larynx, trachea, bronchi, bronchioles, lungs	Mouth, pharynx, esophagus, stomach, small and large intestines, liver, pancreas, rectum	Skin, lungs, liver, kidneys, ureters, urinary bladder, urethra	Hypothalamus, pituitary, thyroid, parathyroids, adrenals, pancreas, ovaries (in females), testes (in males)	Testes, epididymis, vas deferens, urethra, and penis (in males); ovaries, Fallopian tubes, uterus, vagina (in females)
FUNCTIONS	Brings in oxygen needed for cellular respiration and removes excess carbon dioxide from the body	Breaks down food; absorbs nutrients; eliminates wastes	Eliminates waste products from the body	Controls growth, development, and metabolism; maintains homeostasis	Produces gametes; in females, nurtures and protects developing embryo

Homeostasis

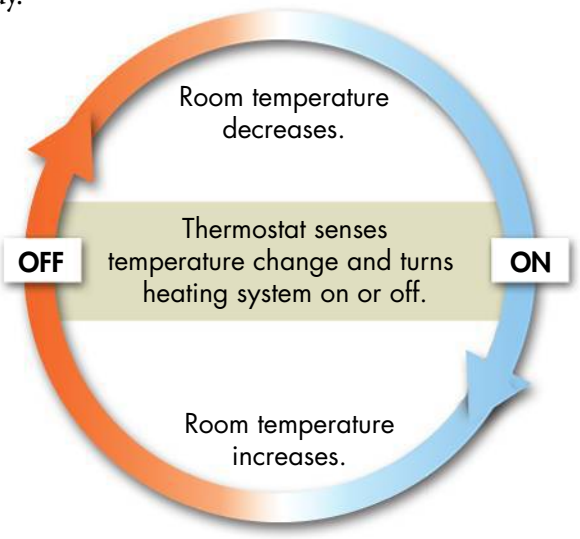
Some things are easy to observe. When you run, swim, or even write, you can see your body at work. However, some things are not easy to see. Your body's systems work behind the scenes to keep your internal environment stable. This stable environment inside your body is called **homeostasis**. You cannot always see homeostasis, but to an organism it means life or death.

Feedback Inhibition Have you ever watched someone drive a car down a fairly straight road? Did you notice that the driver constantly moves the wheel left and right? Making small adjustments to the wheel helps keep the car in the middle of the road. Body systems also constantly make small adjustments. These adjustments keep your body's internal conditions inside a certain range.

▶ ***A Nonliving Example*** One example of a system that automatically keeps conditions within a certain range is a home heating system. Many home heating systems use a furnace that burns oil or natural gas to provide heat. The system uses a device called a thermostat to monitor the home's air temperature. A sensor compares the air temperature to the one you set on the thermostat. When the air temperature is too cool, the thermostat turns the furnace on. Once the air temperature is warm enough, the thermostat turns the furnace off. The thermostat works to keep the air temperature inside a narrow range.

The heating system is using a process called feedback inhibition to control the air temperature in the house. Your body uses **feedback inhibition** to stay in homeostasis. *Feedback* means "response." *Inhibit* means "to block." Feedback inhibition blocks the response to a stimulus. In the heating system, the warm air "feeds back" on the thermostat. The thermostat then "blocks" the release of more warm air by turning the furnace off.

▶ ***The Body's Thermostat—A Living Example*** One part of homeostasis is keeping your body temperature steady. Your body uses feedback inhibition to do this. The hypothalamus is the part of your brain that controls body temperature. The hypothalamus acts as your body's thermostat. Sensors in your body tell the hypothalamus when you are too cold or too hot.



Feedback Inhibition
A home heating system uses feedback inhibition. This keeps the environment in the house stable and comfortable.

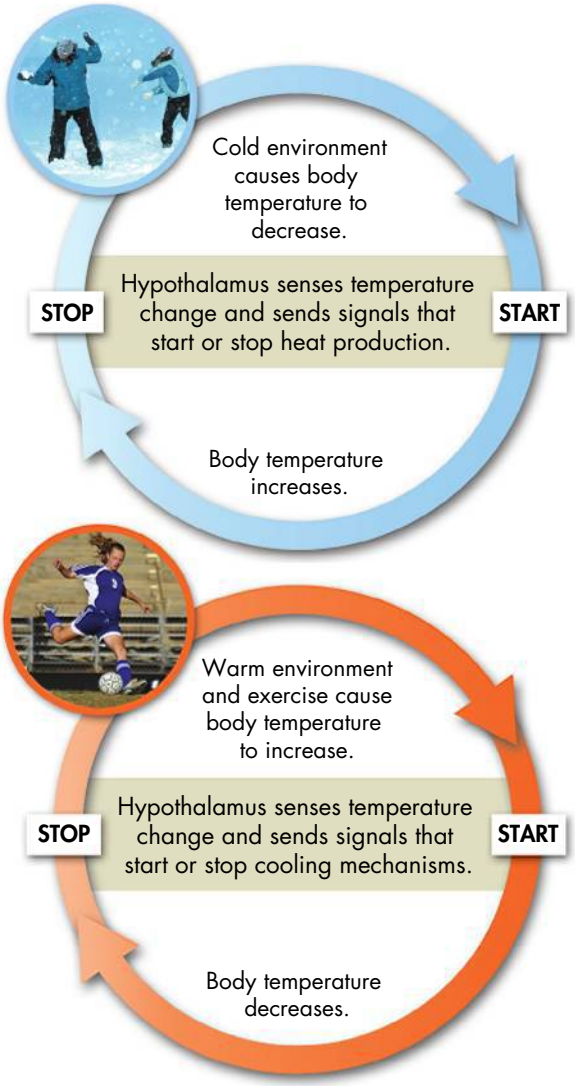
BUILD Vocabulary

homeostasis
the maintainance of relatively constant internal physical and chemical conditions within an organism

feedback inhibition
a response that stops the actions of a stimulus

ACADEMIC WORDS

The noun *inhibition* means "the act of blocking the action of." Therefore, feedback inhibition refers to a response that blocks further action of a stimulus.



Getting Warm and Staying Cool Your hypothalamus uses feedback inhibition to control your body's temperature.

If you are too cold, the hypothalamus tells cells to speed up their activities. The extra activity produces heat to warm your body. When you are warm enough, the hypothalamus tells the cells they can slow down again. If you are too hot, your hypothalamus tells your sweat glands to produce more sweat. The sweat evaporates, cooling your body surface. The hypothalamus also tells your cells to slow down to produce less heat. This is one reason you feel tired and slow on a hot day.

The Liver and Homeostasis The liver, a part of the digestive system, is important in homeostasis. The liver breaks down toxic chemicals in the blood such as ammonia and drugs. The liver converts ammonia to urea, which is less toxic.

Another function of the liver is to control the amount of glucose in the blood. When blood sugar rises, as it does after a meal, the liver removes extra glucose and stores it. High blood glucose levels can damage the eyes, kidneys, heart, and immune system. If levels in the blood fall too far, the nervous system slows down, and you may even pass out. The liver solves this problem by releasing stored sugar back into the blood. In this way, the liver keeps blood sugar from rising or falling beyond normal levels.

Key Question What is homeostasis?

Homeostasis is a state of relative balance in an organism's physical and chemical conditions. Homeostasis continues even when internal and external environments change.

CHECK Understanding

Apply Vocabulary

1. The type of tissue that lines the inner and outer surfaces of the body is called _____ tissue.
2. When the body is in _____, there is a relatively constant level of glucose in the blood.
3. The hypothalamus uses _____ to keep body temperature constant.

Critical Thinking

4. **Explain** What are two roles of the liver in maintaining homeostasis?
5. **Apply Concepts** Do you think that feelings of hunger and fullness are an example of feedback inhibition? Explain.
6. **Write to Learn** Answer the question in the clue to the mystery below.

MYSTERY CLUE

The lab test of Andrew's urine sample showed an abnormal amount of a certain substance. What substance do you think it was? (Hint: Look ahead to p. 731.)

BIOLOGY.com Search Lesson 30.1 GO • Lesson Assessment

30.2 Food and Nutrition

Food and Energy

Have you ever wondered why you feel weak when you are hungry? Or, for that matter, why you need food in the first place? One answer is energy. You need energy to climb stairs, run, and even to think. Just as a car does, your body needs fuel, and it feels weak without it. Food is that fuel.

Energy The energy available in food can be measured in a laboratory. The way it is measured is surprisingly simple—the scientist burns it! When food is burned, most of the energy in the food is converted to heat. Heat is measured in calories. One calorie of heat raises the temperature of 1 gram of water by 1 degree Celsius. The "Calories" you have heard about in food are actually dietary Calories. Notice that a capital *C* is used. One dietary **Calorie** is equal to 1000 calories, or 1 kilocalorie (kcal). Remember that the energy stored in food molecules is released during cellular respiration. This energy is used to produce ATP molecules. ATP powers cellular activities.

Raw Materials Chemical pathways can get energy from almost any type of food. Why, then, does the type of food matter? Food supplies more than energy. It also supplies the raw materials used to build and repair body tissues. These raw materials are the building blocks needed to make molecules like enzymes and DNA. Food contains at least 45 substances that the body needs but cannot make. A healthy diet allows your body to get all of these required substances.

Key Question Why do we need to eat?

Molecules in food contain chemical energy. Cells use this energy to produce ATP. Food also supplies raw materials your body needs to build and repair tissues.

Food Supplies Raw Materials Your body cannot make all of the raw materials it needs to build important molecules. Food contains at least 45 of the substances your body needs but cannot make.

Key Questions

- ***Why do we need to eat?***
- ***What nutrients does your body need?***
- ***What is meant by the term "balanced diet"?***

BUILD Understanding

Two-Column Chart Use a two-column chart to take notes about main ideas and details. List the main ideas in the left column. In the right column, write details that explain the main ideas.

In Your Workbook Go to your workbook for help with using a two-column chart.

BUILD Vocabulary

Calorie
the measure of energy in food; 1 Calorie = 1000 calories, or 1 kilocalorie (kcal)

carbohydrate
A class of nutrients that are the main source of energy for the human body

ACADEMIC WORDS

The word *carbohydrate* means "carbon with water." Substances that are "hydrated" contain water. For each carbon atom, carbohydrates contain roughly one oxygen and two hydrogens, the same proportions found in water (H_2O).

BUILD Vocabulary

fat
nutrient needed by the body for cell membranes, vitamin absorption, regulation, insulation, and energy

protein
a macromolecule that contains carbon, hydrogen, oxygen, and nitrogen; needed by the body for growth and repair

vitamin
an organic nutrient that the body needs in very small amounts

mineral
an inorganic nutrient the body needs in very small amounts

MULTIPLE MEANINGS

In biology, the word *minerals* refers only to inorganic elements like sodium and magnesium. In geology, minerals are the basic units of rocks, and can be elements or compounds.

Nutrients

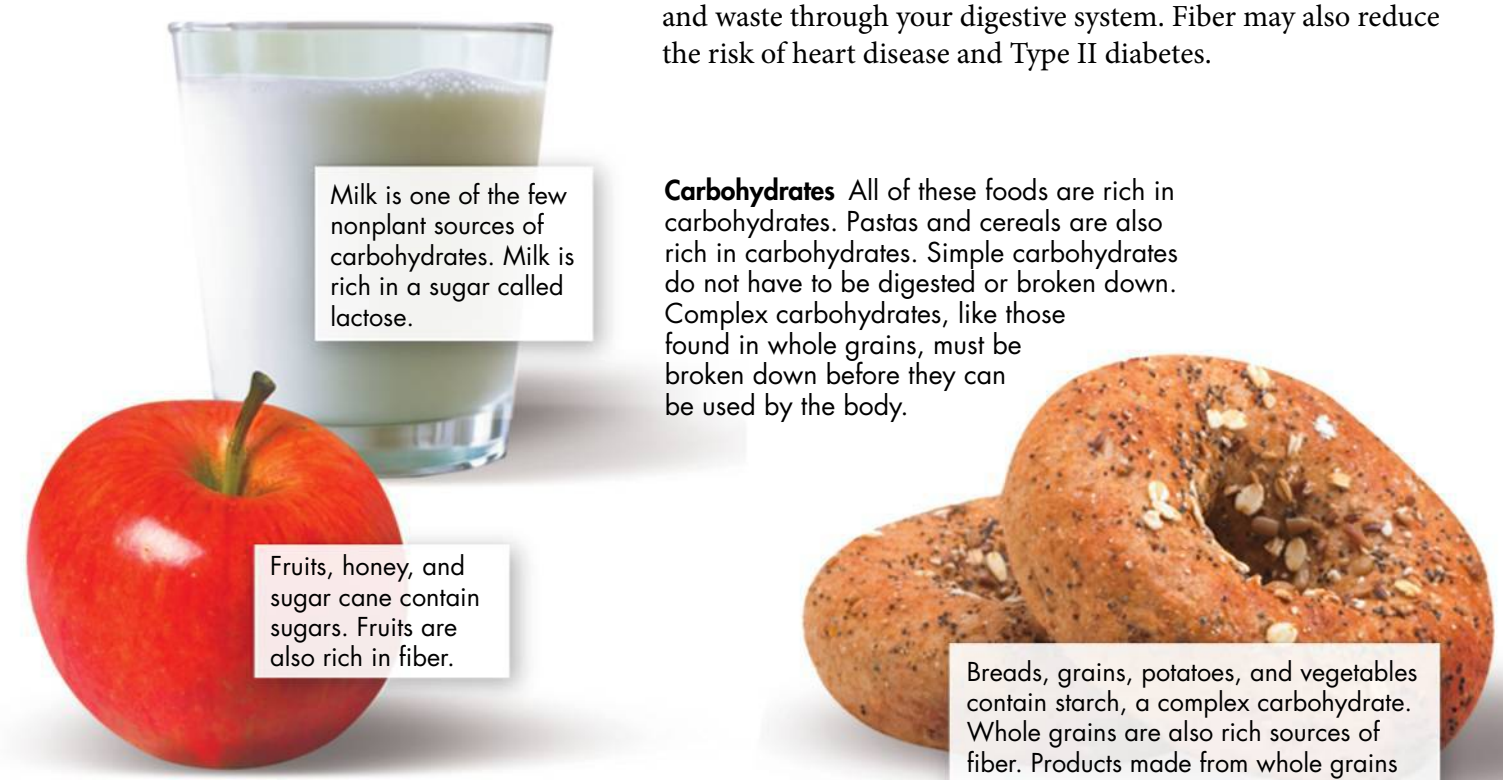
Nutrients are substances in food that supply energy and raw materials. Your body needs the energy and raw materials for growth, repair, and maintenance. There are six main types of nutrients—water, carbohydrates, fats, proteins, vitamins, and minerals.

Water Every cell in the human body needs water, which is the most important nutrient. Body processes such as chemical reactions are carried out in water. Large amounts of water are found in blood, extracellular fluid, and other bodily fluids. Water is lost from the body in urine and in sweat. You also lose water with every breath you exhale.

Humans need to drink at least 1 liter of fluid each day. Dehydration can occur if the lost water is not replaced. Dehydration leads to problems with many body systems. Under extreme conditions it can be fatal.

Carbohydrates **Carbohydrates** are major sources of food energy for the body. Simple carbohydrates are either monosaccharides, like glucose, or disaccharides, like sucrose, ordinary table sugar. Complex carbohydrates are polysaccharides, like starch and glycogen. Your digestive system breaks down starches into simple sugars. Sugars are absorbed into the blood and carried to the body's cells. Excess blood sugar is converted into glycogen. Glycogen is stored in the liver and in skeletal muscles. Excess sugar can also be converted to fat and stored in the body.

Another complex carbohydrate is cellulose. Cellulose is often called fiber. Your digestive system cannot break down fiber, but you need it in your diet for bulk. Bulk helps muscles move food and waste through your digestive system. Fiber may also reduce the risk of heart disease and Type II diabetes.



Milk is one of the few nonplant sources of carbohydrates. Milk is rich in a sugar called lactose.

Carbohydrates All of these foods are rich in carbohydrates. Pastas and cereals are also rich in carbohydrates. Simple carbohydrates do not have to be digested or broken down. Complex carbohydrates, like those found in whole grains, must be broken down before they can be used by the body.

Fruits, honey, and sugar cane contain sugars. Fruits are also rich in fiber.

Breads, grains, potatoes, and vegetables contain starch, a complex carbohydrate. Whole grains are also rich sources of fiber. Products made from whole grains have more fiber than products made from processed grains.

Fats Our bodies need fats, or lipids, as part of a healthy diet. **Fats** help the body absorb fat-soluble vitamins. Fats are found in cell membranes, nerve cells, and certain hormones. Body fat protects and insulates organs and stores energy.

Fats are made by combining glycerol molecules with fatty acids. Fats with only single bonds between carbons are called saturated. Unsaturated fats contain at least one double bond and fewer hydrogen atoms than saturated fats. Fats with more than one double bond are polyunsaturated. Trans fats are made by adding hydrogen atoms to unsaturated fats. Trans fats have been linked to health problems such as heart disease.

Proteins Proteins have many roles in the body. **Proteins** are used for growth and repair of tissues. Proteins called enzymes speed up chemical reactions in cells. Some proteins regulate different functions. Still others are transport molecules. Proteins can sometimes be used for energy.

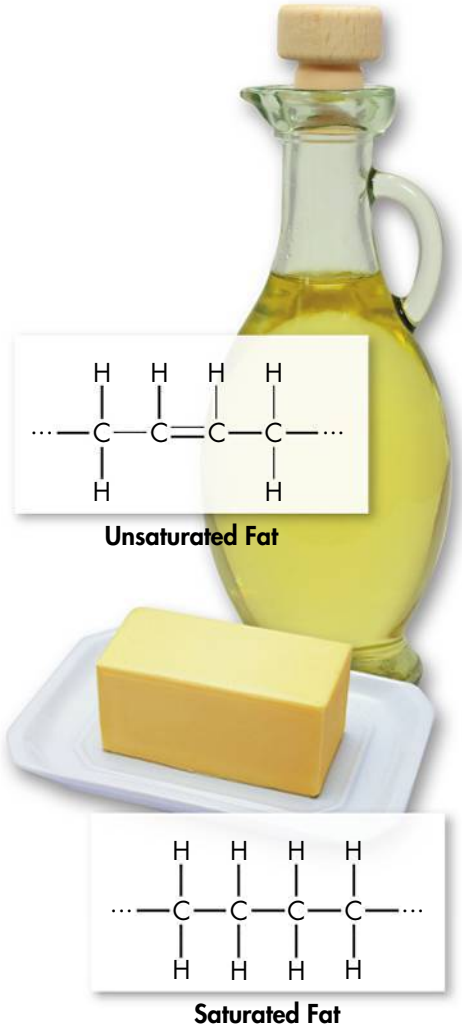
Proteins are polymers of amino acids. The body is able to make 12 of the 20 amino acids used to make proteins. The other eight are essential amino acids. They must come from food. Animal sources usually provide all eight essential amino acids, but most plant foods do not.

Vitamins Organic molecules that the body needs in very small amounts are called **vitamins.** They help perform chemical reactions. Small amounts of the fat-soluble vitamins A, D, E, and K can be stored in body fat. The B vitamins and vitamin C are water-soluble. They dissolve in water and cannot be stored by the body. They must be included in the foods you eat each day.

A diet lacking in certain vitamins can cause serious health problems. Eating a variety of foods will meet the daily vitamin needs of most people.

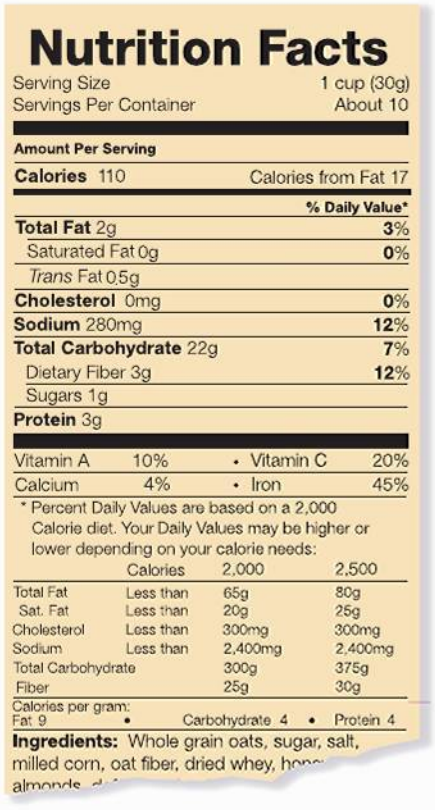
Minerals **Minerals** are inorganic nutrients that the body needs, usually in small amounts. Calcium and iron are two examples of minerals needed by the body. Minerals are needed in the diet to replace those lost in sweat and bodily wastes.

Key Question What nutrients does your body need?
The body needs water, carbohydrates, fats, proteins, vitamins, and minerals.



Fats Most saturated fats are solid at room temperature. Butter contains saturated fats. Most unsaturated fats are liquid at room temperature. Vegetable oils, like this olive oil, contain polyunsaturated fats.

Essential Amino Acid Sources Meat, milk, eggs, and fish contain all eight essential amino acids. Most plant foods do not. However, eating a balanced variety of plant foods, such as corn, other grains, and beans, can provide each of the essential amino acids.



Nutrition Facts

Serving Size 1 cup (30g)
Servings Per Container About 10

Amount Per Serving

Calories 110 Calories from Fat 17

	% Daily Value*
Total Fat 2g	3%
Saturated Fat 0g	0%
Trans Fat 0.5g	
Cholesterol 0mg	0%
Sodium 280mg	12%
Total Carbohydrate 22g	7%
Dietary Fiber 3g	12%
Sugars 1g	
Protein 3g	

Vitamin A 10% • Vitamin C 20%
Calcium 4% • Iron 45%

* Percent Daily Values are based on a 2,000 Calorie diet. Your Daily Values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Ingredients: Whole grain oats, sugar, salt, milled corn, oat fiber, dried whey, hon... almonds...

Food Label Reading food labels can help you track the amount of Calories and nutrients that you eat and drink.

Nutrition and a Balanced Diet

Nutrition is the study of food and its effects on the body. Nutrition tries to determine how food helps the body meet all its various needs. Nutritionists have developed many tools to help people plan healthful diets.

Balancing Your Diet How do you know which foods to eat for a balanced diet? Food labels can be used to choose healthful foods. You can use the labels to decide if you are consuming enough of some of the important vitamins and minerals. Nutrient needs are affected by age, gender, and lifestyle. People who are more active than average have greater energy needs. A person who stops growing or is less active has a lower need for energy.

Maintaining a Healthful Weight Exercising 30 minutes a day and eating a balanced diet helps maintain a healthful weight. Regular physical activity burns excess Calories and strengthens the heart, bones, and muscles.

Controlling fat intake is also important. Foods that contain high amounts of fat are high in Calories. Diets high in saturated and trans fats increase the risk of heart disease, Type II diabetes, or both.

Key Question What is meant by the term "balanced diet"?
A balanced diet provides the nutrients and energy needed for a person to maintain a healthful weight.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The amount of energy in food is measured in _____.
2. _____ are the organic nutrients that are needed to help the body perform chemical reactions.
3. Monosaccharides, disaccharides, and cellulose are all types of _____.

Critical Thinking

4. **Infer** Foods that contain many Calories but few raw materials are said to contain empty Calories. What do you think the term *empty Calories* means?
5. **Compare and Contrast** Saturated and unsaturated fats both are made of glycerol and fatty acids. How is a saturated fat different from unsaturated fat?
6. **Write to Learn** Answer the second clue of the mystery. Why do you think the color of the urine led the doctor to his diagnosis?

MYSTERY CLUE

Philip's and Seth's samples were both a very dark yellow. Neither boy drank water before or during practice. Why do you think they were sent home from practice? (Hint: See p. 720.)

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30.3 The Digestive System

Functions of the Digestive System

When you are hungry, your whole body needs food. But the only system in the body that food actually enters is the digestive system. How does food get to the rest of the body after you digest it? The digestive system's job is to convert the food into useful molecules. Digestion happens in four phases—ingestion, digestion, absorption, and elimination.

Ingestion The first phase in digestion is getting food into the system. Your mouth is the opening of the digestive tract. The process of putting food into your mouth is called *ingestion*.

Digestion As food passes through the digestive tract, it is broken down in two ways—by mechanical digestion and chemical digestion. Mechanical digestion is the physical breakdown of large pieces of food into smaller pieces. These smaller pieces can be swallowed and accessed by digestive enzymes. Chemical digestion is the chemical breakdown of food into smaller pieces. During chemical digestion, enzymes break down food into small molecules that the body can use.

Absorption Once food has been broken into small molecules, it can be absorbed by the small intestines. During absorption, molecules enter the circulatory system from the digestive tract. The circulatory system carries food molecules throughout the body.

Elimination The digestive system cannot digest and absorb all the food that enters your body. Substances that cannot be absorbed travel through the large intestine and are eliminated from the body as feces. Cellulose is one example of a material your body cannot digest.

Key Question What are the functions of the digestive system?

The digestive system breaks down food into molecules the body can use in its cells. Food is processed in four phases—ingestion, digestion, absorption, and elimination.

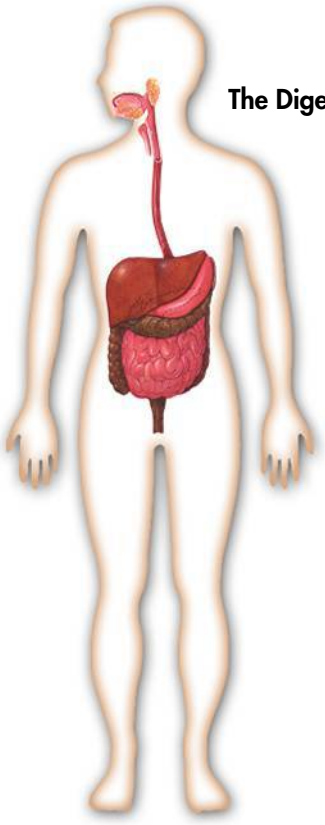
Key Questions

- ***What are the functions of the digestive system?***
- ***What occurs during digestion?***
- ***How are nutrients absorbed and wastes eliminated?***

BUILD Understanding

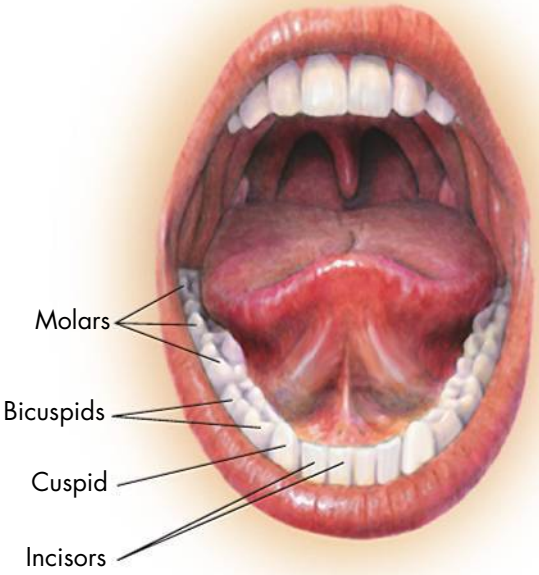
Flowchart Make a flowchart that shows the steps in the process of digestion.

In Your Workbook Refer to your workbook for suggestions about how to use a flowchart to organize your notes.



The Digestive System

The Mouth Digestion begins in the mouth. The tongue, teeth, and saliva form food into a moist lump that can be swallowed.



The Process of Digestion

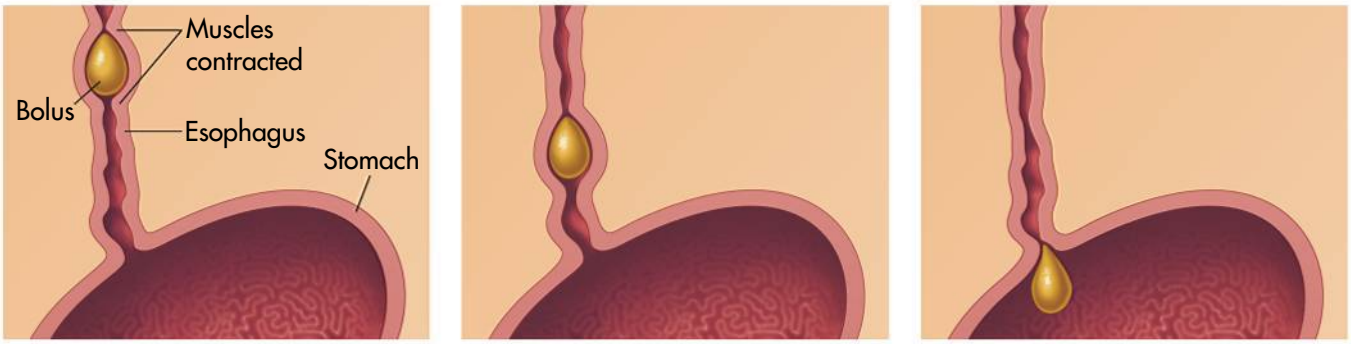
The human digestive system is built around an alimentary canal. An alimentary canal is a one-way tube that passes all the way through the body. The entrance to this tube is the mouth.

Digestion Starts in the Mouth Once food enters your mouth, your teeth begin mechanical digestion. The incisors, cuspids, and bicuspids cut and tear the food. Then the molars grind the food into a paste that you can swallow. Your tongue moves the food around so that all of it can be chewed. While you are chewing, glands in your mouth release *saliva*. Saliva moistens the food and makes it easier to chew.

Saliva contains an enzyme called **amylase** that begins chemical digestion by breaking chemical bonds in starches to release sugars. Another enzyme, called lysozyme, fights infection. Lysozyme digests the cell walls of many bacteria that may enter the mouth with food.

Once food is chewed it moves into the pharynx, which is the back of the throat. As you swallow, a flap of tissue called the epiglottis closes over the opening to the trachea to keep food out. The trachea is the tube that leads from the pharynx to the lungs.

The Esophagus The food paste forms into a clump as it is swallowed. This clump, called a bolus, enters the **esophagus** from the pharynx. The esophagus is a muscular tube that connects the pharynx to the stomach. Muscle contractions push the bolus down the esophagus into the stomach. This process, called **peristalsis,** is shown below. A ring of muscle called the cardiac sphincter closes the esophagus after the bolus enters the stomach. This prevents food from moving back into the esophagus.



Peristalsis Muscles in the walls of the esophagus contract in waves. Each wave pushes the chewed clump of food, or bolus, in front of it. Eventually, the bolus is pushed into the stomach.

Digestion in the Stomach Chemical and mechanical digestion continues in the **stomach.** Tiny glands in the stomach lining release hydrochloric acid, **pepsin,** and mucus. Pepsin is an enzyme that breaks down proteins into smaller pieces, and works best in acidic conditions. Mucus is a fluid that protects the stomach lining from the acid and lubricates the food. Smooth muscle layers in the stomach contract to mix the food with the hydrochloric acid and pepsin. The mixture that leaves the stomach is called chyme.

Digestion in the Small Intestine Chyme enters the upper part of the **small intestine** through the pyloric valve. This area of the small intestine is called the duodenum (doo oh DEE num), and is where most of the digestion and absorption of food occurs. The chyme mixes with enzymes and digestive fluids from the pancreas, liver, and the lining of the duodenum.

▶ ***Pancreas*** The pancreas is a small gland located behind the stomach. The pancreas produces enzymes, sodium bicarbonate, and hormones. The enzymes break down carbohydrates, proteins, lipids, and nucleic acids in the small intestine. Sodium bicarbonate neutralizes the acid in the chyme, protecting the small intestine's lining. It also gives the enzymes the right conditions to work. The hormones, as part of the endocrine system, regulate blood sugar levels.

▶ ***The Liver and Gallbladder*** The liver helps the pancreatic enzymes with fat digestion. The liver produces bile, a fluid loaded with lipids and salts. Bile is stored in the gallbladder until fat enters the duodenum. Fats glob together, making it hard for enzymes to digest them. Bile breaks the fat globs into smaller droplets. This makes it easier for enzymes to digest the fat.

Key Question What occurs during digestion? **During digestion, food travels through the mouth, esophagus, stomach, and small intestine. Mechanical digestion and chemical digestion break food down into molecules that can be absorbed.**

BUILD Vocabulary

amylase
the enzyme in saliva that begins breaking down starches to simple sugars

esophagus
the muscular tube that connects the throat to the stomach

peristalsis
the contractions of smooth muscle that move food through the digestive system

stomach
the organ where chemical and mechanical digestion continues after food leaves the mouth

pepsin
the stomach enzyme that begins protein digestion; it works best in acidic conditions

WORD ORIGINS

The prefix *amyl-* refers to starch. It has both Greek (*amylan*) and Latin (*amylum*) origins. The suffix *–ase* is commonly used to indicate that a substance is an enzyme. Amylase is an enzyme that breaks down starch.

Effects of Digestive Enzymes

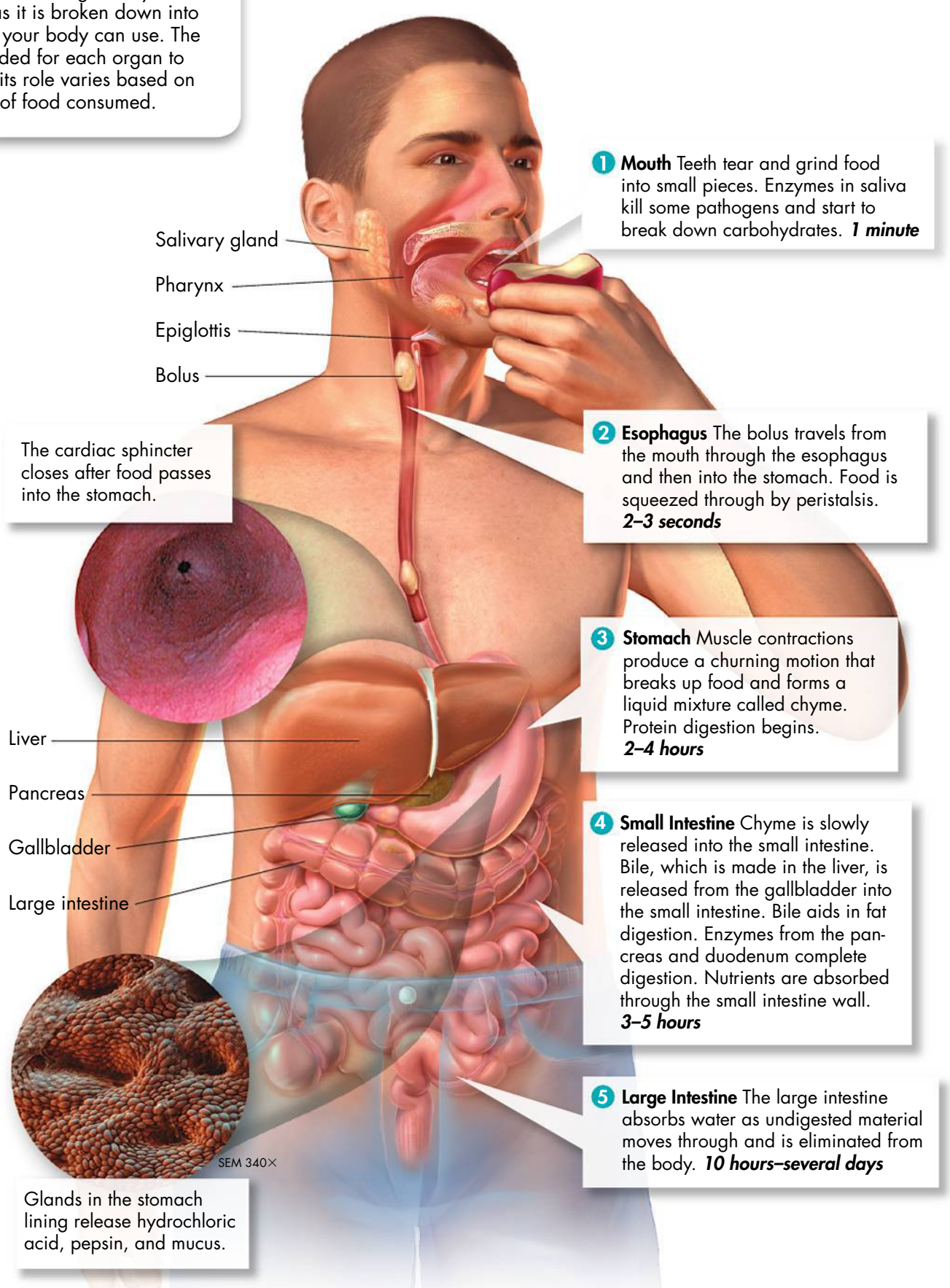
Active Site	Enzyme	Effect on Food
Mouth	Salivary amylase	Breaks down starches into disaccharides
Stomach	Pepsin	Breaks down proteins into large peptides
Small intestine (released from pancreas)	Pancreatic amylase	Continues the breakdown of starch
	Trypsin	Continues the breakdown of protein
	Lipase	Breaks down fat
Small intestine	Maltase, sucrase, lactase	Breaks down remaining disaccharides into monosaccharides
	Peptidase	Breaks down dipeptides into amino acids

Effects of Digestive Enzymes Digestive enzymes speed up the breakdown of foods. This makes nutrients from the foods available to the body.

BUILD Connections

THE DIGESTIVE SYSTEM

Food travels through many organs as it is broken down into nutrients your body can use. The time needed for each organ to perform its role varies based on the type of food consumed.



1 **Mouth** Teeth tear and grind food into small pieces. Enzymes in saliva kill some pathogens and start to break down carbohydrates. ***1 minute***

2 **Esophagus** The bolus travels from the mouth through the esophagus and then into the stomach. Food is squeezed through by peristalsis. ***2–3 seconds***

The cardiac sphincter closes after food passes into the stomach.

3 **Stomach** Muscle contractions produce a churning motion that breaks up food and forms a liquid mixture called chyme. Protein digestion begins. ***2–4 hours***

4 **Small Intestine** Chyme is slowly released into the small intestine. Bile, which is made in the liver, is released from the gallbladder into the small intestine. Bile aids in fat digestion. Enzymes from the pancreas and duodenum complete digestion. Nutrients are absorbed through the small intestine wall. ***3–5 hours***

5 **Large Intestine** The large intestine absorbs water as undigested material moves through and is eliminated from the body. ***10 hours–several days***

SEM 340×

Glands in the stomach lining release hydrochloric acid, pepsin, and mucus.

Absorption and Elimination

Once digestion is finished in the small intestine, nutrients need to be absorbed from the alimentary canal. Absorption occurs in the intestines.

Absorption From the Small Intestine Muscles in the walls of the small intestine contract in waves. These contractions move the chyme down the intestine. By this time, most of the chemical digestion is complete. The chyme is now made of small and medium molecules that can be absorbed.

The structure of the small intestine is specialized for absorption of nutrients. The folded surface of the small intestine is covered in small structures called **villi** (singular *villus*). The villi are covered in tiny microvilli that absorb nutrients from the chyme. Most of the carbohydrates and proteins are absorbed into the capillaries in the villi. Most fats and fatty acids are absorbed by lymph vessels.

Chyme has almost no nutrients by the time it is ready to leave the small intestine. Complex food molecules have been digested and absorbed. The chyme now contains water, cellulose, and undigestable substances.

BUILD Vocabulary

small intestine
the digestive organ where most chemical digestion occurs

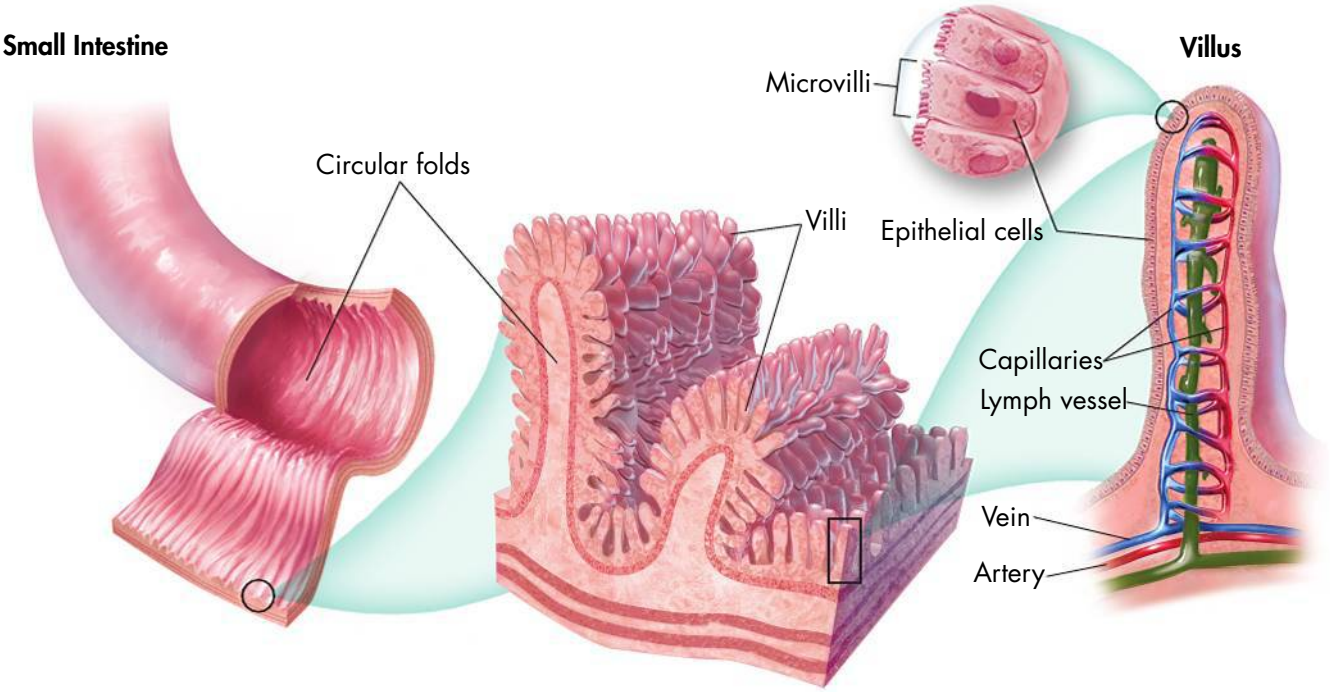
villus
a small, finger-shaped structure lining the small intestine that absorbs nutrients

large intestine
the organ that absorbs water and some vitamins from undigested material; also called the colon

WORD ORIGINS

In Latin, the word *villi* means "shaggy hair." Under a microscope, the villi in the intestine look like tiny hairs projecting from the intestine wall.

Absorption in the Small Intestine The lining of the small intestine consists of many folds. These folds are covered with tiny finger-like structures called villi. Each villus is covered in microvilli that absorb nutrients. Blood capillaries and lymph vessels in the villus carry the nutrients away from the villus.



The Large Intestine This X-ray shows the large intestine and its contents.

Absorption from the Large Intestine Most nutrients have already been absorbed from the chyme before it enters the **large intestine.** The large intestine's job is to remove water from the chyme. The water is absorbed quickly, leaving the undigested material behind. Rich colonies of bacteria in the large intestine feed on this material. They produce compounds the body can use, such as vitamin K. Taking large doses of antibiotics for an infection can destroy these bacteria. When this happens, the body may not get enough vitamin K.

Elimination The waste material left after all of the water is absorbed is called feces. The feces move into the rectum and are eliminated from the body through the anus. If something happens to stop the large intestine from absorbing enough water, a condition called diarrhea occurs. If too much water is absorbed, a condition called constipation occurs.

Key Question How are nutrients absorbed and wastes eliminated?

Most nutrients are absorbed through the walls of the small intestine. The large intestine absorbs water and some vitamins, and prepares waste for elimination.

CHECK Understanding

Apply Vocabulary

Use the highlighted terms from the lesson to complete each sentence correctly.

1. _____ in your saliva begins breaking down starch while you chew.
2. When you swallow, a process called _____ moves the bolus down the esophagus to your stomach.
3. Hydrochloric acid is secreted into the stomach to help _____ digest proteins by lowering the pH.
4. The structures that line the folds in the small intestine are called _____. Blood and lymph vessels in these structures carry absorbed nutrients to the rest of the body.

Critical Thinking

5. **Compare and Contrast** What is the difference between mechanical digestion and chemical digestion?
6. **Explain** How are nutrients absorbed?
7. **Write to Learn** In people with celiac disease, many villi and microvilli are destroyed. How do you think this disease affects their ability to absorb nutrients? Write a short paragraph explaining your answer.

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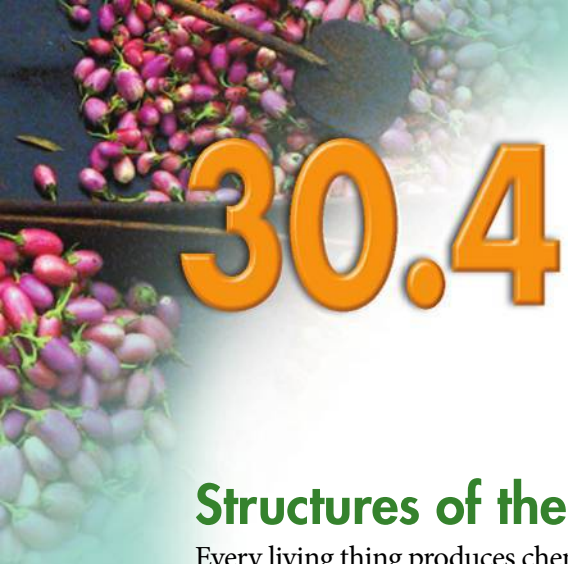


30.4 The Excretory System

Structures of the Excretory System

Every living thing produces chemical waste products. Some waste products are so toxic that they will cause death unless they are eliminated. The process of removing wastes to maintain homeostasis is called **excretion.**

The Skin The skin excretes excess water, salts, and a small amount of urea in sweat. Your skin is always releasing very small amounts of sweat.

The Lungs Carbon dioxide is a waste product of cellular respiration. Your blood transports carbon dioxide from your cells to your lungs. When you exhale, you excrete carbon dioxide and small amounts of water vapor.

The Liver The liver's job in the excretory system is to convert toxic ammonia into urea. The ammonia is produced when protein is broken down in the cells. Blood transports the urea to the kidneys where it can be eliminated from the body.

The Kidneys The major organs of excretion are the kidneys. The kidneys are a pair of fist-sized organs located on either side of the spinal column. The kidneys filter excess water, urea, and other wastes from the blood. The kidneys excrete these wastes as urine.

Key Question What is the main role of the structures of the excretory system?

The excretory system includes the skin, lungs, liver, and kidneys. The system excretes wastes from chemical processes in the body.

Excretion and the Kidneys

Nearly a million individual units process the blood in each kidney. These units are called **nephrons.** Each nephron filters out impurities and collects wastes, then sends the clean blood back into circulation. Blood is purified through two processes—filtration and reabsorption.

Key Questions

- ***What is the main role of the structures of the excretory system?***
- ***How do the kidneys clean the blood?***
- ***How do the kidneys help maintain homeostasis?***

BUILD Understanding

Preview Visuals Examine the visuals in this lesson. Think of questions to ask about the visuals.

In Your Workbook Refer to your workbook to help answer your questions.

BUILD Vocabulary

excretion
the process by which metabolic wastes are eliminated from the body

nephron
an individual unit in the kidney that processes wastes

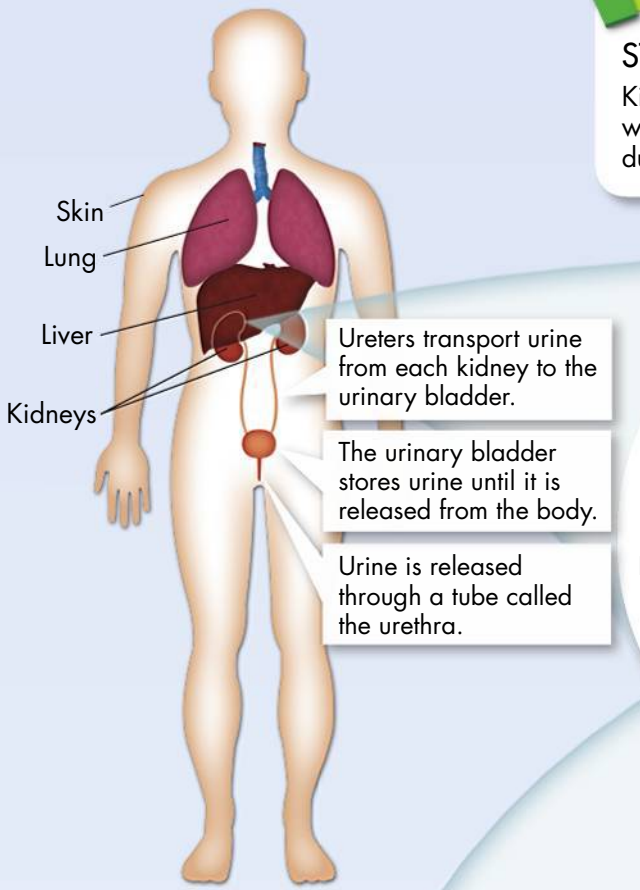
WORD ORIGINS

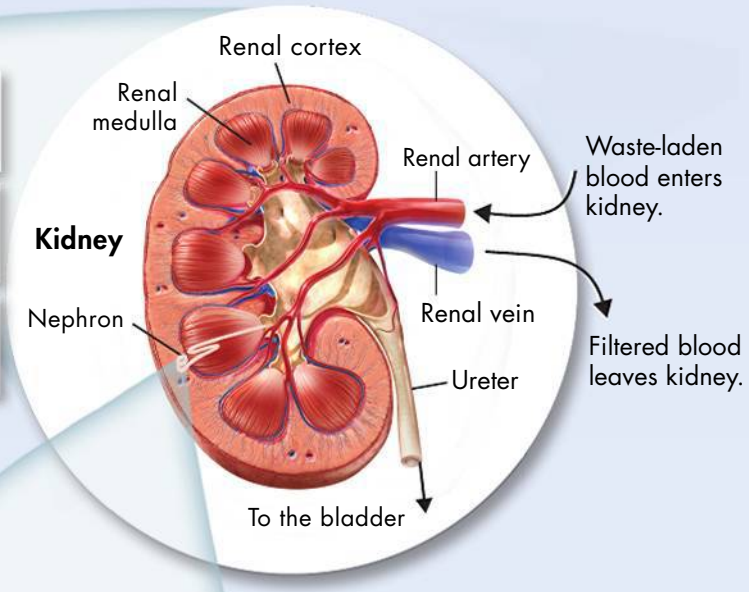
The word *glomerulus* comes from the Latin word *glomus,* which means "ball of yarn." The twisted capillaries of a glomerulus resemble a ball of yarn.

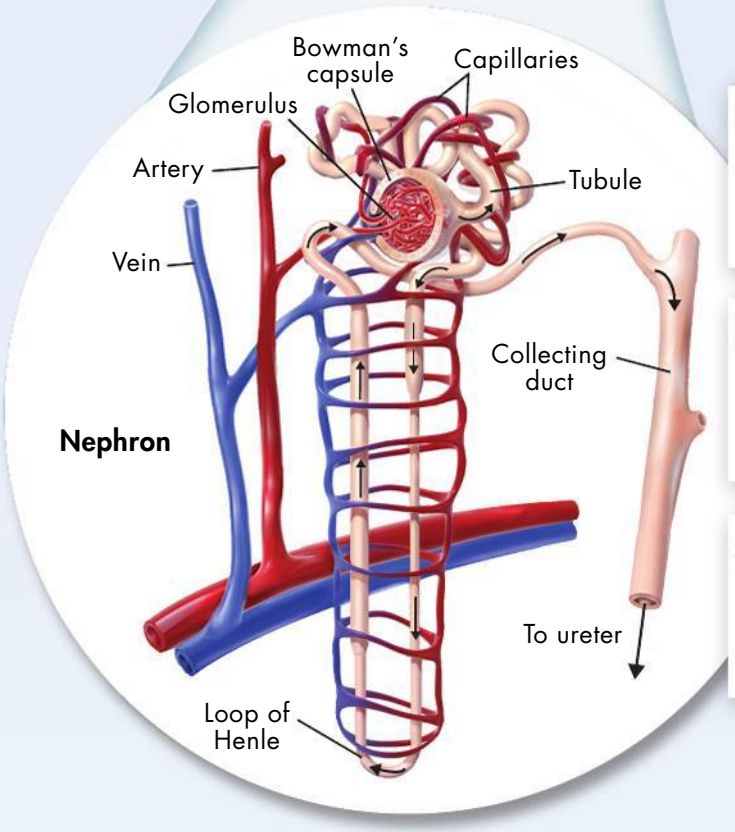
BUILD Connections

STRUCTURE AND FUNCTION OF THE KIDNEYS

Kidneys are made up of nephrons. Blood enters the nephrons, where impurities are filtered out and emptied into the collecting duct. Purified blood leaves nephrons through a vein.







1. **Filtration** Blood enters a nephron through a capillary. From the glomerulus, the filtrate flows into a tubule. Blood cells and large substances remain in the capillary.

2. **Reabsorption** As the filtrate moves through the tubule, water and many other substances that are important to the body are reabsorbed through capillary walls into the blood.

3. **Urine Excretion** Once water and other important substances are reclaimed by the blood, the filtrate is called urine. Collecting ducts gather urine and transport it to a ureter.

Filtration The process of passing a gas or liquid through a filter is called **filtration.** Blood filtration takes place mainly in the **glomerulus** (gloh MUR yoo lus). A glomerulus is a very small, dense network of capillaries. The glomerulus is enclosed in a hollow, cup-shaped structure called Bowman's capsule in the nephron.

Blood is under pressure. This pressure helps fluid from the blood move easily through the walls of the capillaries and into Bowman's capsule. This fluid in the Bowman's capsule, called the filtrate, contains water, urea, glucose, salts, amino acids, and some vitamins. Large substances like proteins and blood cells are too large to move through the capillary walls.

Reabsorption The filtrate contains some waste materials, but most of the filtrate is not waste and must be returned to the blood. Most of the filtrate is returned to the blood through **reabsorption.** Salts, vitamins, amino acids, fats, and glucose are removed from the filtrate by active transport. Water follows these substances into the blood through osmosis.

Almost 99 percent of the water that was filtered out of the blood is reabsorbed in the **loop of Henle.** The loop of Henle is responsible for conserving water and minimizing the amount of filtrate. The filtrate remaining in the tubule is called urine and empties into a collecting duct.

Urine Excretion Urine flows from collecting ducts to the **ureter** of each kidney. The ureters carry urine to the **urinary bladder** for storage. Urine leaves the body through the **urethra.**

Key Question How do the kidneys clean the blood?
The kidneys filter the blood to remove urea, excess water and minerals, and other wastes.

BUILD Vocabulary

filtration
the process of passing a liquid or gas through a filter to remove wastes

glomerulus
the network of capillaries inside the nephron

reabsorption
the process by which water and dissolved substances are taken back into the blood

loop of Henle
the section of nephron tubule that conserves water

ureter
a tube that carries urine from a kidney to the urinary bladder

urinary bladder
the muscular sac that stores urine until it is released

urethra
the tube that connects the urinary bladder to the outside of the body

WORD ORIGINS

The word *ureter* comes from the Greek word *ourētēr*. The word *urethra* comes from the Greek word *ourēthra*. *Ourētēr* and *ourēthra* share the same Greek root word, *ourein*. *Ourein* means "to urinate."

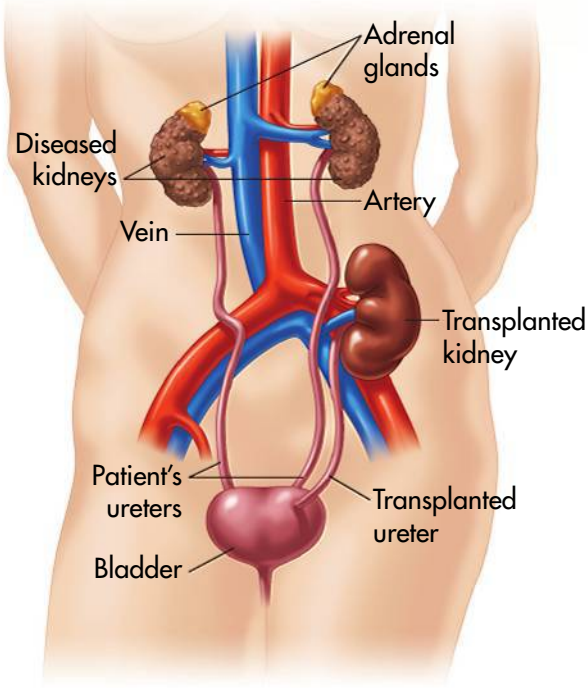
The Kidneys and Homeostasis

The kidneys play an important role in homeostasis. Besides removing wastes, they maintain blood pH and regulate water content.

Control of Kidney Function Kidney function is controlled mainly by the blood's composition. If you have too much salt in your blood, your kidneys will excrete the excess. They will also excrete excess glucose. Glucose in the urine is a sign of diabetes.

Hormones also control kidney function. Your pituitary gland releases antidiuretic hormone (ADH) into your blood when you lose too much water. ADH tells the kidneys to reabsorb more water and excrete less in the urine. When blood has too much water, ADH secretion stops.

Urine Testing Urine tells a lot about your health. The color tells how hydrated you are. If urine is pale yellow, you are well hydrated. Darker urine means that the blood has too little water and your kidneys are conserving water. Protein or glucose in urine can be a sign of high blood pressure or diabetes. Since drugs, including steroids and illegal drugs, usually are not reabsorbed by the kidneys, they end up in the urine.



Kidney Transplantation A healthy kidney and ureter are transplanted from a donor. Diseased kidneys are left in place unless they are infected or causing high blood pressure.

Kidney Disorders

If anything goes wrong with the kidneys, serious health problems will probably occur. Three of these problems are kidney stones, kidney damage, and kidney failure.

▶ ***Kidney Stones*** Sometimes minerals or uric acid salts in the urine form crystals. These crystals can grow into kidney stones. If the stones block a ureter, they cause great pain. Kidney stones can be broken into smaller pieces with sound waves. The pieces are then eliminated in the urine.

▶ ***Kidney Damage*** Many diseases, injuries, and dangerous substances can cause kidneys to function poorly. High blood pressure and diabetes are two of the leading causes of kidney damage in the United States.

▶ ***Kidney Failure*** Kidney failure occurs when the kidneys can no longer clean the blood and maintain homeostasis. Patients in kidney failure must have either dialysis or a kidney transplant. During dialysis, the blood is pumped through a machine that filters it. Dialysis is not painful. Dialysis patients must control their fluid intake and diet. In a kidney transplant, a person receives a kidney and ureter from a donor. The donor and the patient must have similar body chemistries. A person can survive with only one kidney.

Key Question How do the kidneys help maintain homeostasis?
The kidneys respond directly to blood composition and to hormones. Disruption of kidney function can lead to serious health problems.

CHECK Understanding

Apply Vocabulary

Use the highlighted terms from the lesson to complete each sentence correctly.

1. The individual unit in the kidney where filtration and reabsorption takes place is called the _____.
2. The _____ is a tightly wound network of blood vessels that filters the blood.
3. Water reabsorption takes place in the _____.

Critical Thinking

4. **Interpret Visual** Refer back to the figure on page 730. List in order the structures that blood flows through in a kidney.
5. **Apply Concepts** Why do you think protein in the urine is a sign of kidney damage?
6. **Write to Learn** Answer the third clue of the mystery. What characteristics of the urine samples led you to your conclusion about ADH levels?

MYSTERY CLUE

Would Seth's and Philip's blood contain a high level or low level of ADH? (Hint: See p. 731.)

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The Composition of Urine

The kidneys are selective filters. They remove urea, other impurities, and excess salts as blood passes through them. However, important substances such as water, protein and glucose stay in the blood. The collected waste products are excreted in urine. The table shows how the amounts of several important substances differ between the blood and the urine.

Study the data in the table. Notice that only glucose is lower in urine than in blood. All other substances have a higher concentration in the urine than in the blood.

How can you determine how much greater the concentration of a substance is in the urine than in the blood? You can compare the two amounts for a substance by using a ratio. Look at the calculation for potassium:

We want to know how much greater the amount of potassium is in the urine, so we will write our ratio as

$$\frac{\text{Concentration of potassium in urine}}{\text{Concentration of potassium in blood}} = \frac{0.20}{0.02}$$

To find out how many times more concentrated the potassium is in urine than in the blood, simplify the fraction:

$$\frac{0.20}{0.02} = \frac{10}{1}$$

For potassium, the fraction simplifies to 10/1. This means that potassium is ten times more concentrated in the urine than in the blood.

Concentrations of Selected Substances in Blood and Urine

Substance	Average Concentration in Blood (g/mL)	Average Concentration in Urine (g/mL)
Calcium	0.01	0.02
Glucose	0.10	0.00
Potassium	0.02	0.20
Sodium	0.32	0.60
Urea	0.03	2.00

Analyze and Conclude

1. Interpret Data

- Which substance has the highest concentration in the blood?
- Which substance has the lowest concentration in the blood?
- Which substance has the highest concentration in the urine?
- Which substance has the lowest concentration in the urine?

2. Calculate What is the ratio of urea in urine to urea in blood?

$$\frac{\text{Concentration of urea in urine}}{\text{Concentration of urea in blood}} = \frac{\quad}{\quad} = \frac{\quad}{1}$$

3. Predict Remember that urea is produced from ammonia, which is more toxic. Ammonia is produced when cells break down amino acids. Suppose someone eats a diet that is higher in protein than the person's usual diet. What do you think would happen to the urea concentrations in this person's blood and urine?

a. Urea increases in the blood and increases in the urine.

b. Urea increases in the blood and decreases in the urine.

c. Urea decreases in the blood and increases in the urine.

d. Urea decreases in the blood and decreases in the urine.

In Your Workbook Get help for this activity in your workbook.

Real-World Lab GUIDED INQUIRY

Pre-Lab: Digestion of Dairy Products

Problem How can an enzyme deficiency affect digestion?

Materials well plate, sheet of paper, glucose solution, milk, milk-digestion aid, toothpicks, glucose test strips

Lab Manual Chapter 30 Lab

Skills Focus Control Variables, Infer, Draw Conclusions

Connect to the Big idea Food is both a source of raw materials and a source of energy for your body. First the food must pass through your digestive system, where mechanical and chemical processes break the food down into smaller molecules. Enzymes play an essential role in chemical digestion. Different enzymes are needed to digest proteins, fats, and carbohydrates. In this lab, you will explore the role of enzymes in the digestion of milk and other dairy products.

Background Questions

a. **Review** What is an enzyme? Why are enzymes necessary for maintaining homeostasis?

b. **Review** Where do most digestive enzymes enter the digestive system?

c. **Compare and Contrast** Use glucose and sucrose to explain the difference between a monosaccharide and a disaccharide.

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Design an Experiment** What is the purpose of the glucose solution?
2. **Control Variables** What is the control in this lab?
3. **Communicate** Read the instructions on the package of glucose test strips. Then, briefly describe how you will test your samples for the presence of glucose.

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Visit Chapter 30 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Hold your noses as you join the Untamed Science crew to learn what scientists can discover about animals by investigating their scat.

Tutor Tube Tune in to Tutor Tube for another perspective on how homeostasis works in the human body.

Art Review Review your understanding of human body systems.

Art in Motion Watch peristalsis in action in the esophagus.

30 CHAPTER Summary

30.1 Organization of the Human Body

- The human body is organized into four levels: cells, tissues, organs, and organ systems.
- Homeostasis is a state of relative balance in an organism's physical and chemical conditions. Homeostasis continues even when internal and external environments change.

epithelial tissue (p. 714)
connective tissue (p. 714)
nervous tissue (p. 715)
muscle tissue (p. 715)
homeostasis (p. 717)
feedback inhibition (p. 717)

30.2 Food and Nutrition

- Molecules in food contain chemical energy. Your cells use this chemical energy to produce ATP. Food also supplies raw materials your body needs to build and repair tissues.
- The body needs water, carbohydrates, fats, proteins, vitamins, and minerals.
- A balanced diet provides the nutrients a person needs to maintain a healthful weight.

Calorie (p. 719)
carbohydrate (p. 720)
fat (p. 721)
protein (p. 721)
vitamin (p. 721)
mineral (p. 721)

30.3 The Digestive System

- The digestive system breaks down food into molecules the body can use in its cells. Food is processed in four phases—ingestion, digestion, absorption, and elimination.
- During digestion, food travels through the esophagus, stomach, and small intestine. Mechanical digestion and chemical digestion break food down into molecules that can be absorbed.
- The small intestine absorbs most of the nutrients released during chemical digestion. The large intestine absorbs water and some vitamins, and prepares wastes for eliminaion.

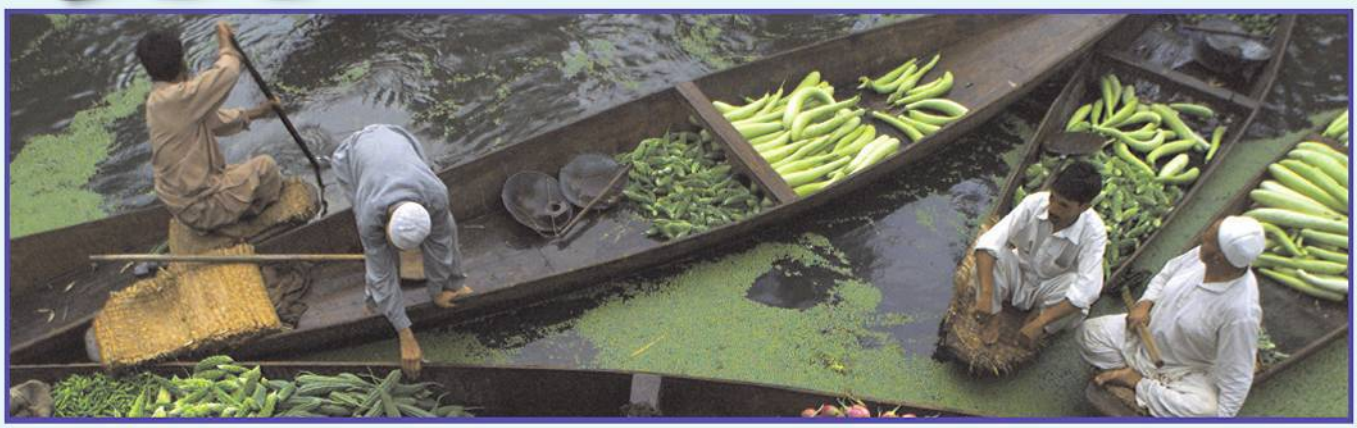
amylase (p. 724)
esophagus (p. 724)
peristalsis (p. 724)
stomach (p. 725)
pepsin (p. 725)
small intestine (p. 725)
villus (p. 727)
large intestine (p. 728)

30.4 The Excretory System

- The excretory system includes the skin, lungs, liver, and kidneys. This system excretes the wastes from chemical processes in the body.
- The kidneys filter the blood to remove urea, excess water and minerals, and other wastes.
- The composition of the blood helps determine what the kidneys remove during filtration. Hormones also tell the kidneys what substances to remove or keep. If the kidneys do not function properly, serious health problems can occur.

excretion (p. 729)
nephron (p. 729)
filtration (p. 731)
glomerulus (p. 731)
reabsorption (p. 731)
loop of Henle (p. 731)
ureter (p. 731)
urinary bladder (p. 731)
urethra (p. 731)

30 CHECK Understanding



Assess the Big idea Homeostasis

Write an answer to the question below.
Q: How are the materials that enter and leave your body related to the processes that maintain homeostasis?

Constructed Response

Write an answer to each of the numbered questions below. The answer to each question should be one or two paragraphs. To help you begin, read the **Hints** below the questions.

1. **How do the digestive and excretory systems work together to help the body maintain homeostasis?**

   Hint The digestive system absorbs nutrients needed to keep the body's cells healthy.

   Hint The excretory system removes wastes and regulates the body's water levels.

2. **Why is mechanical digestion important?**

   Hint Mechanical digestion breaks food into smaller particles.

   Hint Mechanical digestion mixes food with digestive juices.

3. **How could a failure to respond to ADH be dangerous to an athlete?**

   Hint The glomerulus filters water from the blood and the tubules reabsorb what is needed.

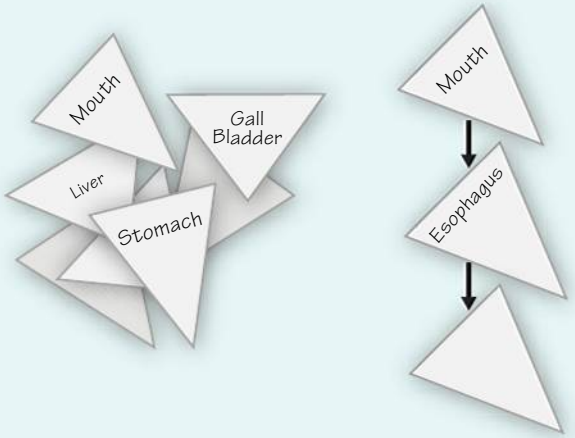
   Hint The pituitary releases ADH when water levels in the body are too low.

Foundations for Learning Wrap-Up

The pinwheels you prepared when you started the chapter are tools you can use to arrange your thoughts about the organization of the human body.

Activity 1 Working with a partner, go through the organs on each pinwheel. Discuss how the organ on each tab relates to the other organs and to the body system to which it belongs.

Activity 2 Working in small groups, create a flowchart that shows, in order, the organs through which food passes as it moves through the digestive system.



30.1 Organization of the Human Body

Understand Key Concepts

1. What do all types of tissue have in common?
   - **a.** They are all made of connective tissue.
   - **b.** They are all made of cells.
   - **c.** They are all found in every organ.
   - **d.** They are all made of organs.
2. Why is it important for an organism to maintain homeostasis?
3. Name the four types of tissues and describe one characteristic of each.

Think Critically

4. **Explain** Would you classify blood as a cell, tissue, or an organ? Explain.

30.2 Food and Nutrition

Understand Key Concepts

5. Inorganic nutrients that your body needs, usually in small amounts, are called
   - **a.** vitamins.
   - **b.** minerals.
   - **c.** proteins.
   - **d.** amino acids.

Test-Taking Tip

Watch for Qualifiers Sometimes questions have qualifiers that are clues to which answers are wrong. A qualifier gives you a limit, such as an amount. In question 5, you are told that the nutrients are usually needed in *small* amounts. Proteins and amino acids are needed in large amounts. So **c** and **d** are wrong answers. In this question you are also given the qualifier *inorganic*. So you can eliminate **a**, because vitamins are organic nutrients.

6. Energy in food is measured in
   - **a.** ATP.
   - **b.** fats.
   - **c.** Calories.
   - **d.** disaccharides.
7. Which nutrients provide the body with energy?
8. In what three ways are proteins important to the body?

Think Critically

9. **Infer** Many food manufacturers have replaced trans fats in their foods with other types of fats. The replacement fats have a lower level of heart disease risk. Some nutritionists fear that people will think foods such as French fries and doughnuts are healthful if they are not made with trans fats. Explain why these foods are still not healthful choices.

30.3 The Digestive System

Understand Key Concepts

10. Where does mechanical digestion begin?
    - **a.** the esophagus
    - **b.** the large intestine
    - **c.** the mouth
    - **d.** the small intestine
11. An enzyme in saliva that can break the chemical bonds in starch is
    - **a.** pepsin.
    - **b.** bile.
    - **c.** amylase.
    - **d.** chyme.
12. Explain why swallowed food does not normally enter the airway leading to the lungs.
13. Describe the functions of the pancreas.

Think Critically

14. **Relate Cause and Effect** Suppose that your doctor prescribed an antibiotic for an infection. The antibiotic killed all the bacteria in your body. What effect would this have on your digestive system?

30.4 The Excretory System

Understand Key Concepts

15. Urine is excreted from the body through the
    - **a.** ureter.
    - **b.** urinary bladder.
    - **c.** urethra.
    - **d.** renal vein.

30 CHECK Understanding

16. Which of the following is the basic functional unit of the kidney?
    a. nephron **c.** Bowman's capsule
    b. glomerulus **d.** loop of Henle
17. What is the role of the skin in excretion?
18. What materials are filtered from the blood in the kidney? What materials are not filtered from the blood?

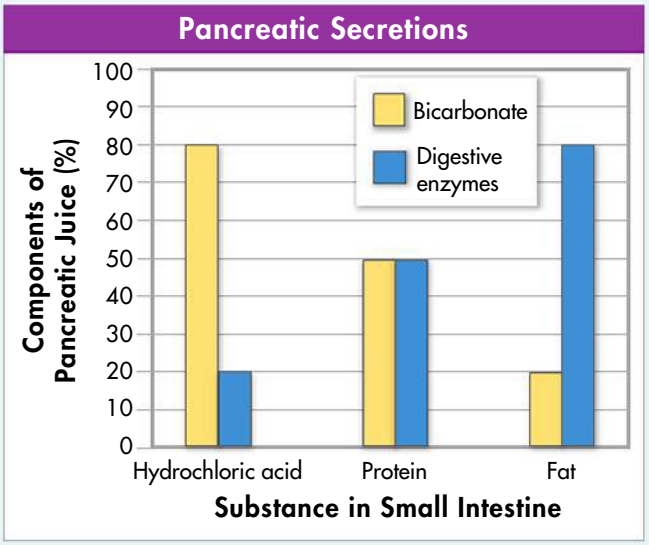
Think Critically

19. **Apply Concepts** Explain why kidney failure can be a fatal condition.

Connecting Concepts

Use Science Graphics

Pancreatic secretions contain sodium bicarbonate and enzymes. The graph shows the secretions of the pancreas in response to three different substances in chyme. Use the graph to answer questions 20 and 21.



20. **Interpret Visuals** Each pair of bars represents the response of the pancreas to a different variable. What are the three variables?
21. **Compare and Contrast** Compare the composition of pancreatic secretions in the presence of hydrochloric acid and fat.

solve the CHAPTER MYSTERY

THE TELLTALE SAMPLE

For centuries, people have studied urine for clues to health and disease. For example, the Greeks knew that diabetics had too much sugar in their urine. They called this disease *diabetes mellitus*. *Mellitus* is the Greek word for "honey."

- **Physical Examination** First, doctors check the color of urine and look for cloudiness. The shade of yellow indicates the amount of water the kidneys are removing from the blood. Urine of a color other than yellow could indicate the presence of blood. Urine should be clear rather than cloudy.
- **Microscopic Examination** Mucus, white blood cells, or microorganisms in urine indicate a possible infection. Crystals may also cause cloudy urine. Crystals in the urine may indicate kidney stones or a problem with the chemical processes in the body.
- **Chemical Examination** Hundreds of chemical tests can be performed on urine. Chemical dipsticks that change color show that other chemicals are present. These tests can reveal a lot about kidney and liver function. They also reveal a lot about overall homeostasis in the body.

1. **Infer** How does urine reveal so much about the health of the human body?
2. **Form an Opinion** Most drug urine tests done for schools do not test for alcohol or tobacco. Why do you think this is the case? Do you agree or disagree? Explain.

Untamed Science **Never Stop Exploring Your World.** Finding the solution to the Telltale Sample mystery is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where this mystery leads.

Standardized Test Prep

Multiple Choice

1. Which of the following is NOT a kind of tissue in the human body?
- **A** epithelial
- **B** connective
- **C** interstitial
- **D** nervous

2. Each of the following aids in the process of digestion EXCEPT
- **A** teeth
- **B** saliva
- **C** stomach
- **D** kidney

3. In the human body, hydrochloric acid is responsible for the low pH of the contents of the
- **A** kidney
- **B** gallbladder
- **C** stomach
- **D** liver

4. Which is NOT a function of the kidneys?
- **A** removal of waste products from the blood
- **B** maintenance of blood pH
- **C** regulation of water content of the blood
- **D** excretion of carbon dioxide

5. The main function of the digestive system is to
- **A** break down large molecules into smaller molecules.
- **B** excrete oxygen and carbon dioxide.
- **C** synthesize minerals and vitamins needed for a healthy body.
- **D** remove waste products from the blood.

6. In the kidneys, both useful substances and wastes are removed from the blood by
- **A** reabsorption.
- **B** excretion.
- **C** dialysis.
- **D** filtration.

7. Which of the following is NOT a role of fats in the body?
- **A** Deposits of fat act as insulation.
- **B** They are components of cell membranes.
- **C** They help with absorption of fat-soluble vitamins.
- **D** They are enzymes.

Questions 8–9

A student is studying the effect of temperature on the action of an enzyme in stomach fluid. The enzyme digests protein. An investigation was set up using five identical test tubes. Each tube contained 40 mL of stomach fluid and 20 mm of glass tubing filled with gelatin. Each tube was subjected to a different temperature. After 48 hours, the amount of gelatin digested in each tube was measured in millimeters. The results for the five test tubes are shown in the table.

Effect of Temperature on Enzyme Action

Test Tube	Temperature (°C)	Amount of Digestion After 48 Hours
1	2	0.0 mm
2	10	3.0 mm
3	22	4.5 mm
4	37	8.0 mm
5	100	0.0 mm

8. Which is the manipulated (independent) variable in this investigation?
- **A** gastric fluid
- **B** length of glass tubing
- **C** temperature
- **D** time

9. Another test tube was set up that was identical to the other test tubes and placed at a temperature of 15°C for 48 hours. What amount of digestion would you expect to occur in this test tube?
- **A** less than 3.0 mm
- **B** between 3.0 mm and 4.5 mm
- **C** between 4.5 mm and 8.0 mm
- **D** more than 8.0 mm

Open-Ended Response

10. Fad diets that boast of rapid weight loss often become popular. Many of these diets involve eating only a limited variety of foods. Explain why these diets are an unhealthful way to lose weight.

If You Have Trouble With . . .

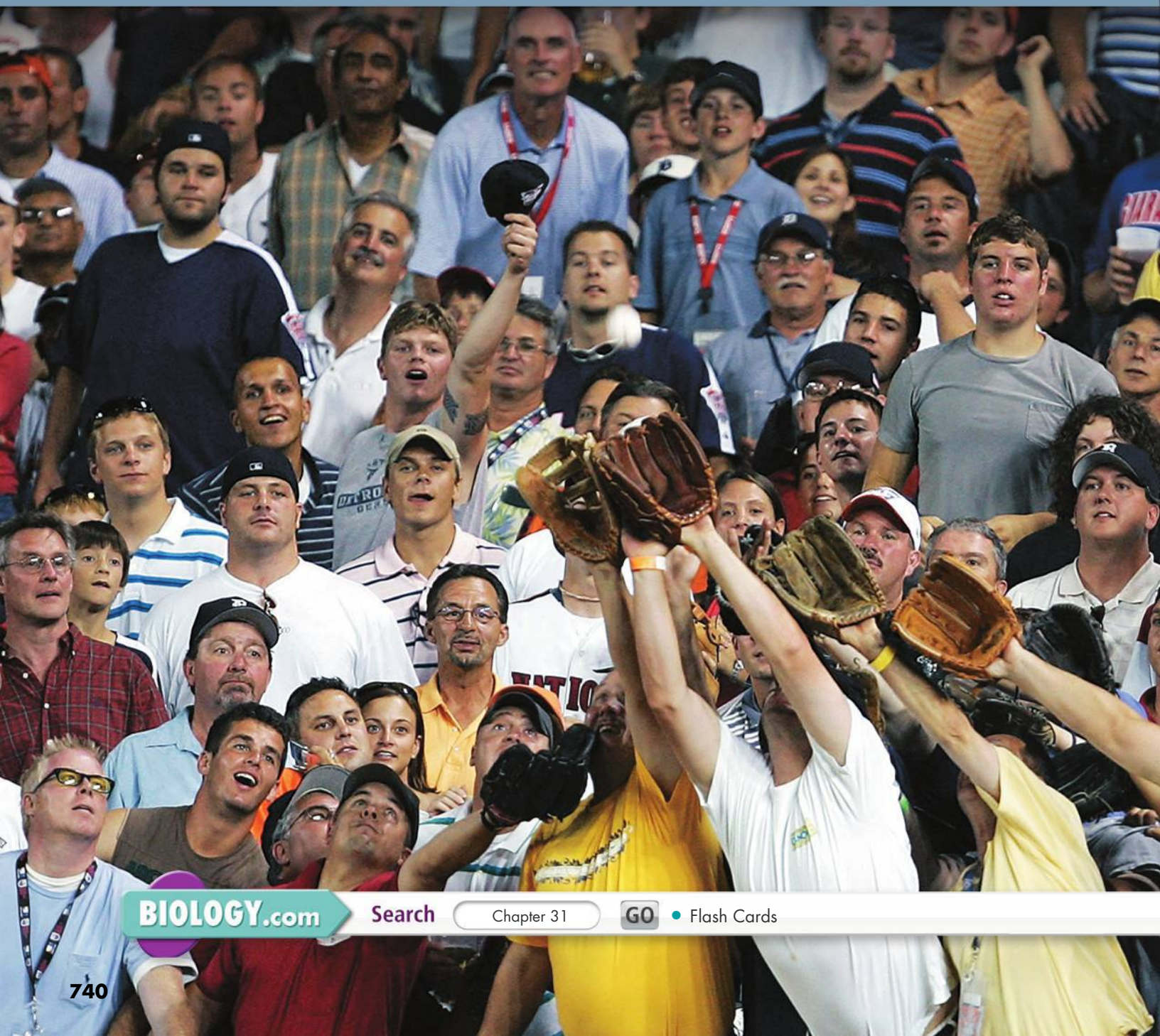
Question	1	2	3	4	5	6	7	8	9	10
See Lesson	30.1	30.3	30.3	30.4	30.3	30.4	30.2	30.3	30.3	30.2

31 The Nervous System

Big idea

Structure and Function

Q: How does the structure of the nervous system allow it to regulate functions in every part of the body?



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INSIDE:

The sights, sounds, and smells at a ball game provide a fan's nervous system with a lot of stimulation.

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

POISONING ON THE HIGH SEAS

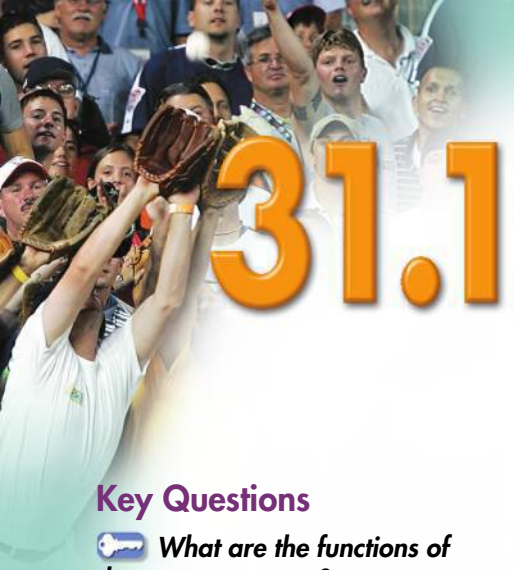
From the middle to late 1700s, Captain James Cook commanded several voyages of discovery. During this time, he sailed to the South Pacific for Great Britain. His discovery of new lands brought him many riches. But the discoveries of new animals were not always pleasant.

September 7, 1774, was a remarkable day on the HMS *Resolution*. The ship's butcher died from a fall, and there was a solar eclipse. A clerk also traded some cloth for a freshly caught fish. Captain Cook ate only a few bites of the fish. But within a few hours, the captain felt an extraordinary weakness in his limbs. He also lost all sense of touch, and he could not sense the weight of objects. It took eleven days for the men who ate the fish to recover. A pig and dog that ate some of the fish's organs were dead by the next morning.

Read for Mystery Clues Look for clues as to how eating this fish could produce such deadly effects. Then, solve the mystery.

FOUNDATIONS for Learning

The nervous system is the control center for the body. Before you read the chapter, cut out about twenty 10 cm × 10 cm squares of paper. Punch small holes in each corner of the squares. As you read the chapter, write a structure or function of the nervous system on each square. Use the squares to keep track of important facts about each structure or function. At the end of the chapter are two activities that use these squares to help you answer the question: How does the structure of the nervous system allow it to regulate functions in every part of the body?



31.1 The Neuron

Key Questions

- ***What are the functions of the nervous system?***
- ***What is the function of neurons?***
- ***How does a nerve impulse begin?***

BUILD Understanding

Flowchart Create a flowchart to show information flow in the nervous system.

In Your Workbook Go to your workbook for help on creating the flowchart. Complete the flowchart in Lesson 31.1.

Functions of the Nervous System

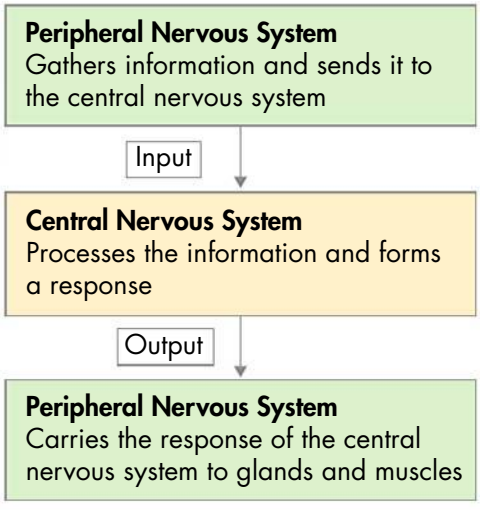
We are all aware of the world outside our bodies. But how do you know about that world? When you opened the book to this page, how did you make this happen? How did the words that you are reading right now get into your mind? The answers to these questions are found in the nervous system.

The nervous system is our window on the world. The nervous system collects information about the body's internal and external environment. The system then processes that information and responds to it. These functions are accomplished by the peripheral nervous system and the central nervous system. The **peripheral nervous system** consists of nerves and supporting cells. This system collects information about the body's external and internal environment. The **central nervous system** consists of the brain and spinal cord. This system processes the information collected by the peripheral nervous system and creates a response. The response is delivered to the appropriate body part through the peripheral nervous system.

Think about what happens when you search for a pencil in your backpack. Your fingertips send information to your central nervous system about the objects you are touching. Your brain processes the information. It determines that the first object you touch is too square to be a pencil. Then your brain sends messages via your peripheral nervous system to the muscles in your hand. The messages command them to keep searching.

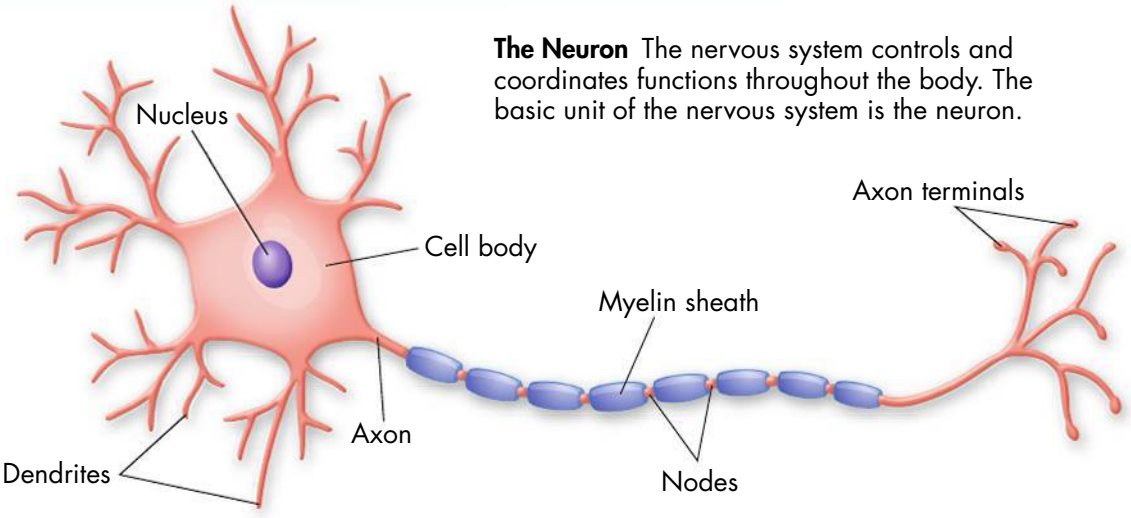
Imagine the billions of messages that are sent throughout your body at any given moment. The messages may tell you to laugh at a funny joke. Or they may tell your brain that it's cold outside. These messages allow the different organs of the body to act together. They also allow the organs to react to conditions in the world around us. How does this communication occur?

Information Flow in the Nervous System



Key Question What are the functions of the nervous system?

The nervous system collects information about the body's internal and external environment. The system then processes that information and responds to it.



The Neuron The nervous system controls and coordinates functions throughout the body. The basic unit of the nervous system is the neuron.

Neurons

The messages carried by the nervous system are electrical signals called impulses. Impulses are carried by cells called neurons.

Types of Neurons Neurons can be classified into three types based on the direction in which an impulse travels. Sensory neurons carry impulses from the sense organs to the spinal cord and brain. Motor neurons carry impulses from the brain and the spinal cord to muscles and glands. Interneurons do the high-level work. They process information from sensory neurons. Then they send commands to other interneurons or to motor neurons.

Structure of Neurons Neurons come in many shapes and sizes, but they all share certain features. The largest part of a typical neuron is its **cell body.** The cell body contains the nucleus and much of the cytoplasm.

Short, branched extensions called **dendrites** spread out from the cell body. They receive impulses from other neurons and carry impulses to the cell body. The long fiber that carries impulses away from the cell body is the **axon.** The axon ends in a series of small swellings called axon terminals. A neuron may have dozens of dendrites, but usually only one axon. Axons and dendrites of different neurons form bundles of fibers called nerves.

The axons of some neurons are insulated by a membrane known as the myelin (MY uh lin) sheath. The myelin sheath around a long axon has many gaps, called nodes. Impulses move along the axon by jumping from one node to the next. Impulses travel faster along these axons than along axons without myelin.

Key Question What is the function of neurons?
Nervous system impulses are carried by cells called neurons.

BUILD Vocabulary

peripheral nervous system
a network of nerves and supporting cells that carries signals into and out of the central nervous system

central nervous system
a system that includes the brain and spinal cord; processes information and creates a response that it delivers to the body

cell body
the largest part of a typical neuron; contains the nucleus and much of the cytoplasm

dendrite
an extension of the cell body of a neuron that carries impulses from the environment or from other neurons toward the cell body

axon
a long fiber that carries impulses away from the cell body of a neuron

MULTIPLE MEANINGS

The dendrites on the cell body of a neuron give the neuron a treelike shape. In geology, a dendrite is a crystal with a treelike shape.

BUILD Vocabulary

resting potential
an electrical charge across the membrane of a resting neuron

action potential
a reversal of charges across the cell membrane of a neuron; also called a nerve impulse

threshold
the minimum level of a stimulus that is required to cause an impulse

synapse
the point at which a neuron can transfer an impulse to another cell

ACADEMIC WORDS

In science, the word *potential* refers to a difference in electrical charge. Another word for *potential* is "voltage." In cells, *potential* is measured in millivolts (mV). In contrast, the *potential* of a typical AA battery is 1.5 volts.

The Nerve Impulse

Nerve impulses are a bit like the flow of an electric current through a wire. To see how this occurs, let's first examine a neuron at rest.

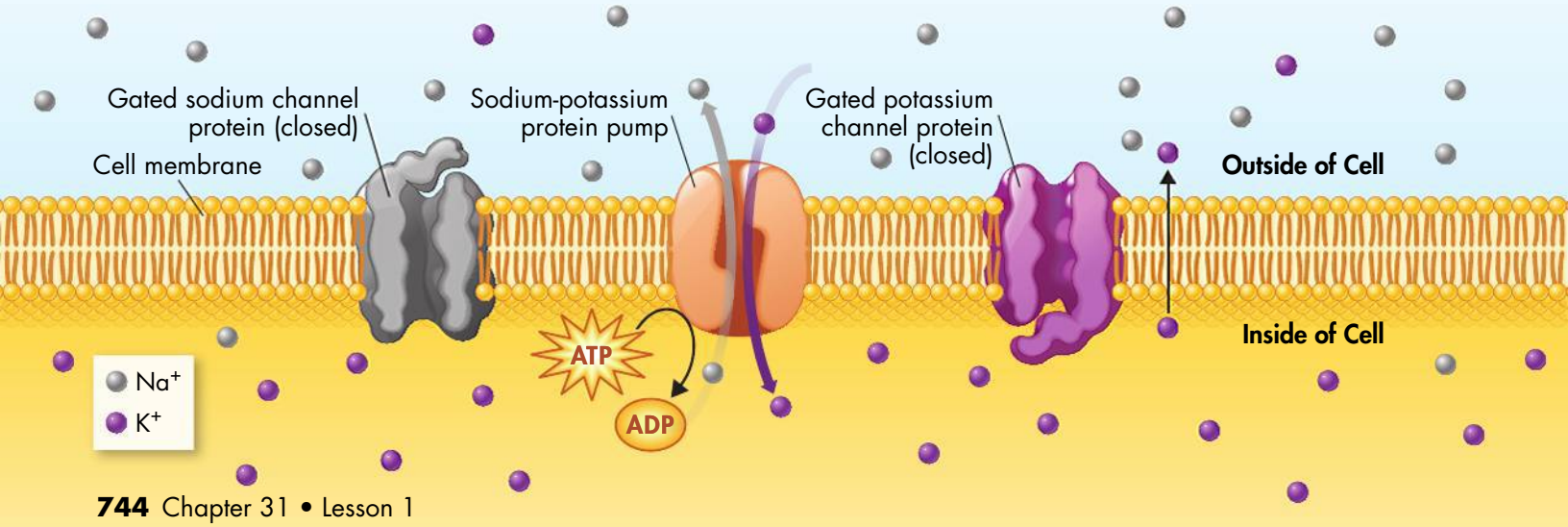
The Resting Neuron Like most cells, neurons have an electrical charge across their cell membranes. The difference in charge between the inside and the outside of a neuron is −70 millivolts (mV). This difference in charge is called the **resting potential.** The resting potential charge is about one twentieth the voltage in a flashlight battery. Where does this potential come from?

Active transport proteins pump sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell. Potassium ions also diffuse back through ungated potassium channel proteins in the neuron's membrane. These potassium channels allow K^+ ions to diffuse across the membrane more easily than Na^+ ions. The concentration of K^+ ions is greater inside the cell because of active transport. This greater concentration causes positively charged K^+ ions to move out of the cell. Then, the inside of the cell becomes negatively charged compared to the outside, producing the resting potential.

The Moving Impulse A neuron stays in its resting state until it receives an impulse because of a stimulus. An impulse begins when a neuron is stimulated by another neuron or by the environment. Once it begins, the impulse travels quickly down the axon toward the axon terminals. Impulses in myelinated axons move even more rapidly because they skip from one node to the next.

The impulse is a sudden reversal of the resting potential. At the leading edge of an impulse, "gated" sodium channels open. Positively charged Na^+ ions flow into the cell. The inside of the membrane temporarily becomes more positive than the outside. This charge reversal is the nerve impulse, or **action potential.**

The Resting Neuron The sodium-potassium pump uses ATP to pump Na^+ ions out of the cell. At the same time, it pumps K^+ ions in. A small amount of K^+ diffuses out of the cell through ungated channels. But gated channels block Na^+ from flowing into the resting neuron.



BUILD Connections

A CHAIN REACTION

With a strong enough push, the fall of one domino leads to the fall of the next. An action potential moves along a neuron in a similar manner.

Once the impulse passes, sodium gates close and gated potassium channels open. The opening of these sodium channels allows K^+ ions to flow out, restoring the resting potential. The neuron is once again negatively charged on the inside. The sodium-potassium pump also keeps working, so the axon will be ready for more action potentials.

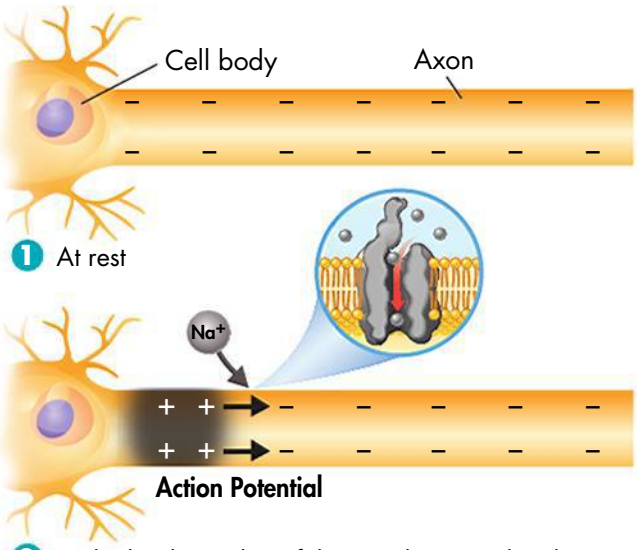
The flow of ions causes sodium channels just ahead of the point of impulse to open. The opening of these sodium channels allows the impulse to move rapidly along the axon. You could compare the flow of an impulse to the fall of a row of dominoes. As each domino falls, it causes the next domino to fall.

Threshold Not all stimuli can start an impulse in a neuron. The minimum level of a stimulus needed to cause an impulse is called the **threshold.** Any stimulus that is weaker than the threshold will not produce an impulse. A nerve impulse is an all-or-none response. Either the stimulus produces an impulse, or it does not produce an impulse.

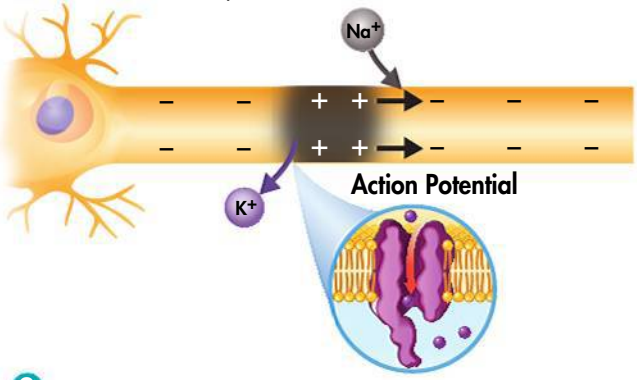
The threshold principle can be illustrated by using a row of dominoes. If you were to gently press the first domino in a row, it might not move at all. A slightly harder push might make the domino wobble back and forth but not fall. A push may be strong enough to cause the first domino to fall into the second. If this push starts the whole row of dominoes falling, then the push is like a threshold stimulus.

All action potentials have the same strength. So how do we sense if a stimulus, like touch or pain, is strong or weak? The brain determines the strength of a stimulus from the frequency of action potentials. A weak stimulus might produce three or four action potentials per second, while a strong one might result in as many as 100 per second.

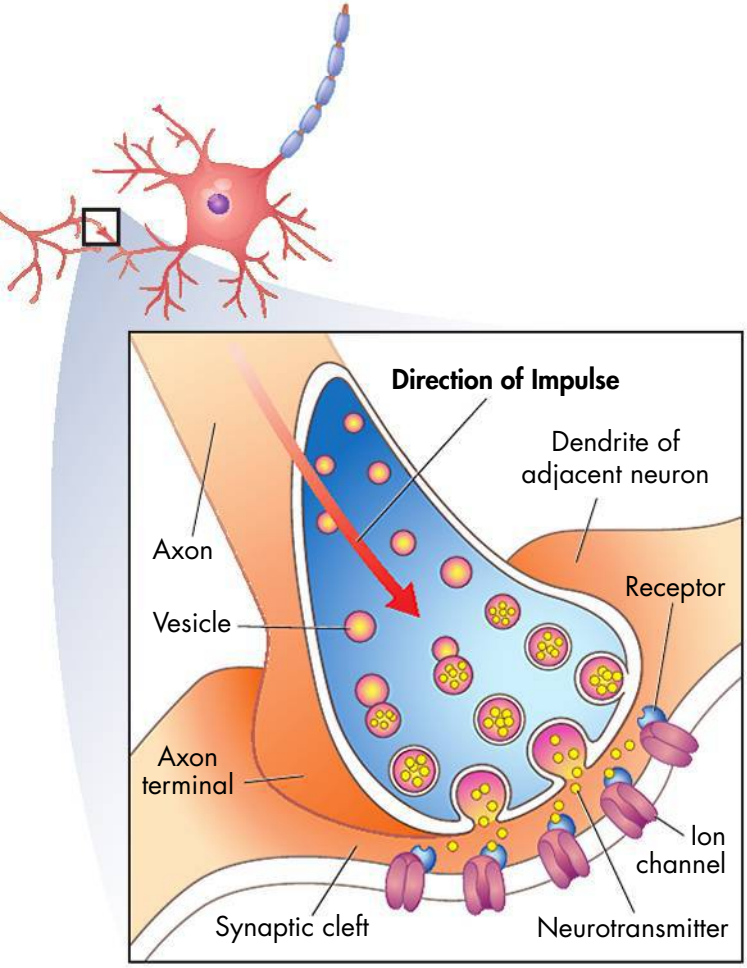
The Moving Impulse Once an impulse begins, it will continue down an axon until it reaches the end. In an axon with a myelin sheath, the impulse jumps from node to node.



2 At the leading edge of the impulse, gated sodium channels open. Na^+ ions flow into the cell, reversing the potential between the cell membrane and its surroundings. This rapidly moving reversal of charge is called an action potential.



3 As the action potential passes, gated potassium channels open, allowing K^+ ions to flow out and restoring the resting potential inside the axon.



The Synapse When an impulse reaches the end of an axon, neurotransmitters are released into the synaptic cleft. The neurotransmitters bind to receptors on the membrane of an adjoining neuron.

The Synapse At the end of the neuron, the impulse reaches an axon terminal. The axon terminal may pass the impulse along to another cell. For example, a motor neuron may pass impulses to a muscle cell. These impulses cause the muscle cell to contract. The point where a neuron transfers an impulse to another cell is called a **synapse** (SIN aps). A space called the synaptic cleft separates the axon terminal from the cell.

The axon terminal at a synapse contains tiny sacs filled with neurotransmitters. Neurotransmitters are chemicals that transmit an impulse across a synapse to another cell. When an impulse arrives at the synapse, the axon releases neurotransmitters. The neurotransmitters diffuse across the synaptic cleft and bind to receptors on the receiving cell's membrane. These receptors then open ion channels in the membrane of the receiving cell. If the stimulation exceeds the cell's threshold, a new impulse begins.

Once their work is done, the neurotransmitters are released from the receptors on the cell surface. Then they are broken down by enzymes in the synaptic cleft. Or they may be taken up and recycled by the axon terminal.

Key Question How does a nerve impulse begin?
An impulse begins when a neuron is stimulated by another neuron or by the environment.

CHECK Understanding

Apply Vocabulary

1. A(n) _____ is the part of a neuron that receives impulses from another neuron and carries it to the cell body.
2. A(n) _____ occurs when gated ion channels open, allowing Na^+ ions to flow into a neuron and reverse the electrical charge across its cell membrane.
3. The beginning of a nerve impulse is a sign that a stimulus has reached the neuron's _____ level.

Critical Thinking

4. **Explain** What happens when a neuron is stimulated by another neuron?
5. **Apply Concepts** Describe how your peripheral nervous system and your central nervous system were involved in a simple activity you performed today.
6. **Write to Learn** Answer the first clue of the mystery.

MYSTERY CLUE

The toxin found in this fish binds to gated sodium channels. This blocks the flow of Na^+ ions into a cell. How do you think this might affect muscle movement? (Hint: See p. 744.)

BIOLOGY.com Search Lesson 31.1 GO • Lesson Assessment

31.2 The Central Nervous System

The Brain and the Spinal Cord

The nervous system contains billions of neurons, each capable of carrying impulses and sending messages. What keeps them from sending impulses everywhere and acting like an unruly mob? Is there a central place where information is processed, decisions are made, and order is enforced?

Brain The control point of the central nervous system is the brain. The major areas of the brain are the cerebrum, cerebellum, and brain stem. Each of these areas is responsible for processing and relaying information. Like the central processing unit of a computer, information processing is the brain's primary task.

Most organs in the body function to maintain homeostasis. But the brain itself is constantly changed by its interactions with the environment. Sensory experience changes many of the patterns of neuron connections in the brain. Stem cells in the brain also produce new neurons throughout life. Many of these new cells form in regions connected with learning and memory. These changes make the brain highly flexible.

Spinal Cord Most of the neurons that enter and exit the brain do so in the spinal cord. The spinal cord is a large cluster of neurons and other cells. The spinal cord is the main communication link between the brain and the rest of the body. It is a bit like a major telephone line. It carries thousands of signals at once between the central and peripheral nervous systems. Thirty-one pairs of spinal nerves branch out from the spinal cord. These pairs connect the brain to different parts of the body. Certain kinds of information, including many reflexes, are processed directly in the spinal cord. A reflex is a quick, automatic response to a stimulus. Pulling your hand back quickly when pricked by a pin is an example of a reflex.

Key Question Where does processing of information occur in the nervous system?

The major areas of the brain are the cerebrum, cerebellum, and brain stem. Each of these areas is responsible for processing and relaying information. The spinal cord is the main communication link between the brain and the rest of the body.

Key Questions

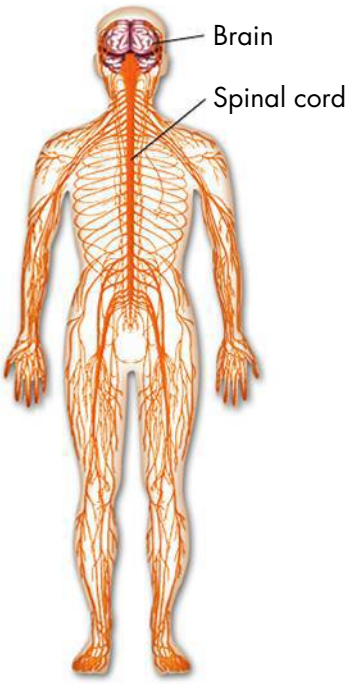
Where does processing of information occur in the nervous system?

How do drugs change the brain and lead to addiction?

BUILD Understanding

Concept Map As you read, make a concept map that shows how the structures of the central nervous system are related to each other.

In Your Workbook Go to your workbook for help making a concept map. Complete the concept map in Lesson 31.2.



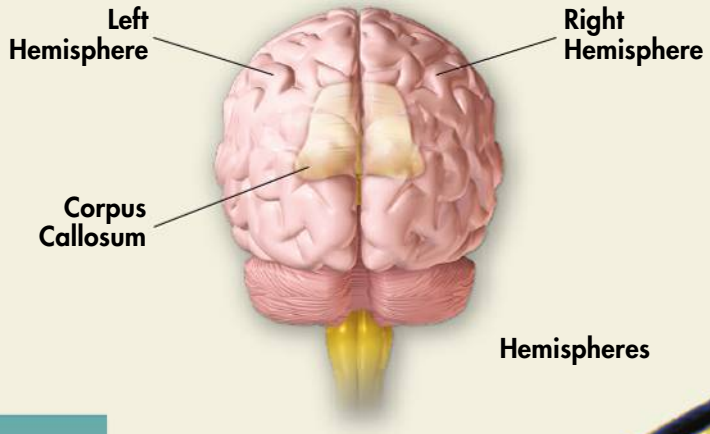
The Central Nervous System The central nervous system consists of the brain and spinal cord.

BUILD Connections

THE BRAIN

The brain contains billions of neurons and other supporting tissue. The brain processes, relays, and forms responses to an unbelievable amount of information every moment.

In Your Workbook Explore the parts of the brain by completing the activity in Lesson 31.2.



Cerebrum

The largest region of the human brain is the cerebrum. The **cerebrum** is responsible for the voluntary, or conscious, activities of the body. It is the site of intelligence, learning, and judgment.

Hemispheres A deep groove from front to back divides the cerebrum into right and left hemispheres. A band of tissue called the corpus callosum connects the hemispheres.

Remarkably, each hemisphere deals mainly with the opposite side of the body. Sensations from the left side of the body go to the right hemisphere. Sensations from the right side go to the left hemisphere. Commands to move muscles are generated in the same way.

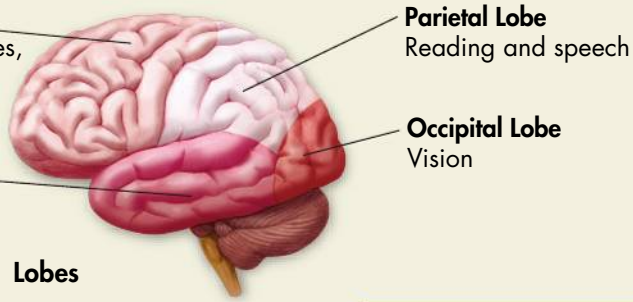
Each hemisphere is divided into four regions called lobes. The lobes are named for the skull bones that cover them. Each lobe is associated with different functions.

Cerebral Cortex The cerebrum has two layers. The outer layer is called the cerebral cortex. It consists of densely packed nerve cell bodies known as gray matter. The cerebral cortex processes information from the sense organs and controls body movements. It is also where thoughts, plans, and learning are processed. Folds and grooves on the outer surface of the cerebral cortex greatly increase its surface area.

White Matter The inner layer of the cerebrum is known as white matter. Its whitish color comes from bundles of axons with myelin sheaths. These bundles may connect different areas of the cerebral cortex or they may connect the cerebrum to different areas of the brain.

Limbic System

Many important functions have been linked to the structures that make up the limbic system. A region deep within the brain called the amygdala (uh MIG duh luh), has been associated with emotional learning. This includes fear and anxiety, as well as the formation of long-term memories. The limbic system is also associated with the brain's pleasure center. This region produces feelings of satisfaction and well-being.



Lobes

Thalamus and Hypothalamus

The thalamus and hypothalamus are found between the brain stem and the cerebrum. The thalamus receives messages from sensory receptors throughout the body. It then relays the information to the proper region of the cerebrum for further processing. Just below the thalamus is the hypothalamus. The **hypothalamus** recognizes and analyzes hunger, thirst, fatigue, anger, and body temperature. The hypothalamus also helps to coordinate the nervous and endocrine systems.

Cerebellum

The second largest region of the brain is the **cerebellum.** Information about muscle and joint position, and other sensory inputs, are sent to the cerebellum. The commands to move muscles come from the cerebral cortex. The sensory information allows the cerebellum to coordinate and balance the actions of these muscles. This ability to coordinate muscle actions allows the body to move gracefully and efficiently. When you begin any new activity involving muscle coordination, the cerebellum actually learns the movements. It then coordinates the actions of many individual muscles when the movement is repeated.

Brain Stem

The **brain stem,** located just below the cerebellum, connects the brain and spinal cord. The brain stem includes three regions—the midbrain, the pons, and the medulla oblongata. Each region regulates the flow of information between the brain and the rest of the body. The brain stem controls some of the body's most important functions. These functions include regulation of blood pressure, heart rate, breathing, and swallowing. The brain stem keeps the body functioning even when you lose consciousness from sleep or injury.

BUILD Vocabulary

cerebrum
the part of the brain responsible for voluntary activities of the body; the "thinking" region of the brain

hypothalamus
the portion of the brain that acts as a control center for recognition and analysis of hunger, thirst, fatigue, anger, and body temperature

cerebellum
the part of the brain that coordinates movement and controls balance

brain stem
a structure that connects the brain and spinal cord; includes the medulla oblongata and the pons

dopamine
a neurotransmitter that is associated with the brain's pleasure and reward centers

PREFIXES

The prefix *hypo-* means "under or below." The hypothalamus is located below the thalamus in the brain.

Addiction and the Brain

Synapses transfer messages from cell to cell, doing the conscious work of thinking. Synapses also do the less-conscious work of producing feelings and emotions. What would happen if a chemical changed the way those synapses worked? Such chemicals might change behavior.

Nearly every addictive substance affects brain synapses. These substances include illegal drugs such as heroin, methamphetamine, and cocaine. They also include legal drugs such as tobacco and alcohol. The chemistry of each drug is different. But they all produce changes in one particular group of synapses. These synapses use the neurotransmitter **dopamine.** They are associated with the brain's pleasure and reward centers.

When an activity brings us pleasure, neurons in the hypothalamus and the limbic system release dopamine. Dopamine molecules stimulate other neurons across these synapses. This stimulation produces the sensation of pleasure and a feeling of well-being.

Addictive drugs act on dopamine synapses in several ways. Methamphetamine releases a flood of dopamine, producing an instant "high." Cocaine keeps dopamine in the synaptic region longer, intensifying pleasure and suppressing pain. Nicotine and alcohol cause an increase in the release of dopamine.

The brain reacts to excessive dopamine levels by reducing the number of dopamine receptors. Normal activities no longer produce the sensations of pleasure they once did. Addicts feel depressed and sick without their drugs. It takes greater amounts of addictive chemicals to get the same high with fewer receptors. This addiction is hard to break.

Key Question How do drugs change the brain and lead to addiction? **The brain reacts to too much dopamine by reducing the number of dopamine receptors. As a result, normal activities no longer produce the pleasurable feelings they once did.**

CHECK Understanding

Apply Vocabulary

1. The part of the brain that processes information from the eyes, ears, and skin is the _____.
2. The _____ is the part of the brain that recognizes when you are tired and hungry.
3. The part of the brain that learns muscle movements needed for playing a musical instrument or playing a sport is the _____.

Critical Thinking

4. **Explain** What is the role of the spinal cord?
5. **Write to Learn** Write a paragraph that explains how the brain interacts with the environment.

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31.3 The Peripheral Nervous System

The Sensory Division

It's all about input and output. A computer isn't useful unless it can accept input from the world around it. And the result isn't meaningful unless there's a way to output it. The central nervous system faces the same issues. Can you guess what it uses for input and output devices?

The peripheral nervous system consists of all the nerves and associated cells that are not part of the brain or spinal cord, including cranial nerves and spinal nerves. Cranial nerves go through openings in the skull. They stimulate regions of the head and neck. Spinal nerves stimulate the rest of the body. The cell bodies of cranial and spinal nerves are arranged in clusters called ganglia.

The peripheral nervous system is our link with the outside world. It has two major divisions—the sensory division and the motor division. The sensory division transmits impulses from sense organs to the central nervous system. The motor division transmits impulses from the central nervous system to the muscles and glands.

Sensory receptors are cells that transmit information about changes in the internal and external environments. These changes are called stimuli. Sensory receptors are grouped by the type of stimuli to which they respond. When they are stimulated, sensory receptors transmit impulses to sensory neurons. Sensory neurons then transmit impulses to the central nervous system.

Key Question How does the central nervous system receive sensory information?

The peripheral nervous system's sensory division transmits impulses from sense organs to the central nervous system.

Sensory Receptors
Sensory receptors react to a specific stimulus such as light or sound by sending impulses to sensory neurons.

Key Questions

How does the central nervous system receive sensory information?

How do muscles and glands receive commands from the central nervous system?

BUILD Understanding

Venn Diagram As you read, make a Venn diagram that compares the somatic nervous system and the autonomic nervous system.

In Your Workbook Go to your workbook to complete the Venn diagram in Lesson 31.3.

Sensory Receptors

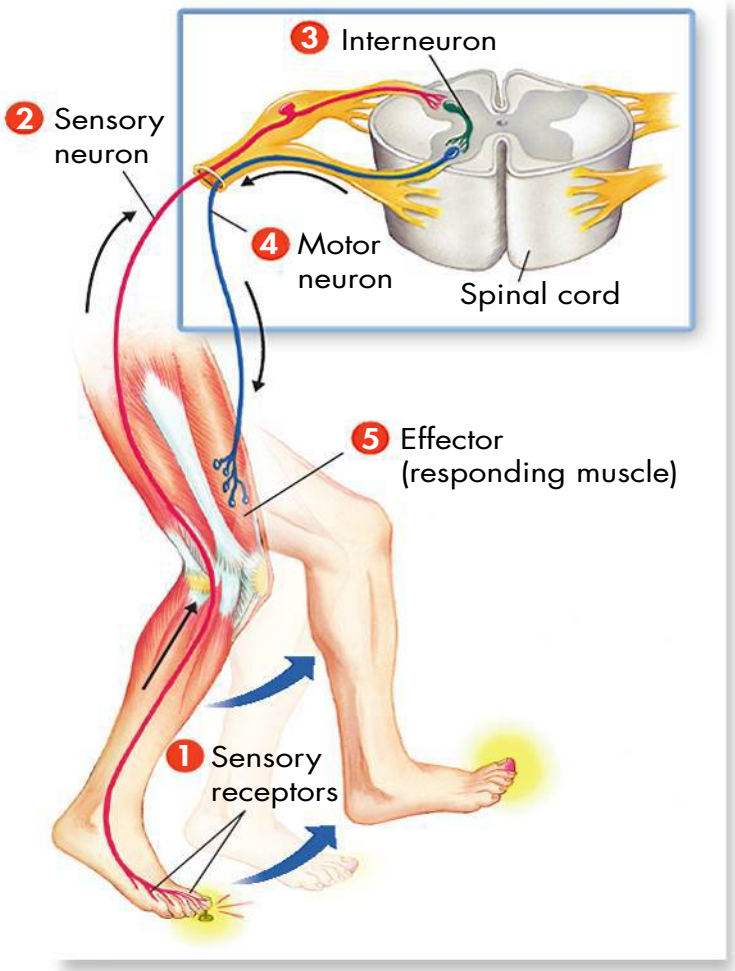
Type	Responds to	Some Locations
Chemoreceptor	Chemicals	Mouth, nose, blood vessels
Photoreceptor	Light	Eyes
Mechanoreceptor	Touch, pressure, vibrations, and stretch	Skin, hair follicles, ears, ligaments, tendons
Thermoreceptor	Temperature changes	Skin, hypothalamus
Pain receptor	Tissue injury	Throughout the body

The Motor Division

The nervous system maintains homeostasis by gathering and processing information from other systems and organs. Then it sends commands to muscles or glands through the peripheral nervous system's motor division. This division has two parts—the somatic nervous system and the autonomic nervous system.

Somatic Nervous System The **somatic nervous system** regulates body activities that are under conscious control. These activities include movement of skeletal muscles. But when your body is in danger, the central nervous system may take over.

▶ ***Voluntary Control*** When you wiggle your toes, you use motor neurons of the somatic nervous system. Impulses from the brain are carried through the spinal cord, synapsing with motor neuron dendrites. Axons from these motor neurons extend from the spinal cord, carrying the impulses directly to muscles. These impulses cause muscle contractions that produce voluntary movements.



Reflex Arc When you step on a tack, sensory receptors stimulate a sensory neuron. The neuron relays the signal to an interneuron within the spinal cord. The signal is then sent to a motor neuron. This neuron stimulates a muscle that lifts your leg.

▶ ***Reflex Arcs*** The somatic nervous system is generally considered to be under conscious control. But some actions of the system occur automatically. Suppose you accidentally step on a tack with your bare foot. Your leg may pull back before you even notice the pain. This rapid response is a reflex. It is caused by impulses that travel a pathway called a **reflex arc.** 1 Sensory receptors react to the feeling of the tack, sending an impulse to sensory neurons. 2 Sensory neurons relay the information to the spinal cord. 3 An interneuron in the spinal cord processes the information and forms a response. 4 A motor neuron carries impulses that stimulate a muscle (its effector). 5 The muscle contracts, moving your leg. At the same time, impulses carry information about the injury to your brain. But by the time your brain interprets the pain, your leg and foot have already moved.

The spinal cord does not control all reflexes. Many reflexes that involve structures in your head are controlled by the brain. For example, blinking and sneezing are controlled by the brain.

Autonomic Nervous System The **autonomic nervous system** regulates involuntary activities. These activities are not under conscious control. For instance, when you start to run, the autonomic nervous system speeds up your heart rate. It increases blood flow to the skeletal muscles and stimulates the sweat glands. It also slows down the contractions of smooth muscles in the digestive system. You may not be aware of some of these activities. But all of them help you run faster and farther.

The autonomic nervous system has two equally important parts, the sympathetic and parasympathetic nervous systems. In general, these systems have opposite effects on each organ they influence. The two systems produce a level of fine control that coordinates organs throughout the body.

For example, heart rate is increased by the sympathetic nervous system. But it is decreased by the parasympathetic nervous system. In general, the sympathetic system prepares the body for intense activity. When it is stimulated, blood pressure increases and energy-rich sugar is released into the blood. Activities not related to the body's "fight or flight" response to stress also shut down. But the parasympathetic system causes what might be called the "rest and digest" response. It lowers heart rate and blood pressure and activates digestion. It also activates pathways that store food molecules in the tissues of the body.

Key Question How do muscles and glands receive commands from the central nervous system? **The peripheral nervous system's motor division transmits impulses from the central nervous system to muscles or glands.**

BUILD Vocabulary

somatic nervous system
the part of the peripheral nervous system that carries signals to and from skeletal muscles

reflex arc
the sensory receptor, sensory neuron, motor neuron, and effector that are involved in a quick response to a stimulus

autonomic nervous system
the part of the peripheral nervous system that regulates activities that are involuntary, or not under conscious control; made up of the sympathetic and parasympathetic subdivisions

ROOT WORDS

The word *autonomic* comes from the word *autonomy*, which means "the state of being self-governing." The autonomic nervous system is the "self-governing" part of the peripheral nervous system.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The sensory receptors and effector are parts of a _____.
2. The heart, lungs, and muscles of the digestive tract are regulated by the _____.
3. When you reach for a glass of water, your hand and arm muscles are being controlled by the _____.

Critical Thinking

4. **Explain** Is a reflex a part of the central nervous system, the peripheral nervous system, or both?
5. **Apply Concepts** Give three examples of stimuli that your sensory division is responding to right now.
6. **Write to Learn** Answer the second clue to the mystery.

MYSTERY CLUE

Think about Captain Cook's symptoms of weakness. What part of his nervous system did consumption of the fish affect the most? (Hint: See p. 752.)

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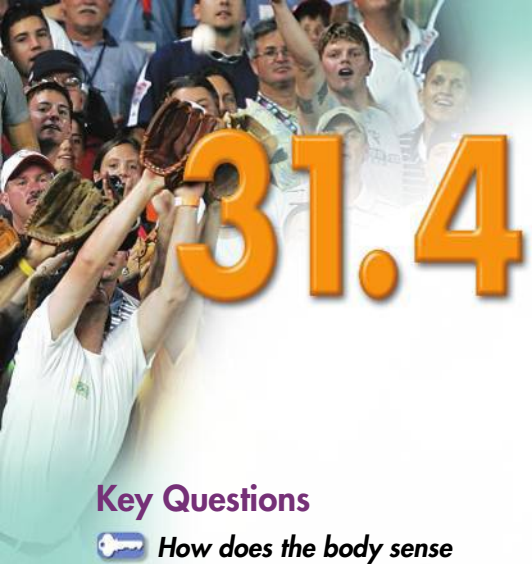


31.4 The Senses

Key Questions

- ***How does the body sense touch, temperature, and pain?***
- ***How are the senses of smell and taste similar?***
- ***How do the ears and brain process sounds and maintain balance?***
- ***How do the eyes and brain produce vision?***

BUILD Understanding

Preview Visuals Before reading, preview the figure The Eye. Write down at least two questions you have about the information in the figure.

In Your Workbook Go to your workbook for a chart for previewing visuals.

Taste Buds The surface of the tongue contains many tiny projections. Taste buds line the tops of some of these and line the sides of other projections (LM 80×).

Touch and Related Senses

Different sensory receptors in the body respond to touch, temperature, and pain. Your skin has all three receptors, but some are also found in other areas. Nearly all regions of your skin are sensitive to touch.

Touch Human skin contains at least seven types of sensory receptors. Stimulation of these receptors creates the sensation of touch. But not all parts of the body are equally sensitive. For example, there is a higher density of touch receptors on your fingers than on your back.

Temperature Thermoreceptors are sensory cells that respond to heat and cold. They are found throughout the skin. They are also found in the hypothalamus, the part of the brain that senses blood temperature.

Pain Pain receptors are found throughout the body, but not in the brain. Many tissues also have pain receptors that respond to chemicals released during infection or inflammation.

Key Question How does the body sense touch, temperature, and pain? **Different sensory receptors in the body respond to touch, temperature, and pain.**

Smell and Taste

Your senses of smell and taste involve the ability of sensory cells that detect chemicals. These cells, called chemoreceptors, are located in the nose and mouth. They send impulses to the brain that are interpreted as sensations of smell and taste.

Smell Your sense of smell produces thousands of different sensations. Much of what we usually call the "taste" of food and drink is actually smell. Try eating a few bites of food while holding your nose. It seems to have little taste until you release your nose and breathe freely.

Taste The sense organs for taste are the taste buds. Most taste buds are on the tongue. Their sensory cells respond to salty, bitter, sweet, and sour foods. Scientists recently discovered that sensory cells also respond to the amino acid glutamate. This taste is called *umami* (Japanese for "savory").

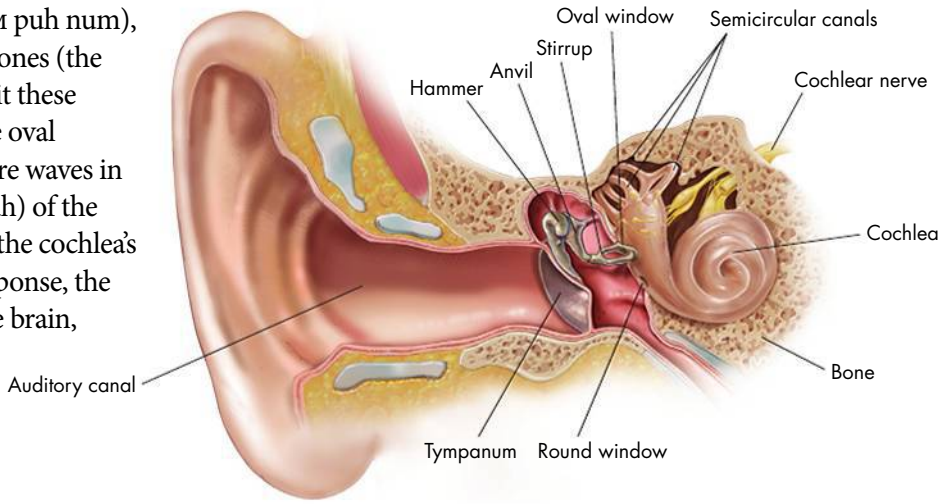
Key Question How are the senses of smell and taste similar? **Sensations of smell and taste are both the result of impulses sent to the brain by chemoreceptors.**

Hearing and Balance

The human ear has two sensory functions—hearing and balance. Mechanoreceptors found in parts of the ear transmit impulses to the brain. The brain translates the impulses into sound and information about changes in position.

Hearing Sound is vibrations moving through the air around us. The ears can distinguish both the pitch and loudness of those vibrations.

Vibrations enter the ear through the auditory canal and cause the tympanum (TIM puh num), or eardrum, to vibrate. Three tiny bones (the hammer, anvil, and stirrup) transmit these vibrations to a membrane called the oval window. Its vibrations create pressure waves in the fluid-filled **cochlea** (KAHK lee uh) of the inner ear. The pressure waves push the cochlea's tiny hair cells back and forth. In response, the hair cells send nerve impulses to the brain, which processes them as sounds.



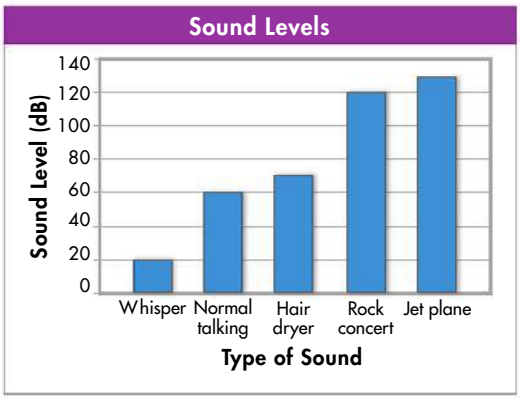
The Ear The structures in the ear transmit sound and allow a person to hear.

INQUIRY into Scientific Thinking

Sound Intensity

Sound intensity, or loudness, is measured in units called decibels (dB). The threshold of hearing for the human ear is 0 dB. For every 10 dB increase, the sound intensity increases ten times.

Based on the graph, how much more intense is a jet engine than a hair dryer?



- The difference between the two sound intensities is

$$130\ dB_{jet} - 70\ dB_{hair\ dryer} = 60\ dB$$

- The jet engine is 60 dB louder than a hair dryer. This means it is 10^6 or 1,000,000 times louder than the hair dryer.

Loud noises can permanently damage the hair cells in the cochlea. These hair cells are the cells that sense vibrations. Exposure to sounds above 80 dB for several hours at a time can damage hearing. Exposure to sounds about 120 dB for even a few seconds can damage hearing.

Analyze and Conclude

1. Calculate How much more intense is normal talking than whispering?

2. Infer Repeated exposure to portable music devices set at high volume can cause hearing damage. Why do you think this damage might not reveal itself for many years?

In Your Workbook Get more help for this activity in your workbook.

BUILD Vocabulary

cochlea the fluid-filled part of the inner ear; contains nerve cells that detect sound

semicircular canal one of three structures in the inner ear that monitors the position of the body in relation to gravity

cornea a tough transparent layer of the eye through which light enters

iris the colored part of the eye

WORD ORIGINS

The word *cochlea* comes from the Greek word *kochlias*, which means "snail shell." The cochlea in the human ear is shaped like a snail shell.

Balance Your ears help your central nervous system maintain your balance. There are three tiny canals just above the cochlea called **semicircular canals.** These canals and two tiny sacs located behind them monitor your body's position.

The canals and sacs are filled with fluid that changes position as the head moves. These movements cause the hair on the hair cells lining the canals and sacs to bend. The brain uses the impulses created by this action to determine body motion and position.

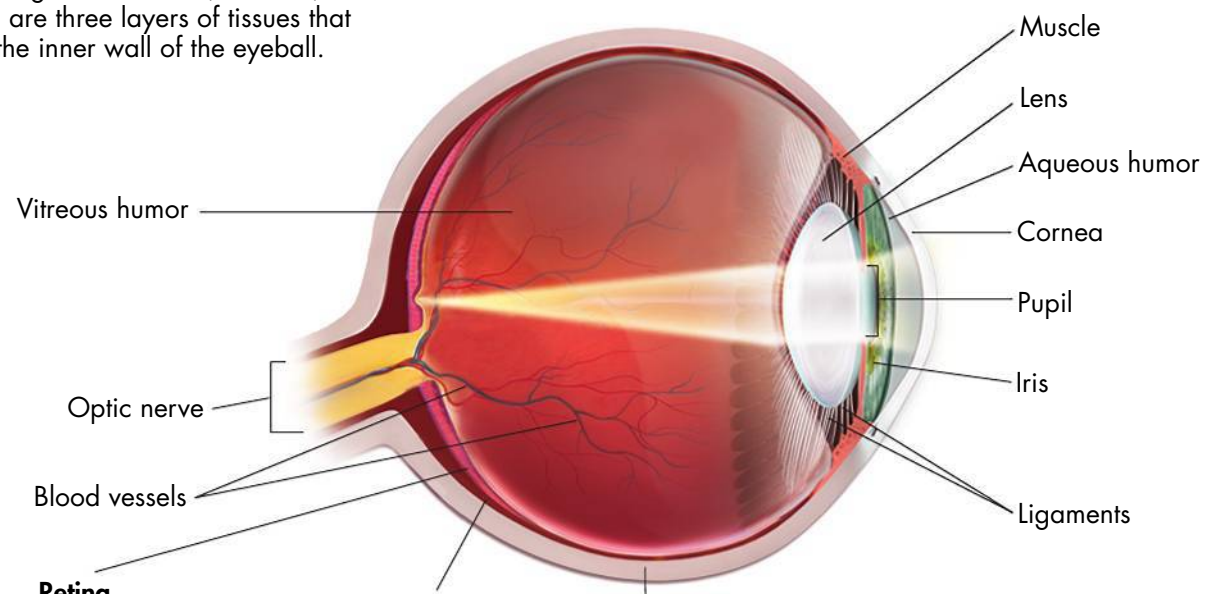
Key Question How do the ears and brain process sounds and maintain balance? **Mechanoreceptors found in parts of the ear transmit impulses to the brain. The brain translates the impulses into sound and information about balance.**

Vision

The world around us is bathed in light that our eyes detect. Vision occurs when photoreceptors in the eyes transmit impulses to the brain. The brain translates these impulses into images.

Structures of the Eye Light enters the eye through a tough transparent layer of cells called the **cornea.** The cornea helps to focus the light. The light passes through a chamber filled with a fluid called aqueous (AY kwee uhs) humor. At the back of the chamber is a disk-shaped structure called the **iris.** The iris is the colored part of the eye.

The Eye The eye is a complicated sense organ. The sclera, choroid, and retina are three layers of tissues that form the inner wall of the eyeball.



The small opening in the middle of the iris is the **pupil.** Tiny muscles in the iris adjust the pupil's size. The pupil controls the amount of light that enters the eye. The pupil becomes smaller in bright light and larger in dim light.

Just behind the iris is the **lens.** Small muscles attached to the lens change its shape. This adjusts the eyes' focus to see near or distant objects clearly. The large chamber behind the lens is filled with a transparent, jellylike fluid called vitreous (VIH tree uhs) humor.

How You See The lens focuses light onto the **retina,** the inner layer of the eye. Photoreceptors in the retina convert light energy into nerve impulses. There are two types of photoreceptors: rods and cones. Rods are extremely sensitive to light, but they do not respond to colors. They only allow us to see black and white. Cones are less sensitive than rods. But they do respond to different colors, producing color vision. Cones are concentrated in the fovea, the site of sharpest vision.

The impulses gathered by this complicated layer of cells leave each eye through the optic nerve. This nerve carries the impulses to the appropriate regions of the brain. There are no photoreceptors where the optic nerve passes through the back of the eye. This lack of photoreceptors produces a blind spot in each image sent to the brain. The brain fills in the holes of the blind spot with information when it processes the impulses.

If the eye just took photographs, the images would be blurry and incomplete. The images we actually see are much more detailed. The reason is the complicated way in which the brain processes and interprets visual information.

Key Question How do the eyes and brain produce vision?
Vision occurs when photoreceptors in the eyes transmit impulses to the brain. The brain translates these impulses into images.

BUILD Vocabulary

pupil a small opening in the iris that admits light into the eye

lens a structure in the eye that focuses light rays on the retina

retina the innermost layer of the eye; contains photoreceptors

WORD ORIGINS

The word *retina* comes from the Middle English word *rethina*. *Rethina* is believed to come from the Latin word *rete*, which means "net."

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. Hair cells in the _____ send information about your body's position to the brain.
2. Muscles in the _____ control the amount of light that enters the eye.
3. Photoreceptors in the _____ convert light energy into nerve impulses.
4. The _____ is a fluid-filled structure with cells that detect sound.

Critical Thinking

5. **Infer** Some people suffer from night blindness. Which type of photoreceptor is likely not functioning correctly?
6. **Write to Learn** Answer the third clue of the mystery.

MYSTERY CLUE

Based on Cook's symptoms, which of his senses was greatly affected by the toxin? Explain. (Hint: See p. 754.)

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Real-World Lab

GUIDED INQUIRY

Pre-Lab: Testing Sensory Receptors for Touch

Problem What factors affect a person's ability to sense gentle pressure on skin?

Materials bent paper clips, metric ruler

Lab Manual Chapter 31 Lab

Skills Focus Measure, Analyze Data, Draw Conclusions

Connect to the Big idea Your nervous system coordinates your response to stimuli from outside your body and inside your body. Sensory receptors react to stimuli by sending impulses to sensory neurons. Each receptor can detect only one type of stimulus. Receptors are classified by the type of stimuli to which they respond. Some respond to light, some to pain, some to chemicals, and so on. Mechanoreceptors are cells that respond to touch, pressure, vibrations, and stretch.

In this lab, you will investigate the mechanoreceptors in your skin that respond to gentle touch. You will compare the relative density of these receptors in three areas of your skin. You will also identify other factors that could affect a person's response to touch.

Background Questions

a. **Review** Which division of the peripheral nervous system transmits signals from receptors in your skin to your brain?

b. **Relate Cause and Effect** List two reasons why a touch might not produce a nerve impulse.

c. **Infer** People who are visually impaired use their fingertips to read books that are printed in Braille. In Braille, each letter of the alphabet is represented by a unique pattern of dots. What feature of the dots allows a reader to distinguish one set of dots from another?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Predict** Which area will have the highest density of receptors for gentle pressure—your fingertips, the back of your hand, or your forearm?
2. **Control Variables** Why must you have your eyes closed while your partner touches your skin with the bent paper clip?
3. **Predict** Will you and your partner have the same density of touch receptors in a given area of skin? Give a reason for your prediction.

BIOLOGY.com Search Chapter 31 GO

Visit Chapter 31 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Hold on tightly as the Untamed Science crew takes you on a quick tour of how animal toxins affect the body.

Art Review Review your understanding of the structures in the eyes and ears with this drag-and-drop activity.

InterActive Art Watch a nerve impulse move down a neuron.

Visual Analogy Compare an action potential moving along a neuron to a row of falling dominoes.

Art in Motion View a short animation that shows how a reflex arc works.

31 CHAPTER Summary

31.1 The Neuron

- The nervous system collects information about the body's internal and external environment. The system then processes that information and responds to it.
- Nervous system impulses are transmitted by cells called neurons.
- An impulse begins when a neuron is stimulated by another neuron or by the environment.

peripheral nervous system (p. 742)
central nervous system (p. 742)
cell body (p. 743)
dendrite (p. 743)
axon (p. 743)
resting potential (p. 744)
action potential (p. 744)
threshold (p. 745)
synapse (p. 746)

31.2 The Central Nervous System

- The major areas of the brain are the cerebrum, cerebellum, and brain stem. Each of these areas is responsible for processing and relaying information. The spinal cord is the main communication link between the brain and the rest of the body.
- The brain reacts to too much dopamine by reducing the number of dopamine receptors. As a result, normal activities no longer produce the pleasurable feelings they once did.

cerebrum (p. 748)
hypothalamus (p. 749)
cerebellum (p. 749)
brain stem (p. 749)
dopamine (p. 750)

31.3 The Peripheral Nervous System

- The peripheral nervous system's sensory division transmits impulses from sense organs to the central nervous system.
- The peripheral nervous system's motor division transmits impulses from the central nervous system to muscles or glands.

somatic nervous system (p. 752)
reflex arc (p. 752)
autonomic nervous system (p. 753)

31.4 The Senses

- Different sensory receptors in the body respond to touch, temperature, and pain.
- Sensations of smell and taste are both the result of impulses sent to the brain by chemoreceptors.
- Mechanoreceptors found in parts of the ear transmit impulses to the brain. The brain translates the impulses into sound and information about balance.
- Vision occurs when photoreceptors in the eyes transmit impulses to the brain. The brain translates these impulses into images.

cochlea (p. 755)
semicircular canal (p. 756)
cornea (p. 756)
iris (p. 756)
pupil (p. 757)
lens (p. 757)
retina (p. 757)

31 CHECK Understanding

Assess the Big idea Structure and Function

Write an answer to the question below.
Q: How does the structure of the nervous system allow it to regulate functions in every part of the body?

Constructed Response

Write an answer to each of the numbered questions below. The answer to each question should be one or two paragraphs. To help you begin, read the **Hints** below the questions.

1. What is the purpose of sodium-potassium pumps in a neuron?

   Hint The sodium-potassium pump moves sodium and potassium ions across the cell membrane.

   Hint Nerve impulses are reversals of resting potentials, which are electrical charges across the cell membrane.

2. Why must neurotransmitters be broken down or removed after a cell responds to a nerve impulse?

   Hint Axon terminals release neurotransmitters during a nerve impulse.

   Hint Neurotransmitters must bind to receptors on a cell to stimulate a response from the cell.

3. How do hair cells in the ear help transmit nerve impulses?

   Hint Hair cells are found in the cochlea, the semicircular canal, and the sacs associated with the semicircular canal.

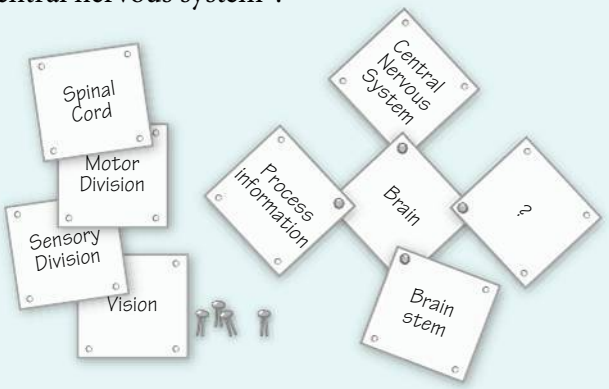
   Hint Hair cells are mechanoreceptors.

Foundations for Learning Wrap-Up

Use the note squares you prepared when you started the chapter as tools to organize your thoughts about the nervous system.

Activity 1 Working with a partner, use your note squares to quiz each other about the structures and functions of the nervous system.

Activity 2 Working as a group, create idea "nervous systems" from your note squares by connecting the corners of the squares with brass fasteners. Use main ideas to create the "brain" and "spinal cord." Use details to create the "peripheral nerves." How do the "peripheral nerves" explain the main ideas in the "central nervous system"?



31.1 The Neuron

Understand Key Concepts

1. The basic units of structure and function in the nervous system are

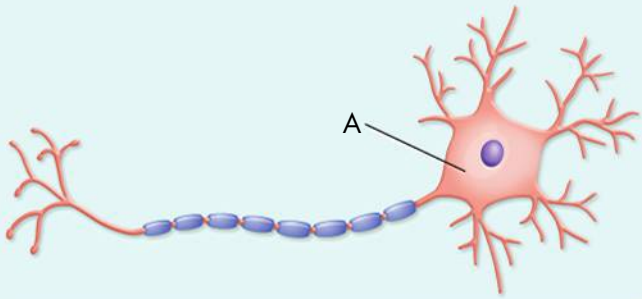
a. neurons. **c.** dendrites.

b. axons. **d.** neurotransmitters.

2. In the diagram below, the letter A is pointing to a(n)

a. myelin sheath. **c.** dendrite.

b. axon. **d.** cell body.



Test-Taking Tip

Interpret Graphics When you are asked to identify a structure in a figure, it is helpful to first review and label the figure. Question 2 includes the figure of a neuron. First, identify all the structures in the answer choices. The myelin sheath surrounds the axon. The axon is a long fiber that extends from the cell body. Dendrites are the short extensions of the cell body. The cell body contains the nucleus. So, **A** is pointing to the cell body.

3. The place where a neuron transfers an impulse to another cell is the

a. synapse. **c.** myelin sheath.

b. dendrite. **d.** receptor.

4. Why can an action potential be described as an all-or-none event?

Think Critically

5. **Infer** Suppose part of an axon is cut so that it does not connect to its cell body. How would that affect the transmission of impulses?

31.2 The Central Nervous System

Understand Key Concepts

6. The central nervous system consists of the

a. sense organs.

b. reflexes.

c. brain and spinal cord.

d. sensory and motor neurons.

7. Voluntary activities, or conscious activities of the body, are controlled primarily by the

a. medulla oblongata. **c.** cerebellum.

b. cerebrum. **d.** brain stem.

8. Describe the relationship between the brain stem and the spinal cord.

Think Critically

9. **Infer** Why might the folding of the cerebral cortex be important?

31.3 The Peripheral Nervous System

Understand Key Concepts

10. The sympathetic nervous system and parasympathetic nervous system are specific divisions of the

a. peripheral nervous system.

b. central nervous system.

c. somatic nervous system.

d. autonomic nervous system.

11. How do reflexes protect the body from injury?

12. What is the function of the sensory division of the peripheral nervous system?

Think Critically

13. **Apply Concepts** A routine examination by a doctor usually includes a knee-jerk reflex test. What is the purpose of this test?

31 CHECK Understanding

31.4 The Senses

Understand Key Concepts

14. The senses of taste and smell involve sensory receptors called

a. photoreceptors. **c.** thermoreceptors.

b. chemoreceptors. **d.** mechanoreceptors.

15. What are the functions of the rods and cones?

16. What are the five basic tastes?

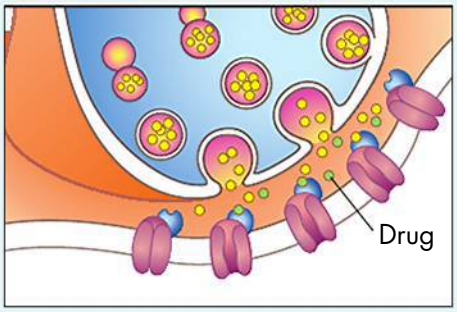
Think Critically

17. **Sequence** Trace the path of sound through the ear.

Connecting Concepts

Use Science Graphics

Use the illustration to answer questions 18 and 19.



18. **Interpret Visuals** This illustration shows a drug

a. interfering with enzymes that break down a neurotransmitter at a synapse.

b. mimicking a neurotransmitter.

c. stimulating an axon terminal.

d. stimulating enzymes that break down a neurotransmitter at a synapse.

19. **Apply Concepts** Alcohol is called a depressant, because it depresses (slows) respiration and heart rate. Which part of the autonomic nervous system does alcohol most likely stimulate?

solve the CHAPTER MYSTERY

POISONING ON THE HIGH SEAS

A naturalist named Georg Forster traveled with Captain Cook. One of his sketches suggests that the crew ate a fish called *Tetraodon lagocephalus sceleratus*. This fish is also known as the Silverstripe blaasop. Bacteria that live in its liver, gonads, intestines, and skin produce a poison called tetrodotoxin. The poison can remain in the fish even after cooking the fish at high temperatures. Tetrodotoxin binds to and blocks voltage-gated sodium channels. It especially affects the peripheral nervous system.

Today, some Japanese chefs are specially trained to prepare fish that contain this toxin. The dish, called fugu, is highly prized by some diners. The prepared fish has a unique taste. It also makes the mouth and throat tingle when it is eaten. If fugu is not prepared correctly, it can lead to dangerous problems for the diner. Death is even possible.

Obviously, tetrodotoxin doesn't poison the fish that produce it. Studies of the fish's genome have revealed a mutation in an important gene. This gene codes for the structure of sodium channel proteins. The mutation changes the surface shape of the channel. This change prevents the toxin from binding to it.

1. **Infer** Some fish fillets are cooked and served with the skin left on. Would this be a safe way to prepare and serve fugu?

2. **Apply Concepts** Describe in your own words why the fish are not affected by their own toxin.

UntamedScience **Never Stop Exploring Your World.** Finding the solution to this mystery is just the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where this mystery leads.

Standardized Test Prep

Multiple Choice

1. The largest and most prominent part of the human brain is the
A cerebrum. **C** thalamus.
B cerebellum. **D** brain stem.

2. The point of connection between two neurons is called a
A threshold. **C** neurotransmitter.
B synapse. **D** dendrite.

3. The part of a neuron that carries impulses away from the cell body is called a(n)
A axon. **C** vesicle.
B dendrite. **D** synapse.

4. The minimum stimulus level that will cause a neuron to produce an action potential is called the
A resting potential. **C** threshold.
B impulse. **D** synapse.

5. The part of the brain responsible for collecting sensory input from the body and relaying it to appropriate brain centers is the
A limbic system. **C** cerebellum.
B thalamus. **D** cerebrum.

6. The major function of the spinal cord is
A emotional learning and memory storage.
B control of voluntary muscle movements.
C fine control of detailed muscle movement.
D a principal communication path between the brain and the rest of the body.

7. Involuntary activities carried out throughout the body are the primary responsibility of the
A somatic nervous system.
B autonomic nervous system.
C spinal cord.
D limbic system.

8. The part of the eye which contains photoreceptor cells is the
A cornea. **C** retina.
B iris. **D** optic nerve.

Questions 9–10

Blood alcohol concentration (BAC) is a measure of the amount of alcohol in the blood per 100 mL of blood. In some states, if a driver has a BAC of 0.08 percent, he or she is considered legally drunk. The table below lists an average BAC as alcohol consumption increases. Use the information in the table to answer the questions.

Blood Alcohol Concentration (Percent)

Drinks in One Hour	Body Mass					
	45 kg	54 kg	63 kg	72 kg	81 kg	90 kg
1	0.04	0.03	0.03	0.02	0.02	0.02
2	0.07	0.06	0.05	0.05	0.04	0.04
3	0.11	0.09	0.08	0.07	0.06	0.06
4	0.14	0.12	0.10	0.09	0.08	0.07
5	0.18	0.15	0.13	0.11	0.10	0.09
6	0.21	0.18	0.15	0.14	0.12	0.11
7	0.25	0.21	0.18	0.16	0.14	0.13
8	0.29	0.24	0.21	0.18	0.16	0.14

9. How many drinks in one hour would cause a 63 kg person to have a BAC of 0.08 percent?
A 1 **C** 5
B 3 **D** 7

10. If a 54 kg person had 3 drinks in one hour, what would his or her BAC percentage be?
A 0.06 **C** 0.09
B 0.08 **D** 0.11

Open-Ended Response

11. How do the parasympathetic and sympathetic nervous systems work together in the body?

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10	11
See Lesson	31.2	31.1	31.1	31.1	31.2	31.2	31.3	31.4	31.2	31.2	31.3

32 Skeletal, Muscular, and Integumentary Systems

Big idea

Structure and Function

Q: What systems form the structure of the human body?

The skeletal and muscular systems of this gymnast work together as she moves.

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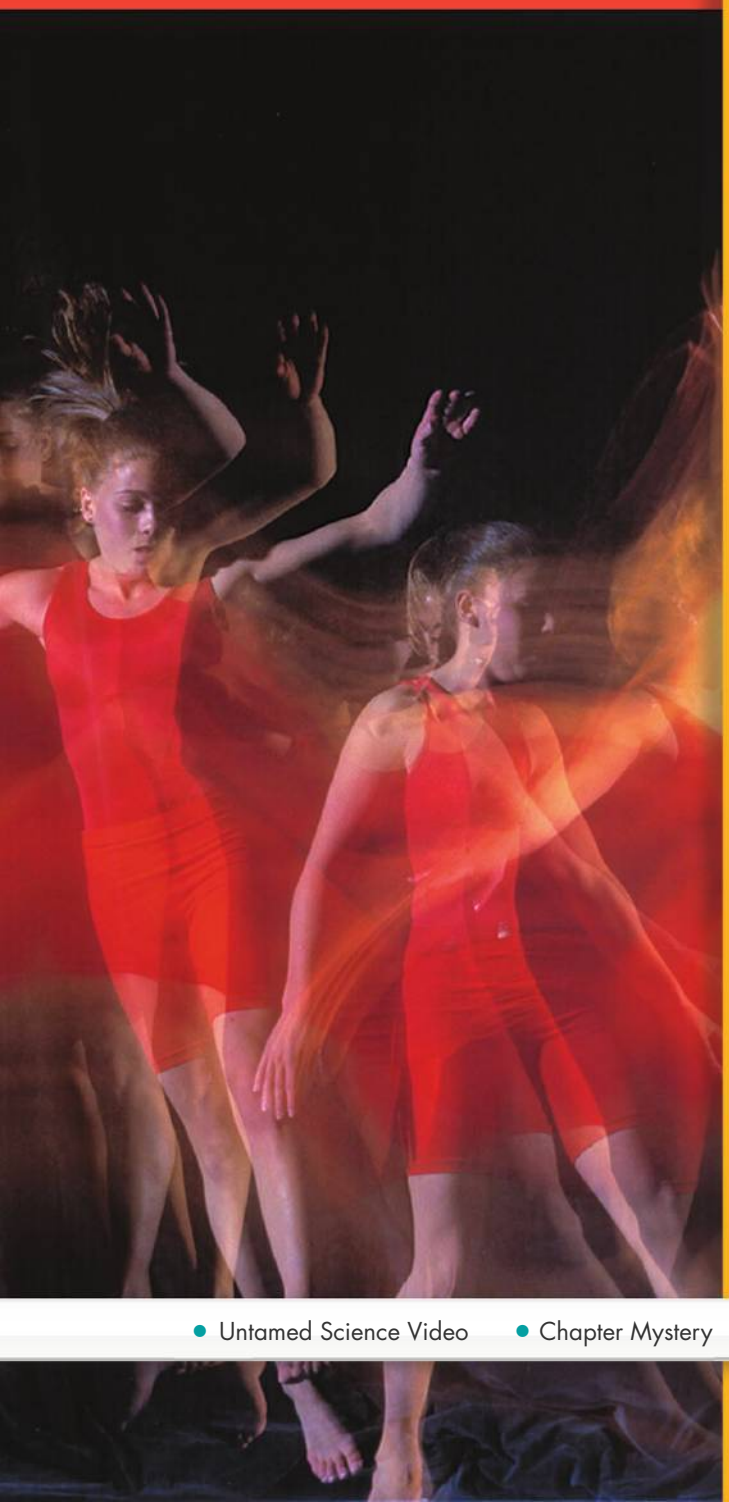


- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

THE DEMISE OF A DISEASE

In the early 1900s, many children suffered from a disease called "rickets." Children with rickets had very soft, weak bones. These children often had bowed legs, twisted wrists, and many other problems with their bones. Many children with rickets were poorly nourished. Most of them lived in northern cities of the United States. Doctors were puzzled as to why few poorly nourished children living in the south had rickets.

No one knew the cause of rickets or how to cure the disease. Some people thought that cod liver oil cured rickets. Scientists wanted to find answers. What was the connection between rickets and northern cities? And could cod liver oil really be a cure?

Read for Mystery Clues As you read this chapter, look for clues that helped scientists form ideas about the cause of rickets. Then, solve the mystery.

FOUNDATIONS for Learning

Draw and label a three-column chart as shown below. As you read, list the functions in the second column. Cut the third column into flaps. Use the flaps to cover the second column as you study. At the end of the chapter are two activities that you can do with the chart to help answer the question: What systems form the structure of the human body?

STRUCTURES	FUNCTIONS	
Skeletal system		
Smooth muscle		
Cardiac muscle		
Skeletal muscle		
Integumetary system		

32.1 The Skeletal System

Key Questions

- ***What are the functions of the skeletal system?***
- ***What is the structure of a typical human bone?***
- ***What is the role of joints?***

BUILD Understanding

T-Chart As you read the lesson, make a T-chart. Start with a two-column chart. In the left column, rewrite the headings in this lesson as questions. In the right column, write answers to the questions.

In Your Workbook Go to your workbook to learn more about making a T-chart. Complete the T-chart for Lesson 32.1.

FUNCTIONS OF THE SKELETON

Support The bones of the skeleton support and give shape to the human body.

Protection Bones protect the delicate internal organs of the body. For example, the ribs form a basketlike cage around the heart and lungs.

Movement Bones work with muscles to produce movement.

Mineral Storage Bones store minerals, including calcium. Minerals are important to many body processes. When blood calcium levels are low, some calcium is released from bones.

Blood Cell Formation Many kinds of blood cells are formed in soft tissue in the middle of some bones

The Skeleton

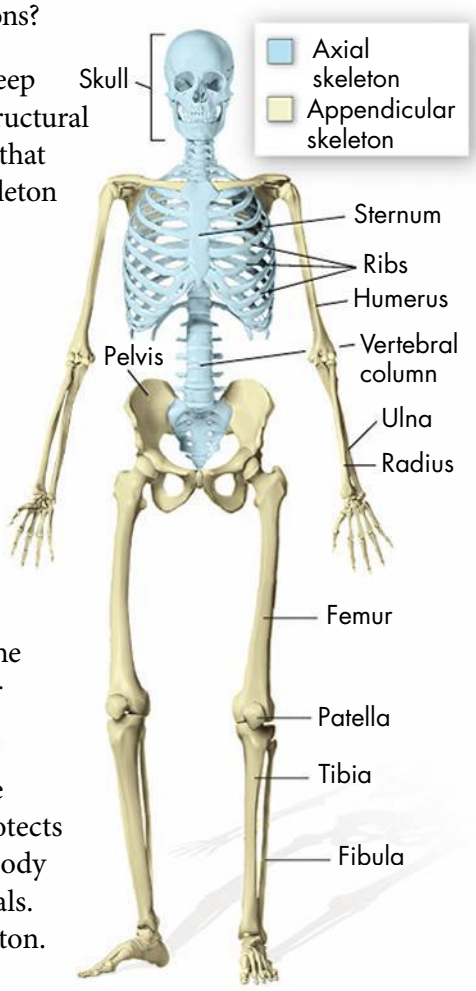
An animal's skeleton is so durable that it can often be recognized thousands of years after the animal's death. Because bones are so hard, it's easy to think of them as lifeless. If that were true, what would happen if a bone broke? As you know, broken bones can heal. What does that tell you about our skeletons?

Structure of the Skeleton To keep their shape, all organisms need structural support. Cells have cytoskeletons that support their shapes. The cytoskeleton also makes it possible for cells to move. Vertebrates have internal skeletons called endoskeletons. The vertebrate skeleton supports the body. It also makes it possible for the body to move.

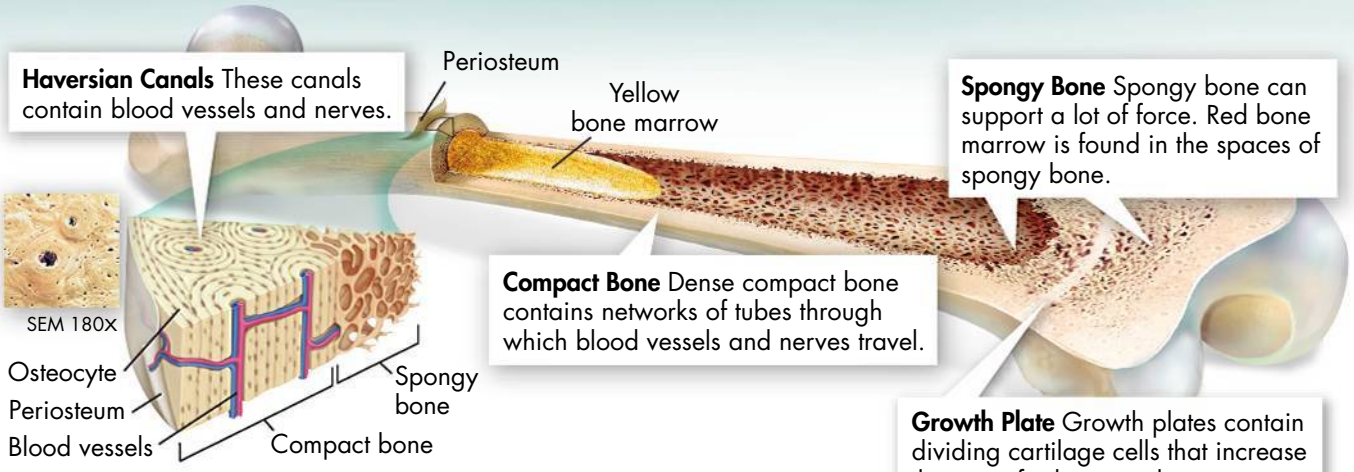
An adult person has 206 bones. Some of these bones are in the axial skeleton. Others are in the appendicular skeleton. The skull, backbone, and ribs form the **axial skeleton.** The bones of the arms and legs, pelvis, and shoulder form the **appendicular skeleton.**

Functions of the Skeleton The skeleton holds the body up. It protects the internal organs. It helps the body move. The skeleton stores minerals. Blood cells form within the skeleton.

Key Question What are the functions of the skeletal system? **The skeleton holds the body up and protects the internal organs. The skeleton helps the body move. It stores minerals and is the site of blood cell formation.**



The Skeleton The human skeleton is made of living tissue that has many functions.



Structure of a Bone A long bone such as the femur is surrounded by the periosteum. Below the periosteum, Haversian canals run through the bone. Nerves and blood vessels run through the canals.

Bones

The mass of a bone is mostly mineral salts. Most of those salts are calcium and phosphorus. This composition makes it easy to think that bones are not really living tissue. However, bones are very much alive.

Structure of Bones Bones are made up of living cells and protein fibers. Calcium salts surround the fibers. The outer layer of bone is called periosteum (pehr ee AHS tee um). Nerves and blood vessels run through the bone in tubes. These tubes are called Haversian (huh VUR zhun) canals. Many bones have a tissue called bone marrow inside them. Yellow bone marrow stores fat. Red bone marrow contains stem cells that develop into blood cells.

Development of Bones Most of the skeleton of a human embryo is made of cartilage. **Cartilage** (KAHR tl ij) is softer and more flexible than bone. As an embryo grows, bone slowly takes the place of the cartilage. This process is called ossification (ahs uh fih KAY shun) and begins up to seven months before birth. It continues throughout life. Cells called osteoblasts (AHS tee oh blasts) add minerals that replace the cartilage. Most osteoblasts become osteocytes. Osteocytes help keep bones healthy.

Bone Remodeling and Repair Some osteoblasts continue to build bone tissue throughout a person's life. Osteoclasts are cells that break down bone tissue. Together, osteoblasts and osteoclasts allow bones to get stronger after exercise and injuries.

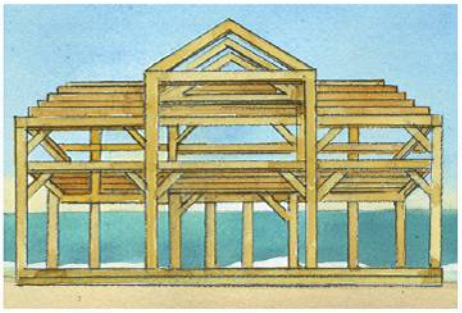
Osteoporosis Osteoporosis is a serious disorder in which bone breaks down more quickly than it is rebuilt. It weakens the bones of many older people to the point where the bones may break easily. Getting plenty of calcium in the diet can help prevent osteoporosis. Also, weight-bearing exercises such as walking help prevent osteoporosis.

Key Question What is the structure of a typical human bone?
Bones are made up of living cells and protein fibers. The fibers are surrounded by calcium salts.

BUILD Connections

A person could not stand up without a bony skeleton, just as a house could not stand without its wooden frame.

In Your Workbook Go to your workbook to label the parts of the skeleton.



BUILD Vocabulary

axial skeleton
the skeleton that supports the central axis of the body; consists of the skull, vertebral column, and the rib cage

appendicular skeleton
the bones of the arms and legs along with the bones of the pelvis and shoulder area

cartilage
a type of connective tissue that is softer and more flexible than bone. In adults, cartilage supports both the nose and the ears.

joint
the place where one bone attaches to another bone

ligament
a tough connective tissue that holds bones together in a joint

WORD ORIGINS

The word *ligament* comes from the word *ligare*, a Latin word meaning "to tie." Ligaments "tie" two bones together.

Joints

A place where two or more bones meet is called a **joint.** Connective tissues hold the bones together. Joints let bones move without damaging each other.

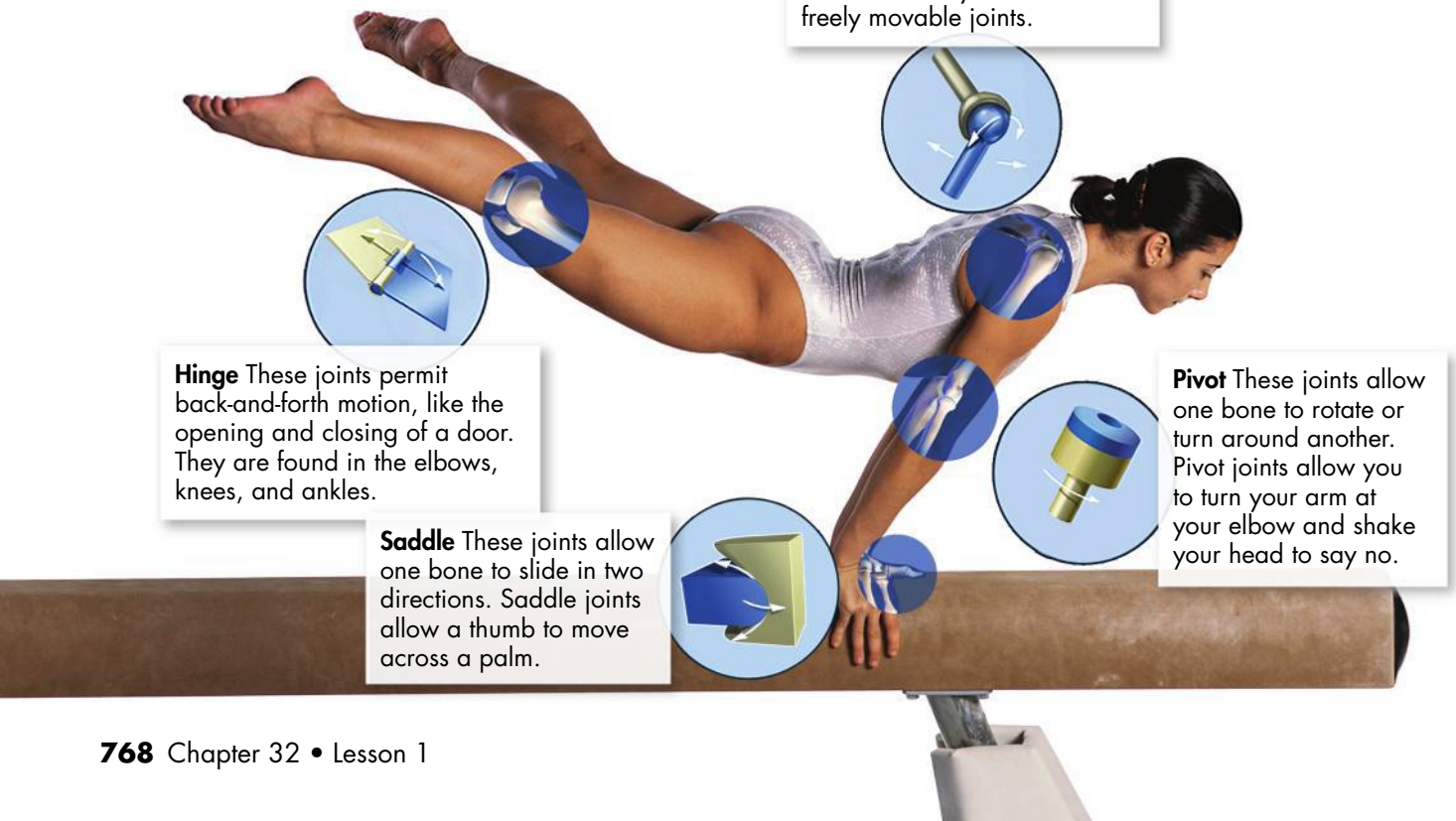
Types of Joints Some joints, such as those of the shoulders, allow a lot of movement. Others, like the joints of the fully developed skull, allow no movement at all. There are three kinds of joints—immovable, slightly movable, and freely movable.

▶ ***Immovable Joints*** Immovable joints do not allow movement. The bones grow together until they are fused. The places where the bones in the skull meet are immovable joints.

▶ ***Slightly Movable Joints*** Slightly movable joints allow a small amount of movement. In immovable joints, the bones join and grow together. In slightly movable joints, the bones are separated from each other. The joints between the two bones of the lower leg are slightly movable joints. The joints between vertebrae are also slightly movable joints.

▶ ***Freely Movable Joints*** Freely movable joints allow movement in two or more directions. There are several kinds of freely movable joints. The types of joints are based on the amount of movement allowed by the joint.

Freely Movable Joints Freely movable joints make actions possible.



Ball-and-Socket Found in the shoulders and hips, these joints allow for movement in many directions. They are the most freely movable joints.

Hinge These joints permit back-and-forth motion, like the opening and closing of a door. They are found in the elbows, knees, and ankles.

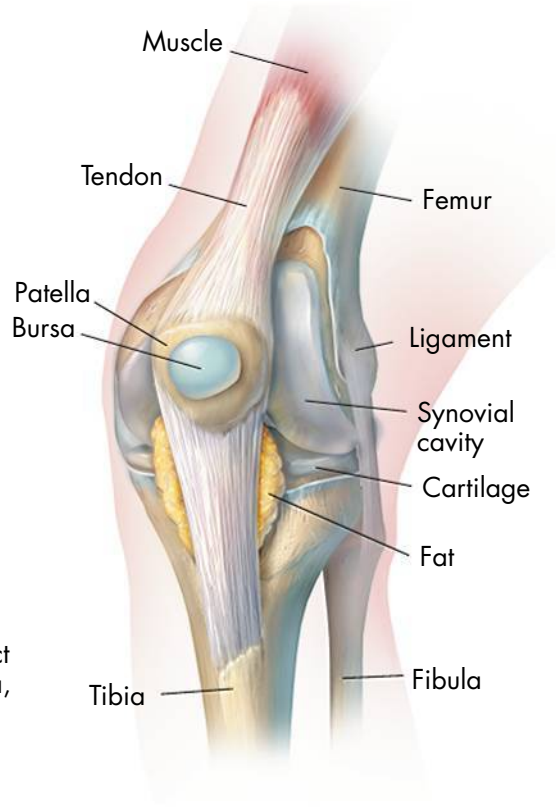
Saddle These joints allow one bone to slide in two directions. Saddle joints allow a thumb to move across a palm.

Pivot These joints allow one bone to rotate or turn around another. Pivot joints allow you to turn your arm at your elbow and shake your head to say no.

Structure of Joints In freely movable joints, cartilage covers the surfaces where two bones come together. This protects the bones from damage as they move against each other. A joint capsule also surrounds the joint. The joint capsule helps hold the bones together while still allowing for movement.

The joint capsule has two layers. The outer layer forms strips of tough connective tissue called ligaments. The ligaments are connected to the membranes around the bones. **Ligaments** hold the bones in a joint together. The inner layer of the joint capsule is called the synovial (sih NOH vee uhl) cavity. This cavity holds cells that make synovial fluid. Small pockets of synovial fluid are called bursae (BUR see; singular: bursa). Synovial fluid allows the surfaces of the bones to slide over each other smoothly. Bursae also act as tiny shock absorbers.

Key Question What is the role of joints?
Connective tissue in joints holds bones together. Joints allow bones to move without damaging each other.



The Knee Cartilage and bursae protect the knee joint. The tibia, femur, patella, and fibula make up the knee joint. Ligaments hold these bones together.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. Connective tissues within a _____ hold two or more bones together.
2. The _____ forms the central axis of the skeleton.
3. _____ supports the body and is more flexible than bone.

Critical Thinking

4. **Compare and Contrast** Explain how a human knee joint is similar to a door hinge. How is it different from a door hinge?
5. **Relate Cause and Effect** Wear and tear over the years often leads to a condition called osteoarthritis. The cartilage in the joints of fingers, knees, and hips begins to break down. What is the likely effect on the bones?
6. **Write to Learn** Answer the first clue of the mystery.

MYSTERY CLUE

Children with rickets have soft, cartilagelike bones that may bend under their own weight. Why might their bones be so soft? (Hint: See p. 767.)

BIOLOGY.com Search Lesson 32.1 GO • Lesson Assessment • InterActive Art

32.2 The Muscular System

Key Questions

- ***What are the main kinds of muscle tissue?***
- ***How do muscles contract?***
- ***How do muscle contractions cause movement?***

BUILD Understanding

Concept Map As you read, make a concept map that shows the relationship of ideas in this section.

In Your Workbook Go to your workbook for help in completing the concept map. Complete the concept map for Lesson 32.2.

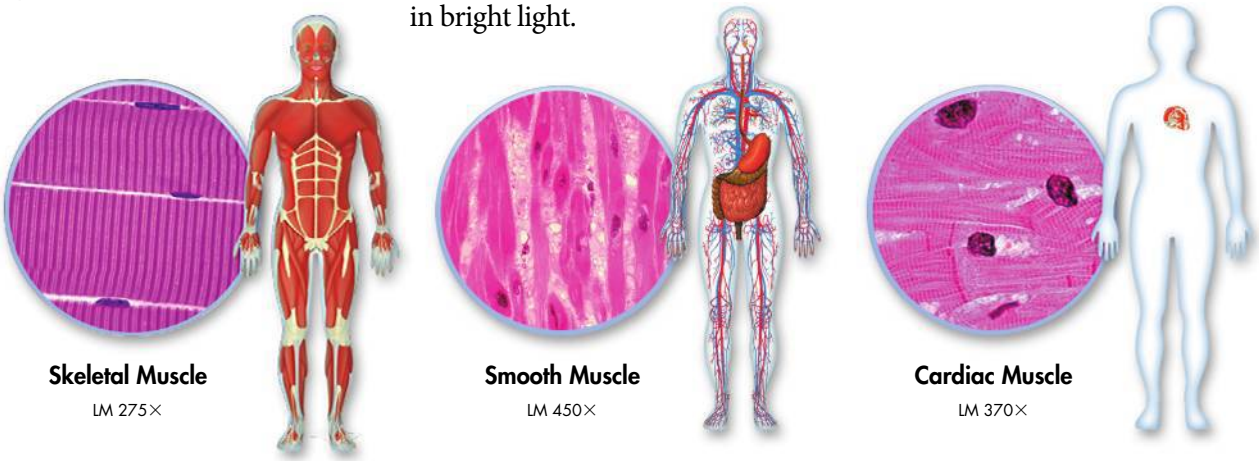
Muscle Tissue

You know that bones provide support, but it's muscles attached to your bones that make movements possible. Did you know that about one third of the mass of a person's body is muscle? Large muscles in your arms and legs help your body move. These large muscles are part of the muscular system. However, this system is also made up of thousands of tiny muscles. These tiny muscles help move blood through the body and move food through the digestive system. Muscles power every movement of the body. There are three kinds of muscle: skeletal, smooth, and cardiac. Each kind of muscle performs a different function.

Skeletal Muscles Skeletal muscles are often connected to bones. They help the body make voluntary movements. Dancing and waving are voluntary. You decide to dance or wave. When viewed under a microscope, skeletal muscle looks striped. The stripes in skeletal muscle are called striations.

Skeletal muscle cells are large and have many nuclei. The cells are not always the same length. However, they are often long and thin. Skeletal muscle cells are often called **muscle fibers.**

Smooth Muscles Smooth muscle cells do not have striations. They look smooth under the microscope. These cells usually have only one nucleus. Smooth-muscle movements are usually involuntary. This means that you can't control these muscles. Smooth muscles form part of the walls of hollow parts of your body such as the stomach, blood vessels, and intestines. Smooth muscles move food through your digestive tract. Smooth muscles control the way blood flows through your circulatory system. Smooth muscles even change the size of the pupils of your eyes in bright light.



Skeletal, Smooth, and Cardiac Muscle Skeletal muscle cells appear striped under the microscope. Smooth muscle cells appear to be smooth. Cardiac muscle cells, like skeletal muscle cells, look striped.

Skeletal Muscle LM 275×

Smooth Muscle LM 450×

Cardiac Muscle LM 370×

The cells in smooth muscles are connected to one another by gap junctions. Gap junctions allow the electrical impulses that trigger contractions to move from one muscle cell to the next.

Cardiac Muscle Cardiac muscle is found only in the heart. Cardiac muscle is striated like skeletal muscle, but its cells are smaller. Cardiac muscle cells almost always have only one or two nuclei. Cardiac muscle is not under voluntary control. Like smooth muscle cells, cardiac muscle cells are also connected by gap junctions.

Key Question What are the main kinds of muscle tissue?
The three kinds of muscle tissue are skeletal muscle, smooth muscle, and cardiac muscle.

Muscle Contraction

Muscles cause parts of the body to move by getting shorter, or contracting, from end to end. Two kinds of filaments work together to cause contractions. These two filaments are called myosin and actin.

Muscle Fiber Structure Muscle fibers are filled with tightly packed filament bundles called **myofibrils** (MY uh FI bruhlz). Each myofibril is made up of two kinds of filaments. The thick protein filaments are called **myosin** (MY uh sin). The thin protein filaments are called **actin.** These filaments overlap within the myofibril. This pattern forms the striations that can be seen through a microscope. Actin filaments are bound together in areas called Z lines. Two Z lines and the filaments between them make up a unit called a sarcomere.

BUILD Vocabulary

muscle fiber
a long slender skeletal muscle cell

myofibril
a tightly packed filament bundle found within skeletal muscle fibers

myosin
a thick filament of protein found in skeletal muscle cells

actin
a thin filament of protein found in muscle cells

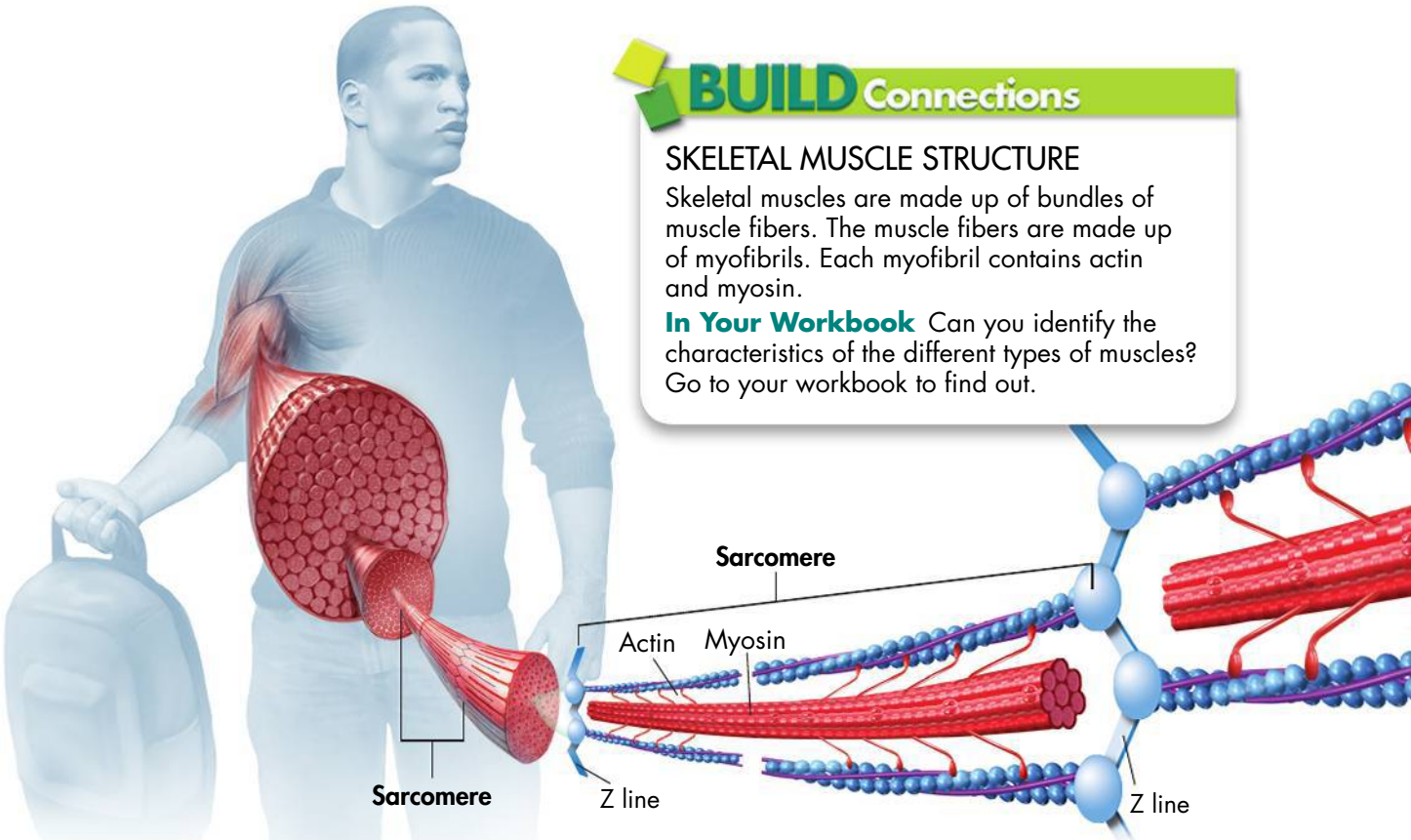
PREFIXES
The prefix *myo-* in *myofibril* and *myosin* means "muscle."

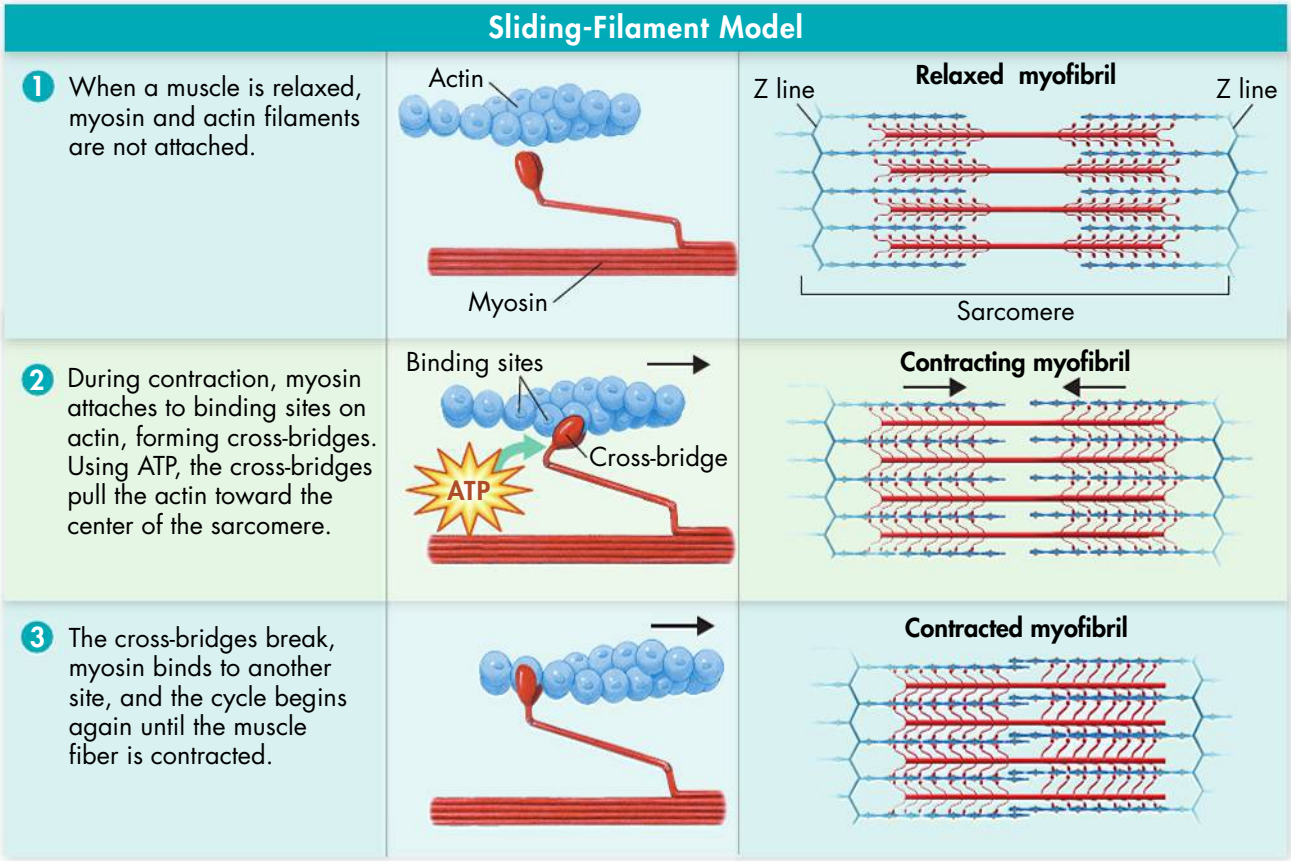
BUILD Connections

SKELETAL MUSCLE STRUCTURE

Skeletal muscles are made up of bundles of muscle fibers. The muscle fibers are made up of myofibrils. Each myofibril contains actin and myosin.

In Your Workbook Can you identify the characteristics of the different types of muscles? Go to your workbook to find out.





Sliding-Filament Model During muscle contraction, interaction between myosin and actin causes a muscle fiber to contract.

The Sliding-Filament Model

Myosin and actin are like tiny engines that make your muscles move. When muscles are relaxed, the actin and myosin are not connected. During a muscle contraction, myosin connects to actin. The connections are called cross-bridges. The cross-bridges change shape and pull the actin filaments toward the center of the sarcomere. This action makes the fiber shorter. Then the cross-bridge breaks. The myosin connects to another place along the actin filament. As cross-bridges are made and the filaments slide past each other, the fiber gets shorter. The energy for this process comes from ATP. The sliding-filament model of muscle contraction shows how this process takes place. These contractions allow you to run, lift a heavy box, or even turn a page in a book.

Control of Muscle Contraction

When you want to move your arm, the nervous system sends an impulse to certain muscles. Motor neurons carry the impulses directly to the muscle cells. The place where a motor neuron and muscle cell meet is called a neuromuscular (noo roh MUS kyoo lur) junction. Motor neurons release acetylcholine (as ih til KOH leen) to trigger the contraction. Acetylcholine (ACh) causes calcium to move into the muscle cell. Calcium causes the cross-bridges to form between actin and myosin, and the contraction begins.

A muscle cell contracts until the motor neuron stops releasing ACh. Any remaining ACh is destroyed. The muscle cell pumps calcium back into storage. The cross-bridges stop forming, the contraction ends, and the muscle relaxes.

Key Question How do muscles contract?
During a muscle contraction, myosin filaments form cross-bridges with actin filaments. The cross-bridges change shape and pull the actin filaments toward the center of the sarcomere. This action shortens the fiber.

Muscles and Movement

Muscles can cause movement only by contracting in one direction. Yet, you know from experience that you can use your muscles in many directions. You can push and pull. How is this possible? Muscles work together to move your bones.

How Muscles and Bones Work Together Bones and joints act as levers. A lever is a machine that works around a fixed point. The fixed point is called the fulcrum. A seesaw is an example of one kind of lever. Skeletal muscles are connected to bones by tough tissue called **tendons.** By pulling on bones, tendons make bones work like levers.

The joint acts as the fixed point of the lever. Most of the time, several muscles pull in different directions around a joint to move the lever. When one muscle contracts, the other relaxes. In this way, muscles work in opposing pairs. Consider the muscles in your upper arm. When your biceps muscle contracts, it pulls the lower part of your arm. Your arm bends at the elbow joint. When the triceps muscle contracts, it opens the elbow joint. A controlled movement, such as holding a tennis racket, requires both muscles.

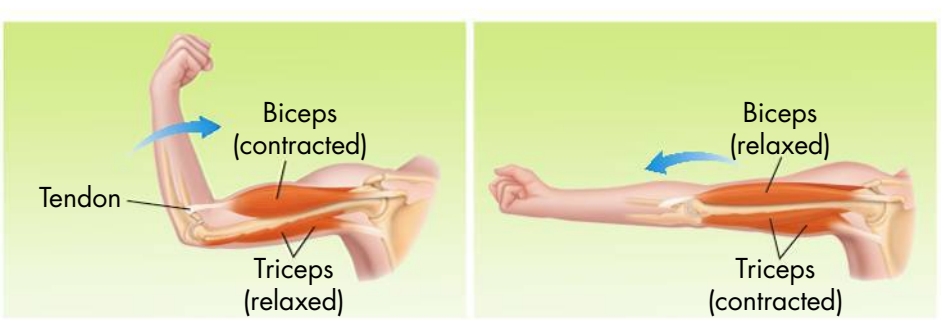
Exercise and Health Regular exercise is important for muscle strength and flexibility. Healthy muscles stay firm. Exercise increases the number of filaments in muscle cells. The large number of filaments increases the strength and size of the muscles.

Key Question How do muscle contractions cause movement? **Skeletal muscles cause movement by pulling on body parts as the muscles contract.**

BUILD Vocabulary

tendon
a tough connective tissue that connects skeletal muscles to bones

WORD ORIGINS
The word *tendon* comes from the Latin word meaning "to stretch."



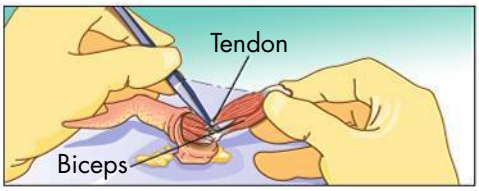
Opposing Muscle Groups By contracting and relaxing, the biceps and triceps in the upper arm enable you to bend or straighten your elbow.

INQUIRY into Scientific Thinking

What Do Tendons Do?

In Lesson 32.2, you learned how the biceps and triceps work together to make your arm move. In this activity, you will explore how the biceps muscle and one of its tendons make a chicken wing move.

1. Put on gloves and an apron. Place a chicken wing on a paper towel. Peel back or cut away the skin and fat of the largest wing segment to expose the biceps. **CAUTION:** *Do not touch your face with your hands during the lab.*
2. Find the tendon that attaches the biceps to the bones of the middle segment of the wing.
3. Use forceps to pull on the tendon of the biceps and observe what happens to the chicken wing.
4. Your teacher will tell you how to clean your tools and dispose of the chicken wing and gloves. Wash your hands.



Analyze and Conclude

1. Observe What happened when you pulled on the tendon? In a live chicken, what structure would pull on the tendon to move the wing?

2. Compare and Contrast Observe the back of your hand as you move each of your fingers in turn. How is the way the wing moves similar to the way your fingers move?

In Your Workbook Go to your workbook for more help with this activity.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. A muscle is made up of groups of _____.

2. Skeletal muscles are joined to bones by tough tissue called _____.

3. Tightly packed bundles of actin and myosin filaments are called _____.

Critical Thinking

4. Compare and Contrast Compare and contrast the structure and function of the three kinds of muscle tissue.

5. Explain Describe how a muscle contracts.

6. Write to Learn Answer the second clue of the mystery. Write a paragraph that includes the terms *actin*, *myosin*, and *muscle fiber*.

MYSTERY CLUE

Children with rickets may suffer from muscle spasms. What might they be lacking that could cause uncontrolled muscle movements? (Hint: See p. 772.)

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32.3 Skin—The Integumentary System

Integumentary System Functions

What's the largest organ in your body? No, it's not your ears or stomach, or even your lungs or heart. Would you be surprised to learn that the largest organ is the skin? You may think of the skin only as the outside of your body. However, the skin has many functions besides just covering your body. Skin is part of the integumentary system. The integumentary system is made up of the skin, hair, nails, and several glands.

Protection The most important function of the skin is to protect the inside of your body. The skin keeps germs and dirt from entering the body. Hairs keep dirt and germs from entering the nose, ears, and eyes. The skin keeps the body from drying out and protects against the sun's rays. Nails, which are produced by the skin, protect the tips of fingers and toes.

Body Temperature Regulation Body cells generate heat. The skin releases the extra heat, keeping the body temperature stable. Hair helps stop heat loss from the head.

Excretion Your sweat glands are always releasing a little sweat. Sweat takes waste, such as urea and salts, out of the body.

Information Gathering The skin helps you sense what is happening in the outside environment. The skin receives information about pressure, heat, cold, and pain and sends the information to the nervous system.

Vitamin D Production The skin makes vitamin D. This is one of the skin's most important functions. The body uses vitamin D to absorb calcium and phosphorus from the small intestine. The skin needs sunlight in order to make vitamin D.

Key Question What are the main functions of the integumentary system?

The integumentary system protects the body from dirt and germs. It also protects the body from the sun's rays and keeps the body from drying out. The integumentary system works to maintain body temperature. It also removes wastes, gathers information, and produces vitamin D.

Key Questions

- ***What are the main functions of the integumentary system?***
- ***What are the structures of the integumentary system?***
- ***What are some problems that affect the skin?***

BUILD Understanding

Preview Visuals Before you read, preview the figure Structure of the Skin on the next page. Make a two-column table. In the first column, list structures labeled in the figure. As you read, fill in the function of each structure in the second column.

In Your Workbook Go to your workbook for help in completing the table. Complete the table for Lesson 32.3.

BUILD Vocabulary

epidermis
the outer layer of the skin

dermis
the layer of skin found beneath the epidermis

WORD ORIGINS

The prefix *epi-* in *epidermis* comes from the Greek word meaning "on" or "upon." *Dermis* comes from the Greek *derma*, meaning "skin."

Integumentary System Structures

The skin, hair, and nails work together to carry out the functions of the integumentary system. Skin has three layers—the epidermis, dermis, and hypodermis.

Epidermis The outer layer of the skin is the **epidermis.** The epidermis has two layers. Cells in the inner layer of epidermis divide quickly. The newer cells push older cells to the surface of the skin. These older cells produce a tough protein called keratin. As the cells fill up with keratin, they die, forming the outer layer of the skin.

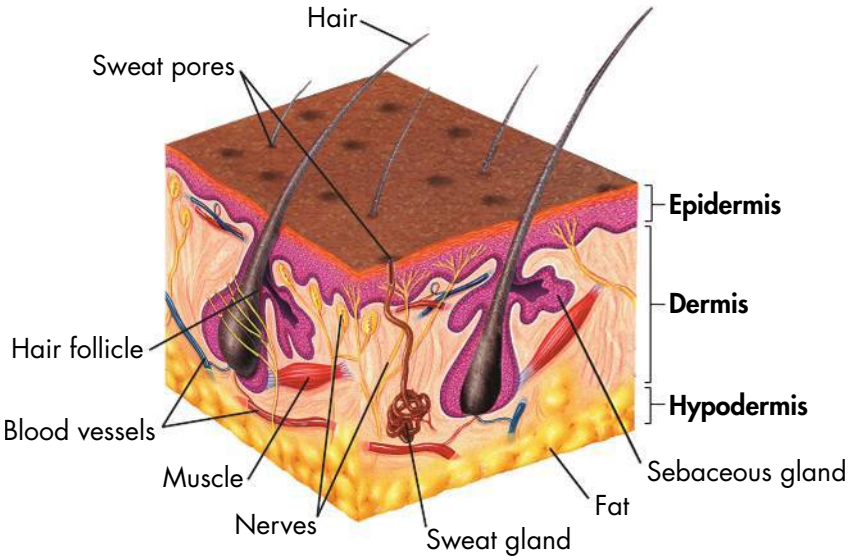
The epidermis contains a dark brown pigment called melanin. Melanin protects the skin from the sun. Melanin is made by cells called melanocytes (MEL uh noh syts). These cells make more melanin in people with darker skin.

Dermis The **dermis** is the middle layer of skin, below the epidermis. The dermis helps keep the body temperature stable. On a cold day, the blood vessels in the dermis narrow. This keeps heat from escaping through the skin. On hot days, the blood vessels widen and sweat glands release sweat. Sweat takes heat away from your body as it evaporates.

Sebaceous (suh BAY shus) glands in the dermis make an oily substance called sebum. Sebum helps to keep the epidermis flexible and waterproof. It can also kill bacteria on the skin.

Hair and Nails Hair and nails are made mostly of keratin. Nails cover and protect the tips of the fingers and toes. Hair on the head protects the scalp from the sun's rays. It also keeps the head warm. Eyelashes and hairs in the nostrils and external ear canals keep dirt from entering the body. Hair is made by cells at the base of hair follicles. Hair follicles are pockets of epidermal cells that grow into the dermis.

Key Question What are the structures of the integumentary system? **The skin, hair, nails, and several glands make up the integumentary system.**



Structure of the Skin The skin has three layers. The outer layer is called the epidermis. The middle layer is called the dermis. The deepest layer is called the hypodermis.

Skin Problems

The skin is always interacting with the environment. This interaction can cause many different problems. These problems can be as simple as a small scrape or as serious as skin cancer.

Acne Sometimes, sebum and dead skin cells form plugs in hair follicles. Trapped bacteria can then cause infection. Acne results from a bacterial infection of the sebaceous glands. Severe acne can leave scars on your skin for the rest of your life. A person with severe acne should see a dermatologist, a doctor who treats the skin.

Hives People with allergies sometimes get hives. During an allergic reaction, histamine causes small blood vessels to get bigger. Fluid can ooze from the vessels and move into the skin. This fluid causes swelling that leads to hives.

Skin Cancer Excessive tanning, outside or in a tanning bed, can cause skin cancer. Melanoma is the most dangerous form of skin cancer. Over 60,000 people are diagnosed with melanoma every year in the United States. As many as 8000 people die from it each year in the United States.

You can help protect yourself from skin cancer. Avoid tanning beds. Wear a hat and sunglasses whenever you plan to be outside for a long time. Always use a sunscreen that protects against UV-A and UV-B rays.

Key Question What are some problems that affect the skin?
Acne, hives, and skin cancer are some problems of the skin.

Basal cell carcinoma and squamous cell carcinoma are two of the most common types of skin cancer. Both types rarely spread to other parts of the body, but early treatment is important to prevent tissue damage.

Basal Cell Carcinoma

Squamous Cell Carcinoma

Melanoma

Melanomas are cancers that develop from melanocytes. Without early treatment, the cancer spreads to other organs in the body.

Skin Cancer Early detection is important in treating skin cancer. A sore that does not heal or a sudden change in a mole may be a sign of skin cancer. A mole that is larger than 6 mm or has irregular borders should be checked by a doctor. A mole that is an odd color should also be checked by a doctor.

CHECK Understanding

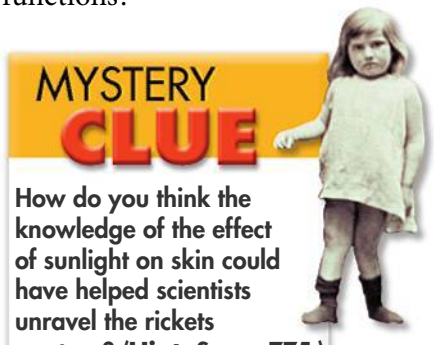
Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. New cells in the inner layer of the _____ push older cells out to the surface of the skin.
2. The middle layer of the skin is called the _____.

Critical Thinking

3. **Apply Concepts** Explain two ways that the skin can help remove excess heat from the body.
4. **Sequence** Explain the events that lead to acne.
5. **Write to Learn** Answer the third clue of the mystery. How is sunlight important to the skin's functions?



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Pre-Lab: Comparing Limbs

Problem How is the structure of skeletal muscles and bones related to the functions of these body parts?

Materials disposable plastic gloves, chicken wing, disposable dissection tray, dissecting scissors, forceps, colored pencils or markers

Skills Focus Observe, Infer, Compare and Contrast

Connect to the Big idea The structure of your bones reflects the different functions of your skeleton. For example, your bones must be strong enough to support your body and protect internal organs. Your bones must also be rigid so that they provide a system of levers on which skeletal muscles can act.

Skeletal muscles have a structure that enables them to move bones around fixed points called joints. In skeletal muscles, the cells are long and narrow, which is why these cells are also called muscle fibers. When muscle fibers contract, they pull on the bone to which a muscle is attached. This force causes the bone to move in the direction of the contraction.

In this lab, you will observe and compare the structure and function of a human arm and leg. You will also compare the arm with a chicken wing.

Background Questions

a. Review What motion does a hinge joint allow? What motion does a pivot joint allow? Which of these joints are found in your elbows and knees?

b. Review What role does cartilage play in freely movable joints?

c. Explain How is it possible for bones to move in more than one direction around a joint?

d. Compare and Contrast How are a ligament and a tendon similar? How are they different?

Pre-Lab Questions

1. Observe How will you observe the structure and function of your elbow and knee joints?

2. Relate Cause and Effect Why is it important to wear goggles and disposable gloves while examining the chicken wing?

3. Predict Will the arrangement of bones and muscles in a chicken wing be similar to the arrangement in a human arm? Why or why not?

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Visit Chapter 32 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Hold onto your seats as the Untamed Science crew whisks you to NASA to learn about the effect space travel has on an astronaut's bones.

Tutor Tube Watch an analogy to help you learn the sliding-filament model of muscle contraction.

Art Review Review your understanding of the structures of the skin.

InterActive Art Watch how the various joints in the body move.

Art in Motion Watch the process of muscle contraction.

Visual Analogy How is the skeleton like the framework of a house?

32 CHAPTER Summary

32.1 The Skeletal System

- The skeleton holds the body up and protects the internal organs. The skeleton helps the body move. It stores minerals and is the site of blood cell formation.
- Bones are made up of living cells and protein fibers. The fibers are surrounded by calcium salts.
- Connective tissue in joints holds bones together. Joints allow bones to move without damaging each other.

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axial skeleton (p. 766)
appendicular skeleton (p. 766)
cartilage (p. 767)
joint (p. 768)
ligament (p. 769)

32.2 The Muscular System

- The three kinds of muscle tissue are skeletal muscle, smooth muscle, and cardiac muscle.
- During a muscle contraction, myosin filaments form cross-bridges with actin filaments. The cross-bridges change shape and pull the actin filaments toward the center of the sarcomere. This action shortens the fiber.
- Skeletal muscles cause movement by pulling on body parts as the muscles contract.

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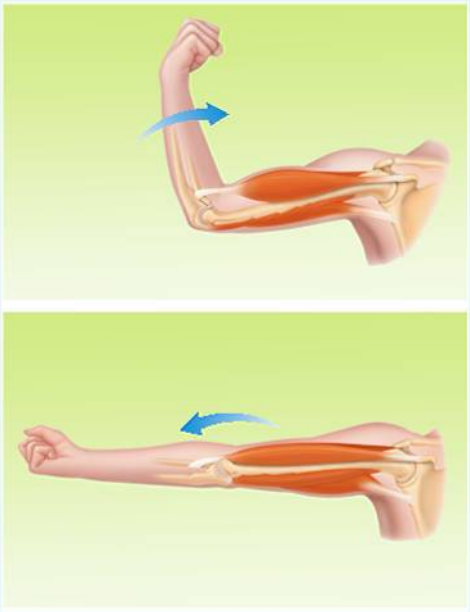
muscle fiber (p. 770)
myofibril (p. 771)
myosin (p. 771)
actin (p. 771)
tendon (p. 773)



32.3 Skin—The Integumentary System

- The integumentary system protects the body from dirt and germs. It also protects the body from the sun's rays and keeps the body from drying out. The integumentary system works to maintain body temperature. It also removes wastes, gathers information, and produces vitamin D.
- The skin, hair, nails, and several glands make up the integumentary system.
- Acne, hives, and skin cancer are some problems of the skin.

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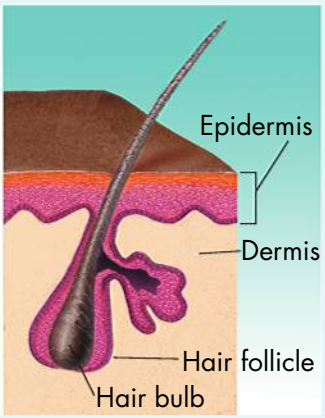
epidermis (p. 776)
dermis (p. 776)



32 CHECK Understanding

Assess the Big idea Structure and Function

Write an answer to the question below.

Q: What systems form the structure of the human body?

Constructed Response

Write an answer to each of the numbered questions below. The answer to each numbered question should be one or two paragraphs long. To help you begin, read the **Hints** below each of the questions.

1. **How does the sliding-filament model explain how muscles contract?**

   Hint When muscles are relaxed, the actin and myosin filaments are not connected.

2. **How do opposing muscle groups make a joint act as a lever?**

   Hint The part of the lever that does not move is called the fulcrum.

   Hint When one muscle in the group contracts, the other relaxes.

3. **Explain the statement, "In many ways, a bone is never finished growing."**

   Hint Osteoclasts break down bone minerals. Osteoblasts build bone tissue.

Foundations for Learning Wrap-Up

Use the table you prepared at the start of the chapter as a tool to help you organize your thoughts about the structures and functions of body systems.

Activity 1 Working with a partner, fold your paper so that only the structures are visible. Take turns quizzing each other about the structures and functions listed.

Activity 2 Your lists are separated into structures and functions. In a small group, discuss how the structure of each organ or system relates to its functions. For example, how do different structures of the skeleton help it perform its many functions? You may want to add rows for this information.

STRUCTURES	FUNCTIONS	
Skeletal system	• Support, • Protection • Movement • Mineral storage • Blood cell formation	
Smooth muscle	• Involuntary movement • Form part of the wall of blood vessels, intestines, stomach	
Cardiac muscle	• Involuntary movement • Most of the heart	
Skeletal muscle	• Voluntary movement • Move bones around joints	
Integumetary system	• Protects the body from dirt and germs • Protects from the sun • Keeps the body from drying out • Maintains body temperature • Removes wastes • Gathers infroamtion • Produces vitamin D	

32.1 The Skeletal System

Understanding Key Concepts

1. The network of tubes that runs through compact bone is called the
   a. periosteum. **c.** Haversian canals.
   b. joint. **d.** marrow.

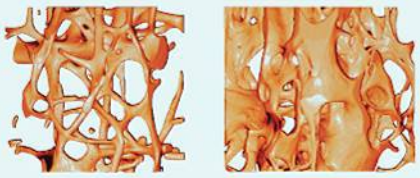
Test-Taking Tip

Eliminate Incorrect Answers If you are having trouble answering a multiple-choice question, eliminate answers you know are not correct. This will help you find the correct answer. In question 1, answer **a** is the thin outer layer of the bone. Answer **b** is the place where two or more bones meet. Answer **d** is the soft tissue inside some bones where fat is stored and blood cells are formed. Once you have eliminated these answers, you see that answer **c** is the correct answer. Nerves and blood vessels run through the Haversian canals.

2. Ossification begins up to seven months before birth. What happens during ossification?
   a. Bones lose minerals and mass.
   b. Cartilage is replaced by bone.
   c. Vitamin D is made.
   d. Bones fracture more easily.
3. Which connective tissue joins two bones at a joint?
   a. bursae
   b. ligaments
   c. tendons
   d. cartilage
4. Draw a diagram of a long bone and label the structures.
5. Which type of freely movable joint allows for the greatest range of motion?
6. **Infer** Disks of rubbery cartilage are found between the individual bones in the backbone. What function do you think these disks serve?

Think Critically

7. **Interpret Visuals** Look at the images below. One shows a healthy bone tissue. The other shows signs of osteoporosis. Which bone sample do you think shows signs of osteoporosis, choice *a* or choice *b*? Explain.



a. **b.**

8. **Use Models** Imagine that you want to build a robotic arm that works the way the human elbow works. Describe or sketch the elbow that you could use in your model.

32.2 The Muscular System

Understand Key Concepts

9. Which kind of muscle tissue is striated and has cells that have only one or two nuclei?
   a. cardiac **c.** smooth
   b. skeletal **d.** voluntary
10. Which two protein filaments are involved in muscle contraction?
    a. sarcomere and myofibril
    b. actin and myosin
    c. periosteum and cartilage
    d. ATP and acetylcholine
11. Describe the primary function of each of the three types of muscle tissue.
12. Describe how acetylcholine affects a muscle cell.
13. Explain this statement: "Most skeletal muscles work in opposing pairs."

Think Critically

14. **Relate Cause and Effect** Certain bacteria make a toxin that affects motor neurons. The toxin prevents motor neurons from releasing acetylcholine. Explain what effect this toxin is likely to have on the body.

32 CHECK Understanding

32.3 Skin—The Integumentary System

15. What is the outer layer of skin called?

a. dermis **c.** epidermis

b. keratin **d.** melanin

16. Which of the following is a function of the eyelashes and hairs in the ears and nose?

a. They keep the body warm.

b. The help in the production of vitamin D.

c. They stop dirt and germs from entering the body.

d. They produce keratin.

17. In what layer of the skin do newer cells push older cells to the surface of the body?

a. the epidermis

b. the hypodermis

c. the dermis

d. the sebum

18. Describe three ways the integumentary system protects the body.

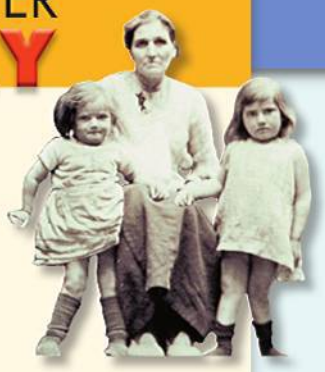
19. Describe two ways the integumentary system helps regulate body temperature.

Connecting Concepts

Use Science Graphics

20. **Infer** Cartilage does not appear on X-ray film. Instead, it is seen as a clear area between the shaft and the ends of bones. Examine the X-rays shown below. Which hand belongs to the youngest person? Explain.

solve the CHAPTER MYSTERY



THE DEMISE OF A DISEASE

The research on the cause and a cure for rickets found two results. Both cod liver oil and exposure to ultraviolet light could prevent and cure rickets.

Cod liver oil has a nutrient involved in bone health. Starting in the 1930s, many parents in the United States gave their children a daily dose of cod liver oil.

The research also suggested that the sun influences bone health. This explained why children in colder climates were more likely to have rickets. They had little sun exposure during winter months.

But scientists still did not understand how such different treatments could have the same outcome.

Through the work of many scientists, we now know that both treatments provide vitamin D. Cod liver oil gives the body vitamin D. And, when exposed to the sun's rays, the skin helps the body make vitamin D. Vitamin D also helps the body absorb calcium and phosphorus from the digestive system.

Today, children are no longer given cod liver oil. Instead, vitamin D is added to milk. Rickets is now rare in the United States.

1. **Explain** Why were children in southern cities less likely to develop rickets?

2. **Compare and Contrast** Describe the structure of the bones of a healthy child in comparison to the bones of a child who developed rickets.

UntamedScience Solving the Demise of a Disease mystery is just the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mystery leads.

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Standardized Test Prep

Multiple Choice

1. What determines differences in skin color among individuals?
- **A** number of melanocytes
- **B** amount of melanin produced by each melanocyte
- **C** amount of keratin in the skin
- **D** amount of sebum produced

2. Smooth muscle is found in the
- **A** walls of blood vessels.
- **B** heart.
- **C** neuromuscular junctions.
- **D** joints.

3. All of the following are important roles of the skeletal system EXCEPT
- **A** protection of internal organs.
- **B** facilitation of movement.
- **C** storage of mineral reserves.
- **D** regulation of body temperature.

4. Which of the following supplies the energy required for muscle contractions?
- **A** myosin
- **B** ATP
- **C** acetylcholine
- **D** actin

5. The tough layer of connective tissue surrounding each bone is called
- **A** tendon.
- **B** ligament.
- **C** periosteum.
- **D** cartilage.

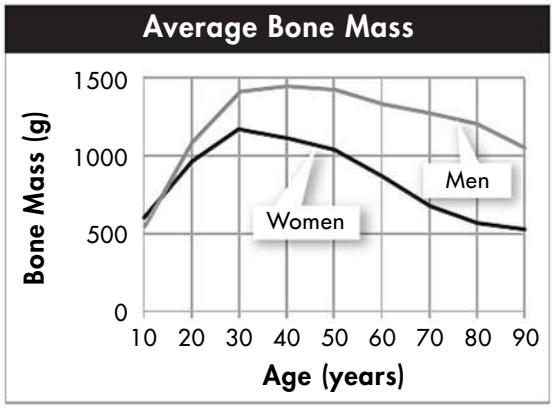
6. Joints that allow one bone to rotate around another are
- **A** gliding joints.
- **B** ball-and-socket joints.
- **C** hinge joints.
- **D** pivot joints.

7. Which of the following is NOT found in skin tissue?
- **A** keratin
- **B** collagen
- **C** marrow
- **D** melanin

8. What is a function of sebum?
- **A** It moistens the hair and skin.
- **B** It gives skin its color.
- **C** It insulates the body.
- **D** It makes nails and hair rigid.

Questions 9–10

As people age, the mineral content of their bone decreases. People who fail to build enough bone in adolescence and young adulthood or who lose bone at a faster than normal rate are at risk for developing osteoporosis. The graph below shows typical bone mass of men and women through most of the life span.



9. Between which ages do both men and women gain bone mass at the highest rate?
- **A** 10–20 years
- **B** 20–30 years
- **C** 30–40 years
- **D** 50–60 years

10. A valid conclusion that can be drawn from this graph is that, on average,
- **A** women lose more bone mass as they age than men do.
- **B** men lose more bone mass as they age than women do.
- **C** women and men lose the same bone mass as they age.
- **D** men continue to gain bone mass as they age.

Open-Ended Response

11. Doctors recommend that women eat calcium-rich foods and get plenty of exercise during adolescence and early adulthood. How could this help prevent osteoporosis later in life?

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10	11
See Lesson	32.3	32.2	32.1	32.2	32.1	32.1	32.3	32.3	32.1	32.1	32.1

33 Circulatory and Respiratory Systems

Big idea

Structure and Function

Q: How do the structures of the circulatory and respiratory systems allow for their close functional relationship?

Usually, we are not conscious of breathing, but we can control it during activities, such as swimming.

BIOLOGY.com Search Chapter 33 GO • Chapter Mystery

INSIDE:

- Untamed Science Video
- Flash Cards

CHAPTER MYSTERY

IN THE BLOOD

At the age of 60, John had surgery to send blood around blocked vessels in his heart. Since then, he has eaten less fat and stuck to an exercise program. Still, today he is meeting with his doctor. Fatty deposits are re-forming in his heart's vessels.

Down the hall, 6-year-old Lila is seeing her doctor today, too. Her vessels are also clogged. She is dangerously close to having a heart attack.

Both of these patients suffer from a genetic disease that affects a substance in their blood. What is the disease? Why did it affect them at such different ages?

Read for Mystery Clues As you read this chapter, look for clues about this disease. Then, solve the mystery at the end of the chapter.

FOUNDATIONS for Learning

Before you read this chapter, fold and cut a piece of paper as shown below to make a table tent. Then, label each "flap" with the words *circulatory*, *lymphatic*, and *respiratory*. As you read, take notes about the structures and functions of each body system on the inside of the flap. At the end of the chapter are two activities that use the table tent to help answer the question: How do the structures of the circulatory and respiratory systems allow for their close functional relationship?

33.1 The Circulatory System

Key Questions

- ***What are the functions of the circulatory system?***
- ***How does the heart pump blood through the body?***
- ***What are three types of blood vessels?***

BUILD Understanding

Preview Visuals Before you read, look at the visual, The Heart. Draw a two-column chart. In the left column, write the structures listed in the image. In the right column, write down the functions of each structure.

In Your Workbook Go to your workbook for help completing the chart.

BUILD Connections

A CITY'S TRANSPORTATION SYSTEM

The human circulatory system is like the highways and streets of a large city.

In Your Workbook
Go to your workbook to compare the needs of a person living in a large city with the needs of a cell in the body.

Functions of the Circulatory System

More than 1 million Americans suffer a heart attack each year. Of those, more than one-third die. This sad fact shows how important the heart and circulatory systems are to life.

Some animals have only a few cells. These cells are in direct contact with the outside of the animal's body. These animals are able to get all of the oxygen and nutrients they need through active transport and diffusion. They also remove wastes through active transport and diffusion. The human body, on the other hand, has millions of cells that are not on the outside of the body. Because it has so many cells, the human body needs a circulatory system. This system carries oxygen, nutrients, and other things the body needs throughout the body. It also removes wastes.

You can think of the human body as a large city. The cells are like people who live in the city. The people need things that are made elsewhere in the city. They need food. They need to get rid of garbage, and they need to move around the city. Your cells need similar things. How are these needs met in a city? The needs are met by the city's streets, highways, and subway or train lines. In the human body, the circulatory system meets these needs. This system is made up of the heart, blood vessels, and blood.

Key Question What are the functions of the circulatory system?

The circulatory system carries oxygen, nutrients, and other substances throughout the body. It also removes wastes.

The Heart

Most of the time, you probably do not even notice your heart at work. But you notice it beating when you exercise.

Heart Structure An adult's heart beats about 72 times a minute. It beats more quickly during exercise. Your heart is about the size of your fist. It is almost all muscle. The muscles begin contracting before you are born. They stop only when you die. The layer of muscle in the walls of your heart is called the **myocardium.** Strong contractions of this muscle pump blood through the circulatory system.

The heart has four chambers. Each of the two upper chambers is called an **atrium** (plural: atria). Blood enters the heart through the atria. The lower chambers are called **ventricles.** They pump blood out of the heart.

Blood Flow Through the Heart Blood from the body enters the heart through the right atrium. Blood from the lungs enters the heart through the left atrium. Blood moves from the atria into the ventricles. Valves between the atria and ventricles keep the blood from flowing in the wrong direction. There are also valves at the exits of each ventricle. This system of valves keeps blood moving in one direction through the heart, similar to traffic on a one-way street.

BUILD Vocabulary

myocardium
the thick middle muscle layer of the heart

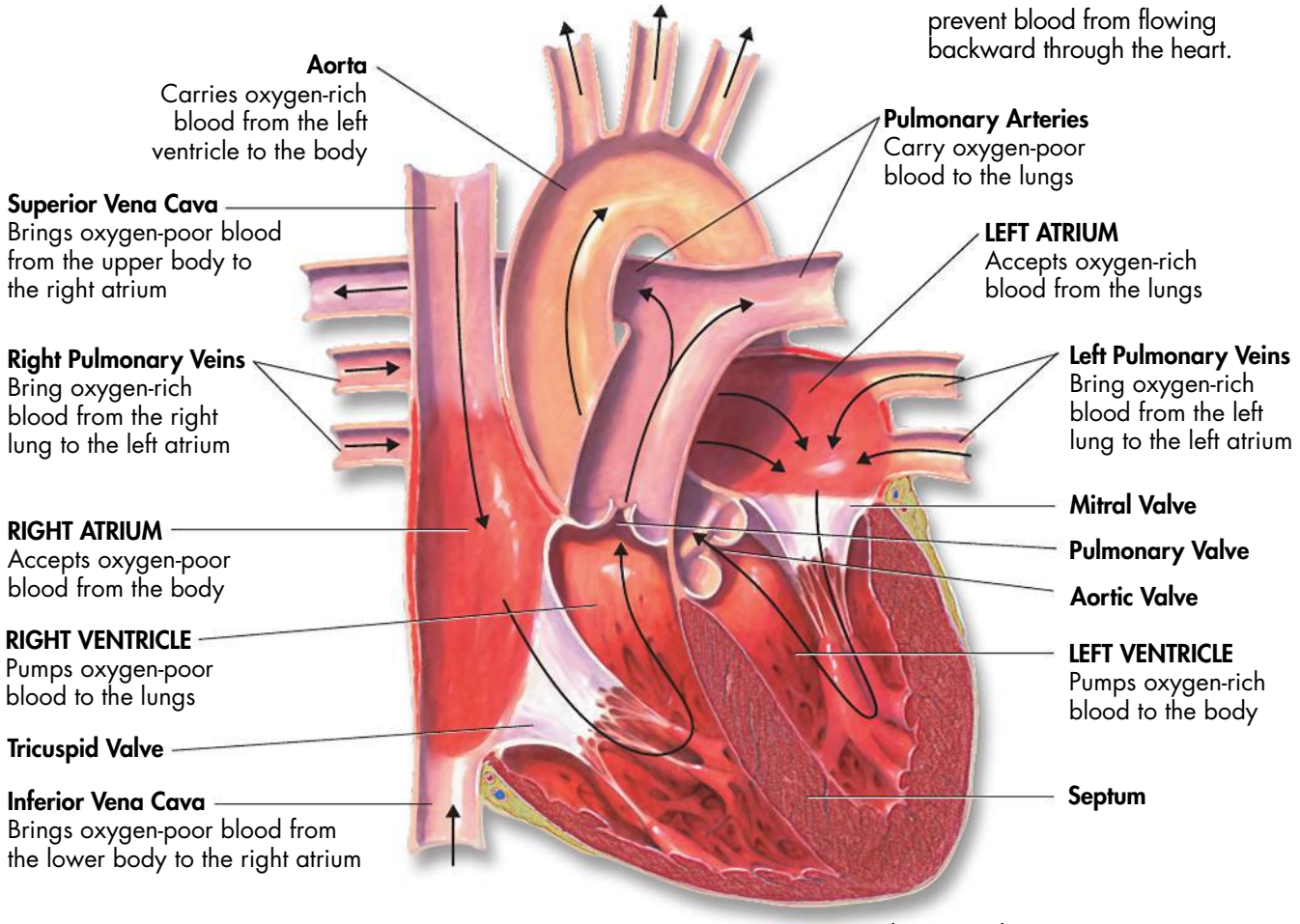
atrium
an upper chamber of the heart that receives blood from the rest of the body

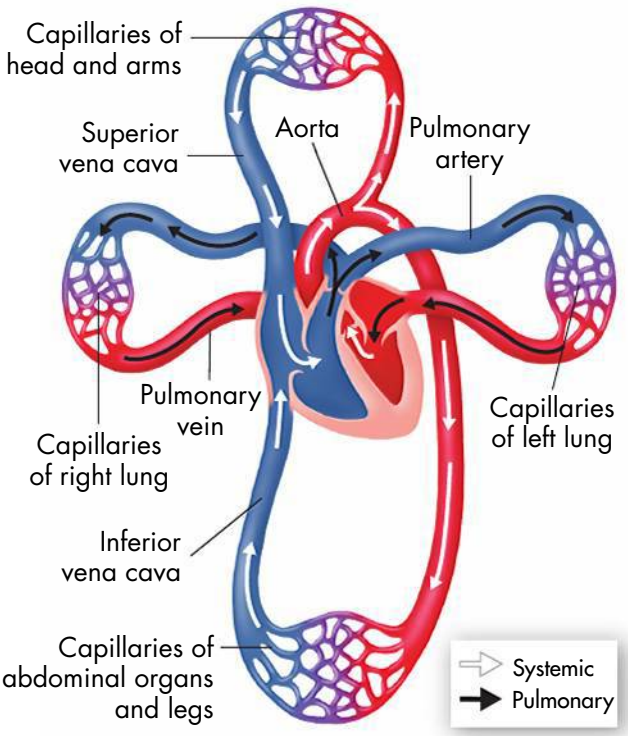
ventricle
a lower chamber of the heart that pumps blood out of the heart to the rest of the body

WORD ORIGINS

The word *cardiac*, the prefix *cardio-*, and the suffix *-cardium* are all based on the Greek word *kardia*, which means "heart."

The Heart The human heart has four chambers: the right atrium, the right ventricle, the left atrium, and the left ventricle. Valves prevent blood from flowing backward through the heart.





Circulation Pathways The circulatory system is divided into two pathways: pulmonary circulation and systemic circulation. Notice that the blue in this image represents oxygen-poor blood. The red represents oxygen-rich blood.

The Heart's Blood Supply

The heart itself gets very little oxygen and nutrients from the blood it pumps through its chambers. Instead, a pair of vessels called *coronary arteries* run through the heart tissue. These provide blood to the heart muscle.

Circulation

The heart acts as two pumps. One pump pushes blood to the lungs. The second pump pushes blood to the rest of the body.

▶ ***Pulmonary Circulation*** The first pump is the right side of the heart. It sends oxygen-poor blood from the heart to the lungs. This path is called pulmonary circulation. The blood picks up oxygen and gets rid of carbon dioxide in the lungs. Then the blood flows to the left side of the heart.

▶ ***Systemic Circulation*** The left side of the heart pumps oxygen-rich blood to the rest of the body. This path is called systemic circulation. The blood brings oxygen to the body's cells.

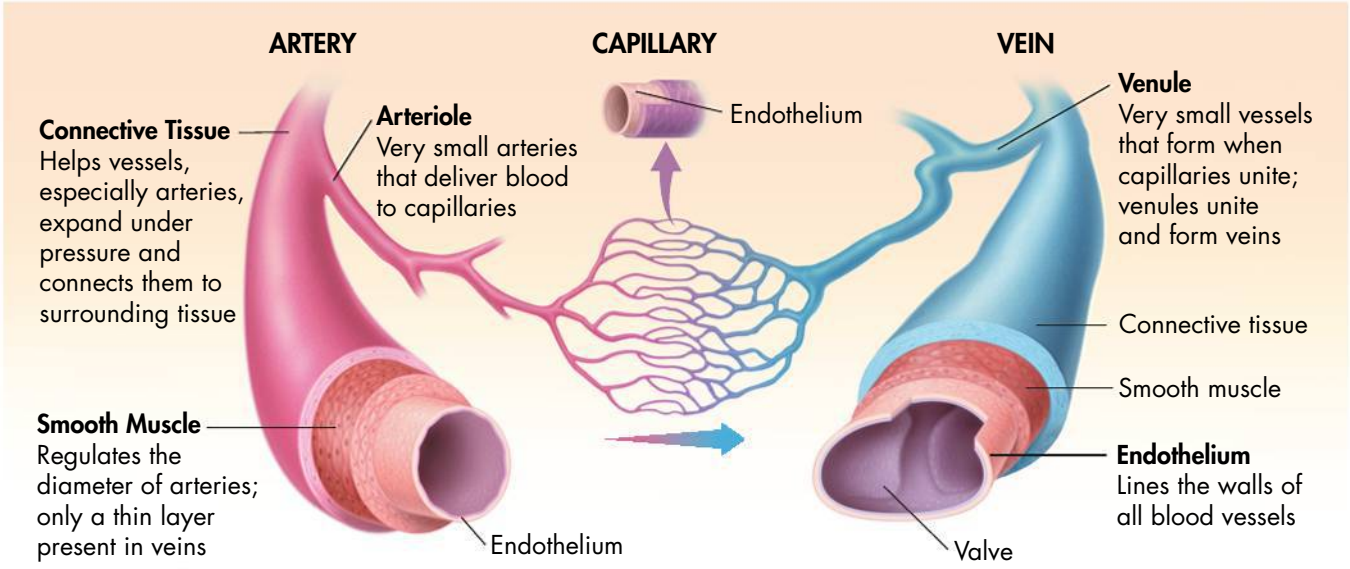
Heartbeat

The heartbeat must be controlled. First the atria contract and then the ventricles contract. A small group of cardiac muscle fibers, called the SA node, is found in the right atrium. The SA node is sometimes called the pacemaker because it "sets the pace" of the heartbeats. The SA node sends an electrical impulse to the atria, and they contract. The impulse then goes to another group of muscle fibers called the AV node. The impulse is delayed for a moment, giving the atria time to contract. Blood flows into the ventricles, which contract. The ventricles pump blood out of the heart.

Key Question How does the heart pump blood through the body?

Contractions of the myocardium cause the atria and then the ventricles to contract, pumping blood through the body.

Structure of Blood Vessels The structure of blood vessel walls contributes to the vessels' functions.



Blood Vessels

Oxygen-rich blood leaving the left ventricle passes into the aorta. The aorta is the first of many vessels that carry blood through the body and back to the heart.

Arteries, Capillaries, and Veins As blood flows through the circulatory system, it moves through three kinds of blood vessels—arteries, capillaries, and veins. **Arteries** carry blood from the heart. Their thick walls can handle the pressure of the blood as it is pumped through them. **Capillaries** are tiny blood vessels. Many are so narrow that the blood cells pass through them in single file. Oxygen and nutrients diffuse through their thin walls into tissues. Carbon dioxide and other wastes move from tissues into capillaries. The blood returns to the heart through **veins.** When the skeletal muscles around many veins contract, they squeeze the veins. This squeezing action helps push the blood back toward the heart. Many veins also have valves to keep blood from flowing backward.

Blood Pressure Have you ever had your blood pressure taken at the doctor's office? Blood pressure that is too high or too low can cause big problems throughout the body. Skeletal muscles relax or contract if blood pressure is too high or too low. The kidneys help regulate blood pressure by controlling the amount of water in blood.

Key Question What are three types of blood vessels?
The three types of blood vessels are arteries, capillaries, and veins.

BUILD Vocabulary

artery
a large blood vessel that carries blood away from the heart to the tissues of the body

capillary
the smallest blood vessel; brings nutrients and oxygen to the tissues and absorbs carbon dioxide and waste products

vein
a blood vessel that carries blood from the body back to the heart

MULTIPLE MEANINGS

The word *artery* is often used to refer to major roads. This use of the term is making the same analogy between a city or town's transportation system and the body's circulatory system that was made at the beginning of this lesson.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. Powerful contractions of the _____ pump blood through the circulatory system.
2. Oxygen-rich blood is pumped out of the heart to the body through the left _____.

Critical Thinking

3. **Apply Concepts** Why do humans need a circulatory system?
4. **Relate Cause and Effect** How would damage to the SA node affect the heart's function?
5. **Sequence** Through which blood vessels does blood flow on its path from the heart, to the rest of the body, and back to the heart?
6. **Write to Learn** Answer the first mystery clue. What is the function of the coronary arteries?

MYSTERY CLUE

The coronary arteries and vessels that branch from them are relatively narrow. Why is the heart especially susceptible to a disease that narrows blood vessels? (Hint: See p. 788.)

BIOLOGY.com Search Lesson 33.1 GO • Lesson Assessment

33.2 Blood and the Lymphatic System

Key Questions

- ***What is the function of each component in blood?***
- ***What is the function of the lymphatic system?***
- ***What are three common circulatory diseases?***
- ***What is the connection between cholesterol and circulatory disease?***

BUILD Understanding

Concept Map As you read, draw a concept map to organize the information in this lesson.

In Your Workbook Go to your workbook for help completing the concept map. Complete the concept map for Lesson 33.2.

Blood

Most likely, when you think about body tissues, you think of something with a definite shape, like muscle or skin. But blood is a tissue, too. It just happens to be in a liquid form. Blood has many important functions. It carries oxygen. It helps your body fight disease. It carries sources of energy such as sugars and fats. The different parts of blood also help keep body temperature stable and form clots to close wounds. How does this unusual tissue perform so many functions?

Plasma The human body contains 4 to 6 liters of blood. More than half of the body's blood is made up of a straw-colored fluid called **plasma.** Plasma is about 90 percent water. The other 10 percent is made up of dissolved gases, salts, nutrients, enzymes, hormones, waste products, plasma proteins, cholesterol, and other important compounds.

The water in plasma helps to control body temperature. Some proteins in plasma carry substances throughout the body. Others help the body fight infection or form blood clots.

Red Blood Cells The most numerous cells in blood are red blood cells. The main function of **red blood cells** is to carry oxygen through the body. They are red because of the iron in hemoglobin. Hemoglobin is a protein that binds to oxygen in the lungs. Hemoglobin releases the oxygen in capillary networks in other parts of the body. Red blood cells also carry carbon dioxide to the lungs.

Red blood cells are disks that are thinner in their center than along their edges. They are made in bone marrow. As they mature and fill with hemoglobin, they lose their nuclei and other organelles. Red blood cells stay in the blood for about 120 days. The cells are then destroyed in the liver and spleen.

Blood Cells The red disks in this micrograph are red blood cells. The gold spheres are white blood cells. The pink fragments are platelets. (SEM 1866×)

White Blood Cells The main function of the **white blood cells** is to protect the body against infection, fight parasites, and attack bacteria. For example, B lymphocytes produce antibodies that provide immunity. When the body is fighting an infection, it makes more white blood cells. White blood cells do not always stay in blood vessels. Many white blood cells can move through capillary walls to fight pathogens. A pathogen is anything that can make you sick.

In a healthy person, there are many more red blood cells than white blood cells. Like red blood cells, white blood cells are made in bone marrow. Unlike red blood cells, white blood cells keep their nuclei and can live for years.

Platelets Losing too much blood can kill a person. Fortunately, a minor scrape or cut usually stops bleeding quickly. Why? Such minor wounds stop bleeding quickly because blood clots. The cytoplasm of some bone marrow cells divides into thousands of pieces. These pieces break away and enter the blood as **platelets.** Platelets are surrounded by cell membranes. Platelets and plasma proteins form blood clots. Platelets become sticky when they touch a broken blood vessel. They cluster around the wound, and the blood begins to clot.

Key Question What is the function of each component in blood?
Plasma controls body temperature, carries substances through the body, and fights infection. Red blood cells carry oxygen. White blood cells fight infection. Platelets form blood clots.

BUILD Vocabulary

plasma
the straw-colored liquid portion of the blood

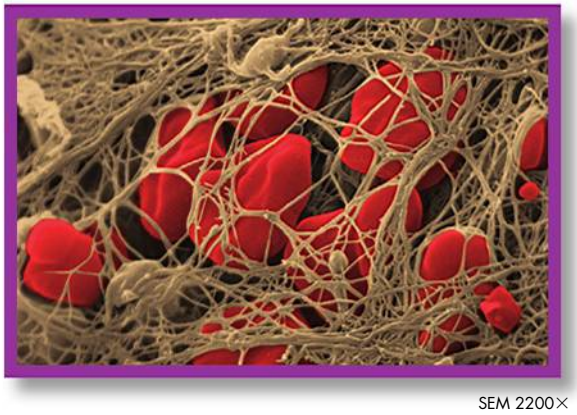
red blood cell
a blood cell containing hemoglobin that carries oxygen

white blood cell
a type of blood cell that guards against infection, fights parasites, and attacks bacteria

platelet
a cell fragment released by bone marrow that helps in blood clotting

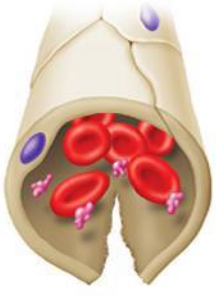
SUFFIXES

The suffix *-let* in *platelet* means "little." Under the microscope, platelets look like small, broken plates.

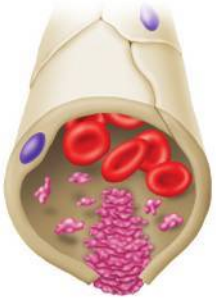


SEM 2200×

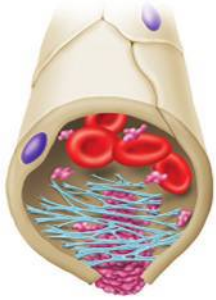
How Blood Clots Form When the clot is formed, filaments develop a net that prevents blood from leaving the damaged vessel.



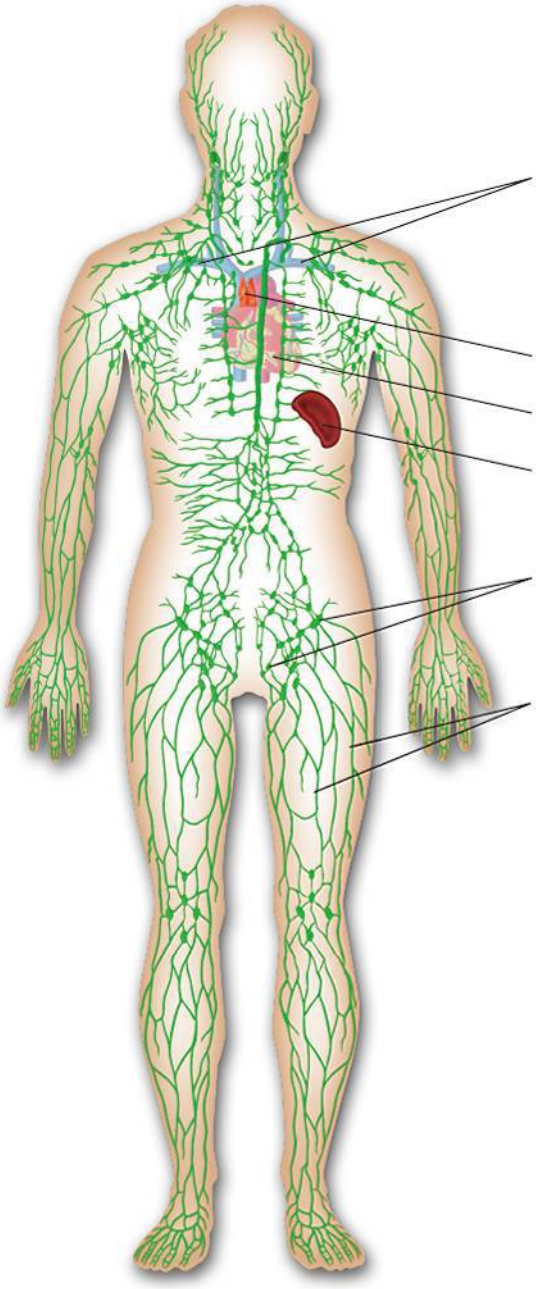
1 Capillary Wall Breaks
A blood vessel is injured by a cut or scrape.



2 Platelets Take Action
Platelets clump at the site, which triggers a series of reactions.



3 Clot Forms
An enzyme called thrombin causes sticky fibrin filaments to form the clot. The clot seals the damaged area and prevents further loss of blood.



The Lymphatic System The lymphatic system is a network of vessels, nodes, and organs. This system recycles fluids from tissues and plays a role in nutrient absorption and immunity.

The Lymphatic System

As blood passes through the capillaries, some cells and parts of plasma leave the blood vessels. The cells and plasma form a fluid called **lymph.** Lymph carries nutrients, oxygen, and salts. Most of the lymph moves back into the capillaries. The rest becomes part of the lymphatic system. The lymphatic system collects the lymph, "screens" it for pathogens, and returns it to the circulatory system.

Role in Circulation Lymph collects in a system of lymphatic capillaries. It slowly moves into larger vessels. There is no pump in the lymphatic system. Instead, valves keep lymph from moving backwards. Skeletal muscles help move lymph through the system. Lymph is returned to the blood through openings in veins just below the shoulders.

Role in Nutrient Absorption The lymphatic system helps the body absorb nutrients. Lymph vessels running along the intestines pick up fats and fat-soluble vitamins. The vessels carry these nutrients into the blood.

Role in Immunity There are hundreds of lymph nodes throughout the body. These lymph nodes act as filters. They trap pathogens, damaged cells, and debris as lymph flows through them. White blood cells in the lymph nodes destroy the pathogens, damaged cells, and debris. When large numbers of pathogens are trapped in the lymph nodes, the lymph nodes may swell. When you are sick, you may notice "swollen glands" in your neck. You are really feeling swollen lymph nodes.

The thymus and spleen are organs of the lymphatic system. Certain white blood cells, called T lymphocytes, mature in the thymus. The spleen filters blood in much the same way that lymph nodes filter lymph. The spleen also removes old or damaged blood cells and stores platelets.

Key Question What is the function of the lymphatic system?
The lymphatic system collects lymph, filters it for pathogens, and returns it to the circulatory system. Lymph vessels also pick up fats and fat-soluble vitamins from the intestines.

Circulatory System Diseases

Three common and serious diseases of the circulatory system are heart disease, stroke, and high blood pressure. Damage to the heart or brain can be fatal.

Heart Disease Heart disease is the leading cause of death in the United States. Heart muscle needs a constant supply of oxygen. Yet, the heart gets blood through only two coronary arteries and their smaller branches. Most forms of heart disease are caused when it becomes difficult for blood to flow through these vessels.

One type of heart disease is **atherosclerosis** (ath ur oh skluh ROH sis). Atherosclerosis is a condition in which fatty deposits called plaque build up in artery walls. The arteries become stiff. The plaque can make it difficult for blood to pass through the artery. The cap on a plaque can also rupture and cause a blood clot to form. The clot can block the artery. A heart attack happens as heart muscle cells are damaged and die from a lack of oxygen.

Symptoms of a heart attack include nausea, shortness of breath, and chest pain. People also often complain of pain in the neck, jaw, or left arm. These symptoms need *immediate* medical attention in order to save heart muscle.

Stroke When the blood supply to the brain is interrupted, some brain cells die. This event is called a stroke. Sometimes, a blood clot blocks a blood vessel in the brain and causes a stroke. A stroke may also be caused when a weak blood vessel breaks and causes bleeding in the brain. Symptoms include dizziness, severe headache, numbness, and trouble seeing or speaking. Some strokes cause death. Other strokes may cause paralysis or loss of speech.

High Blood Pressure A blood pressure reading above 140/90 is considered high. Doctors also call this condition hypertension. The heart is struggling to push blood through blood vessels. This pressure may damage the heart and the blood vessels. High blood pressure can lead to heart attack, stroke, and kidney damage.

Key Question What are three common circulatory diseases?
Three common circulatory diseases are heart disease, stroke, and high blood pressure.

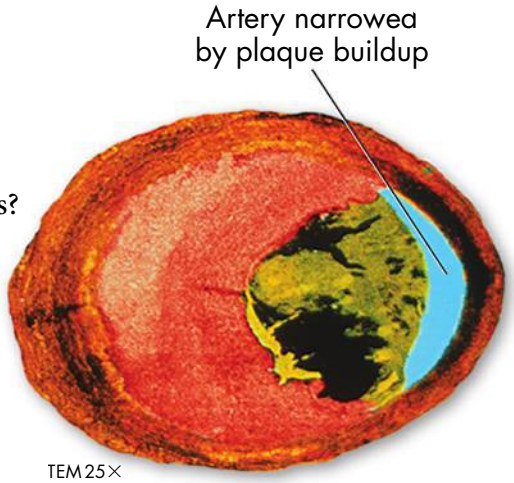
BUILD Vocabulary

lymph
a fluid that is filtered out of the blood

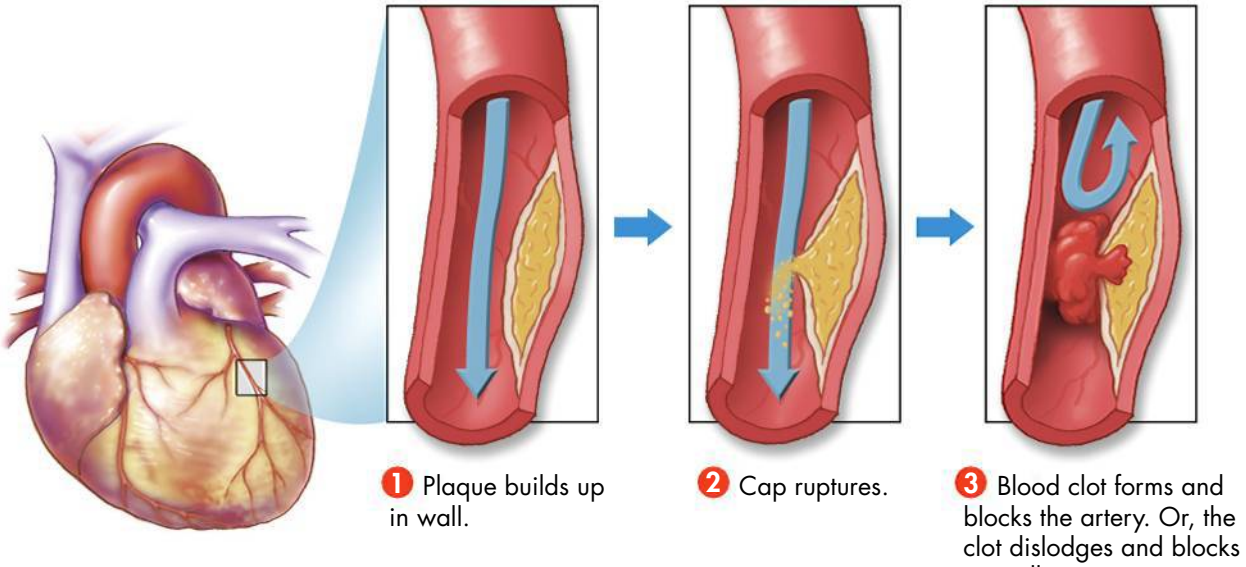
atherosclerosis
a condition in which fatty deposits called plaque build up on the inner walls of the arteries

WORD ORIGINS

Atherosclerosis comes from the Greek words *athero,* meaning "gruel" or "paste" and *sclerosis,* meaning "hardness." Atherosclerosis is the hardening of arteries that results from fatty deposits.



Atherosclerosis Most heart attacks happen when a plaque bursts in a coronary artery. A clot forms. The clot may block the artery. The clot could also break off and block a smaller artery.



Understanding Circulatory Disease

Many factors affect a person's risk for heart disease and stroke. Some risk factors can be controlled and others cannot. Risk factors that cannot be controlled include a person's age and family history. Gender is another uncontrollable risk factor. Men have more heart attacks than women. Some controllable risk factors include choosing a healthy diet, exercising regularly, and not smoking. High blood pressure and high cholesterol are risk factors that can sometimes be controlled by medications. Researchers have learned a lot about cholesterol and how it is related to heart disease.

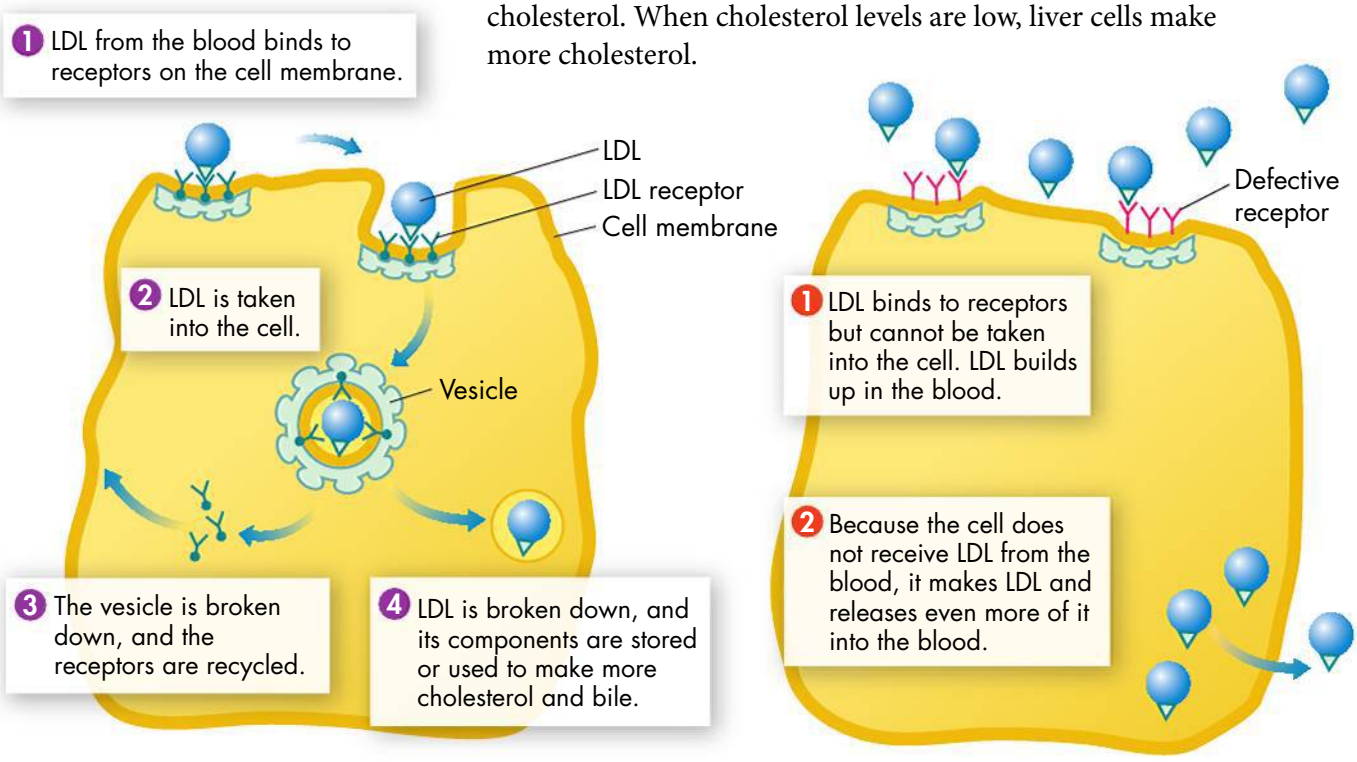
What Is Cholesterol? Cholesterol is part of animal cell membranes. The body uses it to make bile, vitamin D, and some hormones. Two substances carry cholesterol in the blood—low-density lipoprotein (LDL) and high-density lipoprotein (HDL). LDL becomes part of plaque. HDL generally helps the body remove cholesterol.

The liver makes cholesterol, which then moves through the blood to other body tissues. People also get cholesterol when they eat meat, eggs, dairy foods, and most fried foods.

Cholesterol and Atherosclerosis High cholesterol levels can lead to atherosclerosis and a higher chance of heart attack. Researchers Michael Brown and Joseph Goldstein received a Nobel Prize in 1985 for their study about cholesterol.

Cholesterol and the LDL Receptor Brown and Goldstein found LDL receptors on liver cells. When blood cholesterol levels are high, liver cells take the LDL from the blood and do not make more cholesterol. When cholesterol levels are low, liver cells make more cholesterol.

LDL Receptors Liver cells with normal LDL receptors take up LDL and use it or store it. But liver cells with defective LDL receptors cannot remove cholesterol from the blood.



Cell With Normal LDL Receptors **Cell With Defective LDL Receptors**

Brown and Goldstein also found that some people carry genes that make defective LDL receptors. In these people, the liver cells cannot remove cholesterol from the blood. Also, the liver cells do not receive the signal to stop making cholesterol.

From Genetic Disease to the Public The genetic disorder helps us understand high cholesterol in people who do not have the disorder. People who eat high-fat diets store cholesterol in their liver cells. The liver cells then stop making LDL receptors. The liver cells stop removing cholesterol from blood. All of the excess cholesterol remains in the blood vessels. Therefore, a high-fat diet can cause symptoms that are similar to a genetic disorder.

Brown and Goldstein's work led to the development of drugs that can help people with high cholesterol. Some of these drugs stop the liver cells from making cholesterol. This causes the liver to make more LDL receptors. The LDL receptors remove extra cholesterol from the blood.

Keeping Your Circulatory System Healthy It is much easier to prevent heart disease than to cure it. Healthy habits when you are young help protect your heart. By eating a healthy diet, exercising regularly, and not smoking, you can help keep your circulatory system healthy.

Key Question What is the connection between cholesterol and circulatory disease? **High cholesterol levels can lead to atherosclerosis and a higher chance of heart attack and stroke.**

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The main function of _____ is to carry oxygen throughout the body.
2. Blood clotting is made possible by plasma proteins and cell fragments called _____.
3. The lymphatic system collects _____, removes pathogens from it, and returns it to the circulatory system.
4. When plaque builds up in artery walls and causes them to stiffen, the condition is called _____.

Critical Thinking

5. **Infer** Hemophilia is a genetic disorder. One of the proteins in the clotting pathway does not work properly. What do you think happens to a person with hemophilia who has a minor cut?
6. **Relate Cause and Effect** Why do you think atherosclerosis may lead to high blood pressure?
7. **Write to Learn** Answer the second clue of the mystery. Remember that you inherit genes from both of your parents. Look back at Chapter 14 to review inheritance patterns.

MYSTERY CLUE

What genetic defect do both mystery patients carry? Can you think of a genetic reason why Lila's symptoms are so much worse than John's? (Hint: See p. 794.)

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33.3 The Respiratory System

Key Questions

- ***What is the function of the respiratory system?***
- ***How are oxygen and carbon dioxide exchanged and transported throughout the body?***
- ***What mechanisms are involved in breathing?***
- ***How does smoking affect the respiratory system?***

BUILD Understanding

Flowchart As you read, make a flowchart that shows the path of air through the respiratory system.

In Your Workbook Go to your workbook to learn more about making a flowchart. Complete the flowchart for Lesson 33.3.

BUILD Vocabulary

pharynx
a tube at the back of the mouth that serves as a passageway for both air and food; also called the throat

larynx
a structure in the throat that contains the vocal cords

trachea
a tube that connects the larynx to the bronchi; also called the windpipe

WORD ORIGINS

The word *trachea* comes from the Greek phrase that means "rough artery." Rings of cartilage form the trachea and give it a rough surface.

Structures of the Respiratory System

Why do we need to breathe? All cells in our body, especially brain cells, need oxygen all of the time. Without oxygen, many cells die in minutes. The respiratory and circulatory systems work together to get oxygen to our cells.

For organisms, rather than single cells, *respiration* means the exchange of gases between a body and the environment. When you breathe in, your respiratory system picks up oxygen from the air. When you breathe out, your respiratory system lets carbon dioxide out into the air. The respiratory system is made up of the nose, pharynx, larynx, trachea, bronchi, and lungs.

Nose The lungs are made of some of the most delicate tissues in the body. Before entering the lungs, air must be filtered, moistened, and warmed. Hairs lining the inside of the nose trap large particles from the air. The air is warmed in the nasal cavity and sinuses. Mucus in these spaces moistens the air and catches even more dust particles.

Pharynx, Larynx, and Trachea Air moves from the nose to the throat, or **pharynx.** The pharynx is an area at the back of the mouth. Air and food move through the pharynx. When you swallow, a flap of tissue called the epiglottis at the back of the pharynx protects the airway. The epiglottis makes certain that the food moves into the esophagus.

Air moves from the pharynx to the larynx. The **larynx** contains the vocal cords. When muscles pull the vocal cords together, the air moving between them causes the cords to vibrate and produce sounds.

Air moves from the larynx to the **trachea,** or windpipe. Mucus in the trachea traps more particles from the air. Cilia push the particles and mucus away from the lungs toward the pharynx. From there, the mucus and particles can be swallowed or spit out.

Lungs Air moves from the trachea into two large tubes in the chest. These tubes are called **bronchi** (singular: bronchus). Each bronchus leads to a lung. Inside the lung, each bronchus divides into smaller and smaller passageways. These passageways are called bronchioles. These and the bronchi are surrounded by smooth muscles. These muscles are controlled by the autonomic nervous system. The contracting and relaxing of these muscles changes the size of the bronchi and bronchioles.

The bronchioles continue to divide until they reach a series of dead ends. The tiny air sacs at the end of the bronchioles are called **alveoli** (al VEE uh ly) (singular: alveolus). Alveoli are grouped in bunches, like grapes. Many capillaries surround each alveolus.

Key Question What is the function of the respiratory system?
The respiratory system picks up oxygen from the air we breathe in. It releases carbon dioxide back into the air when we breathe out.

BUILD Vocabulary

bronchus
one of two large tubes in the chest cavity that leads from the trachea to the lungs

alveolus
the tiny air sac at the end of a bronchiole in the lungs that provides surface area for gas exchange to occur

INQUIRY into Scientific Thinking

GUIDED INQUIRY

What's in the Air?

Your respiratory system has several structures that catch particles from the air before they can reach the lungs. For example, hairs in the nose trap large particles. In this activity, you will observe some of the particles in the air you breathe.

1. Trace the outline of a microscope slide onto a piece of graph paper. Cut out the outline and tape it to the slide.
2. Repeat step 1 to make four more slides.
3. Choose five places to put your slides. Some of your spots should be inside. Some should be outside.
4. On each piece of graph paper, write your initials, the date, and where you plan to place the slide.
5. Cover the front of each slide with a thin coat of petroleum jelly.
6. Leave your slides in your chosen spots for at least 24 hours.
7. Collect the slides and look at them under a microscope. Count the number of particles in ten of the squares on each slide. Record your results.

Analyze and Conclude

1. Observe Where had you placed the slide that had the most particles? Where had you placed the slide with the fewest particles?

2. Draw Conclusions Were you surprised by the results? Why or why not?

3. Apply Concepts List the structures in your body that prevent most of these particles from entering your lungs.

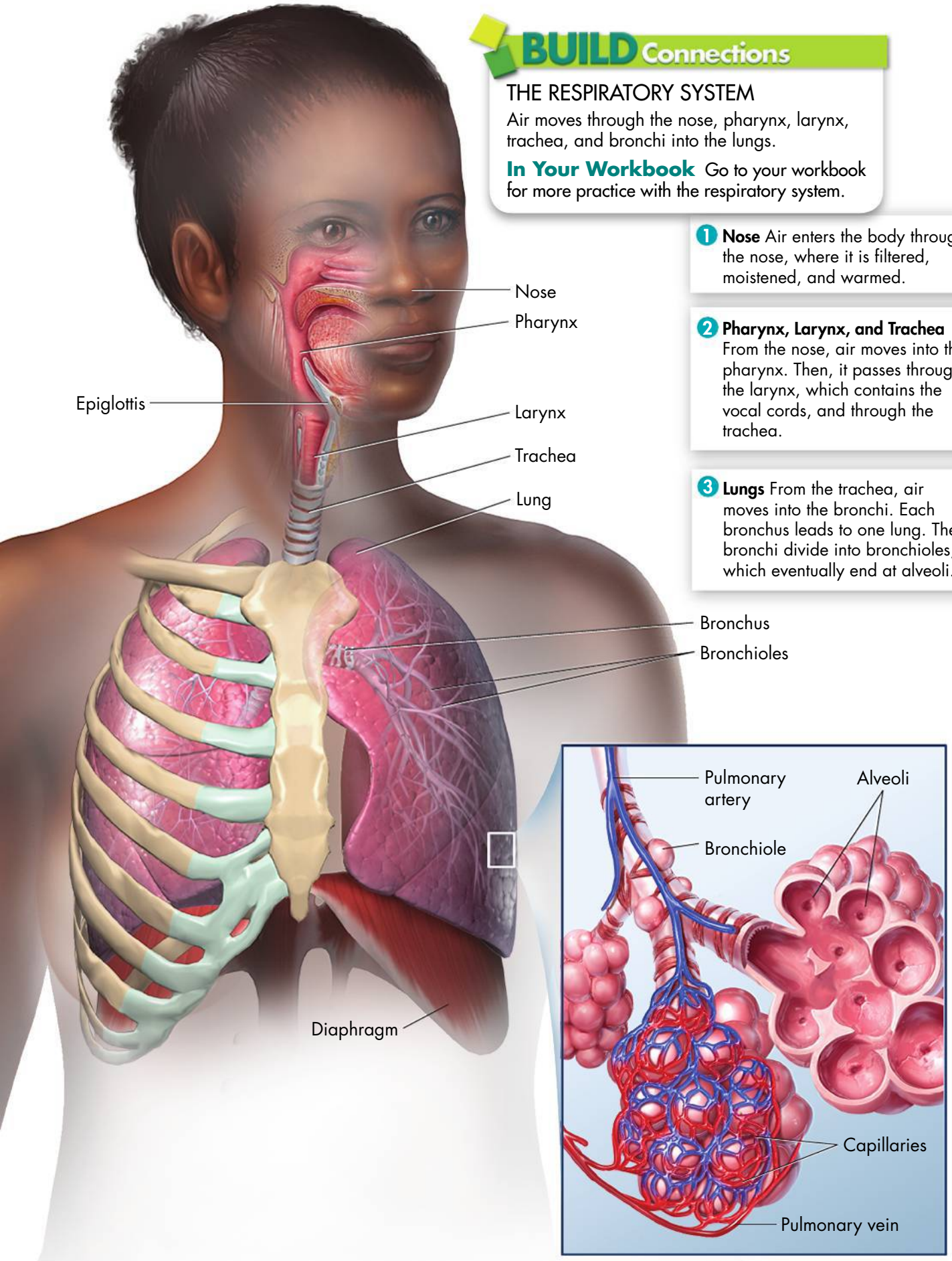
In Your Workbook Get more help for this activity in your workbook.

BUILD Connections

THE RESPIRATORY SYSTEM

Air moves through the nose, pharynx, larynx, trachea, and bronchi into the lungs.

In Your Workbook Go to your workbook for more practice with the respiratory system.



1. **Nose** Air enters the body through the nose, where it is filtered, moistened, and warmed.

2. **Pharynx, Larynx, and Trachea** From the nose, air moves into the pharynx. Then, it passes through the larynx, which contains the vocal cords, and through the trachea.

3. **Lungs** From the trachea, air moves into the bronchi. Each bronchus leads to one lung. The bronchi divide into bronchioles, which eventually end at alveoli.

Gas Exchange and Transport

Each healthy lung has about 150 million alveoli. The alveoli provide an enormous amount of surface area for gas exchange. Oxygen and carbon dioxide are exchanged across the alveoli and capillaries.

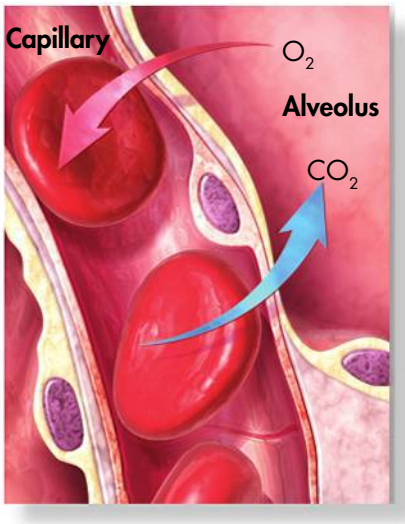
Gas Exchange The inner walls of alveoli are moist. When air enters the alveoli, oxygen dissolves in the moisture. There is more oxygen in the alveoli than in the blood inside the capillaries. So, the oxygen diffuses across thin capillary walls into the blood. At the same time, carbon dioxide diffuses into the alveoli.

Transport Oxygen diffuses passively from alveoli into capillaries. But diffusion stops if the oxygen concentration in the blood and the alveoli are the same. That's why hemoglobin in red blood cells is important. Hemoglobin binds to dissolved oxygen and removes it from the plasma. This helps to keep the concentration in the blood low.

Carbon dioxide diffuses from body tissues to capillaries in three ways. Most carbon dioxide combines with water in the blood. This combination forms carbonic acid. The rest dissolves in plasma or binds to proteins, including hemoglobin, in blood. When the blood reaches the lungs, the carbon dioxide is released into alveoli and exhaled.

Key Question How are oxygen and carbon dioxide exchanged and transported throughout the body?

Oxygen and carbon dioxide diffuse across the thin walls of alveoli and capillaries. Hemoglobin carries oxygen and some carbon dioxide. Carbon dioxide also dissolves in plasma or reacts with water to form carbonic acid.



Gas Exchange Inside the lungs, the bronchi divide into bronchioles, which eventually end at alveoli. Carbon dioxide and oxygen diffuse across the walls of capillaries and alveoli.

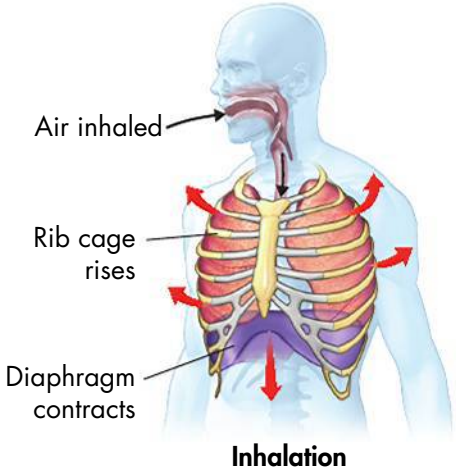
Breathing

There are no muscles connected to our lungs. Breathing is driven by air pressure, the diaphragm, and muscles attached to the ribs.

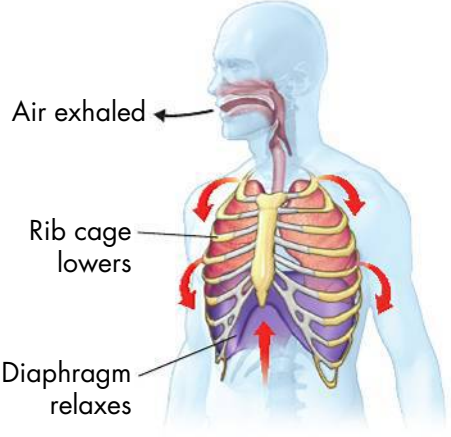
Inhalation At the bottom of the chest cavity is a large muscle called the **diaphragm.** When you inhale, the diaphragm and muscles raise the rib cage. Because the lungs are sealed, this forms a small vacuum. Air rushes in to fill the space.

Exhalation Usually exhalation is passive. The diaphragm and rib cage relax. This relaxation causes air to be pushed out of the body. But to blow out a candle, sing, or yell, you need more force. The muscles between the ribs and the abdominal muscles can contract to push the air out.

This system works only because the chest cavity is sealed. If a wound punctures the chest, air may leak into the chest cavity. This leaking air makes breathing impossible.



Inhalation



Exhalation

Breathing During inhalation, the rib cage rises and the diaphragm contracts. This increases the size of the chest cavity. During exhalation, the rib cage lowers and the diaphragm relaxes. This decreases the size of the chest cavity.

BUILD Vocabulary

diaphragm
a large flat muscle at the bottom of the chest cavity that helps with breathing

MULTIPLE MEANINGS

In a camera, a diaphragm controls the amount of light that enters the camera. In the chest cavity, the diaphragm is a muscle that controls the amount of air that enters the body.

Breathing and Homeostasis You can control your breathing almost anytime you want. Yet, breathing is not purely voluntary, which is why people who drown have water in their lungs. When they lose consciousness, they "breathe" water into their lungs.

There is a breathing center in the brain that helps to control breathing and maintain homeostasis. The breathing center receives signals about the levels of carbon dioxide in the body. When carbon dioxide levels in the blood go up, the brain signals the diaphragm and chest muscles to contract. If carbon dioxide levels reach a certain point, you cannot keep yourself from breathing.

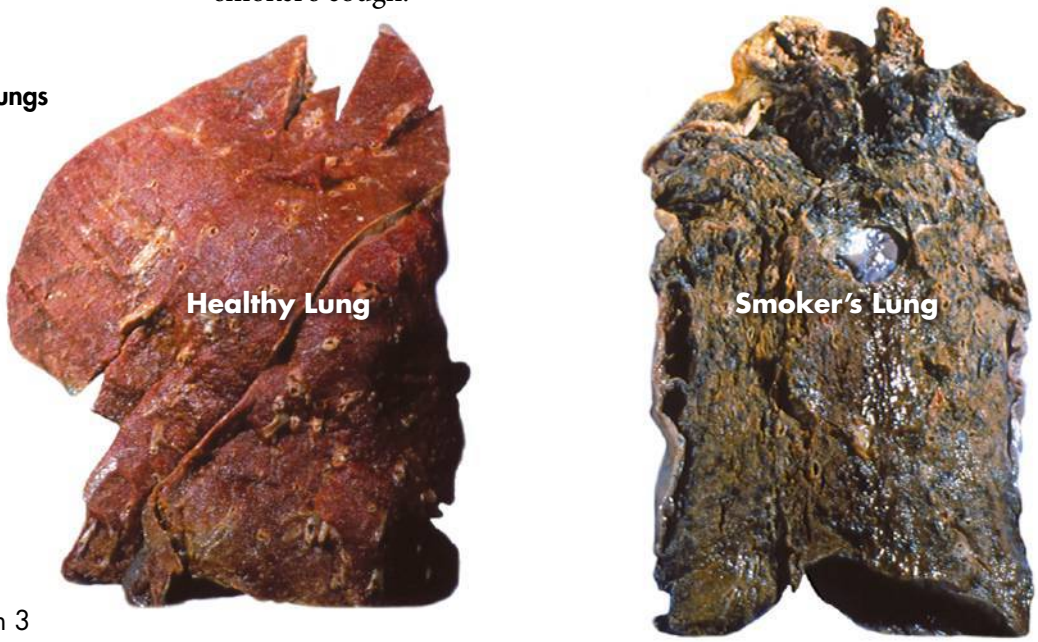
Key Question What mechanisms are involved in breathing?
Movements of the diaphragm and rib cage change the size of the chest cavity. Air rushes in during inhalation and is pushed out during exhalation.

Smoking and the Respiratory System

The respiratory system filters out many particles that could damage the lungs. But some particles and chemicals can still reach the lungs. Chemicals in tobacco smoke damage structures throughout the respiratory system.

Effects on the Respiratory System Three of the most dangerous things in tobacco smoke are nicotine, carbon monoxide, and tar. Nicotine is addictive. It increases heart rate and blood pressure. Carbon monoxide blocks hemoglobin from binding with oxygen, which means that the blood cannot carry as much oxygen. Tar holds at least 60 compounds that cause cancer.

Tobacco smoke also damages cilia in the trachea. This damage allows more particles to enter the lungs. It also traps smoke-filled mucus along the passageways. Trapped particles and mucus lead to smoker's cough.



Effects of Smoking on the Lungs Chemicals in the smoke damage cilia in the lungs. The damage that smoking can cause is visible in the photograph on the right.

Diseases Caused by Smoking Smoking can cause permanent damage to the respiratory system. The damage from smoking can lead to chronic bronchitis, emphysema, and lung cancer. Smoking lowers life expectancy.

In chronic bronchitis, the bronchi become inflamed and clogged with mucus. Affected people often find simple activities, like climbing stairs, very hard. Emphysema (em fuh SEE muh) makes it hard to breathe because the lung tissue is damaged. People with this condition cannot get enough oxygen into the body. They cannot rid the body of extra carbon dioxide.

By the time lung cancer is found, it usually has spread to other parts of the body. Few people with lung cancer live more than five years after their diagnosis. About 87 percent of lung cancer deaths are due to smoking.

Other Effects of Smoking Smoking also hurts the circulatory system. It raises blood pressure, making the heart work harder to get oxygen to the body. Nonsmokers are also affected by secondhand smoke. Studies now show that children of smokers are twice as likely as children of nonsmokers to have asthma or other respiratory problems. Babies of women who smoked during pregnancy face many complications. Some of these can lead to lifelong problems.

Key Question How does smoking affect the respiratory system?
Chemicals in tobacco smoke damage structures throughout the respiratory system.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The cavity at the back of the mouth called the _____ serves as a passageway for both air and food.
2. When you inhale, the _____ contracts and the rib cage rises.

Critical Thinking

3. **Explain** Describe the process of gas exchange in the lungs. What is hemoglobin's role in gas exchange?
4. **Relate Cause and Effect** Carbon monoxide gas binds to hemoglobin more easily than oxygen does. Based on this information, why do you think carbon monoxide alarms in homes have saved many lives?
5. **Apply Concepts** People with emphysema cannot exhale as much carbon dioxide as people with healthy lungs can. Why do you think this leaves them short of breath?
6. **Write to Learn** Answer the third clue of the mystery.

MYSTERY CLUE

John's doctor told him that if he hadn't stopped smoking, he probably would not have lived past the age of 50. Explain the doctor's reasoning. (Hint: See p. 801.)

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Pre-Lab: Tidal Volume and Lung Capacity

Problem What factors can affect lung capacity?

Materials round balloons, metric ruler, meterstick

Lab Manual Chapter 33 Lab

Skills Focus Measure, Form a Hypothesis, Design an Experiment, Interpret Graphs

Connect to the Big idea Your lungs and circulatory system work together to provide the oxygen your cells need for cellular respiration. In your lungs, oxygen diffuses from the air you inhale into your blood. Carbon dioxide, a waste product of cellular respiration, diffuses from your blood into the inhaled air. Your lungs must have a large enough volume, or capacity, to supply all your cells with the oxygen they need.

Most of the time your lungs do not fill to capacity. But they can take in more air when you want to dive underwater or when you want to sing a long phrase without having to take another breath. In this lab, you will measure the volume of air you exhale when you are breathing normally and the volume of air you exhale after you take a deep breath.

Background Questions

a. **Sequence** List in order, from exterior to interior, the parts of the respiratory system that air passes through as you inhale.

b. **Review** Why does oxygen diffuse from inhaled air in the alveoli into the capillaries?

c. **Compare and Contrast** What is the difference between respiration and cellular respiration?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Control Variables** What is the one difference between the procedures in Part A and Part B?

2. **Design an Experiment** Why must you use round balloons for this experiment?

3. **Predict** Which do you think will be greater—your estimated vital capacity or your measured vital capacity? Why?

BIOLOGY.com Search Chapter 33 GO

Visit Chapter 33 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Bundle up as the Untamed Science crew journeys to cold climates to show us how some animals handle extreme environments.

Art in Motion View a short animation that shows the beating of the heart as well as the transmission of impulses from the SA and AV nodes.

Art Review Review your understanding of the different parts of the respiratory system.

InterActive Art Watch an animation that shows the process of breathing and the production of sound.

Visual Analogy Compare the structure and function of the circulatory system to a system of highways and secondary roads.

33 CHAPTER Summary

33.1 The Circulatory System

- The circulatory system carries oxygen, nutrients, and other substances throughout the body. It also removes wastes from body tissues.
- Heart action spreads through the myocardium, as first the atria and then the ventricles contract, pumping blood through the body.
- Arteries, capillaries, and veins are three kinds of blood vessels.

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myocardium (p. 787)
atrium (p. 787)
ventricle (p. 787)
artery (p. 789)
capillary (p. 789)
vein (p. 789)

33.2 Blood and the Lymphatic System

- Plasma carries heat and a number of important substances through the body.
- Red blood cells carry oxygen. Hemoglobin in red blood cells binds to oxygen in the lungs and releases it in the capillaries.
- White blood cells fight infection.
- Platelets and plasma proteins form blood clots.
- The lymphatic system collects lymph, filters it for pathogens, and returns it to the circulatory system. It also picks up fat and fat-soluble nutrients from the intestines.
- Three common circulatory diseases are heart disease, stroke, and high blood pressure.
- High cholesterol levels can lead to atherosclerosis and a higher chance of heart attack and stroke.

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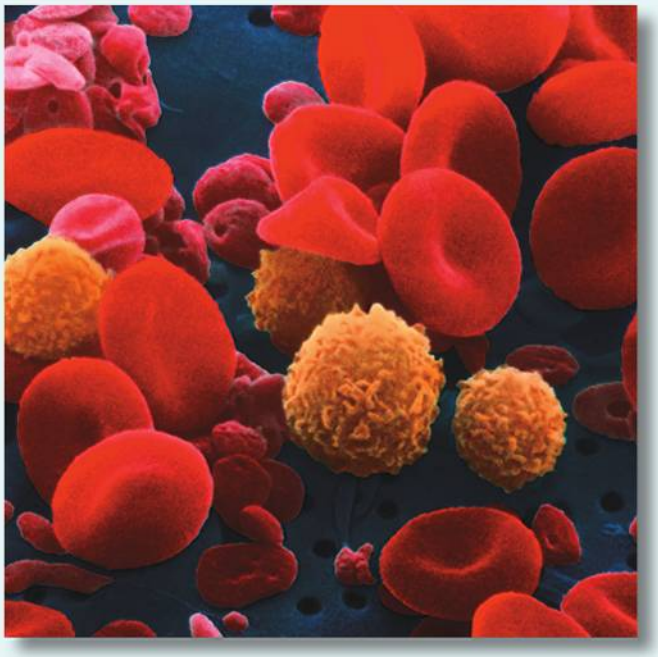
plasma (p. 790)
red blood cell (p. 790)
white blood cell (p. 791)
platelet (p. 791)
lymph (p. 792)
atherosclerosis (p. 793)



33.3 The Respiratory System

- The human respiratory system picks up oxygen from the air when you inhale. It releases carbon dioxide back into the air when you exhale.
- Oxygen and carbon dioxide diffuse across the thin walls of alveoli and capillaries. Hemoglobin carries oxygen and some carbon dioxide. Carbon dioxide also dissolves in plasma or reacts with water to form carbonic acid.
- Movements of the diaphragm and rib cage change the size of the chest cavity. Air rushes in during inhalation and is pushed out during exhalation.
- Chemicals in tobacco smoke damage structures throughout the respiratory and circulatory systems.

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pharynx (p. 796)
larynx (p. 796)
trachea (p. 796)
bronchus (p. 797)
alveolus (p. 797)
diaphragm (p. 799)

33 CHECK Understanding

Assess the Big idea Structure and Function

Write an answer to the question below.

Q: How do the structures of the circulatory and respiratory systems allow for their close functional relationship?

Constructed Response

Write an answer to each of the questions below. The answer to each question should be one or two paragraphs long. To help you begin, read the **Hints** below each of the questions.

1. **Explain how the structure of blood vessel walls contributes to the vessels' functions.**

   Hint As blood flows through the circulatory system, it moves through three kinds of blood vessels—arteries, capillaries, and veins.

   Hint Arteries carry blood away from the heart. Veins carry blood back to the heart.

   Hint Capillaries are the smallest blood vessels.

2. **Compare and contrast the functions of the lymphatic system and the rest of the circulatory system.**

   Hint The circulatory system includes the heart, blood vessels, and blood.

   Hint The lymphatic system is part of the circulatory system. The lymphatic system is a network of vessels, nodes, and organs including the spleen and thymus.

3. **Compare and contrast cellular respiration and respiration at the level of an organism.**

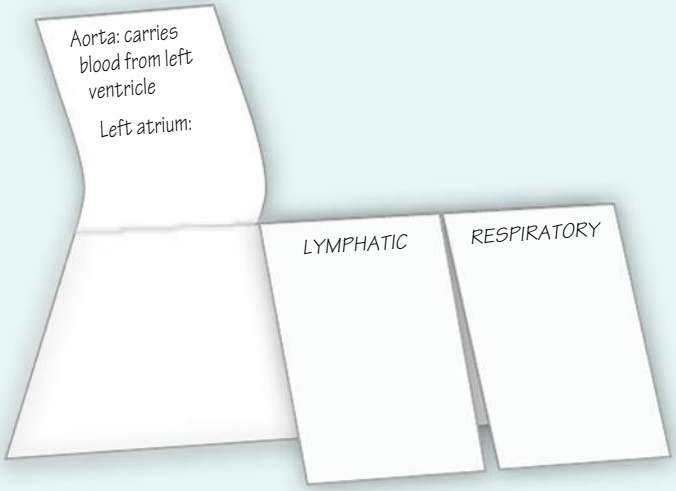
   Hint Cellular respiration is the process that releases energy from food, such as a sugar, when there is oxygen present. Review cellular respiration in Chapter 9.

   Hint For organisms, rather than single cells, *respiration* means gas exchange between a body and the environment.

Foundations for Learning Wrap-Up

Use the table tent you made while reading the chapter to help you organize your thoughts about the respiratory and circulatory systems.

Activity 1 Working with a partner, review the structures and functions of the respiratory, lymphatic, and circulatory systems. Add any structures and functions you may have missed. Then, quiz each other about the structures and functions of each system.



Activity 2 Work in a group. One person reads aloud any function in any system and anyone in the group can identify the structure. For every correct answer, add a tick mark to your table tent. Take turns. The person with the most tick marks at the end is the winner.

Extension: Working with a partner, read aloud the name of any structure in any system. Your partner has to spell the structure correctly. Take turns.

33.1 The Circulatory System

Understand Key Concepts

1. Which of the following is NOT a type of blood vessel?
   a. bronchus **c.** capillary
   b. artery **d.** vein
2. The circulatory system includes the
   a. lungs, heart, and brain.
   b. lungs, blood vessels, and heart.
   c. heart, blood, and blood vessels.
   d. heart, trachea, and alveoli.

Test-Taking Tip

Choose Among Similar Answers As you read each answer choice, notice what they have in common. In question 2, every answer choice includes *heart*. So, the heart must be part of the circulatory system. The heart pumps blood through the body, so the circulatory system includes "blood." Only answer **c** includes blood.

3. Which of the following describes the function of the circulatory system?
   a. It digests food.
   b. It carries oxygen and nutrients to the body's tissues and removes wastes from the tissues.
   c. It lets a person breathe.
   d. It responds to light and sound.
4. Compare the size and structure of arteries, capillaries, and veins.
5. Compare pulmonary circulation and systemic circulation.

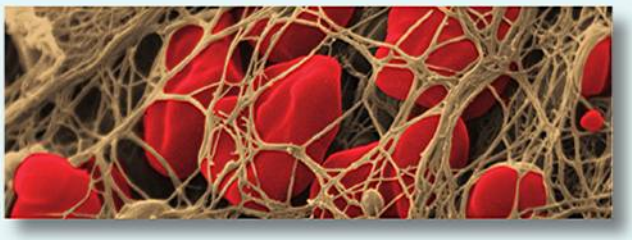
Think Critically

6. **Apply Concepts** Some large veins have one-way valves, which keep blood flowing in only one direction. Why don't arteries need similar valves?

33.2 Blood and the Lymphatic System

Understand Key Concepts

7. Cells that protect the body by engulfing foreign cells or by producing antibodies are
   a. red blood cells. **c.** platelets.
   b. plasma. **d.** white blood cells.
8. The process shown below is made possible by plasma proteins and cell fragments called
   a. hemoglobins. **c.** platelets.
   b. thrombins. **d.** lymphocytes.



9. What are the primary functions of the lymphatic system?
10. List three common circulatory diseases.

Think Critically

11. **Apply Concepts** Why would a person with a low red blood cell count feel tired?
12. **Compare and Contrast** Explain how high blood cholesterol develops in a person with a genetic disorder versus someone who eats a high-fat diet.

33.3 The Respiratory System

Understand Key Concepts

13. The tiny hollow air sacs in the lungs where gas exchange takes place are called
   a. alveoli. **c.** capillaries.
   b. lymph nodes. **d.** bronchioles.
14. Which structure of the respiratory system contains the vocal cords?
   a. pharynx **c.** trachea
   b. diaphragm **d.** larynx

33 CHECK Understanding

15. The large flat muscle that moves up and down and changes the volume of the chest cavity is the
    a. pharynx. **c.** trachea.
    b. diaphragm. **d.** larynx.

16. What is the function of the respiratory system?

Think Critically

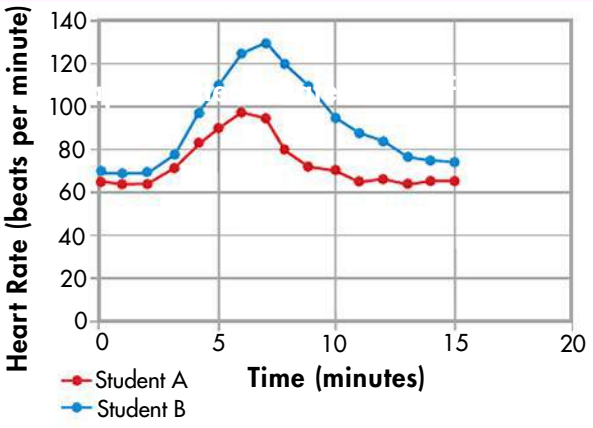
17. **Infer** Tobacco smoke can kill white blood cells in the respiratory tract. The white blood cells help keep the respiratory system clean by consuming debris. How do you think this contributes to the development of smoker's cough?

Connecting Concepts

Use Science Graphics

The following graph is based on pulse rates taken each minute for two students doing the same exercises. The exercises begin at minute 1 and end at minute 8. Use the graph to answer questions 18–20.

Pulse Rate and Exercise



18. **Interpret Graphs** At about which minute did each student reach his or her highest heart rate?
19. **Draw Conclusions** Which of the two students is most likely in better physical condition? What evidence from the graph supports your answer?
20. **Predict** What other changes in the circulatory and respiratory systems would you expect to take place in the time interval shown?

solve the CHAPTER MYSTERY

IN THE BLOOD

Both John and Lila have a genetic disease called familial hypercholesterolemia. This disease is caused by a gene defect on chromosome 19. John is heterozygous for the disorder. He inherited one functional copy of the gene and one defective copy. Although his liver cells make a mixture of normal and defective LDL receptors, his blood cholesterol levels were so high that he had serious atherosclerosis by age 35. Most people with this disease have had a heart attack by age 60.

Lila is homozygous for the defective allele—a very rare condition. Her liver cells do not produce any functional LDL receptors. Her atherosclerosis became apparent when she was only 4 years old. Fatty deposits can be seen in the corneas of her eyes and beneath the skin near her elbows and knees.

Research on this genetic defect helped uncover the role of liver cell LDL receptors in regulating blood cholesterol. Researchers then applied that information to cases of high cholesterol among the general public. The result was the development of several new classes of drugs that are helping many people live longer.

1. **Apply Concepts** Is familial hypercholesterolemia a dominant or recessive disorder? Explain your answer.
2. **Infer** Most heterozygous patients can keep their LDL levels under control with medication that prevents their liver from making cholesterol. But these medications generally do not lower the LDL levels of homozygous patients. Why do you think that is so?

UntamedScience **Never Stop Exploring Your World.** Finding the solution to the In the Blood mystery is just the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where the mysteries of the circulatory system lead.

Standardized Test Prep

Multiple Choice

1. In the human heart, oxygen-rich blood would be found in the
- **A** right atrium and the right ventricle.
- **B** right atrium and the left atrium.
- **C** left atrium and the left ventricle.
- **D** right ventricle and the left ventricle.

2. Which statement BEST describes an interaction between the circulatory system and the respiratory system that helps maintain homeostasis?
- **A** Blood plasma transports salts, nutrients, and proteins through the body to keep it healthy.
- **B** The diaphragm and rib cage work together to move air into and out of the lungs.
- **C** Lymph nodes filter out bacteria that could cause disease.
- **D** Blood cells pick up and carry oxygen from the lungs to the body's cells.

3. A heartbeat begins with an impulse from the
- **A** nervous system.
- **B** sinoatrial (SA) node.
- **C** atrioventricular node.
- **D** aorta.

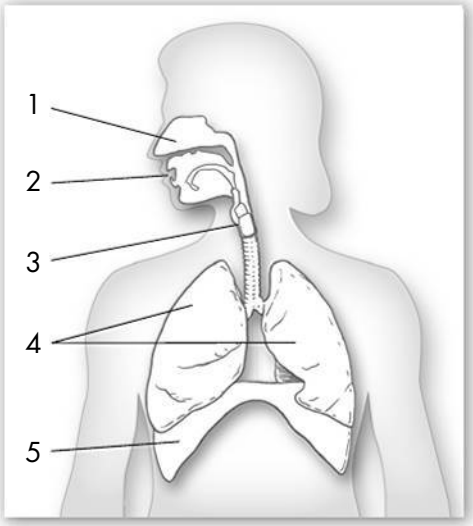
4. All of the following are components of human blood EXCEPT
- **A** plasma.
- **B** mucus.
- **C** phagocytes.
- **D** platelets.

5. Nicotine in tobacco
- **A** is not addictive.
- **B** lowers blood pressure.
- **C** blocks the transport of oxygen.
- **D** increases heart rate.

6. Antibodies are produced by
- **A** red blood cells.
- **B** platelets.
- **C** B lymphocytes.
- **D** hormones.

Questions 7–10

Use the diagram below to answer the questions that follow.



7. Which structure's primary function is to warm and moisten inhaled air?
- **A** 1
- **B** 3
- **C** 4
- **D** 5

8. Which structure contains the vocal cords?
- **A** 1
- **B** 2
- **C** 3
- **D** 4

9. Damage to which structure can lead to emphysema?
- **A** 2
- **B** 3
- **C** 4
- **D** 5

10. Which structure contains alveoli?
- **A** 2
- **B** 3
- **C** 4
- **D** 5

Open-Ended Response

11. Explain why the risk factors for heart disease and strokes are similar.

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10	11
See Lesson	33.1	33.3	33.1	33.2	33.3	33.2	33.3	33.3	33.3	33.3	33.2

34 Endocrine and Reproductive Systems

Big idea

Homeostasis

Q: How does the body use chemical signals to maintain homeostasis?

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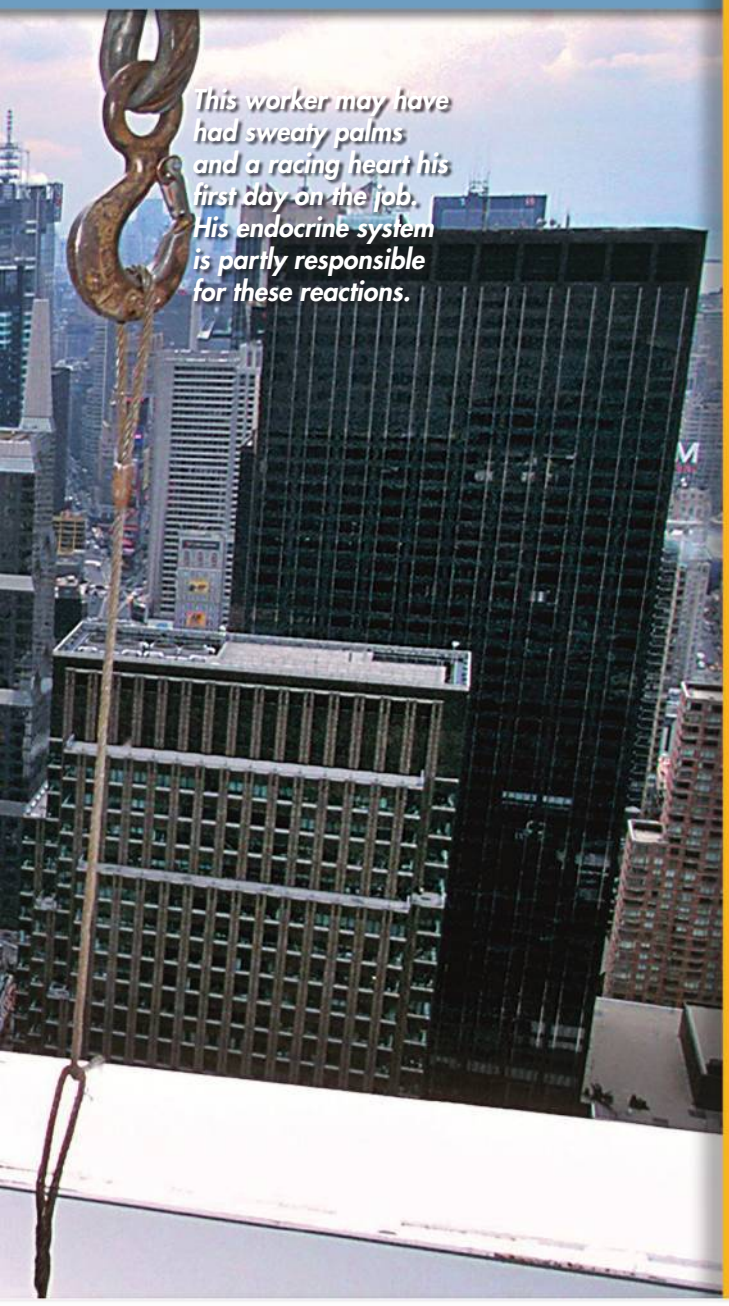
INSIDE:



This worker may have had sweaty palms and a racing heart his first day on the job. His endocrine system is partly responsible for these reactions.

- Untamed Science Video
- Flash Cards

CHAPTER MYSTERY

OUT OF STRIDE

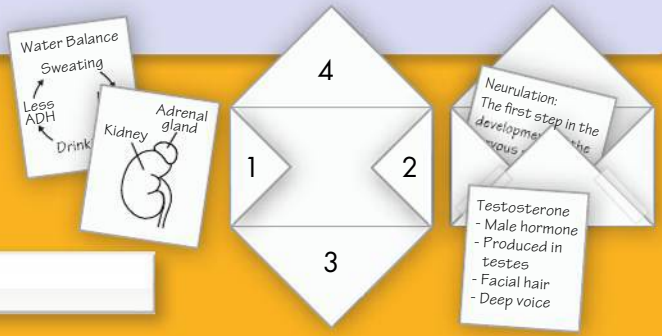
Lisa trained hard during spring track and over the summer. But as the new school year approached, she wasn't satisfied. She felt she needed to be faster for her team to win the state cross-country championship. A teammate suggested she lose a few pounds. Lisa had already lost weight over the summer, but she decided to lose some more.

Lisa continued her exhausting workouts. She also stopped snacking before practice and avoided high-calorie foods. She did lose weight. But she was always tired. She also noticed that she had not had a menstrual period in four months. The week before the championship meet, she collapsed in pain at practice. She had suffered a stress fracture to her lower leg. Her season was over.

Read for Mystery Clues Lisa's doctor told her that all of her symptoms were related to a single cause. As you read this chapter, look for clues to explain why too much exercise and dieting had these effects on Lisa. Then, solve the mystery.

FOUNDATIONS for Learning

Think of the Big Idea as a collection of facts that are connected to each other. Before you read the chapter, make an envelope from the pattern below. Fold the flaps in order along the lines. Glue or tape flap 3 to flaps 1 and 2. As you read the chapter, write important facts about each lesson or draw a picture to help you remember important facts on a slip of paper. Put your slips of paper in your envelope. At the end of the chapter are two activities that use the facts to help answer the question: How does the body use chemical signals to maintain homeostasis?



34.1 The Endocrine System

Key Questions

- ***What are the components of the endocrine system?***
- ***How do hormones affect cells?***

BUILD Understanding

Compare/Contrast Table
As you read, make a table that compares and contrasts the two different types of hormones.

In Your Workbook
Refer to your workbook to learn how to make a compare/contrast table. Complete the compare/contrast table for Lesson 34.1.

Hormones and Glands

Your nervous system works like a telephone, with neurons acting as wires. Nerve impulses transmit messages directly from one cell to another cell. Your endocrine system works more like a radio station. It "broadcasts" chemical messages to all the cells in the body. The chemicals that carry these messages are called **hormones.** Hormones are released in one part of the body and travel through the blood to other parts of the body. Hormones can act on almost every cell in the body.

Hormones Hormones act by binding to specific chemical receptors on cell membranes or inside cells. Cells that have receptors for a particular hormone are called *target cells*. A cell must have receptors for a particular hormone for the hormone to affect it.

The body's responses to hormones are slower and last longer than its responses to nerve impulses. It may take several minutes, hours, or days for a hormone to have its full effect on its target cells. A nerve impulse may take only a fraction of a second to act on its target cells.

Glands A gland is an organ that produces and releases a secretion. **Exocrine glands** release their secretions through tube-like structures called ducts. Exocrine secretions are released either out of the body or directly into the digestive system. Exocrine glands include those that release sweat, tears, and digestive juices. **Endocrine glands** usually release their secretions (hormones) directly into the blood. Blood transports the secretions throughout the body. Bones, fat tissue, the heart, and the small intestine also produce and release hormones.

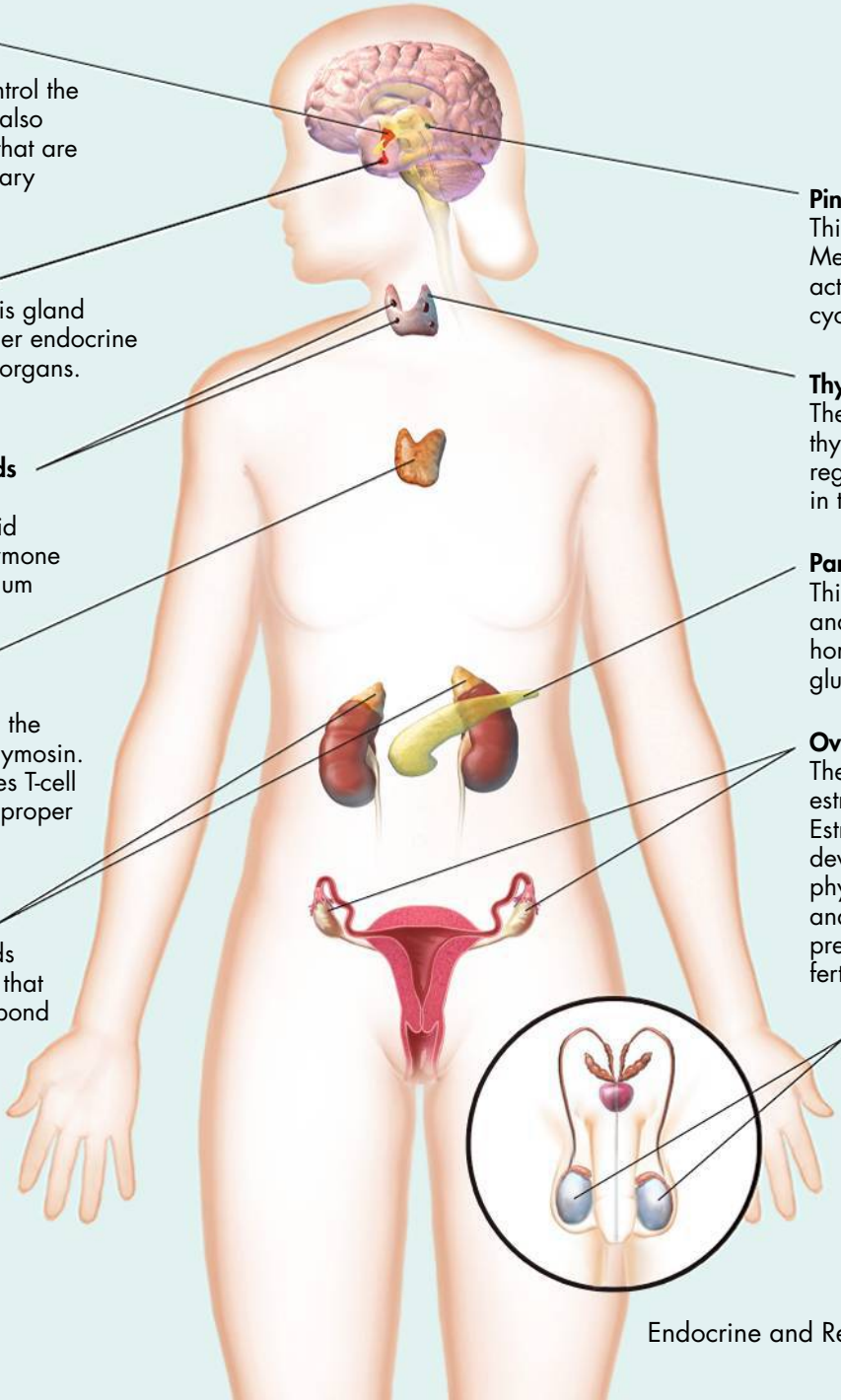
The Endocrine System
The endocrine system acts like a radio station. It broadcasts messages to the body's cells using hormones.

Prostaglandins Endocrine glands were once believed to be the only organs that produced hormones. However, nearly all cells produce small amounts of hormonelike substances called **prostaglandins** (prahs tuh GLAN dinz). Prostaglandins are modified fatty acids that are produced by a wide range of cells. They are sometimes called "local hormones" because they generally affect only nearby cells and tissues.

Key Question What are the components of the endocrine system?

The endocrine system is made up of glands that release hormones into the blood. Hormones deliver messages throughout the body.

Major Endocrine Glands
Endocrine glands produce hormones that affect many parts of the body.



Hypothalamus
This gland makes hormones that control the pituitary gland. It also makes hormones that are stored in the pituitary gland.

Pituitary Gland
Hormones from this gland regulate many other endocrine glands and some organs.

Parathyroid Glands
These four glands release parathyroid hormone. This hormone regulates the calcium level in the blood.

Thymus
During childhood, the thymus releases thymosin. Thymosin stimulates T-cell development and proper immune response.

Adrenal Glands
The adrenal glands release hormones that help the body respond to stress.

Pineal Gland
This gland releases melatonin. Melatonin regulates rhythmic activities such as sleep-wake cycles.

Thyroid
The thyroid produces thyroxine. Thyroxine regulates metabolism in the body.

Pancreas
This gland produces insulin and glucagon. These hormones regulate blood glucose levels.

Ovaries
These glands produce estrogens and progesterone. Estrogens stimulate development of female physical characteristics and of eggs. Progesterone prepares the uterus for a fertilized egg.

Testes
These glands produce testosterone. This hormone stimulates development of sperm and male physical characteristics.

BUILD Vocabulary

hormone
a chemical produced in one part of an organism that affects another part of the same organism

exocrine gland
a gland that releases its secretions, through tube-like structures called ducts, directly into an organ or out of the body

endocrine gland
a gland that releases its secretions (hormones) directly into the blood, which transports the secretions to other areas of the body

prostaglandins
modified fatty acids that are produced by a wide range of cells; generally affecting only nearby cells and tissues

WORD ORIGINS

Prostaglandins get their name from a gland in the male reproductive system, the prostate, in which they were first discovered.

Hormone Action

Hormones fall into two general groups—steroid hormones and nonsteroid hormones. Steroid hormones are produced from a lipid called cholesterol. Nonsteroid hormones include proteins, small peptides, and modified amino acids. Each type of hormone acts on a target cell in a different way.

Steroid Hormones Because steroid hormones are lipids, they can easily cross cell membranes. Inside the cell, a steroid hormone binds to a receptor found only in the hormone's target cells. The hormone and receptor form a hormone-receptor complex that enters the cell nucleus.

In the nucleus, the hormone-receptor complex regulates gene expression. Steroid hormones can turn whole sets of genes on or off. This can cause dramatic changes in the activity of a cell or organism.

Nonsteroid Hormones Nonsteroid hormones cannot pass through the cell membranes of their target cells. Instead, they bind to receptors on the cell membrane. This activates enzymes on the inner surface of the membranes. The activated enzymes release secondary messengers such as calcium ions, nucleotides, and even fatty acids.

Secondary messengers relay the hormone's message inside the cell. These secondary messengers can activate or inhibit a wide range of cell activities.

Key Question How do hormones affect cells?
Steroid hormones enter the nucleus and change the way genes are expressed in a target cell. Nonsteroid hormones bind to receptors on cell membranes. They cause the release of secondary messengers that affect cell activities.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. An _____ gland releases its secretions through ducts.
2. A _____ is a chemical messenger that is released from a cell and acts on other cells nearby.

Critical Thinking

3. **Compare and Contrast** How are hormones and prostaglandins similar? Different?
4. **Explain** Explain the difference between endocrine glands and exocrine glands.
5. **Write to Learn** Answer the first mystery clue. Write a paragraph that explains why you think maintaining adequate fat reserves is important.

MYSTERY CLUE

Fat tissue may send signals to the hypothalamus when fat reserves are low. Lisa's body fat percentage dropped from 17 percent to 9 percent. Could this have affected such signals?

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34.2 Glands of the Endocrine System

The Human Endocrine Glands

The endocrine system is different from other organ systems. Most of the glands in the endocrine system are scattered throughout the body. However, they still work as a single system, regulating a wide variety of activities.

Pituitary Gland The pituitary gland is a bean-sized gland that hangs under the base of the brain. A slender stalk of tissue attaches it to the brain. It is divided into two parts: the anterior pituitary and the posterior pituitary. The pituitary gland secretes some hormones that directly regulate many body functions. It secretes other hormones that control the actions of other endocrine glands.

Hypothalamus The hypothalamus links the central nervous system to the endocrine system. It directly and indirectly controls the secretions of the pituitary gland.

Neurons connect the posterior pituitary to the hypothalamus. The cell bodies in the hypothalamus produce two hormones, antidiuretic hormone (ADH) and oxytocin. These hormones are stored in the axons, which extend into the pituitary. When the cell bodies are stimulated, the axons release the hormones into the blood.

The hypothalamus indirectly controls the anterior pituitary with **releasing hormones.** These hormones are secreted into blood vessels that lead to the pituitary. Each releasing hormone controls a different pituitary hormone.

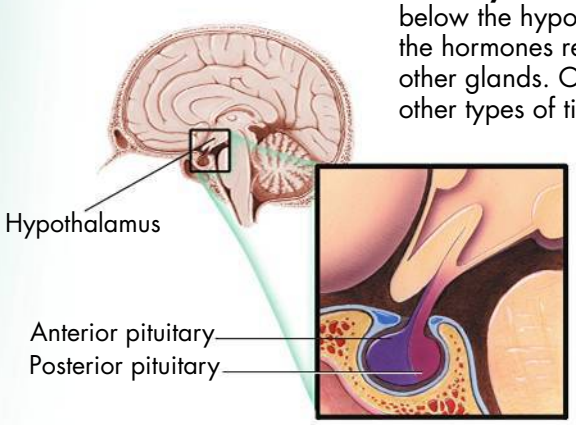
Key Questions

- ***What are the functions of the major endocrine glands?***
- ***How are endocrine glands controlled?***

BUILD Understanding

Concept Map As you read, develop a concept map that shows the relationship between the human endocrine glands.

In Your Workbook Go to your workbook for help in completing your concept map for Lesson 34.2.



Pituitary Gland The pituitary gland is located below the hypothalamus in the brain. Some of the hormones released by the pituitary control other glands. Other hormones released affect other types of tissues.

BUILD Vocabulary

releasing hormone
a hormone produced by the hypothalamus that makes the anterior pituitary secrete hormones

corticosteroid
a steroid hormone produced by the adrenal cortex

epinephrine
a hormone released by the adrenal glands that increases heart rate and blood pressure and prepares the body for intense physical activity; also called adrenaline

norepinephrine
a hormone released by the adrenal glands that increases heart rate and blood pressure and prepares the body for intense physical activity

PREFIXES

The prefix *nor-* means "parent of." Scientists use this prefix to indicate when one compound is made from another compound. This prefix tells us that the body makes epinephrine from norepinephrine.

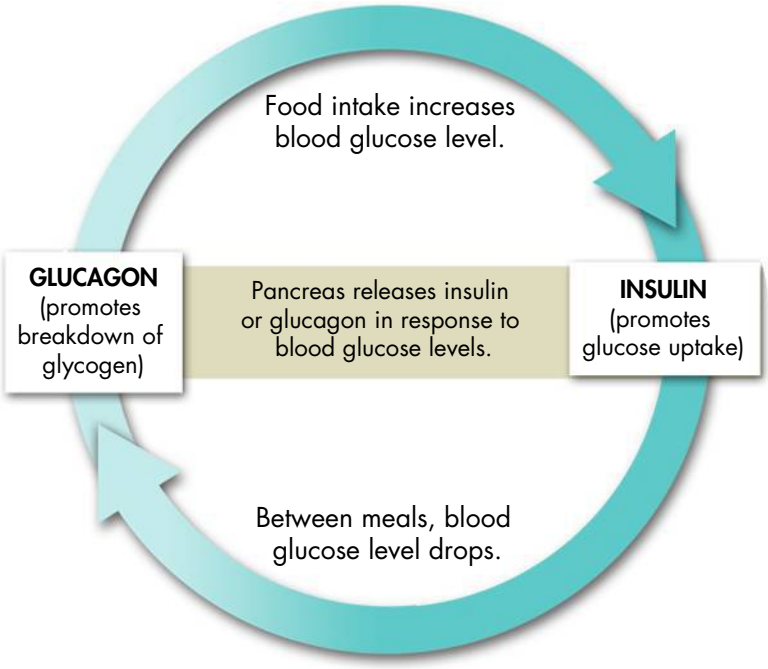
Adrenal Glands The adrenal glands, which sit on top of the kidneys, have two layers. The outer layer is the adrenal cortex. It produces a group of steroid hormones called **corticosteroids** (kawr tih koh STEER oydz). Aldosterone (al DAHS tuh rohn) regulates blood volume and pressure. The adrenal cortex releases aldosterone when blood volume decreases. Cortisol helps control the metabolism of carbohydrates, fats, and proteins. The adrenal gland releases cortisol during physical stress, such as intense exercise.

The inner part is the adrenal medulla. It produces **epinephrine** and **norepinephrine.** When you are under stress, the sympathetic nervous system sends impulses to the adrenal medulla. The adrenal medulla releases large amounts of these hormones, causing heart rate and blood pressure to rise. Epinephrine and norepinephrine also widen air passageways in the lungs and cause the release of extra glucose.

Pancreas The pancreas is an exocrine gland that releases digestive enzymes to help break down food. The pancreas is also an endocrine gland. It has clusters of cells that release hormones into the blood. These clusters, called the "islets of Langerhans," contain both beta cells and alpha cells. Beta cells secrete the hormone insulin. Alpha cells secrete the hormone glucagon.

▶ ***Blood Glucose Regulation*** Insulin and glucagon work together to keep blood glucose levels stable. Blood glucose levels rise after you eat, which causes the pancreas to release insulin. Insulin causes cells to take glucose out of the blood. Liver cells, skeletal muscle cells, and fat tissue store the glucose. Storing glucose in these cells keeps blood glucose from rising too rapidly. Liver and muscle cells store the glucose as glycogen, while the glucose in fat is converted to lipids.

Blood glucose levels drop within one or two hours after a person has eaten. As a result, the pancreas releases glucagon. Glucagon stimulates the liver and skeletal muscle cells to break down glycogen and release glucose into the blood. Glucagon also causes fat cells to break down fats and convert them to glucose. These actions help raise the blood glucose to normal levels.



Blood Glucose Control Insulin and glucagon are opposing hormones. They make sure that blood glucose levels stay within a normal range.

▶ ***Diabetes Mellitus*** Diabetes mellitus occurs when the body fails to produce or properly respond to insulin. Diabetes causes very high blood glucose levels. Very high blood glucose levels can damage almost every system and cell in the body.

There are two types of diabetes mellitus. Type I diabetes is an autoimmune disorder that destroys beta cells. Type I diabetes usually develops in people before age 15. People with Type I secrete little to no insulin. Type I diabetics must follow a strict diet and get a daily dose of insulin.

People with Type II diabetes produce insulin, but it does not bind to insulin receptors properly. Type II usually starts in people after age 40. However, it is increasing rapidly in young people due to childhood obesity. In its early stages, Type II diabetes can often be controlled through diet and exercise.

Thyroid and Parathyroid Glands The thyroid gland is located in the neck and wraps around the upper part of the trachea. It plays a major role in regulating the body's metabolism and blood calcium levels. It produces two hormones: **thyroxine** and *calcitonin*. Thyroxine stimulates cells to become more active, use more energy, and produce more heat. Iodine is needed to make thyroxine. An iodine deficiency causes the thyroid to enlarge. This is called a goiter.

Calcitonin reduces blood calcium levels by signaling the kidneys to reabsorb less calcium from filtrate. It also inhibits calcium absorption from the small intestine and promotes absorption into bones. Its opposing hormone is parathyroid hormone (PTH), which is produced by the parathyroid glands. These glands are located on the back side of the thyroid. PTH increases the release of calcium from the bone. It also increases calcium reabsorption in the kidneys, and calcium uptake in the digestive system.

The Reproductive Glands The gonads—ovaries and testes—are the body's reproductive glands. The gonads serve two important functions: the production of gametes and the secretion of sex hormones. You will learn more about the gonads and their hormones in the next lesson.

Key Question What are the functions of the major endocrine glands?

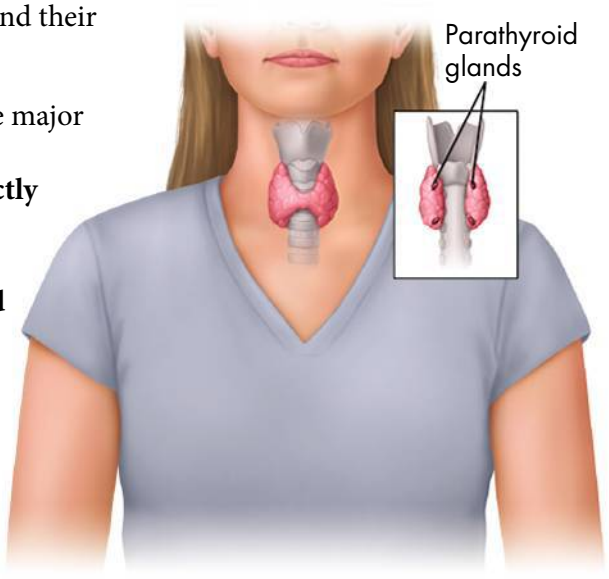
The pituitary gland secretes hormones that directly regulate many body functions or control other endocrine glands. The hypothalamus controls the secretions of the pituitary gland. The thyroid gland helps regulate the body's metabolic rate. The gonads produce gametes and secrete sex hormones.

BUILD Vocabulary

thyroxine
a hormone produced by the thyroid gland, which increases the metabolic rate of cells throughout the body

ACADEMIC WORDS

Hormones such as thyroxine have very long official names based on their chemical structure. Scientists sometimes give these hormones shorter names for everyday use. The official chemical name for thyroxine is *O*-(4-Hydroxy-3, 5-diiodophenyl)-3,5-diiodo-L-tyrosine.



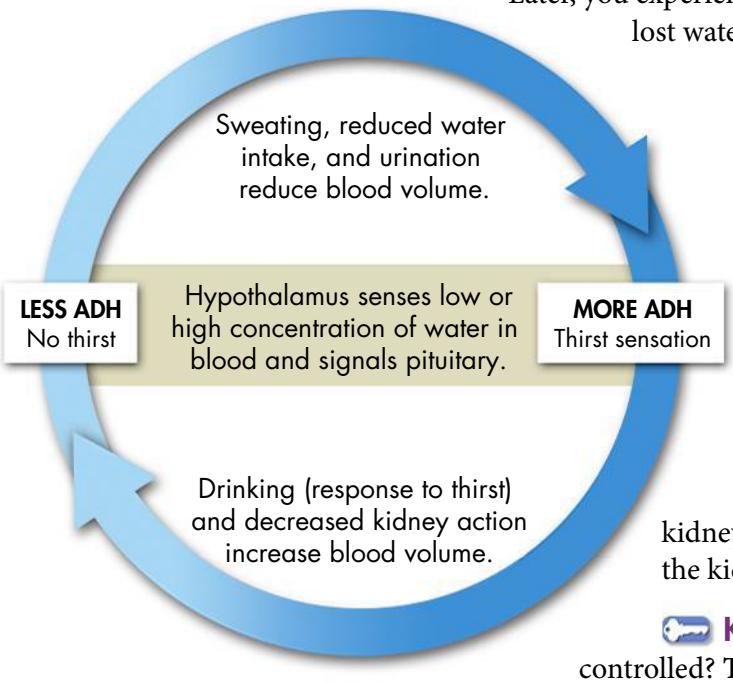
Thyroid Gland The thyroid makes thyroxine, which speeds up metabolism and helps control growth and development.

Control of the Endocrine System

Like most other body systems, the endocrine system is regulated by feedback mechanisms, which help the body maintain homeostasis.

When you exercise heavily, you lose water as sweat. If water loss continued, you would become dehydrated. As you lose water, the blood becomes more concentrated. The hypothalamus responds by signaling the posterior pituitary to release antidiuretic hormone (ADH). ADH signals the kidneys to remove less water from the blood. Later, you experience a sensation of thirst. Thirst is a signal to replace lost water.

Water Balance
The hypothalamus and posterior pituitary use a feedback mechanism to regulate water balance.



When you finally drink, you might take in a liter of water. Most of the water is absorbed by the blood. This rapid absorption could dilute the blood too quickly. Large amounts of water would diffuse out of the blood into body tissues. Body cells would swell with the excess water. The hypothalamus prevents this by signaling the pituitary to release less ADH when the blood becomes dilute. The kidneys respond by removing more water from the blood. So, the homeostatic system sets limits for water in the blood. When blood has too little water, ADH is released and the kidneys conserve water. An oversupply of water causes the kidneys to eliminate excess water in the urine.

Key Question How are endocrine glands controlled? **The endocrine system is regulated by feedback mechanisms that function to maintain homeostasis.**

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. _____ helps regulate metabolism by stimulating cells to become more active.
2. Aldosterone is a _____ that helps regulate blood pressure and volume.

Critical Thinking

3. **Compare and Contrast** Compare and contrast the two types of diabetes.
4. **Explain** Describe how the hypothalamus controls the secretions of the posterior pituitary gland.
5. **Write to Learn** Answer the second mystery clue.

MYSTERY CLUE

One effect of cortisol is the release of calcium from bones into the blood. This makes the calcium available for skeletal muscles. How could this effect of cortisol have contributed to Lisa's condition? (Hint: See p. 814.)

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34.3 The Reproductive System

Sexual Development

The reproductive system may be the only system in the body that isn't necessary for the survival of an individual. But without the reproductive system, the human species itself would not survive. In some ways, this makes the reproductive system the most important system in the body.

Male and female human embryos look almost identical until they are about seven weeks old. Then male gonads begin secreting testosterone, causing the male reproductive system to develop. In females, the gonads produce estrogens instead of testosterone. Estrogens cause the female reproductive system to develop.

Testosterone and estrogens are steroid hormones that are primarily produced in the gonads. They control sexual development of the human embryo. They also act on other cells and tissues. Testosterone causes facial hair to grow and increases muscular development in males. It also causes the male voice to deepen. Estrogens stimulate breast development and widening of the hips in females.

The testes and the ovaries cannot produce active reproductive cells until puberty. Puberty is a period of rapid growth and sexual maturation. The reproductive system becomes fully functional during puberty, which usually occurs between ages 9 and 15. Puberty begins in the brain, when the hypothalamus signals the release of two hormones from the pituitary. These hormones are follicle-stimulating hormone (FSH) and luteinizing hormone (LH).

Key Question What effects do estrogens and testosterone have on females and males?

Estrogens stimulate breast development and widening of the hips in females. Testosterone stimulates the growth of facial hair, muscular development, and deepening of the voice in males.

The Male Reproductive System

The release of LH stimulates cells in the testes to produce increased amounts of testosterone. Testosterone causes the male physical changes associated with puberty. Testosterone also works with FSH to stimulate sperm development. When puberty is finished, the

Key Questions

- ***What effects do estrogens and testosterone have on females and males?***
- ***What are the main functions of the male reproductive system?***
- ***What are the main functions of the female reproductive system?***
- ***What are some of the most commonly reported sexually transmitted diseases?***

BUILD Understanding

Preview Visuals Before you read, preview the diagram called Sperm. Think about how you would describe this diagram.

In Your Workbook Go to your workbook for help in previewing this visual.

BUILD Vocabulary

testis
the primary male reproductive organ; produces sperm

ovary
in animals, the primary female reproductive organ; produces eggs

MULTIPLE MEANINGS

In plants, an ovary is a structure that surrounds and protects seeds.

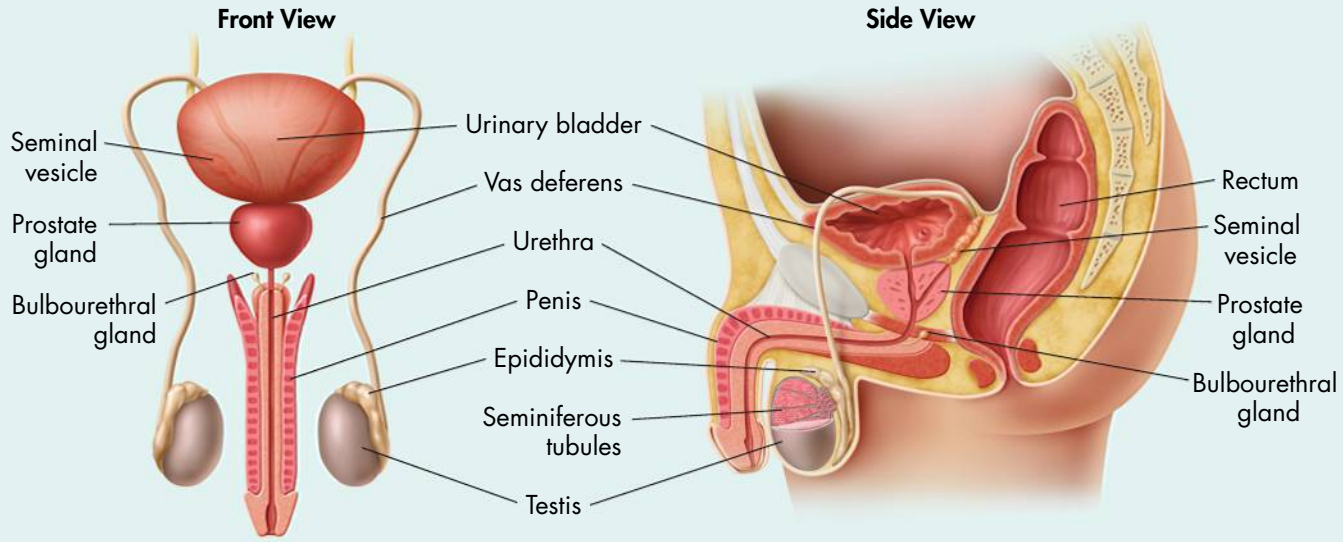
Testes The **testes** (singular: testis) are the primary male reproductive organs. Just before or just after birth, they descend from the abdomen into an external sac called a *scrotum*. This external sac is necessary because sperm must be cooler than body temperature (37° Celsius) to develop properly.

Sperm Development Inside each testis are clusters of hundreds of tiny tubules called seminiferous (sem uh NIF ur us) tubules. Sperm develop inside these tubules from specialized diploid cells. The diploid cells divide by meiosis to form the haploid nuclei found in mature sperm. A haploid cell contains only a single set of chromosomes.

Sperm move from the seminiferous tubules into the epididymis (ep uh DID ih mis) to mature and be stored. Some of the sperm move from the epididymis into another tube called the vas deferens. The vas deferens extends upward from the scrotum into the abdominal cavity. Here it merges with the urethra, which leads to the outside of the body through the penis.

Glands lining the reproductive tract produce seminal fluid. This fluid provides nutrients for the sperm. It also protects them from the acidity of the female reproductive tract. The combination of seminal fluid and sperm is called *semen*.

Sperm Release When the male is sexually aroused, the penis becomes erect. Contractions of smooth muscles in the reproductive tract then eject semen from the penis. This process is called ejaculation. Ejaculation is regulated by the autonomic nervous system, so it is not completely voluntary. If ejaculation takes place in or near the female reproductive tract, sperm may enter and successfully fertilize an egg.

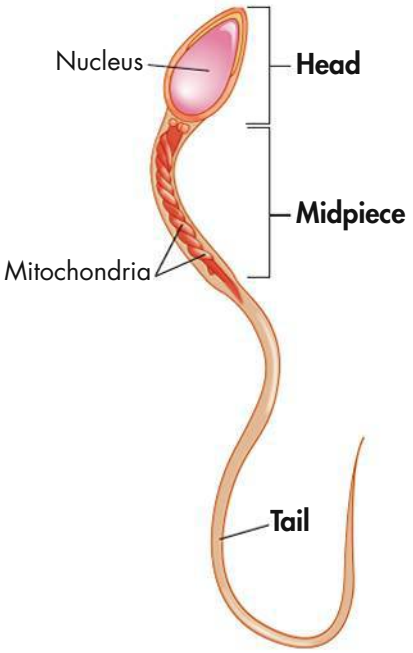


Male Reproductive System The main structures of the male reproductive system produce and deliver sperm.

Sperm Structure The head of a mature sperm cell contains a highly condensed nucleus. Its midpiece is packed with mitochondria that provide energy to the sperm. The tail (flagellum) moves the sperm forward. The tip of the head has a small cap that contains enzymes needed for fertilization.

Key Question What are the main functions of the male reproductive system?

When puberty is complete, the male reproductive system is fully functional, meaning that the male can produce and release active sperm.



Sperm Sperm have large numbers of mitochondria. The mitochondria provide power for a sperm cell's trip through the female reproductive tract. If a sperm reaches an egg, enzymes in its cap can break down the egg's outer layer.

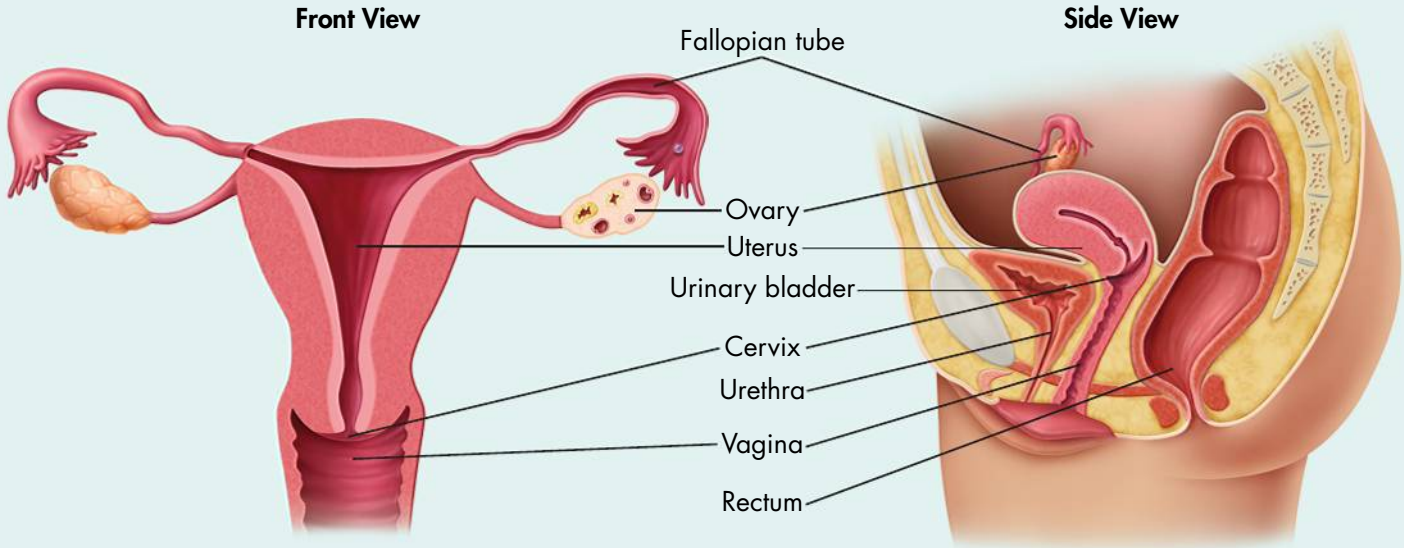
The Female Reproductive System

The **ovaries** are a female's primary reproductive organs. When puberty starts, FSH stimulates cells inside the ovaries to produce more estrogens. FSH also signals the ovaries to start producing egg cells.

Female Reproductive Structures Each ovary contains up to 400,000 primary follicles. A follicle is a cluster of cells surrounding a single egg, or ovum. The follicle helps the egg mature. Then the egg is released into the reproductive tract, where it can be fertilized by a sperm. Only about 400 mature eggs are released in a female's lifetime.

Other structures in the female reproductive system include the Fallopian tubes, uterus, cervix, and the vagina.

Female Reproductive System The main function of the female reproductive system is to produce eggs. The ovaries are the main organs of the female reproductive system.



BUILD Vocabulary

menstrual cycle
a regular sequence of events in which an egg develops and is released from the body

ovulation
the release of a mature egg from the ovary into one of the Fallopian tubes

The Menstrual Cycle One mature egg is usually produced and released from an ovary every 28 days or so. The process of egg production and release is part of the **menstrual cycle.** A menstrual cycle involves the ovaries, the lining of the uterus, and the endocrine system. Hormones from the hypothalamus, the pituitary, and the ovaries regulate this cycle.

During this cycle, an egg develops and is released from the ovary. If the egg is not fertilized, it leaves the body along with the lining of the uterus. If the egg is fertilized, then the menstrual cycle stops and embryonic development begins. The menstrual cycle includes the follicular phase, ovulation, the luteal phase, and menstruation.

▶ ***Follicular Phase*** Blood estrogen levels are low on day 1 of the menstrual cycle. The hypothalamus reacts to the low levels by producing a releasing hormone. The releasing hormone causes the anterior pituitary to release FSH and LH. These hormones stimulate the ovaries, causing a follicle to mature.

As the follicle develops, the cells surrounding the egg grow larger. The cells release more and more estrogens, causing FSH and LH levels to drop. The estrogens also cause the lining of the uterus to thicken so it can receive a fertilized egg. An egg matures in about 12 days.

▶ ***Ovulation*** The follicle releases more and more estrogens as it grows until the estrogens reach a certain level. This increased estrogen level triggers a burst of FSH and LH, causing the follicle to rupture. This rupture releases the egg into the Fallopian tube, a process called **ovulation.** Eggs are stalled in metaphase of meiosis II when they are released. Eggs remain in this phase of meiosis unless they are fertilized. Cilia push the egg down the Fallopian tube toward the uterus.

Ovulation (LM 160×)

▶ ***Luteal Phase*** Immediately after ovulation, the cells of the ruptured follicle change. The follicle turns yellow and is now called the *corpus luteum* (which means "yellow body"). The corpus luteum is still releasing estrogens, but it also begins releasing the steroid hormone, progesterone. Progesterone causes the uterine lining to develop. These hormones slow down the release of FSH and LH. This blocks the growth of more follicles during the cycle.

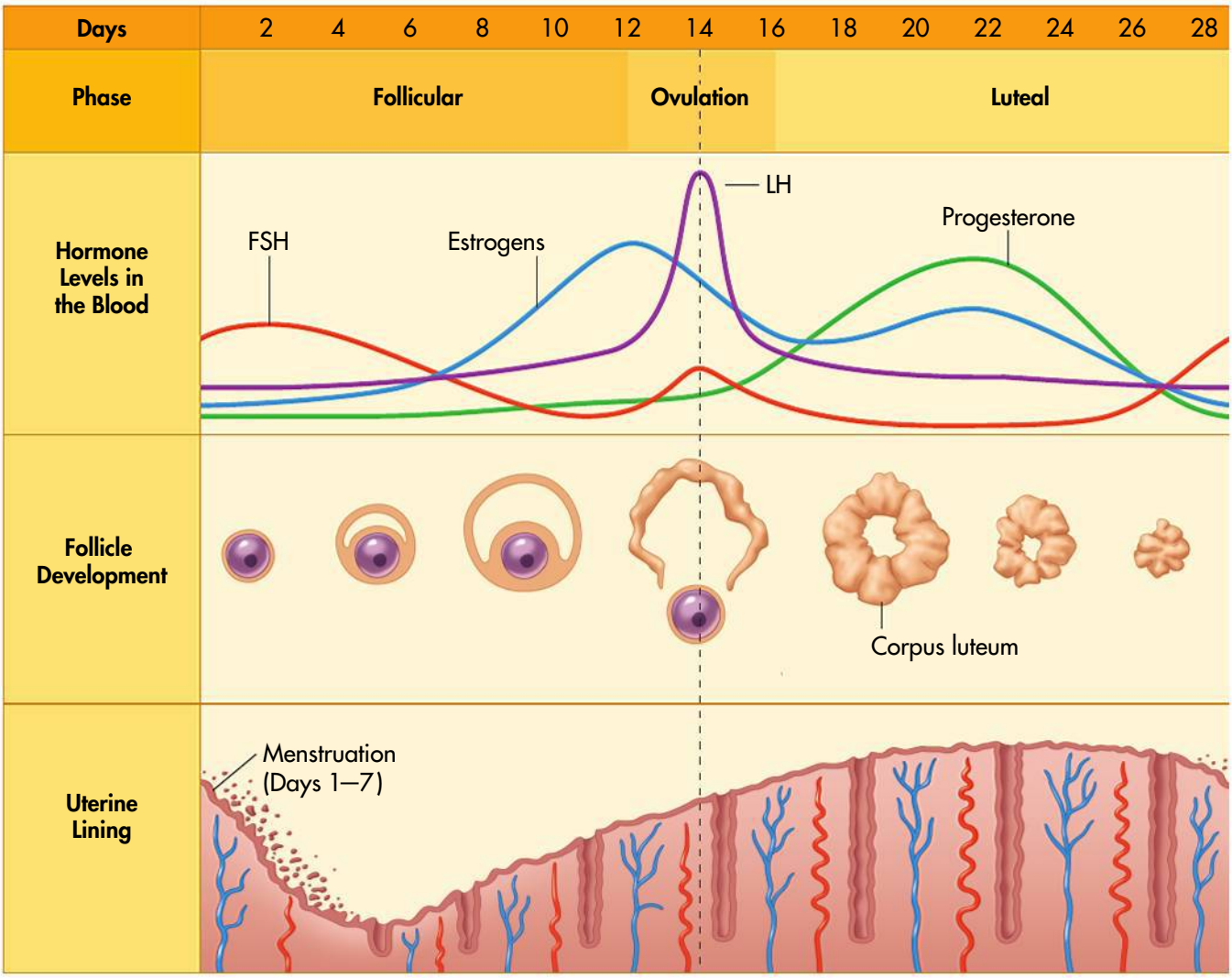
If the egg remains unfertilized, LH levels fall. This decrease in LH levels causes the corpus luteum to collapse. The collapse causes estrogen levels to decrease, and the follicular phase begins again.

▶ ***Menstruation*** When the new follicular phase starts, estrogen levels drop, causing the uterine lining to loosen. The tissue, blood, and the unfertilized egg are discharged through the vagina. This phase, called **menstruation,** lasts three to seven days. Estrogen production declines when a female is in her late forties to early fifties. This decrease in estrogen production stops ovulation and menstruation permanently. This phase is called menopause.

BUILD Connections

THE MENSTRUAL CYCLE

The menstrual cycle includes several phases. Notice the changes in hormone levels in the blood, follicle development, and the uterine lining.



Pregnancy The menstrual cycle stops if a woman becomes pregnant. An egg is most likely to be fertilized during the first two days after ovulation. A fertilized egg immediately completes meiosis and undergoes mitosis. It divides several times, forming a ball of cells that implants into the uterine lining. Soon, the uterus and embryo begin to release hormones that keep the corpus luteum functioning. This allows the uterine lining to nourish and protect the embryo for several weeks. It also blocks the menstrual cycle from starting again.

Key Question What are the main functions of the female reproductive system?

The main function of the female reproductive system is to produce eggs. It also prepares the female's body to nourish a developing embryo.

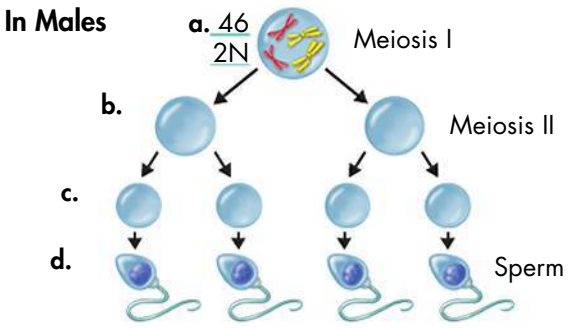
INQUIRY into Scientific Thinking

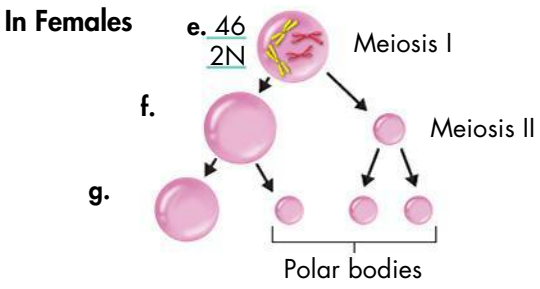
Tracing Human Gamete Formation

1. Cells in the testes and ovaries undergo meiosis as they form gametes—sperm and eggs. In meiosis, cells start out as diploid (2N) cells. Remember, before meiosis begins, chromosomes replicate, but the cell does not divide. If the cell starts with 46 chromosomes (23 pairs), how many total chromosomes are present in the cell after this replication?

2. At the end of meiosis I, the two daughter cells each have two copies of each chromosome. But the cells do not have homologous pairs. Are the daughter cells 2N or N?

3. Look at the diagrams to the right. For each letter, indicate how many chromosomes are in the cells at that stage. Is the cell diploid (2N) or haploid (N)? Answers *a.* and *e.* have been provided for you.





Analyze and Conclude

1. Interpret Visuals For every cell that undergoes meiosis in a male or female, how many more sperm than eggs are produced?

2. Infer What percentage of sperm cells will contain a Y chromosome?

In Your Workbook Get more help for this activity in your workbook.

Sexually Transmitted Diseases

Some diseases are spread by sexual contact. These diseases are called **sexually transmitted diseases (STDs).** STDs can be caused by bacteria or by viruses. Bacterial STDs include chlamydia, gonorrhea, and syphilis. Viral STDs include hepatitis B, genital herpes, and genital warts. Unlike bacterial STDs, viral STDs cannot be treated with antibiotics. Some viral STDs can be fatal. Tens of thousands of people die from AIDS each year. Human papillomavirus (HPV), which causes genital warts, is a major cause of cervical cancer.

STDs can be avoided. The safest way is to abstain from sexual contact before marriage. The next safest way is to use a condom, but even condoms do not provide 100 percent protection.

Key Question What are some of the most commonly reported sexually transmitted diseases?

Some of the most common bacterial STDs are chlamydia, gonorrhea, and syphilis. Some of the most common viral STDs are hepatitis B, genital herpes, genital warts, and AIDS.

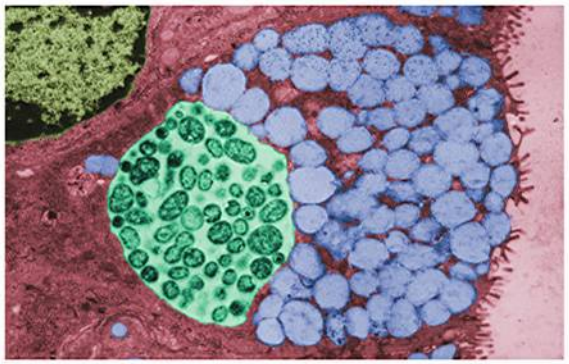
BUILD Vocabulary

menstruation
the discharge of blood and the unfertilized egg from the body

sexually transmitted disease (STD)
a disease that is spread from person to person by sexual contact

WORD ORIGINS

The word *menstruation* comes from the Latin word *mensis*, meaning "month."



Infection This electron micrograph shows a group of *Chlamydia trachomatis* bacteria in green. The bacteria are growing inside a cell within the female reproductive tract. The bacteria will eventually cause the cell to burst, and the infection will spread.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. _____ are the primary male reproductive organs.
2. The _____ is characterized by a follicular phase, ovulation, and a luteal phase.

Critical Thinking

3. **Evaluate** Why do you think young people are especially at risk for STDs?
4. **Compare and Contrast** Compare and contrast the sexual development of male and female embryos.
5. **Sequence** Explain how sperm develop.
6. **Write to Learn** Answer the third clue of the mystery.

MYSTERY CLUE

Low fat reserves in women are related to low FSH and LH levels. Tests showed that Lisa's blood had very low levels of these hormones. How might this have affected her menstrual cycle? (Hint: See p. 820.)

BIOLOGY.com Search Lesson 34.3 GO • Lesson Assessment

34.4 Fertilization and Development

Key Questions

What takes place during fertilization and the early stages of human development?

What important events occur during the later stages of human development?

BUILD Understanding

Flowchart As you read, draw a flowchart that shows the steps from fertilized egg to newborn baby.

In Your Workbook Go to your workbook to learn more about making a flowchart. Complete the flowchart for Lesson 34.4.

Fertilization and Early Development

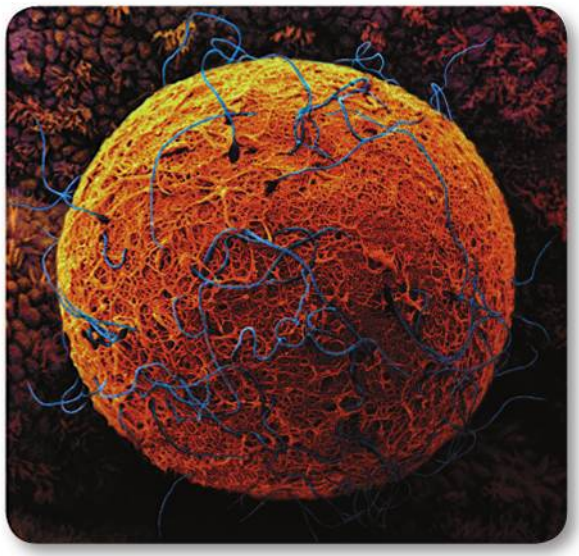
Is anything more amazing than the formation of a new human from a single cell? The story of human development begins with the gametes. Gametes are sperm produced in the testes and egg cells produced in the ovaries. The process of development begins when a sperm and an egg cell fuse into a single cell.

Fertilization Hundreds of millions of sperm are released when semen is ejaculated into the vagina through the penis. Semen is generally released just below the cervix. The cervix is the opening that connects the vagina to the uterus. Sperm swim through the cervix and uterus into the Fallopian tubes. If an egg is in one of the Fallopian tubes, its chances of being fertilized are good.

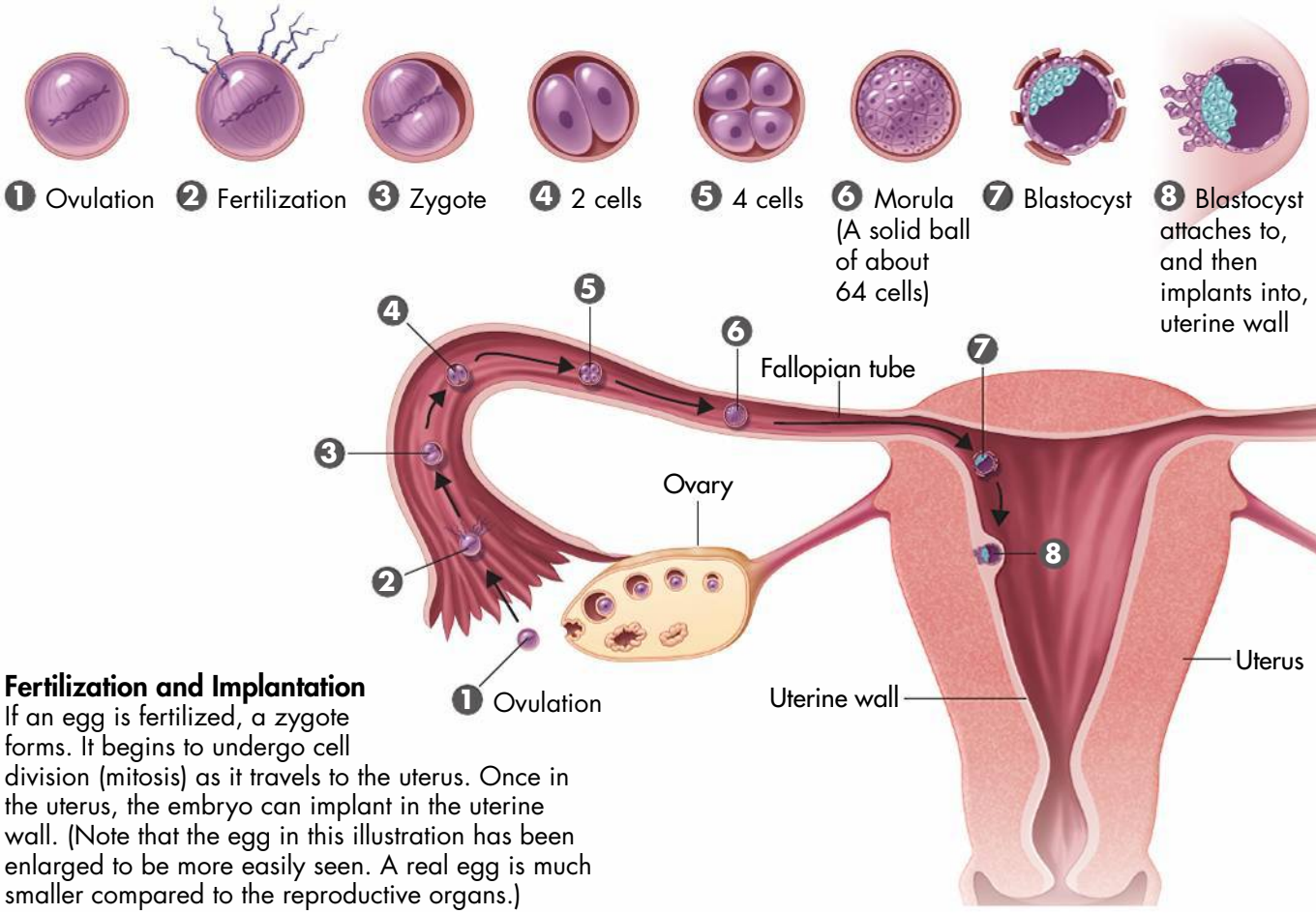
The egg has a protective outer layer. A sperm can attach to binding sites on this layer. Its head then releases powerful enzymes that break down this protective layer. The sperm and egg are haploid (N). The sperm nucleus enters the egg, and their chromosomes are brought together. The two haploid nuclei fuse to form a single diploid (2N) nucleus. The nucleus contains a single set of chromosomes from each parent cell. The fertilized egg is called a **zygote,** or embryo.

The egg contains a layer of particles just inside its outer layer. It releases the contents of these particles when the sperm enters the egg. The material in the particles forms a barrier that prevents other sperm from attaching to, or entering, the egg.

Key Question What takes place during fertilization?
The fusion of a sperm and an egg is called fertilization.



Sperm Meet Egg Many sperm usually reach an egg. But only one sperm can successfully break through the egg's protective layer (SEM 650x).



Fertilization and Implantation If an egg is fertilized, a zygote forms. It begins to undergo cell division (mitosis) as it travels to the uterus. Once in the uterus, the embryo can implant in the uterine wall. (Note that the egg in this illustration has been enlarged to be more easily seen. A real egg is much smaller compared to the reproductive organs.)

Multiple Embryos Sometimes two eggs are released during the same menstrual cycle. If both are fertilized by different sperm, fraternal twins may result. Fraternal twins are not identical in appearance and may even be different sexes. If a single zygote splits apart, it produces two genetically identical embryos. These two identical embryos are called identical twins. Because they result from the same fertilized egg, identical twins are always the same sex.

Implantation The zygote begins to undergo mitosis inside the Fallopian tube. As the embryo grows, the ball of cells develops a cavity in the center. This hollow ball of cells is called the **blastocyst.** About six or seven days after fertilization, it attaches to the uterus wall. The blastocyst then grows into the tissues of the mother, a process called implantation.

At this point, cells in the blastocyst begin to specialize. This process is called differentiation. Differentiation causes the various types of body tissues to develop. A cluster of cells develops inside the inner cavity of the blastocyst. The body of the embryo will develop from this cluster. The remaining cells will differentiate into tissues that support and protect the embryo.

BUILD Vocabulary

zygote
a fertilized egg

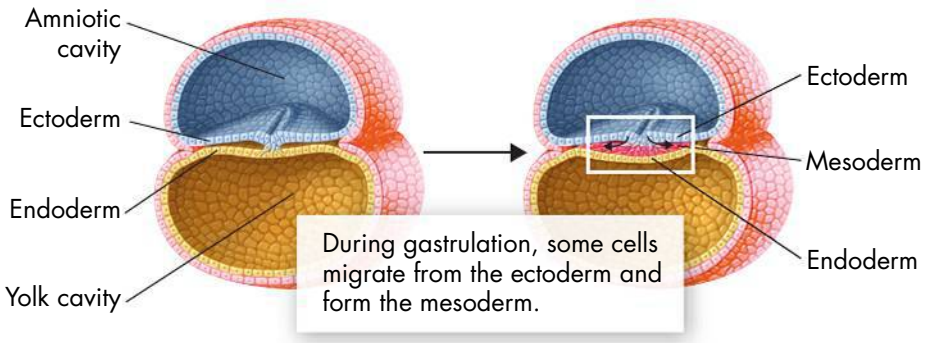
blastocyst
a stage of early development in mammals that consists of a hollow ball of cells

placenta
a specialized organ in placental mammals through which respiratory gases, nutrients, and wastes are exchanged between the mother and her developing young

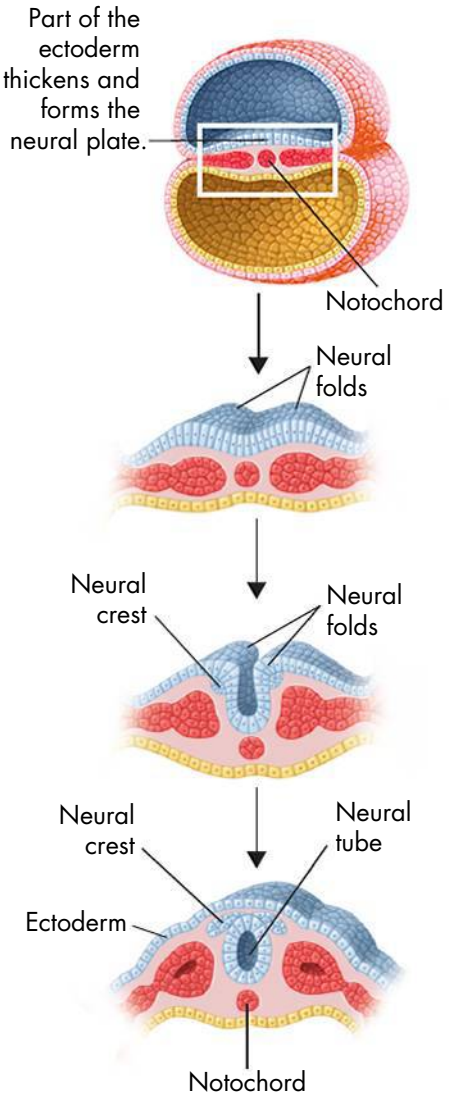
fetus
a human embryo after eight weeks of development

SUFFIXES

A *cyst* is a fluid-filled sac that forms in animal tissues. A structure in the body that has a fluid-filled cavity often has a name ending in *-cyst.* A blastocyst is a hollow ball of cells with a cavity in the center that contains fluid.



Gastrulation All of the organs and tissues of the embryo are formed from these three layers.



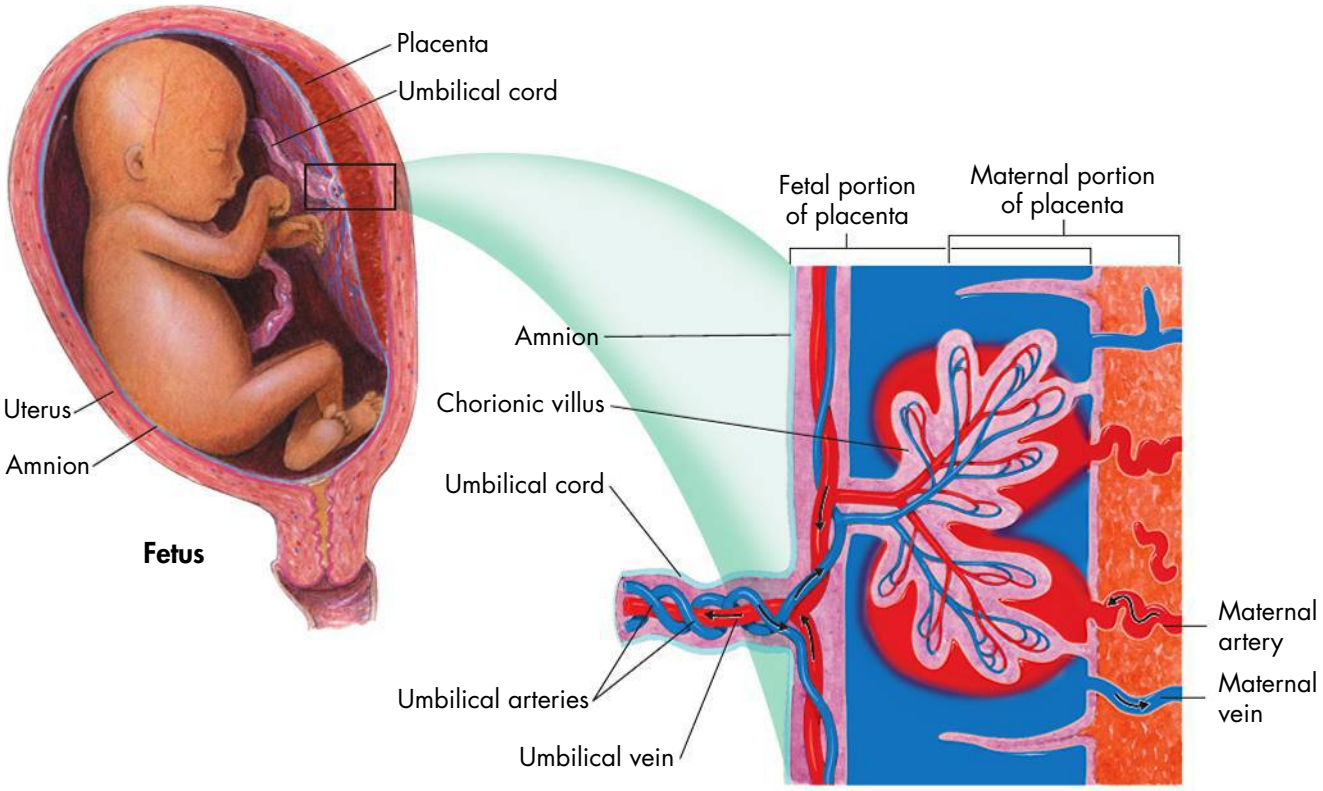
Neurulation During neurulation, changes in the ectoderm lead to formation of the neural tube. The neural tube will develop into the brain and spinal cord. Cells from the neural crest will develop into many types of nerves.

Gastrulation As development continues, the embryo begins a series of dramatic changes. These changes will produce the key structures and tissue layers of the body. One key event in early development is gastrulation (gas troo LAY shun). During gastrulation, three cell layers—the ectoderm, mesoderm, and endoderm—form. The ectoderm and endoderm form first. Then cells from the ectoderm migrate to form the mesoderm.

The ectoderm will develop into the skin and the nervous system. Mesoderm cells will differentiate into tissues such as bones, muscle, blood cells, and gonads. Endoderm forms the linings of organs in the digestive system, respiratory system, and excretory system.

Neurulation Gastrulation is followed by neurulation (NUR uh lay shun), an important step in the development of the nervous system. First, mesodermal tissue differentiates into the notochord. Ectoderm near the notochord also thickens, forming the neural plate. The raised edges of the neural plate form the neural crest and the neural folds. The folds gradually move together to form the neural tube. This will become the brain and spinal cord. Neural crest cells migrate to other areas, becoming nerve cells, skin pigment cells, and other structures.

If the neural tube does not close completely, a serious birth defect can result. Most cases of this defect, called spina bifida, can be prevented by the vitamin folic acid. Neurulation usually occurs before a woman knows she's pregnant. So, folic acid is an important nutrient in any woman's diet.



The Placenta The placenta is the connection between the mother and the embryo or fetus. The embryo gets oxygen and nutrients through the placenta. It sends wastes and carbon dioxide back to the mother through the placenta as well. The overlapping brackets show how the chorionic villi extend into the uterine lining.

The Placenta

Specialized membranes form to protect and nourish the embryo as it develops. A sac called the amnion surrounds the embryo. It is filled with amniotic fluid, which cushions and protects the embryo. A sac called the chorion forms outside the amnion. Small, fingerlike projections called chorionic villi form on its outer surface.

The villi extend into the uterine lining, forming a vital organ called the **placenta.** The placenta connects the mother and embryo. The mother's blood and the embryo's blood flow past each other, separated by chorionic tissue. Gases, nutrients, and wastes diffuse across this tissue. Two arteries and a vein form the umbilical cord that connects the embryo to the placenta.

After eight weeks, the embryo is about 8 cm long and is called a **fetus.** Most major organs and tissues are fully formed by three months. The fetus may begin to move and show signs of reflexes.

Key Question What takes place during the early stages of human development?

Key events in early development are gastrulation and neurulation. Gastrulation produces the three cell layers of the embryo. Neurulation leads to the formation of the nervous system.

Later Development

Most tissues and organs of the embryo have been formed after three months of development. But many systems will need about six more months of development to survive outside the uterus.

Months 4–6 Fetal tissues become more complex and specialized during the fourth, fifth, and sixth months. They also begin to function during this time. The fetal heart becomes large enough to be heard with a stethoscope. Bone continues to replace the cartilage that forms the early skeleton. A layer of soft hair grows over the skin of the fetus. As the fetus increases in size, the mother's abdomen swells to make room for it. The mother also begins to feel the fetus moving.

Months 7–9 The organ systems of the fetus mature during the last three months before birth. The fetus also doubles in mass. The lungs and other organs go through a series of changes needed for life outside the uterus. The fetus can now regulate its own body temperature. The central nervous system and lungs finish developing, too. The pictures below show an embryo and a fetus at different stages of development.

A fetus needs about nine months to develop fully. Babies born before eight months of development are called premature babies. They often have severe breathing problems because their lungs are not fully developed.

Key Question What important events occur during the later stages of human development?

During the fourth, fifth, and sixth months, tissues become more complex and specialized. They also begin to function. During the last three months before birth, organ systems mature. The fetus grows in size and mass.

Human Development At 7 weeks, most organs have begun to form and the heart (large, dark, rounded structure) is beating. By 14 weeks, the hands, feet, and legs have reached their birth proportions. The eyes, ears, and nose are well developed. At 20 weeks, muscles are more developed, and eyebrows and nails have grown in. At full term, a fetus can live on its own.

Embryo at 7 Weeks

Fetus at 14 Weeks

Fetus at 20 Weeks

Fetus at Full Term

Childbirth Birth occurs about nine months after fertilization. Many factors trigger birth. One is the release of the hormone oxytocin from the mother's posterior pituitary gland. Oxytocin causes a series of rhythmic contractions, known as labor, to begin. During labor, the cervix expands until it is large enough for the head of the baby to pass through. The amniotic sac breaks, and the fluid it contains rushes out of the vagina. Soon, contractions force the baby out through the vagina. Most babies are delivered head first.

Babies often cough or cry when they emerge from the vagina. These actions help clear fluid from the baby's lungs, allowing the baby to start breathing almost immediately. The umbilical cord is clamped and cut. A small piece remains attached to the baby. This piece soon dries and falls off, leaving a scar called the navel. Now the newborn is independent. It can supply its own oxygen, excrete its own wastes, and maintain its body temperature.

A final series of uterine contractions expels the placenta and the empty amniotic sac. This is called the afterbirth. Within a few hours, the mother's pituitary releases the hormone prolactin. Prolactin signals the mother's breast tissues to produce milk. The mother's milk contains all the nutrients the baby needs for growth and development during the first few months of life.

Newborns Twins, ten minutes after birth, adjusting to life outside the uterus

Infant and Maternal Health The placenta acts as a barrier, but some diseases and chemicals can still cross it. Fetuses can be infected with AIDs. The virus that causes rubella (German measles) can cause birth defects. Alcohol, heroin, cocaine, and nicotine can also harm a fetus. A pregnant woman must behave responsibly and get proper medical care to protect the life inside her.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The hollow ball of cells that attaches to the uterine wall is the _____.
2. After eight weeks of development, an embryo is called a _____.

Critical Thinking

3. **Explain** What is the role of the placenta?
4. **Relate Cause and Effect** How do the results of gastrulation and neurulation contribute to human development?
5. **Quick Write** Doctors often recommend that pregnant women avoid many medications. Write one paragraph explaining why you think this is important.

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Pre-Lab: Diagnosing Endocrine Disorders

Problem Can you diagnose an endocrine disorder based on a patient's symptoms?

Lab Manual Chapter 34 Lab

Skills Focus Analyze Data, Draw Conclusions, Relate Cause and Effect

Connect to the Big idea Organs of the endocrine system secrete hormones into the blood. Each hormone triggers a response in specific cells. Almost every cell in the body is affected by at least one hormone. The endocrine system regulates important processes such as growth, metabolism, and water balance. If one part of the endocrine system is not working properly, the body will be thrown off balance. If the imbalance is severe, it could threaten the health, or even the life, of a person.

Endocrinologists are medical doctors who diagnose and treat disorders of the endocrine system. The clues these doctors use to solve their mysteries are a patient's symptoms and the results of lab tests. In this lab, you will model the process of diagnosing endocrine disorders.

Background Questions

a. **Review** Why doesn't every hormone affect every cell in the body?

b. **Review** Use a flowchart to describe the feedback loop for regulating the metabolic rate.

c. **Use Analogies** How are the hormones that regulate the level of glucose in the blood similar to the muscles that bend and straighten an arm?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Interpret Tables** When patients complain of fatigue they are usually referring to a lack of energy or motivation. Which conditions listed in the data table have fatigue as a symptom?

2. **Apply Concepts** Why do doctors typically use blood tests to diagnose endocrine disorders?

3. **Infer** Why is it important for doctors to consider the age and gender of a patient when diagnosing a disorder?

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Visit Chapter 34 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video The Untamed Science crew helps us better understand the role epinephrine plays in regulating our response to fear and danger.

Art Review Review your understanding of the major endocrine glands in the body.

Art in Motion Watch how steroid and nonsteroid hormones act differently on cells.

34 CHAPTER Summary

34.1 The Endocrine System

- The endocrine system is made up of glands that release hormones into the blood. Hormones deliver messages throughout the body.
- Steroid hormones can easily cross cell membranes. After they enter the nucleus, they change the way genes are expressed in target cells.
- Nonsteroid hormones bind to receptors on cell membranes. They cause the release of secondary messengers inside the cell. Secondary messengers then affect cell activities.

hormone (p. 810)
endocrine gland (p. 810)
exocrine gland (p. 810)
prostaglandin (p. 811)

34.2 Glands of the Endocrine System

- Hormones secreted by the pituitary gland directly regulate many body functions. Pituitary hormones also control the actions of other endocrine glands.
- The hypothalamus controls the secretions of the pituitary gland.
- The adrenal glands release hormones that help the body prepare for—and deal with—stress.
- Insulin and glucagon help to keep the blood glucose level stable.
- The thyroid gland has a major role in regulating the body's metabolism.
- The two functions of gonads are the production of gametes and the secretion of sex hormones.
- The endocrine system is regulated by feedback mechanisms that function to maintain homeostasis.

releasing hormone (p. 813)
corticosteroids (p. 814)
epinephrine (p. 814)
norepinephrine (p. 814)
thyroxine (p. 815)

34.3 The Reproductive System

- In females, the sex hormones cause breast development and a widening of the hips. In males, they cause the growth of facial hair and increased muscular development. They also cause deepening of the voice.
- The main functions of the male reproductive system are to produce and release active sperm.
- The main function of the female reproductive system is to produce egg cells. The system also prepares the female's body to nourish an embryo.
- Common bacterial STDs include chlamydia, gonorrhea, and syphilis. Common viral STDs include hepatitis B, genital herpes, genital warts, and AIDS.

testis (p. 818)
ovary (p. 819)
menstrual cycle (p. 820)
ovulation (p. 820)
menstruation (p. 821)
sexually transmitted disease (STD) (p. 823)

34.4 Fertilization and Development

- Fertilization occurs when a sperm and an egg cell fuse to form one cell.
- Gastrulation produces the three cell layers of the embryo. Neurulation leads to the formation of the nervous system.
- Fetal tissues become more complex and specialized during the fourth, fifth, and sixth months.
- The organ systems of the fetus mature during the last three months before birth. The fetus also doubles in mass.

zygote (p. 824)
blastocyst (p. 825)
placenta (p. 827)
fetus (p. 827)

34 CHECK Understanding

Assess the Big idea Homeostasis

Write an answer to the question below.

Q: How does the body use chemical signals to maintain homeostasis?

Constructed Response

Write an answer to each of the numbered questions below. The answer to each question should be one or two paragraphs. To help you begin, read the **Hints** below the questions.

1. **How do the hypothalamus and pituitary gland work together to help the body maintain homeostasis?**

   Hint The hypothalamus has direct and indirect control over the pituitary.

   Hint Pituitary hormones regulate other endocrine glands as well as other tissues and organs.

2. **Why is it important for the menstrual cycle to stop during pregnancy?**

   Hint The uterine lining becomes part of the placenta during pregnancy.

   Hint Estrogen levels fall at the end of the luteal phase.

3. **Why is it important that the egg cell prevents more than one sperm from fertilizing it?**

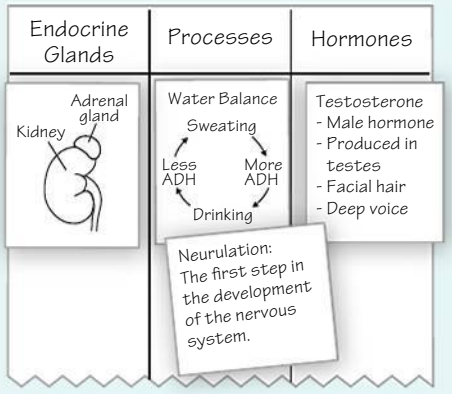
   Hint A sperm and egg cell each contain a haploid (N) nucleus.

Foundations for Learning Wrap-Up

The facts you collected as you read the chapter are tools you can use to arrange your thoughts about the endocrine and reproductive systems.

Activity 1 Work with a partner. On a separate sheet of paper, draw and label a chart with the following categories: Hormones, Endocrine glands, and Processes. Invite your partner to choose one card from your envelope and place it in the correct category on the chart. You then have to tell your partner everything you remember about the fact. Take turns. As you sort your facts, you may need to make up your own categories.

Activity 2 Working in small groups, create chains of related facts by pulling facts from each of the categories you created with your partners in Activity 1. Identify how the body uses chemical signals to maintain homeostasis in each chain of facts.



34.1 The Endocrine System

Understand Key Concepts

1. Which is a chemical messenger that can directly influence gene expression?

a. nonsteroid hormone **c.** ATP

b. steroid hormone **d.** receptor

Test-Taking Tip

Find Key Words in the Question As you read the question, look for key words that can help you answer it. In question 1, the key words are *chemical messenger.* A chemical messenger is a hormone, so you know that answer **a** or **b** is correct. Read the question again. Another key word is *directly*. Only a steroid hormone can cross cell membranes and enter the nucleus. It affects the cell directly. The correct answer is **b**.

2. A modified fatty acid that is released by a cell and affects local cells and tissues is probably a(n)

a. nonsteroid hormone. **c.** prostaglandin.

b. steroid hormone. **d.** exocrine secretion.

3. Many body functions are influenced by the action of two hormones with opposing effects. Why are such pairs of hormones useful?

Think Critically

4. Infer After a hormone is secreted by a gland, the circulatory system transports it throughout the body. Why doesn't every cell respond to the hormone?

34.2 Glands of the Endocrine System

Understand Key Concepts

5. A hormone that helps regulate blood calcium levels are produced by the

a. posterior pituitary. **c.** thyroid.

b. thymus. **d.** pancreas.

6. Which hormone influences a person's rate of metabolism?

a. PTH **c.** thyroxine

b. aldosterone **d.** calcitonin

7. How does the secretion of epinephrine prepare the body to handle emergencies?

8. What happens if blood glucose levels are not properly regulated?

Think Critically

9. Apply Concepts The heartbeat of a swimmer was found to increase significantly both before and during a swim meet. Explain why this could happen.

34.3 The Reproductive System

Understand Key Concepts

10. The diagram shows the female reproductive system. Which structure is located at the X?

a. uterus

b. Fallopian tube

c. ovary

d. cervix

11. Which male reproductive structure releases sperm into the urethra?

a. epididymis **c.** prostate gland

b. vas deferens **d.** testis

12. Which two hormones stimulate the gonads to produce their hormones?

Think Critically

13. Apply Concepts Sperm cells contain many mitochondria. Explain how mitochondria might influence sperm activity.

34.4 Fertilization and Development

Understanding Key Concepts

14. Another name for a fertilized egg is a

a. gastrula. **c.** zygote.

b. placenta. **d.** blastocyst.

34 CHECK Understanding

15. Fertilization usually occurs in the
    a. uterus. **c.** Fallopian tube.
    b. vagina. **d.** ovary.
16. Explain the importance of the three layers that form during gastrulation.
17. What is the function of the placenta?

Think Critically

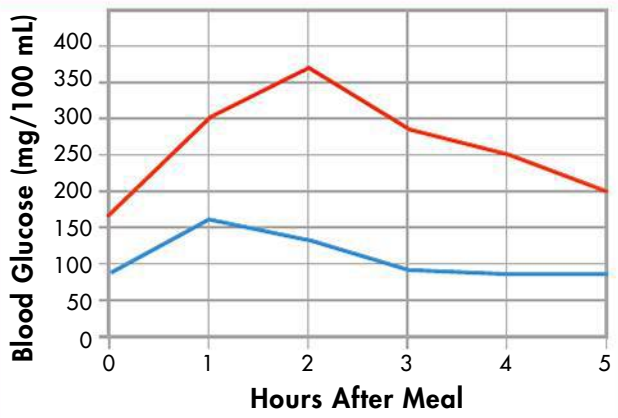
18. **Infer** Occasionally, a zygote does not move into the uterus. Instead, it attaches to the wall of a Fallopian tube. Why might this be a very dangerous situation for the mother?

Connecting Concepts

Use Science Graphics

The graph shows the levels of glucose in the blood of two people during a five-hour period immediately following the ingestion of a typical meal. Use the graph to answer questions 19 and 20.

Blood Glucose Level After Eating



19. **Interpret Graphs** How long does it take the blood glucose level of the person represented by the blue line to return to a homeostatic value?
20. **Draw Conclusions** Which line represents a person who may have diabetes? Which line represents a person who does not have diabetes? Explain your answer.

solve the CHAPTER MYSTERY

OUT OF STRIDE

A healthful diet and exercise contribute to maintaining a healthy body. But a balance between the two is important. Lisa lost this balance. The reactions from her endocrine system led to a disorder known as the female athlete triad. The triad consists of three factors:

- **Disordered Eating** Lisa did not provide her body with enough nutrients and energy to support all of its functions.
- **Amenorrhea** Lack of menstrual cycles for three or more months is called amenorrhea. Lisa's hypothalamus detected her low energy levels. As a result, it did not signal the pituitary to release FSH and LH. This caused her menstrual cycle to stop and her estrogen levels to drop.
- **Weakened Bones** Lisa's bones lost more calcium than normal because of high cortisol and low estrogen levels. She also did not consume enough calcium because of her poor diet. This made her bones weak. Weak bones are at risk for stress fractures.

The problems associated with the female athlete triad are related to poor nutrition. Lisa used more energy and nutrients than she took in. The reaction of her endocrine system was normal, but it had negative effects on her health.

1. **Relate Cause and Effect** Explain why the menstrual cycle cannot continue without FSH and LH.
2. In your own words, explain what led to Lisa's stress fracture. What are some ways that Lisa can prevent this from happening again?

UntamedScience **Never Stop Exploring Your World.** Finding the solution to the Out of Stride mystery is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where this mystery leads.

Standardized Test Prep

Multiple Choice

1. Which sequence correctly describes the route sperm take through the human male reproductive system?
A vas deferens, urethra, epididymis
B epididymis, vas deferens, urethra
C vas deferens, epididymis, urethra
D urethra, epididymis, vas deferens

2. Each of these terms refers to a stage in the human menstrual cycle EXCEPT
A ovulation. **C** corpus phase.
B luteal phase. **D** follicular phase.

3. Which of the following is NOT an endocrine gland?
A pituitary gland **C** sweat gland
B parathyroid gland **D** adrenal gland

4. During which stage of embryonic development does the neural tube form?
A implantation **C** neurulation
B gastrulation **D** fertilization

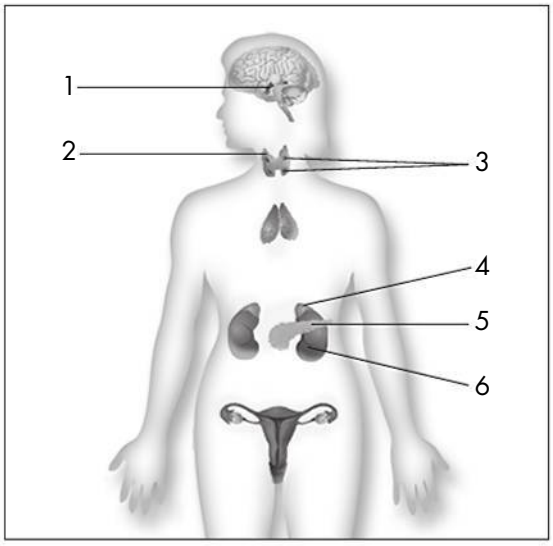
5. Which of the following is a cluster of cells that surround a developing egg?
A follicle **C** ovary
B blastocyst **D** ovum

6. The structure(s) in the male reproductive system that stores mature sperm until they are released by the male reproductive system is (are) the
A vas deferens. **C** seminiferous tubules.
B penis. **D** epididymis.

7. Which statement best describes the relationship between the hypothalamus and the pituitary gland?
A The anterior pituitary gland makes hormones that are released by the hypothalamus.
B The hypothalamus produces releasing hormones that promote the release of particular hormones from the anterior pituitary.
C The hypothalamus produces releasing hormones that promote the release of particular hormones from the posterior pituitary.
D The posterior pituitary sends nervous signals to the hypothalamus to prompt the release of hormones.

Questions 8–11

The diagram below shows the female endocrine system. Use the diagram to answer the questions.



8. Which gland helps the body prepare for and deal with stress?
A 1 **C** 4
B 2 **D** 6

9. Which gland is both an endocrine and an exocrine gland?
A 2 **C** 4
B 3 **D** 5

10. Which gland secretes growth hormone?
A 1 **C** 3
B 2 **D** 5

11. Which gland secretes thyroxine?
A 1 **C** 3
B 2 **D** 4

Open-Ended Response

12. In a paragraph, describe the difference between the origins of fraternal and identical twins.

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10	11	12
See Lesson	34.3	34.3	34.1	34.4	34.3	34.3	34.2	34.2	34.2	34.2	34.2	34.4

35 Immune System and Disease

Big idea

Homeostasis

Q: How does the body fight against invading organisms that may disrupt homeostasis?

German soldiers on their way to a possible bird flu outbreak

BIOLOGY.com Search Chapter 35 GO • Flash Cards

INSIDE:

- 35.1 Infectious Disease
- 35.2 Defenses Against Infection
- 35.3 Fighting Infectious Disease
- 35.4 Immune System Disorders

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY

THE SEARCH FOR A CAUSE

In 1975, researcher Allen Steere faced a medical mystery. Thirty-nine children and several adults living in one small area in Connecticut were suffering from joint pain and inflammation. The children's symptoms looked like a rare form of childhood arthritis. The adults' symptoms seemed like age-related arthritis. But why would so many cases of arthritis appear in such a small population in such a short time?

Steere thought that there must be some other reason that so many people were getting sick. The patients all lived in small towns and rural places. Their symptoms all started at more or less the same time of year. Could all of these people be suffering from a disease no one had discovered yet?

Read for Mystery Clues As you read this chapter, look for clues about this disease. Then, solve the mystery at the end of the chapter.

FOUNDATIONS for Learning

Before you read this chapter, make an undercover vocabulary tool as shown below. As you read, write each vocabulary word from the chapter in the first column. Write the definition in your own words in the second column. Then cut and fold the third column into tabs to cover the definitions. You may need to make more than one undercover vocabulary tool. At the end of the chapter there are two activities that use the undercover vocabulary tool to help you answer the question: How does the body fight against invading organisms that may disrupt homeostasis?

Chapter 35	Definition	
Infectious Disease	A disease caused by bacteria, virus, or parasite. These are too small to see with the naked eye.	
Germ Theory	An idea that infectious diseases are caused by things you can't see with	

35.1 Infectious Disease

Key Question

What causes infectious disease?

How are infectious diseases spread?

BUILD Understanding

Two-Column Chart Use a two-column chart to list the ways diseases are spread and describe each way.

In Your Workbook Go to your workbook for a two-column chart to complete.

Causes of Infectious Disease

For thousands of years, people believed that sicknesses were caused by evil spirits, steam rising from dirty marshes, or dead plants and animals. This is not all that surprising. Until people had microscopes, they were not able to see most causes of disease!

About 150 years ago two scientists worked out a new explanation for how people get sick. Based on their observations and experiments, French chemist Louis Pasteur and German bacteriologist Robert Koch discovered that **infectious diseases** are caused by microorganisms. Infectious diseases cause changes to the body that disrupt normal body functions. The theory that microorganisms cause infectious diseases was called the **germ theory of disease.** Microorganisms used to be called germs. But today, the word *germ* has no scientific meaning.

Pathogens and Parasites

If *germ* is not a scientific term, how should we describe the causes of infectious disease? Infectious diseases can be caused by viruses, bacteria, "protists," fungi, and parasites. Anything that can cause an infectious disease is called a pathogen.

Key Question What causes infectious disease?
Infectious diseases are caused by microorganisms. Diseases can be caused by viruses, bacteria, fungi, "protists," or parasites.

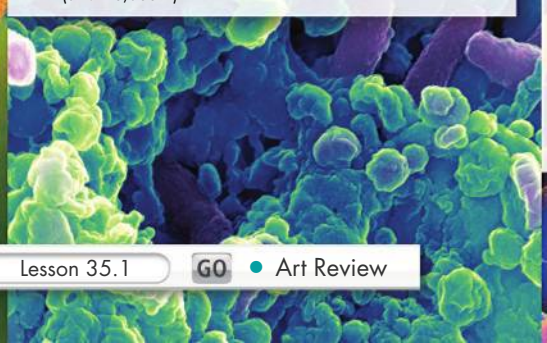
Examples of Agents of Disease Infectious diseases are caused by pathogens and parasites. These organisms invade a body and disrupt its normal functions.

Viruses
Characteristics: nonliving, replicate by inserting their genetic material into a host cell and taking over many of the host cell's functions
Diseases Caused: common cold, influenza, chicken pox, warts

▼ ***Influenza Virus,* Strain taken from a Beijing 1993 epidemic** (TEM 120,000×)

Bacteria
Characteristics: break down the tissues of an infected organism for food, or release toxins that interfere with normal activity in the host
Diseases Caused: streptococcus infections, diphtheria, botulism, anthrax

▼ ***Mycobacterium* causes tuberculosis** (SEM 10,600×)



Fungi
Characteristics: cause infections on the surface of the skin, mouth, throat, fingernails, and toenails; dangerous infections may spread from lungs to other organs
Diseases Caused: ringworm, thrush

▼ ***Trichophyton interdigitale* causes athlete's foot** (SEM 2800×)

Koch's Postulates Based on his studies, Koch made a list of steps a scientist must follow to help decide which pathogen causes a specific disease. His steps are known as Koch's postulates.

1. The pathogen must always be found in the body of a sick organism and cannot be found in the body of a healthy organism.
2. The pathogen must be isolated from the sick organism and grown in the laboratory.
3. When the pathogen grown in the lab is given to a healthy organism, that organism must get the same illness.
4. The pathogen must be isolated from the second organism. The pathogen must be exactly the same as the original pathogen.

Koch was given a Nobel Prize in 1905. Today, we know that there are exceptions to his rules. Yet they are still very important steps to follow in order to learn the causes of new and emerging diseases.

Symbionts vs. Pathogens Many microorganisms live in our bodies. Most of them are symbionts. They are either harmless or they help us. Yeast and bacteria grow in the mouth and throat without causing trouble. Bacteria in the large intestine help with digestion and make vitamins.

What is the difference between harmless microorganisms and pathogens? The harmless microorganisms get nutrients, grow, and reproduce without harming normal body functions. Pathogens, on the other hand, cause problems in many ways. Some pathogens kill the cells of their host. Others may block blood flow or take up the host's nutrients.

BUILD Vocabulary

infectious disease
a disease caused by a microorganism that disrupts normal body functions

germ theory of disease
the idea that infectious diseases are caused by microorganisms

MULTIPLE MEANINGS

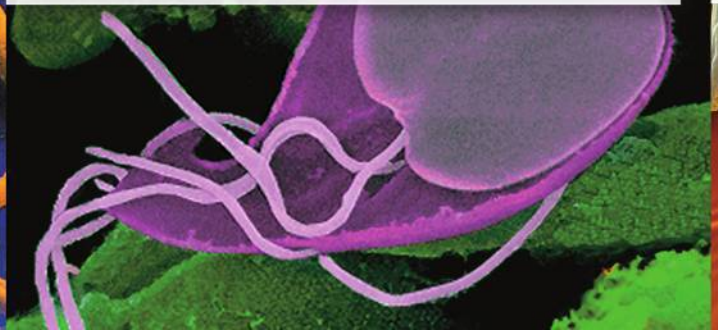
The word *isolate* often means "to set apart from others." In biology and medicine, however, *isolate* means "to remove microorganisms from a person's body and then grow the microorganisms."

How Diseases Spread

Pathogens cause disease. But how are pathogens spread from one person to the next? Some diseases spread through coughing, sneezing, or physical contact. Others spread through body fluids, or contaminated food or water. Some diseases can be spread to humans from other animals.

"Protists"
Characteristics: single-celled eukaryotes may infect people through contaminated water and insect bites; they take nutrients from their host; most cause damage to cells and tissues
Diseases Caused: malaria, African sleeping sickness, intestinal diseases

▼ ***Giardia intestinalis,* causes infection of the digestive tract**
(SEM 3500×)



Parasitic Worms
Characteristics: most parasites that infect humans are wormlike; many enter through mouth, nose, anus, or skin; most live in the intestinal tract where they absorb nutrients from the host
Diseases Caused: trichinosis, schistosomiasis, hookworm, elephantiasis

▼ ***Trichinella spiralis,* causes trichinosis in humans**
(SEM 65×)

Sneezing Some infectious diseases are spread from person to person by sneezing. Thousands of pathogen particles can be released in a sneeze.

Coughing, Sneezing, and Physical Contact

Coughing and sneezing send thousands of tiny droplets flying into the air. Other people can breathe these into their bodies. Some droplets may land on things other people touch. Some pathogens can be spread through almost any body-to-body contact and through towels and some sports equipment. The best way to slow the spread of these pathogens is by washing your hands well and often. If you are ill, cover your mouth when you cough or sneeze.

Exchange of Body Fluids

Some pathogens are spread only through specific kinds of direct contact. Sexually transmitted diseases, including chlamydia and AIDS, are spread through sexual contact. Some, including AIDS, may also be spread when drug users share needles. Diseases that are transmitted through blood and body fluids can be completely prevented only by avoiding sexual activity and drug use.

Contaminated Water or Food

Many pathogens are spread through water contaminated with feces from infected people or other animals. People may drink the water. The water may also carry pathogens onto fruits or vegetables. Pathogens may also be present in seafood and uncooked meat. These foods must be stored and cooked properly.

Animals

Diseases that can be spread from other animals to people are called zoonoses. Mad cow disease, Lyme disease, and Ebola are all zoonoses. An animal that carries one of these diseases from an animal host to a human host is called a **vector.** Vectors do not usually get sick themselves. A person can also pick up pathogens from an animal if the person is bitten or comes in close contact with a sick animal.

Key Question How are infectious diseases spread?
Infectious diseases can be spread through coughing, sneezing, or physical contact. Others spread through body fluids, contaminated food or water, or through bites or contact with other animals.

BUILD Vocabulary

vector
an animal that transports a pathogen to a human

WORD ORIGINS

Vector comes from the Latin word for "bearer" or "carrier." A vector carries the pathogen or parasite to the host.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The _____ states that any infectious disease is caused by microorganisms.
2. West Nile virus is transferred from birds to humans by mosquitos. Mosquitos are _____.

Critical Thinking

3. **Explain** What are some ways that pathogens can cause disease in their hosts?
4. **Apply Concepts** Many pathogens make their hosts very sick without killing the host. Why do you think this is a beneficial adaptation? (**Hint:** Think about how viruses replicate.)
5. **Write to Learn** Answer the first clue of the mystery. Write a paragraph that uses the term *vector*.

MYSTERY CLUE

Many of the sick children remembered getting strange insect bites that summer. The bites developed into rashes. What clue did this give Steere? (Hint: See above.)

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35.2 Defenses Against Infection

Nonspecific Defenses

There are pathogens all around us. Yet we are not usually sick. How do we stay healthy? How do we get better when we are sick? Our bodies have several amazing lines of defense.

First Line of Defense The skin blocks pathogens from entering the body. Cilia in the respiratory tract push pathogens away before they enter the body. Tears, saliva, and mucus have chemicals that break down bacterial cell walls.

Second Line of Defense If a pathogen gets past the skin, the body's second line of defense swings into action.

▶ ***The Inflammatory Response*** When a pathogen enters the body, the **inflammatory response** causes the infected area to become red and painful. Cells called mast cells release histamines. Histamines are chemicals that increase the flow of blood and other fluids to the area around the wound. This fluid can cause swelling. White blood cells, or phagocytes, move from the blood vessels into the tissue. Some of the white blood cells surround and destroy bacteria.

Key Questions

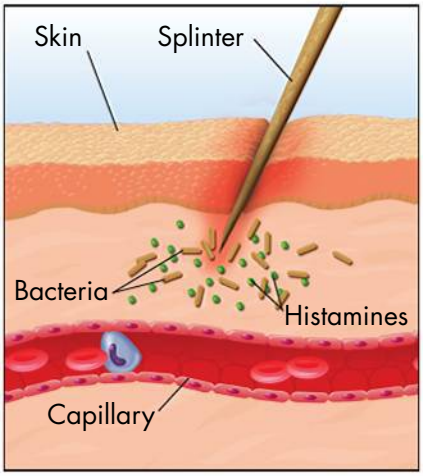
- ***What are the body's nonspecific defenses against pathogens?***
- ***What are the functions of the immune system's specific defenses?***
- ***What are the body's specific defenses against pathogens?***

BUILD Understanding

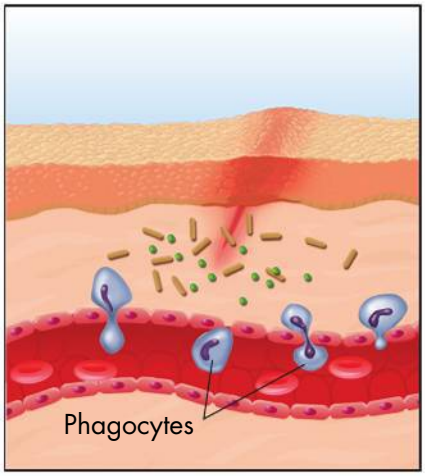
Concept Map Use the headings in this lesson to make a concept map. Add details to your map as you read.

In Your Workbook Go to your workbook for a partially completed concept map for Lesson 35.2.

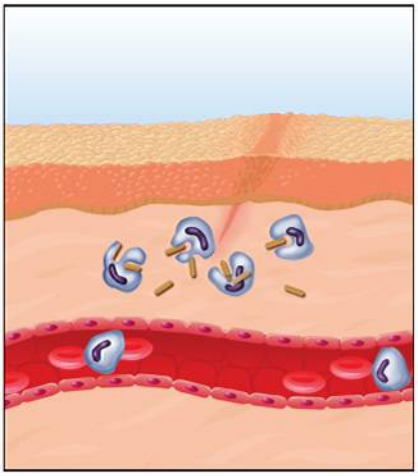
Inflammatory Response The inflammatory response is a nonspecific defense against pathogens. When pathogens enter the body, white blood cells move into the area and destroy the pathogens.



1 In response to the wound and invading pathogens, histamines increase blood flow to the area.



2 Local blood vessels open. Fluid leaves the capillaries and causes swelling. White blood cells move into the tissue.



3 White blood cells called phagocytes destroy the bacteria and damaged cells.

BUILD Vocabulary

inflammatory response
the nonspecific defense reaction to tissue damage caused by injury or infection

immune response
the body's specific recognition of, response to, and memory of a pathogen attack

antigen
a substance that triggers an immune response

antibody
a protein that either attacks antigens directly or produces antigen-binding proteins

WORD ORIGINS

The word part *flamm-* comes from the Latin word that means "to burn." The inflammatory response often causes the area around the wound to become warm to the touch.

B Lymphocytes The antibodies on the surface of a B lymphocyte recognize one specific antigen.

T Lymphocytes T lymphocytes recognize infected body cells. Each T lymphocyte recognizes only one antigen.

▶ ***Interferons*** When a virus enters the body, the body makes interferons. These proteins make it harder for viruses to make their own proteins. In this way, interferons slow down the infection.

▶ ***Fever*** Body temperature may rise during an infection. Fever may slow down or stop the growth of some pathogens. It also speeds up several parts of the immune response.

Key Question What are the body's nonspecific defenses against pathogens? **Nonspecific defenses include skin, hair, tears, the inflammatory response, interferons, and fever.**

Specific Defenses: The Immune System

The body's specific defenses attack particular pathogens with powerful weapons.

Recognizing "Self" A healthy immune system recognizes cells and proteins that belong in the body as "self." Your body's cells and proteins carry chemical markers that act like a secret password. That password tells the immune system "Don't attack me! I belong here!"

Recognizing "Nonself" The immune system's main job is to recognize anything that does not belong in the body. When the system notices something that is "nonself," it attacks. This reaction to specific pathogens is the **immune response.** If the same pathogen enters the body again, the body "recognizes" and attacks it even more quickly.

Antigens The immune response is triggered by certain molecules on the outer surfaces of bacteria, viruses, and parasites. These molecules are called **antigens.** The immune system responds to antigens in two ways. Certain body cells may attack the pathogen directly. Other cells make proteins called antibodies.

The shape of each **antibody** allows it to bind to only one antigen. Some antibodies are attached to immune cells. Other antibodies float around in plasma. Antibodies that bind to antigens act like signal flags. Those signal flags tell the immune system to destroy pathogens.

Lymphocytes The main cells in the immune response are white blood cells called B lymphocytes (B cells) and T lymphocytes (T cells). B cells are made in red bone marrow. T cells are also made in red bone marrow, but mature in the thymus. Each B cell and T cell is able to respond to *one* specific antigen. B cells discover antigens in body fluids. T cells discover infected cells.

Key Question What are the functions of the immune system's specific defenses? **The specific defenses distinguish between "self" and "nonself" and respond to specific pathogens.**

The Immune System in Action

There are two major parts of the specific immune response. They are humoral immunity and cell-mediated immunity.

Humoral Immunity Sometimes antibodies on B cells bind directly to the antigens on the surface of a pathogen. This part of the immune response is called humoral immunity. An antibody is shaped like the letter Y. It has two antigen-binding sites. Both sites recognize the same specific antigen. When the antigen and antibody on the B cell bind, T cells stimulate the B cell to grow and divide quickly. Two kinds of B cells are formed: plasma cells and memory B cells.

▶ ***Plasma Cells*** Plasma cells make antibodies and put them into the bloodstream. Antibodies bind to antigens that are free-floating or attached to pathogens. Then many immune system cells and proteins respond and attack the pathogen.

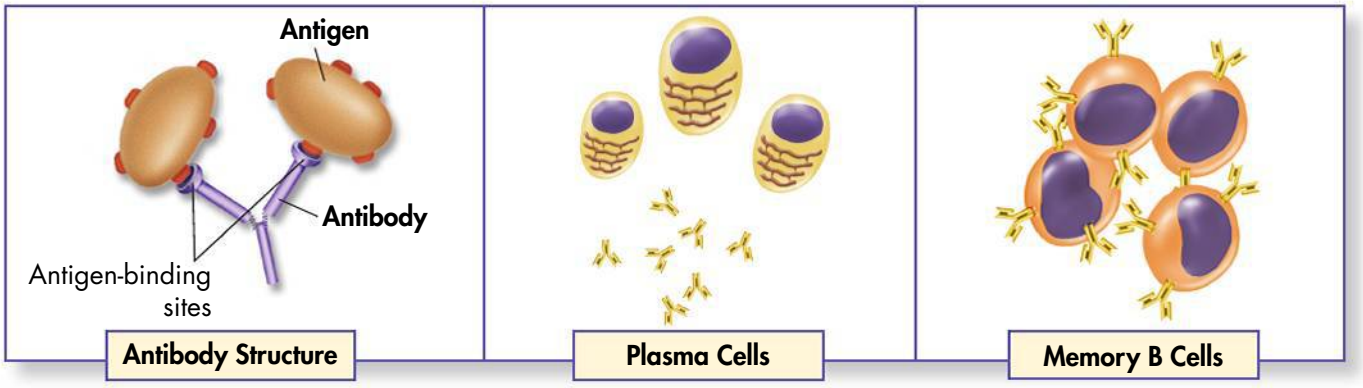
▶ ***Memory B Cells*** Once the pathogen has been "beaten," the plasma cells die. But memory B cells remain. If the same pathogen enters the body again, the memory B cells make plasma cells quickly. This secondary response happens very quickly and gives us long-term immunity to certain diseases.

Cell-Mediated Immunity Some pathogens infect the body's cells. This kind of infection is fought by T cells and macrophages. The response is called cell-mediated immunity. T cells also fight the body's own cells if they become cancerous.

Macrophages are B cells that engulf pathogens. When this happens or when a cell has been infected by a pathogen, the cell displays part of the antigen on its surface. This signals the helper T cells to divide and make more helper T cells. These activate B cells and cytotoxic T cells. Helper T cells also make memory T cells. Cytotoxic T cells kill infected body cells. Memory T cells help the immune system respond quickly if the same pathogen enters the body again.

Key Question What are the body's specific defenses against pathogens?

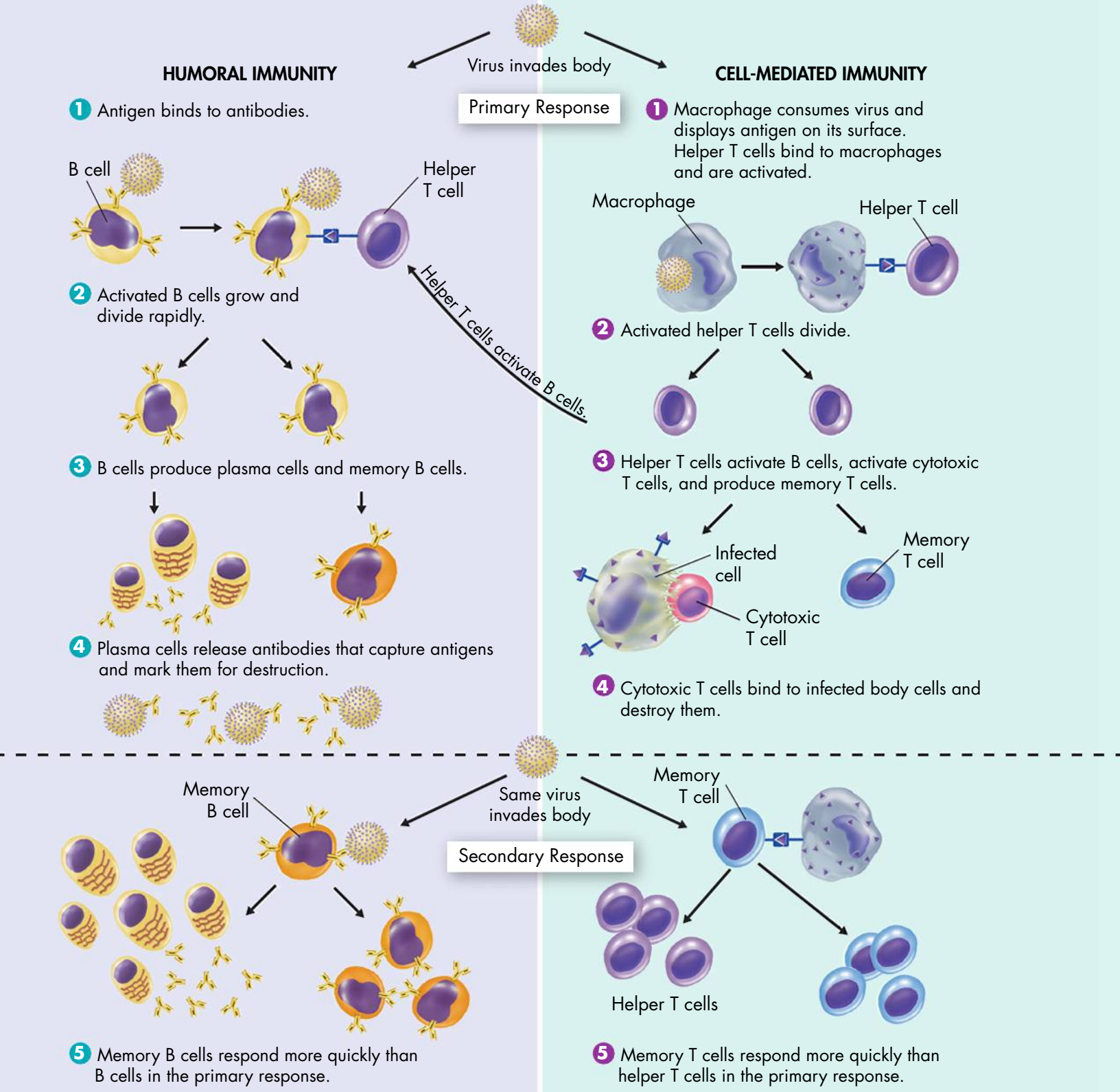
The body's specific defenses are humoral and cell-mediated immunity.



BUILD Connections

SPECIFIC IMMUNE RESPONSE

In humoral immunity, antibodies bind to antigens in body fluids and tag them for destruction by other parts of the immune system. In cell-mediated immunity, body cells that contain antigens are destroyed.



INQUIRY into Scientific Thinking

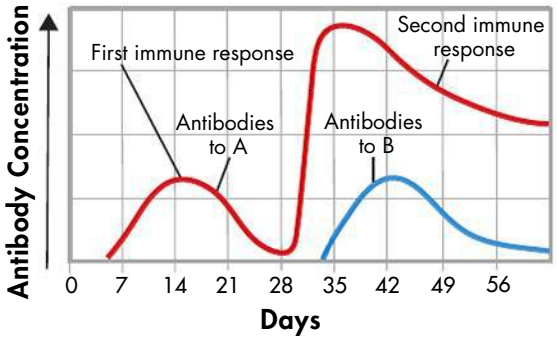
GUIDED INQUIRY

Immune System "Memory"

Your body is able to recognize pathogens and parasites as "nonself." Cells in your immune system recognize and try to destroy pathogens. During the initial infection, your body makes memory B cells. These cells allow your body to respond even more quickly if you are infected by the same pathogen again. Memory B cells make new plasma cells very quickly. Plasma cells then make and release antibodies to respond to the antigens on the surfaces of the pathogen.

The number of antibodies in a person's blood reveals the difference between the first and second immune response. Look at the graph. Assume the person was first exposed to Antigen A on Day 1. On Day 28, the person was exposed to Antigen A again and to Antigen B for the first time. The red line shows the levels of antibodies to Antigen A. The blue line shows the levels of antibodies to Antigen B. Use the graph to answer the questions that follow.

First and Second Immune Response



Analyze and Conclude

1. Interpret Graphs About how long does it take for your body to make antibodies after the first exposure to an antigen? About how long does it take for antibody levels to increase after the second exposure to an antigen?

2. Infer What could explain the significant increase in antibodies to Antigen A seen after Day 30?

In Your Workbook Get more help for this activity in your workbook.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. Histamines are released during a(n) _____.

2. Pathogens have specific _____ that cause an immune response.

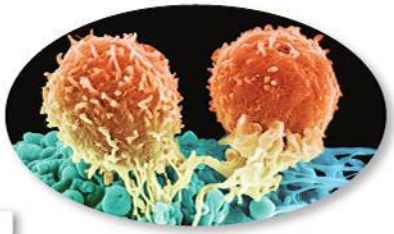
3. The body's specific recognition of, response to, and memory of a pathogen is called the _____.

Critical Thinking

4. Sequence Describe the steps of the inflammatory response.

5. Apply Concepts Although cytotoxic T cells are helpful in the immune system, they also make organ transplantation more difficult. How do you think cytotoxic T cells affect organ transplantation?

6. Write to Learn These two T cells are attached to a cancer cell. What kind of immune response are these cells a part of?



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35.3 Fighting Infectious Disease

Key Questions

- ***How do vaccines and externally produced antibodies fight disease?***
- ***How do public health measures and medications fight disease?***
- ***Why have patterns of infectious diseases changed?***

BUILD Understanding

Venn Diagram Make a Venn diagram that compares and contrasts active and passive immunity.

In Your Workbook Go to your workbook to learn more about making a Venn diagram. Complete the Venn diagram for Lesson 35.3.

Acquired Immunity

More than 200 years ago, English physician Edward Jenner noticed that milkmaids who got a mild disease called cowpox did not get smallpox. At the time, smallpox killed many people.

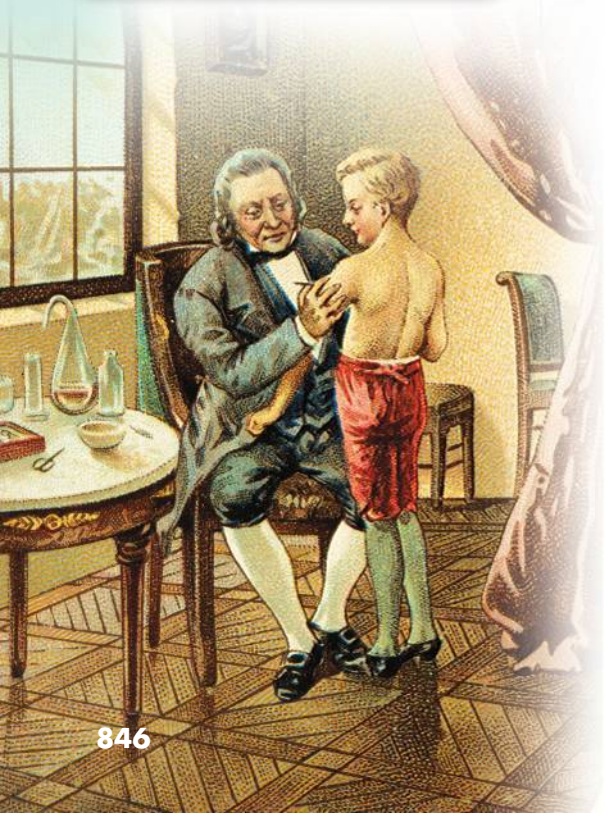
Jenner wondered if people could be protected from smallpox by infecting them with cowpox. Jenner tested his hypothesis on a young boy named James Phipps. His experiment is outlined below:

1. Jenner put fluid from a cowpox sore into a small cut he made on James Phipps's arm.
2. Phipps got cowpox.
3. Two months later, Jenner injected Phipps with fluid from a smallpox infection.
4. Phipps did not get smallpox.

Ever since that time, doctors have used **vaccinations** to produce immunity. Doctors inject patients with a weakened form of a pathogen or a similar but less dangerous pathogen.

Active Immunity Today, we understand how vaccination works. The immune system makes memory B cells and memory T cells in response to antigens carried by the pathogen. This kind of immunity is called **active immunity.** People may develop active immunity after they are vaccinated. People may also develop active immunity after they fight an infection.

Passive Immunity Disease can be prevented in another way. Antibodies made against a pathogen by other individuals or animals can be used to give temporary immunity. If these antibodies are introduced into a person's blood, the result is **passive immunity.** Passive immunity lasts only a short time, because the immune system will destroy the foreign antibodies.



The First Vaccination Edward Jenner used the cowpox virus to vaccinate James Phipps against smallpox.

Passive immunity can also happen naturally. A pregnant woman passes antibodies to her fetus. An infant gets antibodies through breast milk. In some cases, people can be given antibodies like a vaccination. For example, people who have been bitten by a rabid animal are injected with antibodies for the rabies virus.

Key Question How do vaccines and externally produced antibodies fight disease?
The immune system makes memory B cells and memory T cells in response to the antigen in the vaccination. Externally produced antibodies can be used to give temporary immunity.

Public Health and Medications

In 1900, more than 30 percent of deaths in the United States were caused by infectious disease. In 2005, less than 5 percent of deaths were caused by infectious disease. Public health measures and the development of medications helped to make this happen.

Public Health Measures When people live in large groups, behavior, cleanliness of food and water supplies, and sanitation all influence the spread of disease. The field of public health offers services and advice that help keep living conditions healthy. Public health measures help keep the food and water supplies clean. Encouraging vaccinations and recommending ways to avoid getting sick are also public health measures. Rules that make parents get vaccinations for their children, and education about hand washing, have greatly reduced the spread of many diseases.

Medications It is not possible to prevent every infectious disease. Medications are other weapons that can fight pathogens. Antibiotics can kill bacteria. Some antiviral medications can slow down viral activity.

The term *antibiotic* means something that kills bacteria without harming the host. In 1928, Alexander Fleming was the first scientist to discover an antibiotic. Fleming noticed that the mold *Penicillium notatum* seemed to make something that slowed bacterial growth. Research showed that this "something" was a compound Fleming named penicillin. Researchers learned to make large amounts of penicillin just in time to save the lives of thousands of World War II soldiers. Since then, dozens of antibiotics have saved millions of people.

Antibiotics have no effect on viruses. However, antiviral drugs have been made that fight certain viral infections. These drugs generally make it more difficult for viruses to get into the body's cells or to multiply once inside cells.

Key Question How do public health measures and medications fight disease?
Public health measures help keep living conditions healthy. Medications can be used to fight pathogens after someone is sick.

BUILD Vocabulary

vaccination
an injection of a weakened, or a similar but less dangerous, pathogen to produce immunity

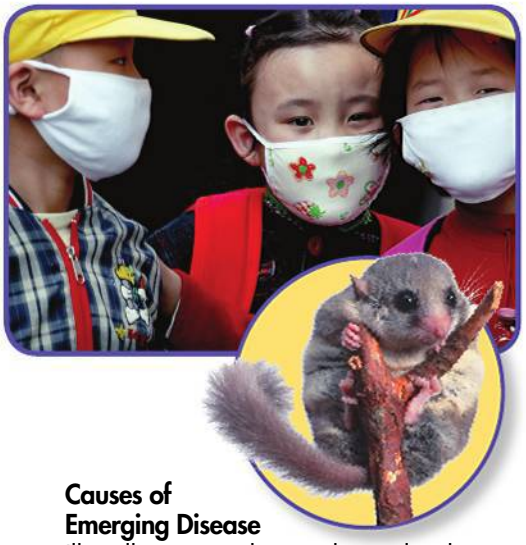
active immunity
immunity that develops as a result of natural or deliberate exposure to an antigen

passive immunity
temporary immunity that develops as a result of natural or deliberate exposure to an antibody

WORD ORIGINS

The word *vaccination* comes from the Latin word *vacca*, meaning "cow," as a reminder of Jenner's work.

Broad Street Pump In 1854, Dr. John Snow interviewed residents and mapped cases to determine the source of a London cholera epidemic. He discovered that a water pump like this replica was the source. This is a major event in the history of public health.



Causes of Emerging Disease Illegally imported animals can lead to the spread of emerging disease. In 2003, dormice and other rodents from Africa spread monkeypox to prairie dogs in the United States. Humans were soon infected. The spread of SARS also has been associated with the wild animal trade.

New and Re-Emerging Diseases

By 1980, many people thought that medicine had won the fight against infectious disease. Vaccination and other public health measures had wiped out polio in the United States. Smallpox had been wiped out around the world. Antibiotics seemed to have bacterial diseases under control. Researchers thought that epidemics would soon be history. They were wrong.

Recently, several new diseases have started making people sick. These include AIDS, SARS, hantavirus, monkeypox, West Nile virus, Ebola, and avian influenza ("bird flu"). Other diseases that people thought were gone are coming back, or re-emerging, and spreading to new places. What's going on?

Changing Interactions With Animals As people clear new land and as environments change, people come in contact with different animals and pathogens. Exotic animal trade, for pets and food, has also given pathogens new chances to jump from animals to humans. Both monkeypox and SARS are thought to have started this way.

Misuse of Medications Misuse of medications has led to the re-emergence of diseases that many people thought were under control. For example, many strains of the pathogens that cause tuberculosis and malaria are becoming resistant to many antibiotics and other medications. In addition, diseases such as measles are coming back because some people are not getting vaccinations.

Key Question Why have patterns of infectious diseases changed?

Through development and the exotic animal trade, people are coming into contact with new animals and pathogens. The misuse of medications has led to the re-emergence of certain diseases.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. The injection of a weakened form, or of a similar but less dangerous form, of a pathogen to give the patient immunity is called a(n) _____.
2. Vaccination provides _____ by exposing a person to an antigen.

Critical Thinking

3. **Compare and Contrast** Describe the difference between active and passive immunity.
4. **Infer** In the past few decades, it has become much easier to travel around the world. How do you think this has affected the spread of emerging diseases? Explain.
5. **Write to Learn** Answer the second clue of the mystery. Think about what the term *antibiotic* means.

MYSTERY CLUE

Steere's patients were helped by antibiotics. What clue did this give him about the disease's pathogen? **(Hint:** **See p. 847.)**

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35.4 Immune System Disorders

When the Immune System Overreacts

Sometimes, the immune system fights the body's own cells. Other times, the immune system itself is weakened by sickness. Then what happens? A strong immune response to harmless antigens can cause allergies, asthma, and autoimmune disease.

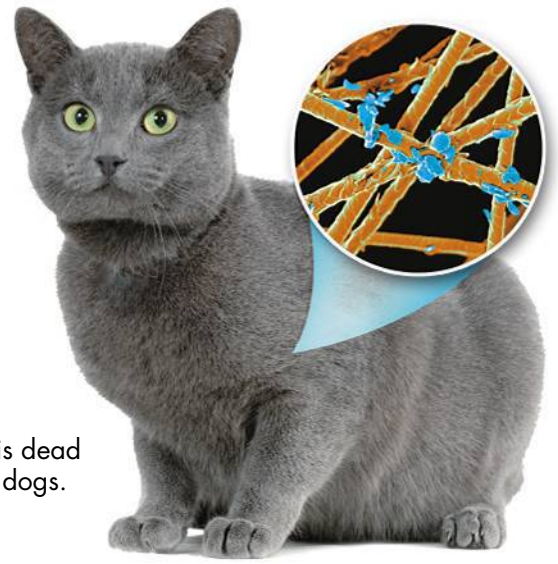
Allergies Antigens on things like pollen, dust mites, and mold can cause allergic reactions. The overreaction of the immune system to these harmless antigens is called an **allergy.** Allergies cause mast cells to release histamines.

Asthma Allergic reactions in the respiratory system can cause asthma. **Asthma** is a disease that causes air passages to narrow. This causes wheezing and coughing. It also makes it difficult for the person to breathe. Asthma attacks can be triggered by infections, exercise, stress, and some medications. Cold or dry air, smoke, pollen, and dust can also cause an attack.

Asthma can be life-threatening. Patients need to take their medication properly. If they do not, an attack can cause long-term harm to the lungs. There is no cure, but some medications can relax the muscles around the airways and relieve symptoms.

Autoimmune Diseases Sometimes the immune system does not properly recognize "self." When this happens, it may attack cells or compounds in the body as if they were pathogens. This kind of illness is called an autoimmune disease. Type I diabetes and lupus are autoimmune diseases. Some autoimmune diseases can be treated with medications that lessen the symptoms. Others are treated by lowering the immune response. These also lower the normal immune response. The patient must be watched carefully.

Key Question How can misguided immune responses cause problems?
A strong immune response to harmless antigens can cause allergies, asthma, and autoimmune disease.



Pet Dander Pet dander is dead skin shed from cats and dogs. It often causes allergies.

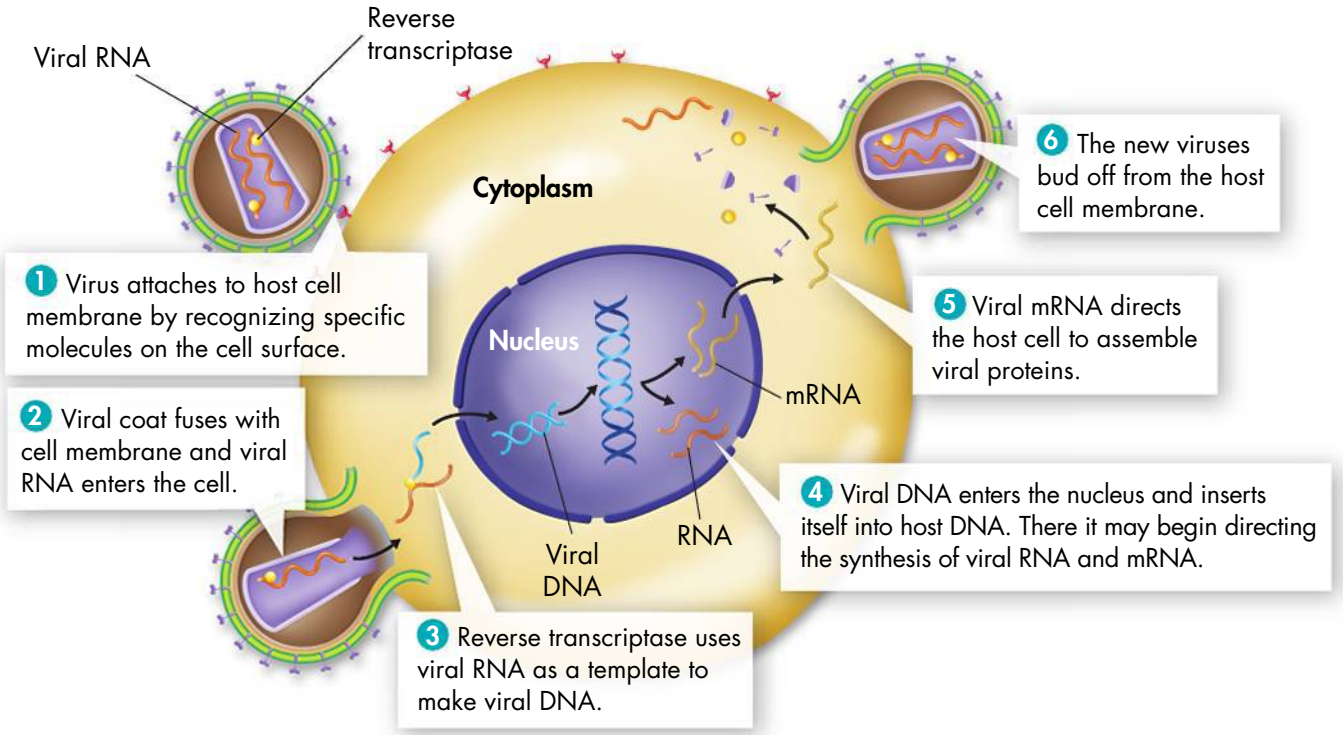
Key Questions

- ***How can misguided immune responses cause problems?***
- ***What causes AIDS and how is it spread?***

BUILD Understanding

Anticipation/Reaction Guide
Before you read this lesson, try to answer the two key questions in your own words. As you read, modify your answers.

In Your Workbook Go to your workbook to complete the Anticipation/Reaction guide for Lesson 35.4.



BUILD Connections

HIV INFECTION

HIV travels through the blood, where it binds to receptors on helper T cells. Inside the cell, the viral DNA directs the cell to make many new viruses. These new viruses are quickly released back into the blood, where they infect more cells.

In Your Workbook Do you know all of the steps of HIV infection? Go to your workbook to find out.

BUILD Vocabulary

allergy an overreaction of the immune system to an antigen

asthma a chronic respiratory disease in which air passages narrow, causing wheezing, coughing, and difficulty breathing

WORD ORIGINS

Allergy comes from the Greek words that mean "different or strange activity." An allergy is a strange or unusual reaction to something that should be harmless to the immune system.

HIV and AIDS

During the late 1970s, doctors began to report that some people were getting very sick from microorganisms that did not usually make people sick. Doctors concluded that these people must have weakened immune systems. Diseases that attack a person with a weakened immune system are called opportunistic diseases. Researchers concluded that these people all had the same disorder. They called it acquired immunodeficiency syndrome (AIDS). Eventually, it was discovered that this "syndrome" was caused by a pathogen new to science.

HIV Researchers discovered the pathogen that causes AIDS in 1983. They called it the human immunodeficiency virus (HIV). HIV is deadly for two reasons. It can hide from the immune system, and it can attack key cells in the immune system. This leaves the body with little protection from other pathogens.

Target: T Cells One of HIV's main targets is helper T cells. Helper T cells are important to the specific immune response. HIV destroys T cells. Eventually, the immune system is unable to fight HIV and other pathogens. When the patient's T cell count drops to about one sixth the normal level, he or she is said to have AIDS.

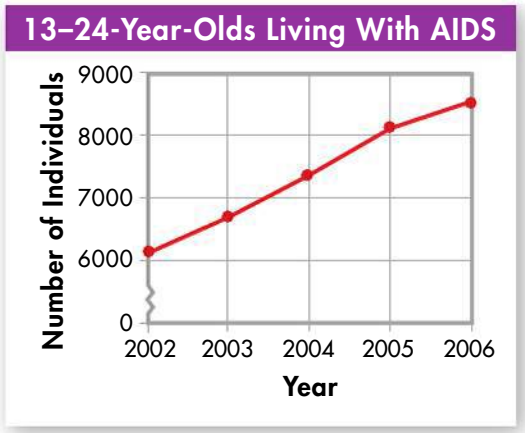
HIV Transmission HIV is deadly. But it does not pass from one person to the next easily. It cannot be passed through coughing, sharing clothes, or any casual contact. HIV can be spread only through contact with infected blood, semen, vaginal secretions, or breast milk.

Preventing HIV Infection You can choose behaviors that reduce your risk of becoming infected with HIV. The only way to be safe from HIV infection is to avoid sexual activity and intravenous drug use. Before 1985, HIV was transmitted to some patients through transfusions of infected blood or blood products. Now that doctors know the cause of HIV, such cases have been virtually eliminated. The blood supply is screened for HIV antibodies. Also, people who engage in certain activities are discouraged from donating blood.

Can AIDS Be Cured? Right now, there is no cure for AIDS. New drugs make it possible to survive HIV infection for years. However, HIV mutates and evolves rapidly. There are many strains that are resistant to most drugs.

The only way to control the virus is to use several expensive drugs. These drugs interfere with some of the virus' enzymes. These drugs are allowing more people in the United States to live with HIV rather than to die from it. However, these drugs are not available in many parts of Africa and Asia. Because HIV can now be treated (but not cured), some people have the dangerous misconception that HIV infection is not serious.

Key Question What causes AIDS and how is it spread?
AIDS is caused by HIV, a virus that attacks the immune system. It is spread though contact with infected blood, semen, vaginal secretions, or breast milk.



13–24-Year-Olds Living With AIDS The number of adolescents and young adults infected with HIV in the United States has been rising steadily since 2002.

CHECK Understanding

Apply Vocabulary

Use the highlighted words from the lesson to complete each sentence correctly.

1. An unusually strong immune response to an antigen is called a(n) _____.
2. A chronic respiratory illness that involves wheezing and narrowed air passages is called _____.

Critical Thinking

3. **Apply Concepts** When a person first visits a doctor about asthma symptoms, the doctor is likely to ask the patient to list times and places his or her asthma attacks tend to happen. Why do you think doctors do this?
4. **Infer** Why is it hard for a person with HIV to fight off other infections?
5. **Draw Conclusions** Look again at the graph at the top of this page. What are two conclusions that you can draw regarding the increasing number of adolescents living with AIDS?
6. **Write to Learn** Answer the third clue in the mystery. Consider what the pathogen might do to the immune system.

MYSTERY CLUE

As with HIV, blood tests of patients with the mystery disease showed that patients were making antibodies to a pathogen. What could be a reason the immune system cannot overcome the disease? (Hint: See p. 850.)

BIOLOGY.com Search Lesson 35.4 GO • Lesson Assessment

Pre-Lab: Detecting Lyme Disease

Problem How can a blood test be used to detect Lyme disease?

Materials well plate, permanent marker, white paper, 400-mL beaker, 100-mL beaker, distilled water, micropipettes, test solutions

Lab Manual Chapter 35 Lab

Skills Control Variables, Interpret Data, Draw Conclusions

Connect to the Big idea To maintain homeostasis, your immune system must defend against invasions by harmful pathogens. Some invaders enter the body through bites from insects. For example, a tiny deer tick can infect you with the bacterium that causes Lyme disease. As a precaution, you should avoid areas where deer ticks are active. If you visit a location where ticks are active, wear clothing that covers the skin and check for ticks.

Symptoms for Lyme disease can vary widely, but many people develop a bull's-eye rash at the location of the bite. People who suspect that they have been exposed to the bacteria that cause Lyme disease should consult a medical professional. Blood tests are used to diagnose Lyme disease. In this lab, you will model one of these tests.

Background Questions

a. Review What is an antigen?

b. Review How does the immune system respond to antigens?

c. Explain Why does the presence of antibodies in blood suggest that a person was exposed to an antigen?

Pre-Lab Questions

Preview the procedure in the lab manual.

1. Sequence Use a flowchart to show the order in which the solutions will be added to the well plate.

2. Infer What is the advantage of having a control for a positive test and a control for a negative test?

3. Control Variables Why must you rinse the micropipette with distilled water before adding a different solution to the well plate?

BIOLOGY.com Search Chapter 35 GO

Visit Chapter 35 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video Be careful what you touch as you follow the Untamed Science crew on a journey through human allergies.

Art Review Review characteristics and examples of the different types of pathogens and parasites with this drag-and-drop activity.

Art in Motion View an animation of HIV infecting a cell.

35 CHAPTER Summary

35.1 Infectious Disease

- Infectious diseases are caused by microorganisms. Diseases can be caused by viruses, bacteria, fungi, "protists," and parasites.
- Infectious diseases can be spread through coughing, sneezing, or physical contact. Others spread through body fluids, contaminated food or water. Some diseases can be spread to humans from other animals.

infectious disease (p. 838)
germ theory of disease (p. 838)
vector (p. 840)

35.2 Defenses Against Infection

- Nonspecific defenses against pathogens include skin, hair, tears, and the inflammatory response. Interferons and fever play an important role in the inflammatory response.
- The immune system's specific defenses distinguish between "self" and "nonself" and respond to specific pathogens.
- The body's specific defenses against pathogens are humoral and cell-mediated immunity.

inflammatory response (p. 841)
immune response (p. 842)
antigen (p. 842)
antibody (p. 842)

35.3 Fighting Infectious Disease

- The immune system makes memory B cells and memory T cells in response to the antigen in the vaccination. Vaccination provides active immunity.
- Antibodies produced against a pathogen by other individuals or animals can be used to give temporary passive immunity.
- Public health measures help keep living conditions healthy. Medications can be used to fight pathogens after someone is sick. Antibiotics kill bacteria. Some antiviral medications can slow down viral activity.
- Through human development and the exotic animal trade, people are coming into contact with new animals and pathogens. The misuse of medications has led to the re-emergence of certain diseases.

vaccination (p. 846)
active immunity (p. 846)
passive immunity (p. 846)

35.4 Immune System Disorders

- A strong immune response to harmless antigens can cause allergies, asthma, and autoimmune disease.
- AIDS is caused by HIV, a virus that attacks the immune system. It is spread though contact with infected blood, semen, vaginal secretions, or breast milk.

allergy (p. 849)
asthma (p. 849)

35 CHECK Understanding

Assess the Big idea Homeostasis

Write an answer to the question below.
Q: How does the body fight against invading organisms that may disrupt homeostasis?

Constructed Response

Write an answer to each of the questions below. The answer to each question should be one or two paragraphs long. To help you begin, read the **Hints** below each of the questions.

1. **Animals infected with the virus that causes rabies often salivate a lot and are more likely than healthy animals to bite other animals. Explain how these symptoms may be beneficial to the virus.**

   Hint Some pathogens are transferred by the exchange of bodily fluids.

   Hint Many viruses cannot live outside a host's body.

2. **Describe several ways that infectious diseases may be spread.**

   Hint Infectious diseases are caused by microorganisms, including bacteria, viruses, and fungi. These microorganisms are called pathogens.

   Hint Pathogens are often spread by symptoms of the disease they cause.

3. **Describe the steps in HIV infection.**

   Hint HIV targets helper T cells.

   Hint HIV uses an enzyme called reverse transcriptase to change the functioning of the cell.

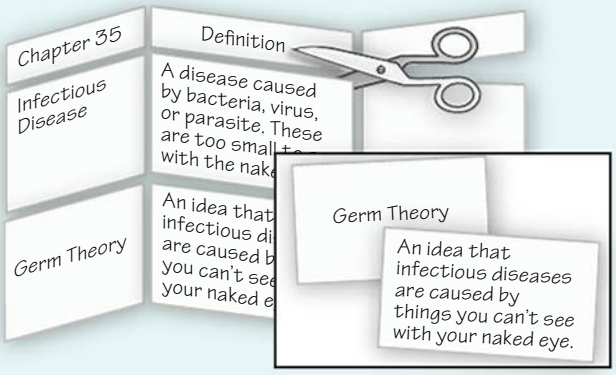
Foundations for Learning Wrap-Up

Use the undercover vocabulary study guide you prepared before reading the chapter as a tool to help you organize your thoughts about homeostasis and the immune system.

Activity 1 Working with a partner, review the definitions you wrote on your undercover vocabulary study guide. If necessary, fill in any missing information and correct any errors. Then, quiz each other about each of the definitions.

Activity 2 Cut apart the vocabulary words and definitions to form two piles of "cards." Then shuffle the cards together. Working with a partner, try to match vocabulary words with their definitions.

Extension: Working with a partner, use the "cards" to make a flowchart describing how the body responds to infection. Challenge yourselves to use as many of the cards as possible.



35.1 Infectious Disease

Understand Key Concepts

1. Anything, including bacteria, viruses, and fungi, that can cause disease is called a(n)

a. antibody. **c.** pathogen.

b. antigen. **d.** vector.

2. Which of the following describes a zoonosis?

a. any disease that can be transmitted through the exchange of bodily fluids

b. any disease that is caused by microorganisms

c. any disease that can be transmitted from animals to humans

d. any disease that disrupts the body's normal functions

Test-Taking Tip

Rephrase the Question You might understand a question better if you rephrase it in your own words. Question 2 asks you to describe *zoonosis*. Rephrase the question to: "Define *zoonosis*." Zoonosis is a disease that can be spread from animals to humans. Answer **c** is the correct choice.

3. What are some things that can prevent the spread of disease?

Think Critically

4. **Compare and Contrast** Compare and contrast harmless microorganisms that live in or on the human body to pathogens.

35.2 Defenses Against Infection

Understand Key Concepts

5. Which of the following structures is NOT involved in the body's first line of defense against infectious disease?

a. skin **c.** T cells

b. hair **d.** tears

6. A nonspecific defense reaction to tissue damage caused by injury or infection is known as

a. the inflammatory response.

b. the immune response.

c. active immunity.

d. passive immunity.

7. Distinguish between humoral immunity and cell-mediated immunity.

Think Critically

8. **Compare and Contrast** How does the secondary response to an antigen differ from the primary response to an antigen?

35.3 Fighting Infectious Disease

Understand Key Concepts

9. Antibodies made by animals are sometimes injected into a human to provide temporary immunity. This kind of immunity is called

a. active immunity. **c.** vaccination.

b. passive immunity. **d.** zoonosis.

10. Who discovered the first antibiotic and how did he discover it?

11. List two public health measures that have reduced the spread of infectious disease.

Think Critically

12. **Apply Concepts** How are human activities such as land-clearing related to the spread of new and re-emerging diseases?

35.4 Immune System Disorders

Understand Key Concepts

13. The main target cells of HIV are

a. mast cells. **c.** B cells.

b. T cells. **d.** red blood cells.

35 CHECK Understanding

14. A strong response by a person's immune system to a harmless antigen is called
    a. cell-mediated immunity.
    b. an allergy.
    c. an antibiotic.
    d. an autoimmune disease.
15. Describe how HIV makes an infected person unable to fight off other infections.

Think Critically

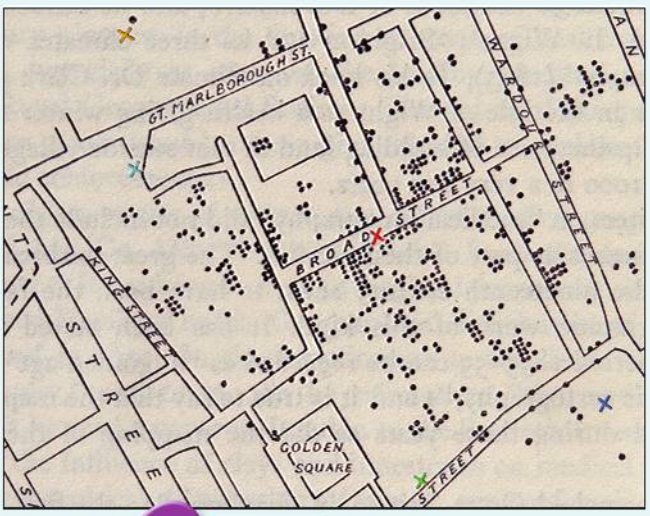
16. **Apply Concepts** Why is a second bee sting more dangerous than the first for a person who is allergic to bee stings?

Connecting Concepts

Use Science Graphics

John Snow made a map similar to the one below to help him determine the source of the cholera outbreak in London in 1854. The dots represent the locations of people who died of cholera. The Xs represent pumps. Use the map to answer questions 17 and 18.

17. **Infer** Which pump do you think Snow determined was most likely the source of the cholera outbreak? Explain.
18. **Apply Concepts** Do you think a map such as this one could be used to discover the source of a food poisoning outbreak? Explain.



solve the CHAPTER MYSTERY

THE SEARCH FOR A CAUSE

Many of the patients suffering from this new disease lived in Lyme, Connecticut. The new disease was named Lyme disease, after the town. A researcher found a bacterium called *Borrelia burgdorferi* in deer ticks. These ticks had been captured in wooded areas near the patients' homes. Steere also found this bacterium in the patients. Could this bacterium be the cause of Lyme disease?

Steere infected healthy mice with the bacterium in his laboratory. The infected mice showed signs of the disease. Steere took bacteria from the sick mice and injected them into healthy mice. This second set of mice also became sick.

Now researchers know that a bite from a deer tick carrying *B. burgdorferi* can spread Lyme disease. The bacteria "swim" through tissues around the tick bites, causing the spreading rash. The bacteria can infect many types of cells. Some of the proteins made by the bacteria look like proteins around human nerve cells. This may cause an autoimmune response that leads to arthritis and other problems.

1. **Explain** What set of rules did Steere use to determine if *B. bergdorferi* was the pathogen responsible for Lyme disease?
2. **Infer** Deer and deer ticks thrive in wooded areas that grow back after the areas have been cleared and at the edges of woodlands. How might suburban development contribute to an increase in Lyme disease?

UntamedScience **Never Stop Exploring Your World.** Finding the solution to this medical mystery is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where this mystery leads.

Standardized Test Prep

Multiple Choice

1. All of the following prevent pathogens from entering the human body EXCEPT
A red blood cells. **C** mucus.
B tears. **D** skin.

2. Which of the following is NOT part of the inflammatory response?
A White blood cells rush to infected tissues.
B Blood vessels near the wound shrink.
C Phagocytes engulf and destroy pathogens.
D The wound becomes red.

3. What is the role of a vector in the spread of disease?
A A vector is an inanimate object, such as a doorknob, where pathogens may collect.
B A vector must infect a host for its life cycle to continue.
C Vectors usually do not suffer from the infection, they just spread it from host to host.
D A vector is a pathogen.

4. Which type of lymphocyte produces antibodies that are released into the bloodstream?
A cytotoxic T cells **C** phagocytes
B helper T cells **D** plasma cells

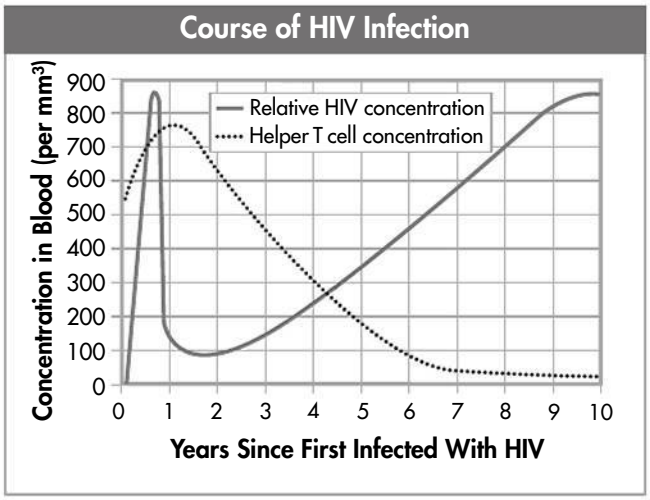
5. Which of the following is NOT a white blood cell?
A interferon **C** cytotoxic T cell
B macrophage **D** lymphocyte

6. Which is an example of naturally occurring passive immunity?
A vaccination
B exposure to a disease
C an infant consuming antibodies in breast milk
D antibodies injected from another person

7. How do medications help a person with asthma?
A They counteract the effects of histamines.
B They suppress the immune system.
C They increase mucus production in the lungs.
D They relax smooth muscles around airways.

Questions 8–9

A researcher measured the concentrations of HIV and T cells in 120 HIV-infected patients over a period of 10 years. Her data are summarized in the graph.



8. What happened to the HIV concentration over years 2 through 9?
A It stayed about the same, then suddenly increased.
B It stayed about the same, then suddenly decreased.
C It steadily increased.
D It steadily decreased.

9. What is probably responsible for the change in HIV concentration during the first year?
A immune response
B inflammatory response
C passive immunity
D HIV stopped replicating

Open-Ended Response

10. Explain why some symptoms of disease such as coughing and sneezing are advantageous to the pathogen that causes the disease.

If You Have Trouble With . . .										
Question	1	2	3	4	5	6	7	8	9	10
See Lesson	35.2	35.2	35.1	35.2	35.2	35.3	35.4	35.4	35.4	35.1

UNIT 8 The Human Body

Unit Project

A Tour Through the Human Body

Have you ever imagined what it would be like to shrink down to microscopic size and tour the inside of the human body? What interesting things would you see and hear? What "dangers" might you encounter?

Your Task Create a travel brochure in which you persuade a person to "visit" the human body. Discuss the various "attractions" inside the body to show how well you understand the systems.

Be sure to

- include at least one attraction for each organ system covered in this unit.
- design the brochure so that it is clear and easy to follow.
- be creative!

Reflection Questions

1. **Score your brochure using the rubric below. What score did you give yourself?**
2. **What did you do well in this project?**
3. **What needs improvement?**
4. **What "attractions" would you choose to visit? Why?**
5. **Exchange travel brochures with a partner. What attractions did he/she include?**

Assessment Rubric

Score	Scientific Content	Quality of Brochure
4	Brochure reveals an exceptionally thorough understanding of the human organ systems.	Brochure is clear, informative, and creative.
3	Brochure reveals a solid understanding of the human organ systems.	Brochure effectively conveys information about various attractions.
2	Brochure reveals a limited understanding of the human organ systems.	Brochure could be more clear and creative. It needs some editing.
1	Brochure reveals significant misunderstandings about the human organ systems.	Brochure is unclear and needs significant editing.