SB3. Students will derive the relationship between single-celled and multi-celled organisms and the increasing complexity of systems. **SB5.** Students will evaluate the role of natural selection in the development of the theory of evolution. **Also covers: SCSh2, SCSh4, SCSh9, SB4**

CHAPTER 26 Arthropods

Section 1
Arthropod Characteristics

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

Section 2
Arthropod Diversity

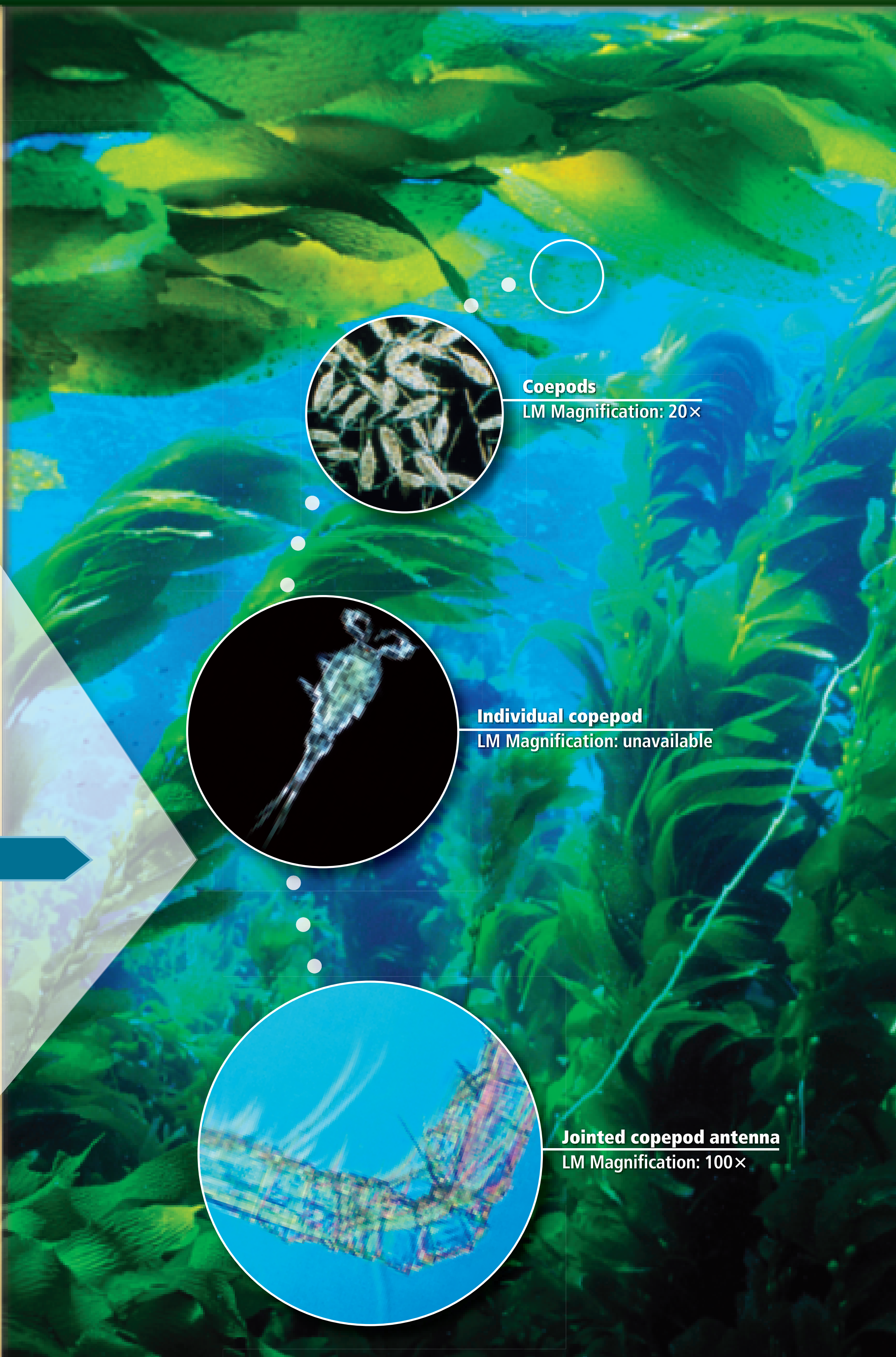
MAIN Idea Arthropods are classified based on the structure of their segments, types of appendages, and mouthparts.

Section 3
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.

BioFacts

- Copepods are tiny, but they exist in such large numbers that they are a major source of protein in the oceans.
- A single copepod might eat 200,000 microscopic diatoms in one day.
- Copepod eggs can lie dormant for months or years until conditions are right for hatching.



(bkgd)Ralph A. Clevenger/CORBIS, (t)Sinclair Stammers/Photo Researchers, (c)Laguna Design/Photo Researchers, (b)Clouds Hill Imaging Ltd./CORBIS

Start-Up Activities

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.

Procedure

1. Read and complete the lab safety form.
2. Create a data table to record your observations.
3. Observe the physical characteristics of live or preserved **specimens of a crayfish** and a **pill bug.** Record your observations in your data table. **Warning:** ***Treat live animals in a humane manner at all times.***
4. Observe the movements of the two animals, if possible, and record your observations.

Analysis

1. **Describe** the structures of the two animals that are similar.
2. **Identify** the defensive structure that the two animals have in common. How does this feature allow them to protect themselves from predators?

Biology Online

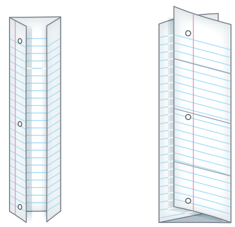
Visit biologygmh.com to:

- study the entire chapter online
- explore Concepts in Motion, the Interactive Table, Microscopy Links, Virtual Labs, and links to virtual dissections
- access Web links for more information, projects, and activities
- review content online with the Interactive Tutor and take Self-Check Quizzes

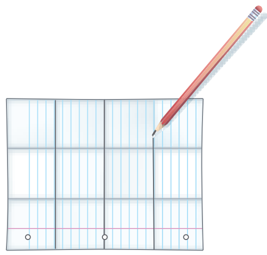
FOLDABLES™ Study Organizer

Arthropod Adaptations Make the following Foldable to help you understand and compare arthropod adaptations to terrestrial and aquatic habitats.

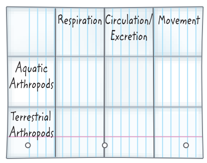
STEP 1 Fold one sheet of paper into thirds lengthwise. Then fold the paper into fourths widthwise.



STEP 2 Unfold, lay the paper lengthwise, and draw lines along the folds.



STEP 3 Add the following labels to your table as shown: *Respiration*, *Circulation/Excretion*, *Movement*, *Aquatic Arthropods*, and *Terrestrial Arthropods*.



FOLDABLES **Use this Foldable with Section 26.1.** As you read the section, record what you learn about the differences between terrestrial and aquatic arthropods.

Section 26.1

SB3b. Compare how structures and function vary between the six kingdoms (archaebacteria, eubacteria, protists, fungi, plants, and animals). SB5b. Explain the history of life in terms of biodiversity, ancestry, and the rates of evolution. **Also covers: SCSh2a–b, SCSh9c, SB5d**

Objectives

- **Evaluate** the importance of exoskeletons, jointed appendages, and segmentation to arthropods.
- **Compare** organ system adaptations in arthropods.
- **Differentiate** arthropod organs that enable them to maintain homeostasis.

Review Vocabulary

ganglion: a group of nerve cell bodies that coordinates incoming and outgoing messages

New Vocabulary

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

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.

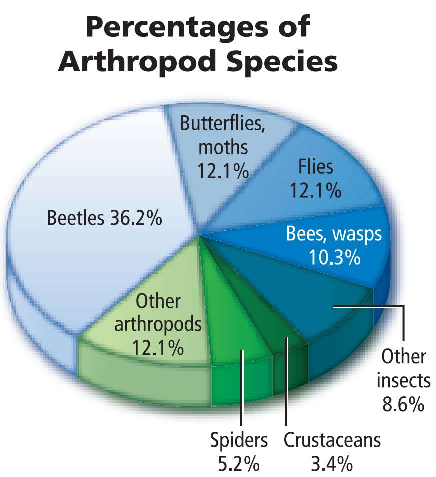
Arthropod Features

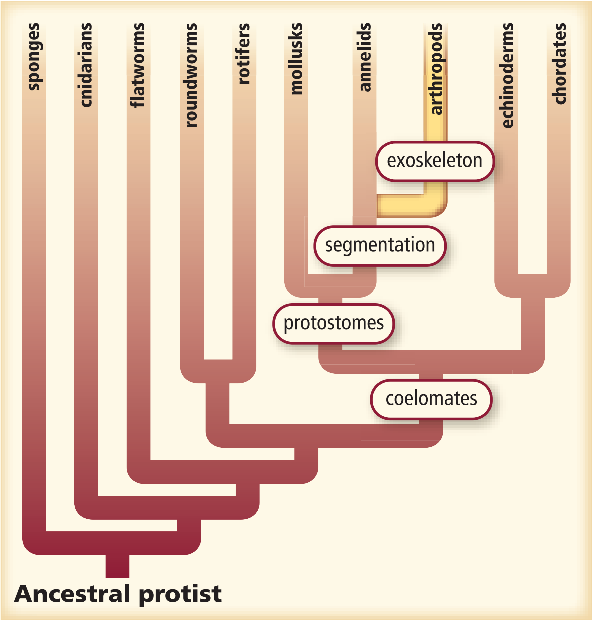
Copepods belong to phylum Arthropoda (ar THRAH puh duh). Between 70 and 85 percent of all named animal species are arthropods (AR thruh pahdz). As shown in **Figure 26.1,** the majority of arthropods are insects, which includes beetles, butterflies, moths, flies, bees, and wasps.

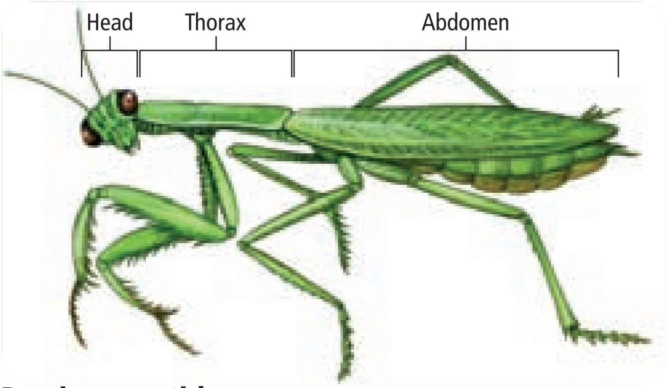
Find arthropods on the evolutionary tree shown in **Figure 26.1.** Follow the branches and you will see that, like annelids, arthropods are segmented invertebrates with bilateral symmetry, coelomate body cavities, and protostome development. Unlike annelids, arthropods have exoskeletons with jointed 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.

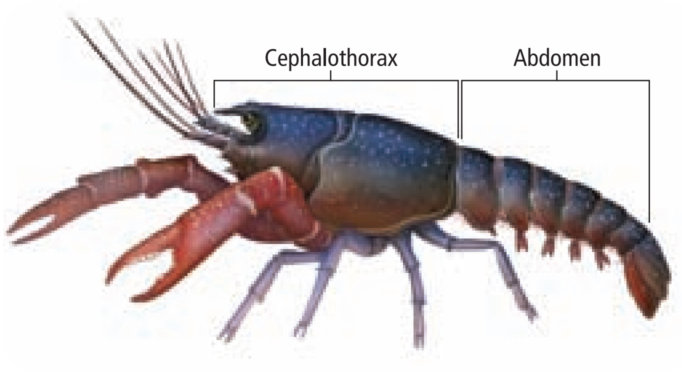
Figure 26.1 Most arthropods are insects, as shown by the blue segments on the graph. Arthropods are coelomates and show protostome development.
Interpret *Crustaceans and spiders make up what percentage of arthropods?*







Praying mantid



Crayfish

Figure 26.2 Some segments in arthropods are fused. The praying mantid shows fusion of segments into its head, thorax, and abdomen. The crayfish shows a different fusion of segments into its cephalothorax and abdomen.

Segmentation Like annelids, arthropods are segmented, which allows for efficient and complex movements. Notice in **Figure 26.2** that the praying mantid'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 the senses of 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 26.2,** have the thorax region fused with the head into a 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.

Exoskeleton In addition to segmented bodies, arthropods have hard exoskeletons on the outside of their bodies, similar to a lightweight suit of armor. Recall from Chapter 24 that 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. Recall from Chapter 20 that chitin is 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 as nails" 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 it bears the pull of tiny muscles; 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 bear the pull of the large muscles that the fly would not be able to move under the weight of the exoskeleton.

■ **Figure 26.3** Like a door hinge, the joint in this fly's leg can bend in only one direction.
Explain ***How do 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 26.3** 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.

LAUNCH Lab

Review **Based on what you've 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 26.4** 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 26.4** Arthropods must molt so that their bodies can continue to grow. This tarantula has just come out of its outgrown exoskeleton.

Mark Moffett/Minden Pictures

Figure 26.5 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 26.5.** 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 26.1.** 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 26.1

Compare Arthropod Mouthparts

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 you observed.
2. **Infer** the type of diet each arthropod might eat based upon your observations of their mouthparts.

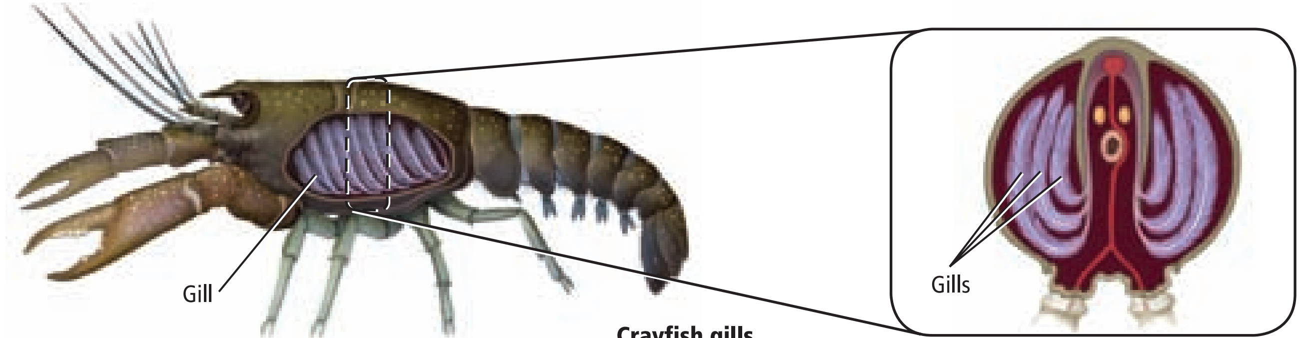
Visualizing Respiratory Structures

Figure 26.6

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

Gills

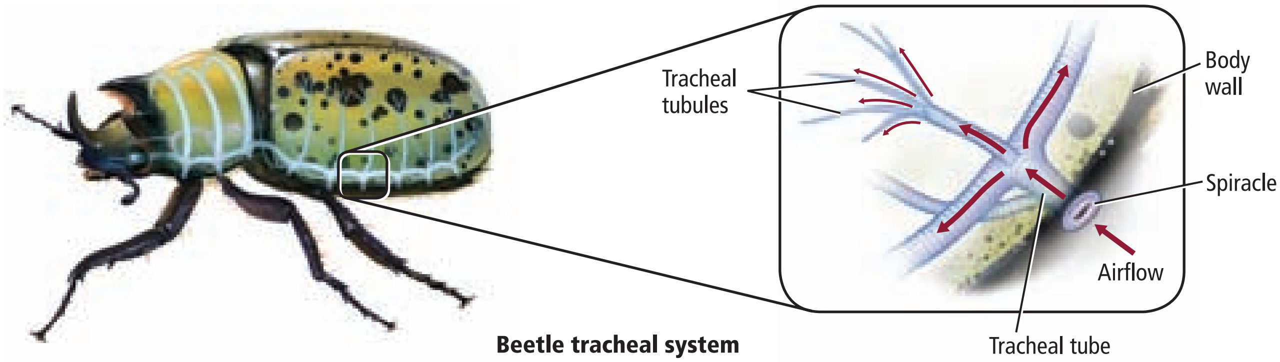
A crayfish lives in an aquatic environment and uses gills to obtain oxygen. The cross section illustrates how the gills are divided. This provides a large surface area in a small space for the exchange of gases.



Crayfish gills

Tracheal Tubes

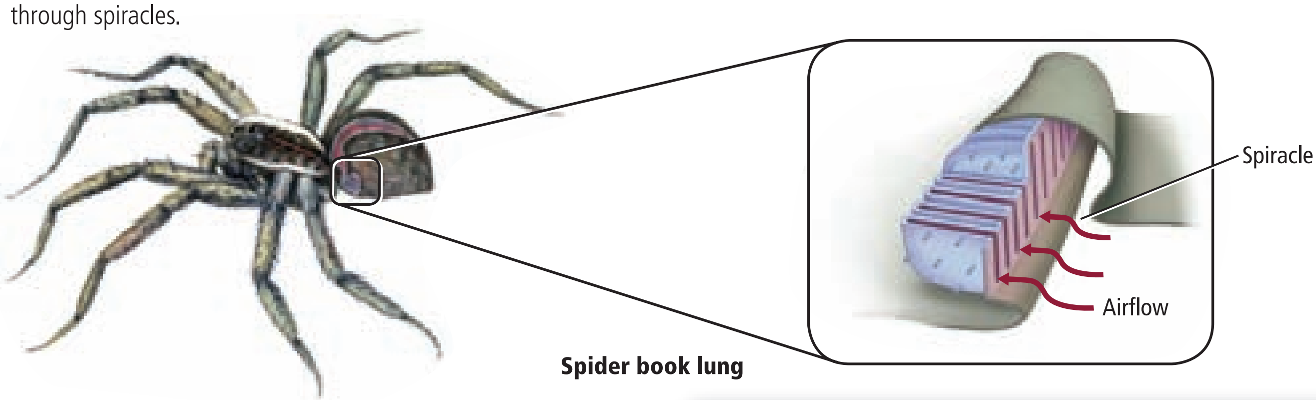
Insects such as this beetle have tracheal tubes that branch into smaller and smaller tubules to carry oxygen throughout the body. Air enters the respiratory system through spiracles, then travels from the tracheal tubes to tracheal tubules until it reaches muscle.



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 **Interactive Figure** To see an animation of arthropod respiratory structures, visit biologygmh.com. Biology Online

Respiration Arthropods obtain oxygen by using one of three structures—gills, tracheal tubes, or book lungs. Recall from Chapter 25 that 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 26.6,** 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,** shown in **Figure 26.6,** 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 26.6,** 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 26.7,** 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.

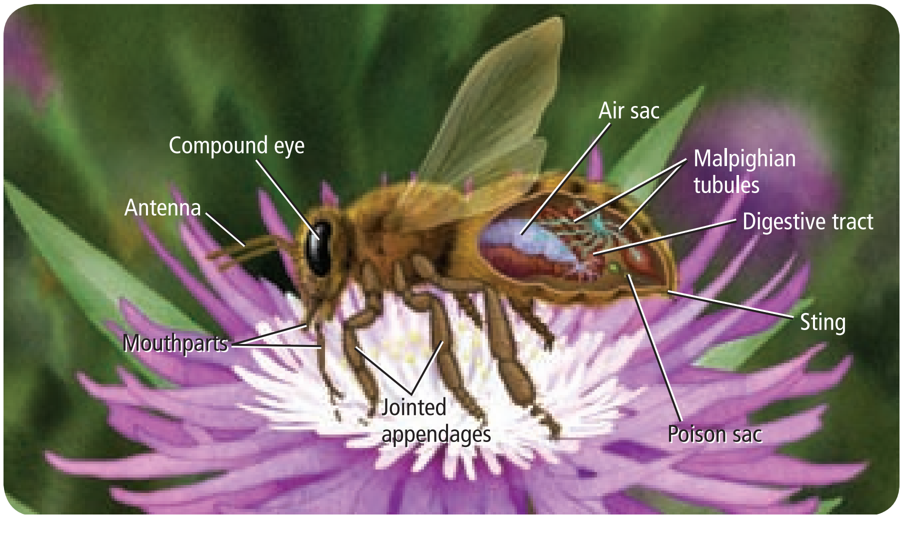
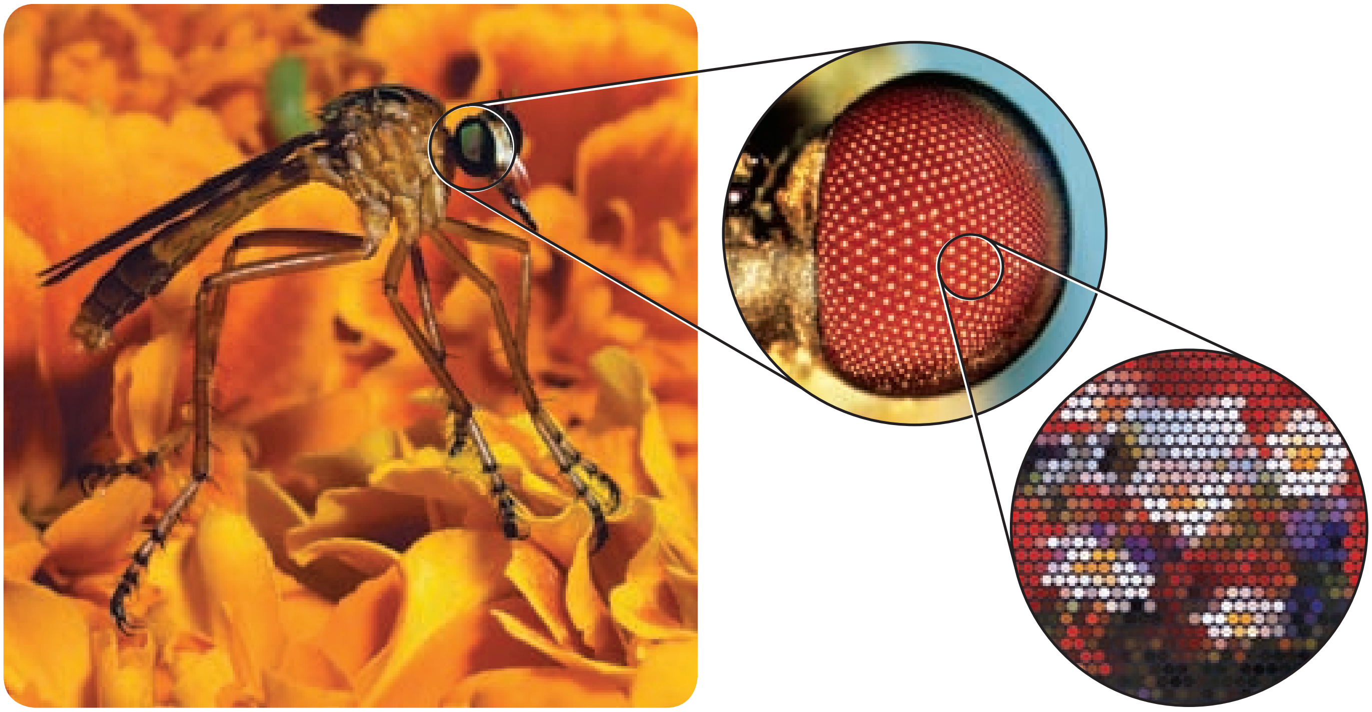


Figure 26.7 Most arthropods get rid of cellular wastes through Malpighian tubules.
Describe *another function of Malpighian tubules.*



■ **Figure 26.8** 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 ***If a fly has blurry vision, how does it stay safe from predators?***

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 26.8,** 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. For more information on biology careers, visit biologygmh.com.

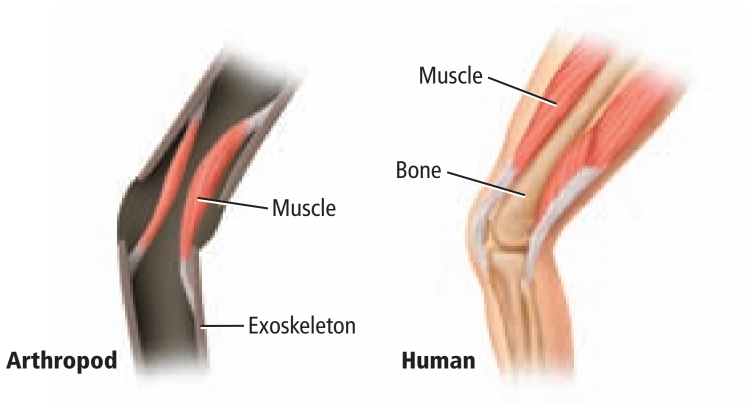


Figure 26.9 You can see the muscles of an arthropod attached inside of the exoskeleton to each side of the joint. The muscles in a human limb are attached to the outer surfaces of the internal skeleton.

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 26.9** 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 26.1 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 Scientifically

5. *Formulate Models* Design an arthropod adapted to conditions on a cold and windy mountaintop with low-growing grasses and arthropod-eating birds.
6. WRITING in **Biology** Write a paragraph describing how an arthropod might protect itself while waiting for its new exoskeleton to harden after molting.