28–1 Introduction to the Arthropods

If you have ever admired a spider's web, watched the flight of a butterfly, or eaten shrimp, you have had close encounters with members of the phylum Arthropoda (ahr-THRAHP-oh-duh). In terms of evolutionary success, which can be measured as the number of living species, arthropods are the most diverse and successful animals of all time. At least three quarters of a million species have been identified—more than three times the number of all other animal species combined!

What Is an Arthropod?

Arthropods include animals such as insects, crabs, centipedes, and spiders. **Arthropods have a segmented body, a tough exoskeleton, and jointed appendages.** Like annelids, arthropods have bodies that are divided into segments. The number of these segments varies among groups of arthropods.

Arthropods are also surrounded by a tough external covering, or **exoskeleton.** The exoskeleton is like a suit of armor that protects and supports the body. It is made from protein and a carbohydrate called **chitin** (KY-tun). Exoskeletons vary greatly in size, shape, and toughness. The exoskeletons of caterpillars are firm and leathery, whereas those of crabs and lobsters are so tough and hard that they are almost impossible to crush by hand. The exoskeletons of many terrestrial, or land-dwelling, species have a waxy covering that helps prevent the loss of body water. Terrestrial arthropods, like all animals that live entirely on land, need adaptations that hold water inside their bodies.

All arthropods have jointed appendages. **Appendages** are structures such as legs and antennae that extend from the body wall. Jointed appendages are so distinctive of arthropods that the phylum is named for them: *arthron* means "joint" in Greek, and *podos* means "foot."

Guide for Reading

Key Concepts
- What are the main features of arthropods?
- What are the important trends in arthropod evolution?
- What happens when an arthropod outgrows its exoskeleton?

Vocabulary
exoskeleton
chitin
appendage
tracheal tube
spiracle
book lung
Malpighian tubule
molting

Reading Strategy: Finding Main Ideas Before you read, skim the section to find the three boldface sentences. Copy each sentence onto a notecard. As you read, make notes of supporting details.

Figure 28–1 Arthropods such as the cave millipede have a body usually composed of segments, a tough exoskeleton, and jointed appendages. Observe the millipede's legs, which are adapted for walking.

SECTION RESOURCES

Print:
- ***Teaching Resources,*** Lesson Plan 28–1, Adapted Section Summary 28–1, Adapted Worksheets 28–1, Section Summary 28–1, Worksheets 28–1, Section Review 28–1
- ***Reading and Study Workbook A,*** Section 28–1
- ***Adapted Reading and Study Workbook B,*** Section 28–1

Technology:
- ***iText,*** Section 28–1
- ***Transparencies Plus,*** Section 28–1

Section 28–1

1 FOCUS

Objectives

28.1.1 ***Identify*** the defining features of arthropods.
28.1.2 ***Describe*** the important trends in arthropod evolution.
28.1.3 ***Explain*** growth and development of arthropods.

Guide for Reading

Vocabulary Preview

Explain that the prefix *ex-* derives from a Latin word meaning "out of." Thus, an *exoskeleton* is a skeleton that is "out of" the body, or on the outside of the body. The word *exit,* meaning a way "out of" a room, derives from the same Latin word.

Reading Strategy

Have students make an outline of the section, using the blue heads as the first level of the outline and the green heads as the second level.

2 INSTRUCT

What Is an Arthropod?

Use Visuals

Figure 28–1 Make sure students understand the meaning of the term *appendage* at this point. Explain that, basically, an appendage is an "attachment" to a body segment of an arthropod. Refer students to the photo, and point out that each pair of the millipede's legs is a pair of appendages attached to a segment. In the case of a millipede, each abdominal segment has two pairs of legs. Explain that in most arthropods, segments have fused and appendages have become modified to perform many functions other than locomotion. In a crayfish, the first two appendages are antennae. Another pair of appendages, the first pair of legs, bear large claws used for defense and to catch, pick up, crush, and cut food. L2

28–1 (continued)

Evolution of Arthropods

Make Connections

Earth Science Show students one or more fossils of trilobites, and have them observe the structure of these early arthropods. Review the process by which fossils are formed. Then, explain that trilobites became extinct at the end of the Permian Period, about 245 million years ago. Geologists and paleontologists use trilobite fossils to date rocks and correlate rock formations in different locations. Fossils that can be used in dating are called index fossils. An index fossil is a fossil that is associated with a particular span of geologic time. If a rock formation contains a trilobite fossil, it can be dated as having formed before 245 million years ago. L2

Form and Function in Arthropods

Build Science Skills

Comparing and Contrasting Divide the class into small groups, and give each group a grasshopper in a small container, a crayfish in water in a basin, lettuce, and a small piece of bologna. Have students place the lettuce in the grasshopper's container and use a hand lens to observe the grasshopper's mouthparts as it eats. Then, have students place the bologna into the basin and observe with a hand lens the crayfish's mouthparts as it eats. Ask students to make drawings of what they observe and write a comparison of the structures of these arthropods' mouthparts. L2 L3

▲ **Figure 28–2** Trilobites, such as the fossilized one shown above, were marine arthropods that were abundant more than 500 million years ago. They were divided into many body segments, each with a walking leg. Trilobites became extinct some 200 million years ago. **Living arthropods generally have fewer body segments and more specialized appendages than ancestral arthropods.**

Evolution of Arthropods

The first arthropods appeared in the sea more than 600 million years ago. Since then, arthropods have moved into all parts of the sea, most freshwater habitats, the land, and the air. **The evolution of arthropods, by natural selection and other processes, has led to fewer body segments and highly specialized appendages for feeding, movement, and other functions.**

A typical primitive arthropod was composed of many identical segments, each carrying a pair of appendages. Its body probably closely resembled that of a trilobite (TRY-loh-byt), shown in **Figure 28–2.** This early body plan was modified gradually. Body segments were lost or fused over time. Most living arthropods, such as spiders and insects, have only two or three body segments. Arthropod appendages also evolved into different forms that are adapted in ways that enable them to perform different functions. These appendages include antennae, claws, walking legs, wings, flippers, mouthparts, tails, and other specialized structures.

These gradual changes in arthropods are similar to the changes in modern cars since the Model T, the first mass-produced automobile. The Model T had all the basic components, such as an internal combustion engine, wheels, and a frame. Over time, the design and style of each component changed, producing cars as different as off-road vehicles, sedans, and sports cars. Similarly, modifications to the arthropod body plan have produced creatures as different as a tick and a lobster.

Form and Function in Arthropods

Arthropods use complex organ systems to carry out different essential functions. As with all animals, organ systems are interrelated; the functioning of one system depends on that of other systems. For example, the digestive system breaks food into nutrient molecules, which then move into blood in the circulatory system. The blood carries the nutrients to body cells.

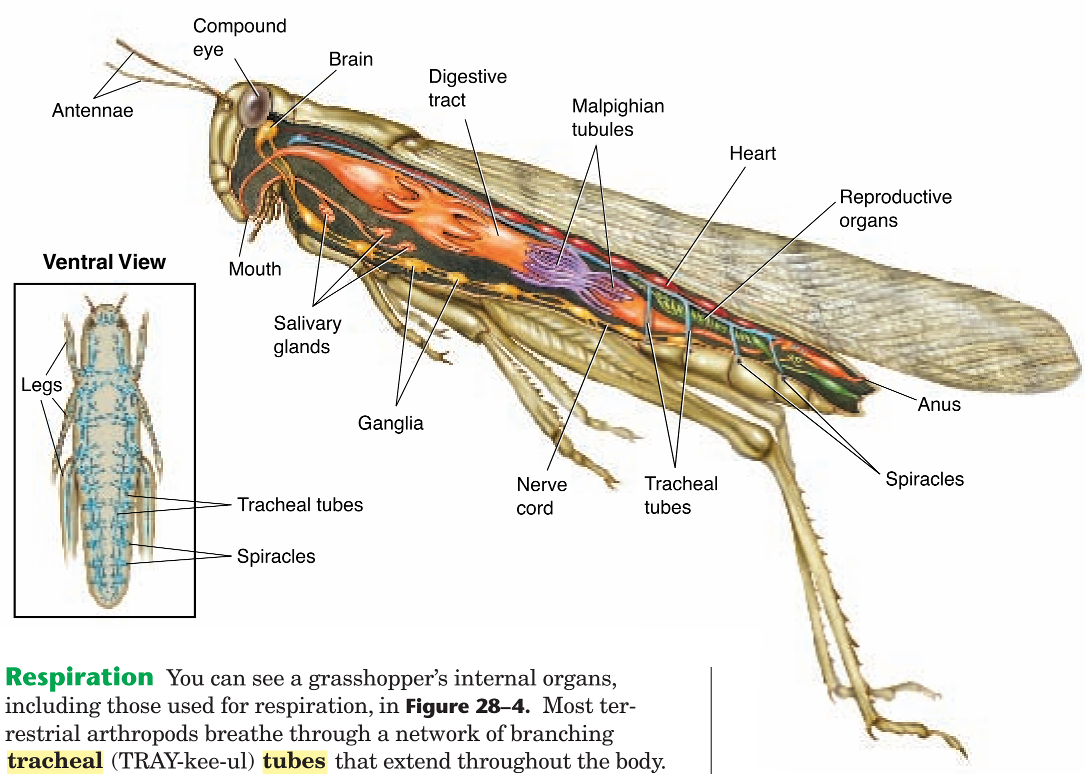
Feeding Arthropods include herbivores, carnivores, and omnivores. There are arthropod bloodsuckers, filter feeders, detritivores, and parasites. Arthropod mouthparts have evolved in ways that enable different species to eat almost any food you can imagine. Their mouthparts range from pincers or fangs to sickle-shaped jaws that can cut through the tissues of captured prey. The mouthparts of a nut weevil are shown in **Figure 28–3.**

◀ **Figure 28–3** This photo of a nut weevil illustrates how its mouthparts are adapted in ways that enable it to bore into and eat nuts. **Applying Concepts** *Do you think a nut weevil would be able to capture and eat other arthropods? Explain your answer.*

UNIVERSAL ACCESS

Inclusion/Special Needs
Have students make a table with two columns. The left column should have the label Essential Functions. Before reading, have students list in that column the seven physiological processes animals need to carry out. The right column should have the label Arthropod Form and Function. Have students complete this column as they read the section. Explain that they should make notes about important concepts and terms in that column. L1

Less Proficient Readers
Read the subsection Form and Function in Arthropods aloud. Stop after you have read about each function and refer to Figure 28–4. Call on volunteers to read the labels on the figure that are associated with each function. For instance, after you read about feeding in arthropods, students should identify the mouth and digestive tract. After you read about respiration, students should identify the tracheal tubes and spiracles, and so on through the functions. L1 L2



▲ **Figure 28–4** The grasshopper has organ systems typical of most arthropods. These organ systems carry out functions such as circulation, excretion, response, and movement. Arthropods have several different types of respiratory organs. In insects, tracheal tubes (inset) move air throughout the tissues of the body. **Interpreting Graphics** ***Where is the grasshopper's nerve cord located?***

Respiration You can see a grasshopper's internal organs, including those used for respiration, in **Figure 28–4.** Most terrestrial arthropods breathe through a network of branching **tracheal** (TRAY-kee-ul) **tubes** that extend throughout the body. Air enters and leaves the tracheal tubes through **spiracles** (SPEER-uh-kulz), which are small openings located along the side of the body. Other terrestrial arthropods, such as spiders, respire using book lungs. **Book lungs** are organs that have layers of respiratory tissue stacked like the pages of a book. Most aquatic arthropods, such as lobsters and crabs, respire through featherlike gills. The horseshoe crabs, however, respire through organs called book gills.

Circulation Arthropods have an open circulatory system. A well-developed heart pumps blood through arteries that branch and enter the tissues. Blood leaves the blood vessels and moves through sinuses, or cavities. The blood then collects in a large sinus surrounding the heart. From there, it re-enters the heart and is again pumped through the body.

Excretion Most terrestrial arthropods, such as insects and spiders, dispose of nitrogenous wastes using Malpighian (mal-PIG-ee-un) tubules. **Malpighian tubules** are saclike organs that extract wastes from the blood and then add them to feces, or digestive wastes, that move through the gut. In aquatic arthropods, diffusion moves cellular wastes from the arthropod's body into the surrounding water.

CHECKPOINT ***What is the function of Malpighian tubules?***

Go Online NSTA SCILINKS
For: Links on arthropods
Visit: www.SciLinks.org
Web Code: cbn-8281

Use Visuals

Figure 28–4 Point out that this grasshopper is a representative arthropod and that other members of the phylum have somewhat different structures. Explain that a grasshopper, which is an insect, has three body sections. From front to back, the sections are called the head, thorax, and abdomen. Point out that all three pairs of legs, as well as the pair of wings, are attached to the grasshopper's thorax, as in all insects. Then, call on volunteers to explain the function of each of the labeled parts of this arthropod. L2

Build Science Skills

Using Models Help students understand that book lungs provide a large surface area for gas exchange, by having them compare the surface areas of an open book and a closed book. First, ask students to calculate the total surface area of the front and back covers of a book. Then, have them divide that book into 10 sections, holding the pages together with large paper clips. Ask students to calculate the total surface area of the book with the page surfaces exposed. Students will find that the total surface area of the divided book is 10 times that of the closed book. L2 L3

Go Online NSTA SCILINKS
Download a worksheet on arthropods for students to complete, and find additional teacher support from NSTA SciLinks.

TEACHER TO TEACHER

When introducing arthropod form and function, have students determine how different arthropods get rid of their waste products. Students should correlate the environment in which each arthropod lives to the method it uses for getting rid of wastes. Correlations should also be made for respiration, circulation, method of movement, and reproduction. This application will also help students to better understand the role the environment plays in evolution.

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Answers to . . .

CHECKPOINT *Malpighian tubules extract wastes from the blood.*

Figure 28–3 *No, because the structure of a weevil's mouthparts is adapted to drilling and piercing, not grasping and crushing.*

Figure 28–4 *The nerve cord is located in the ventral part of the grasshopper's body.*

28–1 (continued)

Quick Lab

Objective Students will be able to draw a conclusion about how responses to odor help crickets survive. L2

Skill Focus **Observing, Inferring, Drawing Conclusions**

Materials live crickets in terrarium, wooden blocks

Time 15 minutes

Advance Prep Crickets can be purchased inexpensively at a pet shop or bait shop. Place the crickets in a screen-covered aquarium or other transparent container. Rub one wooden block with fresh grass clippings or freshly chopped leaves. Rub a second block with moist soil. Soak a third block overnight in water with hair or feathers. Leave the fourth block unscented. Label each block with the name of its odor.

Safety Students should wear disposable plastic gloves if they handle the crickets. Dispose of the gloves properly after the activity. Make sure students wash their hands with soap and warm water before leaving the lab. Caution students to be careful not to injure the crickets. Some students may have allergies; check before selecting leaves and other materials for their odor.

Strategies You may want to make a data table on the chalkboard or an overhead projector so that students or groups can record data for the whole class.

Expected Outcomes Crickets will avoid blocks scented with hair or feathers and climb mostly on the one rubbed with grass clippings.

Analyze and Conclude

1. Students should observe that crickets prefer the block rubbed with grass clippings.
2. The crickets' preference for a particular block and avoidance of others indicates that they can respond to odors.
3. Odors provide clues to where foods such as grass and predators such as insect-eating mammals or birds are located. Crickets can respond to these cues by following them toward food and away from predators.

Quick Lab

Do crickets respond to odors?

Materials live crickets in terrarium, wooden blocks

Procedure

1. **Predicting** Crickets are common in grassy areas. They eat leaves and are eaten by mice, some birds, and other animals. Record a prediction of how the crickets will respond to the odors of grass, soil, and hair.
2. Put on plastic gloves. On a separate sheet of paper, copy the data table shown. Your teacher will provide a set of blocks labeled with the odors they carry. Place the blocks in the container with the crickets so that the blocks do not touch each other. **CAUTION:** *Place the blocks in the container gently to avoid injuring the crickets.*

Data Table

Time (min)	Number of Crickets			
	Grass	Soil	Hair	Control
1				
2				

3. In your data table, record the number of crickets on each block every minute for 10 minutes.
4. Wash your hands with soap and warm water.

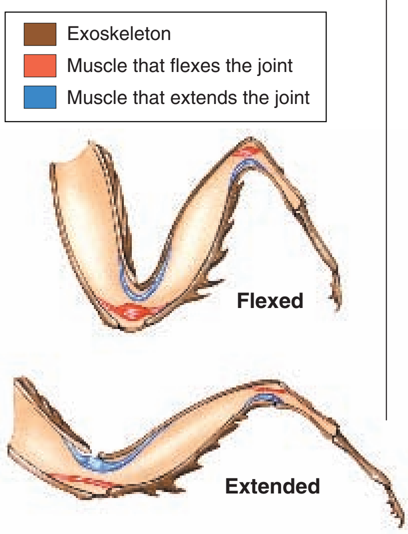
Analyze and Conclude

1. **Observing** Did the crickets tend to climb on some blocks more than others? If so, which blocks did they prefer?
2. **Inferring** What can you infer from these results about the ability of crickets to respond to odors?
3. **Drawing Conclusions** How could the behavior you observed help crickets survive? Explain your answer.

Response Most arthropods have a well-developed nervous system. All arthropods have a brain. The brain serves as a central switchboard that receives incoming information and then sends outgoing instructions to muscles. Two nerves that encircle the esophagus connect the brain to a ventral nerve cord. Along this nerve cord are several ganglia, or groups of nerve cells. These ganglia coordinate the movements of individual legs and wings. Most arthropods have sophisticated sense organs, such as compound eyes for gathering information from the environment. Compound eyes may have more than 2000 separate lenses and can detect color and motion very well.

Movement Arthropods move using well-developed groups of muscles that are coordinated and controlled by the nervous system. In arthropods and other animals, muscles are made up of individual muscle cells. Muscle cells can contract, or become shorter, when stimulated by nerves. Other cells in animals' bodies do not have this ability. Muscles generate force by contracting and then pulling on the exoskeleton.

At each body joint, different muscles either flex (bend) or extend (straighten) the joint. This process is diagrammed in **Figure 28–5.** The pull of muscles against the exoskeleton allows arthropods to beat their wings against the air to fly, push their legs against the ground to walk, or beat their flippers against the water to swim.



▲ **Figure 28–5** This diagrammatic representation shows how muscles attached to the exoskeleton bend and straighten the joints. (Actual muscles are much larger than those shown here.) **Applying Concepts** *How are muscles controlled and coordinated?*

CHECKPOINT *How do arthropods move?*

BIO INSIGHTS

FACTS AND FIGURES

For arthropods, every decision is a no-brainer One of the great differences between animals such as arthropods and "higher" animals is the fact that the responses of arthropods depend only on the various stimuli received by their nerves. Although arthropods have a well-developed nervous system and a simple brain, it is a mistake to attribute "thought" to these animals. Unlike some animals, arthropods do not depend on "thought" or "decision making"; most behaviors are genetically programmed. Their reactions in a particular situation are almost totally predictable. Aristotle, the great observational scientist, was the first to notice that wasps can remain alive and at almost normal activity levels even when their heads have been removed.

Reproduction Terrestrial arthropods have internal fertilization. In some species, males have a reproductive organ that places sperm inside females. In other species, the males deposit a sperm packet that is picked up by the females. Aquatic arthropods may have internal or external fertilization. External fertilization takes place outside the female's body. It occurs when females release eggs into the external environment and males shed sperm around the eggs.

Growth and Development in Arthropods

An exoskeleton does not grow as the animal grows. Imagine that you are wearing a suit of armor fitted exactly to your measurements. Think of it not only as skintight but as part of your skin. What would happen when you grew taller and wider? Arthropods have this same difficulty. **When they outgrow their exoskeletons, arthropods undergo periods of molting.** During **molting,** an arthropod sheds its entire exoskeleton and manufactures a larger one to take its place. Molting is controlled by the arthropod's endocrine system. An animal's endocrine system regulates body processes by means of chemicals called hormones.

As the time for molting approaches, skin glands digest the inner part of the exoskeleton, and other glands secrete a new skeleton. When the new exoskeleton is ready, the animal pulls itself out of what remains of the original skeleton, as shown in **Figure 28–6.** This process can take several hours. While the new exoskeleton is still soft, the animal fills with air or fluids to allow room for growth before the next molting. Most arthropods molt several times between hatching and adulthood. This process is dangerous to the animal because it is vulnerable to predators while its shell is soft. To protect themselves, arthropods typically hide during the molting period or molt at night.

▲ **Figure 28–6** **When they become too large for their exoskeletons, arthropods undergo periods of molting.** This cicada has just molted and is climbing out of its old exoskeleton.

28–1 Section Assessment

1. **Key Concept** What are the main features of arthropods?
2. **Key Concept** What is the evolutionary trend for segmentation in arthropods?
3. **Key Concept** How is the process of molting related to growth in arthropods?
4. What body system controls molting?
5. How are both the circulatory and excretory systems involved in removing nitrogenous wastes from an arthropod's body?
6. **Critical Thinking** **Comparing and Contrasting** How are the muscle cells of arthropods and other animals different from other body cells? How does this difference enable movement?

Focus on the BIG Idea

Cellular Basis of Life Use what you learned about cellular respiration in Chapter 9 to explain why every cell in an arthropod's body needs oxygen. Then, describe how the respiratory system delivers the needed oxygen.

Growth and Development in Arthropods

Build Science Skills

Observing Have students investigate what types of arthropods live in soil. Take the class outdoors to a field, vacant lot, or wooded area. Divide the class into small groups, and have each group mark a 0.5-m^2 area on the ground. Have students put on disposable plastic gloves. Then, let students dig up the soil to a depth of 8–10 centimeters and examine it for living arthropods and molted exoskeletons. Caution students not to touch living arthropods. Challenge students to identify as many arthropods as they can on their own and by using field guides. L2 L3

3 ASSESS

Evaluate Understanding

Call on students to explain how arthropods carry out the seven essential functions: feeding, respiration, circulation, excretion, response, movement, and reproduction.

Reteach

Have students make their own drawing of the grasshopper shown in Figure 28–4. Then, help them to classify each label in the drawing according to which of the seven essential functions it is related to.

Focus on the BIG Idea

Students should describe cellular respiration and explain that every cell needs oxygen to carry out the chemical reactions involved in making the glucose used by all cells for energy. They should also describe the respiratory systems of different arthropods. In their descriptions, students should explain the function of tracheal tubes, spiracles, book lungs, and gills in various arthropods.

28–1 Section Assessment

1. Arthropods have a segmented body, a tough exoskeleton, and jointed appendages.
2. The evolution of arthropods has led to fewer body segments in some groups.
3. During molting, an arthropod sheds its entire exoskeleton and manufactures a larger one to take its place. This process creates room for growth.
4. The endocrine system
5. In most terrestrial arthropods, wastes from cells move through the circulatory system to the Malpighian tubules, which extract wastes from blood.
6. Muscle cells can contract when stimulated by nerves. Muscles generate force by contracting and then pulling on the exoskeleton.

Answers to . . .

CHECKPOINT *They use well-developed groups of muscles that generate force by pulling on the exoskeleton.*

Figure 28–5 *The nervous system controls and coordinates the action of muscles.*