UNIT 7
Invertebrates

THEMES

Scientific Inquiry Biologists continue to study invertebrates with observations and technology.

Diversity Special adaptations enable invertebrates to live in a wide variety of ecosystems.

Energy Food supplies the energy needed to carry out life functions.

Homeostasis Excretory cells and organs maintain homeostasis in invertebrates.

Change Natural selection over a period of time results in newly evolved species of invertebrates.

Chapter 24
Introduction to Animals

Chapter 25
Worms and Mollusks

Chapter 26
Arthropods

Chapter 27
Echinoderms and Invertebrate Chordates



WebQuest

CAREERS IN BIOLOGY

Entomologists are scientists who study insects and their behavioral patterns. Entomologists who conduct research, such as this field entomologist is doing, contribute to a better understanding of the ecosystem's function as a whole.



CHAPTER 24

Introduction to Animals



ConnectED

Your one-stop online resource
connectED.mcgraw-hill.com

- Video
- Audio
- Review
- Inquiry
- WebQuest
- Assessment
- Concepts in Motion
- Multilingual eGlossary

Launch Lab

What is an animal?

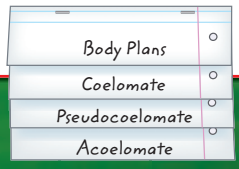
Although animals share some characteristics with all other living organisms, they also have unique characteristics. In this lab, you will compare and contrast two organisms and determine which one is an animal.

For a lab worksheet, use your StudentWorks™ Plus Online.

Inquiry Launch Lab

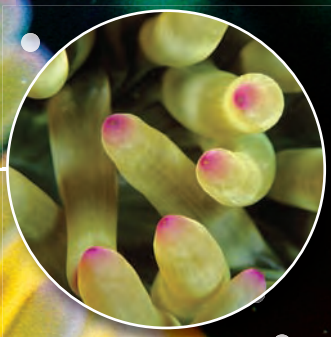
FOLDABLES®

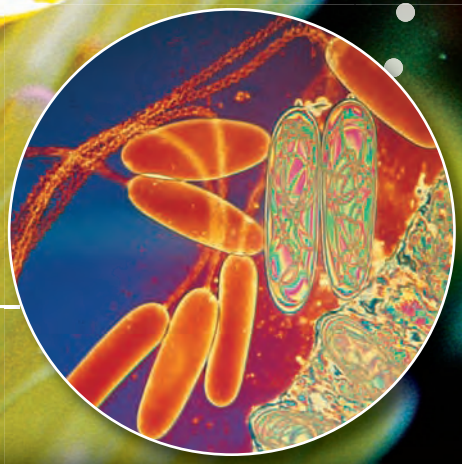
Make a layered-look book using the titles shown. Use it to organize your notes on body plans.



Sea anemone

Sea anemone tentacles





Nematocysts
LM Magnification: 500×

THEME FOCUS Diversity

Animals have a wide variety of characteristics, including body plans and adaptations.

BIG Idea Animal phylogeny is determined in part by animal body plans and adaptations.

Section 1 • Animal Characteristics

Section 2 • Animal Body Plans

Section 3 • Sponges and Cnidarians

Section 1

Reading Preview

Essential Questions

- How do adaptations enable animals to live in different habitats?
- How is structure and function related in animals?
- What are the stages of embryonic development in animals?

Review Vocabulary

protist: diverse group of unicellular or multicellular eukaryotes that lack complex organ systems and live in moist environments

New Vocabulary

invertebrate
exoskeleton
endoskeleton
vertebrate
hermaphrodite
zygote
internal fertilization
external fertilization
blastula
gastrula
endoderm
ectoderm
mesoderm

Multilingual eGlossary

Animal Characteristics

MAIN Idea **Animals are multicellular, eukaryotic heterotrophs that have evolved to live in many different habitats.**

Real-World Reading Link When you think of animals, you might think of creatures that are furry and fuzzy. However, animals can have other outer coverings, such as feathers on birds and scales on fishes. Some animals even might be mistaken for plants.

General Animal Features

Recall that biologists have created an evolutionary tree to organize the great diversity of living things. The ancestral animals at the beginning of the evolutionary tree are eukaryotic and multicellular—they are made up of many cells. The tiger in **Figure 1** and all other present-day animals might have evolved from choanoflagellates (KOH uh noh FLA juh layts), which are protists that formed colonies in the sea 570 million years ago. Choanoflagellates, such as the ones shown in **Figure 1,** might have been the earliest true animals. As animals evolved from this multicellular ancestor, they developed adaptations in structure that enabled them to function in numerous habitats. These features mark the branching points of the evolutionary tree and are discussed in the next section. In this section, you will learn about the characteristics that all animals have in common.

Feeding and Digestion

Animals are heterotrophic, so they must feed on other organisms to obtain nutrients. A sea star obtains its food from a clam it has pried open, and a butterfly feeds on nectar from a flower. The structure or form of an animal's mouth parts determines how its mouth functions. You can investigate how some animals obtain food by performing **MiniLab 1.** After obtaining their food, animals must digest it. Some animals, such as sponges, digest their food inside specific cells. Others, such as earthworms and humans, digest their food in internal body cavities or organs.

Figure 1 Present-day animals, such as this Bengal tiger, might have evolved from choanoflagellates such as this colony of *Zoothamnium*.



Bengal tiger

LM Magnification: 50×



Colony of *Zoothamnium*

Support

Just as animals digest their food in different ways, they support their bodies in different ways. Between 95 and 99 percent of animal species are **invertebrates**—animals without backbones. The bodies of many invertebrates are covered with **exoskeletons,** which are hard or tough outer coverings that provide a framework of support. Exoskeletons also protect soft body tissues, prevent water loss, and provide protection from predators. As the animal grows, like the cicada in **Figure 2,** it must shed the old exoskeleton and make a new one. This process is called molting.

Some invertebrates, such as sea urchins and sea stars, have internal skeletons called **endoskeletons.** If an animal has an endoskeleton and a backbone, it is called a **vertebrate.** An endoskeleton grows with the animal, like the squirrel in **Figure 2.** The material making up the endoskeleton varies. Sea urchins and sea stars have endoskeletons made of calcium carbonate, sharks have endoskeletons made of cartilage, and fishes, amphibians, reptiles, birds, and mammals have endoskeletons made of bone. An endoskeleton protects internal organs, provides support for the body, and can provide an internal brace for muscles to pull against.

Reading Check **Distinguish** between vertebrates and invertebrates.

Habitats

Animal bodies have a variety of adaptations, such as those for feeding, digestion, and support. These body variations enable animals to live in numerous habitats. Vertebrates and invertebrates live in oceans, in freshwater, and on land. They can be found in deserts, grasslands, rain forests, polar regions, and all other land biomes and aquatic ecosystems.



Cicada



Squirrel

Figure 2 A cicada must shed its old exoskeleton (outlined in white) in order to grow. A squirrel has an endoskeleton that grows as the squirrel grows.
Infer *how an exoskeleton might be a disadvantage for animals.*

MiniLab 1

Investigate Feeding in Animals

Inquiry MiniLab

How do animals obtain food? Small aquatic animals called hydras consume brine shrimp as their food source.

Procedure

1. Read and complete the lab safety form.
2. Obtain several **hydras** in a **plastic Petri dish** containing **water.**
3. Add several **brine shrimp** to the dish. Using a **hand lens or stereomicroscope,** observe the activity of the hydras.
4. Record your observations.

Analysis

1. **Draw Conclusions** Based on your observations, how do the hydras react to the food?
2. **Infer** What factors in their environment might influence how the hydras find food?

CAREERS IN BIOLOGY

Systematist Using observation, inference, and the latest technology, a systematist classifies new species based on evolutionary relationships.

Animal Cell Structure

No matter where an animal lives or what adaptations it has, its cells do not have cell walls. Recall that plants also are multicellular organisms, but their cells have cell walls. The cells of all animals, except sponges, are organized into structural and functional units called tissues. A tissue is a group of cells that is specialized to perform a specific function. For example, nerve tissue is involved in the transmission of nerve impulses throughout the body and muscle tissue enables the body to move.

Connection to History Beginning with Aristotle in the fourth century B.C. and continuing into the nineteenth century, living organisms were classified into two kingdoms—Animalia (animals) and Plantae (plants). In 1866, Ernst Haeckel, a German scientist, proposed adding a third kingdom called Protista. The organisms in this kingdom are mainly unicellular eukaryotes. Some protists have cell walls, while others do not, making them neither plant nor animal. During the 1960s, as more was learned about cell structure, bacteria and fungi were placed into their own kingdoms. **Figure 3** illustrates how the classification of living things continues to develop.

Movement

The evolution of nerve and muscle tissues enables animals to move in ways that are more complex and faster than organisms in other kingdoms. This is one notable characteristic of the animal kingdom. A gecko running across a ceiling, a mosquito buzzing around your ear, and a school of minnows swimming against the current are all exhibiting movements unique to animals. Some animals are stationary as adults, yet most have a body form that can move during some stage of development.

Figure 3

History of Classification

The process of scientifically classifying organisms began in 350 B.C. when Aristotle, a Greek philosopher, placed organisms into two large groups—plant and animal. Advances in scientific knowledge and technology helped develop the classification system we use today.

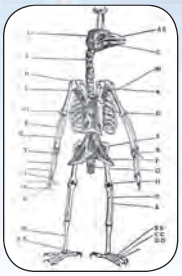
Concepts in Motion

The Interactive Timeline



1735 Biologist Carolus Linnaeus devises a classification system for all organisms using Latin binomial nomenclature.

1500 | 1600 | 1700 | 1800



1555 The book *L'Histoire de la Nature des Oyseaux* (Natural History of Birds) uses body form and structures to classify species.

1682 Naturalist John Ray establishes the use of species as the basic unit of classification.

1859 Naturalist Charles Darwin proposes the classification of organisms based on their shared ancestry.

Reproduction

Most animals reproduce sexually, although some species can reproduce asexually. Most commonly in sexual reproduction, male animals produce sperm and female animals produce eggs. Some animals, such as earthworms, are **hermaphrodites** (hur MAF ruh dites), which produce both eggs and sperm in the same animal body. In general, hermaphrodites produce eggs and sperm at different times, so another individual of the same species still is needed for sexual reproduction.

Fertilization occurs when the sperm penetrates the egg to form a fertilized egg cell called the **zygote** (ZI goht). Fertilization can be internal or external. **Internal fertilization** occurs when the sperm and egg combine inside the animal's body. For example, male turtles fertilize the eggs of the female internally. **External fertilization** occurs when egg and sperm combine outside the animal's body. This process requires an aquatic environment for the sperm to swim to the egg. In many fishes, the female lays eggs in the water and the male sheds sperm over the eggs, as shown in **Figure 4.**

Recall that asexual reproduction means that a single parent produces offspring that are genetically identical to itself. Although few animal species reproduce asexually, when they do, they use one or more methods to do so. Some of the common methods of asexual reproduction follow.

- budding—an offspring develops as a growth on the body of the parent
- fragmentation—the parent breaks into pieces and each piece can develop into an adult animal
- regeneration—a new organism can regenerate, or regrow, from the lost body part if the part contains enough genetic information
- parthenogenesis (par thuh noh JE nuh sus)—a female animal produces eggs that develop without being fertilized

Reading Check **Infer** the advantages and disadvantages of asexual reproduction in animals.



Figure 4 Fertilization is external in some fishes. In the photo, strands of sperm are being shed over eggs laid in the water.

Infer *why animals lay a large number of eggs when fertilization is external.*



1977 Microbiologist Carl Woese uses ribosomal RNA to show the evolutionary relationships among organisms.

2003 Paleontologists find feathered dinosaur fossils that might alter the classification of some species.

1900

2000

1891 Marine zoologist Mary Jane Rathbun begins establishing the basic taxonomic information on crustaceans.

1982 Biologist Lynn Margulis is instrumental in reorganizing and improving the classification of organisms into the current five kingdoms.

2009 A partial skull fossil of *Homo floresiensis* causes debate among scientists as they work to determine if it is an early *Homo sapiens* or a new species.

Vocabulary

Word origin

Gastrula

gastr– prefix; from Greek; meaning *stomach* or *belly*

–ula suffix; from Latin; meaning *resembling*

Early development In most animals, the zygote undergoes mitosis and a series of cell divisions to form new cells. After the first cell division, in which the zygote forms two cells, the developing animal is called an embryo. The embryo continues to undergo mitosis and cell division, forming a solid ball of cells. These cells continue to divide, forming a fluid-filled ball of cells called the **blastula** (BLAS chuh luh), as shown in **Figure 5.** During these early stages of development, the number of cells increases, but the total amount of cytoplasm in the embryo remains the same as that in the original cell. Therefore, the total size of the embryo does not increase during early development.

In animals such as lancelets, the outer blastula is a single layer of cells, while in animals such as frogs, there might be several layers of cells surrounding the fluid. The blastula continues to undergo cell division. Some cells move inward to form a **gastrula** (GAS truh luh), a two-cell-layer sac with an opening at one end. A gastrula looks like a double bubble, one bubble inside another bubble.

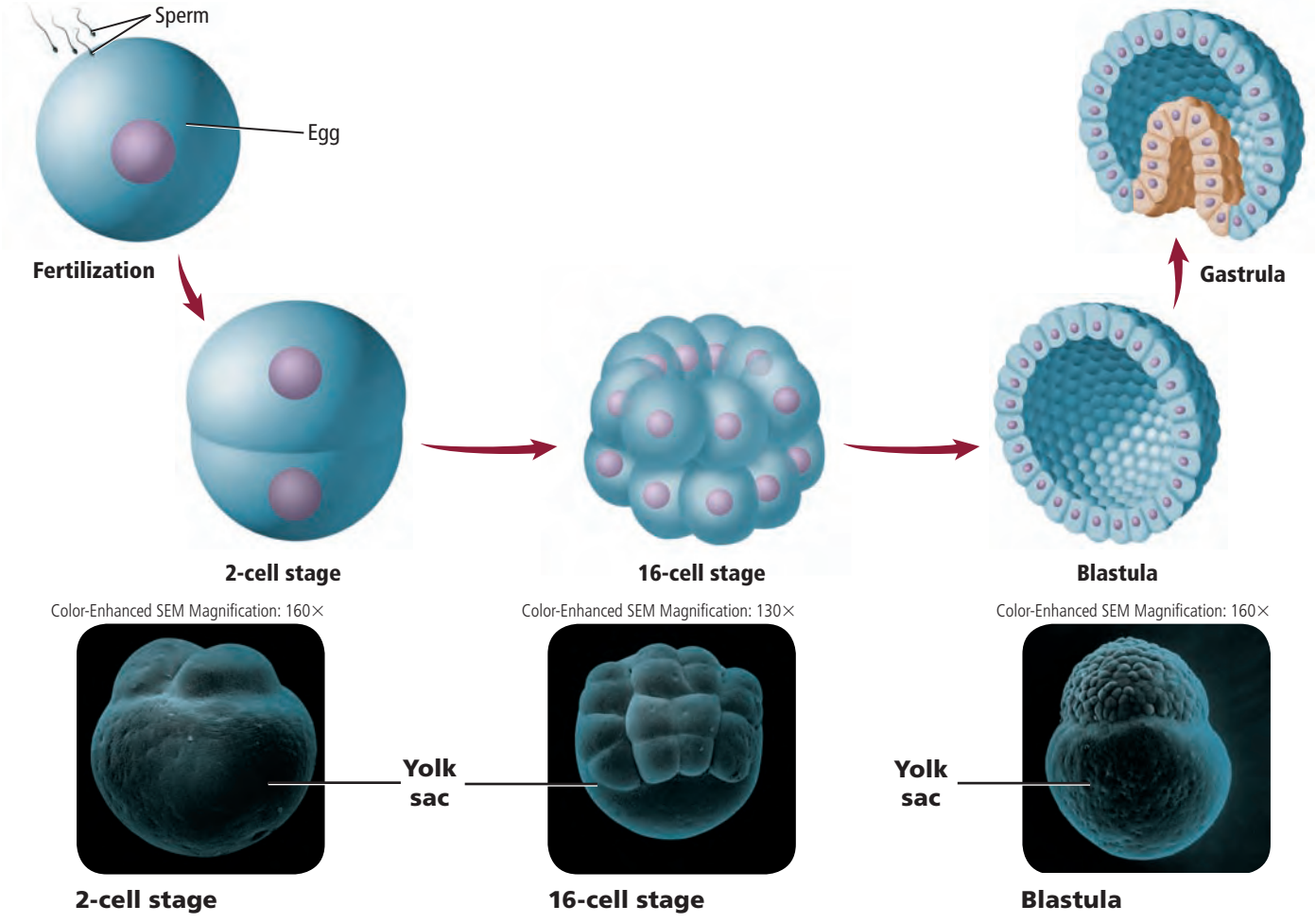
Look again at **Figure 5.** Notice how the diagrams of the two-cell stage, the 16-cell stage, and the blastula differ from the photographs of these same stages. The diagrams illustrate early development in embryos that develop inside the adult animal. The photographs illustrate early development in embryos that develop outside of the adult animal. The large ball that does not divide is the yolk sac. It provides food for the developing embryo.

Reading Check **Explain** the differences between the blastula and the gastrula.

Figure 5 The fertilized eggs of most animals follow a similar pattern of development. Beginning with one fertilized egg cell, cell division occurs and a gastrula is formed.

Concepts in Motion

Animation



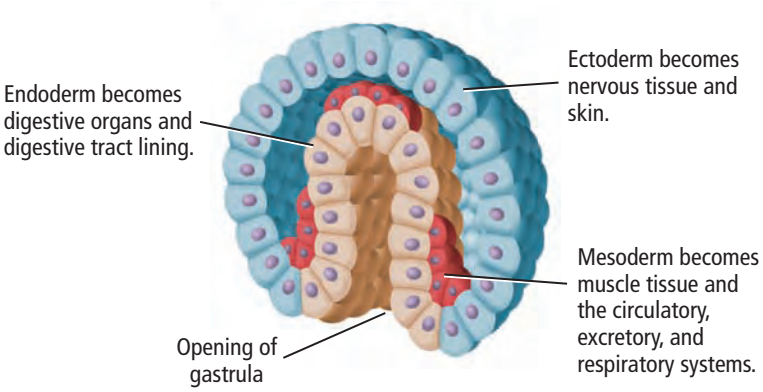


Figure 6 As development continues, each cell layer differentiates into specialized tissues.

Tissue development Notice in **Figure 6** that the inner layer of cells in the gastrula is called the **endoderm.** The endoderm cells develop into the digestive organs and the lining of the digestive tract. The outer layer of cells in the gastrula is called the **ectoderm.** The ectoderm cells in the gastrula continue to grow and become the nervous tissue and skin.

Cell division in some animals continues in the gastrula until another layer of cells, called the **mesoderm,** forms between the endoderm and the ectoderm. In some animals, the mesoderm forms from cells that break away from the endoderm near the opening of the gastrula. In more highly evolved animals, the mesoderm forms from pouches of endoderm cells on the inside of the gastrula. As development continues, mesoderm cells become muscle tissue, the circulatory system, the excretory system, and, in some species of animals, the respiratory system.

Remember that Hox genes might be expressed in ways that give proteins new properties that cause variations in animals. Much of the variation in animal bodies is the result of changes in location, number, or time of expression of Hox developmental genes during the course of tissue development.

Inquiry **Launch Lab**

Review **Based on what you have read about animal characteristics, how would you now answer the analysis questions?**

Section 1 Assessment

Section Summary

- Animals are heterotrophs and must get their nutrients from other organisms.
- Animals have diverse means of support and live in diverse habitats.
- Animal cells do not have cell walls, and most have cells that are organized into tissues.
- Most animals undergo sexual reproduction, and most can move.
- During embryonic development, animal cells become tissue layers, which become organs and systems.

Understand Main Ideas

1. MAIN Idea **Infer** why colonial organisms that lived grouped together might have been one of the first steps toward multicellular organisms in the course of evolution.
2. **Infer** how an exoskeleton enables invertebrates to live in a variety of habitats.
3. **Describe** how the evolution of nerve and muscle tissue is related to one of the main characteristics of animals.
4. **Diagram** how an animal zygote becomes a gastrula.

Think Critically

5. **Model** the stages of cell differentiation in embryonic development by comparing them to pushing in the end of a balloon. Draw a diagram of this process and label it with the stages of cell differentiation.

MATH in Biology

6. Biologists have observed that it is common for an animal that doubles its mass to increase its length 1.26 times. Suppose an animal has a mass of 2.5 kg and is 30 cm long. If this animal grows to a mass of 5 kg, how long will it be?

Assessment **Online Quiz**

Section 2

Reading Preview

Essential Questions

- How are animal body plans related to phylogeny?
- How are body cavities related to animal phylogeny?
- What are the two types of coelomate development?

Review Vocabulary

phylogeny: evolutionary history of a species based on comparative relationships of structures and comparisons of modern life-forms with fossils

New Vocabulary

symmetry
radial symmetry
bilateral symmetry
anterior
posterior
cephalization
dorsal
ventral
coelom
pseudocoelom
acoelomate
protostome
deuterostome

Multilingual eGlossary

Animal Body Plans

MAIN Idea **Animal phylogeny can be determined, in part, by body plans and the ways animals develop.**

Real-World Reading Link People often classify or group things based on what they have in common. If you want to rent an action movie, you would look in the action movie section at the store. You would not find comedies or dramas in this section. In biology, animals generally are classified into groups because they have some of the same features.

Evolution of Animal Body Plans

Recall that the evolutionary tree is organized like a family tree, and the phylogeny of animals is represented by the branches. For example, all of the mammals in **Figure 7** belong on the chordate branch of the tree. The trunk represents the earliest animals and the branches represent the probable evolution of the major phyla of animals from a common ancestor, as shown in **Figure 8.**

Anatomical features in animals' body plans mark the branching points on the evolutionary tree. For example, animals without tissues are grouped separately from animals with tissues, and animals without segments are grouped separately from animals with segments. The relationships among animals on this tree are inferred by studying similarities in embryological development and shared anatomical features. This traditional phylogeny, with animals classified into 35 phyla, is still used by most taxonomists. However, molecular data suggest other relationships among animals. Recent molecular findings, based on comparisons of DNA, ribosomal RNA, and proteins, indicate that the relationships between arthropods and nematodes and between flatworms and rotifers might be closer than anatomical features suggest.

Reading Check **Summarize** the structure of an evolutionary tree.

Figure 7 Although these animals look very different from each other, they all have features that place them on the chordate branch of the evolutionary tree.



Mouse



Ferret



Chimpanzee

Development of Tissues

As animals evolved from the first multicellular forms, the first anatomical feature to indicate a major change in body plan was the development of tissues. Therefore, tissues mark the first branching point on the evolutionary tree. Notice in **Figure 8** that the only animals without tissues are sponges. These animals descended from a common ancestor that lacked tissues, and they are on the no-true-tissue branch of the evolutionary tree. Follow the tissue branch of the evolutionary tree, and you will see that all other phyla have tissues.

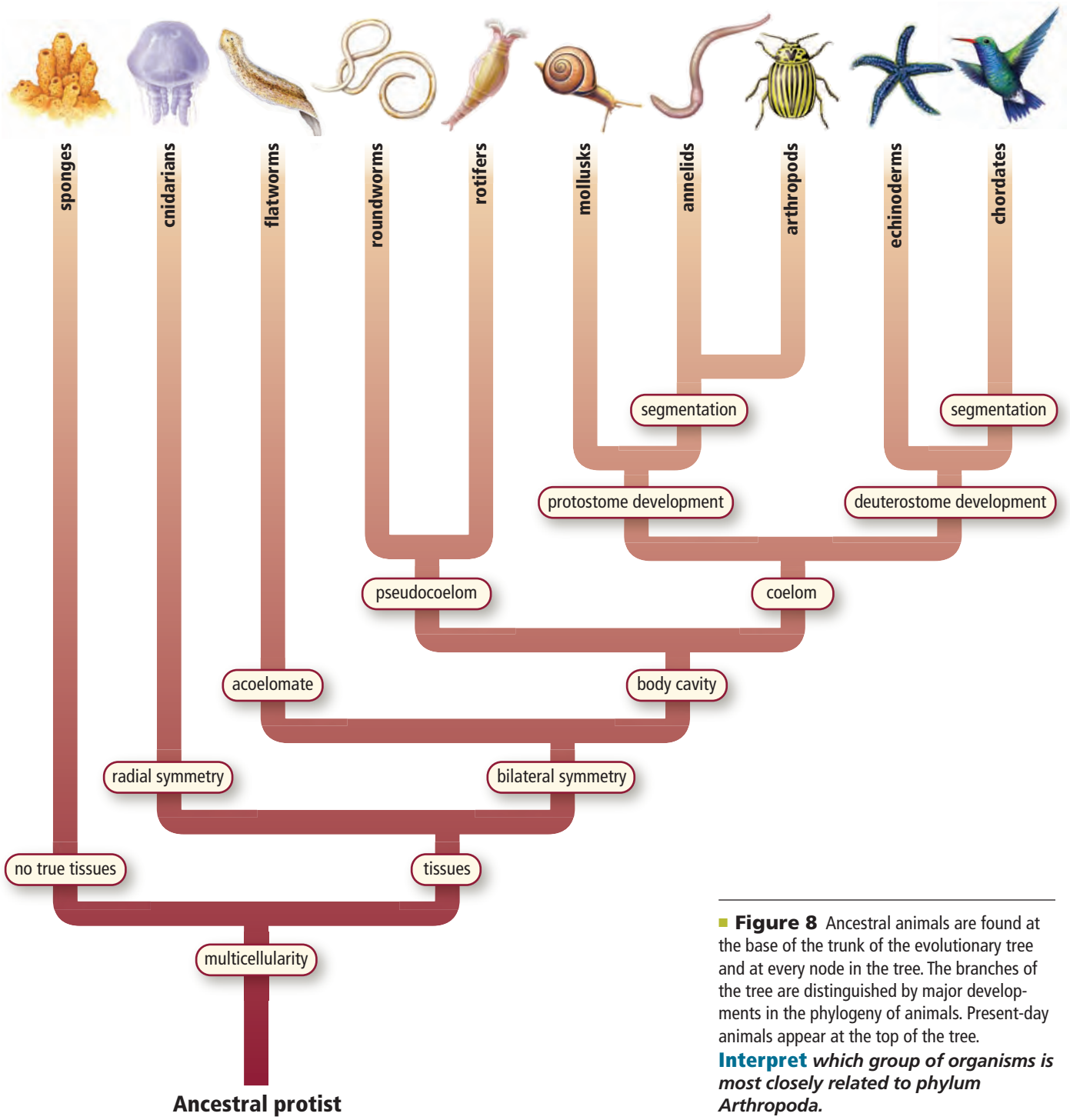
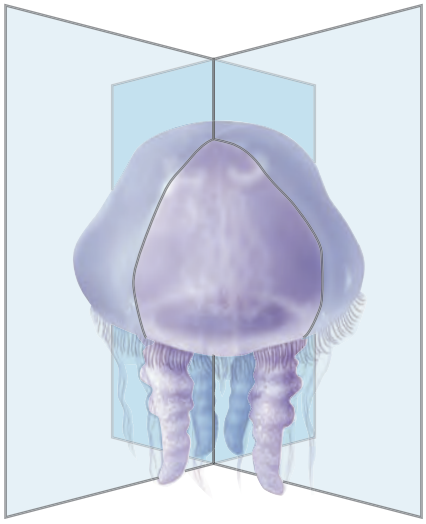


Figure 8 Ancestral animals are found at the base of the trunk of the evolutionary tree and at every node in the tree. The branches of the tree are distinguished by major developments in the phylogeny of animals. Present-day animals appear at the top of the tree.

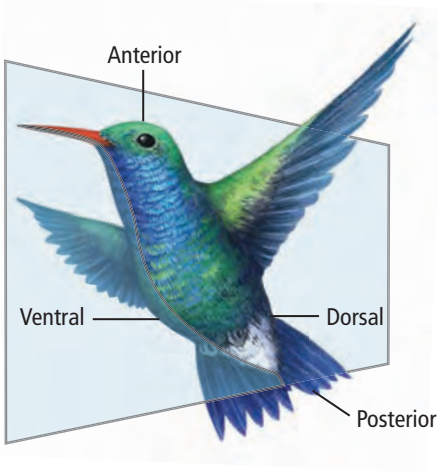
Interpret *which group of organisms is most closely related to phylum Arthropoda.*



Sponge—asymmetry



Jellyfish—radial symmetry



Hummingbird—bilateral symmetry

■ **Figure 9** Animals have different arrangements of body structures. The sponge has an irregular shape and is asymmetrical. The jellyfish has radial symmetry, and the hummingbird has bilateral symmetry.

List ***objects in the classroom that have bilateral symmetry.***

Review Personal Tutor

Video BrainPOP

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Plane

Science usage: an imaginary line that divides a body form into two parts
The dog can be divided into its ventral and dorsal parts by a plane.

Common usage: an aircraft
The pilot flew the plane from Cleveland to Chicago.

Symmetry

Move along the tissue branch on the evolutionary tree in **Figure 8,** and you will find the next branching point to be symmetry. **Symmetry** (SIH muh tree) describes the similarity or balance among body structures of organisms. The type of symmetry an animal has enables it to move in certain ways.

Asymmetry The sponge in **Figure 9** has no tissue and has asymmetry. It is irregular in shape and has no symmetry or balance in its body structures. In contrast, animals with tissues have either radial or bilateral symmetry.

Radial symmetry An animal with **radial** (RAY dee uhl) **symmetry** can be divided along any plane, through a central axis, into roughly equal halves. The jellyfish in **Figure 9** has radial symmetry. Its tentacles radiate from its mouth in all directions, a body plan adapted to detecting and capturing prey moving in from any direction. Jellyfishes and most other animals with radial symmetry develop from only two embryonic cell layers—the ectoderm and the endoderm.

Bilateral symmetry The bird in **Figure 9** has bilateral symmetry. In contrast to radial symmetry, **bilateral** (bi LA tuh rul) **symmetry** means the animal can be divided into mirror image halves only along one plane through the central axis. All animals with bilateral symmetry develop from three embryonic cell layers—the ectoderm, the endoderm, and the mesoderm.

Cephalization Animals with bilateral symmetry also have an **anterior,** or head end, and a **posterior,** or tail end. This body plan is called **cephalization** (sef uh luh ZA shun)—the tendency to concentrate nervous tissue and sensory organs at the anterior end of the animal. Most animals with cephalization move through their environments with the anterior end first, encountering food and other stimuli. In addition to cephalization, animals with bilateral symmetry have a **dorsal** (DOR sul) surface, also called the backside, and a **ventral** (VEN trul) surface, also called the underside or belly.

Body Cavities

In order to understand the next branching point on the evolutionary tree, it is important to know about certain features of animals with bilateral symmetry. Body plans of animals with bilateral symmetry include the gut, which is either a sac inside the body or a tube that runs through the body, where food is digested. A saclike gut has one opening, a mouth, for taking in food and disposing of wastes. A tubelike gut has an opening at both ends, mouth and an anus, and is a complete digestive system that digests, absorbs, and stores food, and disposes of waste.

Coelomates Between the gut and the outside body wall of most animals with bilateral symmetry is a fluid-filled body cavity. One type of fluid-filled cavity, the **coelom** (SEE lum), shown in **Figure 10,** has tissue formed from mesoderm that lines and encloses the organs in the coelom. You have a coelom, as do insects, fishes, and many other animals. Therefore, you are a coelomate. The coelom was a key adaptation in the evolution of larger and more specialized body structures. Specialized organs and body systems that formed from mesoderm developed in the coelom. As more efficient organ systems evolved, such as the circulatory system and muscular system, animals could increase in size and become more active.

Pseudocoelomates Follow the body cavity branch on the evolutionary tree in **Figure 8** until you come to the pseudocoelomates, which are animals with pseudocoeloms. A **pseudocoelom** (soo duh SEE lum) is a fluid-filled body cavity that develops between the mesoderm and the endoderm rather than developing entirely within the mesoderm as in coelomates. Therefore, the pseudocoelom, as shown in **Figure 10,** is lined only partially with mesoderm. The body cavity of pseudocoelomates separates mesoderm and endoderm, which limits tissue, organ, and system development.

Acoelomates Before the body cavity branch on the evolutionary tree in **Figure 8,** notice that the branch to the left takes you to the acoelomate animals. **Acoelomates** (ay SEE lum ayts), such as the flatworm in **Figure 10,** are animals that do not have a coelom. The body plan of acoelomates is derived from ectoderm, endoderm, and mesoderm—the same as in coelomates and pseudocoelomates. However, acoelomates have solid bodies without a fluid-filled body cavity between the gut and the body wall. Nutrients and wastes diffuse from one cell to another because there is no circulatory system.

Review Personal Tutor

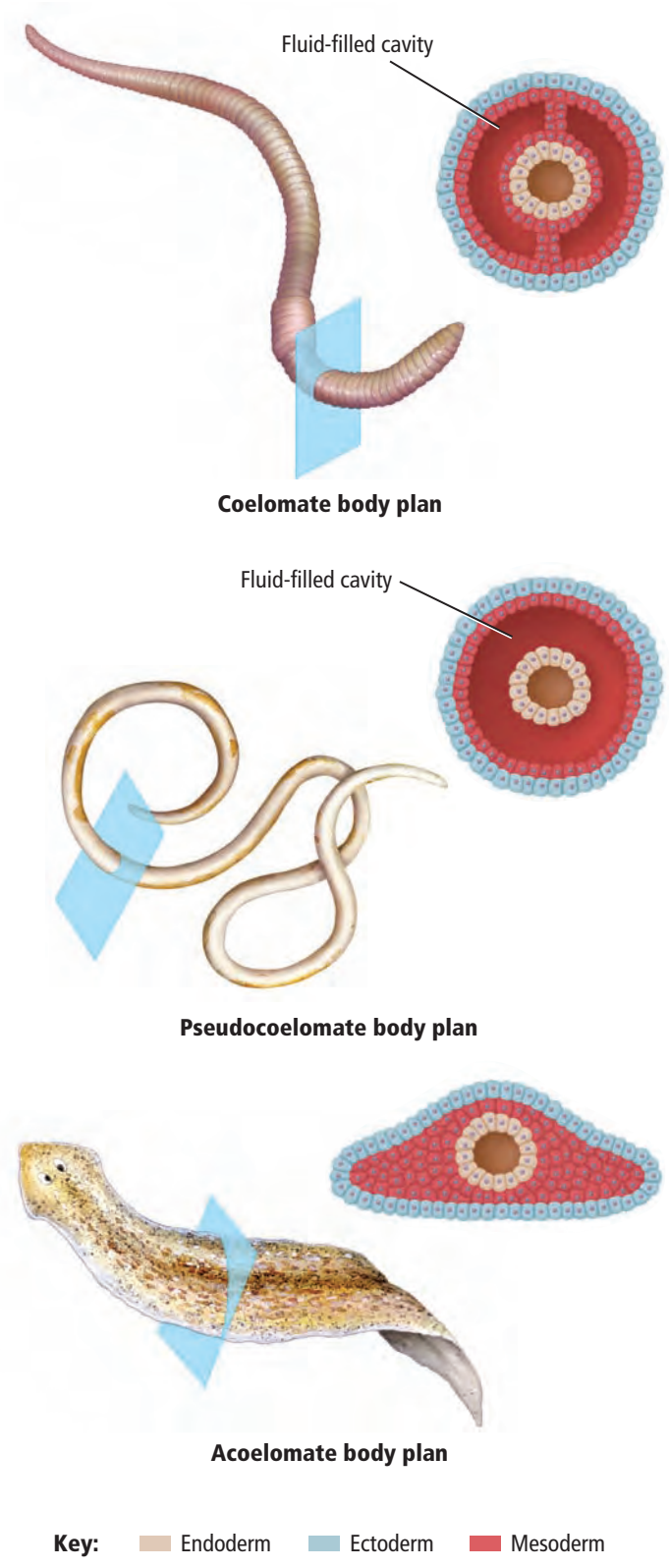


Figure 10 An earthworm has a coelom, a fluid-filled body cavity surrounded completely by mesoderm. The pseudocoelom of a roundworm develops between the mesoderm and endoderm. A flatworm has a solid body without a fluid-filled cavity.

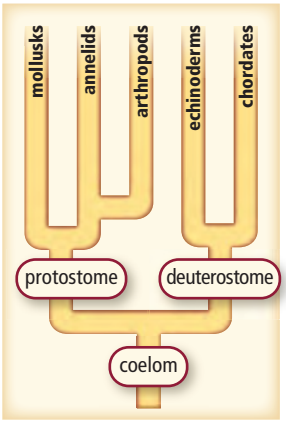


Figure 11 This part of the evolutionary tree shows that protostomes and deuterostomes are branches of coelomate animals.

Development in Coelomate Animals

The evolutionary tree in **Figure 11** begins at the coelomate branch. Notice that two major lines of development have been identified in coelomate animals. One is protostome development, which occurs in animals such as snails, earthworms, and spiders. The other is deuterostome development, which occurs in animals such as sea urchins, dogs, and birds. Biologists can tell if animals are closely related based on their patterns of embryonic development.

Protostomes In organisms that are **protostomes** (PROH tuh stohms), the mouth develops from the first opening in the gastrula. As protostomes develop, the final outcome for each cell in the embryo cannot be altered. If one cell of the embryo is removed, the embryo will not develop into a normal larva, as shown in **Figure 12.** In addition, in the eight-cell stage of embryonic development, the top four cells are offset from the bottom four cells, giving the embryo a spiral appearance. As the embryo continues to develop, the mesoderm splits down the middle. The cavity between the two pieces of mesoderm becomes the coelom.

Deuterostomes In organisms that are **deuterostomes** (DEW tihr uh stohms), the anus develops from the first opening in the gastrula. The mouth develops later from another opening of the gastrula. During the development of deuterostomes, the final outcome for each cell in the embryo can be altered. In fact, each cell in the early embryo, if removed, can form a new embryo, as shown in **Figure 12.** In contrast to protostome development, in the eight-cell stage of embryonic deuterostome development the top four cells are directly aligned on the bottom four cells. As the embryo develops, the coelom forms from two pouches of mesoderm.

Reading Check **Determine** whether you are classified as a protosome or a deuterostome. Explain.

MiniLab 2

Examine Body Plans

Inquiry MiniLab

What is the importance of a body plan? One way to classify animals is by body plan. Looking at cross sections of different animals can help you distinguish between the different body plans.

Procedure

1. Read and complete the lab safety form.
2. Obtain **prepared slides of cross sections of an earthworm and a hydra.** Using a **microscope,** observe each slide under low-power magnification.
3. Sketch each cross section.
4. Obtain **labeled diagrams of cross sections of each animal** from your teacher. Make a list of how your sketches are like the diagrams and another list of how they are different.

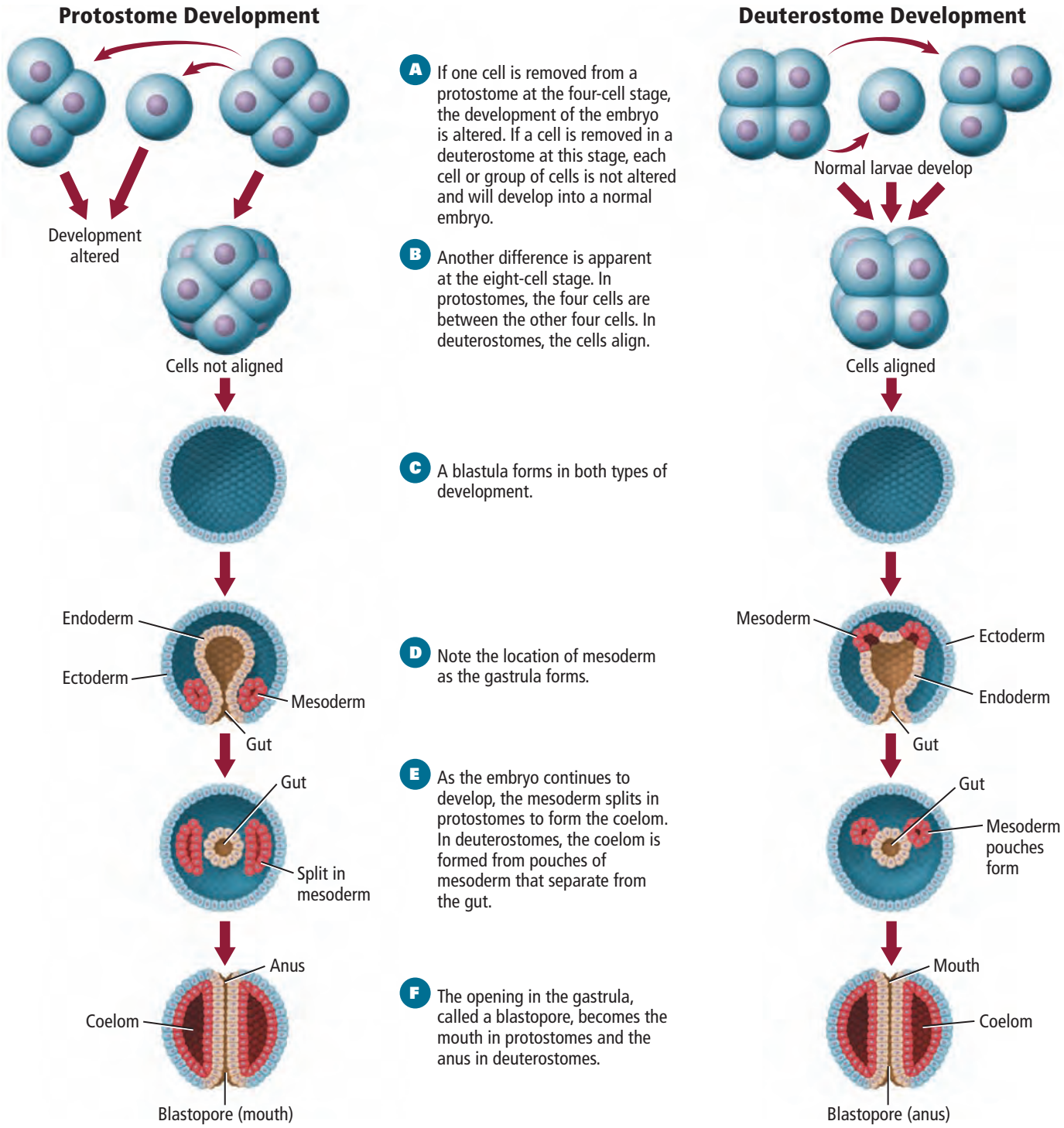
Analysis

1. **Compare and contrast** each animal's type of body cavity. Are they acoelomate or coelomate? What do your observations tell you about the phylogeny of these animals?
2. **Infer** how the body plan of each animal is related to how each of these animals obtains food.

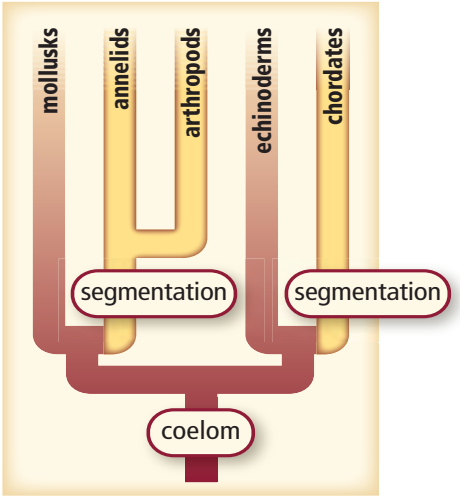
Visualizing Protostome and Deuterostome Development

Figure 12

Developmental differences characterize protostome and deuterostome development.



Concepts in Motion Animation





Scorpion

■ **Figure 13** Segmentation enables a scorpion to move its stinger in different directions to attack prey or for defense.

Segmentation

Examine the next branching point on the evolutionary tree in **Figure 13.** Segmentation is an important feature in the evolution of coelomate animals. Just as a chain is constructed from a series of links, segmented animals can be "put together" from a succession of similar parts.

The segmentation, such as that seen in scorpions, has two advantages. First, segmented animals can survive damage to one segment because other segments might be able to carry out the damaged section's function. Second, movement is more effective because segments can move independently. Therefore, the scorpion in **Figure 13** has more flexibility and can move in ways that are very complex. Segments allow the scorpion to arch its tail over its back to sting prey.

Section 2 Assessment

Section Summary

- Animal phylogeny can be compared to a tree with branches.
- The branches of a phylogenetic evolutionary tree show the relationships among animals.
- Animal phylogeny can be determined, in part, by the animal's type of body cavity or lack of a body cavity.
- After gastrulation, two types of development can occur in coelomate animals.
- Segmentation is an important feature in some coelomate animals.

Understand Main Ideas

1. MAIN Idea **Explain** how body symmetry is related to the phylogeny of animals.
2. **Name** the features marking the main branching points on the evolutionary tree of animals.
3. **Illustrate** how body cavities distinguish branches of development of animals with bilateral symmetry.
4. **Compare and contrast** deuterostome and protostome development.

Think Critically

5. **Diagram** animals not shown in **Figure 9** that have radial and bilateral symmetry. Indicate the type of symmetry by showing planes passing through the animals. Label each animal as having either radial or bilateral symmetry.

WRITING in Biology

6. Write a paragraph summarizing the differences among coelomates, pseudocoelomates, and acoelomates.

Assessment Online Quiz

Section 3

Reading Preview

Essential Questions

- What are the characteristics of sponges and cnidarians?
- How are sponges and cnidarians alike and different?
- What is the ecological importance of sponges and cnidarians?

Review Vocabulary

diploid: cell with two of each kind of chromosome

New Vocabulary

filter feeder
sessile
cnidocytes
nematocyst
gastrovascular cavity
nerve net
polyp
medusa

Multilingual eGlossary

Sponges and Cnidarians

MAIN Idea **Sponges and cnidarians were the first animals to evolve from a multicellular ancestor.**

Real-World Reading Link Have you ever double-bagged your groceries? If so, you have an idea of how a sponge is structured—a layer, or sac, of cells within another sac of cells. These sacs of cells are among the first animals to evolve from the common ancestor of all animals.

Sponges

If you examine a living sponge, you might wonder how these animals do so much with so little. They have no tissues, no organs, and most have no symmetry. You can break apart a sponge into its individual cells and those cells will come together again to form a sponge. Other animals cannot do this.

Locate sponges on the evolutionary tree in **Figure 14.** They are in the phylum Porifera (po RIF uh ruh), which contains between 5000 and 10,000 members. Most live in marine environments. Biologists hypothesize that sponges evolved from the colonial choanoflagellates because sponges have cells that look similar to these protist cells.

Body structure Notice the asymmetrical appearance and bright colors of the sponge in **Figure 14.** It is difficult to think that these are animals, especially if you see one washed up on a beach where it might appear as a black blob. Recall that tissues form from ectoderm, endoderm, and mesoderm in a developing embryo. Sponge embryos do not develop endoderm or mesoderm, and, therefore, sponges do not develop tissues. How does a sponge's body function without tissues?

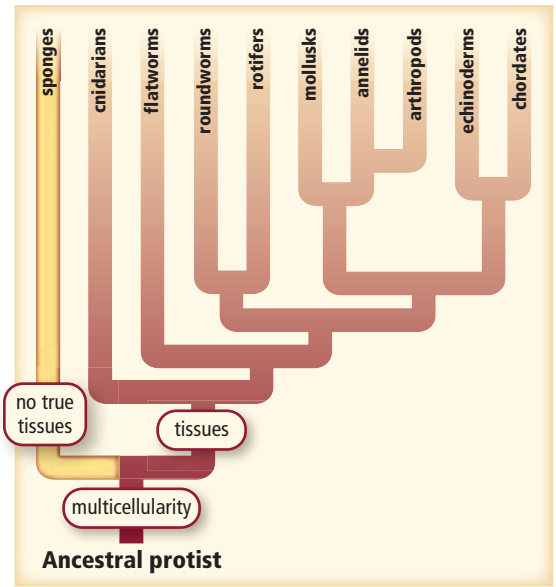




Figure 14 The sponges in the photograph are animals that take in and digest food, grow, and reproduce, even though they lack true tissues.

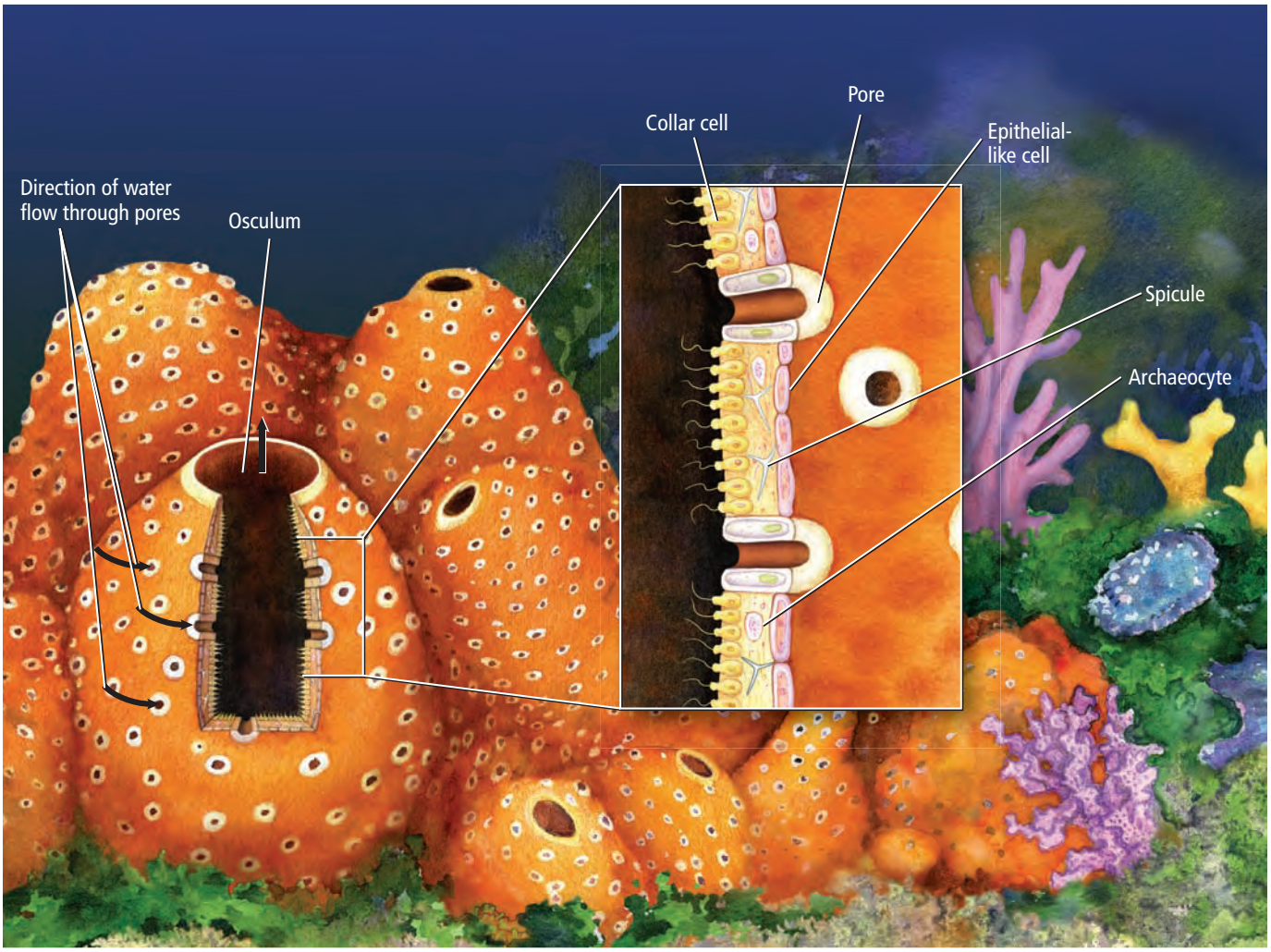


Figure 15 Sponges have no tissues or organs and have a body made of two layers of cells.

Concepts in Motion

Animation

Study Tip

Think Aloud Read the text and captions aloud. As you read, say aloud your questions and comments. For instance, when you come to the mention of **Figure 15,** look at the figure and say how it relates to the text.

Two layers of independent cells with a jellylike substance between the layers accomplish all of the life functions of sponges. As illustrated in **Figure 15,** epithelial-like cells cover the sponge and protect it. Collar cells with flagella line the inside of the sponge. As collar-cell flagella whip back and forth, water is drawn into the body of the sponge through pores. These pores give sponges their phylum name Porifera, which means "pore-bearer." Water and waste materials are expelled from the sponge through the osculum (AHS kyuh lum), which is the mouthlike opening at the top of the sponge.

Feeding and digestion When an organism, such as a sponge, gets its food by filtering small particles from water, it is called a **filter feeder.** Even though this might sound like a process that is not very active, consider that a sponge only 10 cm tall can filter as much as 100 L of water each day. Although sponges have free-swimming larvae, the adults move very little. Adaptations for filter-feeding are common in animals that are **sessile** (SES sul), meaning they are attached to and stay in one place. As nutrients and oxygen dissolved in water enter through the pores in a sponge's body, food particles cling to the cells. Digestion of nutrients takes place within each cell.

Reading Check **Infer** why filter feeding is an adaptive advantage for sponges.



Demosponge



Figure 16 Bath sponges are harvested from the sea and processed for human use.

Support Within the jellylike material that lies between the two cell layers of a sponge are amoeba-like cells—cells that can move and change shape. These amoeba-like cells are called archaeocytes (ar kee OH sites) and are illustrated in **Figure 15.** These cells are involved in digestion, production of eggs and sperm, and excretion. Archaeocytes also can become specialized cells that secrete spicules (SPIH kyuhls), the support structures of sponges. Spicules are small, needlelike structures made of calcium carbonate, silica, or a tough fibrous protein called spongin.

Sponge diversity Biologists place sponges into three classes based on the type of support system each has. Most sponges belong to class Demospongiae (deh muh SPUN jee uh), the demosponges, and have spicules composed of spongin fibers, silica, or both. Natural bath sponges, like the ones in **Figure 16,** have spongin support. Class Calcarea (kal KER ee uh) consists of sponges with spicules composed of calcium carbonate. Calcareous sponges, like the one in **Figure 17,** often have a rough texture because the calcium carbonate spicules can extend through the outer covering of the sponge. The sponges in class Hexactinellida (heks AK tuh nuh LEE duh) are called glass sponges and have spicules composed of silica. These spicules join together to form a netlike skeleton that often looks like spun glass, as illustrated in **Figure 17.**

Video BrainPOP

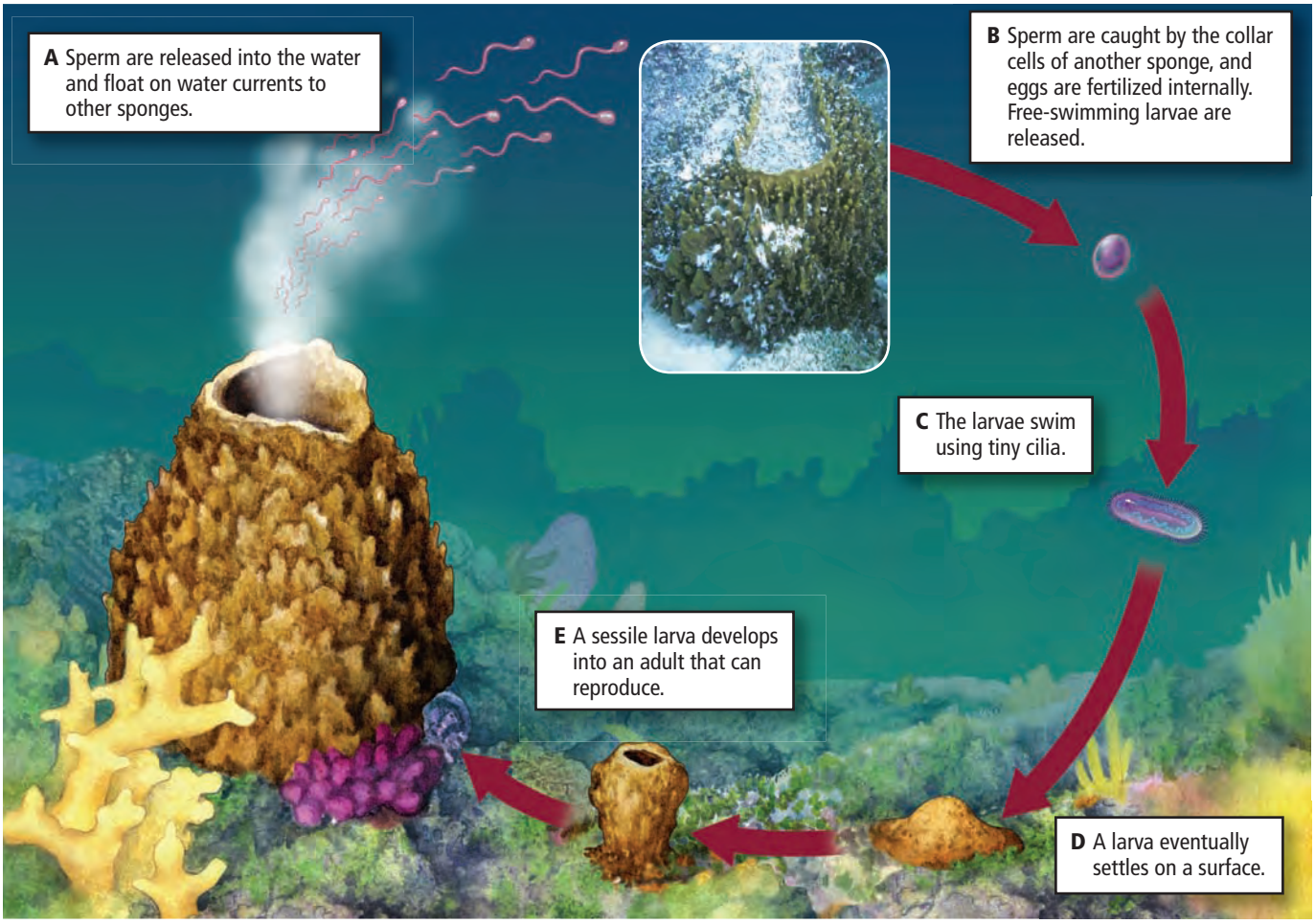
Figure 17 Calcareous sponges are small and have a rough texture. The skeletons of glass sponges look like brittle spun glass.



Calcareous sponge



Glass sponge skeleton



■ **Figure 18** Sexual reproduction in sponges requires water currents to carry sperm from one sponge to another.
Evaluate ***whether fertilization is internal or external in sponge sexual reproduction.***

Response to stimuli Sponges do not have nervous systems. They do have epithelial-like cells that detect external stimuli, such as touch or chemical signals, and respond by closing their pores to stop water flow.

Reproduction Sponges can reproduce asexually by fragmentation, through budding, or by producing gemmules (JEM yewlz). In fragmentation, a piece of sponge that is broken off due to a storm or other event develops into a new adult sponge. In budding, a small growth, called a bud, forms on a sponge, drops off, and settles in a spot where it grows into a new sponge. Some freshwater sponges form seedlike particles called gemmules during adverse conditions like droughts or freezing temperatures. Gemmules contain sponge cells protected by spicules that will survive and grow again when favorable conditions occur.

Most sponges reproduce sexually, as illustrated in **Figure 18.** Some sponges have separate sexes, but most sponges are hermaphrodites. Recall that a hermaphrodite is an animal that can produce both eggs and sperm. During reproduction, eggs remain within a sponge, while sperm are released into the water. Sperm released from one sponge can be carried by water currents to the collar cells of another sponge. The collar cells then change into specialized cells that carry the sperm to an egg within the sponge body. After fertilization occurs, the zygote develops into a larva that is free-swimming and has flagella. The larva eventually attaches to a surface, then develops into an adult.

Reading Check **Describe** the methods by which sponges reproduce.

VOCABULARY
ACADEMIC VOCABULARY
Survive
to remain alive
Sponge gemmules survive despite adverse conditions.

Sponge ecology Although spicules and toxic or distasteful compounds in sponges discourage most potential predators, sponges are food for some tropical fishes and turtles. Sponges also are common habitats for a variety of worms, fishes, shrimp, and colonies of symbiotic green algae. Some sponges even live on and provide camouflage for mollusks, as shown in **Figure 19.**

Sponges also are beneficial to humans. Sponges with spicules made of spongin fibers often are used for household scrubbing purposes. Medical research is focusing on sponge chemicals that appear to discourage prey and prevent infection. Ongoing studies of these sponge chemicals as possible pharmaceutical agents have shown that they might have antibiotic, anti-inflamatory, or antitumor possibilities. They also might have potential importance as respiratory, cardiovascular, and gastrointestinal medicines.

Connection to Health For example, researchers discovered a powerful antitumor substance in the deep water sponge shown in **Figure 20.** This substance, discodermolide (disk uh DER muh lide), stops cancer cells from dividing by breaking down the nucleus and rearranging the microtubule network. Recall that microtubules are part of a cell's skeleton and help the cell maintain its shape. Note the differences in the nuclei and microtubules between the untreated and treated cancer cells in **Figure 20.**

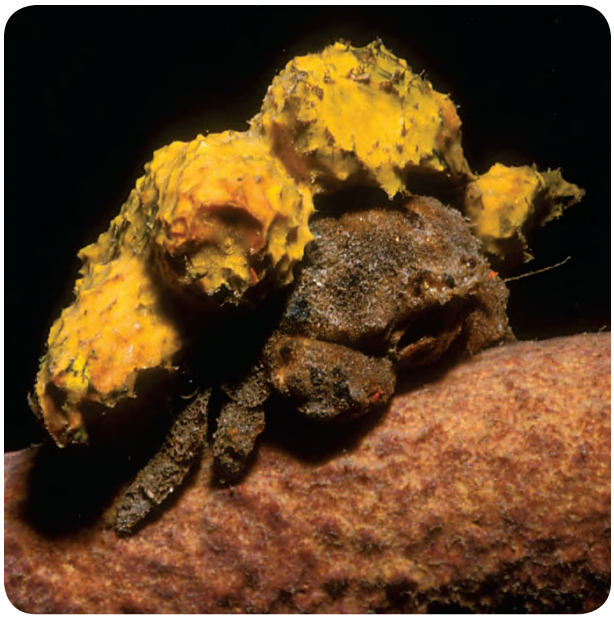
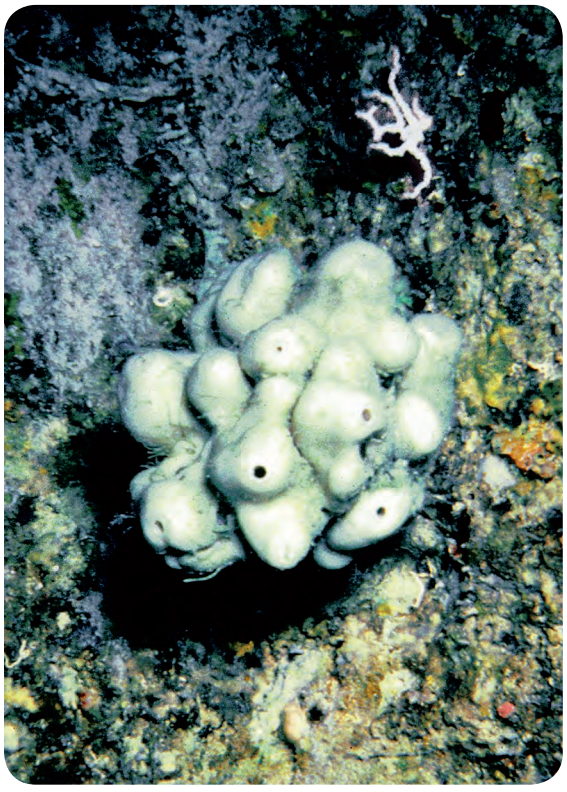
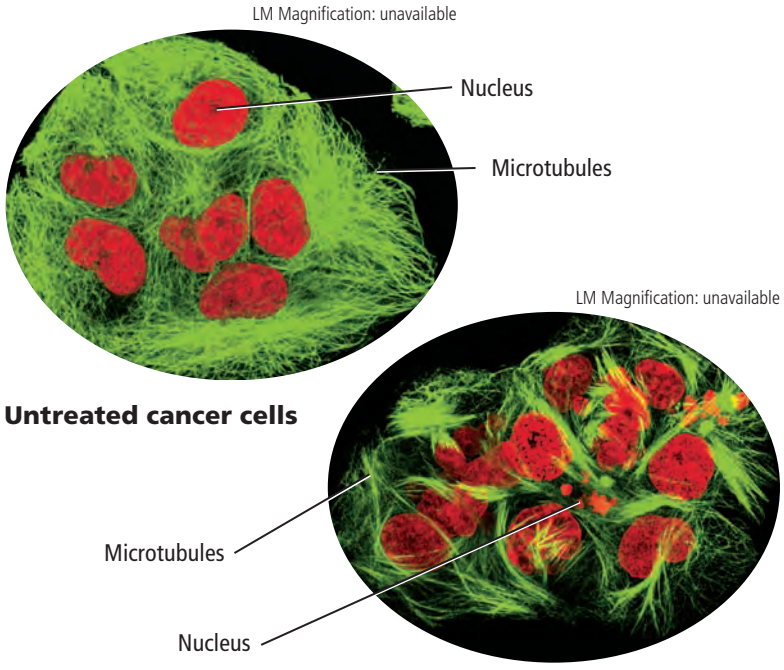


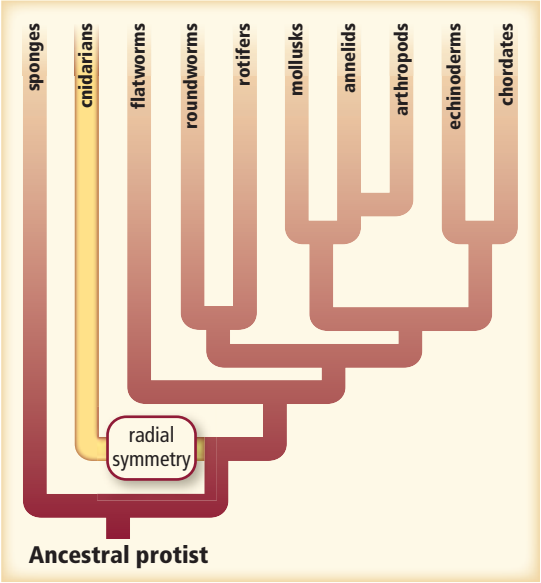
Figure 19 This crab hides from predators by carrying a living sponge on its back. The crab uses two pairs of legs to hold the sponge in place.

Figure 20 Discodermolide, a substance taken from the sponge *Discodermia dissoluta,* breaks down the nucleus in a cancer cell and rearranges its microtubules.



Discodermia dissoluta







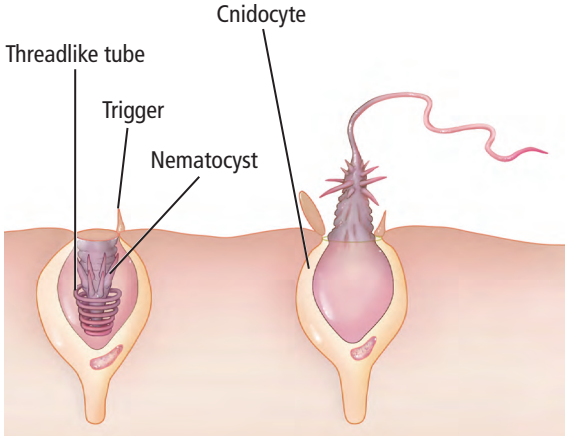
Jellyfish—free floating



Sea anemone—sessile

Figure 21 Cnidarians have radial symmetry and can be free floating or sessile.
Explain how radial symmetry helps a cnidarian obtain food.

Figure 22 Stinging cells that contain nematocysts are discharged from the tentacles of cnidarians when prey touches them.



Cnidarians

Imagine that you go snorkeling around a coral reef, and you wear a bodysuit to protect yourself from the stings of jellyfishes that float on the water. Later, when you go ashore to visit a tidepool, you might see colorful sea anemones that look somewhat like flowers. The jellyfish and sea anemone in **Figure 21** belong to phylum Cnidaria (ni DARE ee uh). This phylum consists of about 10,000 species, most of which are marine.

Body structure Like sponges, cnidarians (ni DARE ee uns) have one body opening and most have two layers of cells. However, in cnidarians, the two cell layers are organized into tissues with specific functions. The outer layer functions in protecting the internal body, while the inner layer functions mainly in digestion. Because cnidarians have tissues, they also have symmetry. As shown in **Figure 21,** cnidarian bodies have radial symmetry. Recall that radial symmetry enables slow moving or sessile animals to detect and capture prey from any direction. Cnidarians are adapted to aquatic floating or sessile attachment to surfaces under the water.

Feeding and digestion Cnidarian tentacles are armed with stinging cells called **cnidocytes** (NI duh sites). Cnidarians get their name from these stinging cells. Cnidocytes contain nematocysts, as shown in **Figure 22.** A **nematocyst** (nih MA tuh sihst) is a capsule that holds a coiled, threadlike tube containing poison and barbs.

Connection to Physics A nematocyst works like a tiny but very powerful harpoon. Remember that osmosis is the diffusion of water through a selectively permeable membrane. The pressure provided by this flow of water is called osmotic pressure. The water inside an undischarged nematocyst is under an osmotic pressure of more than 150 atmospheres. This pressure is about 20 times the pressure in an inflated bicycle tire.

In response to being touched or to a chemical stimulus, the permeability of the nematocyst membrane increases, allowing more water to rush in. As the osmotic pressure increases, the nematocyst discharges forcefully. A barb is capable of penetrating a crab shell.

Nematocyst discharge is one of the fastest cellular processes in nature. It happens so quickly—in just 3/1000ths of a second—that it is impossible to escape after touching these cells. After capture by nematocysts and tentacles, the prey is brought to the mouth of the cnidarian.

The inner cell layer of cnidarians surrounds a space called the **gastrovascular** (gas troh VAS kyuh lur) **cavity,** illustrated in **Figure 23.** Cells lining the gastrovascular cavity release digestive enzymes over captured prey. Undigested materials are ejected through the mouth. Recall that digestion occurs within each cell of a sponge. However, in cnidarians, digestion takes place in the gut cavity, a major evolutionary adaptation.

Response to stimuli In addition to cells adapted for digestion, cnidarians have a nervous system consisting of a **nerve net** that conducts impulses to and from all parts of the body. The impulses from the nerve net cause contractions of musclelike cells in the two cell layers. The movement of tentacles during prey capture is the result of contractions of these musclelike cells. Cnidarians have no blood vessels, respiratory systems, or excretory organs. Look at **Table 1** to compare the structures and functions of sponges and cnidarians.

Reading Check **Contrast** a cnidarian's response to stimuli from a sponge's response.

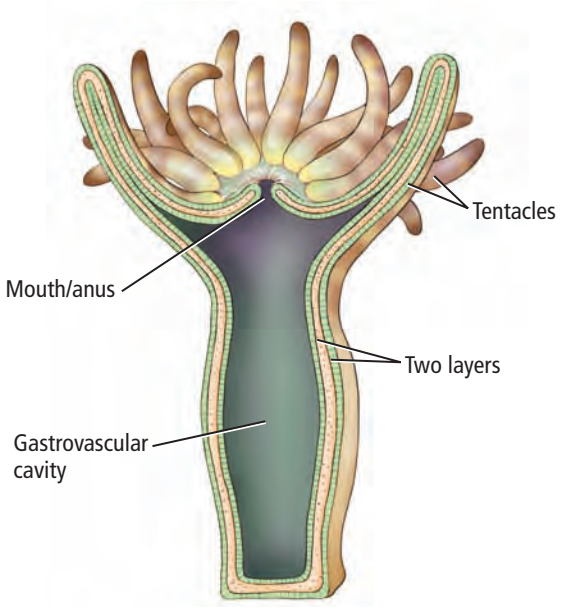


Figure 23 A cnidarian's mouth leads directly into its gastrovascular cavity. Because the digestive tract has only one opening, wastes are expelled through the mouth.

Table 1 **Comparison of Sponges and Cnidarians**

Concepts in Motion Interactive Table

	Sponges	Cnidarians
Example		
Body Plan	• Generally has asymmetry	• Has radial symmetry
Feeding and digestion	• Filter feed • Digestion takes place within individual cells	• Capture prey with nematocysts and tentacles • Digestion takes place in gastrovascular cavity
Movement	• Sessile	• Aquatic floating or sessile
Response to stimuli	• No nervous system • Cells react to stimuli	• Simple nervous system consisting of a nerve net
Reproduction	• Hermaphrodites reproduce sexually • Asexual reproduction by fragmentation, budding, or gemmule production	• Separate sexes reproduce sexually • Polyp stage reproduces asexually by budding

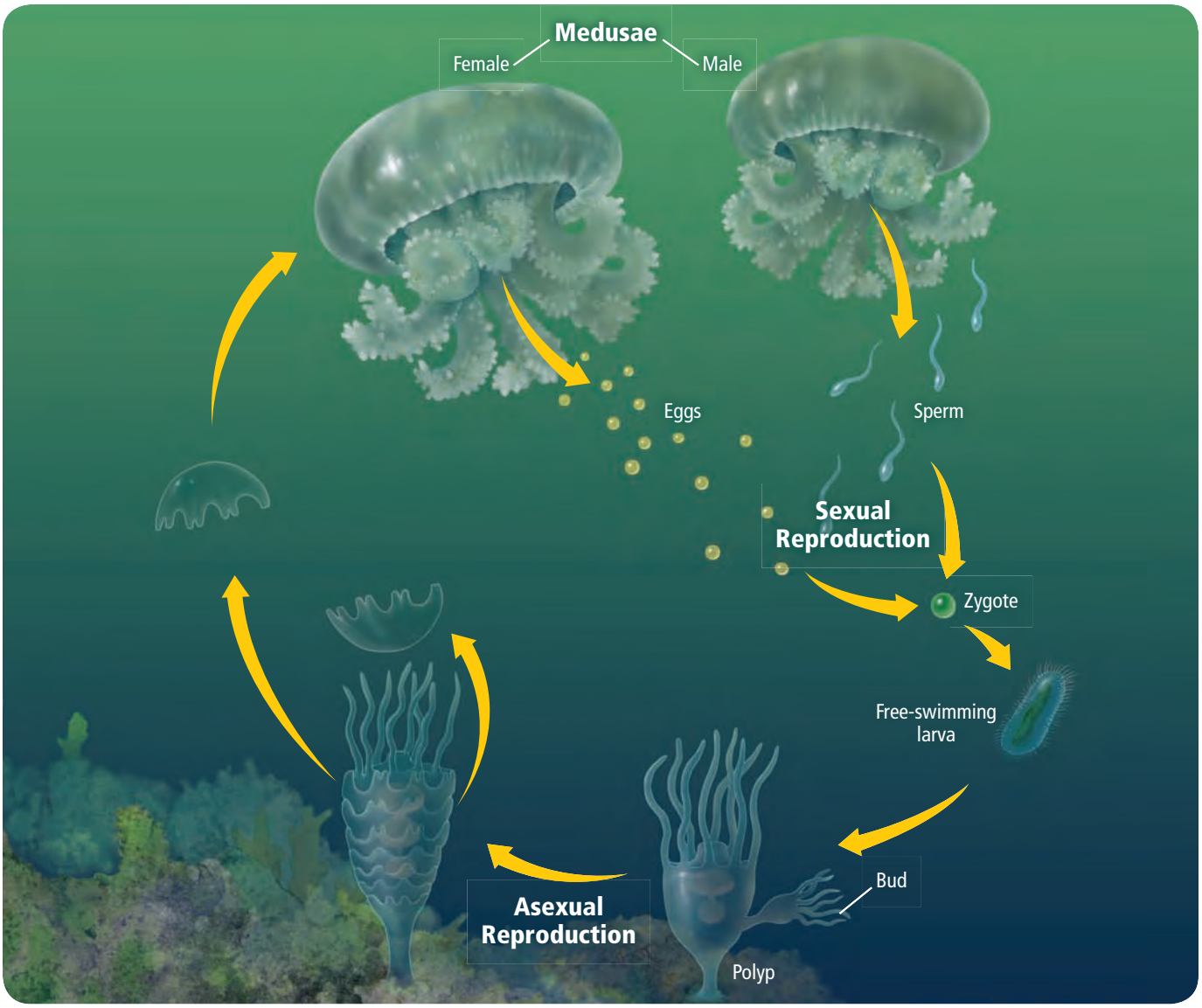


Figure 24 Jellyfishes reproduce by alternating sexual and asexual stages of their life cycle.

Concepts in Motion

Animation

Reproduction In addition to stinging cells, cnidarians have another adaptation not seen in most animals of recent origin. Most cnidarians have two body forms: a **polyp** (PAH lup) with a tube-shaped body and a mouth surrounded by tentacles, and a **medusa** (mih DEW suh) (plural, medusae) with an umbrella-shaped body and tentacles that hang down. The mouth of a medusa is on the ventral surface between the tentacles.

The two body forms of cnidarians can be observed in the life cycle of jellyfishes, illustrated in **Figure 24.** To reproduce, jellyfishes in the medusa stage release eggs and sperm into the water where fertilization occurs. The resulting zygotes eventually develop into free-swimming larvae that settle and grow into polyps. These polyps reproduce asexually to form new medusae. It would be easy to confuse the life cycle of cnidarians with the alternation of generations in plants. However, in plants, one generation is diploid and the other is haploid. In cnidarians, both the medusae and polyps are diploid animals.

Reading Check **Compare** the larvae of sponges and cnidarians.

CAREERS IN BIOLOGY

Marine Ecologist Using submersibles and deep-sea robots, a marine ecologist studies the relationships between marine animals and their environments.

Cnidarian diversity There are four main classes of cnidarians: Hydrozoa, the hydroids; two classes of jellyfishes, Scyphozoa and Cubozoa (the box jellyfishes); and Anthozoa, the sea anemones and corals.

Hydroids Most of the approximately 2700 known species of hydroids have both polyp and medusa stages in their life cycles. Most hydroids form colonies, such as the Portuguese man-of-war in **Figure 25.** Another well-known hydroid is the freshwater hydra, which is unusual because it has only a polyp stage.

Jellyfishes There are about 200 known species of jellyfishes. They are transparent or translucent in appearance and float near the water's surface. The medusa is the dominant body form, although a polyp stage does exist. They are called jellyfishes because the substance between the outer body covering and the inner body wall is jellylike. The structure of the inner and outer body layers with the jellylike structure between can be compared to a jelly sandwich. The box jellyfishes take their name from the boxlike medusae that are their dominant form. The stings of some box jellyfish species can be fatal to humans.

Sea anemones and corals Generally colorful and inviting, sea anemones and corals still possess stinging cells like all cnidarians. The 6200 known species of sea anemones and corals are different from the jellyfishes because the polyp stage is the dominant stage of their life cycles. Recent research indicates that these anthozoans might have bilateral symmetry. This would alter the evolutionary tree because this adaptation usually is seen only in animal groups that evolved later than cnidarians.

Sea anemones live as individual animals, while corals live in colonies of polyps. Corals secrete protective calcium carbonate shelters around their soft bodies. The living portion of a coral reef is a thin, fragile layer growing on top of the shelters left behind by previous generations. Coral reefs form from these shelters over thousands of years.

Coral polyps extend their tentacles to feed, as shown in **Figure 26.** They also harbor symbiotic photosynthetic protists called zooxanthellae (zoh oh zan THEH lee). The zooxanthellae produce oxygen and food that corals use, while using carbon dioxide and waste materials produced by the corals. These protists are primarily responsible for the bright colors found on healthy coral reefs.

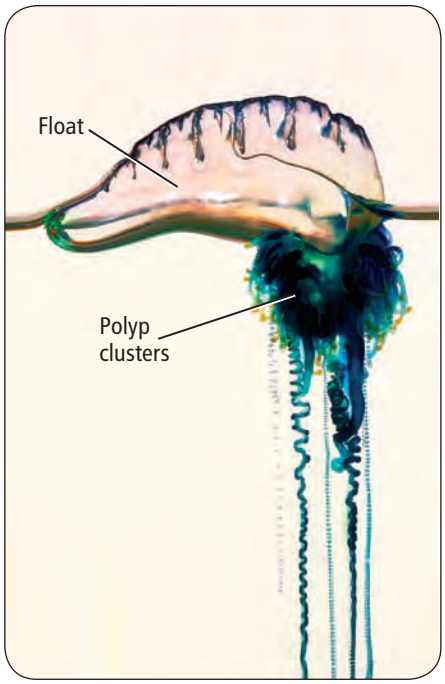
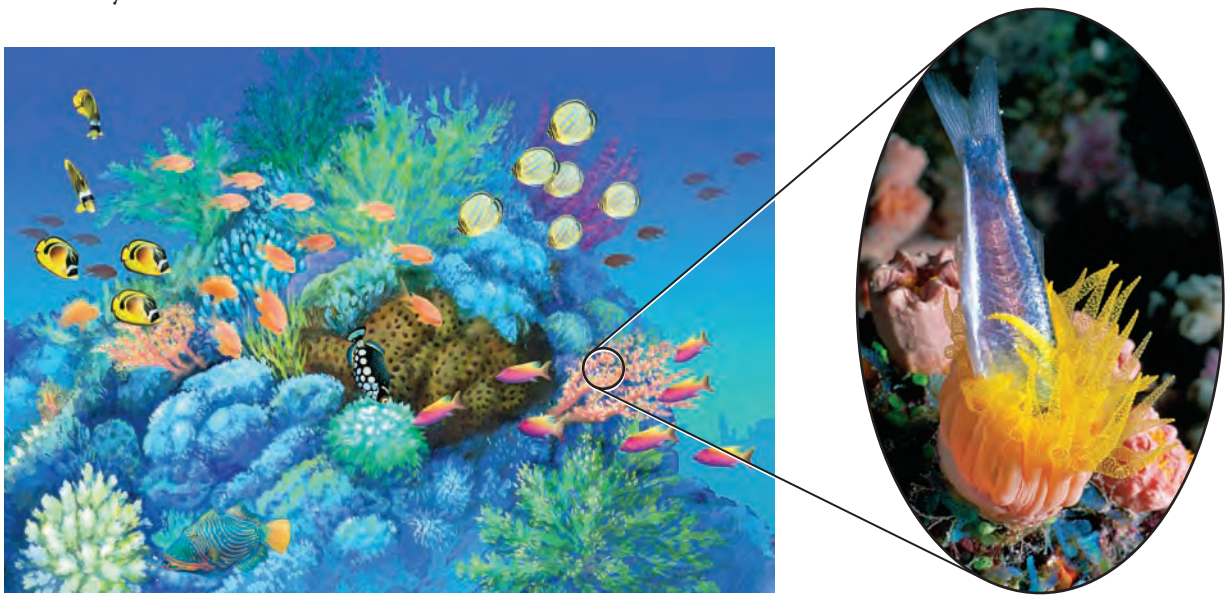


Figure 25 This Portuguese man-of-war is composed of a colony of hydroids. One hydroid polyp forms the large float, while other hydroid polyps cluster beneath the float.

Figure 26 Coral polyps capture food by extending their tentacles.



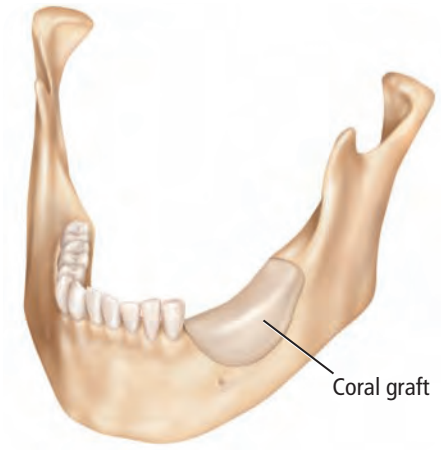


Figure 27 Surgeons use treated hydroxyapatite to make implants for reconstructing facial bones, such as this jaw.

The health of a coral reef depends on proper water temperature, adequate light, and appropriate water depth. If these environmental conditions deteriorate in areas where there are reefs, the health of the reef might also deteriorate. You can examine this problem in **Data Analysis Lab 1.**

Cnidarian ecology Mutualism, a relationship in which both organisms benefit, is common in cnidarians. One species of sea anemone wraps itself around hermit crabs' shells; the anemones obtain food scraps and the crabs are protected. Some sea slugs feed on cnidarians and incorporate the unfired nematocysts into their bodies for their own defense. As shown in the photo at the beginning of the chapter, clown fishes are protected by the tentacles of anemones. One theory as to how clown fishes are protected from the tentacles of anemones is that the fish incorporates mucus from an anemone into its own mucous coating, which prevents the nematocysts from discharging.

People benefit from cnidarians in many ways. Some people enjoy visiting a coral reef. In the medical field, some stony coral species are used in surgical procedures. A calcium phosphate mineral in coral called hydroxyapatite (hi DROX ee ap uh TITE) can be treated so that it has the same structure and chemical composition as human bone. Small pieces of coral are implanted as bone grafts, especially in face and jaw reconstruction and in arm and leg surgery. The grafts anchor to the adjacent bone, as shown in **Figure 27,** and are eventually replaced by new human bone growth.

DATA ANALYSIS LAB 1

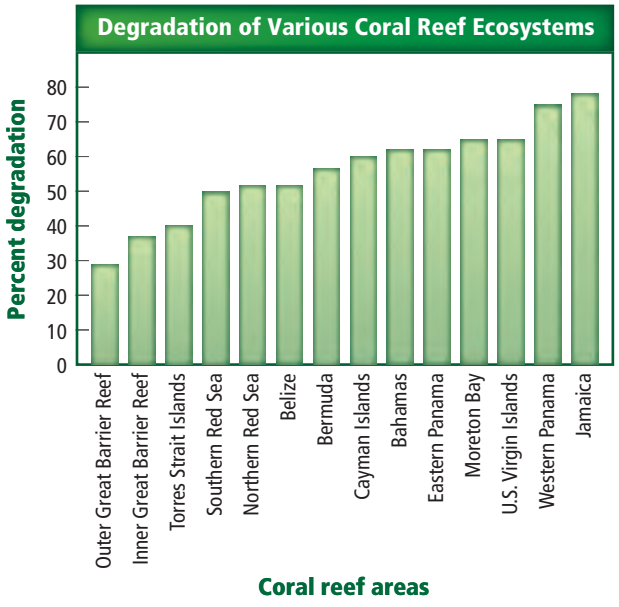
Based on Real Data*

Interpret Data

Where are coral reefs being damaged?
Some corals have ejected their symbiotic algae and become bleached, or lost their coloring. Coral reef bleaching is a common response to reef ecosystem damage. However, some corals appear to be recovering from bleaching.

Data and Observations

The graph indicates the percentage of the damage that has occurred to specific reefs.



Think Critically

1. **Interpret** What part of the world has suffered the most damage to its coral reefs? What part of the world has suffered the least damage to its reefs?
2. **Model** On a world map, locate the coral reefs noted in the graph. Color code the map based on the percent of degradation.

*Data obtained from: Pandolfi, J.M. et al., 2003. Global trajectories of the long-term decline of coral reef ecosystems. *Science* 301 (5635): 955–958.

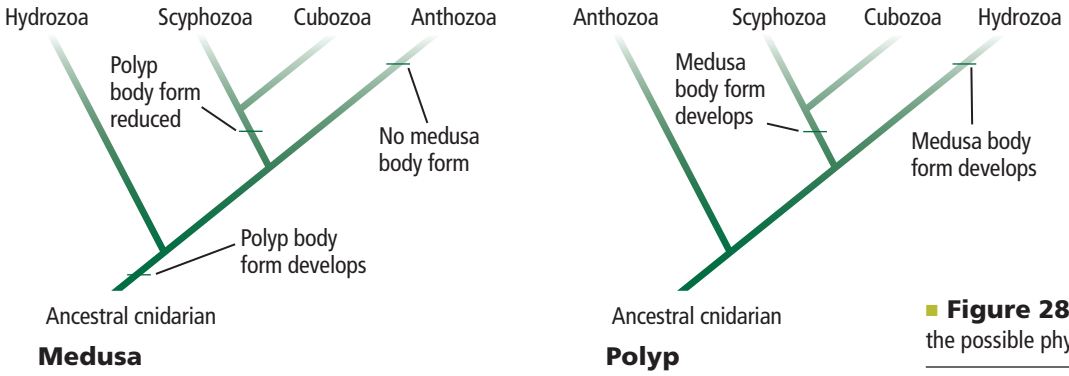


Figure 28 The two cladograms illustrate the possible phylogeny of cnidarians.

Evolution of cnidarians There are two major interpretations of the phylogeny of cnidarians. The fact that cnidarians have two body forms, medusa and polyp, raises the question of whether the ancestral cnidarian had a medusa or a polyp body form. The cladograms in **Figure 28** present both interpretations.

In the cladogram on the left, the ancestral cnidarian has a medusa body form. As cnidarians evolved, a polyp stage developed. The life cycles of hydrozoans have both polyp and medusa stages. As the scyphozoans and cubozoans developed, the medusa stage became the dominant stage in their life cycles. The most highly evolved cnidarians, the anthozoans, have no medusa stage.

In the cladogram on the right, the ancestral cnidarian has a polyp body form. The anthozoans evolved first, and the polyp stage is the dominant stage of their life cycles. The medusa stage evolved independently in hydrozoans and in scyphozoans and cubozoans. Notice how the classes of cnidarians are arranged in each cladogram.

Section 3 Assessment

Section Summary

- Sponges can be described according to animal features they do not have and according to features they do have.
- Sponges do not have tissues, but carry out the same life functions as other animals.
- Cnidarians have unique features that other animals do not have.
- Cnidarians have more highly evolved body forms and structures than sponges.
- Sponges and cnidarians are important to the ecology of their habitats and to humans.

Understand Main Ideas

1. MAIN Idea **Explain** why sponges and cnidarians were the first animals to evolve.
2. **Describe** the differences between the body plans of sponges and cnidarians.
3. **List** two characteristics that are unique to sponges and two characteristics that are unique to cnidarians.
4. **Demonstrate** your knowledge of cnidarians by describing how they affect other marine organisms.

Think Critically

5. **Hypothesize** how nematocysts are an adaptive advantage for cnidarians.

MATH in Biology

6. Review the text under the heading *Cnidarian diversity.* Make a circle graph that shows the proportions of each of the three groups of cnidarians to the total numbers of cnidarians. In addition to the groups in this section, there are 900 species of other cnidarians. Analyze this information and hypothesize why one group is so much smaller than the others.

Biology & Society

Beautiful and Endangered: Coral Reefs

Coral reefs dot the coasts around the world and cover over 284,000 square kilometers. People are fascinated by beautiful and delicate corals and by the populations that inhabit reef ecosystems. Ironically, human behaviors have contributed to the endangerment of coral reefs.

What are coral reefs? Not all corals form reefs, but those that do begin the process when individual polyps attach to rocks. They do this by secreting a calcium carbonate exoskeleton that cements the polyps in place. As the polyps die over time, the exoskeletons are left behind and a coral reef forms. Many corals have a symbiotic relationship with the alga zooxanthellae. These algae provide the corals with nutrients gained through photosynthesis, and they use the carbon dioxide produced by the corals.



This healthy coral reef shows no sign of bleaching, disease, or pollution.

Why are coral reefs important? Coral reefs form some of the most diverse ecosystems in the world. About 25 percent of all marine species live in coral reefs, and scientists estimate that reefs also support millions of undiscovered species. The biodiversity of reefs is valuable and irreplaceable.

What is happening to coral reefs? Coral reefs face natural threats, including extreme weather conditions and predation. Many coral reefs have been damaged by human activities, such as fishing practices that employ dynamite or poison. Some polluted runoff stimulates the growth of nonbeneficial algae, which smothers corals. Tourist activities like diving and snorkeling also damage corals. Some divers and snorkelers break off pieces of coral to sell or to take home as souvenirs. Other divers collect live corals to sell for use in aquariums.

Sometimes, corals become so stressed that they expel their symbiotic algae. This is a phenomenon known as "bleaching" because the stressed corals lose their bright colors and appear white. Scientists do not yet completely understand why coral bleaching occurs. They think one of the main causes is rising ocean temperatures. Other possible factors include pollution, bacteria, solar radiation, and changes in salinity. Coral reefs that expel their algae are more likely to become diseased, and the corals will die unless the symbiotic algae are replaced.

VISUAL COMMUNICATION

Make a Movie Research with your classmates what can be done to help keep coral reefs from becoming extinct. Write a script for a short movie about coral reefs. Include facts about what they are, why they are in danger, and what people can do to help. Include visuals such as photographs, maps, and costumes.

WebQuest

BIOLAB

Design Your Own

FIELD INVESTIGATION: WHAT CHARACTERISTICS DO ANIMALS HAVE?

Background: **A small pond is an ecosystem in which organisms interact to accomplish essential life functions. They exhibit a wide variety of body plans, obtain food in different ways, and use various methods of movement.**

Question: *What kinds of animals live in ponds?*

Materials

wading boots
tweezers
aquarium
Petri dishes
dissecting microscopes
Choose other materials that would be appropriate for this lab.

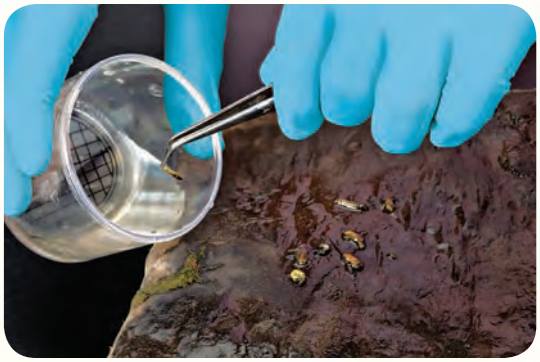
Safety Precautions



WARNING: ***Handle living animals with care.***

Plan and Perform the Experiment

1. Read and complete the lab safety form.
2. Locate a pond to use for your observations and collections. Make sure you have permission to use the pond.
3. Determine methods to observe and record animals that you see at the pond that you do not collect.
4. Design and construct a data table to record your observations.
5. Make sure your teacher approves your plan before you proceed.
6. **Cleanup and Disposal** Wash your hands after handling any live organisms. Return the animals and any pond water to the pond. Wash and return all reusable lab materials and correctly dispose of other materials used in the lab as directed by your teacher.



Analyze and Conclude

1. **Use Scientific Explanations** How were you able to determine if the organisms you observed were animals?
2. **Summarize** the adaptations used for obtaining food that you observed. Were any of the adaptations similar to those you observed in **MiniLab 1?**
3. **Compare and contrast** the methods of movement used by each of the animals you observed.
4. **Interpret Data** Look at drawings or photographs of the animals you observed. What do these illustrations tell you about the body plan of each organism? What gut type does each animal have?
5. **Error Analysis** What other types of observations could you make to verify your conclusions about each organism?

WRITING in Biology

Make a Booklet Choose one of the animals you observed in your pond study. Develop an illustrated booklet that shows how this animal obtains food, how it reproduces, its body plan, and its stages of development. Share the information with your class.



Chapter 24 Study Guide

THEME FOCUS Diversity All animals show some form of symmetry such as radial, bilateral, or asymmetrical symmetry.

BIG Idea Animal phylogeny is determined in part by animal body plans and adaptations.

Section 1 Animal Characteristics

invertebrate (p. 693)
exoskeleton (p. 693)
endoskeleton (p. 693)
vertebrate (p. 693)
hermaphrodite (p. 695)
zygote (p. 695)
internal fertilization (p. 695)
external fertilization (p. 695)
blastula (p. 696)
gastrula (p. 696)
endoderm (p. 697)
ectoderm (p. 697)
mesoderm (p. 697)

MAIN Idea **Animals are multicellular, eukaryotic heterotrophs that have evolved to live in many different habitats.**

- Animals are heterotrophs and must get their nutrients from other organisms.
- Animals have diverse means of support and live in diverse habitats.
- Animal cells do not have cell walls and most have cells that are organized into tissues.
- Most animals undergo sexual reproduction and most can move.
- During embryonic development, animal cells become tissue layers, which become organs and systems.

Section 2 Animal Body Plans

symmetry (p. 700)
radial symmetry (p. 700)
bilateral symmetry (p. 700)
anterior (p. 700)
posterior (p. 700)
cephalization (p. 700)
dorsal (p. 700)
ventral (p. 700)
coelom (p. 701)
pseudocoelom (p. 701)
acoelomate (p. 701)
protostome (p. 702)
deuterostome (p. 702)

MAIN Idea **Animal phylogeny can be determined, in part, by body plans and the ways animals develop.**

- Animal phylogeny can be compared to a tree with branches.
- The branches of a phylogenetic evolutionary tree show the relationships among animals.
- Animal phylogeny can be determined, in part, by the animal's type of body cavity or lack of a body cavity.
- After gastrulation, two types of development can occur in coelomate animals.
- Segmentation is an important feature in some coelomate animals.

Section 3 Sponges and Cnidarians

filter feeder (p. 706)
sessile (p. 706)
cnidocyte (p. 710)
nematocyst (p. 710)
gastrovascular cavity (p. 711)
nerve net (p. 711)
polyp (p. 712)
medusa (p. 712)

MAIN Idea **Sponges and cnidarians were the first animals to evolve from a multicellular ancestor.**

- Sponges can be described according to animal features they do not have and according to features they do have.
- Sponges do not have tissues, but carry out the same life functions as other animals.
- Cnidarians have unique features that other animals do not have.
- Cnidarians have more highly evolved body forms and structures than sponges.
- Sponges and cnidarians are important to the ecology of their habitats and to humans.

Review Vocabulary eGames

Chapter 24 Assessment

Section 1

Vocabulary Review

Match the definitions below with the correct vocabulary terms from the Study Guide page.

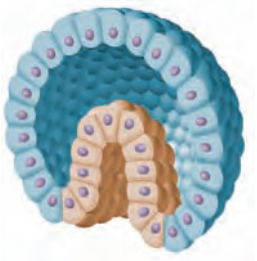
1. a hard outer covering that provides support

2. fluid-filled ball of cells formed by miotic cell division of the embryo

3. an animal that produces both eggs and sperm

Understand Main Ideas

Use the diagram below to answer question 4.



4. The embryo is in which stage of development?
A. gastrula **C.** egg cell
B. blastula **D.** zygote

5. Which material is not found in endoskeletons?
A. calcium carbonate **C.** silica
B. bone **D.** cartilage

6. Hox genes are active during which process?
A. cell differentiation **C.** digestion
B. movement **D.** neural stimulation

Constructed Response

7. MAIN Idea Select an animal and describe its adaptations and characteristics specific to its environment.

8. **Open Ended** Describe the advantages and disadvantages of internal and external fertilization.

Think Critically

9. **Interpret** this statement by Hans Spemann, a biologist who studied embryonic development: "We are standing and walking with parts of our body which could have been used for thinking had they developed in another part of the embryo."

10. **Hypothesize** what might happen to an embryo that suffers damage to some mesoderm cells.

Section 2

Vocabulary Review

Distinguish between the vocabulary terms in each pair.

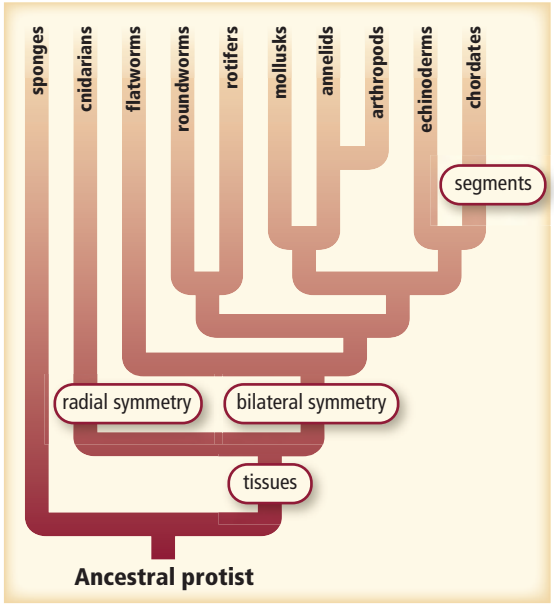
11. bilateral symmetry and radial symmetry

12. ventral and dorsal

13. coelom and pseudocoelom

Understand Main Ideas

Use the diagram below to answer questions 14 and 15.



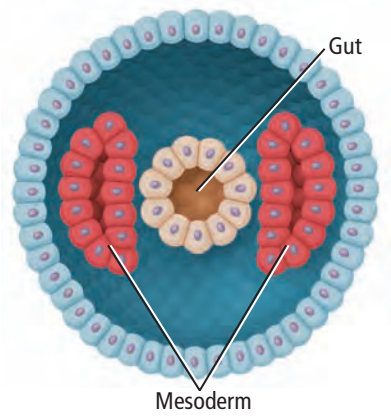
14. Based on the evolutionary tree above, which statement is true?
A. True tissues evolved after bilateral symmetry.
B. Segments evolved after bilateral symmetry.
C. The common animal ancestor was a sponge.
D. Most animals have radial symmetry.

15. On the evolutionary tree, which animals are related most closely?
A. an annelids and mollusks
B. flatworms and annelids
C. roundworms and annelids
D. annelids and echinoderms

16. **CAREERS IN BIOLOGY** An embryologist, a scientist who studies embryos, discovers a new marine animal. When one cell is removed during its early development, this cell develops into a complete animal. This animal is which of the following?

A. acoelomate
B. deuterostome
C. protostome
D. pseudocoelomate

Use the diagram below to answer question 17.



17. What does the location of the mesoderm indicate about this embryo?

A. The cells are directly aligned.
B. The outcome of each cell can be changed.
C. The mouth develops from the gastrula opening.
D. The coelom forms from pouches of mesoderm.

18. The evolution of an internal body cavity had adaptive advantage in all the following areas except for which?

A. circulation
B. movement
C. feeding
D. muscular system

19. Based on the evolutionary tree in **Figure 8,** what characteristics does an annelid have that a flatworm does not?

A. a coelom, a body cavity, bilateral symmetry, and no tissues
B. a coelom and segmentation
C. a coelom, protostome development, and segmentation
D. a pseudocoelom, a body cavity, and bilateral symmetry

20. What is the lighter undersurface of a frog called?

A. dorsal surface
B. ventral surface
C. anterior surface
D. posterior surface

Constructed Response

21. **Open Ended** Construct a working model of cell differentiation using clay, salt dough, or other materials. Make the first stage, then make that stage into the next, and that stage into the next until you have completed the steps.

22. **Open Ended** Describe three examples not discussed in this chapter of each type of symmetry.

Think Critically

23. MAIN Idea Biologists have recently determined that some sea anemones seem to possess bilateral symmetry. Hypothesize how this changes ideas for how and when bilateral symmetry evolved.

24. THEME FOCUS Diversity Explain how segmentation and exoskeletons gave some animals an adaptive advantage over those that were not segmented and did not have exoskeletons.

Section 3

Vocabulary Review

For each set of terms below, choose the term that does not belong and explain why it does not belong.

25. cnidocyte, nematocyst, cnidarian, spicule

26. pores, gemmule, filter feeder, nematocyst

27. alternation of generations, polyp, spongin, medusa

Understand Main Ideas

Use the diagram below to answer question 28.



28. The animal in the diagram above possesses which characteristic?

A. cephalization
B. cnidocytes
C. bilateral symmetry
D. asymmetry

Assessment Online Test Practice

29. Cnidarians evolved directly from which group?
- **A.** sponges
- **B.** multicellular choanoflagellates
- **C.** flatworms
- **D.** animals with bilateral symmetry

Use the image below to answer question 30.



30. How does the animal shown in the image reproduce?
- **A.** fragmentation
- **B.** external fertilization
- **C.** internal fertilization
- **D.** regeneration

31. Which is not a characteristic of sponges?
- **A.** filter feeding
- **B.** digestion inside cells
- **C.** asymmetry
- **D.** tissues

32. Which pair of words is mismatched?
- **A.** sponges, filter feeding
- **B.** cnidarians, nematocysts
- **C.** sponges, free swimming larva
- **D.** cnidarians, spicules

Constructed Response

33. Open Ended Examine the classified section in the newspaper to see how it is organized. Then use your knowledge of cnidarians to write an ad to describe an ideal jellyfish homesite.

Think Critically

34. MAIN Idea Evaluate the importance of sponges and cnidarians in animal phylogeny.

35. Create Make a concept map using the following words: coral, polyp, cnidocyte, reef, calcium carbonatea and zooxanthellae.

Summative Assessment

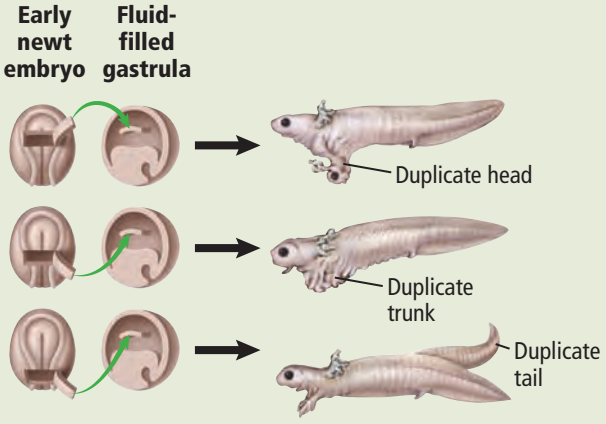
36. BIG Idea Imagine you are working in a university laboratory. You are given an unknown invertebrate and told to determine its phylogeny. What characteristics would you use to accomplish this?

37. WRITING in Biology Write an editorial for a newspaper advocating protection for coral reefs. Explain the dangers that corals are facing, and make suggestions about what could be done to preserve and protect reefs.

DBQ Document-Based Questions

Transplantation experiments with early embryos of newts show that when tissue responsible for tail development was added into a different fluid-filled gastrula, it caused the effects shown below.

Data obtained from: Niehrs, C. 2003. A tale of tails. *Nature* 424: 375–376.



38. When a section from the top of the area was transplanted, where did the new tissue grow?

39. When a section from the bottom of the area was transplanted, where did the new tissue grow?

40. Make a summary statement that describes where new tissue grew when portions of the embryo responsible for tail development were transferred to fluid in the gastrula.

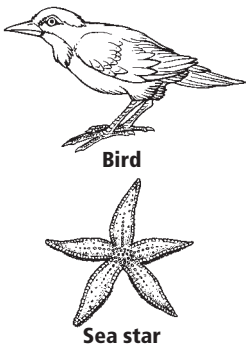
Standardized Test Practice

Cumulative

Multiple Choice

1. Which color of flower is most likely to attract nocturnal pollinators such as bats and moths?
- **A.** blue
- **B.** red
- **C.** violet
- **D.** white

Use the illustration below to answer questions 2 and 3.



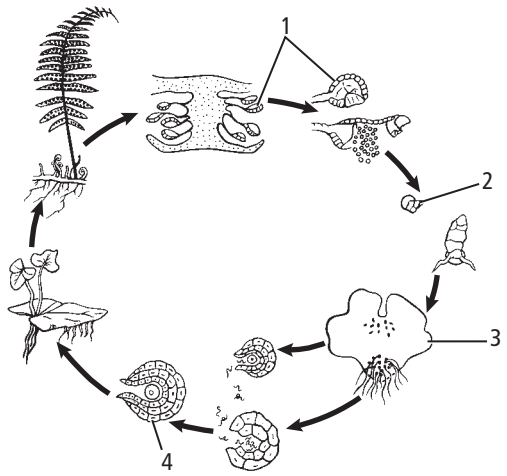
2. How would you describe the body symmetry of the animals shown in the above illustration?
- **A.** Both have bilateral symmetry.
- **B.** Both have radial symmetry.
- **C.** The sea star has bilateral symmetry and the bird has radial symmetry.
- **D.** The sea star has radial symmetry and the bird has bilateral symmetry.

3. How does the body shape of the sea star help with its survival?
- **A.** It enables the sea star to capture many kinds of prey.
- **B.** It enables the sea star to capture prey from many directions.
- **C.** It enables the sea star to move through the water quickly.
- **D.** It enables the sea star to move through the water feebly.

4. Which structure in nonvascular plants is similar to roots in vascular plants?
- **A.** chloroplast
- **B.** mucilage
- **C.** rhizoid
- **D.** sporophyte

5. Which hormone stimulates the ripening of fruit?
- **A.** auxin
- **B.** cytokinins
- **C.** ethylene
- **D.** gibberellins

Use the diagram below to answer question 6.



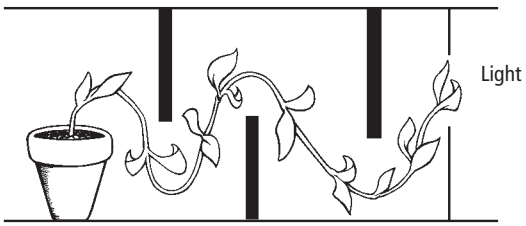
6. At which stage of the fern life cycle does the chromosome number change from haploid to diploid?
- **A.** 1
- **B.** 2
- **C.** 3
- **D.** 4

7. Which is the role of sclerenchyma cells in plants?
- **A.** gas exchange
- **B.** photosynthesis
- **C.** food storage
- **D.** support

8. What evidence would help scientists determine that colonial organisms were an early step in the evolution of multicellularity?
- **A.** similarities in DNA or RNA of early multicellular organisms and colonial unicellular organisms
- **B.** differences in DNA or RNA of early multicellular organisms and colonial unicellular organisms
- **C.** similarities of early multicellular organisms and present-day multicellular organisms
- **D.** differences between early multicellular organisms and present-day multicellular organisms

Short Answer

Use the diagram below to answer question 9.

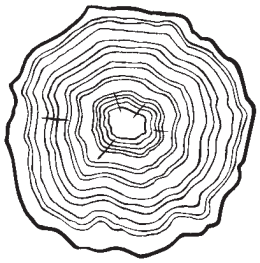


9. A student conducted an experiment using the above set up. Explain the purpose of this experiment.

10. Which type of fossils would tell a paleontologist the most about the soft tissues of an animal?

11. Explain why most spore-producing plants live in moist areas.

Use the diagram below to answer question 12.



12. How is the age of a tree estimated? What is the approximate age of this tree?

13. Name four flower adaptations that attract insects.

14. What are three kinds of evidence that can be used to confirm whether animals with different body structures are related closely?

Extended Response

15. *Plasmodium* is a sporozoan that causes the disease malaria. Identify the different stages of the sporozoan that occur in mosquitoes. Assess the importance of the stages of the life cycle that occur in mosquitoes.

16. Why does Mendel's law of segregation only apply to organisms that reproduce sexually?

17. Summarize egg development and fertilization in flowering plants.

Essay Question

Pollen analysis, or palynology, is an important tool used in archaeology. Palynologists take samples of soil from archaeological sites and analyze the pollen from different soil layers. By examining the changes in pollen types over time, palynologists can learn about historical land use. The pollen in the soil indicates how the land was used—whether it was cultivated, a forest was cleared, or if it was abandoned.

Using the information in the paragraph above, answer the following question in essay format.

18. Scientists have been trying to find the origin of corn. They know that corn was domesticated from a plant called *teosinte* that grew somewhere in the central valley of Mexico between 12,000 and 6,000 years ago. It often is hard to find intact corncobs because they do not fossilize well. How could a palynologist help determine the origin of corn?

NEED EXTRA HELP?																		
If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Review Section . . .	23.1	24.2	24.2	21.2	22.3	23.1	22.1	24.1, 24.3	22.3	14.1	23.1	22.2	23.2	24.1	19.2	10.2	23.2	23.3

CHAPTER 25

Worms and Mollusks



ConnectED

Your one-stop online resource
connectED.mcgraw-hill.com

- Video
- Audio
- Review
- Inquiry
- WebQuest
- Assessment
- Concepts in Motion
- Multilingual eGlossary

Launch Lab

What do earthworms feel like?

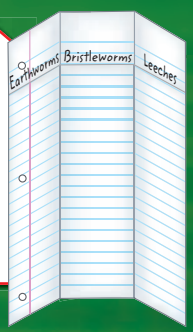
In this lab, you will examine a familiar worm, an earthworm, like the ones in the image above.

For a lab worksheet, use your StudentWorks™ Plus Online.

Inquiry Launch Lab

FOLDABLES®

Make a folded chart using the titles shown. Use it to organize your notes on segmented worms.





THEME FOCUS Energy

All worms obtain energy from other organisms.

BIG Idea Worms and mollusks have evolved to have a variety of adaptations for living as parasites or for living in water or soil.

Section 1 • Flatworms

Section 2 • Roundworms and Rotifers

Section 3 • Mollusks

Section 4 • Segmented Worms

Section 1

Reading Preview

Essential Questions

- What are the adaptations of free-living flatworms and parasitic flatworms?
- How do flatworms maintain homeostasis?
- What are the three classes of flatworms and what are characteristics of each?

Review Vocabulary

acoelomate: an animal without any body cavities

New Vocabulary

pharynx
flame cell
ganglion
regeneration
scolex
proglottid

Multilingual eGlossary

Flatworms

MAIN Idea **Flatworms are thin, flat, acoelomate animals that can be free-living or parasitic.**

Real-World Reading Link Think about a time when you were caught in an unexpected rain shower without rain gear. If you were wearing layers of clothing, the rain might not have soaked through to your skin. As you read about worms, think about how it is easier for the rain to move through one thin layer than through multiple heavy layers.

Body Structure

The evolutionary tree in **Figure 1,** shows that flatworms are on the acoelomate branch of the tree, while roundworms are on the pseudocoelomate branch. However, flatworms and roundworms both have bilateral symmetry. They can be divided along only one plane into mirror-image halves. Bilateral symmetry is a major evolutionary step that allows parts of the body to evolve different organs. Animals that have bilateral symmetry also have more efficient movement than animals with radial symmetry.

Phylum Platyhelminthes (pla tee HEL min theez)—flatworms—consists of about 20,000 species. **Figure 1** shows some of the variety seen in this phylum. Flatworms range in length from many meters to 1 mm or less. They have thin, flat bodies that resemble ribbons. Unlike sponges and cnidarians, flatworms have a definite head region and body organs. Recall that flatworms are acoelomates and therefore lack a coelom. Their bodies have no cavities.

Most flatworms are parasites living in the bodies of a variety of animals, but some others are free-living in marine, freshwater, or moist land habitats. Freshwater planarians are often seen on the underside of rocks in swiftly flowing streams.

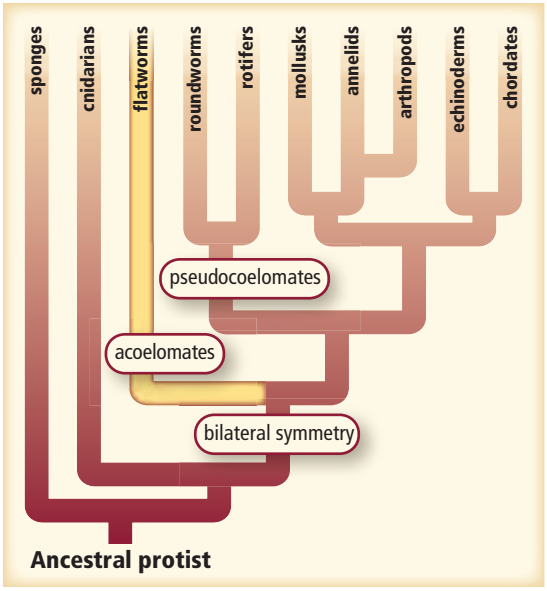
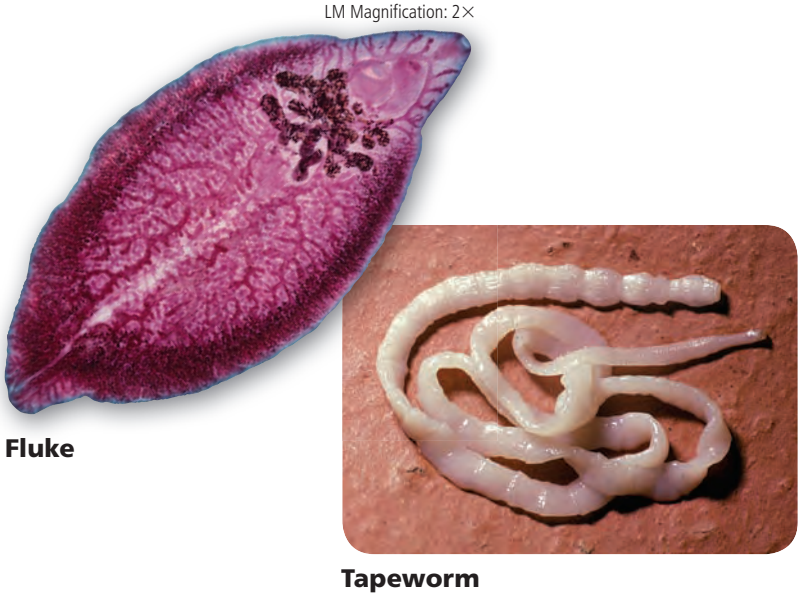


Figure 1 Notice on the evolutionary tree that flatworms, such as flukes and tapeworms, were among the first animals to show bilateral symmetry.
Explain *how the symmetry of flatworms is different from that of cnidarians.*



Fluke

Tapeworm

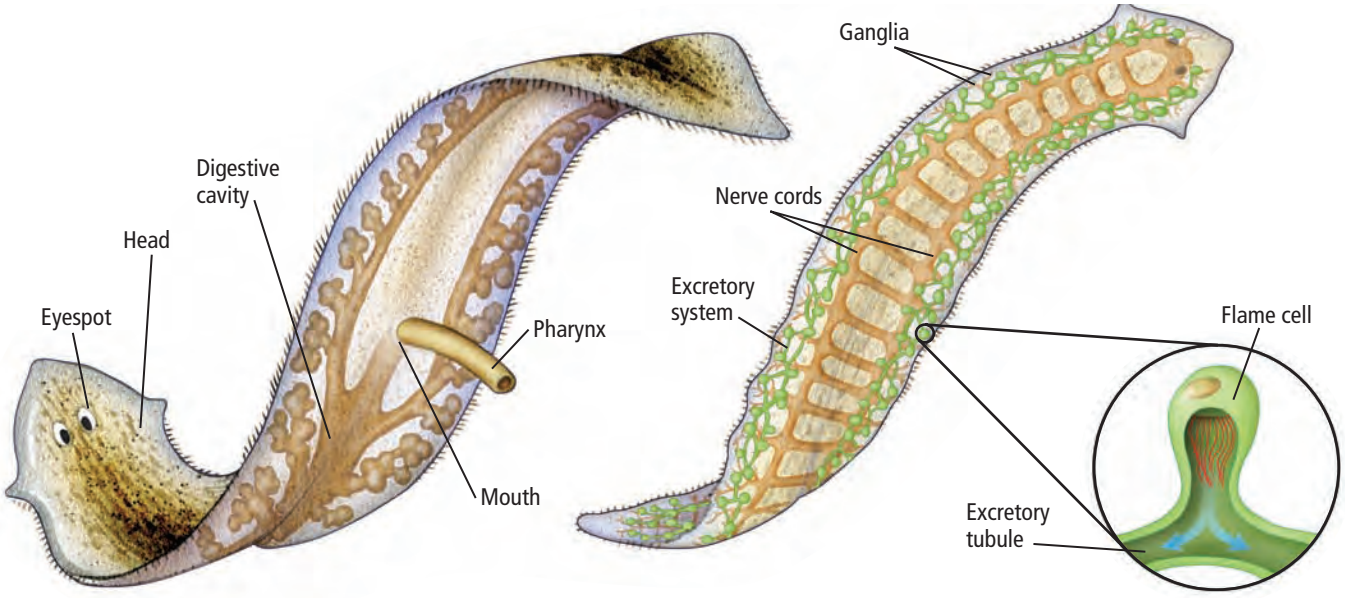


Figure 2 Simple organ systems, such as the excretory and nervous systems, are found in flatworms.

Concepts in Motion

Animation

Inquiry

Video Lab

Feeding and digestion

Free-living flatworms feed on dead or slow-moving organisms. They extend a tubelike muscular organ, called the **pharynx** (FAHR ingks), out of their mouths. The pharynx, shown in **Figure 2,** releases enzymes that begin the digestion of prey. Then food particles are sucked into the digestive tract, where digestion continues. Because flatworms have only one body opening, wastes are ejected through the mouth.

Parasitic flatworms have modified feeding structures called hooks and suckers, which enable them to stay attached to their hosts. Some parasitic flatworms have a reduced digestive system and feed on blood and other body tissues. Other parasitic flatworms lack a digestive system. Because they are so thin, like a single layer of cloth, and are surrounded by nutrients in their host's intestines, these parasites can absorb directly through their body walls partially or completely digested food eaten by the host.

Reading Check **Compare** feeding and digestion in free-living flatworms and parasitic flatworms.

Respiration, circulation, and excretion

Like sponges and cnidarians, flatworms do not have circulatory organs or respiratory organs. Because flatworms are so thin, their cells can use the process of diffusion to move dissolved oxygen and nutrients to all parts of their bodies. Carbon dioxide and other wastes also are removed from flatworm cells by diffusion.

Unlike sponges and cnidarians, flatworms have an excretory system that consists of a network of small tubes that run through the body. On side branches of the tubes, as shown in **Figure 2,** bulblike **flame cells** lined with cilia sweep water and excretory substances into tubules. These substances then exit through pores to the outside of the body. Flame cells were so named because the flickering movements of the cilia inside the cells look like the light of a candle flame. Because flame cells move water out of the body, they keep flatworm cells from becoming waterlogged. In addition to the action of flame cells, flatworms also excrete waste products and maintain homeostatic water balance through their mouths.

Vocabulary

Science usage v. Common usage

Host

Science usage: an animal or plant on which or in which a parasite lives
Some parasitic worms live in the intestines of their hosts.

Common usage: a person who entertains guests
Tyler's dad was the host for the football party.

MiniLab 1

Inquiry MiniLab

Observe a Planarian

How does a planarian behave? Investigate the physical features and behavior of a planarian by observing this common flatworm.

LM Magnification: 10×



Planarian

Procedure

1. Read and complete the lab safety form.
2. Observe the **planarian** in a **water-filled observation dish** by using a **magnifying lens.**
3. Create a data table to record your observations.
4. Record the physical characteristics and behaviors of the flatworm.
5. Place a small piece of **cooked egg white** into the dish, and observe the feeding behavior of the planarian.

Analysis

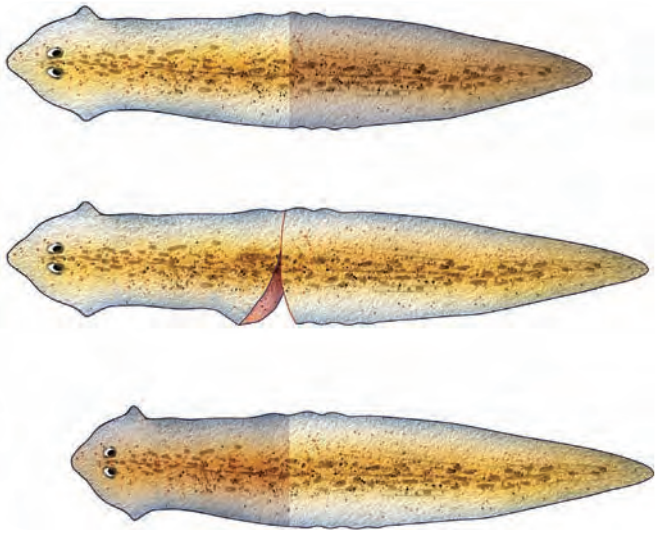
1. **Compare and contrast** the physical features of the planarian with the features of the earthworm you observed in the Launch Lab.
2. **Analyze** how the body shape and movement of a planarian enables it to live in its environment.
3. **Infer** why scientists classify planaria into a group separate from other worms.

Response to stimuli The nervous system regulates the body's response to stimuli. In most flatworms, the nervous system consists of two nerve cords with connecting nerve tissue that run the length of the body. In most flatworms, the connecting nerve tissue looks like the rungs of a ladder, as illustrated in **Figure 2.** At the anterior end of the nerve cords is a small swelling composed of ganglia, which send nerve signals to and from the rest of the body. A **ganglion** (plural, ganglia) is a group of nerve cell bodies that coordinates incoming and outgoing nerve signals.

Movement Some flatworms move by contracting muscles in the body wall. To escape predators and to find food, most free-living flatworms glide by using cilia located on their undersides. Mucus lubricates the worms and improves the gliding motion, while muscular action lets the animals twist and turn. If you have ever tried to loosen planaria worms from the bottoms of rocks, you know that their outer mucus covering enables them to stick tightly—an important adaptation in a swiftly moving stream. You can observe the features and behavior of a flatworm in **MiniLab 1.**

Reproduction Flatworms are hermaphrodites because they produce both eggs and sperm. During sexual reproduction, two different flatworms exchange sperm, and the eggs are fertilized internally. In marine flatworms, zygotes in cocoons are released into the water, where they hatch within a few weeks.

Free-living flatworms can reproduce asexually by **regeneration**, a process in which body parts that are missing because of damage or predation can be regrown. A planarian that is cut in half horizontally can grow a new head on the tail end and a new tail on the head end, forming two new organisms, as shown in **Figure 3.**



■ **Figure 3** Two new planaria form when one planarian is cut in half horizontally. Some planaria can regenerate from almost any piece of their bodies.

Diversity of Flatworms

There are three main classes of flatworms: Turbellaria (tur buh LER ee uh), Trematoda (trem uh TOH duh), and Cestoda (ses TOH duh). Class Turbellaria consists of the free-living flatworms. Class Trematoda and class Cestoda consist of parasitic flatworms.

Turbellarians Members of the class Turbellaria are called turbellarians. Most turbellarians, like planarians, live in marine or freshwater habitats, while some live in moist soils. They vary in size, color, and body shape. As shown in **Figure 4,** turbellarians have eyespots that can detect the presence or absence of light. They also have sensory cells that help them identify chemicals and water movement.

The cells sensitive to chemicals are concentrated on small projections called auricles (OR ih kulz) at the anterior end of the worm. When a planarian hunts, it might wave its head back and forth as it crawls forward, exposing the auricles to chemical stimuli coming from food. At the same time, its eyespots might help it perceive light conditions that would protect it from predators.

Trematodes Flukes belong to class Trematoda—the trematodes. They are parasites that infect the blood or body organs of their hosts. The life cycle of the parasitic fluke *Schistosoma* is shown in **Figure 5.** Notice that this parasite requires two hosts to complete its life cycle.

When humans contract schistosomiasis (shihst tuh soh MI uh sis), the fluke eggs clog blood vessels, causing swelling and eventual tissue damage. Schistosomiasis can be prevented by proper sewage treatment and by wearing protective clothing when wading or swimming in infested water. Schistosomiasis infections are not common in the United States.

LM Magnification: 1×

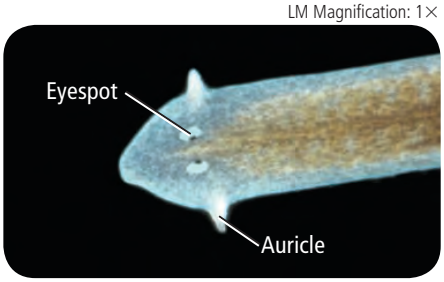
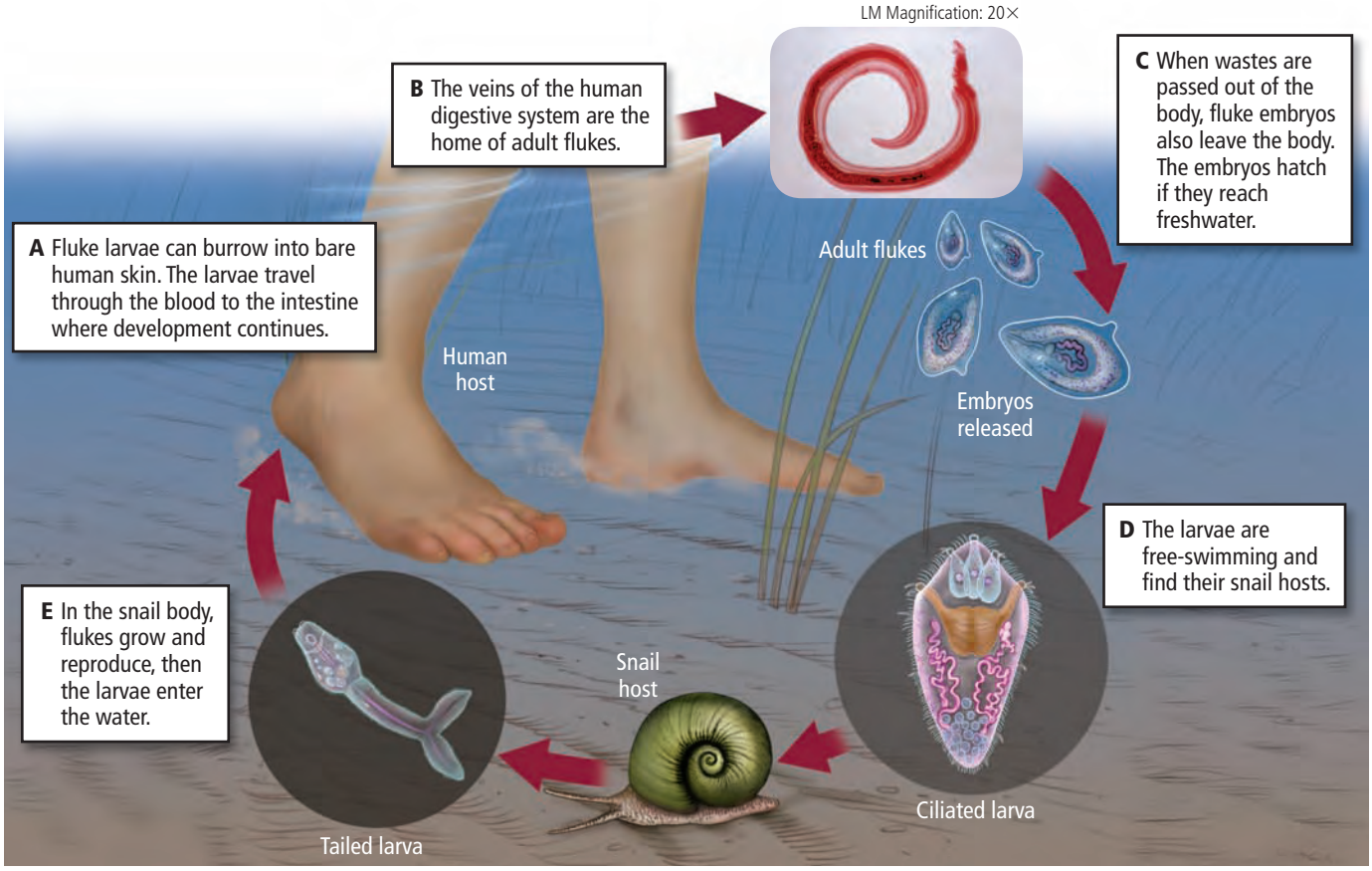


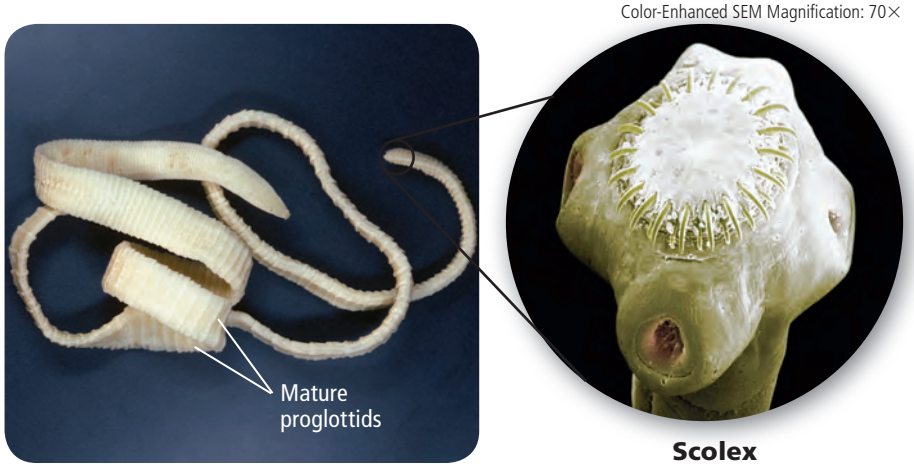
Figure 4 Dark clusters of light-sensitive cells form the eyespots on this planarian. Note the auricles projecting from the same area.

Figure 5 Two hosts—humans and snails—are needed to complete the life cycle of the fluke *Schistosoma.*

Infer ***why the two larval forms of the fluke are different shapes.***



■ **Figure 6** As the proglottids behind the scolex mature, new proglottids form.



Cestodes All tapeworms are members of class Cestoda—the cestodes. They are parasites adapted to life in the intestines of their hosts. Look at the anterior end, or head, of the tapeworm in **Figure 6.** This is the **scolex** (SKOH leks), a knob-shaped structure with hooks and suckers that attach to the intestinal lining of a host, such as a cow or a human.

Behind the scolex of the worm are a series of individual sections called **proglottids** (proh GLAH tihdz), each of which contains muscles, nerves, flame cells, and male and female reproductive organs. Proglottids form continuously; as new ones form near the scolex, older proglottids move farther back and mature. After eggs in the mature proglottids are fertilized, the last segments with developing embryos break off and pass out of the intestines of their hosts. Animals such as cattle might feed on vegetation or drink water contaminated by the tapeworm proglottids, and then the cycle of tapeworm growth is repeated.

When eaten by cattle, tapeworms burrow through intestinal walls, entering blood and muscle. If undercooked infected beef is eaten, human infection by tapeworms is likely. Tapeworm infections are uncommon in industrialized nations because of beef inspections.

Section 1 Assessment

Section Summary

- Flatworms were among the first animals to exhibit bilateral symmetry.
- Flatworms are acoelomates with limited numbers of organs and systems.
- Some flatworms are free-living, and others are parasitic.
- Flatworms that are parasitic have specialized adaptations for parasitic life.

Understand Main Ideas

1. MAIN Idea **Evaluate** the advantages of a flatworm's thin body.
2. **Compare and contrast** the adaptations of free-living flatworms and parasitic flatworms.
3. **Prepare** a chart that compares digestion, respiration, movement, and reproduction in the free-living and parasitic flatworms.
4. **Analyze** the importance of flame cells in a flatworm.

Think Critically

5. **Design** an experiment to determine what habitat conditions planarians prefer.
6. **Evaluate** how the three classes of flatworms are adapted to their habitats. Name the three classes of flatworms in your answer.
7. **Diagram** bilateral symmetry using a planarian as an example. Explain the adaptive advantage of bilateral symmetry to a planarian.

Assessment Online Quiz

Reading Preview

Essential Questions

- What are the similarities between the features of roundworms and flatworms?
- How can roundworms be identified based on movement?
- What are the ways humans risk contracting roundworm parasites?

Review Vocabulary

cilia: short, numerous projections that look like hairs

New Vocabulary

hydrostatic skeleton
trichinosis

Multilingual eGlossary

Roundworms and Rotifers

MAIN Idea **Roundworms and rotifers have a more highly evolved gut than flatworms.**

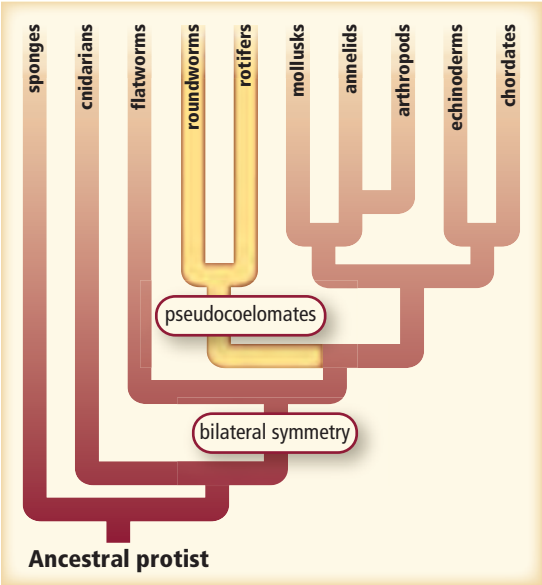
Real-World Reading Link If you were to guess what animal is one of the most common in the world, what animal would you choose? Would you guess a roundworm? With 20,000 species of roundworms known, scientists estimate that there might be 100 times as many more kinds of roundworms still undiscovered.

Body Structure of Roundworms

Roundworms are in phylum Nematoda (ne muh TOH duh) and often are called nematodes. Locate roundworms on the evolutionary tree in **Figure 7.** Notice that they are pseudocoelomates. Recall that pseudocoelomates have a fluid-filled body cavity that is partially lined with mesoderm. Roundworms have bilateral symmetry and are cylindrical, unsegmented worms that are tapered at both ends. Roundworms come in a variety of sizes, as shown in **Figure 7.** Most are less than 1 mm long. However, the longest known roundworm, which lives in certain whales, can grow to 9 m in length.

Roundworms are found in both marine and freshwater habitats and on land. Some are parasites that attach to plants or animals. A spadeful of garden soil might contain one million roundworms. One study revealed that a rotting apple contained 1074 roundworms! Dogs and cats can be plagued by roundworms if they are not wormed when they are young and at regular intervals during adulthood. Roundworms have adaptations that enable them to live in many places.

Figure 7 Roundworms are pseudocoelomates with bilateral symmetry.



SEM Magnification: 150×



Vinegar eel (2 mm in length)



Ascarid worms (10–35 cm in length)

CAREERS IN BIOLOGY

Veterinary Parasitologist As scientists who keep parasites out of the food supply, veterinary parasitologists are responsible for the health of farm and domesticated animals. They determine ways to control and prevent parasites in animals such as cows, pigs, and chickens.

Feeding and digestion Most roundworms are free-living, but some are parasites. Some free-living roundworms are predators of other tiny invertebrates, while others feed on decaying plant and animal matter. Free-living forms have a key evolutionary adaptation in their digestive systems. Recall that in the course of evolution, pseudocoelomate animals were the first to have a body cavity. The pseudocoelom of a nematode separates the endoderm-lined gut from the rest of the body. The movement of food through the gut, or digestive tract, is one-way—food enters through the mouth, and undigested food leaves through an opening at the end of the digestive tract called the anus.

Respiration, circulation, excretion, and response to stimuli Like flatworms, roundworms have no circulatory organs or respiratory organs, and they depend on diffusion to move nutrients and gases throughout their bodies. Most roundworms exchange gases and excrete metabolic wastes through their moist outer body coverings. More complex forms have excretory ducts that enable them to conserve water for living on land, while others have flame cells.

Ganglia and associated nerve cords coordinate nematode responses. Nematodes are sensitive to touch and to chemicals. Some have structures that might detect differences between light and dark.

Movement Roundworms have muscles that run the length of their bodies. These muscles cause the worms' bodies to move in a thrashing manner as one muscle contracts and another relaxes. These muscles also pull against the outside body wall and the pseudocoelom. The pseudocoelom acts as a **hydrostatic skeleton**—fluid within a closed space that provides rigid support for muscles to work against. If you were to observe a roundworm moving, it might resemble a tiny piece of wriggling thread. Learn more about worm movement in **Data Analysis Lab 1.**

DATA ANALYSIS LAB 1

Based on Real Data*

Interpret the Diagram

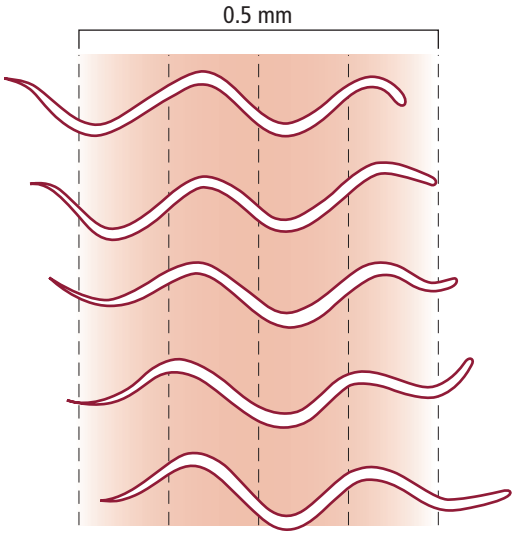
How does a nematode move? A nematode alternately contracts and relaxes muscles that run lengthwise on each side of its body.

Data and Observations

The diagram sequences the movement of a single nematode. Each segment of time is represented by the space between the dotted lines.

Think Critically

1. **Interpret** about how long it took the worm to move to its final location.
2. **Calculate** how far the worm could move in 10 min.
3. **Infer** how worm movement might differ if muscles on one side of its body were damaged.



Time between segments is 0.33 s

*Data obtained from: Gray, J. and H.W. Lissmann. 1964. The locomotion of nematodes. *Journal of Experimental Biology* 41:135–154.

Reproduction Roundworms reproduce sexually. The females produce eggs, and the males, which often are smaller than the females, produce sperm. Fertilization is internal. In free-living roundworms, larvae hatch from the fertilized eggs, then grow into adults. In parasitic roundworms, development often is more complicated, involving one or more hosts or different locations in the host's body.

The adult roundworm *Caenorhabditis elegans (C. elegans),* shown in **Figure 8,** contains only 959 cells; zygotes mature to adults in just three days. These characteristics make it an extremely important subject of research on development, aging, and genetics. *C. elegans* was the first multicellular organism to have its entire genome sequenced. The *C. elegans* genome contains 97 million DNA bases encoding more than 19,000 different genes.

Reading Check **Explain** why the features of *C. elegans* make it a good subject for research.

LM Magnification: 64×



Figure 8 *C. elegans* is the subject of much genetic research. With comparatively few cells and rapid development, scientists can easily research developmental changes.

Diversity of Roundworms

Of the 20,000 known roundworm species, approximately half are parasites. These parasitic roundworms cause a variety of diseases in plants and animals, including humans. Many of these diseases in humans are the result of carelessness, a lack of personal hygiene, or poor sanitation.

Trichinella worms A disease called **trichinosis** (trih keh NOH sis) can be contracted by eating raw or undercooked pork and pork products, or wild game infected with the larvae of *Trichinella,* like the one shown in **Figure 9.** After ingestion by a host organism, the worms mature in one to two days. Female worms with fertilized eggs burrow into the intestinal walls of humans, pigs, and other mammals. After the eggs hatch, the larvae burrow into muscles where they form cysts, causing muscle pain. Trichinosis can be prevented by cooking meat properly.



LM Magnification: 400×

Figure 9 A trichinella worm larva is seen curled up inside of a cyst (purple) in pig muscle. **Infer** ***what kind of physical symptoms a person with trichinosis might have.***

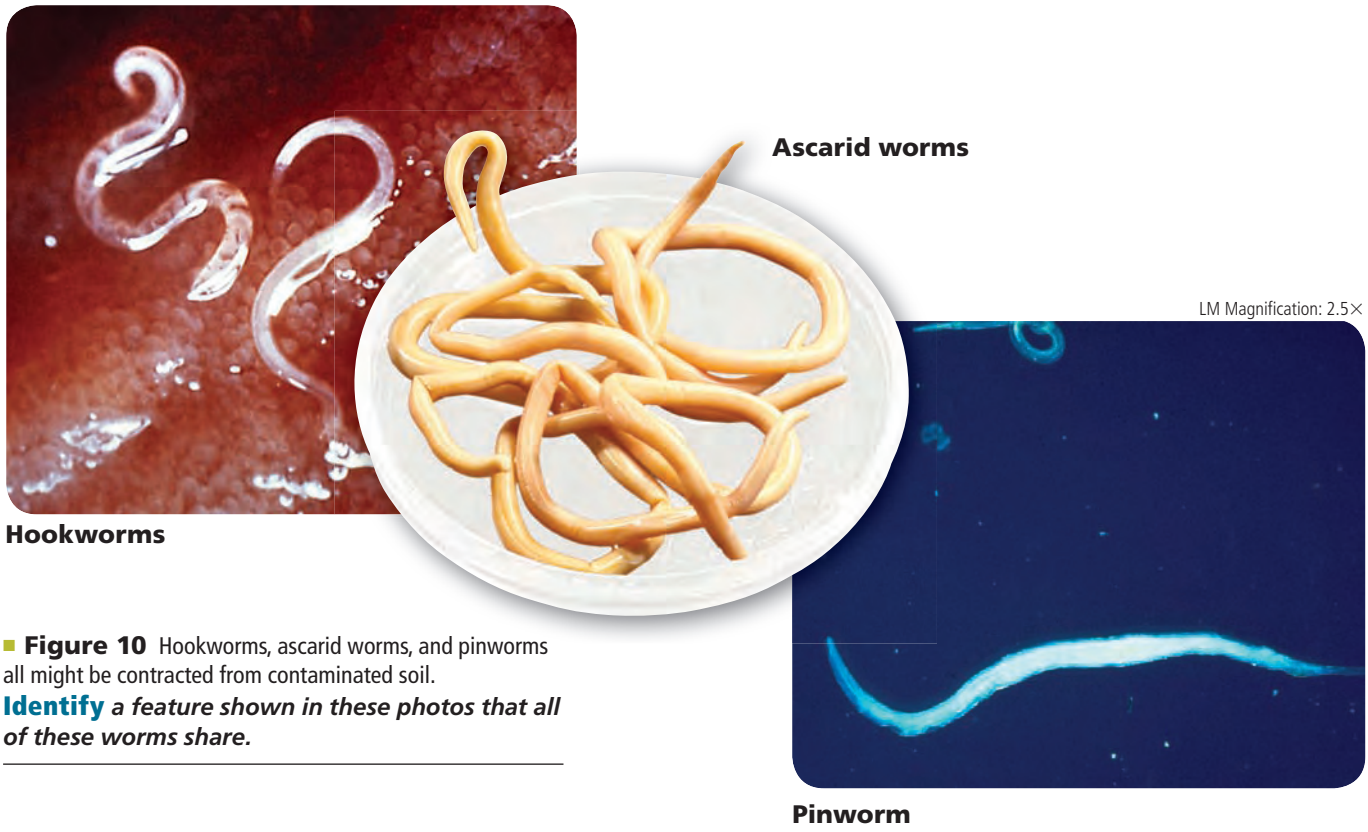


Figure 10 Hookworms, ascarid worms, and pinworms all might be contracted from contaminated soil.
Identify *a feature shown in these photos that all of these worms share.*

Hookworms Hookworm infections are common in warm climates when people go barefoot on contaminated soil. When a hookworm, shown in **Figure 10,** contacts bare human skin, it cuts its way inside, travels in the bloodstream to the lungs, and then to the windpipe, or esophagus, where it is coughed up and swallowed. The parasite then moves to the small intestine, where it attaches to intestinal walls and feeds on blood and other tissue. Hookworm infection can be prevented by wearing shoes.

Ascarid worms The most common worm infection in humans is ascariasis (AS kuh RI uh sus), which is caused by ascarid (AS kuh rid) worms like the ones shown in **Figure 10.** Eggs of ascarid worms are found in soil in subtropical and tropical areas. They enter the human body through the mouth and live in the intestine. Infection can result when unwashed vegetables from contaminated soil are eaten or when hands contaminated with infected soil are put in the mouth, as young children are likely to do. Infection by ascarid worms can be controlled by carefully washing vegetables and hands.

Reading Check **Explain** how humans can prevent infection from hookworms and ascarid worms.

Vocabulary
Word Origin
Nematode
nemato– prefix; from Greek, meaning *thread*
–ode suffix; from the Greek word *oeides,* meaning *similar to*

Pinworms **Figure 10** shows a pinworm, the most common nematode parasite in humans in the United States. The highest incidence of infection occurs in children. At night, female pinworms living in the intestine move out of the anus and lay eggs on nearby skin. When the skin is scratched because of the itching caused by pinworm activity, the eggs are transferred to hands and then to any surface that is touched. These eggs can survive for up to two weeks on surfaces and are ready to hatch if another person ingests them. This infection can spread quickly among children who put toys and other objects in their mouths.

Filarial worms Elephantiasis (el uh fun TI uh sus) is a disease caused by filarial (fuh LER ee uhl) worms, which are roundworm parasites that live in tropical areas. A mosquito is the intermediate host of filarial worms. When a mosquito sucks blood from a person who is infected with this roundworm, worm embryos are passed into the insect's bloodstream. The embryos grow into larvae, which then are passed to another person when the mosquito bites again. Adult worms accumulate in the lymphatic system and obstruct the flow of lymph—the tissue fluid in the spaces between cells. This fluid builds up in tissue, causing legs and other body regions to enlarge. Controlling mosquitoes and using mosquito netting at night can aid in preventing this disease.

Another disease caused by a filarial worm—heartworm—is found in dogs and cats throughout the United States. Heartworms are transmitted to dogs and cats through mosquito bites. Once in the bloodstream, the worms travel to the heart and block the flow of blood. Regular doses of oral medications prevent heartworm in dogs and cats.

Reading Check **Identify** In what parts of the human body do pinworms and filarial worms live?

Nematodes in plants Some species of roundworms cause diseases in plants. Nematodes can infect and kill pine trees, soybean crops, and food plants such as tomatoes. When they infect plant roots, as shown in **Figure 11,** they damage the plant.

Most species of nematodes are either harmless or beneficial to plants. Certain nematodes are used to control the spread of cabbage worm caterpillars, Japanese beetle grubs, and many other pests of crop plants. Spraying a solution of nematodes and water on areas that are infested with crop pests is most effective when the targeted pest is at the stage in its life cycle when it lives in the soil.

Connection to Health In addition to treating plant pests, nematodes are used to control pests of humans and animals. Nematodes eat flea larvae and thus control the flea population in yards. This reduces or eliminates exposure of humans and animals to traditional chemicals used to treat flea infestations.

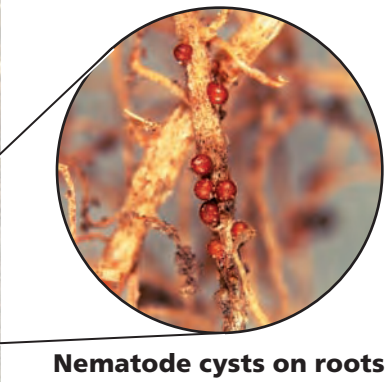
Figure 11 The growth of the vascular system of plants can be slowed down when nematodes move into the roots and form cysts.



Potato plant without nematodes



Potato plant with nematodes



Nematode cysts on roots

LM Magnification: 100×



Figure 12 Rotifers have two rings of cilia at their anterior end.

Rotifers

Rotifers are tiny animals only about 0.1 mm to 0.5 mm in length. The phylum Rotifera, meaning *wheel-bearer,* gets its name from the rings of cilia around the mouths of the animals. About 1800 species of rotifers have been studied, mostly from freshwater habitats, including ponds, streams, and lakes. It would not be unusual to find 40 to 500 rotifers in a liter of pond water. A few species are marine. Refer to the evolutionary tree in **Figure 7** and note that although rotifers and roundworms occupy separate branches, both are pseudocoelomates.

Rotifer features and movement Rotifers are similar to roundworms because they have bilateral symmetry and are pseudocoelomates with a gut open at both ends. Unlike roundworms, however, rotifers move through the water by means of their ciliated wheel-like structures, which are shown in **Figure 12.** The posterior end of a rotifer generally has "toes" and glands that secrete an adhesive material that enables a rotifer to attach itself to a surface in the water.

Organ systems of rotifers Rotifers feed by using cilia to gather protists and organic materials into a complete digestive tract, which includes a mouth and an anus. Like other pseudocoelomates, rotifers exchange gases and excrete metabolic wastes by diffusion through body walls. Sensory structures include sensory bristles and eyespots on the head. Some rotifers reproduce sexually, while others have complex life cycles involving diploid eggs producing diploid females and haploid eggs producing haploid males. These life cycles are dependent on environmental conditions, such as spring rains, frost, or the presence of stagnant water.

Section 2 Assessment

Section Summary

- Roundworms are closely related to flatworms.
- Roundworms, like flatworms, have a limited number of organs and systems.
- Roundworms are either free-living or parasitic.
- Roundworms cause many human and plant diseases.
- Rotifers are pseudocoelomates that appear on a different branch of the evolutionary tree from that of roundworms.

Understand Main Ideas

1. MAIN Idea **Describe** the evolutionary adaptation of the digestive tract of roundworms.
2. **Compare and contrast** the features of flatworms and roundworms.
3. **Explain** how roundworms make their distinctive thrashing movements.
4. **Compare and contrast** the various ways in which humans might risk contracting roundworm parasites.

Think Critically

5. **Hypothesize** Imagine that you are digging in your garden and find some tiny threadlike animals making thrashing movements. Make a hypothesis about what these animals might be. Explain your answer.

MATH in Biology

6. Make a circle graph that shows the number of roundworm species known compared to the estimated number of roundworm species that might exist.

Assessment Online Quiz

Section 3

Reading Preview

Essential Questions

- What is the importance of the coelom to mollusks?
- What is the function of the mantle and what are its adaptive advantages to mollusks?
- What is the importance of mucus and the muscular foot to mollusks?

Review Vocabulary

herbivore: an organism that eats only plants

New Vocabulary

mantle
radula
gill
open circulatory system
closed circulatory system
nephridium
siphon

Multilingual eGlossary

Mollusks

MAIN Idea **Mollusks are coelomates with a muscular foot, a mantle, and a digestive tract with two openings.**

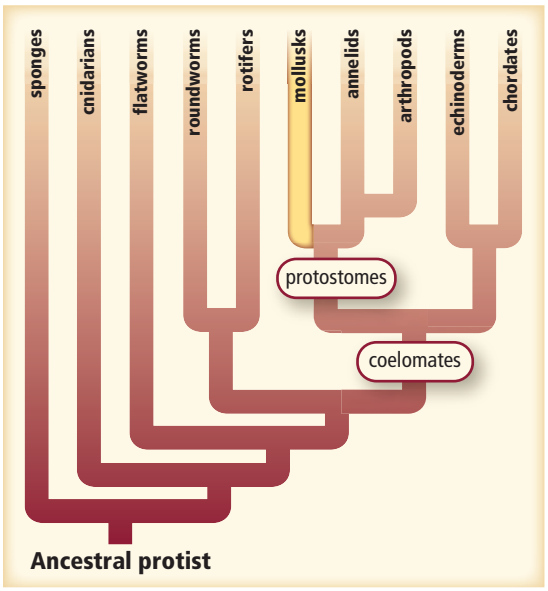
Real-World Reading Link Have you ever watched a rocket blast off into space? The rocket is powered by jet propulsion—a stream of heated gas is forced out of the engine, pushing the rocket in the opposite direction. Some animals, such as octopuses, also move by jet propulsion, forcefully expelling streams of water to push them away from danger.

Body Structure

Mollusks are members of the phylum Mollusca. They range from the slow-moving slug to the jet-propelled squid, from scallops and cuttlefish to chitons and nudibranchs. Mollusks range in size from almost microscopic snails to giant squids, which can grow to be 21 m long.

Look at the evolutionary tree in **Figure 13.** Mollusks, such as the nudibranch and the octopus in **Figure 13,** undergo protostome development and might have been the first animals in the course of evolution to have a coelom, which allowed for the development of more complex tissues and organs. There are more than 110,000 known species of mollusks. Many are marine, some live in freshwater, and others live in moist land environments.

Mollusks are coelomate animals with bilateral symmetry, a soft internal body, a digestive tract with two openings, a muscular foot, and a mantle. The **mantle** (MAN tuhl) is a membrane that surrounds the internal organs of the mollusk. In mollusks with shells, the mantle secretes calcium carbonate to form the shell. Other mollusks, including slugs and squids, are adapted to life without a hard outer covering.




Nudibranch

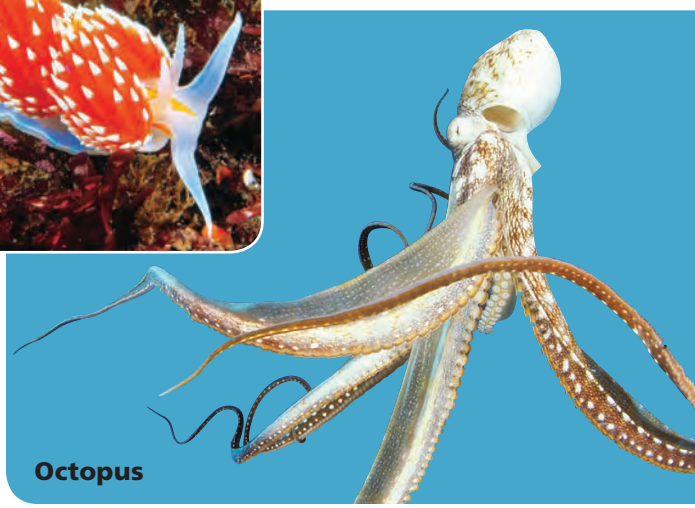

Octopus

Figure 13 Mollusks, such as the nudibranch and octopus, have coeloms. **Infer** *what the main difference is between mollusks and roundworms based on the evolutionary tree.*

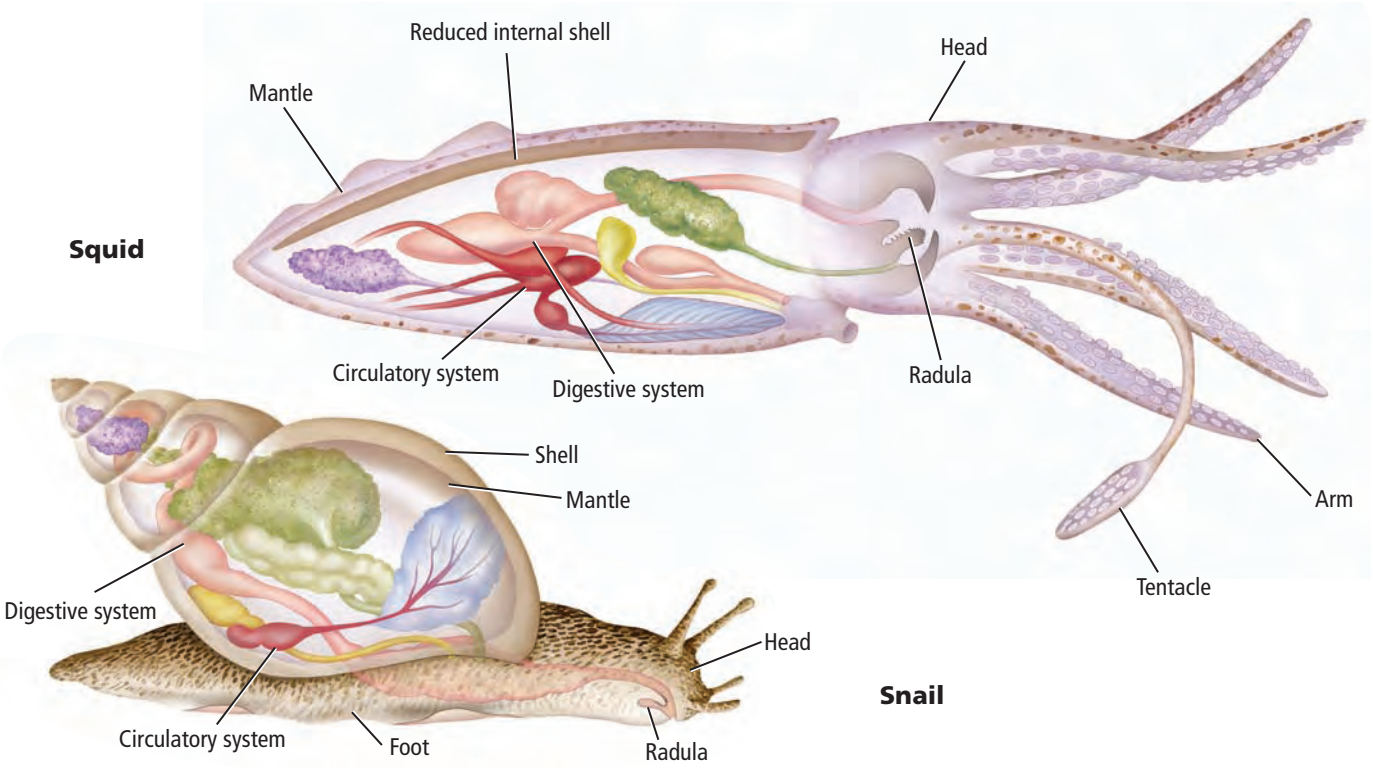


Figure 14 Many mollusks have shells. Inside the shell is a soft body consisting of a foot, organs, and a mantle.
Compare and contrast *the bodies of the snail and the squid.*

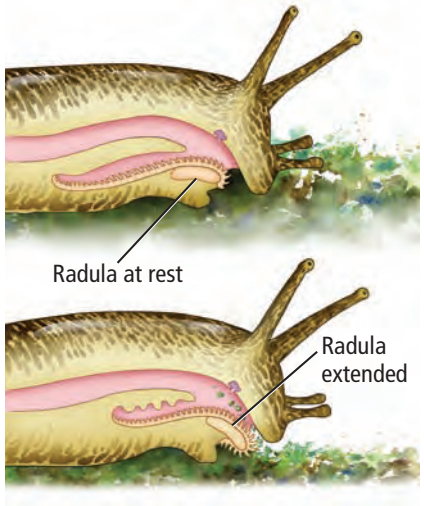
Compare the bodies of the snail and the squid in **Figure 14.** Their external features are very different from each other. However, both have coelomate body plans and highly evolved body systems, such as the digestive system, respiratory system, circulatory system, and nervous system.

Feeding and digestion Many mollusks use a rasping structure called a radula to scrape food into their mouths. Located in a mollusk's mouth, a **radula** (RA juh luh) is a tonguelike organ with rows of teeth, as shown in **Figure 15.** Herbivorous mollusks use their radulas to scrape algae off rocks. Carnivorous mollusks use their radulas to drill into other mollusks and feed on their internal body parts. Some of these predators, such as octopuses and squids, use their radulas to tear up the food they capture with their tentacles. Other mollusks, such as clams, are filter feeders and do not have radulas.

Mollusks have complete guts with digestive glands, stomachs, and intestines, as shown in **Figure 16.** As in roundworms, the digestive system has two openings—a mouth and anus.

Reading Check **Explain** why the evolution of a coelom is important to mollusks.

Figure 15 Many mollusks feed using a radula. At the top, the radula is at rest. At the bottom, you can see the toothlike scraping structures on the radula as it is extended to feed.



Respiration Most mollusks have respiratory structures called gills. **Gills,** shown in **Figure 16,** are parts of the mantle that consist of a system of filamentous projections that are like the fringes of a blanket. Gills contain a rich supply of blood for the transport of oxygen to the blood and for the removal of carbon dioxide from the blood. Gills move water into and through the mantle cavity in a continuous stream. They are highly branched structures, which increase the surface area through which gases can diffuse. This enables the gills to take in more oxygen from water. Land snails and slugs remove oxygen from the air using the lining of their mantle cavities. In some mollusks, the gills also function in filter feeding.

Circulation Mollusks have a well-developed circulatory system that includes a chambered heart. Most mollusks have an **open circulatory system,** in which the blood is pumped out of vessels into open spaces surrounding the body organs. This adaptation enables animals to diffuse oxygen and nutrients into tissues that are bathed in blood and also to move carbon dioxide from tissues into the blood. Slow-moving animals, such as snails and clams, utilize this system effectively because they do not need rapid delivery of oxygen and nutrients for quick movements.

Some mollusks, such as squids, move nutrients and oxygen through a closed circulatory system, which was a major adaptation in the evolution of animals. In a **closed circulatory system,** blood is confined to vessels as it moves through the body. A closed system efficiently transports oxygen and nutrients to cells, where they are converted to usable forms of energy. Mollusks that move quickly, such as octopuses and squids, need more energy than slow-moving mollusks, and the closed circulatory system quickly delivers nutrients and oxygen. A closed circulatory system is like the heating ducts in some houses. A furnace is efficient at delivering warm air to the rooms in a house because the air travels through a series of ducts or pipes. Rooms of a house would not be evenly heated if the furnace did not have a delivery system.

Excretion Most mollusks get rid of metabolic wastes from cellular processes through structures called **nephridia** (nih FRIH dee uh), shown in **Figure 16.** After nephridia filter the blood, waste is passed out through the mantle cavity. Nephridia are an evolutionary adaptation enabling mollusks to efficiently maintain homeostasis in their body fluids.

Response to stimuli Mollusks have nervous systems that coordinate their movements and behavior. Mollusks that are more highly evolved, such as octopuses, have brains. In addition, octopuses have complex eyes similar to human eyes with irises, pupils, and retinas. Most mollusks have simple structures in the eyes that reflect light.

CAREERS IN BIOLOGY

Laboratory Assistant Marine biologists depend on laboratory assistants to help collect specimens, such as mollusks, and to maintain databases. These entry-level workers also set up equipment and prepare samples for testing.

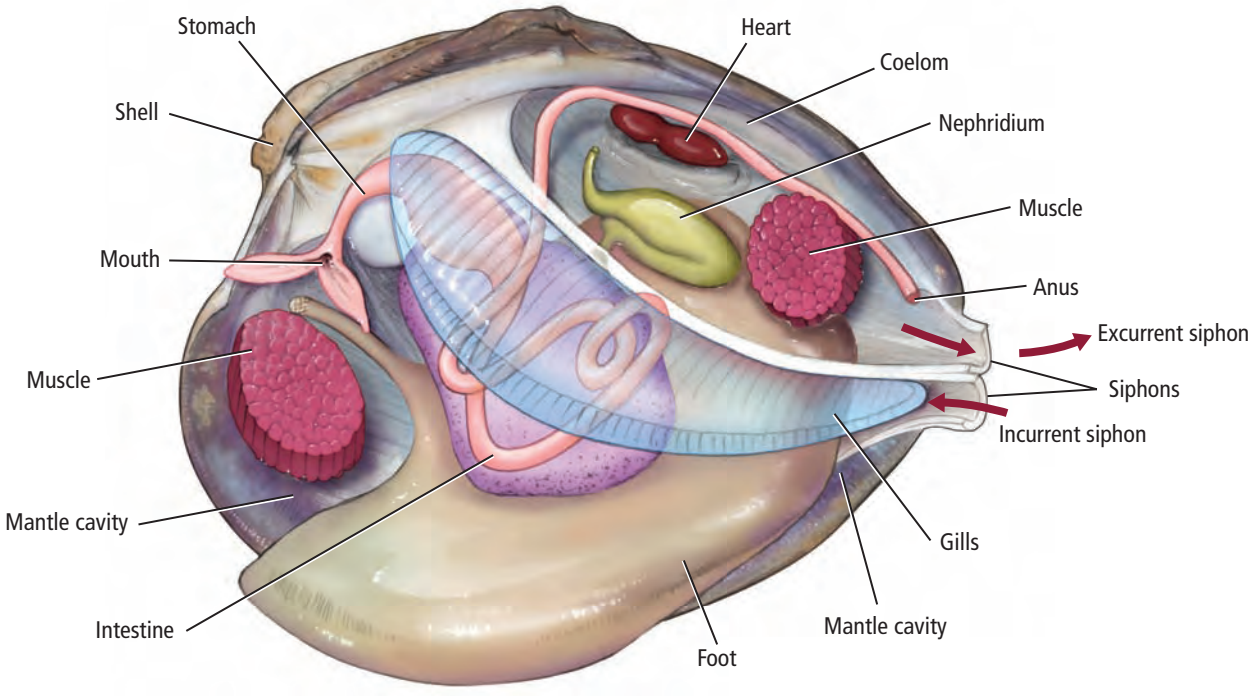


Figure 16 The internal anatomy of a clam illustrates the well-developed organ systems in mollusks.

Visualizing Movement in Mollusks

Figure 17
Mollusks move in a variety of ways. The type of movement used often depends on a mollusk's unique adaptations.

Gastropods

A gastropod moves by sending waves of contractions along its muscular foot. A film of mucus lubricates the foot and helps propel the animal forward.



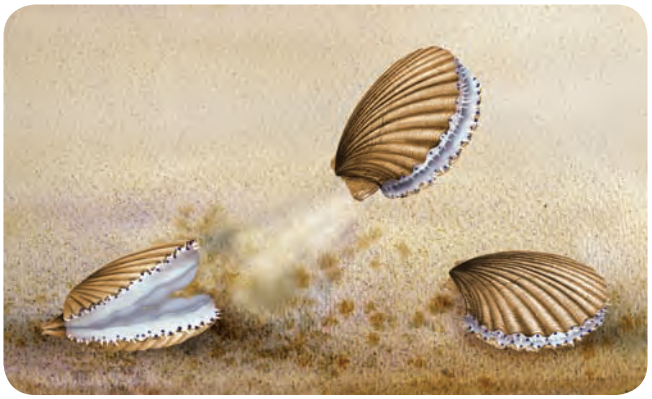
Note the waves of muscle contractions as the snail moves along its mucous trail.



A clam can rapidly bury itself in sand using its muscular foot.

Bivalves

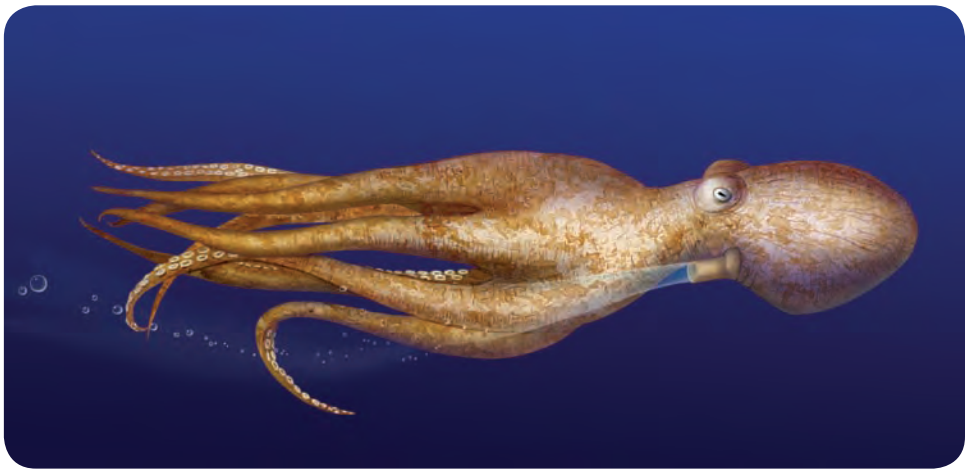
Most bivalves do not move much, unless they are threatened by a predator. Then, a bivalve either uses its muscular foot to burrow into sediment, as shown on the left, or uses jet propulsion to flee, as shown at right.



A scallop pulls its shells together, forcing jets of water toward the shell hinge. The force of the water pushes the scallop in the direction of the shell opening.

Cephalopods

Members of class Cephalopoda, such as octopuses and squids, move by jet propulsion. To avoid predators, a cephalopod draws in water through slits in the body wall. Then the water is pumped rapidly through the siphon, jet-propelling the cephalopod away from danger.



An octopus changes the direction it moves by alternating the direction of its siphon.

Concepts in Motion Animation

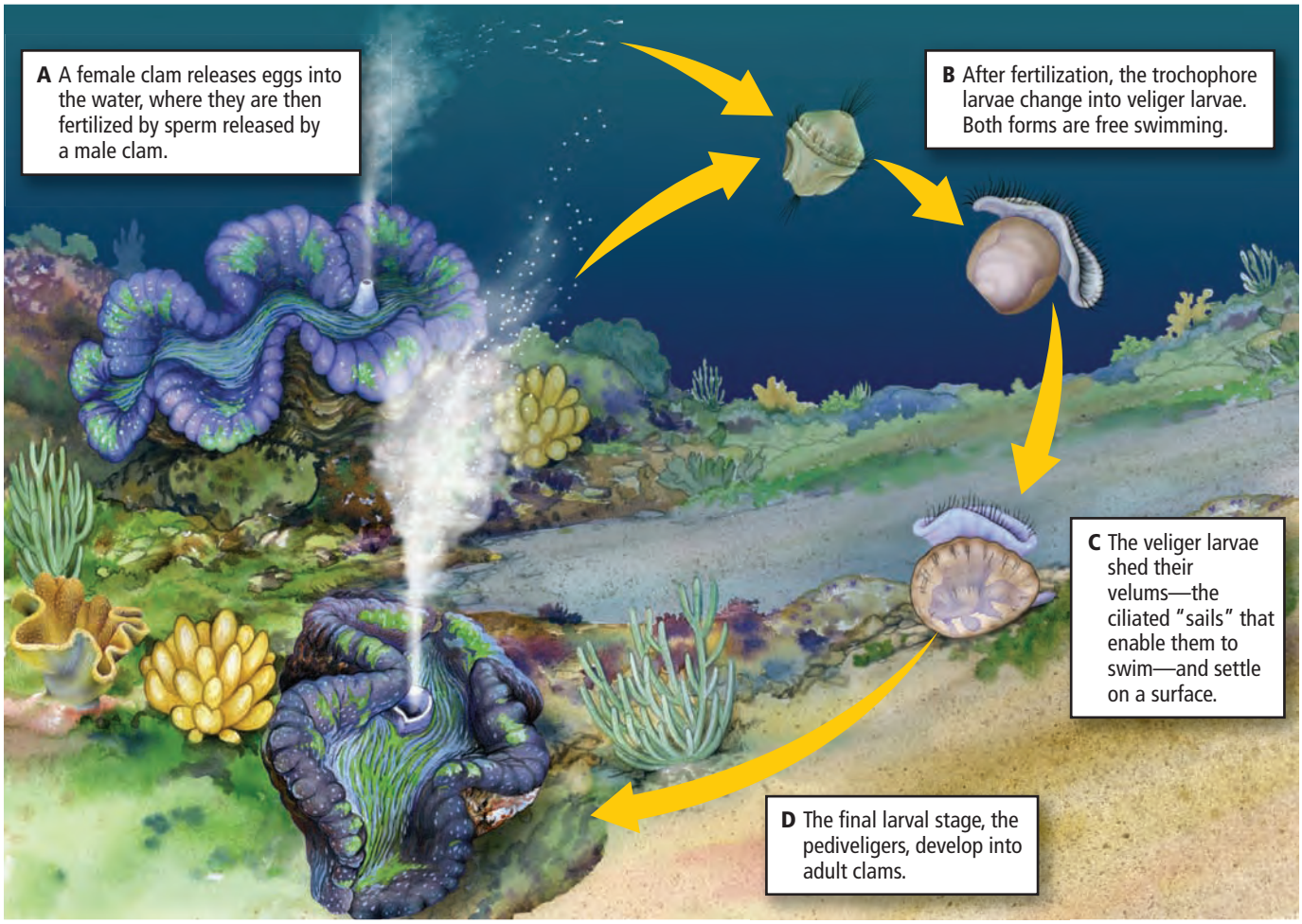
Movement The muscular foot of a clam enables it to burrow into wet sand. Mollusks with two shells can clap their shells together for short bursts of rapid swimming. Most slugs and snails creep along moist areas on a slime trail of mucus secreted by glands in the foot. Octopuses and squids take water into the mantle cavity and expel it through a tube called a **siphon.** When threatened, they can eject the water so rapidly that they appear to be jet-propelled. **Figure 17** illustrates the ways mollusks move.

Reading Check **Compare** movement in two-shelled mollusks, snails, and squids.

Reproduction Mollusks reproduce sexually, as illustrated in **Figure 18.** The males and females of most aquatic species release their eggs and sperm into the water at the same time, and fertilization is external. A few bivalves and many gastropods that live on land are hermaphrodites, in which fertilization takes place internally.

All members of the phylum Mollusca share similar developmental patterns, even though their adult forms vary widely. One larval stage of most mollusks, the trochophore (TRO kuh for), looks very similar to the larval stage of segmented worms, which you will study in Section 4. Because the larval forms are similar in both segmented worms and mollusks, scientists hypothesize that segmented worms and mollusks are closely related.

Figure 18 The life cycle of a clam illustrates the characteristic developmental stages of all mollusks.





Abalone



Scallop

Figure 19 Most gastropods, such as the abalone, have single shells for protection. Bivalves, such as the scallop, have two shells.

Diversity of Mollusks

Animals in the three major classes of mollusks—gastropods, bivalves, and cephalopods—are grouped based on differences in their shell and foot structures.

Gastropods The largest class of mollusks is Gastropoda, the stomach-footed mollusks. The name comes from the way the animal's large foot is positioned under the stomach on the ventral surface. Most species of gastropods have a single shell, like the abalone in **Figure 19.** Single-shelled gastropods also include snails, conches, periwinkles, limpets, cowries, whelks, and cones. They can be found in aquatic habitats and in moist terrestrial habitats, and they can quickly draw their bodies into their shells for protection when they are threatened.

Slugs and nudibranchs do not have shells. They secrete a thick mucus that covers their bodies. To protect themselves, land slugs hide in dark locations under forest or garden litter. Nudibranchs incorporate into their own tissues the poisonous nematocysts of the jellyfishes they eat. The presence of nematocysts is advertised to predator fishes by the bright colors of the nudibranchs.

Bivalves One word—*slow*—best describes most behavior of the class Bivalvia, which are the two-shelled mollusks. Bivalves, such as clams, mussels, oysters, and the scallop shown in **Figure 19,** are all aquatic animals. Most are marine, but some are found in freshwater habitats. Bivalves might seem to be inactive, but they are continuously filter feeding and carrying on all bodily functions.

If you have ever been clamming or have seen people clamming, you know that you might have to dig deeply to find clams because they use a muscular foot to burrow far down into wet sand. Mussels attach to rocks with a sticky, gluelike substance called byssal threads. Scallops are more active than other bivalves because they can clap their shells together to move more quickly through water.

Reading Check **Compare** the foot and shell of a snail with those of a clam.

VOCABULARY

WORD ORIGIN

Gastropod

gastro– prefix; from the Greek word *gaster,* meaning *belly*

–pod suffix; from Greek, meaning *foot*

Cephalopods *Quick* is a word that best describes some behaviors of the class Cephalopoda. Cephalopods are the head-footed mollusks (from the Greek word *cephalo,* meaning *head*, and from *pod,* meaning *foot*), which includes squids, octopuses, chambered nautiluses, and the cuttlefish shown in **Figure 20.** The chambered nautilus is the only cephalopod with an external shell. Squids and cuttlefishes have an internal shell, while octopuses do not have a shell. The foot of a cephalopod is divided into arms and tentacles with suckers, which are used to capture prey.

Protection Although most cephalopods don't have a hard external shell, they have evolved other protective mechanisms. Octopuses forcefully expel water to propel themselves away from threat. They hide in crevices or caves in the daytime. At night, they creep about in search of prey.

When threatened, an octopus shoots out an inky substance that forms a cloud. Scientists hypothesize that the ink visually confuses predators, and it also might act as a narcotic. Octopuses can change color to blend in with their surroundings. Squids and cuttlefishes also use ink and camouflage to escape predators. A chambered nautilus can pull into its shell for protection. It also uses its shell as camouflage. The dark top of the shell blends in with the ocean bottom when it is seen from above, while the white bottom of the shell blends in with the water above when it is seen from below.

Learning Octopuses are considered to be the most intelligent mollusks. They are capable of complex learning, such as being trained to select an object of a certain shape, color, or texture. See **Data Analysis Lab 2** to study this phenomenon.



Cuttlefish

Figure 20 Cuttlefish have eight arms and two tentacles. The tentacles often are not visible because they are withdrawn into pouches under the eyes.

Compare ***the differences between cephalopods and gastropods.***

DATA ANALYSIS LAB 2

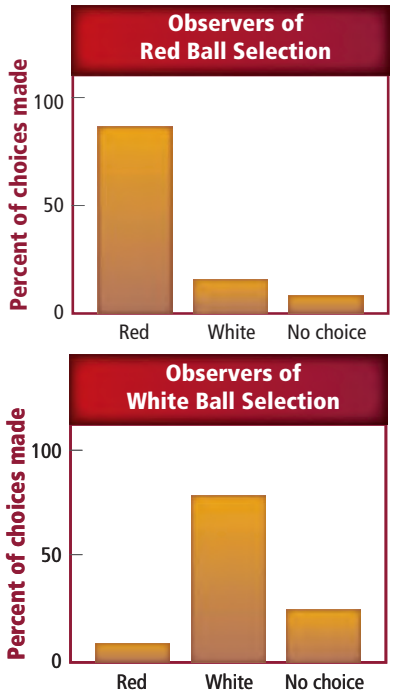
Based on Real Data*

Interpret the Data

Can untrained octopuses learn to select certain objects? Two groups of octopuses were trained to select either a red ball or a white ball. Each trained group was observed by different groups of octopuses that were not trained.

Data and Observations

The graphs show the results of untrained octopus selection of white or red balls.



Think Critically

1. **Analyze** What percentage of octopuses selected the red ball or the white ball after observing the red ball being selected?
2. **Analyze** What percentage of octopuses selected the red ball or the white ball after observing the white ball being selected?
3. **Draw Conclusions** Can untrained octopuses learn by observation? Explain.

*Data obtained from: Fiorito, G. and P. Scotto. 1992. Observational learning in *Octopus vulgaris. Science* 256: 545–547.



Figure 21 Cone snails are prized for their beauty.

Ecology of Mollusks

Mollusks play important roles in aquatic and terrestrial food chains as herbivores, predators, scavengers, and filter feeders. In many areas, certain mollusks are considered keystone species. A keystone is the stone at the top of an arch that holds the arch together, so a keystone species is one whose health influences the health of the entire ecosystem. For example, the hard clam is a keystone species for the Great South Bay in Long Island, New York. These clams filter water, which cleans the ecosystem. If the hard clam population declines, the water isn't filtered. This disrupts the food web, causing algal blooms and a decline in water quality.

The ability of some mussels to accumulate toxins in their body tissues can be useful to scientists who are monitoring water quality. By examining these mollusks, scientists can find out more about water quality than they could by testing the water alone.

Cone snails, as shown in **Figure 21,** are highly prized by collectors for the beauty of their shells. As a result, they might be close to extinction.

Connection to Health Certain cone snails produce powerful venom to kill prey. These venoms are being studied as potential treatments for pain, heart disease, clinical depression, and brain diseases, such as Alzheimer's disease, Parkinson's disease, and epilepsy.

Some mollusks cause damage, while others benefit humans. Some marine bivalve species, such as the shipworm, burrow into wood, causing much damage to wooden marinas and boats. On the other hand, people enjoy beautiful pearls that come from oysters. Pearls result when a grain of sand or a tiny parasite becomes trapped in an oyster. The mantle of the mollusk secretes a coating around the object to protect the mollusk, resulting in a pearl. Cultured-pearl producers implant pieces of shell or tiny plastic spheres in oysters and harvest the cultured pearls in about five to seven years.

Section 3 Assessment

Section Summary

- Mollusks were the first animals in the course of evolution to develop a coelom.
- Mollusks are divided into three main classes based on different characteristics.
- Mollusks have two body features that no other animals have—a mantle and a muscular foot.
- Mollusks have more-developed organ systems than those of roundworms and flatworms.
- Mollusks play important roles in the ecosystems in which they live.

Understand Main Ideas

1. MAIN Idea **Summarize** the main features of the three classes of mollusks.
2. **Evaluate** the ways in which the development of the coelom allowed for adaptations in mollusks that were not possible in earlier animals.
3. **Draw** a diagram of a representative mollusk and show the main evolutionary adaptations common to mollusks.
4. **Analyze** the importance to mollusks of the following adaptations: the mantle, mucus, and the muscular foot.

Think Critically

5. **Design an experiment** A species of bivalves on one beach is a pale color compared to the same species that is a much darker color on a beach 1100 km to the north. Design an experiment that might explain the differences in shell color.
6. **Classify** Make a dichotomous key that would distinguish the differences among the three classes of mollusks.

Assessment Online Quiz

Section 4

Reading Preview

Essential Questions

- What are the similarities among segmented worms, flatworms, and roundworms?
- What is the importance of segmentation as an adaptation for survival in segmented worms?
- What are the features of the three main classes of annelids that make them well-suited for their habitats?

Review Vocabulary

protostome: an animal with a mouth that develops from the opening in the gastrula

New Vocabulary

crop
gizzard
seta
clitellum

Multilingual eGlossary

Segmented Worms

MAIN Idea **Segmented worms have segments that allow for specialization of tissues and for efficiency of movement.**

Real-World Reading Link Suppose that you watch a train as it roars around a curve. The train will follow the curve of the track because it is made up of individual cars that are linked together. The links give the train the flexibility it needs to stay on the track. In the same way, the individual segments that make up a segmented worm enable it to be flexible.

Body Structure

Earthworms are annelids and belong to phylum Annelida, which is characterized by animals with a body plan consisting of segments. As shown on the evolutionary tree in **Figure 22,** both mollusks and annelids undergo protostome development and therefore are considered close relatives.

There are more than 11,000 known species of annelids, most of which live in the oceans. Most of the remaining species are earthworms. Annelids live almost everywhere, except in the frozen soil of the polar regions and in the sand of dry deserts.

Annelids include earthworms, marine worms, such as the ones shown in **Figure 22,** and parasitic leeches. These worms are different from flatworms and roundworms because they are segmented and have a coelom. Most annelids also have a larval stage that is similar to those of certain mollusks, suggesting a common ancestor. Annelids have bilateral symmetry, like flatworms and roundworms, and have two body openings, like roundworms.

Reading Check **Describe** two important ways in which segmented worms are different from flatworms and roundworms.

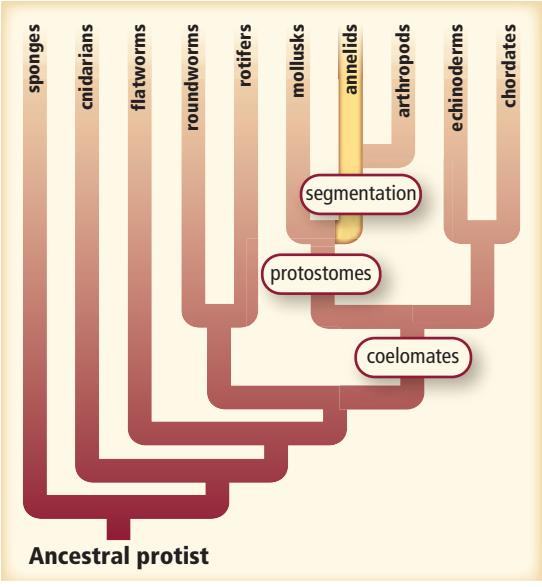


Figure 22 Annelids, like these marine worms, show protostome development, have coeloms, and are segmented.



Fan worm



Bristleworm

Even though annelids have the same cylindrical body shape as roundworms do, annelid bodies are divided into segments. Externally, the segments look like a stack of thick coins or a stack of donuts. Inside the worm, the segments are divided almost completely from each other by walls of tissue, similar to the way that walls separate the segments of a submarine. Each segment contains structures for digestion, excretion, and locomotion. The fluid within the coelom of each segment makes a rigid support system for the worm similar to the rigidity of a filled water balloon.

This rigidity in annelid segments creates a hydrostatic skeleton that muscles can push against. Segmentation also permits segments to move independently of each other and enables a worm to survive damage to a segment, because other segments with the same functions exist.

Segments can be specialized, and groups of segments might be adapted to a particular function. For example, some segments might be adapted to sensing, while others are adapted to reproduction. As you continue to study annelids, earthworms will be used to show examples of typical annelid features.

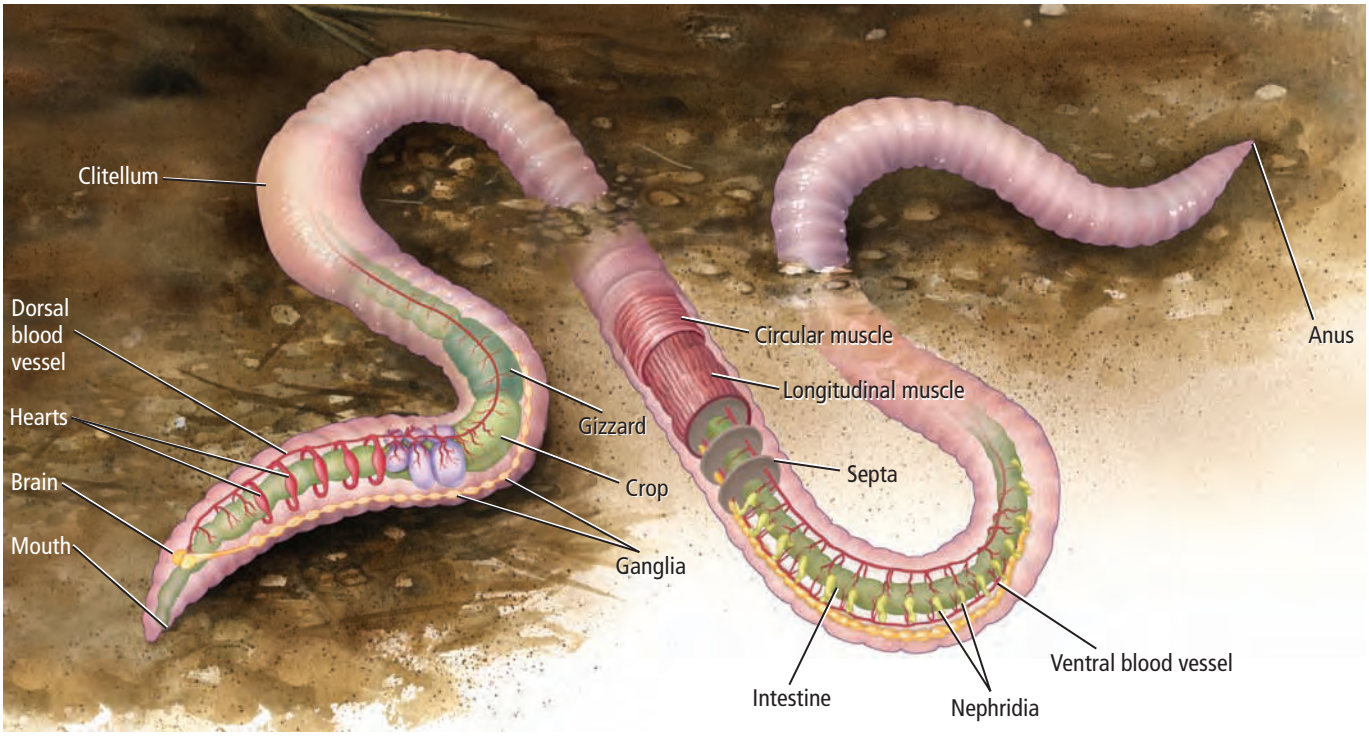
Inquiry **Virtual Lab**

Reading Check **Explain** how segments relate to a hydrostatic skeleton.

Feeding and digestion Running through all earthworm segments from the mouth to the anus is the digestive tract, a tube within a tube. Locate the digestive tract in the earthworm in **Figure 23.** Food and soil taken in by the mouth pass through the pharynx into the **crop,** where they are stored until they pass to the gizzard. The **gizzard** is a muscular sac containing hard particles that help grind soil and food before they pass into the intestine. Nutrients are absorbed in the intestine, then undigested material passes out of the worm's body through the anus. Parasitic annelids have pouches along the digestive tract that hold enough food to last for months.

Figure 23 As an earthworm pushes through the soil, it takes soil into its mouth. Nutrients are absorbed from the organic matter in the soil as it passes through the intestine.

Concepts in Motion
Animation



Circulation Unlike most mollusks, most annelids have a closed circulatory system. Oxygen and nutrients move to various parts of their bodies through their blood vessels. At the same time, carbon dioxide and metabolic wastes are removed from the blood and excreted. Some of the vessels at the anterior end, or head, are large and muscular, as shown in **Figure 24,** and serve as hearts that pump the blood. The blood moves toward the anterior end of the worm in the dorsal blood vessel and toward the posterior end in the ventral blood vessel.

Respiration and excretion Earthworms take in oxygen and give off carbon dioxide through their moist skin. Some aquatic annelids have gills for the exchange of gases in the water. Segmented worms have two nephridia—similar to those in mollusks—in almost every segment. Cellular waste products are collected in the nephridia and are transported in tubes through the coelom and out of the body. Nephridia also function in maintaining homeostasis of the body fluids of annelids, ensuring that the volume and composition of body fluids are kept constant.

Response to stimuli In most annelids, such as the earthworm, the anterior segments are modified for sensing the environment. The brain and nerve cords, composed of ganglia, are shown in the earthworm in **Figure 23.** You might have seen an earthworm quickly withdraw into its burrow when you shine a flashlight on it or step close to it. These observations show that earthworms can detect both light and vibrations.

Movement When an earthworm moves, it contracts circular muscles surrounding each segment. This squeezes the segment and causes the fluid in the coelom to press outward, like paste in a tube of toothpaste being squeezed. Because the fluid in the coelom is confined by the tissues between segments, the fluid pressure causes the segment to get longer and thinner. Next, the earthworm contracts the longitudinal muscles that run the length of its body. This causes the segment to shorten and return to its original shape, pulling its posterior end forward and resulting in movement.

Many annelids have setae on each segment. **Setae** (SEE tee) (singular, seta), as shown in **Figure 25,** are tiny bristles that push into the soil and anchor the worm during movement. By anchoring some segments and retracting others, earthworms can move their bodies forward and backward, segment by segment.

Reading Check **Describe** how longitudinal and circular muscles work together to enable an earthworm to move.

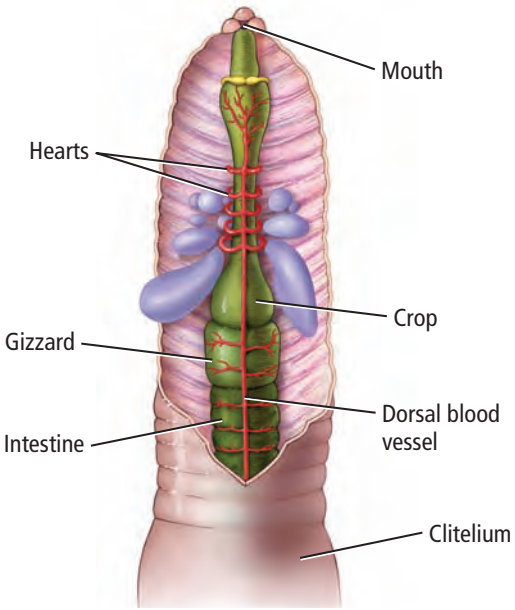


Figure 24 An earthworm has five hearts that pump blood through its circulatory system.

Inquiry **Launch Lab**

Review **Based on what you've read about earthworm movement, how would you now answer the analysis questions?**

Figure 25 This earthworm cross section shows how the setae extend from the body. Setae dig into soil and anchor the worm as it pushes forward.

Evaluate ***whether an earthworm would move faster on a rough or a smooth surface.***

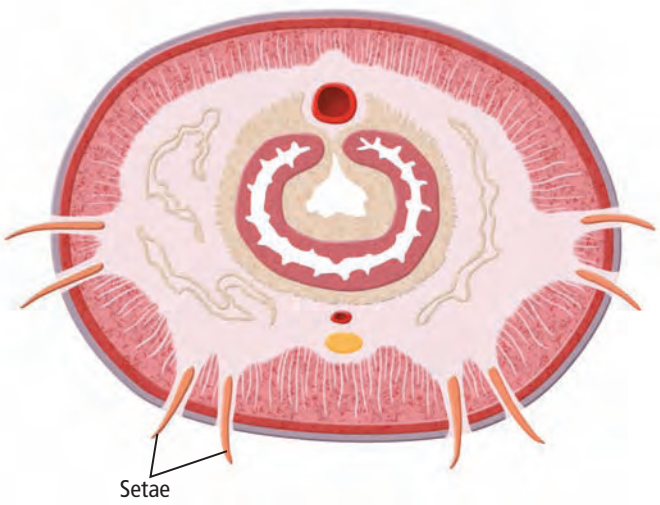




Figure 26 After developing in the cocoon for two to three weeks, a young earthworm hatches.

FOLDABLES®
Incorporate information from this section into your Foldable.

Reproduction Annelids can reproduce both sexually and asexually. Most annelids have separate sexes, but some, such as earthworms and leeches, are hermaphrodites. Sperm are passed between two worms near segments called the clitella (singular, clitellum). Refer to **Figure 23** and notice that the **clitellum** is a thickened band of segments. It produces a cocoon from which young earthworms hatch, as shown in **Figure 26.** Sperm and eggs pass into the cocoon as it slips forward off the body of the worm. After fertilization, the young are protected in the cocoon as they develop. Some annelids reproduce asexually by fragmentation. If a worm breaks apart, the missing parts can be regenerated.

Diversity of Annelids

The phylum Annelida is divided into three classes: class Oligochaeta (ohl ih goh KEE tuh)—the earthworms and their relatives, class Polychaeta (pah lih KEE tuh)—the bristleworms and their relatives, and class Hirudinea (hur uh DIN ee uh)—the leeches.

Earthworms and their relatives Earthworms probably are the best-known annelids. They are used as bait for fishing and are found in garden soil. An earthworm can eat its own mass in soil every day. Earthworms ingest soil to extract nutrients. In this way, earthworms aerate the soil—they break up the soil to allow air and water to move through it.

In addition to earthworms, class Oligochaeta—the oligochaetes (AH lee goh keetz)—includes tubifex worms and lumbriculid worms. Tubifex worms are small, threadlike aquatic annelids that are common in areas of high pollution. Lumbriculid (lum BRIH kyuh lid) worms are freshwater oligochaetes that are about 6 cm long and live at the edges of lakes and ponds. You can observe a feature common to oligochaetes in **MiniLab 2.**

MiniLab 2

Observe Blood Flow in a Segmented Worm

Inquiry MiniLab

How does blood flow in a segmented worm? The California blackworm has a closed circulatory system and a transparent body. Its blood can be viewed as it flows along the dorsal blood vessel.

Procedure

1. Read and complete the lab safety form.
2. Moisten a piece of **filter paper** with **spring water** and place it in a **Petri dish.**
3. Examine a **blackworm** on the moist paper using a **stereomicroscope.**
4. Locate the dorsal blood vessel in a segment near the midpoint of the worm. Observe how blood flows in each segment.
5. Use a **stopwatch** to record how many pulses of blood occur per minute. Repeat this for two more segments, one near the head and one near the anus of the worm. Record your data in a table.

Analysis

1. **Summarize** how blood moves through each segment, including the direction of blood flow.
2. **Compare and contrast** the rate of blood flow near the head, at the midpoint, and near the anus of the worm.



Bristleworm



Fan worms

■ **Figure 27** Note the paddlelike parapodia on the bristleworm, which are used for swimming and crawling. Fan worms withdraw quickly into their tubes when there is a disturbance in the water.

Marine annelids Polychaetes (PAH lee keetz), which belong to class Polychaeta, mainly are marine animals. They include bristleworms and fan worms, shown in **Figure 27.** Polychaetes have head regions with well-developed sense organs, including eyes. Most body segments of polychaetes have many setae. Most body segments also have a pair of appendages called parapodia, shown in **Figure 27,** which are used for swimming and crawling. Fan worms are sessile—they stay in one place—and are filter feeders. They trap food in the mucus on their fan-shaped structures. If there is a threat nearby, fan worms retreat into their tubes.

Leeches As shown in **Figure 28,** leeches in class Hirudinea are external parasites with flattened bodies and usually have no setae. Most leeches live in freshwater streams or rivers, where they attach to the bodies of their hosts—including fishes, turtles, and humans. Leeches attach to their hosts using front and rear suckers. When a leech bites, its saliva contains chemicals that act as an anesthetic. Other chemicals in the saliva reduce swelling and prevent the host's blood from clotting.

Reading Check **Describe** the habitats of the three classes of annelids.



Leech

■ **Figure 28** A leech uses its suckers to attach to its host and feeds by drawing blood into its muscular pharynx.

Compare and contrast ***the feeding methods of leeches and tapeworms.***

Ecology of Annelids

Segmented worms play important roles in the ecology of ecosystems. Some are beneficial to plants and animals, while others benefit humans.

Earthworms Many different animals, including frogs and birds, eat earthworms as a part of their diets. Earthworms also mix leaf litter into soil, aerating it so that roots can grow easily and water can move through the soil efficiently. Both functions are important for healthy ecosystems. However, nonnative earthworms are moving into areas, especially northern forests, where they are altering ecosystems in harmful ways. The consumption of leaf litter on forest floors by nonnative earthworms removes the shelter and moisture needed by many native plants and animals. Earthworms can be introduced into new habitats inadvertently by fishers and gardeners when the earthworms left from a day's fishing are dumped on the ground, or when a nursery plant from another part of the country is planted in a home garden.

Polychaetes Marine polychaetes help convert the organic debris of the ocean floor into carbon dioxide. Marine plant plankton take in carbon dioxide and use it during photosynthesis. Marine polychaetes are an important part of the diet of many marine predators.

Hirudinea Leeches have been used as medical treatments for centuries. They were used to suck blood out of patients who were believed to be ill because of an excess of blood. Today, leeches are used after microsurgical procedures to prevent blood from accumulating in the surgical area. However, there are drawbacks to using leeches. They have a small feeding capacity and must be replaced often. They can cause bacterial infections, and many people cringe at the thought of having a leech attached to them. To solve these problems, a nonliving mechanical leech has been designed to do the work of the animal. **Table 1** summarizes the ecological benefits of earthworms, polychaetes, and leeches.

Reading Check **Evaluate** the effects of removing polychaetes from oceans.

VOCABULARY

ACADEMIC VOCABULARY

Convert
to change from one form to another
Through photosynthesis, plants convert water and carbon dioxide to sugar and oxygen.

Table 1 **Ecological Importance of Annelids** Concepts in Motion Interactive Table

Type of Annelid	Example	Characteristics	Habitat	Ecological Benefit
Earthworms		• Few setae on most body segments	Terrestrial	• They aerate soil so roots can grow more easily and water can move efficiently. • They are food for many different animals.
Polychaetes		• Well-developed sense organs • Many setae on most body segments • Parapodia	Mainly marine	• They convert organic debris in oceans into carbon dioxide, which is used by marine plankton for photosynthesis.
Leeches		• Usually no setae on body segments • Front and rear suckers	Mainly freshwater	• They maintain blood flow after microsurgery.

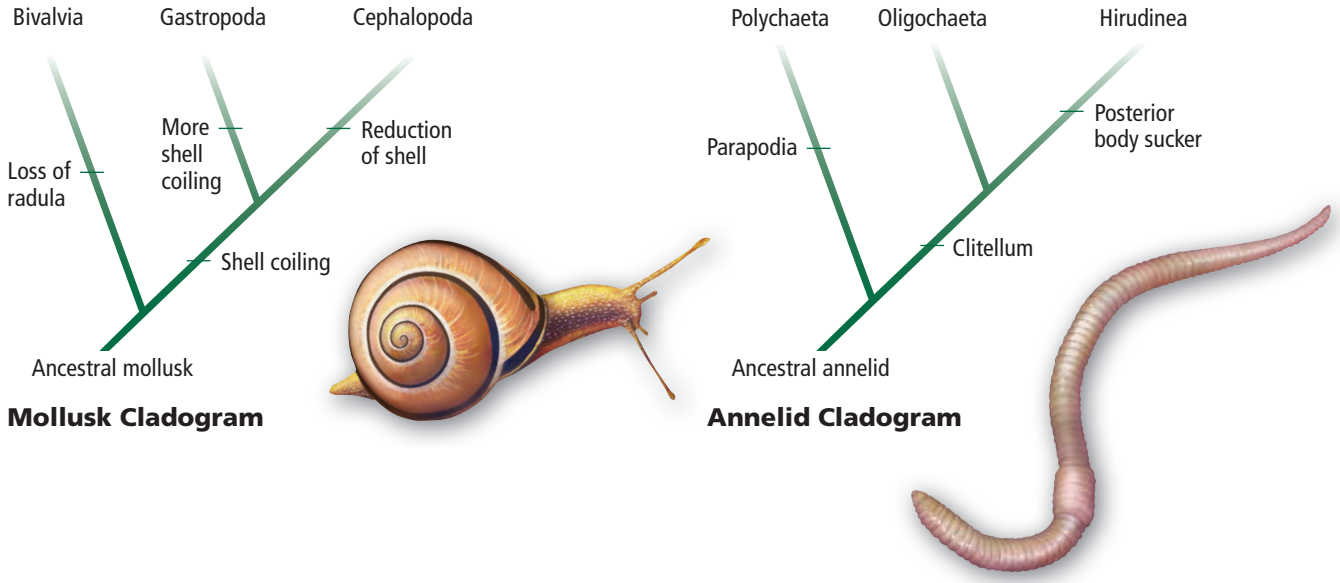


Figure 29 These cladograms show how mollusks and annelids might have evolved.

Evolution of Mollusks and Annelids

In **Figure 29,** the cladogram on the left is one interpretation of the evolution of mollusks. As shown, gastropods have more shell coiling than cephalopods do. In shell coiling, the shell grows in a circular manner, making it more compact and more stable than an uncoiled shell. Cephalopods have a reduced shell. Bivalves are considered to have evolved later than gastropods and cephalopods because they lack a radula.

The cladogram on the right in **Figure 29** is one interpretation of the evolution of annelids. In this interpretation, early segmented worms—the polychaetes—developed parapodia in the course of their evolution. Later annelids—the oligochaetes and leeches—developed clitella. Leeches developed posterior body suckers even later.

Section 4 Assessment

Section Summary

- Two main body features characterize annelids and distinguish them from roundworms and flatworms.
- There are three main classes of annelids based on distinctive features.
- Segmentation is an adaptation important to evolution.
- Annelids are important parts of terrestrial and marine habitats.

Understand Main Ideas

1. MAIN Idea **Summarize** how segmentation was an important evolutionary milestone.
2. **Compare and contrast** earthworms to flatworms and roundworms.
3. **Model** Using clay or salt dough, make models of typical examples from the three classes of annelids. Describe the adaptations that enable each annelid to live in its environment.
4. **Summarize** how earthworm muscles interact to cause movement.

Think Critically

5. **Hypothesize** Form a hypothesis about what might happen to a farm field if earthworms suddenly disappeared.
6. **Compare and contrast** circulation in annelids and mollusks.

WRITING in Biology

7. Write a paragraph explaining why leeches might be used after microsurgical procedures based on what you know about leech saliva.

In the Field

Career: Marine Biologist

The Search for the Giant Squid

For centuries, sailors told stories of encounters with fearsome monsters while on long sea voyages. Today, scientists acknowledge that two species of squid might be the real-life animals lurking behind the old sailors' tales. The giant squid *(Architeuthis dux)* and colossal squid *(Mesonychoteuthis hamiltoni)* are rarely seen in the wild because they live at extreme depths. Most specimens studied by scientists were washed up on beaches or caught in deep-sea fishing nets.

Marine biologist Steve O'Shea discovered that giant squid can grow up to 12.8 meters in length. They are thought to be the largest invertebrates in the world. Colossal squid are shorter but often weigh more than giant squid. Both species have eight arms and two tentacles covered with sucker rings or hooks for catching prey.

On a research expedition in 2000-2001, O'Shea sailed the waters around South Island, New Zealand. He searched for larval giant squid, which are 9 to 13 mm in size. He intended to raise the squid in captivity to study its life cycle. Although he caught several larval giant squid, none have survived in captivity.

Other scientists have made breakthroughs in the study of giant squid. In September 2004, a ship crewed by two Japanese scientists followed a group of sperm whales, known predators of giant squid, to a spot about 600 miles southeast of Tokyo. The scientists, Tsunemi Kubodera and Kyoichi Mori, lowered a baited fishing line into the ocean and waited.



This image, taken by Japanese scientists in 2006, shows a giant squid as it is hauled on board a research vessel.

When a giant squid took the bait, they raised the line and took photos of the squid as it struggled to free itself. The 25-foot-long squid eventually tore itself free, but it left behind one of its tentacles, which scientists later studied.

As O'Shea, Kubodera, and other scientists continue to search for and study giant and colossal squid, they likely will add to our knowledge of these animals. This new knowledge will bring them from the realm of myths into the light of scientific inquiry.

VISUAL COMMUNICATION

Make a Model Research the structure of either the giant squid or the colossal squid. Create a model that accurately shows prey-catching structures and body proportions. Present your model to the class.

WebQuest

BIOLAB

HOW DO WORMS AND MOLLUSKS MOVE?

Background: **The worm and mollusk phyla display wide diversity in behavior and physical characteristics. Throughout this chapter, you have been introduced to some of the various species that make up these phyla. In this lab, you will compare the form of movement used by a flatworm (a planarian), a roundworm (a vinegar eel), a mollusk (a land snail), and a segmented worm (a blackworm).**

Question: *What kind of motion do worms and mollusks display?*

Materials

plastic droppers (2)
petri dish (1 or 2)
microscope slide (1 or 2)
coverslip (1 or 2)
500-mL beaker
magnifying lens
dissecting microscope
light microscope
spring water or aged tap water (500 mL)
live cultures of planaria, vinegar eels, land snails, and blackworms

Safety Precautions



WARNING: ***Be sure to treat live animals in a humane manner at all times. Use caution when working with a microscope, glass slides, and coverslips.***

Procedure

1. Read and complete the lab safety form.
2. Create a data table to record your observations.
3. Observe the movement of a flatworm by placing it in a drop of water in a petri dish or on a slide with no coverslip.
4. Make a wet mount of a vinegar eel and observe its movement under low-power magnification.
5. Place a land snail on a petri dish. Gently tip the dish to observe the snail's movement from underneath.
6. Place a blackworm on a moist paper towel and observe it with a magnifying lens.
7. Place the blackworm in a beaker of aged tapwater and observe its movement.
8. Record your observations in your data table.
9. **Cleanup and Disposal** Wash reusable materials and place them where your teacher directs. Return all live specimens to the cultures provided by your teacher.

Analyze and Conclude

1. **Compare and contrast** the movements of the flatworm, roundworm, land snail, and segmented worm.
2. **Infer** how the forms of the flatworm, roundworm, land snail, and segmented worm are designed to enable the animals to move.
3. **Describe** what happens to each segment of the blackworm as it crawls on land.
4. **Compare** the forward and backward motion of the blackworm on land. How might this be an adaptation for survival?
5. **Infer** how the blackworm might be able to escape from predators in the water.

APPLY YOUR SKILL

Experiment Design an experiment that you could perform to investigate how temperature affects worm and mollusk movement. If you have all the materials you will need, you might want to conduct the experiment.



Chapter 25 Study Guide

THEME FOCUS Energy All worms obtain energy from other organisms, though some worms are parasitic and others are free-living.

BIG Idea **Worms and mollusks have evolved to have a variety of adaptations for living as parasites or for living in water or soil.**

Section 1 Flatworms

pharynx (p. 727)
flame cell (p. 727)
ganglion (p. 728)
regeneration (p. 728)
scolex (p. 730)
proglottid (p. 730)

MAIN Idea **Flatworms are thin, flat, acoelomate animals that can be free-living or parasitic.**

- Flatworms were among the first animals to exhibit bilateral symmetry.
- Flatworms are acoelomates with limited numbers of organs and systems.
- Some flatworms are free-living, and others are parasitic.
- Flatworms that are parasitic have specialized adaptations for parasitic life.

Section 2 Roundworms and Rotifers

hydrostatic skeleton (p. 732)
trichinosis (p. 733)

MAIN Idea **Roundworms and rotifers have a more highly evolved gut than flatworms.**

- Roundworms are closely related to flatworms.
- Roundworms, like flatworms, have a limited number of organs and systems.
- Roundworms are either free-living or parasitic.
- Roundworms cause many human and plant diseases.
- Rotifers are pseudocoelomates that appear on a different branch of the evolutionary tree from that of roundworms.

Section 3 Mollusks

mantle (p. 737)
radula (p. 738)
gill (p. 738)
open circulatory system (p. 739)
closed circulatory system (p. 739)
nephridium (p. 739)
siphon (p. 741)

MAIN Idea **Mollusks are coelomates with a muscular foot, a mantle, and a digestive tract with two openings.**

- Mollusks were the first animals in the course of evolution to develop a coelom.
- Mollusks are divided into three main classes based on different characteristics.
- Mollusks have two body features that no other animals have—a mantle and a muscular foot.
- Mollusks have more developed organ systems than those of roundworms and flatworms.
- Mollusks play important roles in the ecosystems in which they live.

Section 4 Segmented Worms

crop (p. 746)
gizzard (p. 746)
setae (p. 747)
clitellum (p. 748)

MAIN Idea **Segmented worms have segments that allow for specialization of tissues and for efficiency of movement.**

- Two main body features characterize annelids and distinguish them from roundworms and flatworms.
- There are three main classes of annelids based on distinctive features.
- Segmentation is an adaptation important to evolution.
- Annelids are important parts of terrestrial and marine habitats.

Review Vocabulary eGames

Chapter 25 Assessment

Section 1

Vocabulary Review

Use what you know about the vocabulary terms found on the Study Guide page to answer the following questions.

1. What is a group of nerve cell bodies that coordinates ingoing and outgoing messages?
2. What is a tubelike muscular organ that releases digestive enzymes?
3. What structure attaches to the intestinal lining of a host with hooks and suckers?

Understand Main Ideas

Use the diagram below to answer question 4.



4. What function does the structure in the diagram perform?
   - **A.** digestion
   - **B.** movement
   - **C.** maintains homeostasis
   - **D.** provides support
5. Which animals have proglottids?
   - **A.** flukes
   - **B.** planarians
   - **C.** tapeworms
   - **D.** roundworms
6. Which classification fits a flatworm that is free-living?
   - **A.** Turbellaria
   - **B.** Cestoda
   - **C.** Trematoda
   - **D.** Nematoda
7. Which is not involved in planarian movement?
   - **A.** cilia
   - **B.** muscles
   - **C.** mucus
   - **D.** flame cells

Constructed Response

8. **Open Ended** A certain tapeworm secretes a chemical that slows the intestinal pulsations of its host. This helps to ensure that the tapeworm is not expelled from the body of the host. Explain how adding this chemical to a drug for humans might increase the drug's effectiveness.
9. MAIN Idea Design a parasitic worm for an animal that lives in the desert. Remember to consider how the animal will contract the parasite and how the parasite will stay within its host.

Think Critically

10. THEME FOCUS Energy Design an experiment that could determine what a planarian prefers to eat.

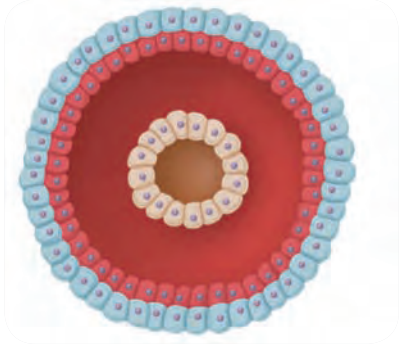
Section 2

Each of the following sentences is false. Make each sentence true by replacing the italicized word with a vocabulary term from the Study Guide page.

11. Roundworms are bilaterally symmetrical, cylindrical, and have *segmented bodies.*
12. *Schistosomiasis* can be prevented by cooking meat properly.
13. A fluid-filled space that provides rigid suppor for muscles to work against is *an exoskeleton.*

Understand Main Ideas

Use the diagram below to answer questions 14 and 15.



14. Which feature of roundworms is illustrated in the diagram above?
   - **A.** pseudocoelom
   - **B.** scolex
   - **C.** circulatory system
   - **D.** nervous system
15. The feature in the diagram led to which adaptation in roundworms?
   - **A.** a coelom
   - **B.** a gut
   - **C.** a mantle
   - **D.** segments

Constructed Response

16. Short Answer Make a diagram that shows the life cycle of a beef tapeworm.

17. Open Ended Select a human parasite and indicate with a key on a map of the world where the parasite is most common. Research online to find information.

Think Critically

18. Concept Mapping Make a concept map that uses the following words: nematode, pseudocoelomate, digestive tract with two openings, parasitic, free-living, lengthwise muscles, host.

19. MAIN Idea Suppose that you find a tiny worm in the garden. How could you determine whether it is a flatworm or a roundworm?

Section 3

Vocabulary Review

An analogy is a comparison relationship between two pairs of words and can be written in the following manner: A is to B as C is to D. In the analogies that follow, one of the words is missing. Complete each analogy with a vocabulary term from the Study Guide page.

20. Kidney is to metabolic waste as _____ is to cellular waste.

21. Tongue is to candy as _____ is to algae.

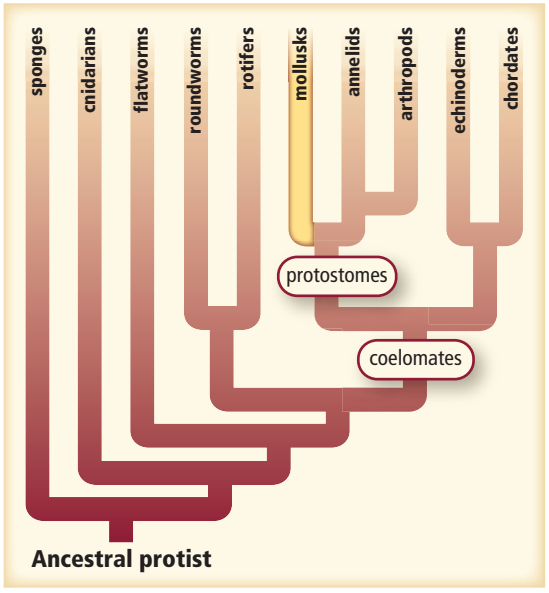
22. Legs are to running as _____ is to jet-propelled swimming.

Understand Main Ideas

23. If the mantle of a bivalve was damaged, the bivalve would not be able to perform which function?
A. maintain its shell
B. digest food
C. circulate blood
D. excrete wastes

24. Which word pair is related most closely?
A. shell, circulation
B. radula, feeding
C. jet-propelled swimming, bivalve
D. open circulatory system, octopus

Use the diagram below to answer questions 25 and 26.



25. MAIN Idea The phylogenetic tree of animals shows that mollusks have which feature?
A. a pseudocoelom
B. a coelom
C. a solid body
D. shells

26. Which group is related most closely to mollusks?
A. nematodes
B. enchinoderms
C. annelids
D. chordates

Constructed Response

27. Open Ended Make a dichotomous key to identify mollusk shells that you find in pictures in books about animals, shells that you have collected, or shells that your teacher supplies.

Think Critically

28. CAREERS IN BIOLOGY Marine biologists know that zebra mussels are pests in many aquatic ecosystems. They form ultradense colonies and can clog pipes leading to water-treatment and industrial plants. However, some marine biologists hypothesize that because the mussels live in such dense groups, they might serve as water-purification systems in places such as zoo ponds and other park ponds that have excessive algal blooms in the summer. Design an experiment that would determine whether zebra mussels could be used to purify water.

Assessment Online Test Practice

Section 4

Vocabulary Review

An analogy is a comparison relationship between two pairs of words and can be written in the following manner: A is to B as C is to D. In the analogies that follow, one of the words is missing. Complete each analogy with a vocabulary term from the Study Guide page.

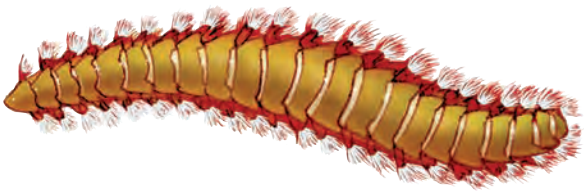
29. Teeth are to human as _____ is to earthworm.

30. Cocoon is to butterfly as _____ is to earthworm.

31. Vacuole is to protist as _____ is to earthworm.

Understand Main Ideas

Use the diagram below to answer questions 32 and 33.



32. Which animal is illustrated in the diagram?

A. roundworm **C.** polychaete
B. leech **D.** earthworm

33. What feature is characteristic of this animal?

A. foot **C.** sucker
B. parapodia **D.** shell

Constructed Response

34. MAIN Idea If global warming continues, predict how earthworms might change as a result of natural selection.

Think Critically

35. CAREERS IN BIOLOGY Rheumatologists, doctors who treat arthritis, have observed that when leeches are applied for a short time to the skin near joints of people affected with arthritis, pain is relieved for up to six months. Design an experiment that could explain this phenomenon.

Summative Assessment

36. BIG Idea Worms have evolved to have a variety of adaptations for living as parasites or for living in water or soil. Give an example of a worm that is parasitic, a worm that lives in soil, and a worm that lives in water. Then, describe a characteristic of each that makes it well suited for that environment.

37. Draw diagrams of a typical example from each of the three classes of mollusks and label the distinctive characteristics.

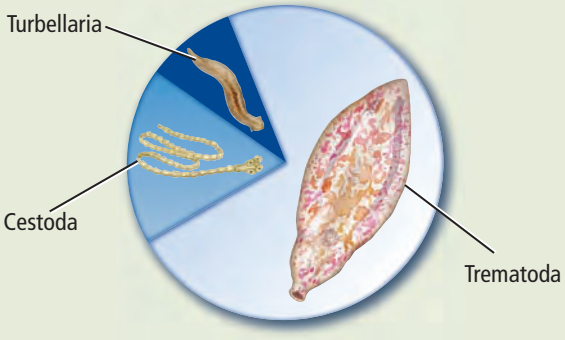
38. Suggest ways to avoid becoming the host of a flatworm.

39. WRITING in Biology Research mollusks that live in areas of hydrothermal vents. Write a report emphasizing the differences between hydrothermal vent mollusks and those that live in the habitats you studied in this chapter.

DBQ Document-Based Questions

The data below represent the percentages of the three main classes of flatworms.

Data obtained from: Pechenik, J. 2005. *Biology of the Invertebrates.* New York: McGraw-Hill.



40. Approximately what percentage of flatworms are flukes?

41. Which group of flatworms has the least number of species?

42. Infer why there might be so many more of one kind of flatworm than any other kind.

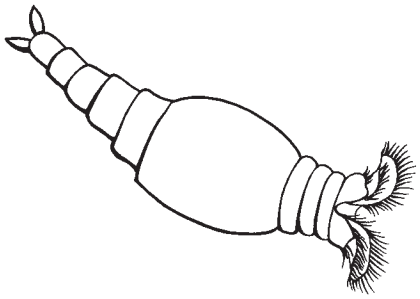
Standardized Test Practice

Cumulative

Multiple Choice

1. During dry weather, pieces of a moss might be scattered by the wind. When it rains, these pieces can grow into new plants. Which process does this display?
- **A.** alternation of generations
- **B.** gametophyte reproduction
- **C.** sporophyte generation
- **D.** vegetative reproduction

Use the diagram below to answer questions 2 and 3.



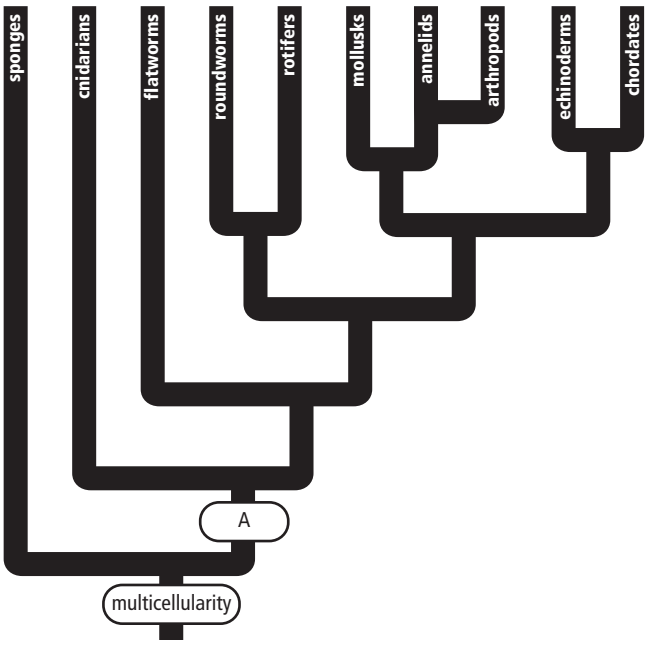
2. In which phylum does the animal shown in the figure belong?
- **A.** Annelida
- **B.** Nematoda
- **C.** Platyhelminthes
- **D.** Rotifera

3. Roundworms differ from the organism shown above because roundworms have which characteristic?
- **A.** a complete digestive tract
- **B.** the inability to live in freshwater
- **C.** a smaller body size
- **D.** a body surface covered with cilia

4. Which is one characteristic of all cnidarians?
- **A.** Their tentacles contain cnidocytes.
- **B.** Their tentacles contain fibroblasts.
- **C.** They live only in freshwater environments.
- **D.** They spend some time as sessile animals.

5. Which is an example of a nastic response?
- **A.** bamboo plants growing toward a light
- **B.** corn plant roots growing downward
- **C.** sunflowers tracking the Sun
- **D.** vines growing up a tree

Use the diagram below to answer question 6.



Ancestral protist

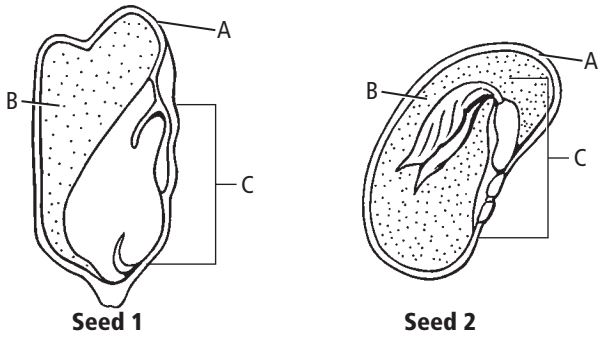
6. Which body structures are typical of all the animals above Point A on the evolutionary tree?
- **A.** cell walls
- **B.** coeloms
- **C.** tentacles
- **D.** tissues

7. How does an aggregate fruit, such as a blackberry or strawberry, form?
- **A.** when a flower has multiple female organs that fuse together
- **B.** when a fruit has multiple seeds that fuse together
- **C.** when multiple flowers from the same plant fuse together
- **D.** when multiple simple fruits fuse together

8. How do hornworts differ from other nonvascular plants?
- **A.** Their cells allow nutrients and water to move by diffusion and osmosis.
- **B.** Their cells can contain a type of cyanobacteria.
- **C.** They can be classified as either thallose or leafy.
- **D.** They have chloroplasts in some of their cells.

Short Answer

Use the diagram below to answer questions 9 and 10.



Seed 1 Seed 2

9. Name the parts of these seeds.

10. Which seed is a monocot and which is a eudicot? How do you know?

11. Explain why squids and clams are both included in phylum Mollusca even though they appear to be very different kinds of animals.

12. What is one thing that humans can do to preserve reefs? Explain your reasoning.

13. Specify an example of an ancestral character and a derived character that angiosperm

14. Describe the alternation of generations in plants.

15. Describe how cellular slime molds reproduce. Identify whether this process is sexual or asexual. Assess how this form of reproduction is beneficial for cellular slime molds.

Extended Response

16. List two reasons why animals benefit from segmentation. Assess the importance of these benefits.

17. Suppose that you are a scientist trying to determine the water quality of a river where mussels live. What data could you collect from the mussels to determine the quality of the river water?

Essay Question

Schistosomiasis is caused by flukes, which have complex life cycles involving specific freshwater snail species as intermediate hosts. Infected snails release large numbers of minute, free-swimming larvae (cercariae) that are capable of penetrating the unbroken skin of a human host. Even brief exposure to contaminated freshwater, such as wading, swimming, or bathing, can result in infection. Human schistosomiasis cannot be acquired by wading or swimming in salt water (oceans or seas). The cercariae of birds and aquatic mammals can penetrate the skin of humans who enter infested freshwater or salt water in many parts of the world, including cool, temperate areas. The cercariae die in the skin but may elicit a puritic rash ("swimmer's itch" or "clam-digger's itch").

Using the information in the paragraph above, answer the following question in essay format.

18. Schistosomiasis is a disease that is most common in sub-Saharan Africa, the Philippines, southern China, and Brazil. Propose a plan to control this disease in a specific area. What steps would need to be taken to keep people from getting the disease? Develop a plan and explain it in a well-organized essay.

NEED EXTRA HELP?																		
If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Review Section . . .	23.1	25.3	25.2	24.3	22.3	24.3	23.3	21.2	23.3	23.3	25.3	24.3	18.2	23.1	19.4	24.2	15.2	25.1

CHAPTER 26

Arthropods



ConnectED

Your one-stop online resource
connectED.mcgraw-hill.com

- Video
- Audio
- Review
- Inquiry
- WebQuest
- Assessment
- Concepts in Motion
- Multilingual eGlossary

Launch Lab

What structures do arthropods have?

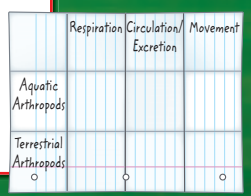
Arthropods form a group of animals that includes all bees, flies, crabs, millipedes, centipedes, spiders, and ticks. Discover the features arthropods share by observing two different arthropods.

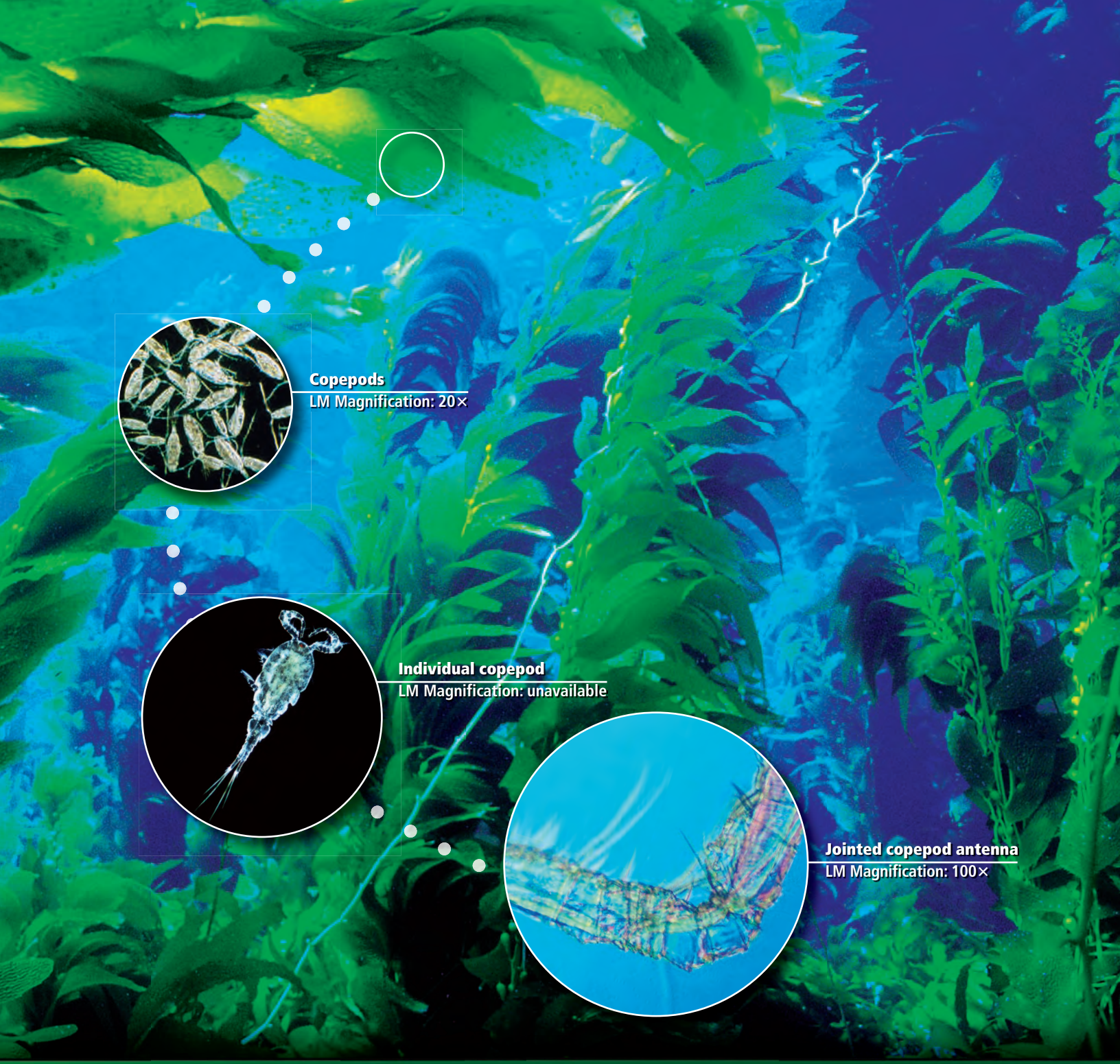
For a lab worksheet, use your StudentWorks™ Plus Online.

Inquiry Launch Lab

FOLDABLES®

Make a chart and label it as shown. Use it to organize your notes about terrestrial and aquatic arthropods.





THEME FOCUS Diversity

Arthropods' specific adaptations allow them to live in many habitats.

BIG Idea Arthropods have evolved to have a variety of adaptations for successful diversity, population, and persistence.

Section 1 • Arthropod Characteristics

Section 2 • Arthropod Diversity

Section 3 • Insects and Their Relatives

Section 1

Reading Preview

Essential Questions

- What is the importance of exoskeletons, jointed appendages, and segmentation to arthropods?
- What are some similarities and differences among the organ systems of arthropods?
- What are the methods used by arthropods to respond to stimuli?

Review Vocabulary

ganglion: a group of nerve cell bodies that coordinates messages

New Vocabulary

thorax
abdomen
cephalothorax
appendage
molting
mandible
tracheal tube
book lung
spiracle
Malpighian tubule
pheromone

Multilingual eGlossary

Arthropod Characteristics

MAIN Idea **Arthropods have segmented bodies and tough exoskeletons with jointed appendages.**

Real-World Reading Link Think about what animal group might have more individuals than any other group. Did copepods come to mind? Even though copepods are numerous, most people have never seen one. The copepods in the opening photo are tiny arthropods that float in the open ocean and feed on even smaller protists. They can be found almost anywhere there is water.

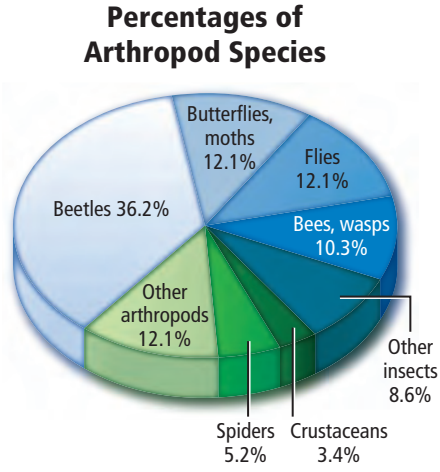
Arthropod Features

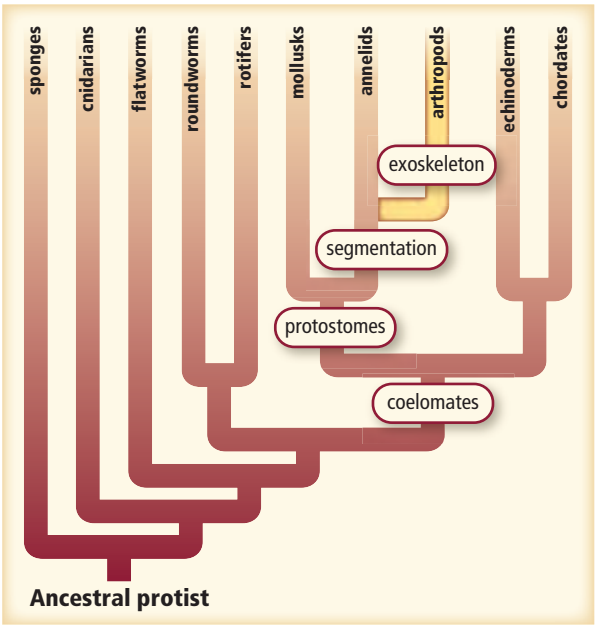
Copepods belong to phylum Arthropoda (ar THRAH puh duh). Between 70 and 85 percent of all named animal species are arthropods (AR thruh pahdz). As shown in the circle graph in **Figure 1,** the majority of arthropods are insects, which includes beetles, butterflies, moths, flies, bees, and wasps.

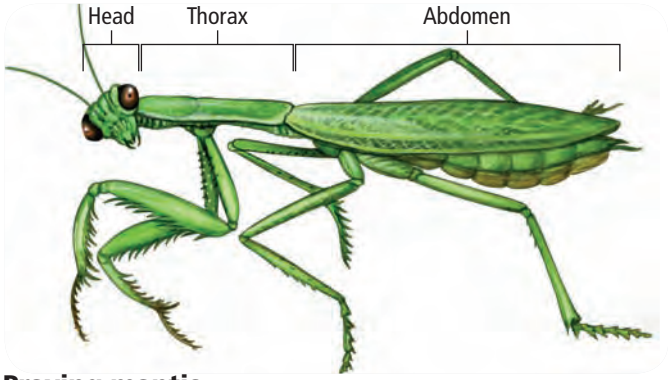
Find arthropods on the evolutionary tree shown in **Figure 1.** Follow the branches and you will see that, like annelids, arthropods are segmented invertebrates with bilateral symmetry, coelomate body cavities, and protostome development. Unlike annelids, arthropods have exoskeletons with jointed appendages that enable them to move in complex ways. All three of these features—segmentation, exoskeletons, and jointed appendages—are important keys to their success.

Reading Check **Compare and contrast** arthropods and annelids.

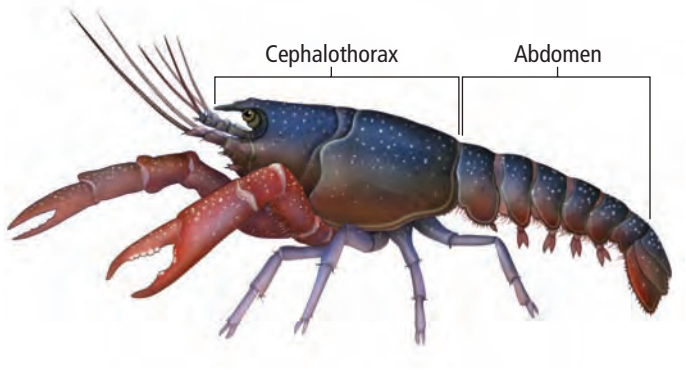
Figure 1 Most arthropods are insects, as shown by the blue segments on the graph. Arthropods are coelomates and show protostome development.
Interpret *what percentage of arthropods is comprised of crustaceans and spiders.*







Praying mantis



Crayfish

Figure 2 Some segments in arthropods are fused. The praying mantis shows fusion of segments into its head, thorax, and abdomen. The crayfish shows a different fusion of segments into its cephalothorax and abdomen.

Review Personal Tutor

Segmentation Arthropods are segmented, allowing for efficient and complex movements. Notice in **Figure 2** that the praying mantis's segments are fused into three main body regions—a head, a thorax, and an abdomen. The heads of arthropods have mouthparts for feeding and various types of eyes. Many have antennae. Antennae are long sensory structures that contain receptors for smell and touch. The **thorax** is the middle body region, consisting of three fused main segments to which, in many arthropods, the legs and wings are attached. The **abdomen,** which also contains fused segments and is at the posterior end of the arthropod, bears additional legs and contains digestive structures and the reproductive organs. Some arthropods, such as the crayfish in **Figure 2,** have the thorax region fused with the head into a single structure called a **cephalothorax** (sef uh luh THOR aks).

In some groups of arthropods, segmentation is more obvious during early development. For example, a caterpillar has many obvious segments, while the adult butterfly has only three body segments.

Reading Check **Summarize** the main body regions in arthropods.

Exoskeleton Arthropods have hard exoskeletons on the outside of their bodies, similar to a lightweight suit of armor. The exoskeleton provides a framework for support, protects soft body tissues, and slows water loss in animals that live on land. It also provides a place for muscle attachment.

Connection to Chemistry The exoskeleton of an arthropod is made of chitin—a nitrogen-containing polysaccharide bound with protein. While the exoskeleton of a grasshopper is leathery, the exoskeletons of some crustaceans, such as lobsters, incorporate calcium salts that harden them to such an extent that a hammer would be needed to crush them. An arthropod's exoskeleton can be hard in some places and thin and flexible in others, providing for movable joints between body segments and within appendages.

There is a limit to how hard and thick an exoskeleton can be. It is thin in small arthropods, such as the copepod, because tiny muscles pull against it; it is thicker in larger arthropods, such as crabs and lobsters, to bear the pull of larger muscles. Imagine a fly as large as a bird. The fly's exoskeleton would have to be so thick to withstand the pull of the large muscles that the fly would not be able to move under the weight of the exoskeleton.



Color-Enhanced SEM Magnification: 11×

■ **Figure 3** Like a door hinge, the joint in this fly's leg can bend in only one direction.
Explain *how jointed appendages benefit animals with exoskeletons.*

Jointed appendages Arthropods have paired appendages. **Appendages** (uh PEN dih juz) are structures, such as legs and antennae, that grow and extend from an animal's body. Appendages of arthropods are adapted for a variety of functions, such as feeding, mating, sensing, walking, and swimming. Notice in **Figure 3** that the appendages of arthropods have joints. To understand how important jointed appendages are, imagine yourself without joints—no finger joints, no wrist, elbow, knee, hip, or ankle joints. Without jointed appendages, you could not play a computer game, sit in a movie theater, shoot a basketball, or even walk. Jointed appendages enable arthropods to have flexible movements and to perform other life functions, such as getting food and mating, that would be impossible without joints.

Inquiry **Launch Lab**

Review **Based on what you have read about arthropod features, how would you now answer the analysis questions?**

Molting Because the exoskeleton of arthropods is made of nonliving material and cannot grow, arthropods must shed their outer coverings in order to grow. This process of shedding the exoskeleton is called **molting.** Arthropods make their own new exoskeletons. Glands in the skin make a fluid that softens the old exoskeleton while the new exoskeleton forms underneath. As the fluid increases in volume, the pressure increases and eventually cracks the old exoskeleton. This process is similar to freezing water in a closed glass container. As the water expands, the glass cracks. **Figure 4** shows a tarantula next to its shed exoskeleton. Before the new exoskeleton hardens, blood circulation increases to all parts of the body and the animal puffs up. Some arthropods also take in air, which assists in making the hardening exoskeleton a little larger for "growing room."



■ **Figure 4** Arthropods must molt so that their bodies can continue to grow. This tarantula has just come out of its outgrown exoskeleton.



Figure 5 This leafcutter ant uses its mandibles to cut a leaf from a tree. Once fungus grows on the leaf cutting, the ant will feed the fungus to its larvae.

Body Structure of Arthropods

Arthropods have complex organ systems that enable them to live in many diverse habitats. Adaptations in several organ systems, such as the respiratory system and the nervous system, have contributed to the success of these animals.

Feeding and digestion The great diversity of arthropods is reflected in their enormous variety of feeding habits and structures. The mouthparts of most arthropods include a pair of appendages called **mandibles** (MAN duh bulz) that can be adapted for biting and chewing, as shown in **Figure 5.** Depending on their feeding habits, other arthropods have mouthparts modified like feathery strainers, stabbing needles, cutting swords, or sucking straws. Observe the structure of arthropod mouthparts in **MiniLab 1.** Arthropods can be herbivores, carnivores, filter feeders, omnivores, or parasites. To digest food, arthropods have a complete, one-way digestive system with a mouth, gut, and an anus, along with various glands that produce digestive enzymes.

Study Tip

Key Ideas Work with another student to determine this section's key ideas. Notice that the headings often are clues to key ideas. Also, many paragraphs have topic sentences that state the key idea.

MiniLab 1

Compare Arthropod Mouthparts

Inquiry MiniLab

How do the mouthparts of arthropods differ? Arthropods eat a wide variety of foods, from nectar and plants to fish and small birds. Explore how the mouthparts of different types of arthropods are designed for their specific diets.

Procedure

1. Read and complete the lab safety form.
2. Create a data table to record your observations about the mouthparts of the arthropods and your inferences about the function of each type of mouth.
3. Using a **magnifying lens** or a **stereomicroscope,** observe the **mouthparts of preserved specimens of different arthropods**. Record your observations in your data table.
4. Infer the specific function of each type of mouth based on the structure of its parts.

Analysis

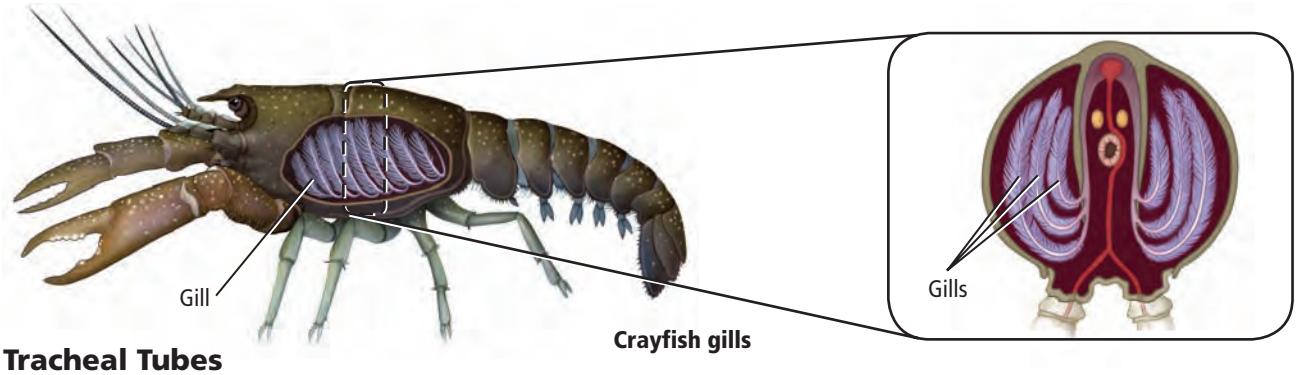
1. **Compare and contrast** the different mouthparts that you observed.
2. **Infer** the type of diet each arthropod might eat based upon your observations of their mouthparts.

Visualizing Respiratory Structures

Figure 6
Arthropods take in oxygen by using one of three basic structures: gills, tracheal tubes, or book lungs.

Gills

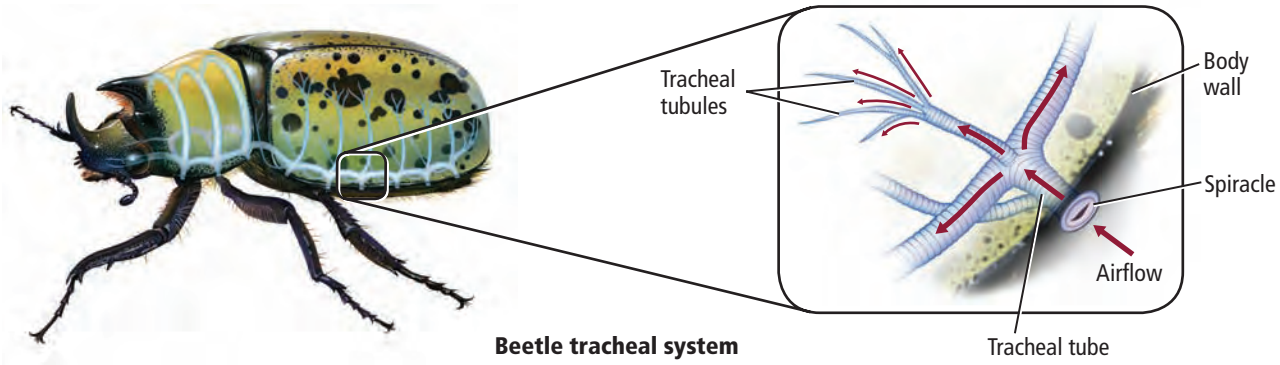
A crayfish lives in an aquatic environment and uses gills to obtain oxygen. The cross section illustrates how the gills are divided. This provides a large surface area in a small space for the exchange of gases.



Crayfish gills

Tracheal Tubes

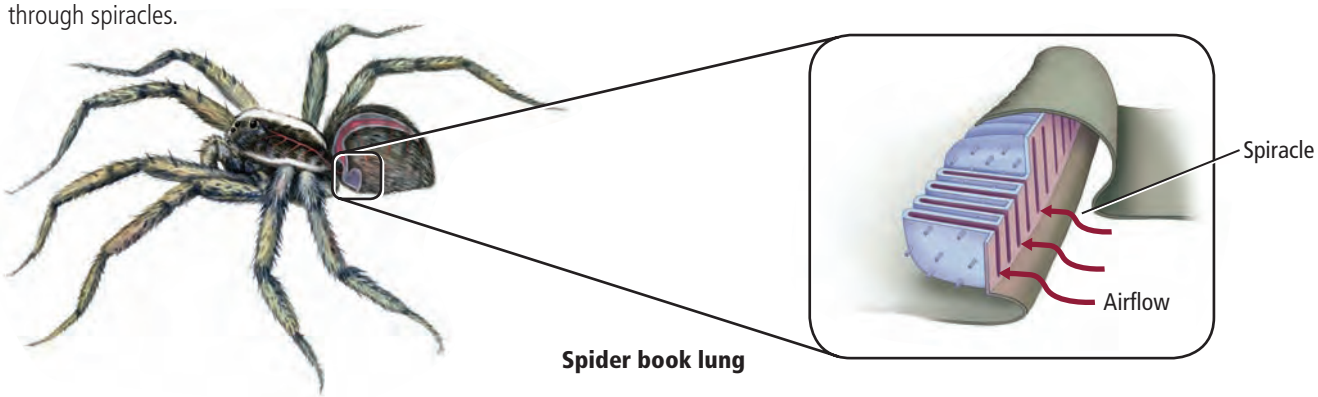
Insects such as this beetle have tracheal tubes that branch into smaller and smaller tubules to carry oxygen throughout the body. Air enters the respiratory system through spiracles, then travels from the tracheal tubes to tracheal tubules until it reaches muscle.



Beetle tracheal system

Book Lungs

This spider uses book lungs to draw in oxygen. As in arthropods with tracheal tubes, air enters the book lungs through spiracles.



Spider book lung

Concepts in Motion Animation

Respiration Arthropods obtain oxygen by using one of three structures—gills, tracheal tubes, or book lungs. Maintaining a certain homeostatic balance of oxygen in body tissues enables animals to have energy for a variety of functions. Most aquatic arthropods have gills, like those shown in **Figure 6,** that function in the same way as the gills in mollusks. All terrestrial arthropod body tissues need to be near airways to obtain oxygen.

Terrestrial arthropods depend on respiratory systems rather than circulatory systems to carry oxygen to cells. Most terrestrial arthropods have a system of branching tubes called **tracheal** (TRAY kee ul) **tubes,** as shown in **Figure 6,** that branch into smaller and smaller tubules. These tubules carry oxygen throughout the body.

Some arthropods, including spiders, have **book lungs,** saclike pockets with highly folded walls for respiration. In **Figure 6,** notice how the membranes in book lungs are like the pages in a book. The folded walls increase the surface area of the lungs and allow an efficient exchange of gases. You also can see how both tracheae and book lungs open to the outside of the body of the arthropod in openings called **spiracles** (SPIHR ih kulz).

Circulation Even though most arthropods do not rely on their circulatory systems to deliver oxygen, they do rely on their circulatory systems to transport nutrients and remove wastes. Arthropod blood is pumped by a heart into vessels that carry the blood to body tissues. The tissues are flooded with blood, which returns to the heart through open body spaces. The blood maintains homeostasis in tissues by delivering nutrients and removing wastes.

Excretion In most arthropods, cellular wastes are removed from the blood through **Malpighian** (mal PIH gee un) **tubules.** These tubules also help terrestrial arthropods preserve water in their bodies to maintain homeostatic water balance. In insects, the tubules, as shown in **Figure 7,** are located in the abdomen, unlike in segmented worms, where nephridia exist in each segment. Malpighian tubules are attached to and empty into the gut, which contains the undigested food wastes to be eliminated from the body. Crustaceans and some other arthropods do not have Malpighian tubules. They have modified nephridia, similar to those in annelids, to remove cellular wastes.

FOLDABLES®
Incorporate information from this section into your Foldable.

VOCABULARY

ACADEMIC VOCABULARY

Transport
to transfer from one place to another
Blood transports nutrients to cells throughout the body.

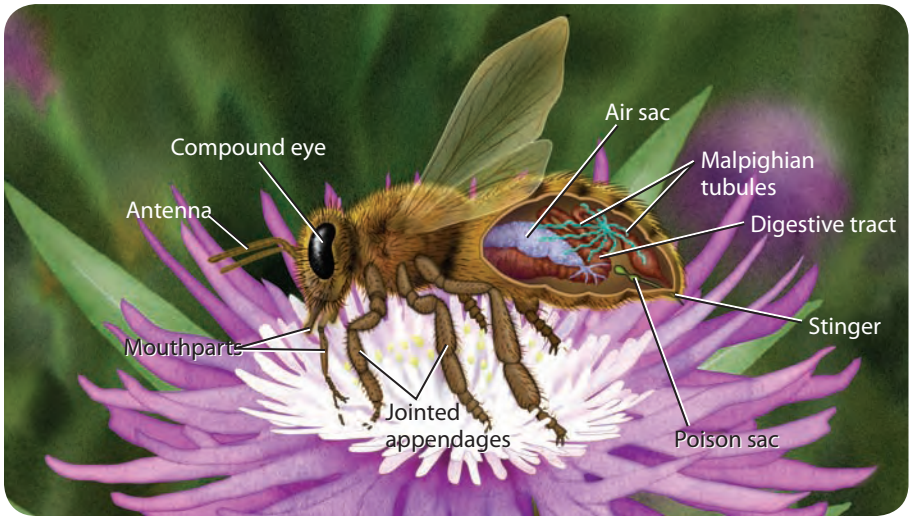


Figure 7 Most arthropods get rid of cellular wastes through Malpighian tubules.
Describe ***another function of Malpighian tubules.***

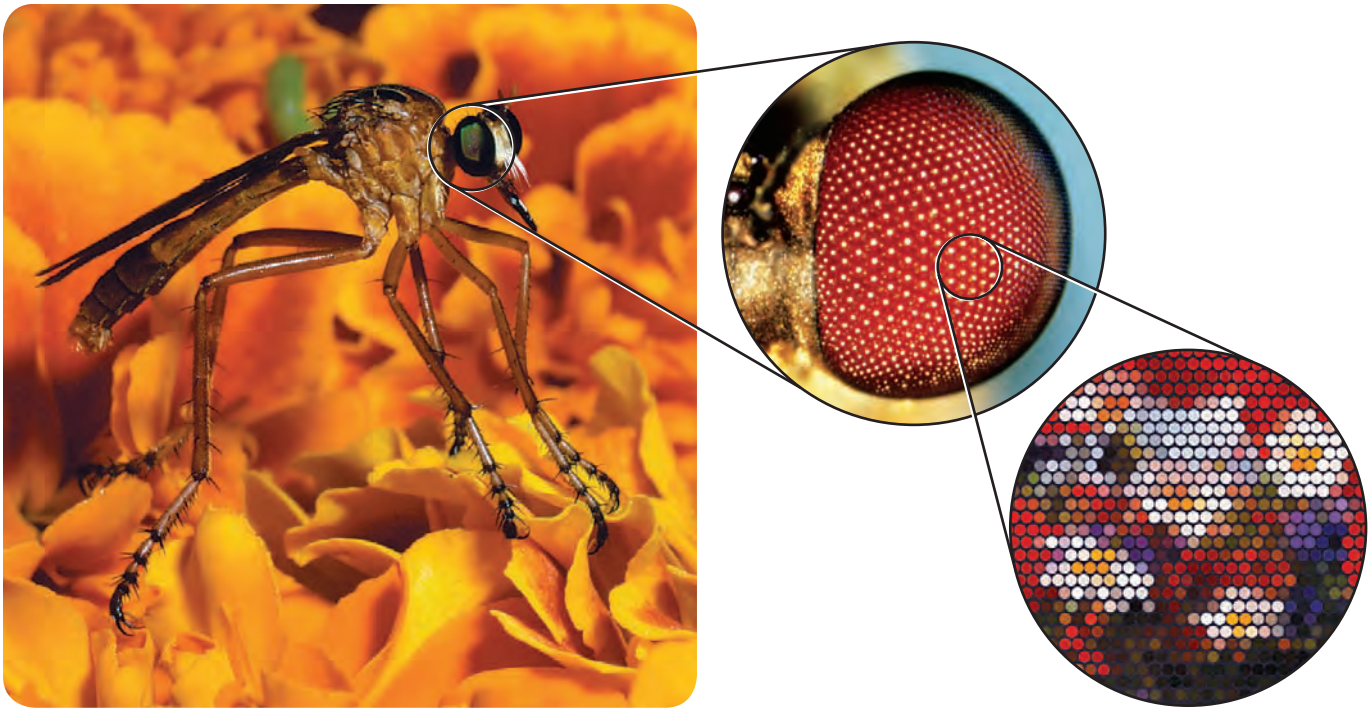


Figure 8 Compound eyes enable flying arthropods to see things in motion easily. The image the fly sees might not be as clear as that seen by a vertebrate. That blurry image is all the fly requires for its way of life.

Infer *how a fly stays safe from predators if it has blurry vision.*

Response to stimuli Most arthropods have a double chain of ganglia throughout their bodies, on the ventral surface. Fused pairs of ganglia in the head make up the brain. Although most behaviors, such as feeding and locomotion, are controlled by the ganglia in each segment, the brain can inhibit these actions.

Vision Have you ever tried to swat a fly with a flyswatter? The fly's accurate vision allows the fly to spot even the slightest movement, and the fly often escapes. Most arthropods have one pair of large compound eyes. A compound eye, as shown in **Figure 8,** has many facets, which are hexagonal in shape. Each facet sees part of an image. The brain combines the images into a mosaic. The compound eyes of flying arthropods, such as dragonflies, enable them to analyze a fast-changing landscape during flight. Compound eyes can detect the movements of prey, mates, or predators, and also can detect colors. In addition, many arthropods have three to eight simple eyes. A simple eye has one lens and functions by distinguishing light from dark. In locusts and some other flying insects, simple eyes act as horizon detectors that help stabilize flight.

Hearing In addition to having eyes that detect movement and distinguish light from dark, many arthropods also have another sense organ called a tympanum (tihm PA num). A tympanum is a flat membrane used for hearing. It vibrates in response to sound waves. Arthropod tympanums can be located on the forelegs as in crickets, on the abdomen as in some grasshoppers, or on the thorax as in some moths.

Chemicals Imagine ants carrying off potato chip pieces, following each other like soldiers marching in formation. Ants communicate with each other by **pheromones** (FER uh mohnz), chemicals secreted by many animal species that influence the behavior of other animals of the same species. The ants use their antennae to sense the odor of pheromones and to follow the scent trail. Arthropods give off a variety of pheromones that signal behaviors such as mating and feeding.

CAREERS IN BIOLOGY

Biochemist As a scientist who determines how biological processes work, a biochemist might study the chemicals in pheromones to develop effective pest-management treatments.

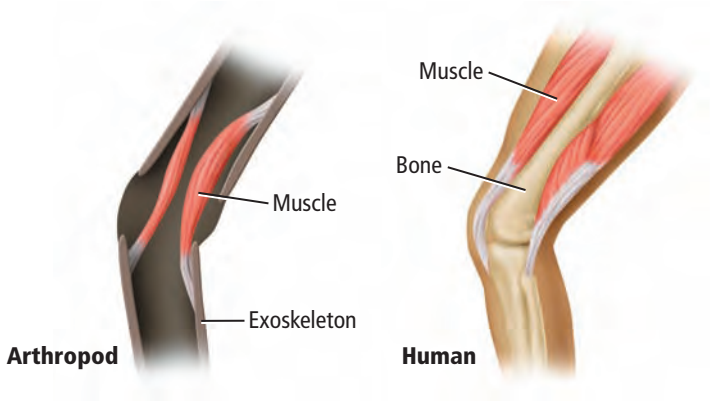


Figure 9 The muscles of an arthropod attach inside of the exoskeleton to each side of the joint. The muscles in a human limb attach to the outer surfaces of the bones.

Movement Think again about the ants carrying the potato chip pieces and how fast they were moving. Arthropods generally are quick, active animals. They are able to crawl, run, climb, dig, swim, and fly because of their well-developed muscular systems. Refer to **Figure 9** to compare muscle attachment in human and arthropod limbs. The muscles in a human leg are attached to the outer surfaces of the bones. The muscles in an arthropod limb are attached to the inner surface of the exoskeleton on both sides of the joint. The strength of muscle contraction in arthropods depends on the rate at which nerve impulses stimulate muscles. In contrast, in vertebrates, the strength of muscle contraction depends on the number of muscle fibers contracting.

Reproduction Most arthropods reproduce sexually and have a variety of adaptations for reproduction. Most arthropods have separate sexes, but a few, such as barnacles, are hermaphrodites and undergo cross-fertilization. Most crustaceans brood, or incubate, their eggs in some way, but they do not care for their hatched offspring. Some spiders and insects also incubate their eggs, and some, such as bees, care for their young.

Section 1 Assessment

Section Summary

- Arthropods can be identified by three main structural features.
- Arthropods have adaptations that make them the most successful animals on Earth.
- Arthropod mouthparts are adapted to a wide variety of food materials.
- In order to grow, arthropods must molt.
- Arthropods have organ system modifications that have enabled them to live in all types of habitats and to increase in variety and numbers.

Understand Main Ideas

1. MAIN Idea **Evaluate** the three main features of arthropods that have enabled them to be successful.
2. **Explain** why jointed appendages are important to an animal with an exoskeleton.
3. **Summarize** the three main methods of respiration in arthropods.
4. **Infer** what might happen to an arthropod that had malformed Malpighian tubules. Be specific.

Think Critically

5. **Design** a model arthropod adapted to conditions on a cold and windy mountaintop with low-growing grasses and arthropod-eating birds.

WRITING in Biology

6. Write a paragraph describing how an arthropod responds to stimuli in its environment. Use a specific example in your paragraph.

Section 2

Reading Preview

Essential Questions

- What are the structures and their functions found in the major groups of arthropods?
- What are the adaptations in the major groups of arthropods?
- What are characteristics of crustaceans and arachnids?

Review Vocabulary

sessile: an organism that is attached to and stays in one place

New Vocabulary

cheliped
swimmeret
chelicera
pedipalp
spinneret

Multilingual eGlossary

Arthropod Diversity

MAIN Idea **Arthropods are classified based on the structure of their segments, types of appendages, and mouthparts.**

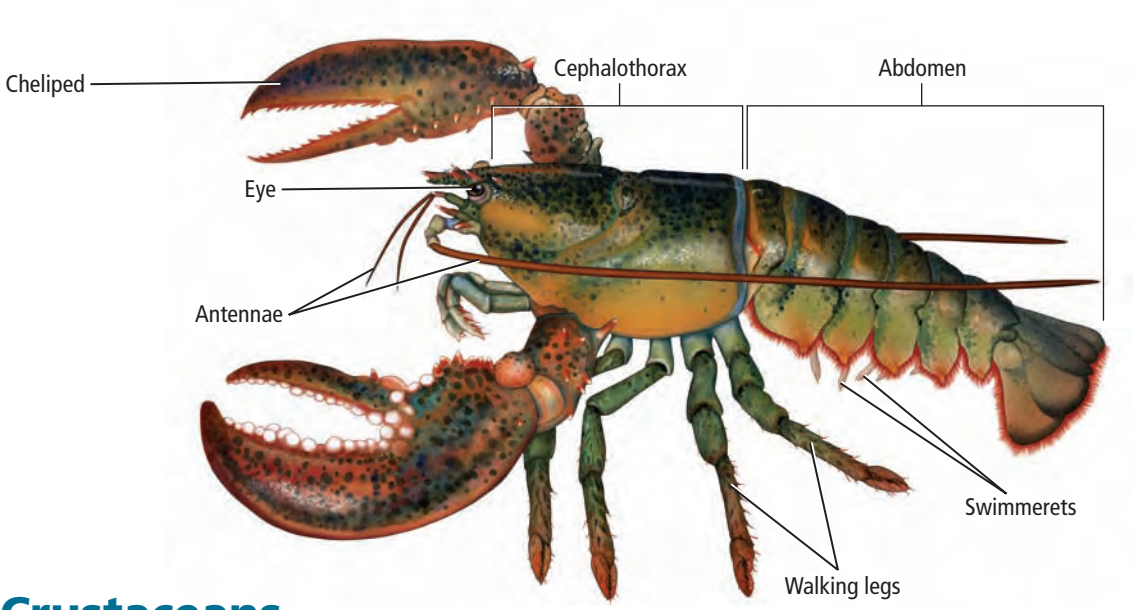
Real-World Reading Link Imagine turning over a rock on the forest floor. The ground beneath the rock suddenly seems to come alive with small animals creeping, crawling, and scurrying every which way. A spider darts under a leaf, a pill bug inches its way out of the light, and ants pour out of a tiny hole. All of these animals are arthropods.

Arthropod Groups

Spiders, pill bugs, and ants are arthropods. In the previous section, you learned why they all are considered arthropods. In the next two sections, you will learn how they differ from one another. Arthropods are classified into groups based on shared similarities, such as the structure of their body segments, appendages, and mouthparts. Taxonomists continue to debate the classification of arthropods. In this section, you will learn about two of the major groups—the crustaceans (krus TAY shunz), such as crabs and lobsters, and the arachnids (uh RAK nids), such as spiders and their relatives. In the next section, you will learn about the third major group—the insects and their relatives. **Table 1** summarizes the common characteristics of the three main groups of arthropods.

Table 1 **Arthropod Characteristics** Concepts in Motion Interactive Table

Group	Crustaceans	Spiders and Their Relatives	Insects and Their Relatives
Example			
Characteristics	Two pairs of antennae, two compound eyes, mandibles, five pairs of legs (chelipeds and walking legs), and swimmerets	No antennae, two body sections (cephalothorax and abdomen), and six pairs of jointed appendages (chelicerae, pedipalps, and four pairs of walking legs)	Antennae, compound eyes, simple eyes, three body sections (head, thorax, and abdomen), three pairs of legs, and generally two pairs of wings on the thorax



Crustaceans

Crabs, shrimps, lobsters, crayfishes, barnacles, water fleas, and pill bugs are crustaceans, and they live in marine, freshwater, and terrestrial habitats. Class Crustacea consists of about 35,000 named species. Most are aquatic and have two pairs of antennae, two compound eyes that are often on the tips of slender movable stalks, and mandibles for chewing. Crustacean mandibles open and close from side to side, instead of in an up-and-down movement like human jaws. Crustaceans possess branched appendages and have a free-swimming larval stage called a nauplius (NAW plee us) larva. A larva is an immature form of an animal that is markedly different in form and appearance from the adult.

Most crustaceans, such as crayfishes, lobsters, and crabs, have five pairs of legs. The first pair of legs—the **chelipeds,** shown in **Figure 10**—has large claws adapted to catch and crush food. Behind the chelipeds are four pairs of walking legs used primarily for locomotion. **Swimmerets** are the short legs behind the walking legs. They are used for reproduction and during swimming. If you have ever seen a lobster swim, you might have been surprised at how it can snap its tail beneath its body and move backward quickly. Some crustaceans, such as barnacles, are sessile and use their legs to kick food into their mouths.

Sow bugs and pill bugs are terrestrial crustaceans that live in damp places, such as under logs. They have seven pairs of legs.

Reading Check **Summarize** the functions of a crustacean's appendages.

■ **Figure 10** Lobsters are aquatic crustaceans. Note the chelipeds for catching and crushing food, the thick cephalothorax with attached walking legs, the antennae, and the abdomen with attached swimmerets.
Consider ***how else a lobster might use its chelipeds.***

Spiders and Their Relatives

Spiders belong to class Arachnida (uh RAK nuh duh) in which there are about 57,000 named species. Arachnids include spiders, ticks, mites, and scorpions.

Most arachnids have two body sections—a cephalothorax and an abdomen—and six pairs of jointed appendages. They do not have antennae. An arachnid's most anterior pair of appendages is modified into mouthparts called **chelicerae** (kih LIH suh ree) (singular, chelicera). Chelicerae are adapted to function as fangs or pincers and often are connected to a poison gland. Most spiders in the United States are not poisonous to humans. Exceptions include the black widow and the brown recluse shown in **Figure 11.**

Inquiry **Virtual Lab**

■ **Figure 11** The inconspicuous brown recluse spider has a violin-shaped mark on its cephalothorax. If a person is bitten by this spider, he or she will require medical treatment because the venom is poisonous to humans.



In arachnids, the second pair of appendages is called the **pedipalps.** Pedipalps are adapted to carry out various tasks. They are used for sensing and holding prey. The pedipalps are also used for reproduction in male spiders and as large pincers in scorpions. The remaining four pairs of appendages in arachnids are used for locomotion.

Spiders All spiders are carnivores. Some spiders, such as wolf spiders and tarantulas, hunt prey. Other spiders catch prey in silken webs. Silk is made from a fluid protein secreted by glands and spun into silk by structures called **spinnerets,** located at the end of a spider's abdomen.

Have you ever watched a spider weave a web? If you have, you might have wondered how the spider seemed to know just what to do and where it managed to get the training to do such intricate work.

Spiders are capable of constructing only specific kinds of webs. This instinctive behavior enables them to do this efficiently and effectively time after time. **Figure 12** shows the stages of construction of an orb web.

After catching an insect or other arthropod in their webs, many spiders wrap their prey in a silken cocoon until they are ready to feed. Digestion begins externally, when a spider secretes digestive enzymes onto its prey. After liquification occurs, the spider ingests the softened food. The remaining nutrients are digested internally.

To reproduce, a male spider deposits sperm on a small web he has built, picks up the sperm, and stores it in a cavity on his pedipalps. After a courtship ritual, the male inserts the sperm into the female. The female lays her eggs in a cocoon spun of spider silk. There can be as many as 100 eggs in one cocoon. The young hatch after about two weeks, then molt between five and ten times before reaching their adult size.

Reading Check **Compare and contrast** the appendages that crustaceans and arachnids use to capture prey.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Weave

Science usage: to spin a web
Spiders weave webs to catch prey.

Common usage: to construct by interlacing strips of material
Artists weave baskets out of reeds and other natural fibers.



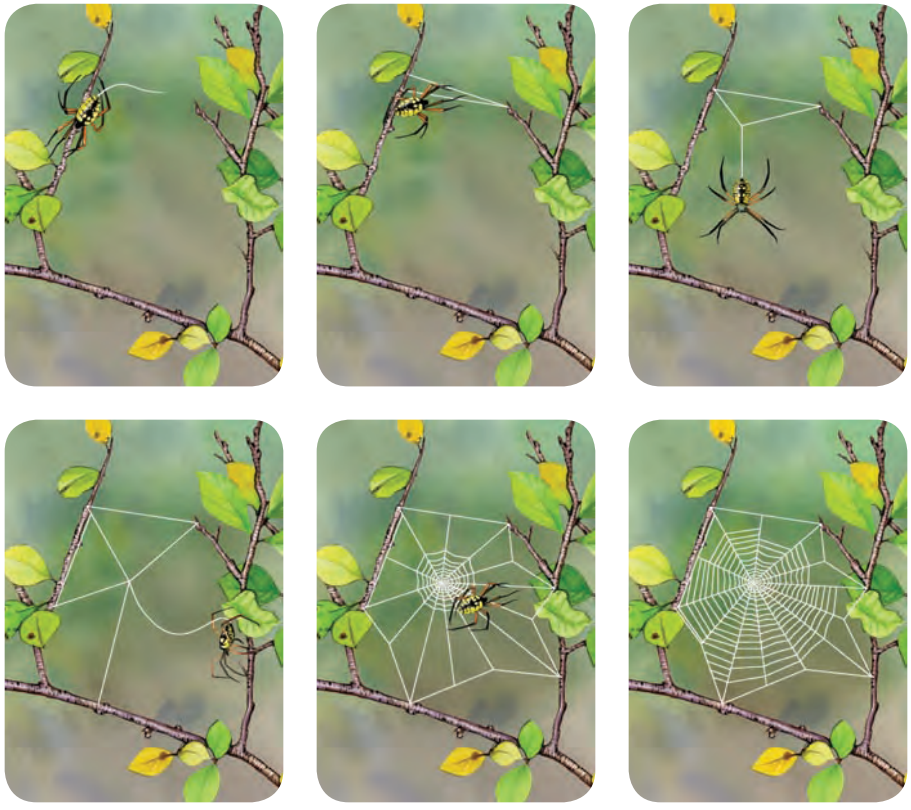


Figure 12 Orb-weaving spiders usually attach their webs to vegetation. An area of the web that is not sticky enables the spider to pass from one side of the web to the other.

Color-Enhanced SEM Magnification: 75×



Tick



Mite



Scorpion

■ **Figure 13** Ticks, mites, and scorpions are in the same class as spiders.
Describe ***the characteristics of class Arachnida that can be seen in the photos.***

Ticks, mites, and scorpions Other members of class Arachnida—ticks, mites, and scorpions—are shown in **Figure 13.** Most mites are less than 1 mm long, with the cephalothorax and abdomen fused into one oval-shaped body section. They can be predators or parasites of other animals. Ticks are parasites that feed on blood after attaching themselves to the surface of their hosts. Ticks also frequently harbor disease-causing agents, such as viruses, bacteria, and protozoans, and introduce them to their hosts when they bite. Some of these diseases, such as Lyme disease and Rocky Mountain spotted fever, affect humans.

Scorpions feed on insects, spiders, and small vertebrates that they capture with their pedipalps and tear apart with their chelicerae. They generally are nocturnal, hiding under logs or in burrows during the day. When you think of a scorpion, you might think of the stinger at the end of the abdomen. Most scorpions that live in the United States do not have venom that is dangerous to people, but their stings can be quite painful. Compare different arthropod groups in **MiniLab 2.**

MiniLab 2

Compare Arthropod Characteristics

? Inquiry MiniLab

How do the physical characteristics of arthropods differ? Classify arthropods by observing specimens from the three major groups of arthropods.

Procedure

1. Read and complete the lab safety form.
2. Create a data table to record your observations of **live or preserved arthropod specimens.** **WARNING:** ***Treat live specimens in a humane manner at all times.***
3. Observe the arthropod specimens and record your observations about their physical characteristics in your data table.

Analysis

1. **Identify** the physical characteristics your arthropod specimens have in common.
2. **Classify** the arthropods into different taxonomic groups.



Figure 14 Horseshoe crabs come to shore to lay eggs in the sand.

Horseshoe crabs Horseshoe crabs are an ancient group of marine animals, related to the arachnids, that have remained basically unchanged since the Triassic period more than 200 million years ago. They have unsegmented heavy exoskeletons in the shape of a horseshoe. The chelicerae, pedipalps, and the next three pairs of legs are used for walking and getting food from the bottom of the sea. The animals feed on annelids, mollusks, and other invertebrates, which they capture with their chelicerae. The posterior appendages are modified with leaflike plates at their tips and can be used for digging or swimming.

Horseshoe crabs, shown in **Figure 14,** come to shore to reproduce at high tide. The female burrows into the sand to lay her eggs. A male adds sperm before the female covers the eggs with sand. Young larvae hatch after a period of being warmed by the Sun and then return to the ocean during another high tide.

Section 2 Assessment

Section Summary

- Arthropods are divided into three major groups.
- Crustaceans have modified appendages for getting food, walking, and swimming.
- The first two pairs of arachnid appendages are modified as mouthparts, as reproductive structures, or as pincers.
- Spiders are carnivores that either hunt prey or trap it in webs that they spin out of silk.
- Horseshoe crabs are ancient arthropods that have remained unchanged for more than 200 million years.

Understand Main Ideas

1. MAIN Idea **Classify** a small, quickly moving arthropod with two pairs of antennae, a segmented body, and mandibles that move from side to side.
2. **Compare and contrast** the ways of life of crustaceans and arachnids, and explain how their body forms are adapted to their environments.
3. **Summarize** the differences in function among the various appendages of spiders.
4. **Identify** the common characteristics among ticks, scorpions, and horseshoe crabs.

Think Critically

5. **Hypothesize** Caribbean spiny lobsters have a navigation system that enables them to return to their original habitat after being moved to an unfamiliar location. Make a hypothesis about what signals the lobsters might use to orient themselves in the direction of their original habitat.
6. **Design an Experiment** A biologist wants to find out what brown recluse spiders eat. After some observation, she hypothesizes that the spiders prefer dead prey to live prey. Design an experiment that would test this hypothesis.

Assessment Online Quiz

Section 3

Reading Preview

Essential Questions

- What are characteristics and adaptations of insects?
- What are similarities and differences between complete and incomplete metamorphosis?
- How do insects interact and communicate with each other?

Review Vocabulary

pollen: a fine powder produced by certain plants when they reproduce

New Vocabulary

metamorphosis
pupa
nymph
caste

Multilingual eGlossary

Insects and Their Relatives

MAIN Idea **Insects have structural and functional adaptations that have enabled them to become the most abundant and diverse group of arthropods.**

Real-World Reading Link Think about a time you were stung by a bee, admired a bright butterfly flitting from flower to flower, or heard a cricket chirp. Insects are everywhere, and they affect your life in many ways.

Diversity of Insects

Scientists estimate that there are as many as 30 million insect species, which is more species than all other animals combined. Recall that arthropods make up about three-fourths of all named animal species. About 80 percent of arthropods are insects. They are the most abundant and widespread of all terrestrial animals. You can find insects in soil, in forests and deserts, on mountaintops, and even in polar regions.

Insects live in many habitats because of their ability to fly and their ability to adapt. Their small size enables them to be moved easily by wind or water. Diversity of insects also is enhanced by the hard exoskeleton that protects them and keeps them from drying out in deserts and other dry areas. In addition, the reproductive capacity of insects ensures that they are successful in any areas they inhabit. Insects produce a large number of eggs, most of the eggs hatch, and the offspring have short life cycles, all of which can lead to huge insect populations.

External Features

Insects have three body areas—the head, thorax, and abdomen, as shown in **Figure 15.** Head structures include antennae, compound eyes, simple eyes, and mouthparts. Insects have three pairs of legs and generally two pairs of wings on the thorax. Some only have one pair of wings, and others do not have wings at all.

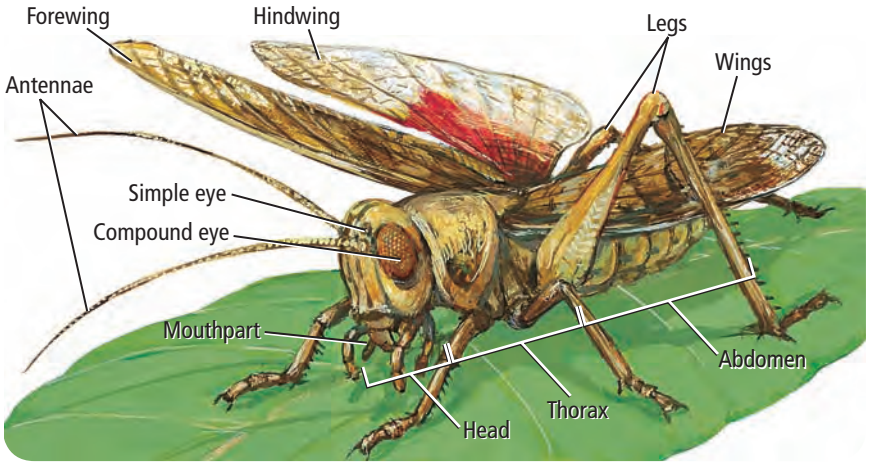


Figure 15 The head, thorax, and abdomen regions of this grasshopper are characteristic of insects.
Compare *how the body regions of insects differ from those of crustaceans.*

Concepts in Motion
Animation

Insect Adaptations

Structural adaptations to legs, mouthparts, wings, and sense organs have led to increased diversity in insects. These adaptations enable insects to utilize all kinds of food and to live in many different types of environments. Taking advantage of a variety of food sources, insects might be parasites, predators, or plant-sap suckers.

Legs Insect legs are adapted to a variety of functions. Beetles have walking legs with claws that enable them to dig in soil or crawl under bark. Flies have walking legs with sticky pads on the ends that enable them to walk upside down. Honeybee legs have adaptations for collecting pollen, while the hind legs of grasshoppers and crickets are adapted to jumping. Water striders have legs adapted to skimming over the surface of water. On its footpads, a water strider has water-repellent hairs that do not break the surface tension of the water. As it skates over the water, this insect propels itself with its back legs and steers with its front legs, like a rear-wheel-drive car.

Mouthparts Insects' mouthparts are adapted to the food they eat, as shown in **Table 2.** Butterflies and moths have a long tube through which they draw nectar from flowers in a motion similar to sipping through a straw. Different types of flies, such as houseflies and fruit flies, have sponging and lapping mouthparts that take up liquids. Some insects, such as leafhoppers and mosquitoes, have piercing mouthparts for feeding on plant juices or prey. Insects such as beetles and ants cut animal skin or plant tissue with their mandibles to reach the nutrients inside.

Table 2 **Insect Mouthparts** Concepts in Motion Interactive Table

Type of mouthpart	Siphoning	Sponging	Piercing/Sucking	Chewing
Example				
Function	Feeding tube is uncoiled and extended to suck liquids into the mouth.	Fleshy end of mouthpart acts like a sponge to mop up food.	A thin, needlelike tube pierces the skin or plant wall to suck liquids into the mouth.	Mandible pierces or cuts animal or plant tissue, and other mouthparts bring food to the mouth.
Insects with adaptation	Butterflies, moths	Houseflies, fruit flies	Mosquitoes, leafhoppers, stink bugs, fleas	Grasshoppers, beetles, ants, bees, earwigs

Wings Insects are the only invertebrates that can fly. Unlike bird and mammal wings that are modified limbs, insect wings are outgrowths of the body wall. Wings are formed of a thin double membrane of chitin, which is the same material that makes up the exoskeleton, and they have rigid veins that give them strength. Wings can be thin, as in flies, or thick, as in beetles. The wings of butterflies and moths are covered with fine scales, as shown in **Figure 16.** Investigate how butterflies might use their wing scales to attract mates in **Data Analysis Lab 1.** Flying requires complex movements of the wings. Forward thrust, upward lift, balance, and steering are all important. Most insects rotate their wings in a figure-eight pattern.

Reading Check **Compare** how wings are like an exoskeleton.

Sense organs Along with leg, mouthpart, and wing adaptations, insects have a variety of adaptations in their sense organs. Recall how arthropods use their antennae and eyes to sense their environment. Insects also have hairlike structures that are sensitive to touch, pressure, vibration, and odor. In addition to visually detecting motion, a fly detects changes in airflow using the hundreds of hairs that cover its body. It is no wonder that a fly often is long gone before the flyswatter can strike.

Some insects detect airborne sounds with their tympanic organs, while others can detect vibrations coming from the ground. These sensory cells often are located on the legs.



Figure 16 Butterfly wings are covered with fine scales.

DATA ANALYSIS LAB 1

Based on Real Data*

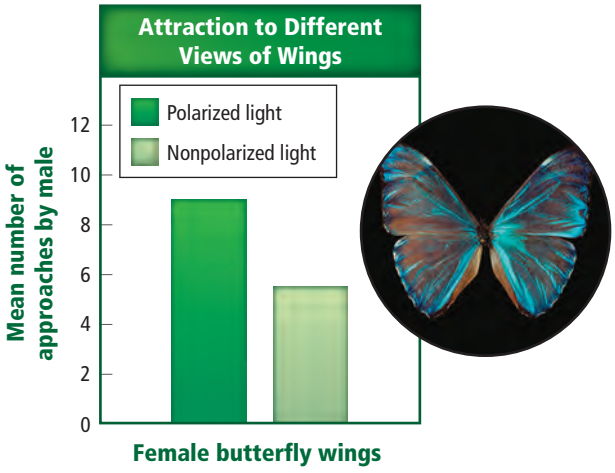
Interpret the Graph

Do butterflies use polarized light for mate attraction? Light waves with electric fields vibrating in the same direction are said to be polarized. Scientists hypothesized that the iridescent wing scales in some butterflies, such as the one shown at right, create polarized light to attract certain males to females. The graph shows the response of males to polarized light versus nonpolarized light from female iridescent butterfly wings.

Think Critically

1. **Interpret the Graph** To which view of wings does the male butterfly respond more often?
2. **Infer** Researchers have noted that forest-dwelling butterflies tend to have iridescent wings, while meadow-dwelling butterflies do not. What might explain this difference?

Data and Observations



*Data obtained from: Sweeney, A., et al. 2003. Insect communication: polarized light as a butterfly mating signal. *Nature* 423: 31-32.

Most insects have keen chemical senses. Chemical receptors, or chemoreceptors, for taste and smell are located on mouthparts, antennae, or legs. Some insects, such as moths, can detect odors several kilometers away. Chemical signals in the form of pheromones enable insects to communicate with one another to attract mates or to gather members in large colonies to migrate or survive periods of cold weather.

Metamorphosis Most insects lay their eggs in a specific habitat where the young can survive. For example, a monarch butterfly lays its eggs on milkweed plants, which the young feed on after they hatch. After hatching, most insects undergo **metamorphosis,** a series of major changes from a larval form to an adult form.

Complete metamorphosis Most insects develop through the four stages of complete metamorphosis—egg, larva, pupa, and adult. As shown in **Figure 17,** when the egg of a butterfly hatches, the wormlike larva that appears commonly is called a caterpillar. At this stage, the larva usually has chewing mouthparts and behaves like a feeding machine. The larva molts several times as it grows. A **pupa** (PYEW puh) is a nonfeeding stage of metamorphosis in which the animal changes from the larval form into the adult form. Adult insects are generally specialized for reproduction. Some adult insects do not live long enough to feed—a female adult mayfly only lives for five minutes. If adults feed, they generally do not compete with larvae for food.

Reading Check **Summarize** the life cycle of an insect that undergoes complete metamorphosis.

Incomplete metamorphosis Insects that undergo incomplete metamorphosis, as shown in **Figure 17,** hatch from eggs as **nymphs** (NIHMFS)—the immature form of insects that look like small adults without fully developed wings. After several molts, nymphs become adults.

VOCABULARY

WORD ORIGIN

Metamorphosis
from the Greek word *metamorphoun,* meaning *to transform*

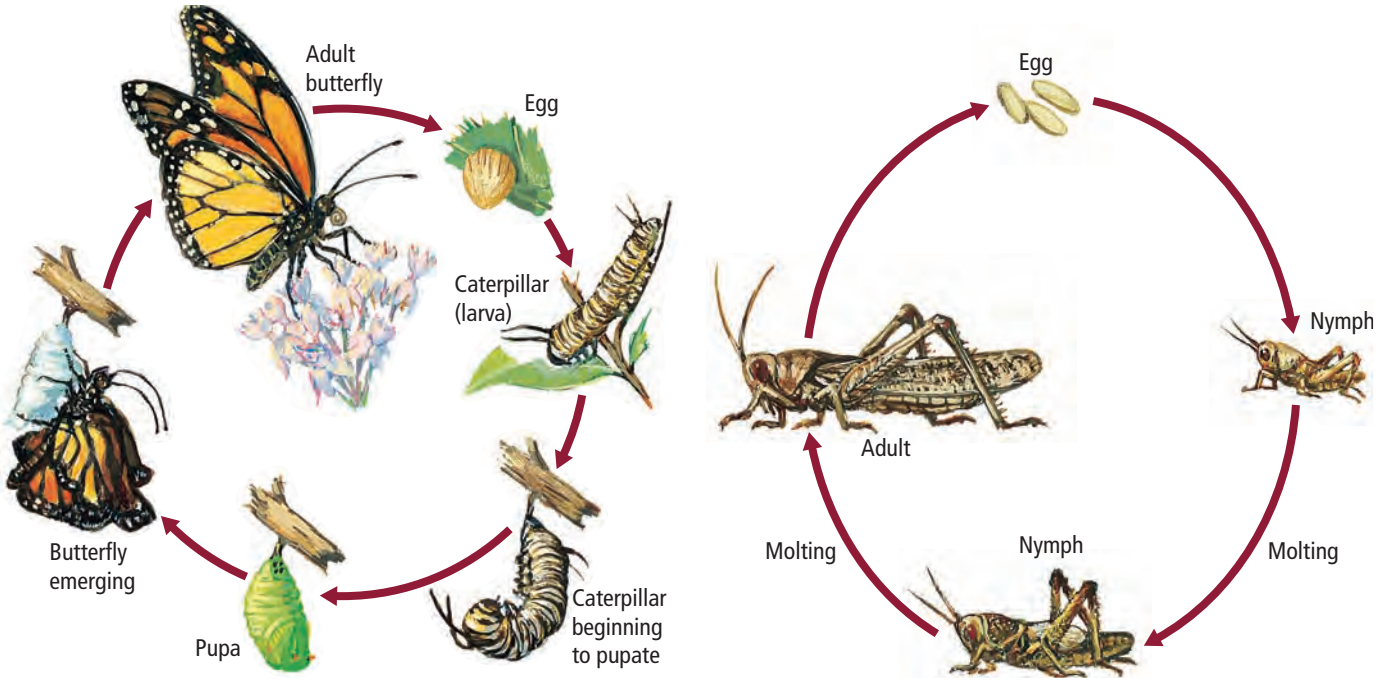
Figure 17 Insects that undergo complete metamorphosis have a resting stage called a pupa. This stage is absent in insects that undergo incomplete metamorphosis.

Concepts in Motion

Animation

Video

BrainPOP



Complete metamorphosis **Incomplete metamorphosis**

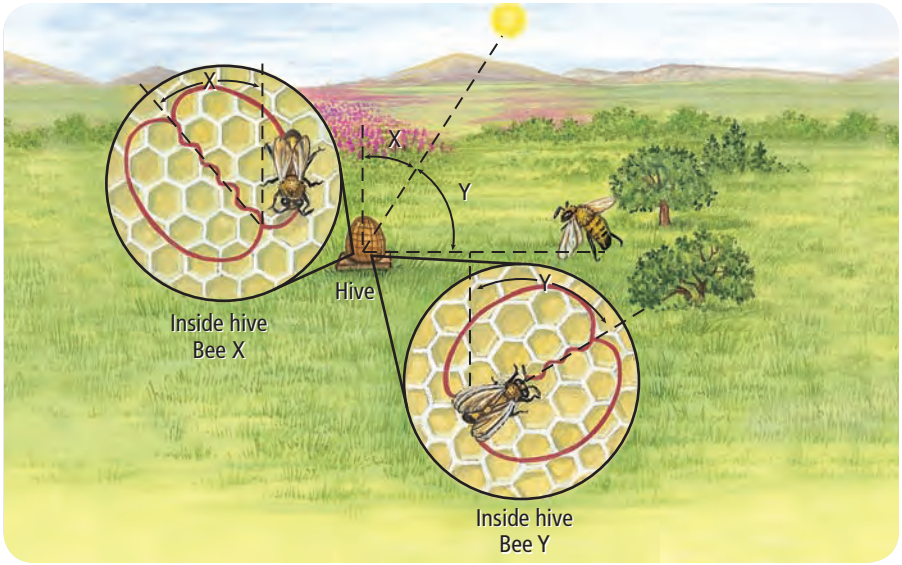


Figure 18 The honeybee's figure-eight waggle dance indicates the direction of the food in relation to the angle of the Sun.
Interpret *where Bee X has found food.*

Concepts in Motion
Animation

Insect societies The players on a basketball team work together to win the game. Insects such as honeybees, ants, and termites organize into social groups and cooperate in activities necessary for their survival. Honeybees have a complex society, with as many as 70,000 bees in one hive. There are three castes in a hive. A **caste** is a group of individuals within a society that perform specific tasks. Workers are females that do not reproduce. They gather nectar and pollen, build the honeycomb, manufacture honey, care for young, and guard the hive. Drones are the reproductive males. The queen is the only reproductive female.

Communication methods Honeybees have evolved an efficient system of communication, using bodily movements to indicate the location of food sources. One of the movements by which honeybees communicate is called the waggle dance, shown in **Figure 18.** This dance is performed when a bee returns to the hive from a faraway food source. First, the returning bee makes a circle with a diameter about three times the bee's length. The bee then moves in a straight line while waggling its abdomen from side to side. The orientation of the line indicates the direction to the food source. Finally, the bee makes another circle in the opposite direction from the first circle. It traces this figure-eight pattern many times. The duration of the dance indicates the distance to the food source.

Connection to Math The most significant part of the waggle dance is the straight line because it tells the other bees where the food is in relation to the hive. The direction of the line relative to the vertical indicates the direction of the food relative to the Sun, as shown in **Figure 18.** If food is located 70 degrees to the right of the Sun, the straight line of the dance will be 70 degrees to the right of vertical.

Round dances also convey information about food sources and are used only if the food is close to the hive. In a round dance, the bee traces a clockwise circle followed by a counterclockwise circle and repeats this dance many times. The dance does not indicate distance or direction.

Ants also have evolved various societal behaviors for living in colonies. Females that do not reproduce gather food, care for young, and protect the colony from predators. Like honeybees, the male ants die after mating with the queen, whose sole function is to lay eggs.

CAREERS IN BIOLOGY

Entomologist Scientists who study insects are entomologists. They might study insect life cycles and behaviors, research insect pests and how to control them, or work with beneficial insects like honeybees. A beekeeper cares for bee colonies that are used for crop pollination and honey production.



Figure 19 Not only are insects important in pollinating flowers, some are important in feeding on harmful insects. This ladybird beetle feeds on plant pests.
Explain *how insects maintain stability in ecosystems.*

Video
What's BIOLOGY Got To Do With It?

Insects and humans It might be difficult to think of insects as beneficial when a mosquito buzzes around your head or when a bee stings you, but insects are an integral part of all ecosystems on Earth. Most insect species are not harmful to humans. Insects pollinate most flowering plants, including almost ten billion dollars' worth of food crops in the United States. They produce honey and silk used by humans and serve as food for many birds, fishes, and other animals. Insect predators, such as praying mantises and ladybird beetles, feed on plant pests such as aphids and mites, as shown in **Figure 19.**

Insects can also be harmful to humans. Lice and bloodsucking flies are human parasites. Fleas can carry plague, houseflies can carry typhoid fever, and mosquitoes can carry malaria, yellow fever, and the West Nile virus. Weevils, cockroaches, ants, and termites cause property destruction. Grasshoppers, corn borers, and boll weevils destroy agricultural crops. Bark beetles, spruce budworms, and gypsy moths can destroy whole portions of forests.

How is all this insect damage kept in check? In the past, chemicals were used indiscriminately to control insects. However, the overuse of chemicals disrupted food chains, reduced numbers of beneficial insects, and insects developed resistance to the insecticides. Use of biological controls has become increasingly important. Integrated pest management, a technique used by many farmers today, offers long-term control of pests. This strategy employs resistant plant varieties, crop rotation, and critical timing of planting and other agricultural practices along with small amounts of chemicals at critical times to control insect pests.

Centipedes and Millipedes

The centipedes of class Chilopoda and the millipedes of class Diplopoda are close relatives of insects. Centipedes move quickly and live in moist places under logs, bark, and stones. They have long, segmented bodies, and each segment has one pair of jointed legs. The first pair of appendages is modified to form poisonous claws, which a centipede uses to kill prey. Most species of centipedes are not harmful to humans.

Millipedes have two pairs of appendages on each of their abdominal segments and one pair on each of their thorax segments. Millipedes are herbivorous and live, as centipedes do, in moist places under logs or stones. Unlike centipedes, they do not wriggle quickly, but walk with a slow, graceful motion. Millipedes do not have poisonous claws and feed primarily on damp and decaying vegetation. Compare the centipede and millipede in **Figure 20.**

Figure 20 Centipedes have one pair of appendages on each segment and poison claws on the first segment. Millipedes have two pairs of appendages on each abdominal segment, while the thorax has one pair of appendages on each segment.



Centipede



Millipede



Trilobite fossil

Color-Enhanced SEM Magnification: 750×



Tardigrade

Figure 21 Extinct trilobites are considered to be some of the first arthropods. They were abundant in Cambrian times. Tardigrades, belonging to a phylum that might be related to annelids and arthropods, are called water bears and can live in areas that are alternately wet and dry.

Evolution of Arthropods

The relationships of tardigrades, trilobites, and arthropods have been under close scrutiny as new evidence is discovered. Fossil records show that trilobites, abundant in the mid-Cambrian but now extinct, were early arthropods. Trilobites, like the one shown in **Figure 21,** were oval, flattened, and divided into three body sections like some modern arthropods. The large number of identical segments of these ancestral arthropods evolved to more specialized appendages and fewer segments in modern arthropods.

Tardigrades also are related to arthropods, but they appear to be related less closely to arthropods than trilobites are. The tardigrade shown in **Figure 21** illustrates why these tiny animals are known commonly as water bears. The largest are 1.5 mm long with four pairs of stubby legs. They feed on algae, decaying matter, nematodes, and other soil animals. They inhabit freshwater, marine, and land habitats. During temperature extremes and drought, tardigrades can survive for years in a completely dry state with reduced metabolism until favorable conditions return.

Section 3 Assessment

Section Summary

- Insects make up approximately 80 percent of all arthropod species.
- A variety of adaptations have enabled insects to live in almost all habitats on Earth.
- Insect mouthparts reflect their diets.
- Most insects undergo metamorphosis.
- In some insects, social structure, including individual specializations, is necessary for the survival of the colony.

Understand Main Ideas

1. MAIN Idea **Evaluate** three adaptations of insects in terms of the role they played in enabling insects to become so diverse and abundant.
2. **Identify** features common to all insects.
3. **List** adaptations of the mouthparts of insects that feed on three different food sources and explain each one.
4. **Identify** one reason most insects undergo complete metamorphosis.

Think Critically

5. **Design an Experiment** Different species of firefly beetles flash their light in different sequences of short and long flashes. Design an experiment that would explain why fireflies flash their lights.

MATH in Biology

6. There are approximately 1.75 million named animal species. About three-fourths of all known animal species are arthropods, and 80 percent of arthropods are insects. Approximately how many named species are insects?

In the Field

Career: Forensic Entomologist

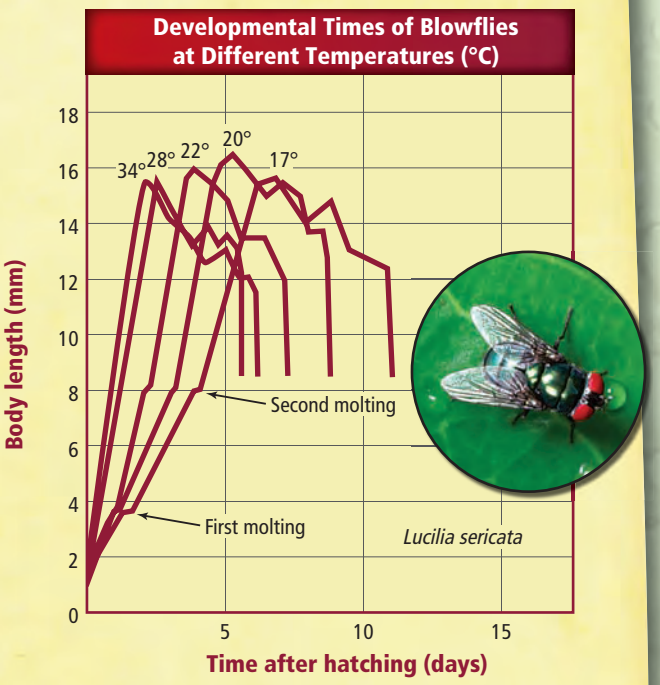
Insect Evidence

Insects often are the first to arrive at a crime scene. Blowflies can arrive within minutes. Over time, other insects arrive. As the insects feed, grow, and lay eggs, they follow predictable developmental cycles. For forensic entomologists, scientists who apply their knowledge of insects to help solve crimes, these cycles reveal information about the time and location of death.

Time of death Forensic entomologists use two methods to determine time of death. The first method is used when the victim has been dead for at least one month. While blowflies and houseflies arrive almost immediately, other species arrive later in the decomposition process. Some species arrive to feed on other insects already at the scene. The succession of insects provides information about the time that passed since death occurred.

When death has occurred within a few weeks, a second method used involves the developmental cycle of blowflies. Within a couple of days, the blowflies lay eggs. The next stages of development are determined in part by temperature, as shown in the graph. Based on the stage of insect development and area temperatures, entomologists can determine a range of days in which the first insects laid eggs in the body, establishing a time of death.

Location of death Insects help determine if a body was relocated after death. If insects found on the body are not native to the habitat where the body is found, investigators can assume that the body was moved. The species that are present also provide clues about the area where death took place.



Limitations In many locations, forensic entomology is less useful in winter, when insects are less active and less abundant. In addition, insects might be prevented from invading a body if it is frozen, buried deeply, or wrapped tightly. In many cases, however, insects can give crucial testimony about the details of a crime.

MATH in Biology

Study the graph to solve this problem: Blowfly larvae with a body length of about 6 mm are found on a corpse with a temperature of 22°C. How much time has passed since death?

WebQuest

BIOLAB

WHERE ARE MICROARTHROPODS FOUND?

Background: **Microarthropods range from 0.1 to 5 mm in size—barely visible to human eyes. Dozens of microarthropod species can be unearthed in one shovelful of soil. Discover these hidden animals during this investigation.**

Question: *What types of microarthropods can be found in your local environment?*

Materials

soil sample
clear funnel
ring stand
gooseneck lamp
wire mesh
beaker
95% ethanol
plastic collection vials
magnifying lens
arthropod field guide
metric ruler

Safety Precautions



Procedure

1. Read and complete the lab safety form.
2. Obtain a sample of leaf litter and soil from your teacher.
3. Create a data table to record your observations.
4. Place the funnel in the ring stand.
5. Cut the mesh screen in a circle so it rests inside the funnel.
6. Pour ethanol into the beaker until the beaker is two-thirds full. Set the beaker under the funnel.
7. Remove your soil sample from the bag and place it carefully on the mesh screen in the funnel.
8. Place the lamp at least 10 cm above the sample. Switch on the light and leave it on for several hours. The heat from the lamp dries the soil. This forces the microarthropods downward until they fall through the screen and into the alcohol.
9. Use a magnifying lens to observe the physical characteristics of the microarthropods you collected.
10. **Cleanup and Disposal** Be certain to properly dispose of the alcohol and specimens you collected by following your teacher's instructions.

Analyze and Conclude

1. **Classify** Place the microarthropods you collected into the three major groups of arthropods. Place unidentified specimens into a separate group.
2. **Graph** Use the data you collected to graph the abundances of each type of arthropod.
3. **Describe** Write a description of the physical characteristics of the microarthropod specimens that you could not classify into any of the three major groups.
4. **Hypothesize** How do microarthropods help create a healthy soil ecosystem?
5. **Error Analysis** Check your classifications against those done by other classmates. Did you classify the microarthropods into the same group? If not, explain why.

SHARE YOUR DATA

Report Research microarthropods and write a short report about their role in the food web and ecosystems. Then present your findings to a group of classmates.

Chapter 26 Study Guide

THEME FOCUS Diversity Segmented exoskeletons, jointed appendages, and diverse body structures enable arthropods to live in nearly every environment.

BIG Idea **Arthropods have evolved to have a variety of adaptations for successful diversity, population, and persistence.**

Section 1 Arthropod Characteristics

thorax (p. 763)
abdomen (p. 763)
cephalothorax (p. 763)
appendage (p. 764)
molting (p. 764)
mandible (p. 765)
tracheal tube (p. 767)
book lung (p. 767)
spiracle (p. 767)
Malpighian tubule (p. 767)
pheromone (p. 768)

MAIN Idea **Arthropods have segmented bodies and tough exoskeletons with jointed appendages.**

- Arthropods can be identified by three main structural features.
- Arthropods have adaptations that make them the most successful animals on Earth.
- Arthropod mouthparts are adapted to a wide variety of food materials.
- In order to grow, arthropods must molt.
- Arthropods have organ system modifications that have enabled them to live in all types of habitats and to increase in variety and numbers.

Section 2 Arthropod Diversity

cheliped (p. 771)
swimmeret (p. 771)
chelicera (p. 771)
pedipalp (p. 772)
spinneret (p. 772)

MAIN Idea **Arthropods are classified based on the structure of their segments, types of appendages, and mouthparts.**

- Arthropods are divided into three major groups.
- Crustaceans have modified appendages for getting food, walking, and swimming.
- The first two pairs of arachnid appendages are modified as mouthparts, as reproductive structures, or as pincers.
- Spiders are carnivores that either hunt prey or trap it in webs that they spin out of silk.
- Horseshoe crabs are ancient arthropods that have remained unchanged for more than 200 million years.

Section 3 Insects and Their Relatives

metamorphosis (p. 778)
pupa (p. 778)
nymph (p. 778)
caste (p. 779)

MAIN Idea **Insects have structural and functional adaptations that have enabled them to become the most abundant and diverse group of arthropods.**

- Insects make up approximately 80 percent of all arthropod species.
- A variety of adaptations have enabled insects to live in almost all habitats on Earth.
- Insect mouthparts reflect their diets.
- Most insects undergo metamorphosis.
- In some insects, social structure, including individual specializations, is necessary for the survival of the colony.

Review Vocabulary eGames

Chapter 26 Assessment

Section 1

Vocabulary Review

An analogy is a relationship between two pairs of words and can be written in the following manner: A is to B as C is to D. *Complete each analogy by providing the missing vocabulary term from the Study Guide page.*

1. Spiracles are to breathing as _____ are to excreting wastes.

2. Compound eye is to sense organ as mandible is to _____.

3. Head is to thorax as _____ is to abdomen.

Understand Main Ideas

Use the diagram below to answer questions 4 and 5.



4. Which labeled structure helps terrestrial arthropods maintain water balance?
- **A.** 1
- **B.** 2
- **C.** 3
- **D.** 4

5. Which labeled structure would an arthropod use to sense odors in its environment?
- **A.** 1
- **B.** 2
- **C.** 3
- **D.** 4

6. Which group of words has one that does not belong?
- **A.** exoskeleton, chitin, molting, growth
- **B.** mandible, antennae, appendage, leg
- **C.** cephalothorax, thorax, head, abdomen
- **D.** simple eye, compound eye, tympanum, thorax

7. The relationship between muscle size and exoskeleton thickness limits which in an arthropod?
- **A.** diet
- **B.** habitat
- **C.** motion
- **D.** size

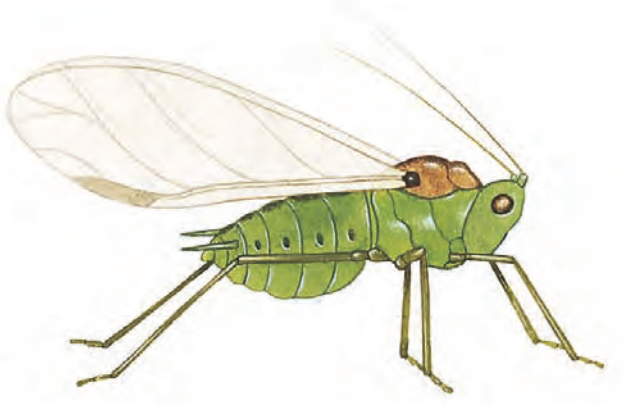
Constructed Response

8. MAIN Idea Make a table that lists arthropod structures, their functions, and an analogy of what each structure is like in a world of human-made devices. For example, a particular bird's bill that pulls insects out of bark might be compared to tweezers that can pull a sliver out of skin. Use the following structures in your table: antennae, exoskeleton, mandibles, tracheal tubes, and tympanum.

9. Open Ended Katydids are members of the grasshopper family. Most katydids are green, but occasionally both pink and yellow katydids appear. Make a hypothesis to explain why pink and yellow katydids sometimes appear.

Think Critically

Use the diagram below to answer question 10.



10. CAREERS IN BIOLOGY Arborists, people who specialize in caring for trees, sometimes spray horticultural oils on fruit trees to control aphids, the plant pest shown in the diagram. Based on your knowledge of insect anatomy, analyze why oils are an effective treatment to control plant pests.

11. Infer Some species of flowers produce heat that attracts certain beetles to live inside the bloom. Infer how the plant and the beetle both benefit from this relationship.

Section 2

Vocabulary Review

For each set of vocabulary terms, explain the relationship that exists.

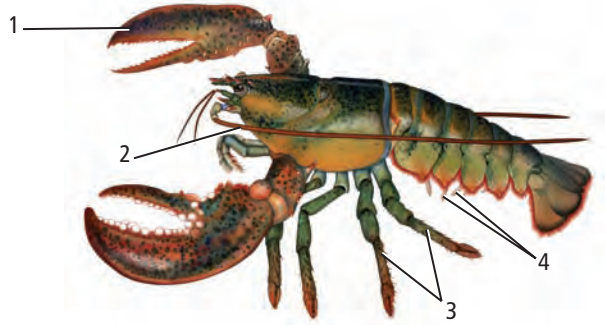
12. cheliped, swimmeret

13. chelicera, pedipalp

14. cheliped, chelicera

Understand Main Ideas

Use the diagram below to answer question 15.



15. Which structure would a lobster use to catch and crush food?

A. 1 **C.** 3
B. 2 **D.** 4

16. Which is not a characteristic of arachnids?

A. chelicerae **C.** spinnerets
B. pedipalps **D.** antennae

17. An animal you found on the forest soil has two body sections, no antennae, and large pincers as the second pair of appendages. What type of animal is it?

A. tick **C.** spider
B. scorpion **D.** lobster

18. In spiders, the spinnerets are involved in which activity?

A. defense **C.** circulation
B. getting rid of waste **D.** spinning silk

19. Which is not a characteristic of mites?

A. one oval-shaped body section
B. carry lyme disease bacteria
C. less than 1 mm long
D. animal parasite

Constructed Response

20. MAIN Idea Compare the body forms of aquatic crustaceans to those of terrestrial arachnids, showing how each is adapted to its environment.

21. **Open Ended** What would happen if crustaceans could not molt?

Think Critically

22. **Formulate Models** Draw and describe a model of a spider that would be adapted to conditions in a hot, dry attic with only crawling insects as a food source.

23. THEME FOCUS Diversity Based on the lobster diagram in **Figure 10** and your knowledge of crustaceans, what adaptations enable a lobster to survive in its aquatic enviroment?

Section 3

Vocabulary Review

For each set of vocabulary terms, choose the one term that does not belong and explain why it does not belong.

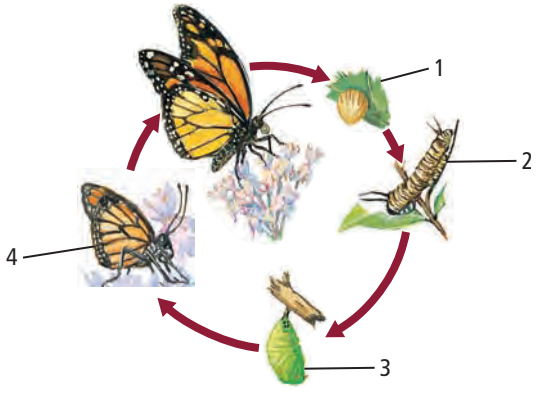
24. incomplete metamorphosis, pupa, larva, adult

25. complete metamorphosis, nymph, adult, molt

26. pupa, larva, nymph, caste, adult

Understand Main Ideas

Use the diagram below to answer question 27.



27. Which stage does not belong in the diagram of complete metamorphosis?

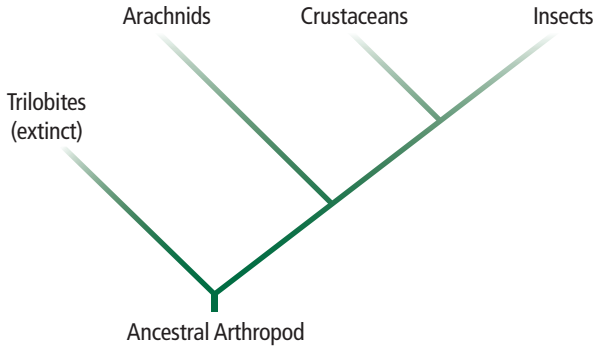
A. 1 **C.** 3
B. 2 **D.** 4

28. If the food is 40 degrees to the right of the Sun, what will be the angle of the straight line of the figure-eight waggle dance?
- **A.** 60 degrees to the right of vertical
- **B.** 40 degrees to the right of vertical
- **C.** 60 degrees to the right of horizontal
- **D.** 40 degrees to the right of horizontal

29. If a farm field has an infestation of insects, which method would the farmer use to manage it for the long-term?
- **A.** genetic engineering
- **B.** insecticides
- **C.** integrated pest management
- **D.** pesticide resistance

Constructed Response

Use the diagram below to answer questions 30 and 31.



30. Open Ended Based on this interpretation of the phylogeny of arthropods, which group developed the earliest? Which group developed most recently?

31. MAIN Idea Examine the cladogram and sequence the order of appearance, from oldest to most modern, of the following features in the evolution of insects: chelicerae, mandibles, body divided into two regions, segmentation. Explain your reasoning.

Think Critically

32. Hypothesize A certain species of beetle looks very much like an ant. Make a hypothesis about the advantage to the beetle of looking like a particular ant.

33. Design an experiment that would answer this question: Why do crickets chirp?

Summative Assessment

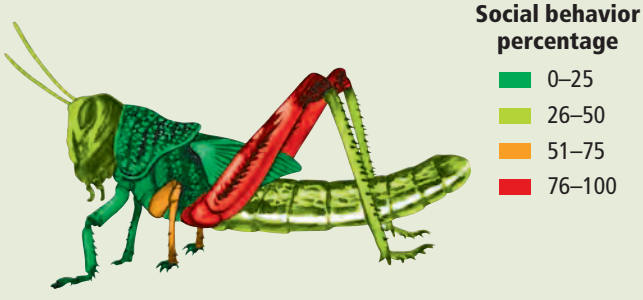
34. BIG Idea Select an arthropod from this chapter. Highlight its adaptations and explain how they help it thrive in its habitat.

35. WRITING in Biology Malaria is spread by mosquitos and is one of the world's worst diseases in terms of numbers of people affected and the difficulties in treating and preventing it. Research and write an essay on how scientists are using fungi to prevent this disease.

DBQ Document-Based Questions

Desert locusts have two distinct phases in their lives: the solitary insect that stays in one area and the social phase in which locusts band together in swarms of billions and move kilometers in search of food. Biologists found that exposing individual insects to jostling by small paper balls induced swarming. Examine the locust below. Each color indicates the percentage of social behavior induced by touching the locust on various parts of the body.

Data obtained from: Enserink, M. 2004. Can the war on locusts be won? *Science* 306 (5703): 1880–1882.



36. What percentage of social behavior resulted from touching the insect's thorax?

37. What part of the insect's body is the most sensitive for generating social activity when it is touched?

38. Draw a conclusion about what physical trigger causes locusts to swarm.

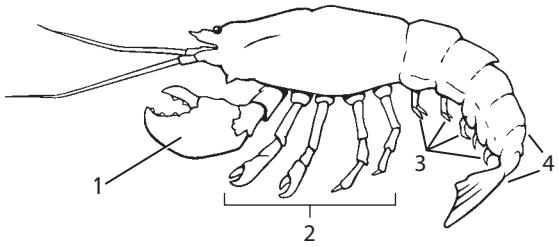
Standardized Test Practice

Cumulative

Multiple Choice

1. Which common function do both the endoskeletons and exoskeletons of animals perform?
- **A.** growing along with the animal
- **B.** preventing water loss
- **C.** supporting the body
- **D.** providing protection from predators

Use the diagram below to answer questions 2 and 3.



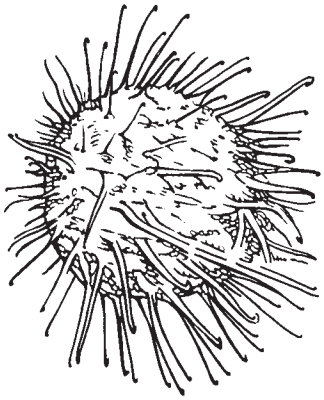
2. In which group does this animal belong?
- **A.** copepods
- **B.** crustaceans
- **C.** insects
- **D.** spiders

3. Which part of the body does this animal use for reproduction?
- **A.** 1
- **B.** 2
- **C.** 3
- **D.** 4

4. How are the organisms in Kingdom Protista different from animals?
- **A.** Some are multicellular.
- **B.** Some are prokaryotes.
- **C.** Some have cell walls.
- **D.** Some have tissues.

5. Which kind of asexual reproduction is possible in flatworms?
- **A.** budding
- **B.** fertilization
- **C.** parthenogenesis
- **D.** regeneration

Use the drawing below to answer question 6.



6. Which is the method of seed dispersal for this seed?
- **A.** animals
- **B.** gravity
- **C.** water
- **D.** wind

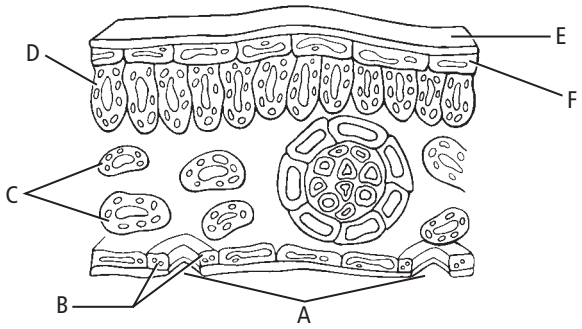
7. Which process is related to sexual reproduction in animals?
- **A.** budding
- **B.** fertilization
- **C.** fragmentation
- **D.** parthogenesis

8. Which is the role of an earthworm's clitellum in reproduction?
- **A.** It breaks off, allowing fragmentation to occur.
- **B.** It indicates whether or not an earthworm is hermaphroditic.
- **C.** It leaves the earthworm's body and forms a cocoon for developing earthworms.
- **D.** It produces sperm and eggs.

9. Which is used to classify protists?
- **A.** feeding
- **B.** habitat
- **C.** structure
- **D.** reproduction

Short Answer

Use the diagram below to answer question 10.



10. Identify the labeled parts of this leaf, and state a function for each part.

11. Which characteristics differentiate arthropods from other invertebrates?

12. Describe embryonic development from a zygote to a gastrula. Provide the name of each stage, and explain how it is unique.

13. What characteristics do all mollusks share?

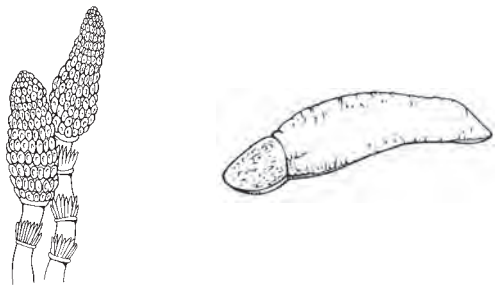
14. Compare and contrast how blood circulates through an insect with the circulation of blood in another kind of animal.

15. Explain the theory of endosymbiosis as it applies to protists. Assess the possible connection between certain organelles in eukaryotic protists and the structures of prokaryotic organisms.

16. Assess the importance of algae to all living things.

Extended Response

Use the illustrations below to answer question 17.



17. The figures above show spores and seeds from different kinds of plants. Explain why one of these structures would have an advantage and would be more likely to be naturally selected.

18. Evaluate the advantages and disadvantages of an exoskeleton.

Essay Question

The world's coral reefs and associated ecosystems are threatened by an increasing array of pollution, habitat destruction, invasive species, disease, bleaching, and global climate change. The rapid decline of these complex and biologically diverse marine ecosystems has significant social, economic, and environmental impacts in the U.S. and around the world. The U.S. Coral Reef Task Force identified two basic themes for national action:

- understand coral reef ecosystems and the processes that determine their health and viability
- reduce the adverse impacts of human activities on coral reefs and associated ecosystems

Using the information in the paragraph above, answer the following question in essay format.

19. *What steps do you think the U.S. should take to preserve coral reef ecosystems?*

NEED EXTRA HELP?																			
If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Review Section . . .	24.1	26.2	26.2	24.1	25.1	23.3	24.1	25.4	19.1	22.2	26.1	24.1	25.3	26.1	19.1	19.3	21.3	26.1	24.3

CHAPTER 27

Echinoderms and Invertebrate Chordates



ConnectED

Your one-stop online resource
connectED.mcgraw-hill.com

- Video
- Audio
- Review
- Inquiry
- WebQuest
- Assessment
- Concepts in Motion
- Multilingual eGlossary

Launch Lab

Why are tube feet important?

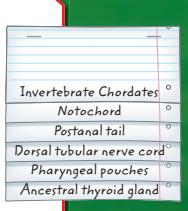
Like all echinoderms, the crown-of-thorns sea star in the opening photo has structures called tube feet. In this lab, you will observe tube feet and determine their function.

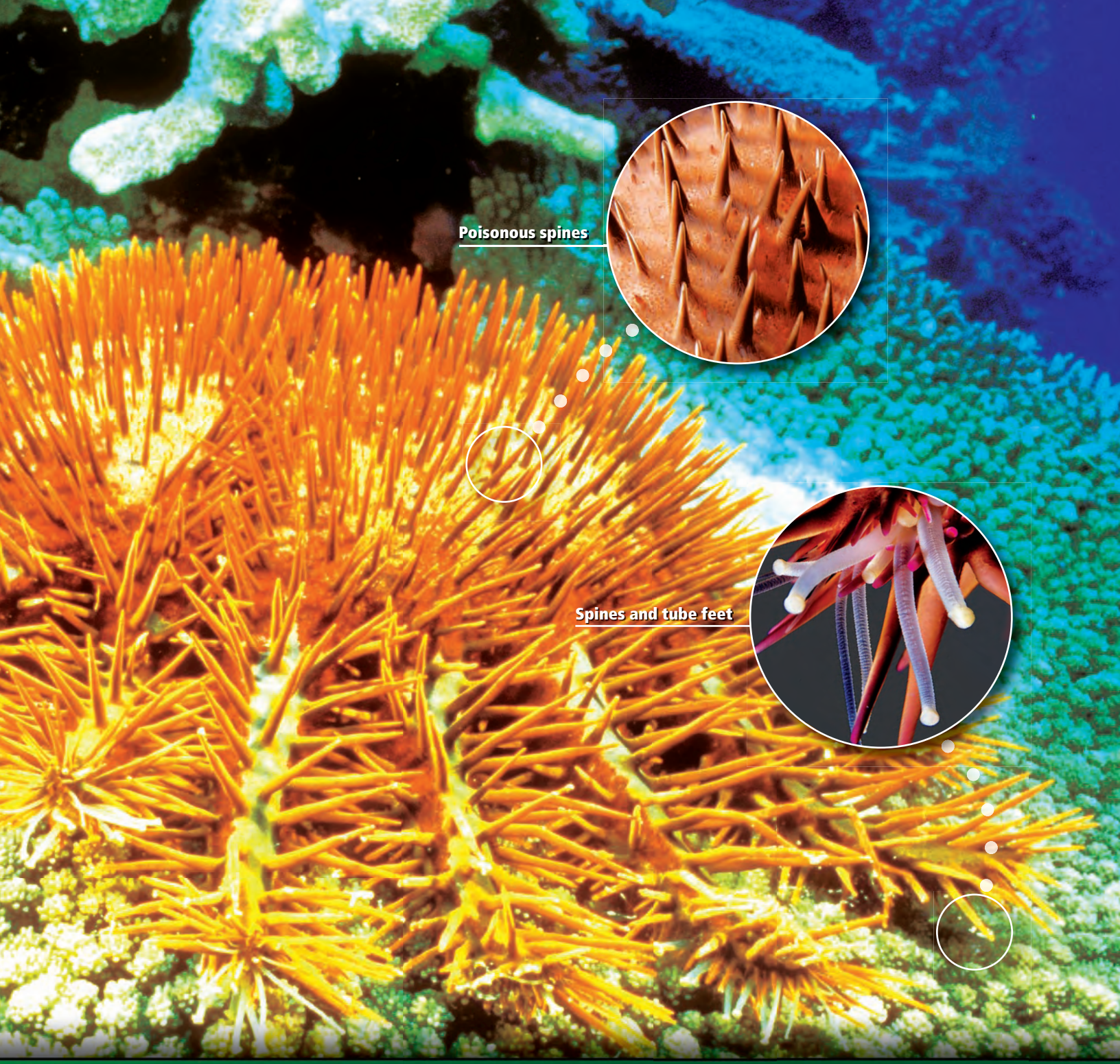
For a lab worksheet, use your StudentWorks™ Plus Online.

Inquiry Launch Lab

FOLDABLES®

Make a layered look-book using the titles shown. Use it to organize your notes on invertebrate chordates.





THEME FOCUS Diversity

Echinoderms and invertebrate chordates have diverse adaptations that allow them to live and thrive in their habitats.

BIG Idea Echinoderms and invertebrate chordates have features that connect them to the chordates that evolved after them.

Section 1 • Echinoderm Characteristics

Section 2 • Invertebrate Chordates

Section 1

Reading Preview

Essential Questions

- What are the characteristics common to echinoderms?
- How do the water-vascular system and tube feet adaptations enable echinoderms to be successful?
- What distinguishes the classes of echinoderms from each other?

Review Vocabulary

endoskeleton: an internal skeleton that provides support and protection and can act as a brace for muscles to pull against

New Vocabulary

pedicellaria
water-vascular system
madreporite
tube foot
ampulla

Multilingual eGlossary

Echinoderm Characteristics

MAIN Idea **Echinoderms are marine animals with spiny endoskeletons, water-vascular systems, and tube feet; they have radial symmetry as adults.**

Real-World Reading Link To take a blood-pressure reading, a health care professional squeezes a bulb that forces air through a tube and into the blood-pressure cuff around your arm. The cuff remains tight around your arm until the pressure is released when the air is let out. Some animals use similar systems to obtain food and move.

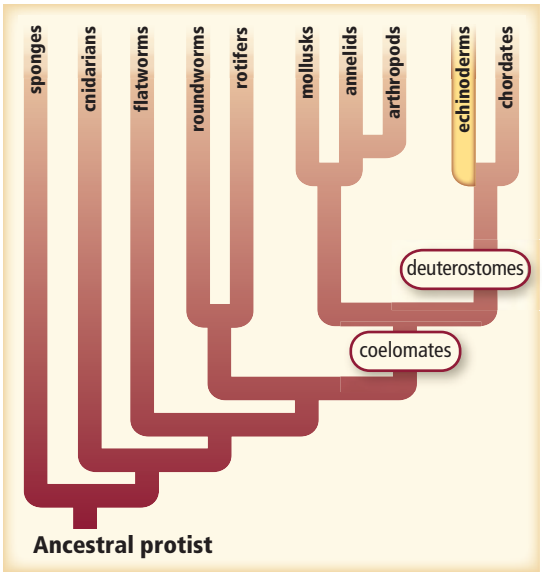
Echinoderms Are Deuterostomes

As shown in the evolutionary tree in **Figure 1,** echinoderms (ih KI nuh durmz) are deuterostomes—a major transition in the phylogeny of animals. Notice how the evolutionary tree branches at deuterostome development.

Recall that mollusks, annelids, and arthropods are protostomes. During development, a protostome's mouth develops from the opening on the gastrula, while a deuterostome's mouth develops from elsewhere on the gastrula. This might not seem important, but consider that only echinoderms and the chordates that evolved after echinoderms have this kind of development. Echinoderms and chordates are related more closely than groups that do not develop in this way. Animals with spinal cords, including humans, are chordates.

The approximately 6000 living species of echinoderms are marine animals and include sea stars, sea urchins, sand dollars, sea cucumbers, brittle stars, sea lilies and feather stars, and sea daisies. Two echinoderms are shown in **Figure 1.**

Figure 1 Echinoderms are marine animals and are the first animals in evolutionary history to have deuterostome development and an endoskeleton.





Purple sea urchin



Feather star

Body Structure

The brittle star is an example of an echinoderm with the spiny endoskeleton that is characteristic of the organisms in this phylum. Echinoderms are the first group of animals in evolutionary history to have endoskeletons. In echinoderms, the endoskeleton consists of calcium carbonate plates, often with spines attached, and is covered by a thin layer of skin. On the skin are **pedicellariae** (PEH dih sih LAH ree ee) (singular, pedicellaria), small pincers that aid in catching food and in removing foreign materials from the skin.

All echinoderms have radial symmetry as adults. In **Figure 2,** you can see this feature in the five arms of the brittle star radiating out from a central disk. However, echinoderm larvae have bilateral symmetry, as shown in **Figure 2.** Bilateral symmetry shows an embryonic link to the vertebrate animals that evolved later.

No other animals with complex organ systems like that of echinoderms have radial symmetry. Scientists theorize that the ancestors of echinoderms did not have radial symmetry. Primitive echinoderms might have been sessile, and radial symmetry developed to enable them to carry on a successful stationary existence. Free-moving echinoderms might have evolved from the sessile animals. Investigate the features of echinoderms in **MiniLab 1.**

Reading Check **Infer** how radial symmetry is important to animals that cannot move quickly.

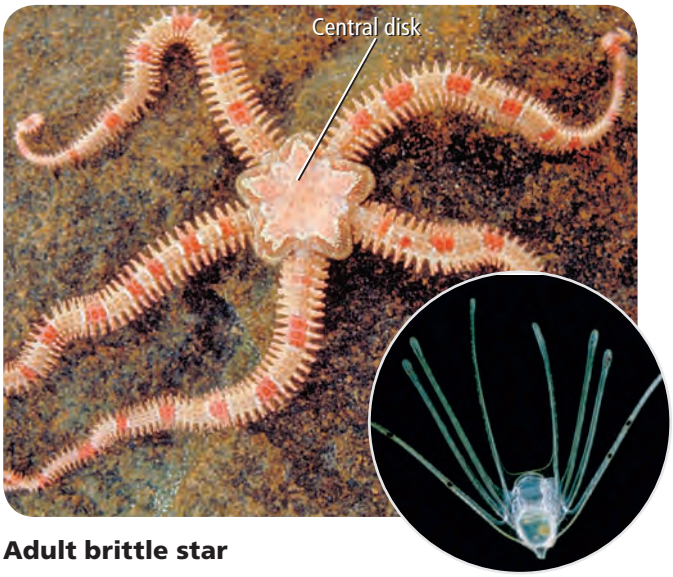


Figure 2 Brittle star larvae have bilateral symmetry and can be divided along only one plane into mirror-image halves. Adult brittle stars have radial symmetry and can be divided through a central axis, along any plane, into equal halves.

MiniLab 1

Observe Echinoderm Anatomy

Inquiry MiniLab

What are the characteristics of echinoderms? Although they have many shapes and sizes, all echinoderms have some features in common.

Procedure

1. Read and complete the lab safety form.
2. Study preserved specimens of **a sand dollar, a sea cucumber, a sea star,** and **a sea urchin.**
3. Create a data table to record your observations. Complete the table by describing the major features of each specimen. Include a sketch of each specimen.
4. Label any external features you can identify.
5. Clean all equipment and return it to the appropriate place. Wash your hands thoroughly after handling preserved specimens.

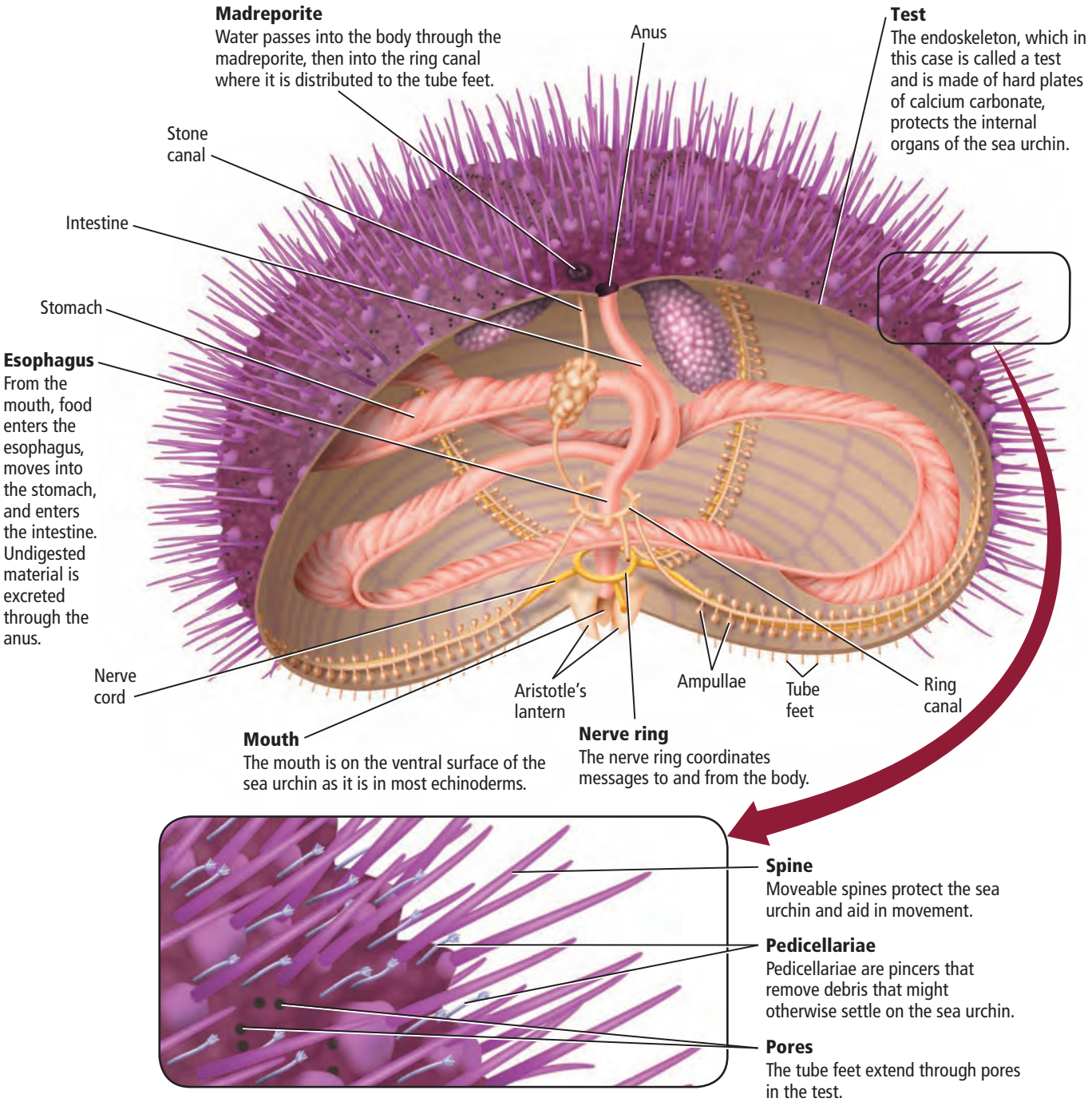
Analysis

1. **Compare** the external features of the echinoderms you studied. Can your observations completely justify why these four organisms are classified in the same phylum? Explain.
2. **Infer** which observed features are most important in helping echinoderms avoid being eaten by predators.

Visualizing an Echinoderm

Figure 3

Sea urchins can be found in tidal areas of the sea. They burrow into crevices in rocks to hide, and they scrape algae with a hard five-plated structure, called Aristotle's lantern, in their mouths. Imagine that these plates are like teeth that move.



Concepts in Motion Animation

Water-vascular system Another feature of echinoderms is their **water-vascular system**—a system of fluid-filled, closed tubes that work together to enable echinoderms to move and get food. The strainerlike opening to the water-vascular system, shown in **Figure 3,** is called the **madreporite** (MA druh pohr it). Water is drawn into the madreporite, then moves through the stone canal to the ring canal. From there, the water moves to the radial canals and eventually to the tube feet.

Tube feet are small, muscular, fluid-filled tubes that end in suction-cuplike structures and are used in movement, food collection, and respiration. The opposite end of the tube foot is a muscular sac, called the **ampulla** (AM pyew luh). When muscles contract in the ampulla, water is forced into the tube foot and it extends. Imagine holding a small, partly inflated balloon in your hand and squeezing it. The balloon will extend from between your thumb and forefinger, which is similar to the way the tube foot extends. The suction-cuplike structure on the end of the tube foot attaches it to the surface. This hydraulic suction enables all echinoderms to move and some, such as sea stars, to apply a force strong enough to open the shells of mollusks, as illustrated in **Figure 4.**

Feeding and digestion Echinoderms use a great variety of feeding strategies in addition to tube feet. Sea lilies and feather stars extend their arms and trap food. Sea stars prey on a variety of mollusks, coral, and other invertebrates. Many species of sea stars can push their stomachs out of their mouths and onto their prey. They then spread digestive enzymes over the food and use cilia to bring the digested material to their mouths. Brittle stars can be active predators or scavengers, and they can trap organic materials in mucus on their arms. Most sea urchins use teethlike plates, shown in **Figure 3,** to scrape algae off surfaces or feed on other animals. Many sea cucumbers extend their branched, mucus-covered tentacles to trap floating food.

Respiration, circulation, and excretion Echinoderms also use their tube feet in respiration. Oxygen diffuses from the water through the thin membranes of the tube feet. Some echinoderms carry out diffusion of oxygen through all thin body membranes in contact with water. Other echinoderms have thin-walled skin gills that are small pouches extending from the body. Many sea cucumbers have branched tubes, called respiratory trees, through which water passes and oxygen moves into the body.

Circulation takes place in the body coelom and the water-vascular system, while excretion of cellular wastes occurs by diffusion through thin body membranes. Cilia move water and body fluids throughout these systems aided by pumping action in some echinoderms. In spite of the simplicity of these organs and systems, echinoderms maintain homeostasis effectively with adaptations that are suited to their way of life.

Reading Check **Summarize** the functions of an echinoderm's tube feet.



Figure 4 A sea star uses its tube feet to open the two shells of a clam.
Describe *the sea star's feeding method.*

Inquiry **Launch Lab**

Review **Based on what you have read about the water-vascular system, how would you now answer the analysis questions?**



Figure 5 A sea star lifts the end of an arm to sense light and movement.

Response to stimuli Echinoderms have both sensory and motor neurons with varying degrees of complexity in different species. In general, a nerve ring surrounds the mouth with branching nerve cords connecting to other body areas.

Sensory neurons respond to touch, chemicals dissolved in the water, water currents, and light. At the tips of the arms of sea stars are eyespots, clusters of light-sensitive cells, illustrated in **Figure 5.** Many echinoderms also sense the direction of gravity. For example, a sea star will return to an upright position after being overturned by a wave or current.

Movement Echinoderm locomotion is as varied as echinoderm body shapes. The structure of the endoskeleton is important for determining the type of movement an echinoderm can undertake. The movable bony plates in the endoskeletons of echinoderms enable them to move easily. Feather stars move by grasping the soft sediments of the ocean bottom with their cirri—long, thin appendages on their ventral sides—or by swimming with up-and-down movements of their arms. Brittle stars use their tube feet and their arms in snakelike movements for locomotion. Sea stars use their arms and tube feet for crawling. Sea urchins move by using tube feet and burrowing with their movable spines. Sea cucumbers crawl using their tube feet and body wall muscles.

Reading Check **Describe** ways that echinoderms move other than using their tube feet.

Vocabulary

Science usage v. Common usage

Structure

Science usage: the arrangement of parts of an organism
The structure of an insect's mouth determines how it functions.

Common usage: something that is constructed, such as a building
The workers built the structure in three months.

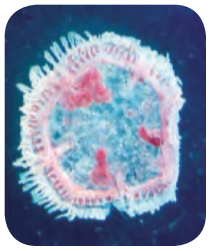
Reproduction and development Most echinoderms reproduce sexually. The females shed eggs and the males shed sperm into the water where fertilization takes place. The fertilized eggs develop into free-swimming larvae with bilateral symmetry. After going through a series of changes, the larvae develop into adults with radial symmetry. Recall that echinoderms have deuterostome development, making them an important evolutionary connection to vertebrates.

The sea star in **Figure 6** is regenerating a lost body part. Many echinoderms can drop off an arm when they are attacked, enabling them to flee while the predator is distracted. Others can expel part of their internal organ systems when threatened. This action might surprise and deter predators. The expelled body parts and lost arms can be regenerated.



Figure 6 This sea star is regenerating one of its arms, a process that can take up to one year.
Explain ***how regenerating body parts helps echinoderms survive.***

Table 1 **Classes of Echinoderms** Concepts in Motion Interactive Table

Class	Asteroidea	Ophiuroidea	Echinoidea	Crinoidea	Holothuroidea	Concentricycloidea
Examples						
Class Members	Sea stars	Brittle stars	Sea urchins, Sand dollars	Sea lilies, Feather stars	Sea cucumbers	Sea daisies
Distinctive Features	• Often five-armed • Tube feet used for feeding and movement	• Often five-armed • Arms break off easily and can be regenerated • Move by arm movement • Tube feet have no suction cups	• Body encased in a test with spines • Sea urchins burrow in rocky areas. • Sand dollars burrow in sand.	• Sessile for some part of life • Sea lilies have long stalks. • Feather stars have long branching arms.	• Cucumber shape • Leathery outer body • Tube feet modified to tentacles near mouth	• Less than 1 cm in diameter • No arms • Tube feet located around a central disk

Echinoderm Diversity

The major classes of living echinoderms include Asteroidea (AS tuh ROY dee uh), the sea stars; Ophiuroidea (OH fee uh ROY dee uh), the brittle stars; Echinoidea (ih kihn OY dee uh), the sea urchins and sand dollars; Crinoidea (kri NOY dee uh), the sea lilies and feather stars; Holothuroidea (HOH loh thuh ROY dee uh), the sea cucumbers; and Concentricycloidea (kahn sen tri sy CLOY dee uh), the sea daisies. Recall that they all are marine animals with radial symmetry as adults, a water-vascular system with tube feet, endoskeletons often bearing spines, and larvae with bilateral symmetry. The classes of echinoderms are summarized in **Table 1.**

Sea stars If you ever have seen an echinoderm, it probably was a sea star. Most species of sea stars have five arms arranged around a central disk. Some, such as the one in **Figure 7,** have more than five arms. Sea stars can be found in shallow water near the shore and in tide pools when the tide recedes. They can be found in groups clinging to rocks by means of their tube feet. A single tube foot can exert a pull of 0.25–0.30 N. This is equal to the force required to lift 25–30 large paper clips. Because a sea star might have as many as 2000 tube feet, it can exert quite a large force as it crawls or opens mollusks for food. Sea stars are important predators in marine ecosystems, feeding on clams and other bivalves. Because of their spiny skin, sea stars usually are not food for other marine predators.

Figure 7 Sunflower stars can have twenty or more arms.





Figure 8 One type of brittle star, the basket star, extends its branched arms into the current to filter feed.
Analyze *how brittle stars are different from sea stars.*

Brittle stars Like sea stars, most brittle stars have five arms, but the brittle star's arms are thin and very flexible, as shown in **Figure 8.** They do not have suckers on their tube feet, so they cannot use them for movement as sea stars do. Brittle stars move by rowing themselves quickly over the bottom rocks and sediments or by snakelike movements of their arms. When attacked by a predator, a brittle star can release an arm and make a quick getaway. The missing arm will be regenerated later. Brittle stars hide in the crevices of rocks by day and feed at night. They feed on small particles suspended in the water or catch suspended materials on mucous strands between their spines.

Some brittle stars respond to light. The spherical structures covering the body of these brittle stars might function as light-gathering lenses. Brittle stars are more abundant and have more numbers of species than any other class of echinoderm.

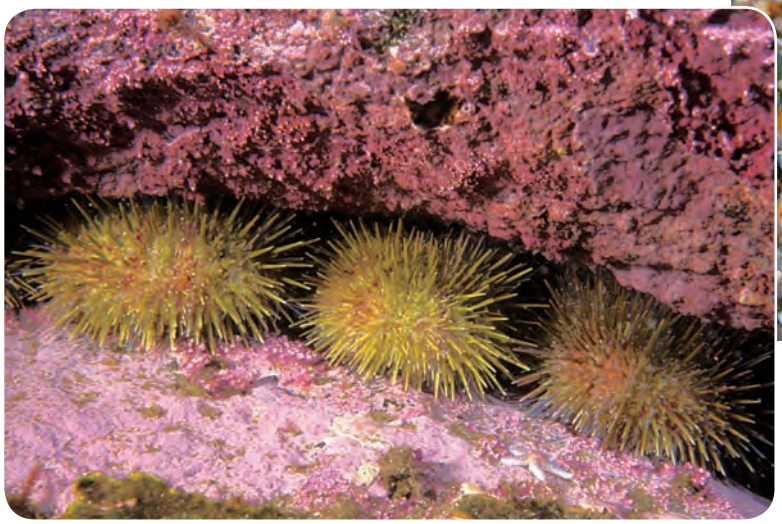
Reading Check **Compare and contrast** the locomotion of sea stars and brittle stars.

Sea urchins and sand dollars Burrowing is a key characteristic of sea urchins and sand dollars. Sand dollars can be found in shallow water burrowing into the sand, while sea urchins burrow into rocky areas. These echinoderms each have a compact body enclosed in a hard endoskeleton, called a test, that looks like a shell. The tube feet extend through pores in the test. Closely fitting plates of calcium carbonate make up the test. Sea urchins and sand dollars lack arms, but their tests reflect the five-part pattern of arms in sea stars and brittle stars. Spines also are an important feature of this class, as seen in **Figure 9.** Some sea urchin spines and pedicellariae contain venom and are used for fending off predators. The poison in pedicellariae can paralyze prey. Sea urchins also can be herbivorous grazers, scraping algae from rocks, while sand dollars filter organic particles from the sand in which they are partially buried.

Figure 9 Sea urchins burrow themselves into rocky crevices with their sharp, movable spines. Sand dollars burrow themselves into the sand, where they filter out small food particles.



Sand dollar



Sea urchins



Aristotle's lantern



Five-sided lantern

Figure 10 Aristotle's lantern is a five-sided mouthpart similar in shape to a five-sided lantern. The force of a sea urchin's chewing plates is so strong that it has been known to chew through concrete.

Connection to History Most sea urchins have a chewing apparatus inside their mouths consisting of five hard plates, similar to teeth. This structure, shown in **Figure 10,** is called Aristotle's lantern. It was named after a description written by Aristotle, a Greek philosopher, in his book *Historia Animalium* (The History of Animals). During Aristotle's lifetime in the fourth century B.C., people used five-sided lanterns with side panels made of thin, translucent horn, called horn lanterns. Aristotle thought the mouth of a sea urchin looked like a horn lantern without the panels.

Sea lilies and feather stars

Fossil records show that sea lilies and feather stars are the most ancient of the echinoderms and were abundant before other echinoderms evolved. They are different from other echinoderms in that they are sessile for part of their lives. As shown in **Figure 11,** sea lilies have a flower-shaped body at the top of a long stalk, while the long-branched arms of feather stars radiate upward from a central area. Though they might stay in one place for a long time, sea lilies and feather stars can detach themselves and move elsewhere. Both sea lilies and feather stars capture food by extending their tube feet and arms into the water, where they catch suspended organic materials.

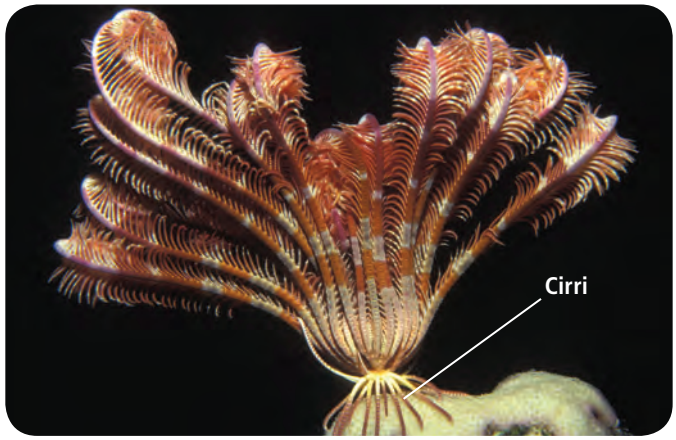
Reading Check **Describe** how feather stars and sea lilies are similar.

Figure 11 This fossil illustrates how a sea lily's body is flower-shaped at the tip of a long stalk. The feather star attaches to the sea floor with its cirri while its arms extend from a central point.

Infer ***how the arms of feather stars are adapted to a lifestyle that includes little movement.***



Sea lily



Feather star

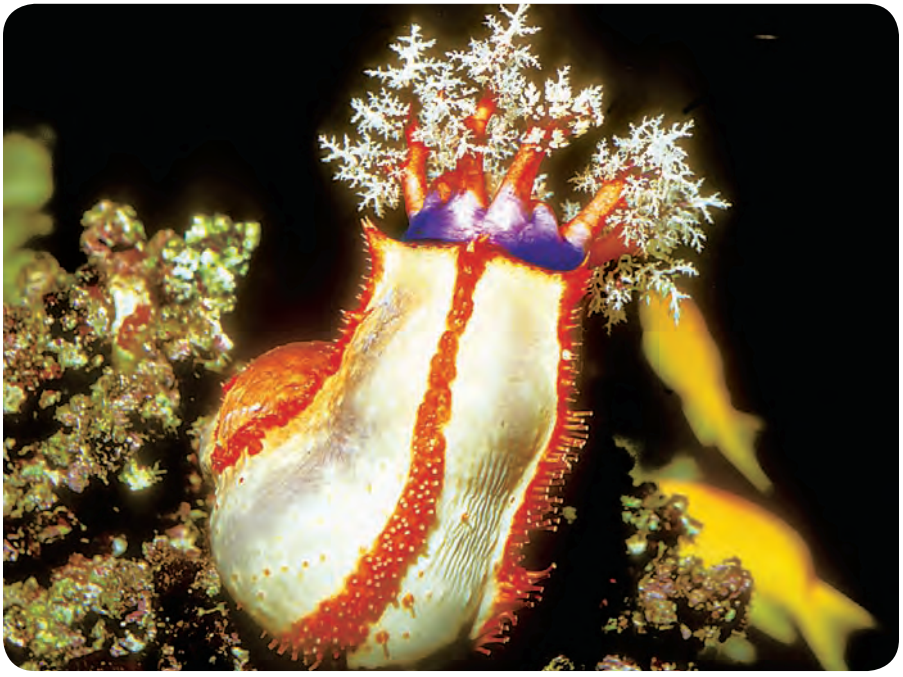
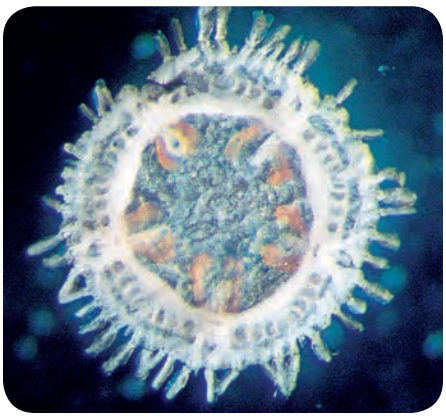


Figure 12 Some of a sea cucumber's tube feet are modified to form tentacles around its mouth. Look closely to see how these tentacles are used to collect food.
Identify *what substance coats the tentacles and helps trap food particles.*

CAREERS IN BIOLOGY

Marine Biologist Scientists in this field study plants and animals, such as echinoderms, that live in the ocean. They also study how pollution affects the marine environment.

Figure 13 Sea daisies are tiny disc-shaped echinoderms.



Sea cucumbers Sea cucumbers do not look like other echinoderms. Some might say they do not even look like animals. Can you guess why they are called sea cucumbers? They look like cartoon cucumbers creeping over the ocean floor. Their elongated bodies move sluggishly by means of tube feet assisted by contractions in their muscular body wall. Their calcium carbonate plates are reduced in size and do not connect as they do in other echinoderms, so their outer bodies generally appear leathery. Some of their tube feet are modified to form tentacles that extend from around their mouths to trap suspended food particles, as shown in **Figure 12.** The tentacles are covered with mucus, which increases their ability to trap food. Once food has been trapped on a tentacle, it is drawn into the mouth where the food is sucked off. This process is similar to licking your finger after putting it in a bowl of pudding.

Sea cucumbers are the only echinoderms to have respiratory organs in the form of respiratory trees. These many-branched tubes pump in seawater through the anus for oxygen extraction. The respiratory tree also functions in excretion by removing cellular wastes.

When a sea cucumber is threatened, it can cast out some of its internal organs through its anus. A potential predator might be confused by this action and move on. The sea cucumber can regenerate its lost parts. Even though the sea cucumber's adaptations might seem odd, it is important to remember that this animal maintains homeostasis with adaptations that fit its way of life in its particular habitat.

Sea daisies Discovered in 1986 off the coast of New Zealand, sea daisies have been difficult to classify and study, because so few have been found. They are less than 1 cm in diameter and are disc-shaped with no arms. Their tube feet are located around the edge of the disc. **Figure 13** shows that they have five-part radial symmetry, as do other echinoderms. Notice the daisy pattern of petals, or tube feet, around the edges of the disc.

Reading Check **Classify** What characteristics place sea daisies in the phylum Echinodermata?

Ecology of Echinoderms

Sea cucumbers and sea urchins are sources of food for people in some countries. The muscles of certain sea cucumbers are eaten as sushi, and dried sea cucumbers are added to flavor soups, vegetables, and meat. The egg masses of sea urchins are eaten raw or slightly cooked.

Commensal relationships exist between some echinoderms and other marine animals. Recall that commensalism is a relationship in which one organism benefits and the other organism is neither helped nor harmed. For example, some species of brittle stars live inside sponges. The brittle star leaves the protective interior of the sponge and feeds on materials that have settled on the sponge.

Echinoderm benefits Marine ecosystems also depend on some echinoderms. When populations of echinoderms decline, a change in the ecosystem is often noted. For example, a sea urchin species that lives in the Caribbean and the Florida keys declined in numbers by more than 95 percent in 1983 due to disease. After this, algae increased greatly on the coral reefs and virtually destroyed the reefs in many areas. Sea urchins and sea cucumbers are bioturbators—organisms that stir up sediment on the ocean floor. This action is important to the entire marine ecosystem, as it makes nutrients in the seafloor available to other organisms.

Echinoderm harm Some echinoderms can harm marine ecosystems. The crown-of-thorns sea star shown in the photo at the beginning of this chapter feeds on coral polyps. When these sea stars increase in numbers, coral reefs are destroyed. Although the causes of the population explosions of these sea stars continue to be debated, the numbers seem to decline on their own. At a later time, they might increase again with no apparent explanation. Sea urchins are a favorite food of sea otters, as shown in **Figure 14.** The number of sea otters in California has declined in recent years, leading to an increase in the number of sea urchins. The sea urchins are eating the kelp forests, destroying the habitat of fish, snails, and crabs.



Figure 14 Without enough sea otters to keep the sea urchin population under control, sea urchins will continue to increase in number, threatening the kelp forests on which they feed.

Section 1 Assessment

Section Summary

- Echinoderms are deuterostomes.
- Adult members of phylum Echinodermata have four major common characteristics.
- Larval echinoderms have bilateral symmetry, which is considered an evolutionary link to chordates.
- Echinoderms exhibit great diversity in feeding and digestion, respiration, circulation, and excretion.
- There are six major classes of living echinoderms.

Understand Main Ideas

1. MAIN Idea Identify the four main features that distinguish adult echinoderms.
2. **Explain** how a water-vascular system works.
3. **Sketch** line drawings that represent each of the six classes of echinoderms.
4. **Suggest** how feeding and movement are related to each other in echinoderms.

Think Critically

5. **Hypothesize** A certain species of red-and-white-striped shrimp is often found on a species of colorful brittle stars. Form a hypothesis about the relationship between the shrimp and the brittle stars.

MATH in Biology

6. If it takes a force of 20 N to pull apart a bivalve's shells, how many tube feet will it take to pull apart a bivalve if each tube foot has a pull of 0.25 N?

Assessment Online Quiz

Section 2

Reading Preview

Essential Questions

- What are the features of invertebrate chordates that place them in the phylum Chordata?
- What are the features of invertebrate chordates that place them with invertebrates?
- What are the similarities between the adaptations of lancelets and sea squirts?

Review Vocabulary

deuterostome: an animal whose mouth develops from cells other than those at the opening of the gastrula

New Vocabulary

chordate
invertebrate chordate
notochord
postanal tail
dorsal tubular nerve cord
pharyngeal pouch

Multilingual eGlossary

Invertebrate Chordates

MAIN Idea **Invertebrate chordates have features linking them to vertebrate chordates.**

Real-World Reading Link Worms, snails, bees, fishes, birds, and dogs are all animals because they share common characteristics. Think about the features these animals have in common and the features that make them different from each other. The animals that share the most features are related more closely than the animals that share only a few features.

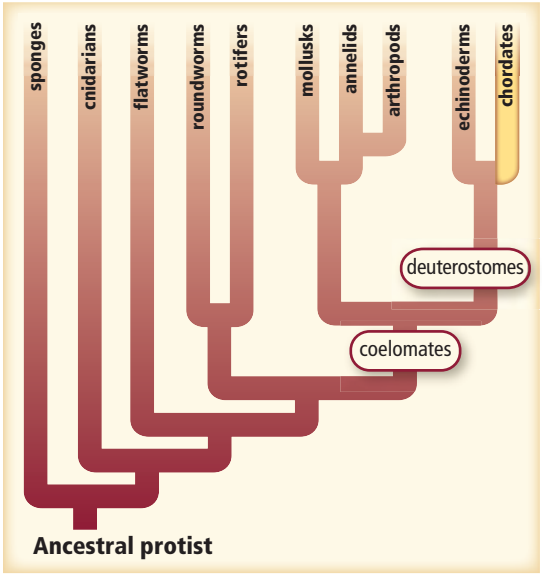
Invertebrate Chordate Features

Look at **Figure 15,** the evolutionary tree of animal phylogeny. Chordates are deuterostomes like echinoderms but they have additional features that echinoderms do not have. Invertebrate chordates include lancelets and tunicates.

Fossil evidence suggests animals such as the lancelet, shown in **Figure 15,** separated from the echinoderms during the Cambrian period. This group of animals is known as the invertebrate chordates. It has become a diverse group over the last 500 million years. The lancelet is also called an amphioxus (am fee AHK sus).

The lancelet is a small eel-like animal that spends most of its life buried in the sand filtering the water for food. They are tiny, headless creatures with translucent, fish-shaped bodies. Fossil and molecular data show that the lancelet is one of the closest living relatives of vertebrates. In 2007, genetic studies showed that tunicates, shown in **Figure 15,** are the closest invertebrate relative to vertebrates. You are more closely related to the lancelet and tunicate than you are to any other invertebrate—yet related very distantly compared to other vertebrates.

Figure 15 Like echinoderms, invertebrate chordates, such as lancelets and tunicates, show deuterostome development.





Lancelet



Tunicate

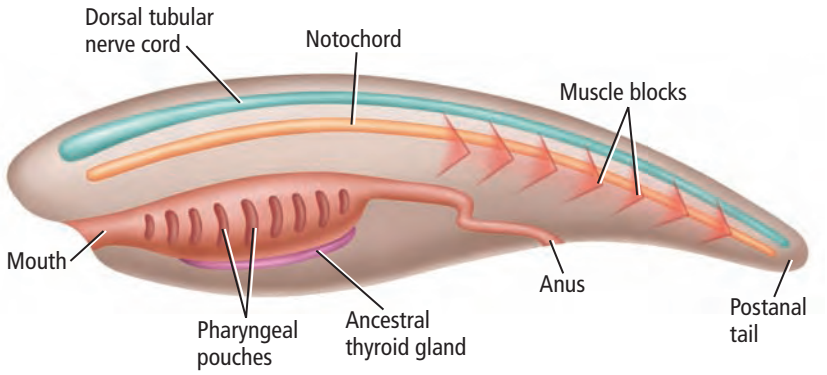


Figure 16 Chordates have a dorsal tubular nerve cord, a notochord, pharyngeal pouches, a postanal tail, and, possibly, some form of a thyroid gland.
Infer *which of these features you had when you were an embryo.*

Chordates are animals belonging to the phylum Chordata (kor DAH tuh) that have four distinctive features at some point in their development—a dorsal tubular nerve cord, a notochord, pharyngeal pouches, and a postanal tail. Recent evidence suggests that all chordates also might have some form of a thyroid gland. In addition, they have a coelom and segmentation. Study **Figure 16** to see the main features of chordates. Recall that vertebrates are animals with backbones. Most chordates are vertebrates. **Invertebrate chordates,** which belong to two of the subphyla of chordates, Cephalochordata and Urochordata, also have a dorsal tubular nerve cord, a notochord, pharyngeal pouches, a postanal tail, and, possibly, an ancestral thyroid gland. However, they have no backbone.

Notochord

The **notochord** (NOH tuh kord) is a flexible, rodlike structure that extends the length of the body. It is located just below the dorsal tubular nerve cord. In most vertebrates, the notochord eventually is replaced by bone or cartilage. In invertebrate chordates, the notochord remains. The flexibility of the notochord enables the body to bend, rather than shorten, during contractions of the muscle segments. An animal with a notochord can make side-to-side movements of the body and tail, the first time in the course of evolution that fishlike swimming is made possible.

Postanal tail

A free-swimming animal moves efficiently by using a postanal tail. A **postanal tail** is a structure used primarily for locomotion and is located behind the digestive system and anus. In most chordates, the postanal tail extends beyond the anus. Tails in nonchordates have parts of the digestive system inside and the anus is located at the end of the tail. The postanal tail with its muscle segments can propel an animal with more powerful movements than the body structure of invertebrates without a postanal tail.

Dorsal tubular nerve cord

In nonchordates, the nerve cords are ventral to, or below, the digestive system and are solid. Chordates have a **dorsal tubular nerve cord** that is located dorsal to, or above, the digestive organs and is a tube shape. The anterior end of this cord becomes the brain and the posterior end becomes the spinal cord during development of most chordates.

Reading Check **Analyze** how a notochord is important to invertebrate chordates.

VOCABULARY
WORD ORIGIN
Notochord
noto- prefix; from Greek, meaning *back.*
-chord from Greek, meaning *cord* or *string*

FOLDABLES®
Incorporate information from this section into your Foldable.

Study Tip

Cooperation Form a group with four other students. Each group member should pick one of the five boldfaced headings under the heading *Invertebrate Chordate Features.* Each group member should read the selected section and then teach the rest of the group the material presented in that section of text.

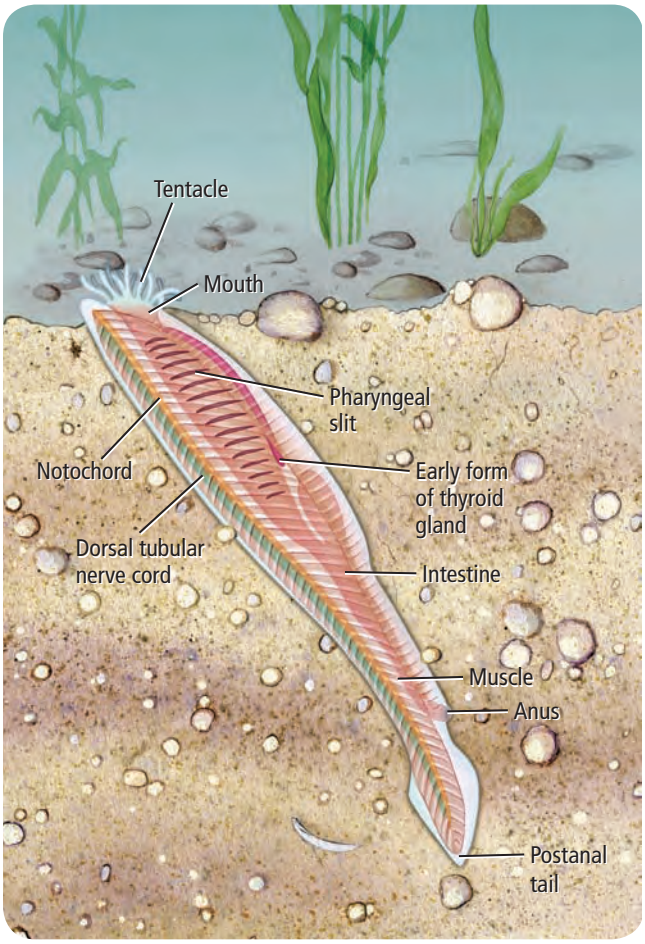


Figure 17 The lancelet is an invertebrate chordate that has the main features of chordates.
Infer ***how the short tentacles surrounding the lancelet's mouth might function.***

Pharyngeal pouches In all embryos, paired structures called **pharyngeal pouches** connect the muscular tube that links the mouth cavity and the esophagus. In aquatic chordates, the pouches contain slits that lead to the outside. These structures were used first for filter feeding and later evolved into gills for gas exchange in water. In terrestrial chordates, the pharyngeal pouches do not contain slits and develop into other structures, such as the tonsils and the thymus gland. Pharyngeal pouches are thought to be evidence of the aquatic ancestry of all vertebrates.

Ancestral thyroid gland The thyroid gland is a structure that regulates metabolism, growth, and development. An early form of a thyroid gland had its origins in cells of early chordates that secreted mucus as an aid in filter feeding. Invertebrate chordates have an endostyle—cells in this same area that secrete proteins similar to those secreted by the thyroid gland. Only vertebrate chordates have a thyroid gland.

Connection to Health Iodine is concentrated in the endostyle and plays an important role in thyroid gland function. It is essential for the production of thyroid hormones. In the United States, iodine is added to salt to prevent iodine deficiency. Other sources of iodine include fish, dairy products, and vegetables grown in iodine-rich soil.

Reading Check **Explain** why an endostyle is considered an early form of a thyroid gland.

Diversity of Invertebrate Chordates

Like echinoderms, all invertebrate chordates are marine animals. There are about 23 species of lancelets belonging to subphylum Cephalochordata. Tunicates, in subphylum Urochordata, consist of about 1250 species.

Lancelets Recall the amphioxus at the beginning of this section. Most lancelets belong to the genus *Branchiostoma* (formerly *Amphioxus).* They are small, fishlike animals without scales. As shown in **Figure 17,** lancelets burrow their bodies into the sand in shallow seas.

Lancelets lack color in their skin, which is only one cell layer deep, enabling an observer to view some body functions and structures. Water flowing through the body can be observed as a lancelet filter feeds. To get food, water enters the mouth of the lancelet and passes through pharyngeal gill slits. Food is trapped and passed on to a stomachlike structure to be digested. Water exits through the gill slits.

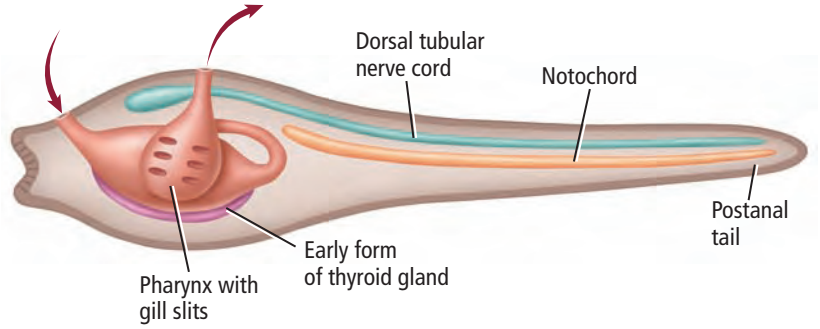


Figure 18 Larval tunicates look like tadpoles and have all of the chordate features. The arrows indicate where water flows into and out of the body.

Just as filter feeding can be observed in the lancelet, its muscles can also be seen. Observe the internal structures of a lancelet in **Figure 17.** The arrangement of segmented muscle blocks is similar to that in vertebrates, enabling lancelets to swim with a fishlike motion. Unlike vertebrates, they have no heads or sensory structures other than light receptors and small sensory tentacles near the mouth. The nervous system consists of main branching nerves and a simple brain at the anterior end of the animal. Blood passes through the body by the action of pumping blood vessels, as there is no true heart. Lancelets have separate sexes, and fertilization is external.

Tunicates Often called sea squirts, tunicates (TEW nuh kayts) are named for the thick outer covering, called a tunic, that covers their small, saclike bodies. Most tunicates live in shallow water; some live in masses on the ocean floor. In general, tunicates are sessile, and only in the larval stages do they show typical chordate features. Locate the notochord, postanal tail, dorsal tubular nerve cord, pharyngeal pouches, and ancestral thyroid gland on the tunicate larva in **Figure 18.**

Water is drawn into the saclike body of an adult tunicate through the incurrent siphon, as shown in **Figure 19,** by the action of beating cilia. Food particles are trapped in a mucous net and moved into the stomach where digestion takes place. In the meantime, water leaves the body, first through gill slits in the pharynx and then out through the excurrent siphon.

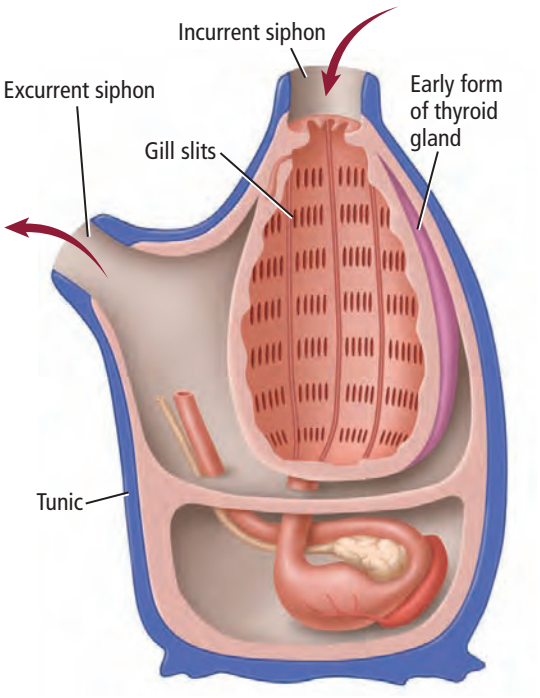
Circulation in the body of the tunicate is performed by a heart and blood vessels that deliver nutrients and oxygen to body organs. The nervous system consists of a main nerve complex and branching neurons. Tunicates are hermaphrodites—they produce both eggs and sperm—with external fertilization.

Why are tunicates called sea squirts? When they are disturbed, they eject a stream of water with force through the excurrent siphon, possibly distracting a potential predator.

Reading Check **Compare** tunicates and lancelets.

Figure 19 Adult tunicates look like sacs. The only chordate features that remain in the adult are pharyngeal gill slits and the thyroid gland. The arrows indicate water flow in and out of the body.
Compare ***other invertebrates that you have studied that are filter feeders.***

Concepts in Motion **Animation**



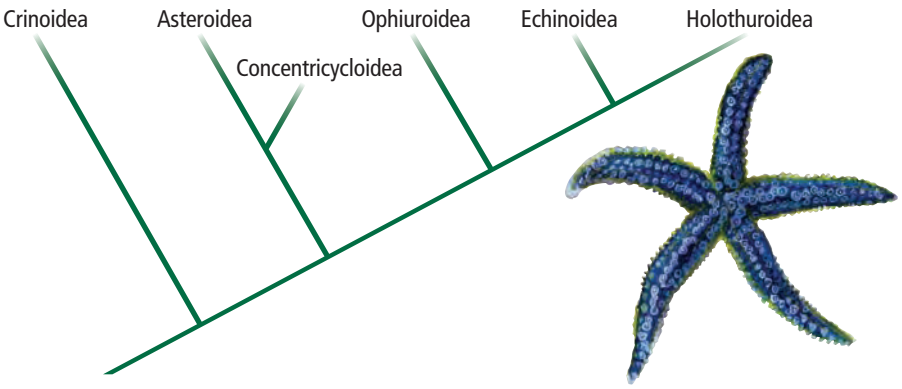


Figure 20 This cladogram shows the phylogeny of echinoderms.
Interpret *which is the most recent class of echinoderms to evolve.*

CAREERS IN BIOLOGY

Evolutionary Biologist Scientists in this field study how organisms have changed and diversified over time. Many evolutionary biologists have specialties that they rely on in the field and in labs.

Evolution of Echinoderms and Invertebrate Chordates

Biologists are studying fossil and molecular evidence to learn how echinoderms and invertebrate chordates are related to the vertebrates that evolved later.

Phylogeny of echinoderms The fossil record of echinoderms extends back to the Cambrian period. Scientists think that they evolved from ancestors with bilateral symmetry because echinoderms have bilaterally symmetrical larvae. Their radial symmetry develops later in the adult stage. Many biologists think that ancient echinoderms were sessile and attached to the ocean floor by a long stalk, just as the sea lily does today.

Echinoderms also undergo deuterostome development. Recall that this type of development links them phylogenetically to chordates, which also have deuterostome development. The cladogram in **Figure 20** shows one interpretation of the evolution of echinoderms.

DATA ANALYSIS LAB 1

Based on Real Data*

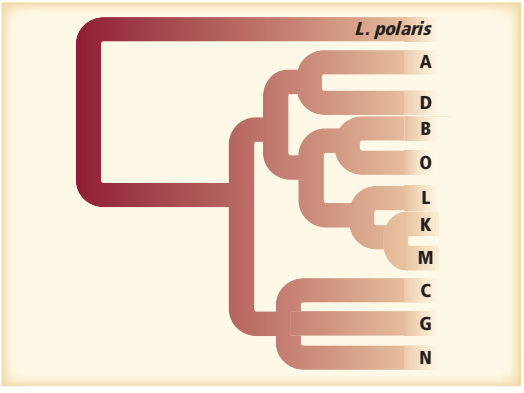
Interpret Scientific Illustrations

How does an evolutionary tree show relationships among sea stars? This evolutionary tree is a representation of various species of sea stars and their phylogenetic history based on molecular data. Each letter represents a specific sea star species.

Think Critically

1. **Identify** which sea star is most closely related to sea star A.
2. **Decide** which is the oldest sea star.
3. **Analyze** which group of sea stars has the most diversity—C,G,N or L,K,M. How did you decide?

Data and Observations



*Data obtained from: Hrincevich, A.W., et al. 2000. Phylogenetic analysis of molecular lineages in a species-rich subgenus of sea stars (*Leptasterias* subgenus *Hexasterias*). *American Zoologist* 40: 365-374.

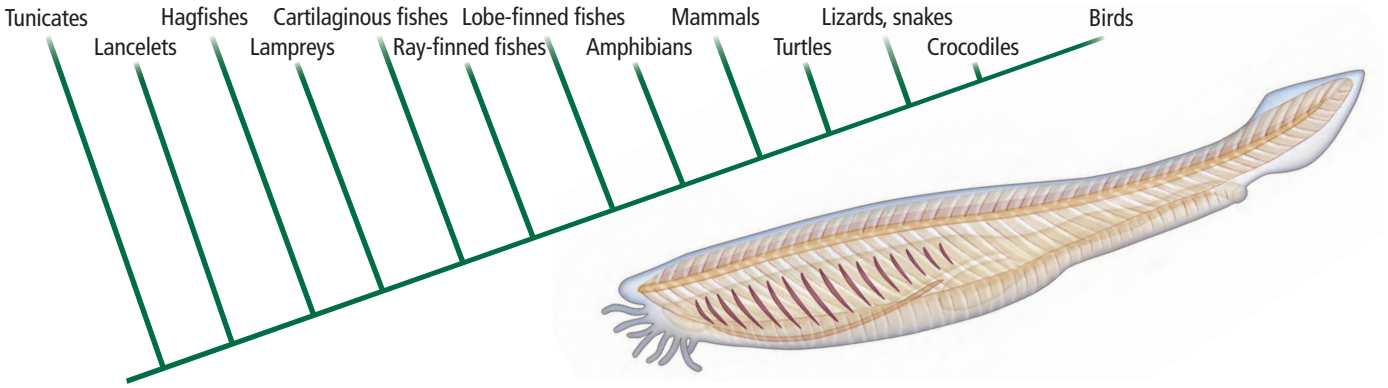


Figure 21 This cladogram shows a possible phylogeny of invertebrate chordates and other chordates that later evolved.

Phylogeny of invertebrate chordates How could sleek, burrowing, fishlike lancelets be close relatives of saclike, sessile sea squirts? They are related because of their dorsal tubular nerve cords, notochords, pharyngeal gill slits, and postanal tails, even if sea squirts have all these features only in their larvae. Beyond this answer, scientists debate about the evolution of these animals and raise still unanswered questions. For example, from which invertebrate chordate did the fishlike tadpole larvae arise? What was the original form of that first fishlike animal?

One thing is certain: the notochord, that flexible tough rod, provided support for the animal, and it also provided a place for muscles to attach. With this arrangement, chordates could swing their backs from side to side and swim through the water, a key development in the evolution of chordates. This advance also led to the first large animals. Examine the cladogram in **Figure 21** to see one interpretation of how chordates are related.

Section 2 Assessment

Section Summary

- Chordates have four main distinguishing features.
- Invertebrate chordates have all of the main features of chordates. They lack a backbone, however, which distinguishes them from vertebrate chordates.
- The notochord is an adaptation which allows invertebrate animals to remain flexible.
- Lancelets are fish-shaped invertebrate chordates that, as adults, have all the main features of chordates.
- Tunicates, or sea squirts, are sac-shaped invertebrate chordates that have chordate features as larvae.

Understand Main Ideas

1. MAIN Idea **Summarize** the main features of invertebrate chordates that show their close relationship to vertebrate chordates.
2. **Draw** a graphic organizer showing the evolution of pharyngeal pouches.
3. **Create** models of a lancelet and a sea squirt from clay or salt dough. Identify features that place these animals in the phylum Chordata.
4. **Compare** the adaptations of sea squirts with those of lancelets that enable them to live in their environments.

Think Critically

5. **Design** an experiment to determine if lancelets prefer a light environment or a dark environment.
6. **Determine** which subphylum of chordates evolved next after the cephalochordates. Use **Figure 21**.

WRITING in Biology

7. Write a paragraph describing how sponges and tunicates are alike. Write another paragraph describing how they are different from each other.

CUTTING-EDGE BIOLOGY

Echinoderms Aid Medical Research

How did the comic book character the Incredible Hulk increase his body size without ripping his body to pieces?

Believe it or not, producers consulted an expert on echinoderms before creating a film about this character because they wondered if any living creature could perform such feats. Sea cucumbers, specifically, can stretch and then shrink back to their normal size, much like the Incredible Hulk does in the film.

Connective tissue When Greg Szulgit was a graduate student in biology, he discovered the amazing power of sea cucumbers to increase their body size and then shrink back to their normal size. How do sea cucumbers change their body size? It is due to their connective tissue, which is the tissue that connects, supports, and surrounds other tissues and organs in the body.

A sea cucumber's connective tissue is similar to a human's connective tissue. Connective tissue fibers contain a protein called collagen. In humans, collagen is a fixed part of the tissue. Szulgit and other researchers found that the collagen in the connective tissue of echinoderms is not fixed, but instead slides back and forth. When the collagen particles in the endoskeleton are sliding past each other, a sea cucumber's body is soft and flexible. A sea cucumber's cells can release a substance that locks the collagen and stops it from sliding. This stiffens its endoskeleton, making it immobile.

Connective-tissue disorders Szulgit studies the sea cucumber's body-stretching abilities with the hope of someday being able to treat connective-tissue disorders in humans. These disorders include osteogenesis imperfecta, Marfan syndrome, and Ehlers-Danlos syndrome.



Because the collagen in a sea cucumber's connective tissue is not fixed, its body can change from the consistency of liquid gelatin to a rigid structure and back again in seconds.

In osteogenesis imperfecta, the body doesn't produce enough collagen or it produces poor quality collagen, leading to fragile bones that break easily. People with Marfan syndrome have connective tissue that is not as stiff as it should be, causing skeletal abnormalities and weakened blood vessels. People with Ehlers-Danlos syndrome have abnormally fragile connective tissue, resulting in joint problems and weakened internal organs.

By studying the connective tissue in echinoderms such as the sea cucumber, researchers are moving closer to successfully treating debilitating illnesses that prevent people from having freedom of movement in their joints due to connective tissue diseases.

WRITING in Biology

Journal Create a biologist's research journal describing his or her work with an echinoderm. The journal should include thorough descriptions, charts, graphs, and sketches of echinoderms.

WebQuest

BIOLAB

INTERNET: HOW DO ECHINODERMS SURVIVE WITHOUT A HEAD, EYES, OR A BRAIN?

Background: **Echinoderms have evolved unlike any other animals on Earth. Lacking eyes and a brain, they also have no heart, and pump seawater through their bodies rather than blood. Some echinoderms can change their endoskeletons from rock hard to nearly liquid within seconds. Some can break off an arm to distract a predator. Sound unusual? Not for echinoderms.**

Question: *How do echinoderms survive in the competitive marine environment?*



These sea stars, basket stars, and sea urchins are from the Gulf of Maine.

Materials

Internet access
echinoderm reference book
field journal

Procedure

1. Read and complete the lab safety form.
2. Design and construct a data table for recording the species; physical characteristics; food sources/strategies for obtaining food; predators; defense strategies; reproduction and development; and other interesting facts about six animals.
3. Choose one species from each of the six major classes of echinoderms to study. List the species in your data table.
4. Research the species you chose and fill in information in your data table. Observe the echinoderms in their natural habitat by visiting a local zoo or aquarium. If you cannot observe the animals in their natural habitats, obtain information about the echinoderms from a reference book or the Internet.
5. Record your observations in your field journal. Transfer the information to your data table.

Analyze and Conclude

1. **Describe** some basic physical characteristics shared by echinoderms.
2. **Compare** sexual and asexual reproductive strategies used by echinoderm species.
3. **Think Critically** Echinoderm larvae and mature echinoderms differ in several important ways. Describe the differences and infer the advantages they provide.
4. **Interpret Data** What are the major food sources of the echinoderms you studied?
5. **Draw Conclusions** Are echinoderms well-adapted to survive in the marine environment? Justify your answer.
6. **Error Analysis** Describe advantages and disadvantages of obtaining information about echinoderms from the Internet.

WRITING in Biology

Resource Book Use the data you gathered to create a fact sheet including photos and interesting information about each echinoderm you studied. Combine your fact sheets with those developed by other students to create an echinoderm resource book for your school's media center.

Chapter 27 Study Guide

THEME FOCUS Diversity Adaptations such as tube feet enable echinoderms and invertebrate chordates to live in their unique habitats.

BIG Idea **Echinoderms and invertebrate chordates have features that connect them to the chordates that evolved after them.**

Section 1 Echinoderm Characteristics

pedicellaria (p. 793)
water-vascular system (p. 795)
madreporite (p. 795)
tube foot (p. 795)
ampulla (p. 795)

MAIN Idea **Echinoderms are marine animals with spiny endoskeletons, water-vascular systems, and tube feet; they have radial symmetry as adults.**

- Echinoderms are deuterostomes.
- Adult members of the phylum Echinodermata have four major common characteristics.
- Larval echinoderms have bilateral symmetry and are considered an evolutionary link to chordates.
- Echinoderms exhibit great diversity in feeding and digestion, respiration, circulation, and excretion.
- There are six major classes of living echinoderms.



Section 2 Invertebrate Chordates

chordate (p. 803)
invertebrate chordate (p. 803)
notochord (p. 803)
postanal tail (p. 803)
dorsal tubular nerve cord (p. 803)
pharyngeal pouches (p. 804)

MAIN Idea **Invertebrate chordates have features linking them to vertebrate chordates.**

- Chordates have four main distinguishing features.
- Invertebrate chordates have all of the main features of chordates. They lack a backbone, however, which distinguishes them from vertebrate chordates.
- The notochord is an adaptation which allows invertebrate animals to remain flexible.
- Lancelets are fish-shaped invertebrate chordates that, as adults, have all the main features of chordates.
- Tunicates, or sea squirts, are sac-shaped invertebrate chordates that have chordate features as larvae.



Review Vocabulary eGames

Chapter 27 Assessment

Section 1

Vocabulary Review

Distinguish between the terms in each of the following pairs.

1. tube foot, ampulla

2. madreporite, water-vascular system

Understand Main Ideas

3. Which is not an echinoderm?

A. 

C. 

B. 

D. 

A. A
B. B
C. C
D. D

4. Which echinoderm is sessile for part of its life?
A. sea cucumber
B. sea lily
C. brittle star
D. sea urchin

5. What three functions do tube feet perform?
A. reproduction, feeding, respiration
B. feeding, respiration, neural control
C. feeding, respiration, movement
D. development, reproduction, respiration

6. What is the function of the water-vascular system?
A. to remove wastes
B. to reproduce
C. for defense
D. for movement and to obtain food

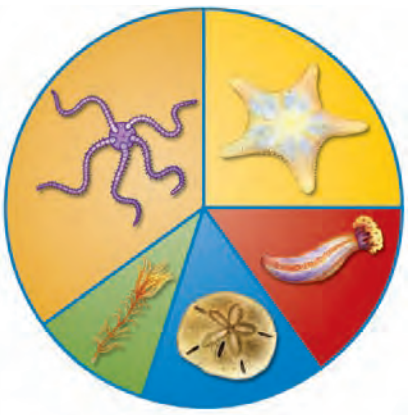
7. Which are involved in protecting an echinoderm?
A. endoskeleton, pedicellariae, spines
B. madreporite, tentacles, endoskeleton
C. water-vascular system, ampulla, pedicellariae
D. exoskeleton, pedicellariae, spines

8. What is the main difference between echinoderm larvae and adults?
A. Larvae are protostomes and adults are deuterostomes.
B. Larvae are deuterostomes and adults are protostomes.
C. Larvae have bilateral symmetry and adults have radial symmetry.
D. Larvae have radial symmetry and adults have bilateral symmetry.

9. Which group of echinoderms has respiratory trees with many branches?
A. sea cucumbers
B. sea stars
C. sea lilies and feather stars
D. sea urchins and sand dollars

Constructed Response

Use the diagram below to answer questions 10 and 11.



10. Short Answer Examine the circle graph and estimate the percentage of echinoderms that are sea cucumbers.

11. Open Ended Examine the circle graph and explain why class Concentricycloidea does not appear with the other classes of living echinoderms.

12. MAIN Idea Scientists have discovered a fossil that has the following characteristics: an endoskeleton similar to that of echinoderms, a tail-like structure with an anus at the end of the tail, a structure that might be a gill, and symmetry similar to echinoderms. How might scientists explain this animal in terms of echinoderm classification?

13. **Open Ended** Tidal animals suffer when water and air temperatures rise beyond the limits of tolerance of the animals. The temperature of sea stars remains about 18 degrees cooler than those of the surrounding mussels on a hot day. Make a hypothesis about why sea stars have a lower body temperature.

Think Critically

14. **THEME FOCUS Diversity** A marine environment is relatively stable. Formulate a hypothesis using examples to explain why echinoderms have so many unique adaptations.

15. **Hypothesize** Some sea urchins seem to have relatively long lifespans. Make a hypothesis about why they live so long.

Section 2

Vocabulary Review

Using the vocabulary terms from the Study Guide page, replace the underlined words with the correct term.

16. Animals that are chordates, but do not have backbones are the close relatives of chordates.

17. Located just below the nerve cord is a structure in chordates that enables invertebrate chordates to swim by moving their tails back and forth.

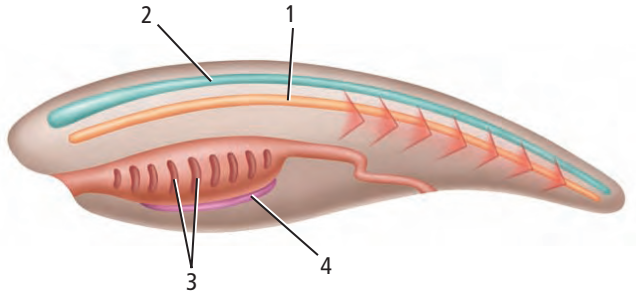
18. The connections between the muscular tube that links the mouth cavity and the esophagus develop slits and are used for filter feeding in some invertebrate chordates.

Understand Main Ideas

19. Chordates have which features at some time in their lives?
   - **A.** water-vascular system, notochord, pharyngeal pouches, postanal tail
   - **B.** tunic, pharyngeal pouches, dorsal tubular nerve cord, postanal tail
   - **C.** tube feet, notochord, pharyngeal pouches, postanal tail
   - **D.** dorsal tubular nerve cord, notochord, pharyngeal pouches, postanal tail

20. Which is the main function of a postanal tail?
   - **A.** circulation
   - **B.** digestion
   - **C.** flexibility
   - **D.** locomotion

Use the diagram below to answer questions 21 and 22.



21. Fishlike swimming is made possible by which labeled structure above?
   - **A.** 1
   - **B.** 2
   - **C.** 3
   - **D.** 4

22. Which structure develops into the brain and spinal cord in most chordates?
   - **A.** 1
   - **B.** 2
   - **C.** 3
   - **D.** 4

23. Which describes adult sea squirts?
   - **A.** They are bilaterally symmetrical.
   - **B.** They have the same adult features as lancelets.
   - **C.** As adults, they have only two chordate features.
   - **D.** They are actively swimming predators.

24. In invertebrate chordates, what does the endostyle secrete?
   - **A.** proteins similar to thyroid hormone
   - **B.** mucus
   - **C.** the notochord
   - **D.** pharyngeal pouches

25. The phylogeny of echinoderms indicates that echinoderms are related to chordates because they both have which feature?
   - **A.** pharyngeal pouches
   - **B.** deuterostome development
   - **C.** protostome development
   - **D.** pseudocoeloms

Assessment Online Test Practice

26. Which structure might be an early form of the thyroid gland?
- **A.** dorsal tubular nerve cord
- **B.** endostyle
- **C.** notochord
- **D.** pharyngeal pouches

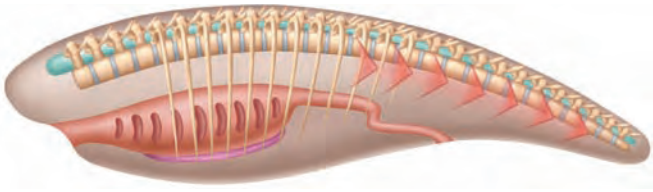
27. Which chordate feature enabled large animals to develop?
- **A.** dorsal tubular nerve cord
- **B.** notochord
- **C.** pharyngeal pouches
- **D.** postanal tail

Constructed Response

28. Open Ended Infer why there are no freshwater invertebrate chordates.

29. Open Ended What would happen if all lancelets disappeared?

Use the diagram below to answer questions 30 and 31.



30. Short Answer Examine the diagram and explain why this animal could not be an invertebrate chordate.

31. MAIN Idea What features does this animal share with invertebrate chordates?

Think Critically

32. Analyze How do the larvae of organisms help scientists classify and determine the phylogeny of animals?

33. Use the Internet Make a visual report of the newest information, both molecular and fossil evidence, gathered by scientists on the origins of chordates.

Summative Assessment

34. BIG Idea Explain the evolutionary relationship between echinoderms, invertebrate chordates, and chordates. Provide specific examples from the chapter to support your statement.

35. WRITING in Biology Create a short descriptive story about a human who now has one of an echinoderm's adaptations. Include how this new adaptation would improve or worsen the character's life.

36. Sea cucumbers protect themselves by casting out their internal organs, but other echinoderms cannot. Hypothesize why this adaptation is found only in sea cucumbers.

37. Sketch a typical lancelet and label its main parts.

38. WRITING in Biology Create a poem that describes your favorite echinoderm. Make sure you point out the actual features of the echinoderm.

DBQ Document-Based Questions

Study the illustration of the progression of development of arms in a specific sea star.

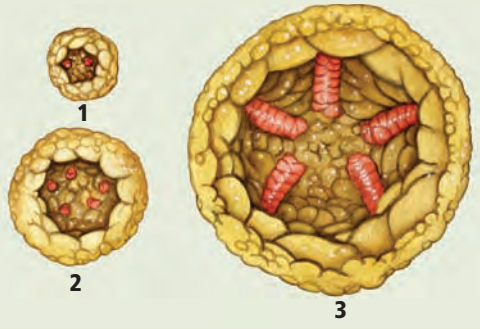


Diagram based on examples from: Sumrall, Colin D., 2005. Unpublished research on the growth stages of *Neoisorophusella lanei*. The University of Tennessee. http://web.eps.utk.edu/Faculty/sumrall/research2.htm

39. What kind of symmetry is shown in the diagram labeled 1?

40. Infer how additional arms might develop.

41. How does the number of arms in diagram 3 reflect the characteristics of all echinoderms?

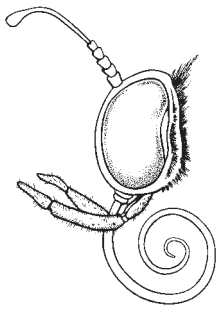
Standardized Test Practice

Cumulative

Multiple Choice

1. In which structure of a flowering plant do eggs develop?
- **A.** anther
- **B.** ovule
- **C.** seed
- **D.** stigma

Use the diagram below to answer question 2.



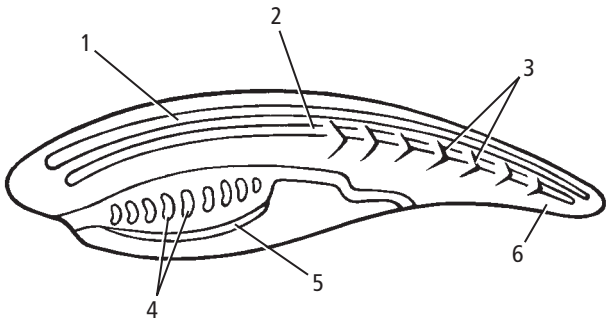
2. Arthropods have specialized mouthparts for feeding. For which type of feeding method is this mouthpart specialized?
- **A.** getting nectar from flowers
- **B.** sponging liquids from a surface
- **C.** sucking blood from a host
- **D.** tearing and shredding leaves

3. Which statement about a group of invertebrates is correct?
- **A.** Cnidarians have collar cells.
- **B.** Flatworms have flame cells.
- **C.** Flatworms have nematocysts.
- **D.** Sponges have a nervous system.

4. Echinoderms have which characteristic that is an evolutionary connection to vertebrates?
- **A.** bilateral symmetry as adults
- **B.** free-swimming larvae
- **C.** deuterostome development
- **D.** radial symmetry as larvae

5. Which special adaptation would be essential for an insect that swims in water?
- **A.** compound eyes
- **B.** modified legs
- **C.** sticky foot pads
- **D.** sharp mouth parts

Use the diagram below to answer questions 6 and 7.



6. Which structure is replaced by bone or cartilage in vertebrate chordates?
- **A.** 1
- **B.** 2
- **C.** 4
- **D.** 5

7. Which structure is a bundle of nerves protected by fluid?
- **A.** 1
- **B.** 3
- **C.** 5
- **D.** 6

8. What kind of body organization or body structure first appeared with the evolution of flatworms?
- **A.** bilateral symmetry
- **B.** coelomic cavity
- **C.** nervous system
- **D.** radial symmetry

9. Suppose a cell from the frond of a fern contains 24 chromosomes. How many chromosomes would you expect to find in the spores?
- **A.** 6
- **B.** 12
- **C.** 24
- **D.** 48

Short Answer

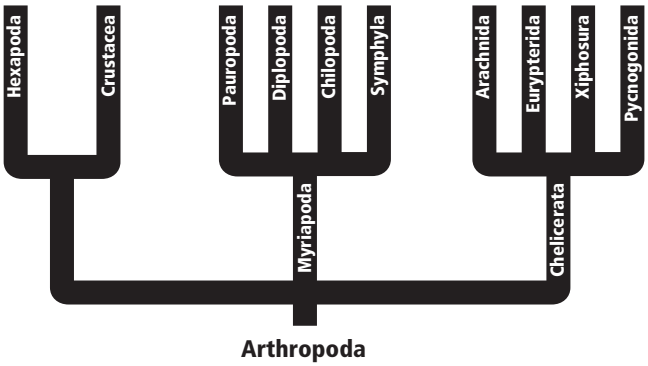
10. Use what you know about the body structure of a sponge to explain how it obtains food.

11. Sea stars are echinoderms that feed on oysters. Justify why oyster farmers should not cut up sea stars and toss the parts back into the water.

12. Evaluate the defense adaptations of the two groups of invertebrate chordates.

13. Contrast the main characteristics of echinoderms with the characteristics of the organisms in another phylum that you already know.

Use the diagram below to answer questions 14 and 15.



14. Write a hypothesis about why horseshoe crabs (in class Xiphosura) are more closely related to spiders than to regular crabs and lobsters.

15. Write a hypothesis about where trilobites would fit into this phylogenetic tree.

Extended Response

16. Explain how echinoderms and annelids are similar, and how they are different.

17. In animals, how are mitosis and meiosis different?

18. Evaluate the idea that it was not a large evolutionary jump for aquatic arthropods to move onto land.

19. Suppose that one crow in an area's population is hatched with longer claws on its feet than other crows in the same population. According to Darwin's theory of natural selection, under what circumstances would this trait become common in the area's crow population?

Essay Question

In the past, many horror movies have featured giant arthropods attacking major cities. These giant arthropods have included ants, grasshoppers, crabs, and spiders. Actually, the largest living insects are not very big. The longest insect, a walking stick, is about 40 cm long. Some marine arthropods grow larger. The largest arthropod is the Japanese spider crab that can grow up to 4 m wide. Some fossil marine arthropods are even larger. However, none of these are nearly as large as the size of the giant arthropod villains in the movies.

Using the information in the paragraph above, answer the following question in essay format.

20. Write an essay about why real-life arthropods cannot become as large as the giant arthropods shown in horror movies.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Review Section . . .	23.3	26.1	25.1	27.1	26.3	27.2	27.2	25.1	21.3	24.3	27.1	27.2	27.2	26.2	26.3	24.2	10.1	26.2	15.1	26.1