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 is measured as the number of living species, arthropods are the most 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.** **Figure 28–1** shows these features in a millipede. 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 boldfaced sentences. Copy each sentence onto a note card. As you read, make notes of supporting details.

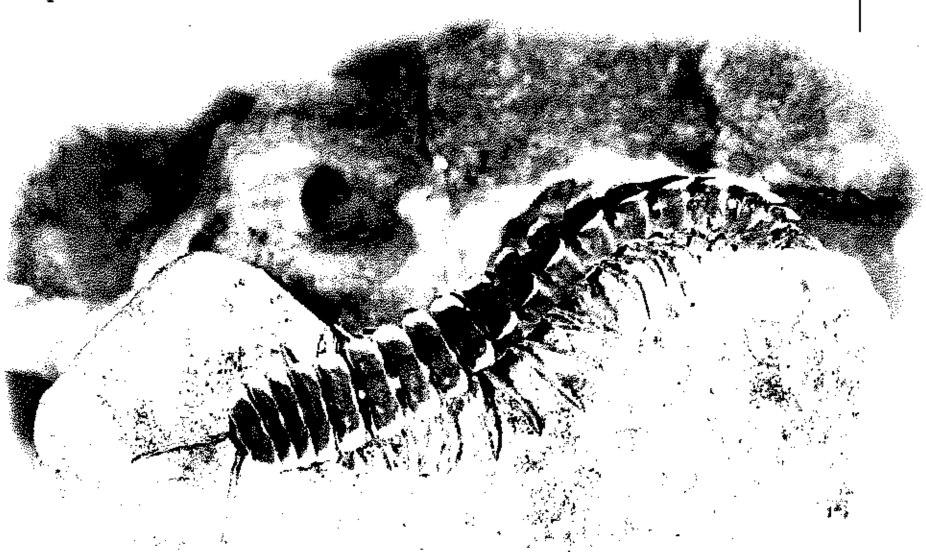
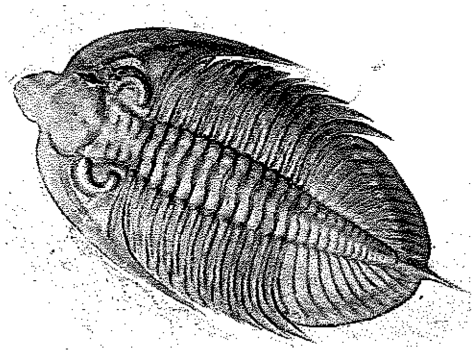


Figure 28–1 Arthropods such as the cave millipede have a body usually composed of segments, a tough exoskeleton, and jointed appendages. Observe the millipede's legs, which are adapted for walking.



▲ **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 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 have different functions. These appendages include antennae, claws, walking legs, wings, flippers, mouthparts, tails, and other specialized structures.

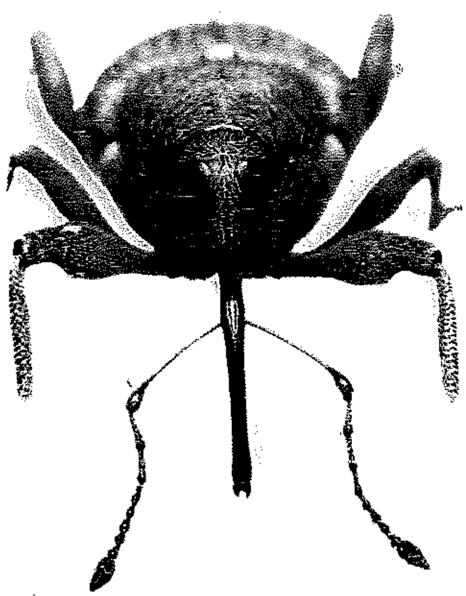
These gradual changes in arthropods are similar to the changes in modern cars since the Model T, the first mass-produced automobile. The Model T had all the basic components, such as an internal combustion engine, wheels, and a frame. Over time, the design and style of each component changed, producing 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.

✓CHECKPOINT *What are the differences between modern arthropods and primitive arthropods?*

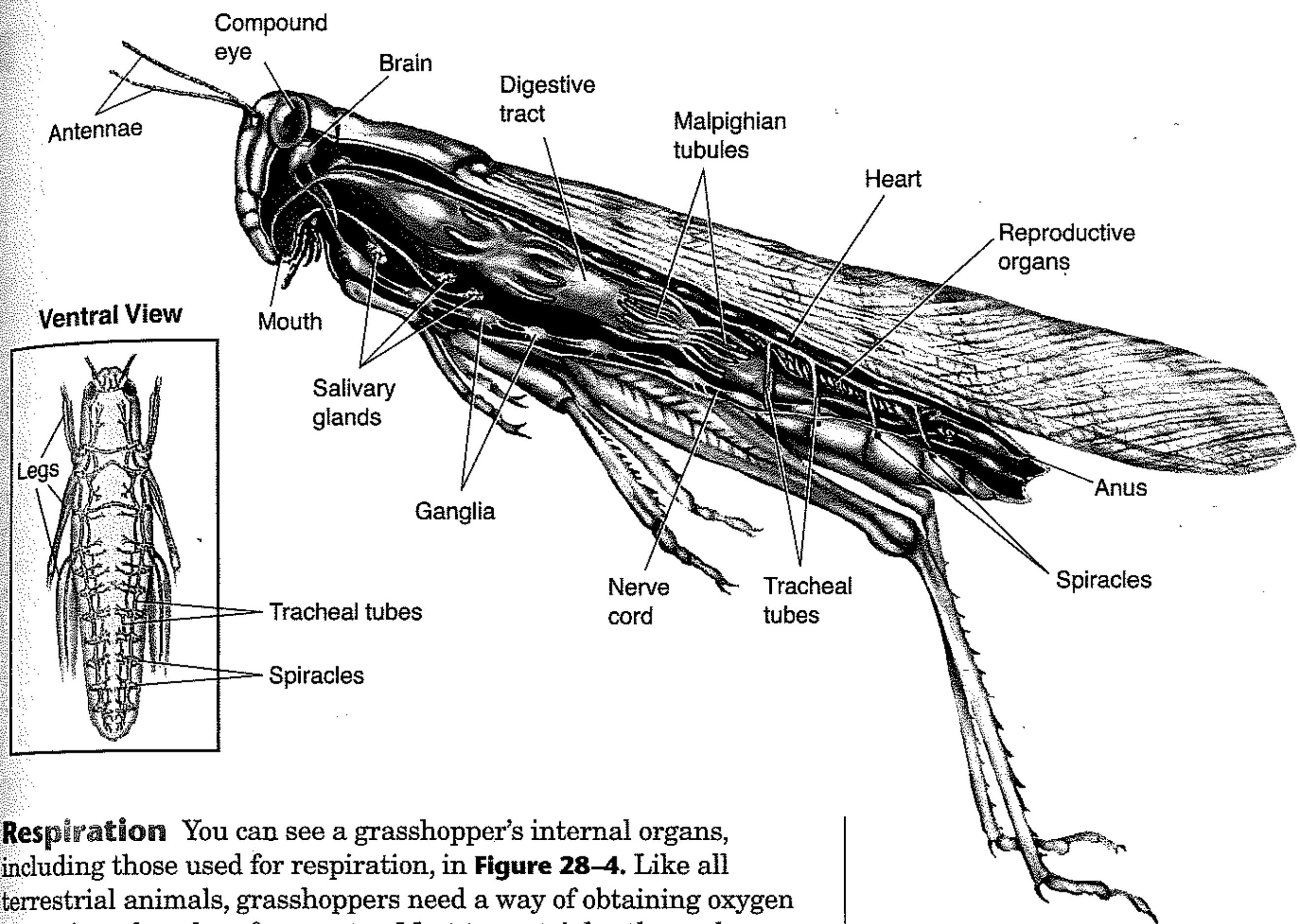
Form and Function in Arthropods

Arthropods use complex organ systems to carry out different essential functions. Some of these organs are found only in this phylum. Most arthropods use tracheal tubes or other specialized organs for respiration, have an open circulatory system, and excrete wastes through saclike tubules.

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 nut weevil uses its mouthparts 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.*



▲ **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.** Like all terrestrial animals, grasshoppers need a way of obtaining oxygen from air rather than from water. 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?*

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 they will respond to the odors of grass, soil, and hair.
2. 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.

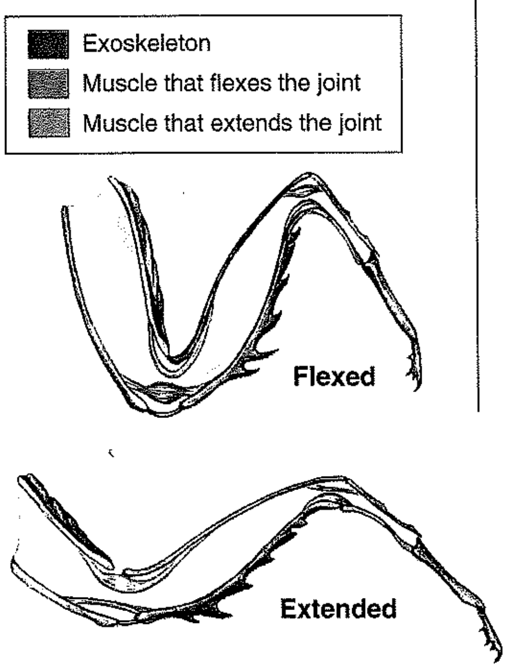
Analyze and Conclude

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 eyes and taste receptors, for gathering information from the environment.

Movement Arthropods move using well-developed groups of muscles that are coordinated and controlled by the nervous system. These 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.

CHECKPOINT *How do arthropods move?*



◀ **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?*

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.

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 because the animal is vulnerable to predators while its shell is soft. To protect themselves, arthropods typically hide during the molting period.

▲ **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 organs are used in arthropod respiration? Which are found in terrestrial arthropods? Aquatic arthropods?
5. **Critical Thinking Inferring** Terrestrial arthropods often have valves that can open and close their spiracles. How are these valves an adaptation to life on land?

iTEXT Assessment Use iText to review the important concepts in Section 28–1.

ALTERNATIVE ASSESSMENT

Creative Writing
Use information from the section to write a one-page short story about a day in the life of an arthropod. Write the story from the point of view of the arthropod.

28–2 Groups of Arthropods

Guide for Reading

Key Concepts
- How are arthropods classified?
- What are the distinguishing features of the three major groups of arthropods?

Vocabulary
cephalothorax
thorax
abdomen
carapace
mandible
cheliped
swimmeret
chelicera
pedipalp
spinneret

Reading Strategy: Building Vocabulary
Before you read, preview new vocabulary by skimming the section and making a list of the boldfaced terms. Leave space to make notes as you read.

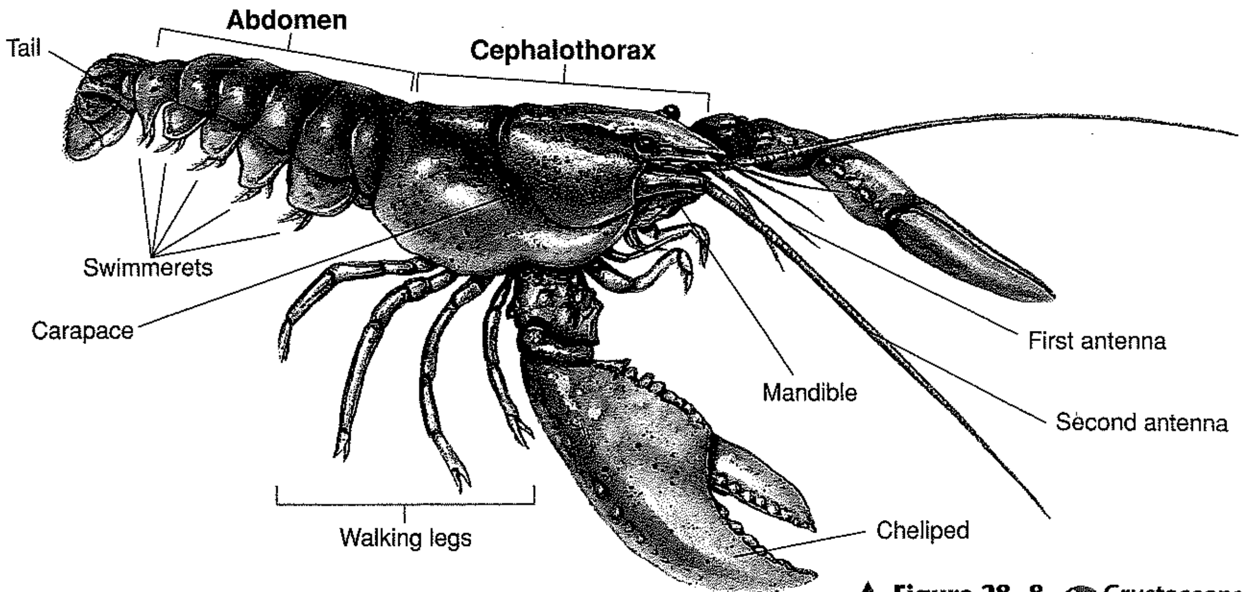
You are a naturalist sent to the rain forests of Brazil to bring back a representative sample of arthropods from the region. You have nets, collection jars, and a good knowledge of arthropods. As you search the forest, your collection grows to include an astonishing array of arthropods—butterflies several centimeters across, armored wormlike animals that move about using dozens of legs, and beetles that defend themselves by shooting out a stream of poisonous liquid. You must organize your collection before you return home, but you know that there are hundreds of thousands of arthropod species. Where to begin?

This is the challenge that has faced biologists for many decades—how to catalogue all the world's arthropods. The diversity of arthropods is daunting to any biologist interested in classification. As you will see, however, arthropod classification is based on a few characteristics. **Arthropods are classified based on the number and structure of their body segments and appendages—particularly their mouthparts.** The three major groups of arthropods are crustaceans, spiders and their relatives, and insects and their relatives.

Crustaceans

The crustaceans (krus-TAY-shunz) are primarily aquatic and include organisms such as crabs, shrimps, lobsters, crayfishes, and barnacles. Crustaceans range in size from small terrestrial pill bugs to spider crabs that have masses around 20 kilograms. **Crustaceans typically have two pairs of branched antennae, two or three body sections, and chewing mouthparts called mandibles.** An example of a crustacean is shown in **Figure 28–7.**

▶ **Figure 28–7 Arthropods are classified based on the number and structure of their body segments and appendages.** The fiddler crab shown here is an example of a crustacean.



▲ **Figure 28–8** **Crustaceans typically have two pairs of antennae, two or three body sections, and chewing mouthparts called mandibles.** Notice these structures in this illustration of a crayfish, an aquatic crustacean.

The crayfish has a body plan, shown in **Figure 28-8,** that is typical of many crustaceans. Its body is divided into a cephalothorax (sef-uh-loh-THAWR-aks) and an abdomen. The anterior **cephalothorax** is formed by fusion of the head with the **thorax,** which lies just behind the head and houses most of the internal organs. The **abdomen** is the posterior part of the body. The **carapace** is the part of the exoskeleton that covers the cephalothorax.

Crustacean appendages vary in form and function. The first two pairs of appendages are antennae, which bear many sensory hairs. In crayfish, antennae are primarily sense organs. In other crustaceans, they are used for filter feeding or swimming. The third pair of appendages are the mandibles. A **mandible** is a mouthpart adapted for biting and grinding food. Gills are attached to the appendages associated with the cephalothorax.

Crayfishes, lobsters, and crabs are members of the largest group of crustaceans: the decapods. The decapods have five pairs of legs. In crayfishes, the first pair of legs, called **chelipeds,** bear large claws that are modified to catch, pick up, crush, and cut food. Behind these legs are four pairs of walking legs. Along the abdomen are several pairs of **swimmerets,** which are flipperlike appendages used for swimming. The final abdominal segment is fused with a pair of paddlelike appendages to form a large, flat tail. When the abdominal muscles contract, the crayfish's tail snaps beneath its body. This pushes the animal backward.

The barnacles are another group of crustaceans. Unlike the decapods, barnacles are sessile, or attached to a single spot. Barnacles are crustaceans that have lost their abdominal segments and no longer use mandibles. Because of their outer shell-like coverings, barnacles were once classified as mollusks. Barnacles attach themselves to rocks along the shore and in tide pools. They even attach to the surface of marine animals such as whales. Barnacles use their appendages to capture and draw food particles into their mouths.

CHECKPOINT *What are the body sections of a crustacean?*

Word Origins

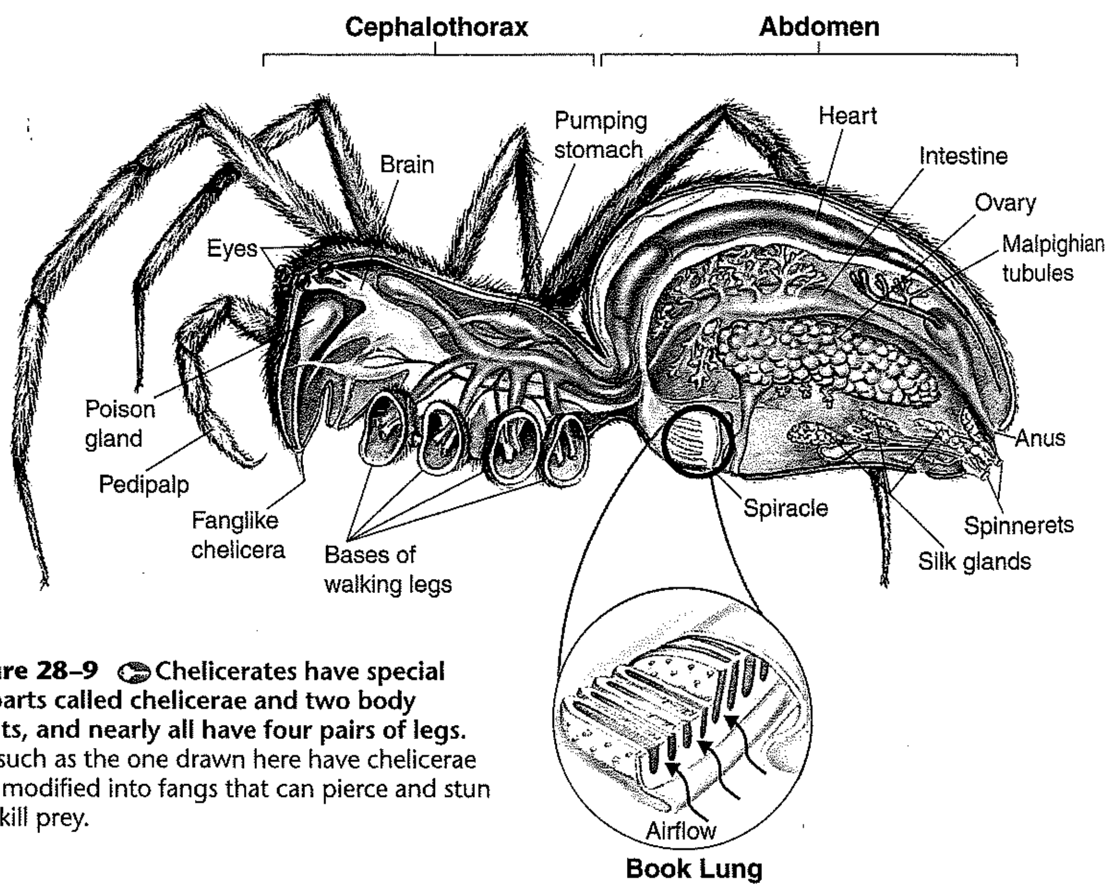
Decapod comes from the Greek word *deka* meaning "ten" and the Greek word *podos* meaning "foot." So, *decapod* means "ten-footed." **If *cephalo* means "head," what do you think the term *cephalopod* means?**

Spiders and Their Relatives

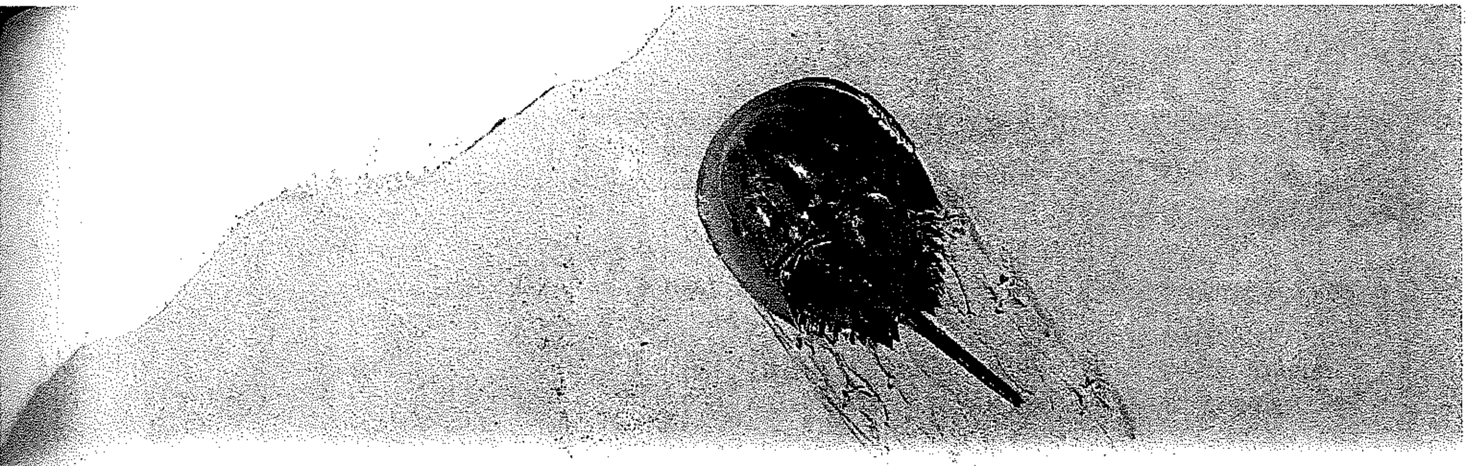
Horseshoe crabs, spiders, ticks, and scorpions are chelicerates. **Chelicerates have mouthparts called chelicerae and two body sections, and nearly all have four pairs of walking legs.** Locate these structures in the spider in **Figure 28–9**. Note that chelicerates lack the antennae found on most other arthropods. As in crustaceans, the bodies of chelicerates are divided into a cephalothorax and an abdomen. The cephalothorax contains the brain, eyes, mouth, and walking legs. The abdomen contains most of the internal organs.

Chelicerates have two pairs of appendages attached near the mouth that are adapted as mouthparts. One pair, called **chelicerae** (kuh-LIS-ur-ee; singular: chelicera), contain fangs and are used to stab and paralyze prey. The other pair, called **pedipalps** (PED-ih-palps), are longer than the chelicerae and are usually modified to grab prey. Chelicerates respire using either book gills or book lungs. Horseshoe crabs, which are aquatic, move water across the membranes of book gills. In spiders, which are terrestrial, air enters through spiracles and then circulates across the surfaces of the book lung.

Chelicerates are divided into two main groups: horseshoe crabs and arachnids. The arachnids include spiders, mites, ticks, and scorpions.



▶ **Figure 28–9 Chelicerates have special mouthparts called chelicerae and two body segments, and nearly all have four pairs of legs.** Spiders such as the one drawn here have chelicerae that are modified into fangs that can pierce and stun or even kill prey.



▲ **Figure 28–10** Horseshoe crabs look a bit like true crabs, but their bodies more closely resemble those of spiders and other chelicerates. The abdomen and cephalothorax of these animals are encased in a hard shell. **Inferring** *From this photograph, what can you infer about the habitat of horseshoe crabs?*

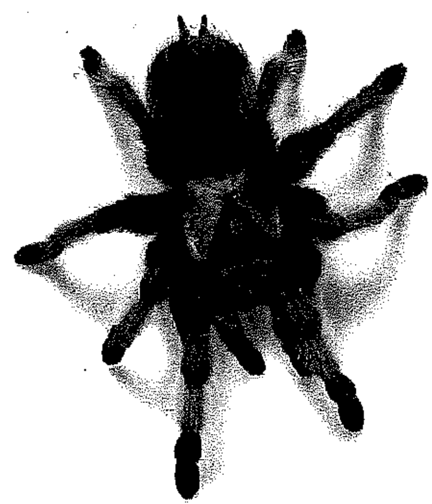
Horseshoe Crabs Horseshoe crabs, shown in **Figure 28–10,** are among the oldest living arthropods. They first appeared more than 500 million years ago and have changed little since that time. Despite their name, horseshoe crabs are not true crabs at all. They are heavily armor-plated, like crabs, but have an anatomy closer to that of spiders. They have chelicerae, five pairs of walking legs, and a long spikelike tail that is used for movement. Horseshoe crabs grow to about the size—and shape—of a large frying pan. They are common along the marshes and shallow bays of the eastern United States seacoast.

Spiders Spiders, the largest group of arachnids, capture and feed on animals ranging from other arthropods to small birds. They catch their prey in a variety of ways. Some spin webs of a strong, flexible protein called silk, which they use to catch flying prey. Others, including the tarantula shown in **Figure 28–11,** stalk and then pounce on their prey. Others lie in wait beneath a camouflaged burrow, leaping out to grab insects that venture too near.

Because spiders do not have jaws for chewing, they must liquefy their food to swallow it. Once a spider captures its prey, it uses fanglike chelicerae to inject paralyzing venom into it. When the prey is paralyzed, the spider injects digestive enzymes into the wounds. These enzymes break down the prey's tissues, enabling the spider to suck the tissues into a specialized pumping stomach. The stomach forces the liquefied food through the rest of the spider's digestive system.

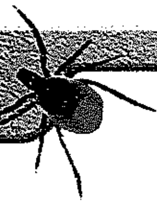
Whether or not they spin webs, all spiders produce silk. Spider silk is much stronger than steel! Spiders spin silk into webs, cocoons for eggs, and wrappings for prey. They do this by forcing liquid silk through **spinnerets,** which are organs that contain silk glands. As the silk is pulled out of the spinnerets, it hardens into a single strand. Web-spinning spiders use that strand to make a web. Spiders can spin webs almost as soon as they hatch; the complicated procedure of spinning webs seems to be preprogrammed behavior.

✓CHECKPOINT *How do chelicerates respire?*



▲ **Figure 28–11** The tarantula shown here is an example of a chelicerate. The chelicerae, or specialized mouthparts, can inject poison by way of a painful bite. **Applying Concepts** *How might this action be useful to tarantulas?*

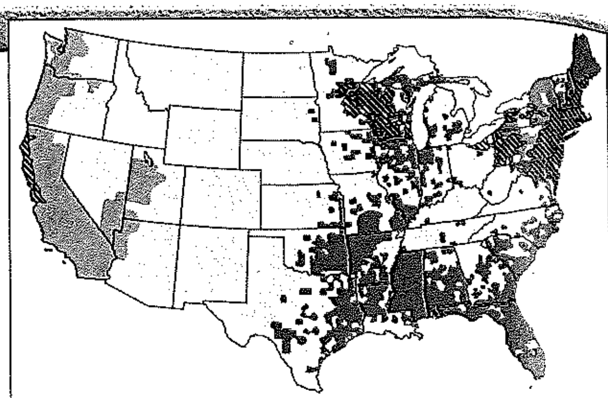
Analyzing Data



Ticks and Lyme Disease

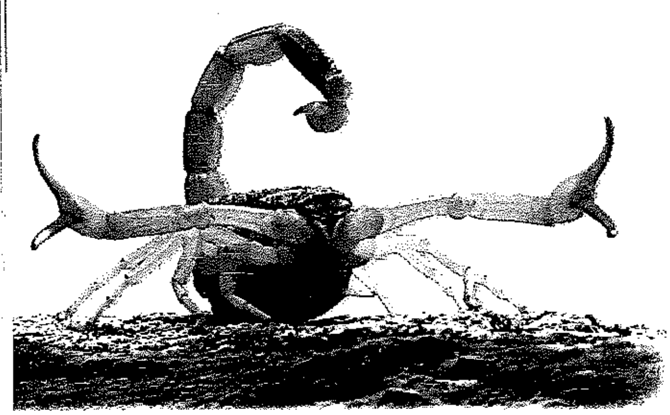
Lyme disease is caused by a bacterium found in two species of small ticks, the deer tick (*Ixodes scapularis*) and the western black-legged tick (*Ixodes pacificus*). Both species are most common in humid, wooded areas. They feed by sucking blood from deer, mice, birds, or humans. In warmer climates where reptiles such as lizards and snakes are most common, deer ticks prefer to feed on reptiles. The disease-causing bacteria are transmitted to the host by the bite of an infected tick. In humans the bacteria can cause a rash, fever, fatigue, joint and muscle pain, and damage to the nervous system. The bacteria do not survive well in reptiles.

The map shows the distribution of the two tick species and reported cases of Lyme disease. Use the map to help you answer the following questions:



1. **Interpreting Graphics** How can you explain the differences in the incidence of Lyme disease within the range of deer ticks?
2. **Formulating Hypotheses** What are two possible reasons that Lyme disease is not common in the parts of the dry southwest where western black-legged ticks are found?

▼ **Figure 28–12** Scorpions are easily recognized by their clawlike pedipalps and curved abdomen that bears a stinger at its tip. Although scorpions inflict stings on humans—usually causing as much pain as a wasp sting—they typically prey on other invertebrates, such as insects. **Comparing and Contrasting** *How do scorpions and spiders capture their prey?*



Mites and Ticks Mites and ticks are small arachnids that are usually parasitic. Their chelicerae and pedipalps are specialized for digging into a host's tissues and sucking out blood or plant fluids. In many species, the chelicerae are needlelike structures that are used to pierce the skin of the host. The pedipalps are often equipped with claws for attaching to the host. These mouthparts are so strong that if a tick begins to feed on you and you try to pull it off, its cephalothorax may separate from its abdomen and remain in your skin!

Mites and ticks parasitize a variety of organisms. Spider mites damage houseplants and are major agricultural pests on crops such as cotton. Others—including chiggers, mange, and scabies mites—cause itching or painful rashes in humans and other mammals. Ticks can transmit bacteria that cause serious diseases, such as Rocky Mountain spotted fever and Lyme disease.

Scorpions Scorpions are widespread in warm areas around the world, including the southern United States. Scorpions have pedipalps that are enlarged into claws, as shown in **Figure 28–12.** The long, segmented abdomen of a scorpion carries a venomous stinger that can kill or paralyze prey. Unlike spiders, scorpions chew their prey, using their chelicerae.

✔ CHECKPOINT *Where are scorpions usually found?*

Insects and Their Relatives

Centipedes, millipedes, and insects are all uniramians (yoo-nuh-RAY-mee-unz), a group that contains more species than all other groups of animals alive today. **Uniramians have jaws, one pair of antennae, and unbranched appendages.** Although they all have unbranched appendages, uniramians have widely varying forms and lifestyles. Centipedes and millipedes have long, wormlike bodies composed of many leg-bearing segments, as shown in **Figure 28–13.** Insects have compact, three-part bodies, and most are adapted for flight. The insects are so diverse and important as a group that they are discussed separately, in the next section.

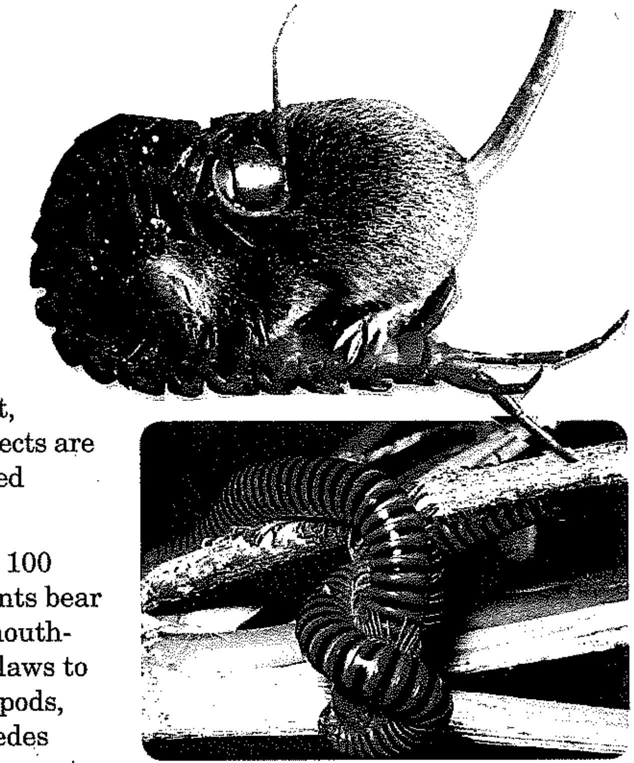


Figure 28–13 **Uniramians such as centipedes and millipedes have jaws, one pair of antennae, and unbranched appendages.** A centipede (top) is a carnivore that feeds on earthworms and other small animals. A millipede (bottom) is a herbivore that feeds on rotting vegetation.

Centipedes Centipedes have from a few to more than 100 pairs of legs, depending on the species. Most body segments bear one pair of legs each. Centipedes are carnivores whose mouthparts include a pair of venomous claws. They use these claws to catch and stun or kill their prey—including other arthropods, earthworms, toads, small snakes, and even mice. Centipedes usually live beneath rocks or in the soil. Their spiracles cannot close, and they lack a waterproof coating on their exoskeleton. As a result, their bodies lose water easily. This characteristic restricts centipedes to moist or humid areas.

Millipedes Like the centipedes, millipedes have a highly segmented body. However, each millipede segment bears two, not one, pairs of legs. These two pairs of legs per segment develop from the fusion of two segments in the millipede embryo. Millipedes live under rocks and in decaying logs. They feed on dead and decaying plant material. Unlike centipedes, they are timid creatures. When disturbed, many millipedes roll up into a ball to protect their softer undersides. They may also defend themselves by secreting unpleasant or toxic chemicals.

28–2 Section Assessment

1. **Key Concept** What characteristics are used to classify arthropods?
2. **Key Concept** How do the three largest groups of arthropods differ?
3. Describe the process of digestion in spiders.
4. Compare and contrast the body plans and feeding habits of millipedes and centipedes.
5. **Critical Thinking Applying Concepts** Suppose you want to catch a crayfish with a net. Should you try to scoop it up head first or tail first? Explain.

iTEXT Assessment Use iText to review the important concepts in Section 28–2.

ALTERNATIVE ASSESSMENT

Designing an Arthropod
Use information from this section to design a new type of arthropod. Make sure that the arthropod has all the characteristics described in this section. Draw the arthropod and give it a name. Include a brief description of what it eats and where it lives.

28–3 Insects

Guide for Reading

Key Concepts
- What are the distinguishing features of insects?
- What two types of development can insects undergo?
- What types of insects form societies?

Vocabulary
incomplete metamorphosis
nymph
complete metamorphosis
pupa
pheromone
society
caste

Reading Strategy: Summarizing As you read, find the most important concepts in each paragraph. Then, use the important concepts to write a summary of what you have read.

What animals other than humans have the greatest impact on the activities of this planet? If you said "insects," you would be correct. From bees that flit from flower to flower to weevils that feed on crops, insects seem to be everywhere. As **Figure 28–14** shows, this single class of animals contains more species than any other group of animals. Ants and termites alone account for nearly one third of all the animal biomass in the Amazon basin.

Many characteristics of insects have contributed to their evolutionary success. These include different ways of responding to stimuli; the evolution of flight, which allowed insects to disperse long distances and colonize new habitats; and a life cycle in which the young differ from adults in appearance and feeding methods. These features have allowed insects to thrive in almost every terrestrial habitat on Earth, as well as in many freshwater and some marine environments.

The insects cover an incredible variety of life forms—from stunning, iridescent beetles and butterflies to the less attractive fleas, weevils, cockroaches, and termites. Biologists sometimes disagree on how to classify insects, and the number of living orders ranges from 26 to more than 30.

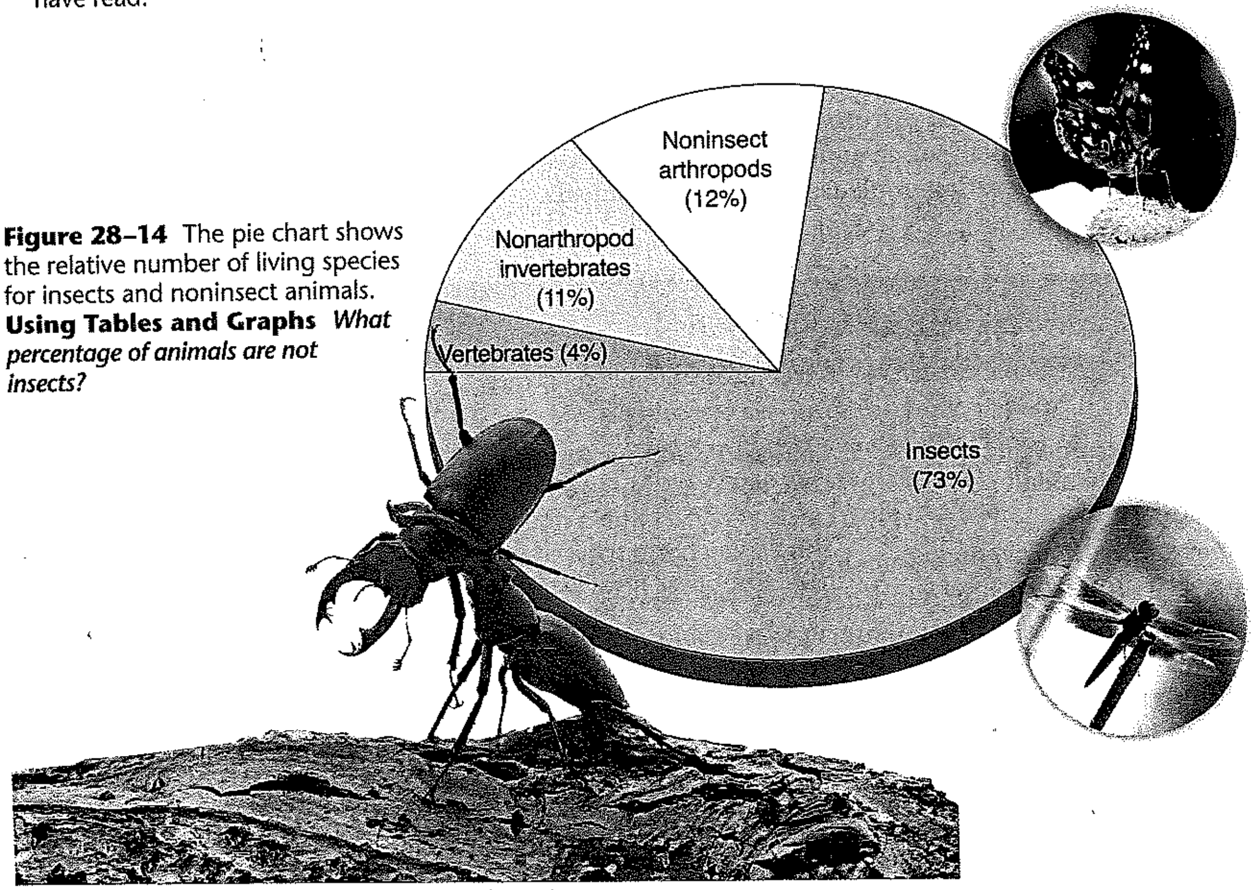
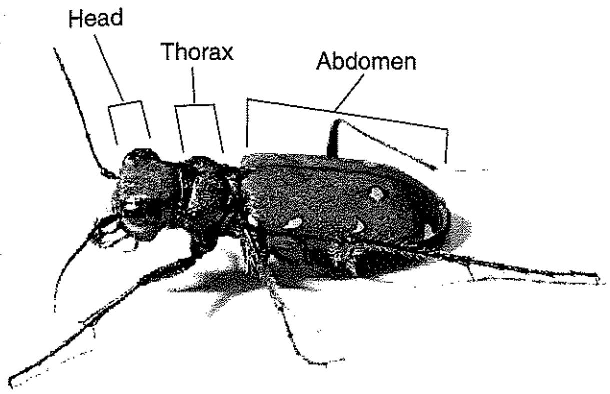


Figure 28–14 The pie chart shows the relative number of living species for insects and noninsect animals. **Using Tables and Graphs** *What percentage of animals are not insects?*



◀ Figure 28–15 Insects have a body divided into three parts—head, thorax, and abdomen. Three pairs of legs are attached to the thorax. In addition to these features, this green tiger beetle has other characteristics of a typical insect—wings, antennae, compound eyes, and tracheal tubes for respiration.

What Is an Insect?

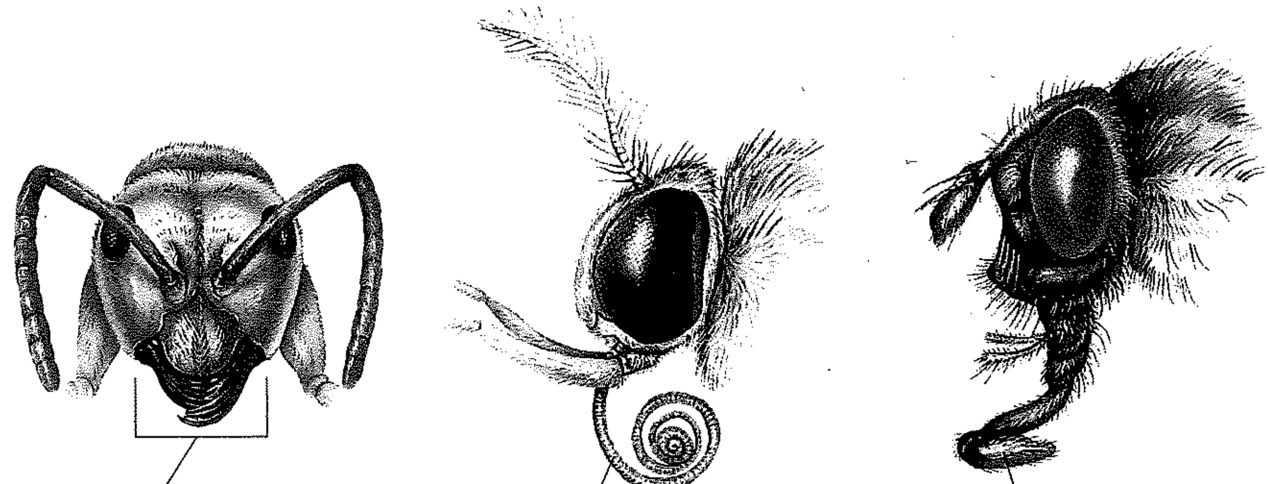
Like all arthropods, insects have a segmented body, an exoskeleton, and jointed appendages. They also have several features that are specific to insects. **Insects have a body divided into three parts—head, thorax, and abdomen. Three pairs of legs are attached to the thorax.** The beetle in **Figure 28–15** exhibits these characteristics. In many insects such as ants, the body parts are clearly separated from each other by narrow connections. In other insects, such as grasshoppers, the divisions between the three body parts are not as sharply defined. A typical insect also has a pair of antennae and a pair of compound eyes on the head, two pairs of wings on the thorax, and tracheal tubes that are used for respiration.

The essential life functions in insects are carried out in basically the same ways as they are in other arthropods. However, insects have a variety of interesting adaptations that deserve a closer look.

✓CHECKPOINT *What are the names of the three parts of an insect's body?*

Responses to Stimuli Insects use a multitude of sense organs to respond to stimuli. Compound eyes are made of many lenses that detect minute changes in color and movement. The brain assembles this information into a single, detailed image. Compound eyes produce an image that is less detailed than what we see. However, eyes with multiple lenses are far better at detecting movement—one reason it is so hard to swat a fly!

Insects have chemical receptors for taste and smell on their mouthparts, as might be expected, and also on their antennae and legs. When a fly steps in a drop of water, it knows immediately whether the water contains salt or sugar. Insects also have sensory hairs that detect slight movements in the surrounding air or water. As objects move toward insects, the insects can feel the movement of the displaced air or water and respond appropriately. Many insects also have well-developed ears that hear sounds far above the human range. These organs are located in what we would consider odd places—behind the legs in grasshoppers, for example.



▲ **Figure 28–16** Insect mouthparts are specialized for a variety of functions. An ant's mouthparts can saw through and then grind food into a fine pulp. The mouthpart of a moth consists of a long tube that can be uncoiled to sip nectar from a flower. Flies have a spongy mouthpart that is used to stir saliva into food and then lap up the food. **Applying Concepts** *What is the function of saliva?*

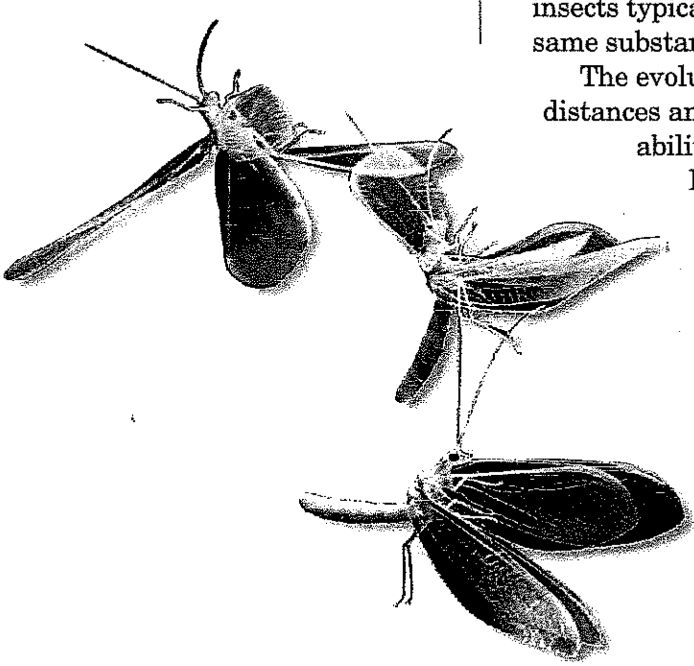
Adaptations for Feeding Insects have three pairs of appendages that are used as mouthparts, including a pair of mandibles. These mouthparts can take on a variety of shapes, as shown in **Figure 28–16.**

Insect adaptations for feeding are not restricted to their mouthparts. Many insects produce saliva containing digestive enzymes that help break down food. The chemicals in bee saliva, for example, help change nectar into a more digestible form—honey. Glands on the abdomen of bees secrete wax, which is used to build storage chambers for food and other structures within a beehive.

Movement and Flight Insects have three pairs of legs, which in different species are used for walking, jumping, or capturing and holding prey. In many insects, the legs have spines and hooks that are used for grasping and defense.

Many insects can fly, as shown in **Figure 28–17.** Flying insects typically have two pairs of wings made of chitin—the same substance that makes up an insect's exoskeleton.

The evolution of flight has allowed insects to disperse long distances and to colonize a wide variety of habitats. Flying abilities and styles vary greatly among the insects. Butterflies usually fly slowly. Flies, bees, and moths, however, can hover, change direction rapidly, and dart off at great speed. Dragonflies can reach speeds of 50 kilometers per hour.



◀ **Figure 28–17** Flying insects, such as this lacewing, move their wings using two sets of muscles. The muscles contract to change the shape of the thorax, alternately pushing the wings down and lifting them up and back. In some small insects, these muscles can produce wing speeds of up to 1000 beats per second! **Drawing Conclusions** *How might the evolution of flight change an animal's habitat?*

Metamorphosis **The growth and development of insects usually involve metamorphosis, which is a process of changing shape and form. Insects undergo either incomplete metamorphosis or complete metamorphosis.** Both complete and incomplete metamorphosis are shown in **Figure 28–18**. The immature forms of insects that undergo gradual or **incomplete metamorphosis,** such as the chinch bug, look very much like the adults. These immature forms are called **nymphs** (NIMFS). Nymphs lack functional sexual organs and other adult structures, such as wings. As they molt several times and grow, the nymphs gradually acquire adult structures. This type of development is characterized by a similar appearance throughout all stages of the life cycle.

Many insects, such as bees, moths, and beetles, undergo a more dramatic change in body form during a process called **complete metamorphosis.** These animals hatch into larvae that look and act nothing like their parents. They also feed in completely different ways from adult insects. The larvae typically feed voraciously and grow rapidly. They molt a few times and grow larger but change little in appearance. Then they undergo a final molt and change into a **pupa** (PYOO-puh; plural: pupae)—the stage in which an insect changes from larva to adult. During the pupal stage, the body is completely remodeled inside and out. The adult that emerges seems like a completely different animal. Unlike the larva, the adult typically can fly and is specialized for reproduction. **Figure 28–18** shows the complete metamorphosis of a ladybug beetle.

CHECKPOINT *What is a pupa?*

DISCOVERY CHANNEL SCHOOL

To find out how insect metamorphosis plays a part in forensic science, view the videotape "Insect Clues: The Smallest Witnesses."

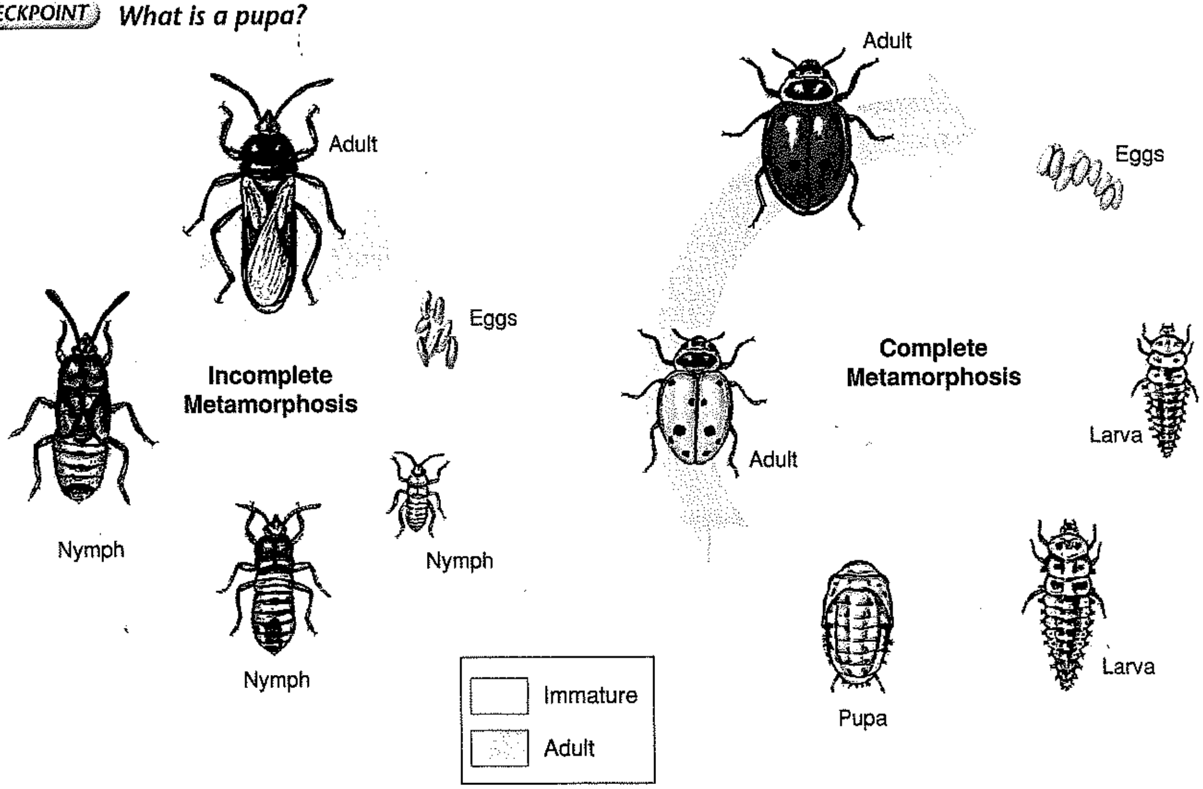


Figure 28–18 **The growth and development of insects usually involve metamorphosis, which is a process of changing shape and form. Insects undergo incomplete metamorphosis or complete metamorphosis.** The chinch bug (left) undergoes incomplete metamorphosis, and the developing nymphs look similar to the adult. The ladybug (right) undergoes complete metamorphosis, and during the early stages the developing larva and pupa look completely different from the adult.

Insects and Humans

Many insects are known for their negative effects. Termites destroy wood structures, moths eat their way through wool clothing and carpets, and bees and wasps produce painful stings. Insects such as desert locusts cause billions of dollars in damage each year to livestock and crops. Boll weevils are notorious for the trouble they cause cotton farmers in the South. Mosquitoes are annoying and have been known to spoil many a leisurely outdoor activity. Only female mosquitoes bite humans and other animals to get a blood meal for their developing eggs. Male mosquitoes, on the other hand, do not bite; they feed on nectar. Many insects, including mosquitoes, cause far more serious damage than itchy bites. Their bites can infect humans with microorganisms that cause devastating diseases such as malaria, yellow fever, and bubonic plague.

Despite their association with destruction and disease, insects also contribute enormously to the richness of human life. Agriculture would be very different without the bees, butterflies, wasps, moths, and flies that pollinate many crops. One third of the food you eat depends on plants pollinated by animals, including insects. Insects also produce commercially valuable products such as silk, wax, and honey. They are even considered a food delicacy in certain countries of Africa and Asia.

CHECKPOINT *How do insects affect humans negatively? Positively?*

Biology and History

Insect-Borne Diseases

For as long as humans and insects have shared planet Earth, humans have been victims of diseases carried by insects. Researchers have discovered which insects transmit specific diseases. Such discoveries have often shed light on how the diseases can be controlled.

1900

1906

Robert Koch discovers that fleas transmit the bubonic-plague bacterium. The plague killed 25% of Europe's population between 1347 and 1351.

1909

Charles Nicolle discovers that one form of typhus, which is caused by a bacterium, is transmitted by the body louse.

1920

Nineteenth amendment to U.S. Constitution gives women the right to vote.

1924

African sleeping sickness is discovered in inhabitants of central Africa. The disease is caused by a protist transmitted by tsetse flies that live in forests and areas near water.

1943

DDT, a powerful insecticide, is used for the first time during World War II to control the spread of typhus. It is also used to control outbreaks of malaria.

Insect Communication

Insects communicate using sound, visual, chemical, and other types of signals. Much of their communication involves finding a mate. To attract females, male crickets chirp by rubbing their forewings together, and male cicadas buzz by vibrating special membranes on the abdomen. Some insects use sound waves to locate prey.

Male fireflies use visual cues to communicate with potential mates. As shown in **Figure 28–19,** a light-producing organ in the abdomen is used to produce a distinct series of flashes. When female fireflies see the signal, they flash back a signal of their own, inducing the males to fly to them. This interaction is sometimes more complicated, however, because the carnivorous females of one genus of fireflies can mimic the signal of another genus—and then lure unsuspecting males to their death!

Many insects communicate using chemical signals. Female moths, for example, attract distant males to them by releasing chemicals. These chemicals are called **pheromones** (FER-uh-mohnz), which are specific chemical messengers that affect the behavior or development of other individuals of the same species. Some pheromones function to signal alarm or alert other insects to the death of a member of the colony. Other pheromones enable males and females to communicate during courtship and mating.

▲ **Figure 28–19** Fireflies use light to communicate with other individuals of their species. They are programmed to respond to specific patterns of light. **Applying Concepts** ***What are some other ways in which insects communicate?***

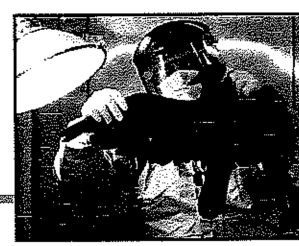
Writing Activity

Some insect-borne diseases have an intermediate host in which the parasite reproduces asexually. Conduct research on the bubonic plague to identify its intermediate host. Write a report on how this host was discovered and how the discovery affected control of the disease.

1957 First satellite launched into orbit

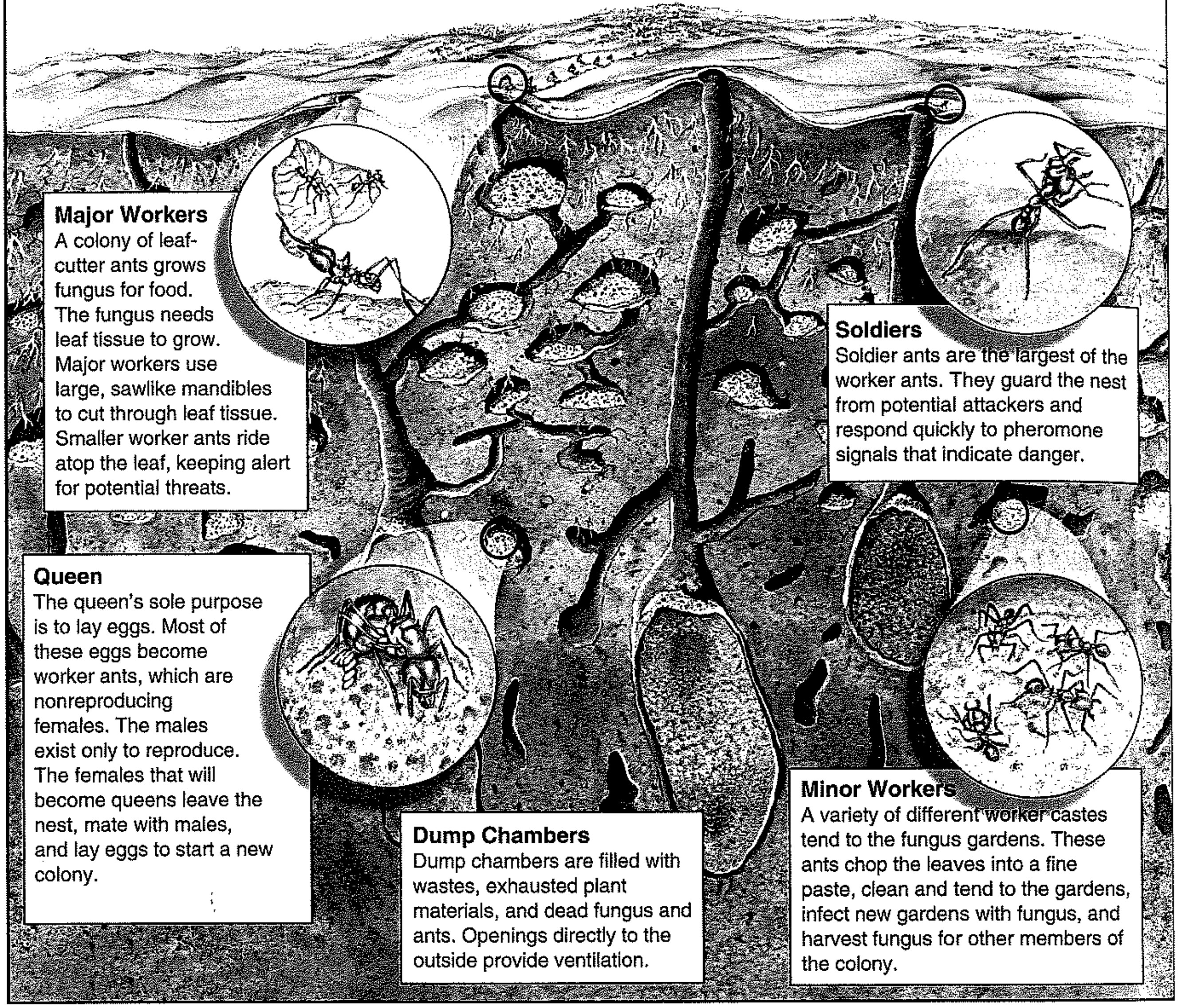
1972 Use of DDT is severely restricted in the United States because it is found to be toxic to fishes, birds, and possibly humans.

1974 The World Health Organization begins to get rid of the black fly population of West Africa. Black flies transmit river blindness, which is caused by a roundworm.



1999 An outbreak of West Nile virus occurs in New York City and its suburbs—the first sighting of this disease in the Western Hemisphere. The disease is carried by mosquitoes and can affect humans as well as birds and livestock. Officials order spraying of insecticides near bodies of water in which mosquitoes might breed.

2000



▲ **Figure 28–20** **Some insects, such as these tropical leaf-cutter ants, form societies.** In a tropical leaf-cutter society, only a single queen reproduces. The queen can produce thousands of eggs in a single day. Several different castes of leaf-cutter ants perform all other tasks within the colony. They care for the queen and her eggs and young; they grow fungus for food; and they build, maintain, and defend the colony's home. One group of workers even cultivates bacteria that produce antibiotics! These antibiotics prevent the growth of parasitic molds on the fungus that the ants use for food.

Insect Societies

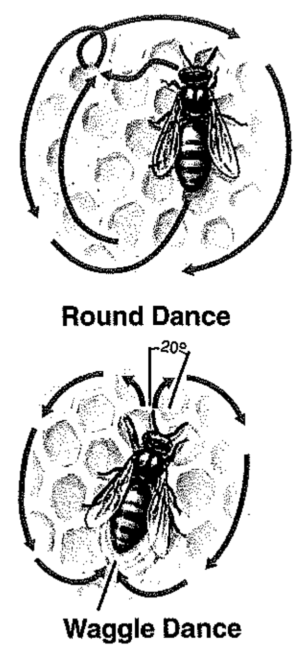
Just as people form teams that work together toward a common goal, some insects live and work together in groups. Unlike people, however, insects act instinctively rather than voluntarily. **Ants, bees, termites, and some of their relatives form complex associations called societies.** A **society** is a group of closely related animals of the same species that work together for the benefit of the whole group. Insect societies may consist of more than 7 million individuals. A tropical leaf-cutter ant colony is shown in **Figure 28–20.**

Castes Within a society, individuals may be specialized to perform particular tasks, or roles. These are performed by groups of individuals called **castes.** Each caste has a body form specialized for its role. The basic castes are reproductive females called queens (which lay eggs), reproductive males, and workers. Most insect societies have only one queen, which is typically the largest individual in the colony.

Communication in Societies A sophisticated system of communication is necessary for the functioning of a society. Each species of social insect has its own "language" of visual, touch, sound, and chemical signals that convey information among members of the colony. When a worker ant finds food, for example, she leaves behind a trail of a special pheromone as she heads back to the nest. Her nest mates can then detect her trail to the food by using sensory hairs on their antennae.

Honeybees communicate with complex movements as well as with pheromones. Worker bees are able to convey information about the type, quality, direction, and distance of a food source by "dancing." As shown in **Figure 28–21,** bees have two basic dances: a round dance and a waggle dance. In the round dance, the bee that has found food circles first one way and then the other, over and over again. This dance tells the other bees that there is food within a relatively short distance from the hive. The frequency with which the dancing bee changes direction indicates the quality of the food source: The more frequent the changes in direction, the greater the energy value of the food.

In the waggle dance, the bee that has found food runs forward in a straight line while waggling her abdomen. She circles around one way, runs in a straight line again, and circles around the other way. The waggle dance tells the other bees that the food is a longer distance away. The longer the bee takes to perform the straight run and the more she waggles, the farther away the food. The direction of the straight run indicates in which direction the food is to be found. The angle of the bee indicates the direction of the food in relation to the sun. For example, if the dancer runs straight up the vertical part of the honeycomb, the food is in the same direction as the sun.



▲ **Figure 28–21** Bees use dances to communicate information about food sources. The round dance indicates that food is fairly close to the hive. The waggle dance indicates that food is farther away. **Interpreting Graphics** ***In what direction does the food lie, according to this bee's waggle dance?***

28–3 Section Assessment

1. **Key Concept** Describe the basic body plan of an insect.
2. **Key Concept** Compare the processes of incomplete and complete metamorphosis. Which involves a dramatic change in form?
3. **Key Concept** Describe the organization of a leaf-cutter ant society. What are the roles of the different castes?
4. What information is passed on by the dances of honeybees? Compare the messages of both types of dances.
5. **Critical Thinking Drawing Conclusions** The compound eyes of insects are better at detecting movement than the fine details of an image. Why might the ability to detect movement be more important in insects than in some other animals, such as humans?

iTEXT Assessment Use iText to review the important concepts in Section 28–3.

MAKING CONNECTIONS

Cells and Societies
Recall from Chapter 7 that the cells in multicellular organisms are specialized to perform specific functions. Compare the individual cells in an organism with the individual members of an insect society.