THEME FOCUS Structure and Function
Arthropods' specific adaptations allow them to live in many habitats.

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

Section 1

Reading Preview

Essential Questions

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

Review Vocabulary

ganglion: a group of nerve cell bodies that coordinates messages

New Vocabulary

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

Multilingual eGlossary

Arthropod Characteristics

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

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

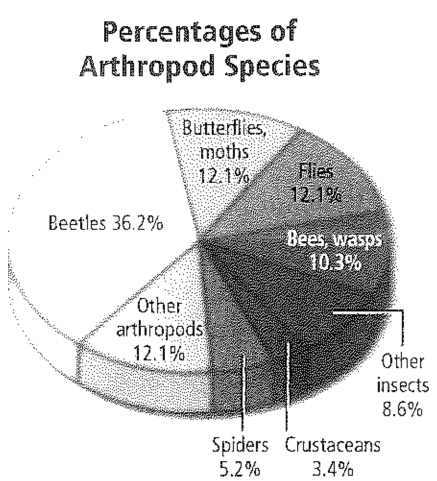
Arthropod Features

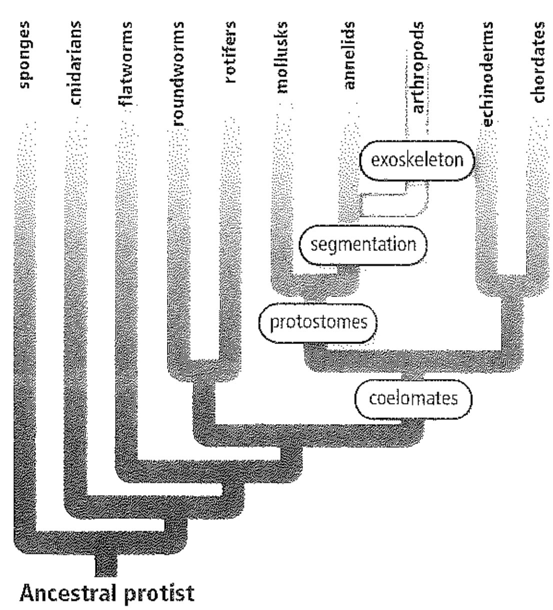
Copepods belong to phylum Arthropoda (ar THRAH puh duh). Between 70 and 85 percent of all named animal species are arthropods (AR thruh pahdz). As shown in the circle graph in **Figure 1,** the majority of arthropods are insects, which includes beetles, butterflies, moths, flies, bees, and wasps.

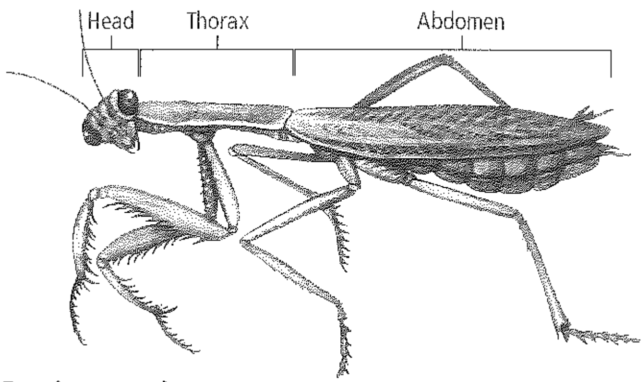
Find arthropods on the evolutionary tree shown in **Figure 1.** Follow the branches and you will see that, like annelids, arthropods are segmented invertebrates with bilateral symmetry, coelomate body cavities, and protostome development. Unlike annelids, arthropods have exoskeletons with jointed appendages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

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

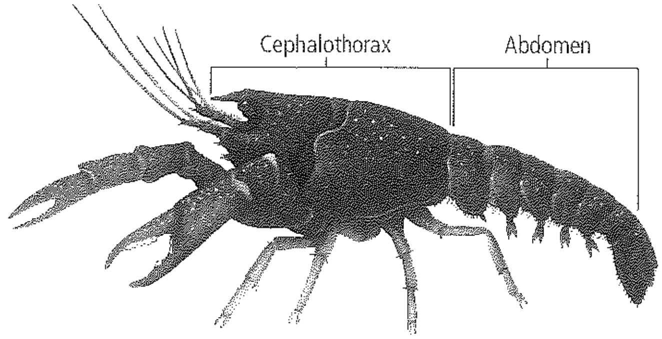
Figure 1 Most arthropods are insects, as shown by the blue segments on the graph. Arthropods are coelomates and show protostome development.
Interpret ***what percentage of arthropods is comprised of crustaceans and spiders.***







Praying mantis



Crayfish

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

Personal Tutor

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

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

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

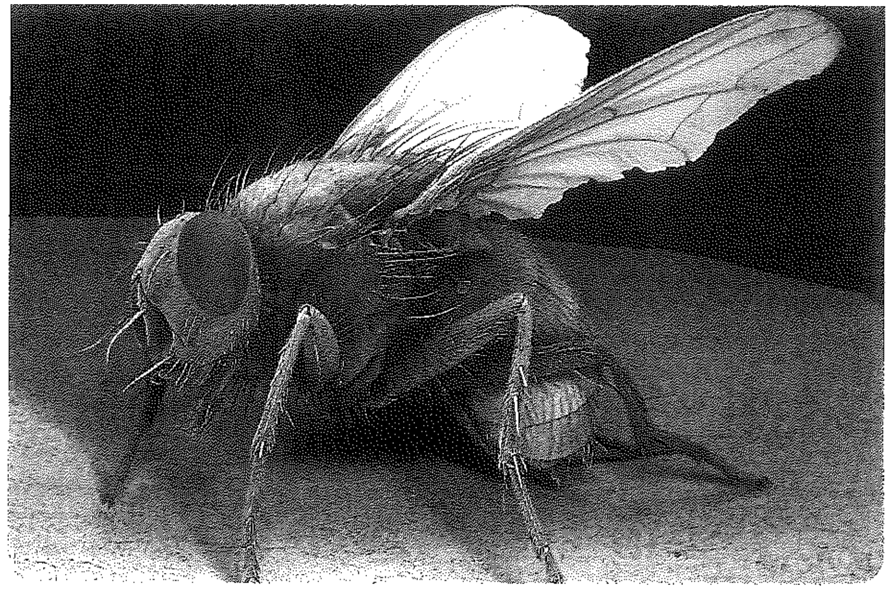
Exoskeleton Arthropods have hard exoskeletons on the outside of their bodies, similar to a lightweight suit of armor. The exoskeleton provides a framework for support, protects soft body tissues, and slows water loss in animals that live on land. It also provides a place for muscle attachment.

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

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

Figure 3 Like a door hinge, the joint in this fly's leg can bend in only one direction.

Explain *how jointed appendages benefit animals with exoskeletons.*



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

Launch Lab

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

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

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

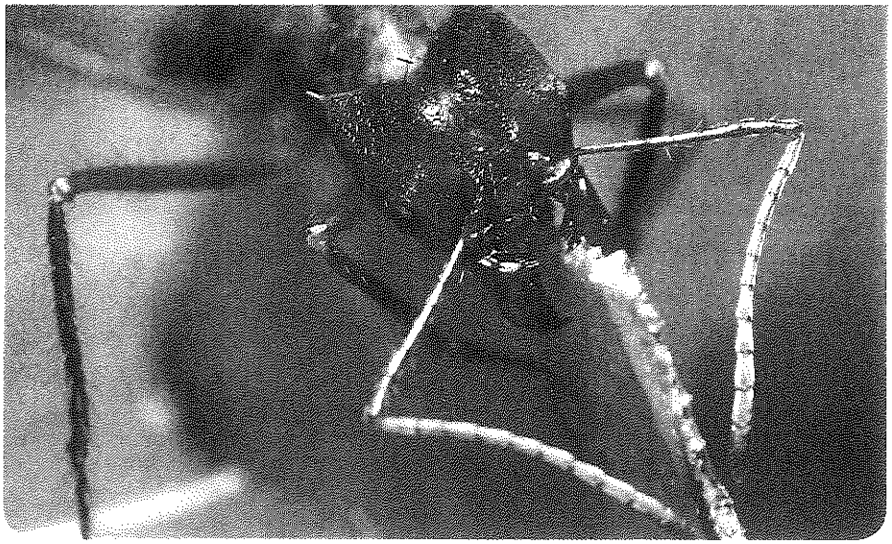


Figure 5 This leafcutter ant uses its mandibles to cut a leaf from a tree. Once fungus grows on the leaf cutting, the ant will feed the fungus to its larvae.

Body Structure of Arthropods

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

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

Study Tip

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

MiniLab 1

Compare Arthropod Mouthparts

MiniLab

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

Procedure

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

Analysis

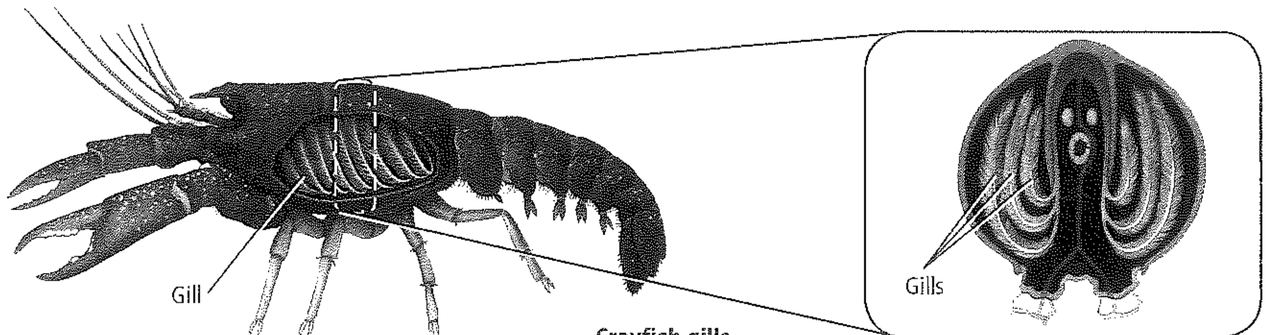
1. **Compare and contrast** the different mouthparts that you observed.
2. **Infer** the type of diet each arthropod might eat based upon your observations of their mouthparts.

Visualizing Respiratory Structures

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

Gills

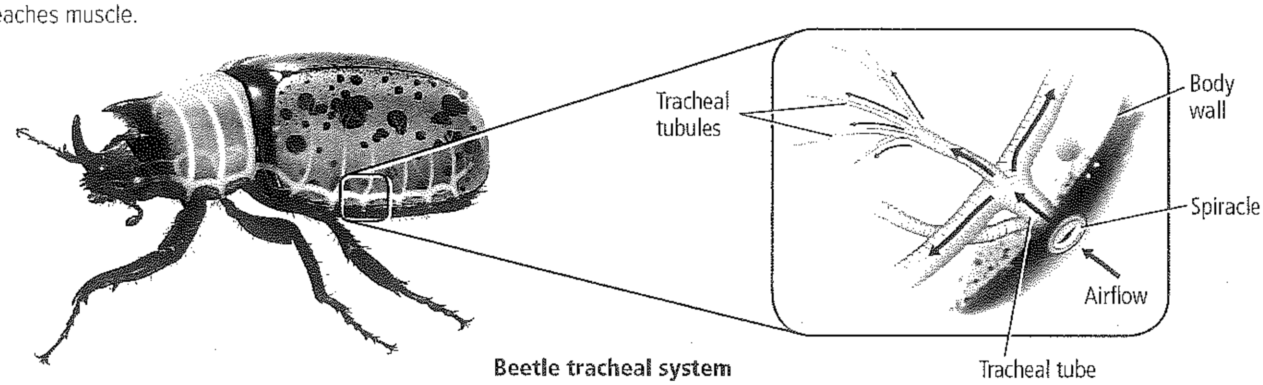
A crayfish lives in an aquatic environment and uses gills to obtain oxygen. The cross section illustrates how the gills are divided. This provides a large surface area in a small space for the exchange of gases.



Crayfish gills

Tracheal Tubes

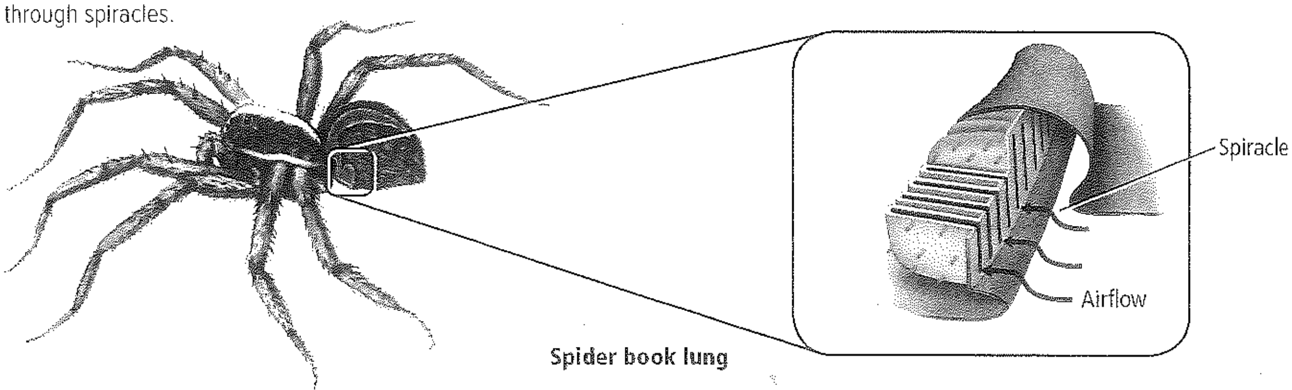
Insects such as this beetle have tracheal tubes that branch into smaller and smaller tubules to carry oxygen throughout the body. Air enters the respiratory system through spiracles, then travels from the tracheal tubes to tracheal tubules until it reaches muscle.



Beetle tracheal system

Book Lungs

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



Spider book lung

Animation

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

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

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

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

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

FOLDABLES
Incorporate information from this section into your Foldable.

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

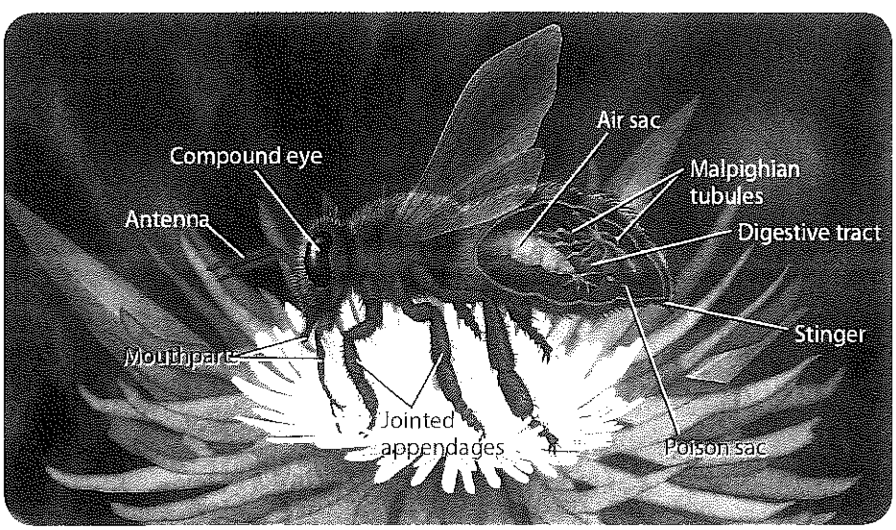


Figure 7 Most arthropods get rid of cellular wastes through Malpighian tubules.
Describe ***another function of Malpighian tubules.***

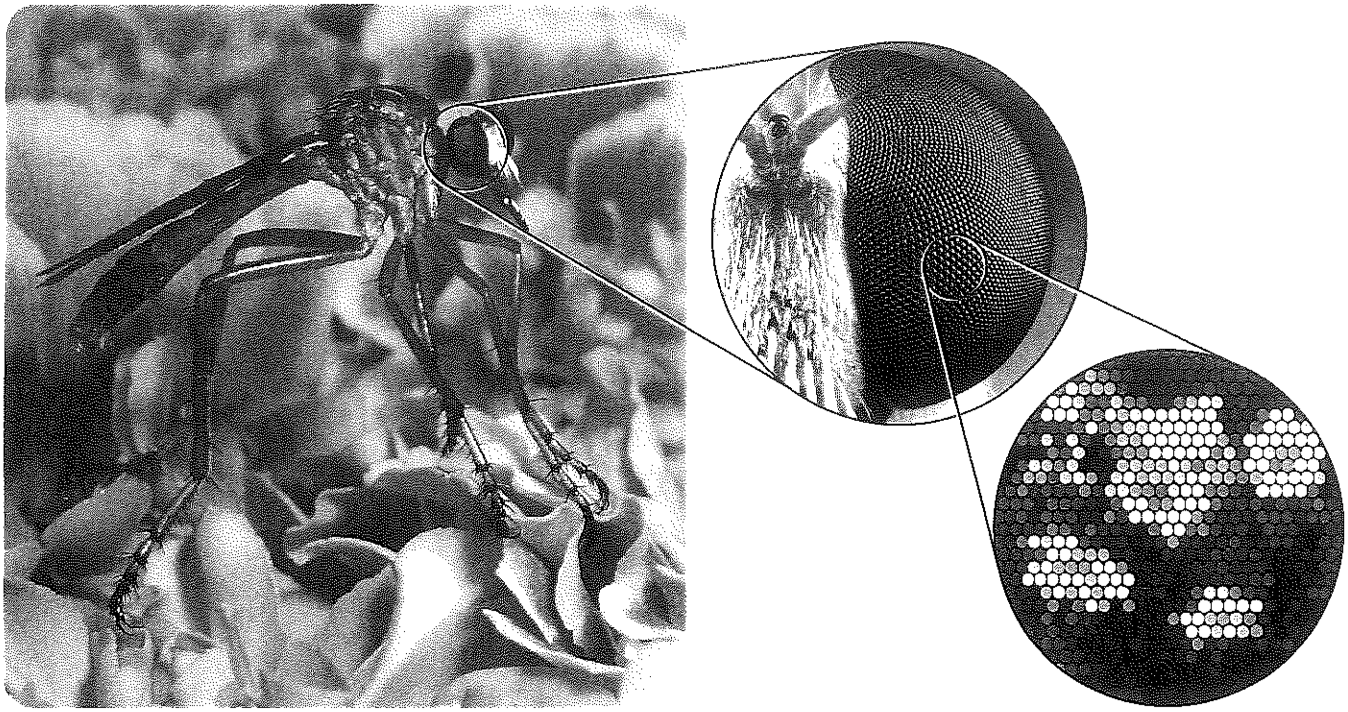


Figure 8 Compound eyes enable flying arthropods to see things in motion easily. The image the fly sees might not be as clear as that seen by a vertebrate. That blurry image is all the fly requires for its way of life.
Infer ***how a fly stays safe from predators if it has blurry vision.***

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.

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

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

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

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

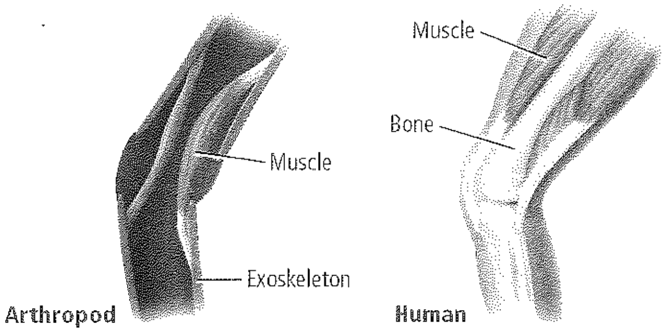


Figure 9 The muscles of an arthropod attach inside of the exoskeleton to each side of the joint. The muscles in a human limb attach to the outer surfaces of the bones.

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

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

Section 1 Assessment

Section Summary

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

Understand Main Ideas

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

Think Critically

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

WRITING in Biology

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

Section 2

Reading Preview

Essential Questions

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

Review Vocabulary

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

New Vocabulary

cheliped
swimmeret
chelicera
pedipalp
spinneret

Multilingual eGlossary

Arthropod Diversity

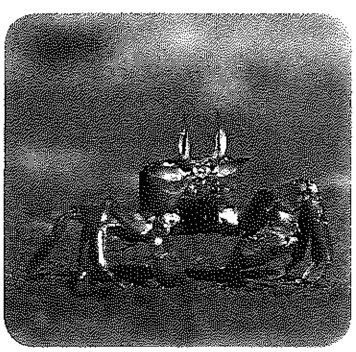
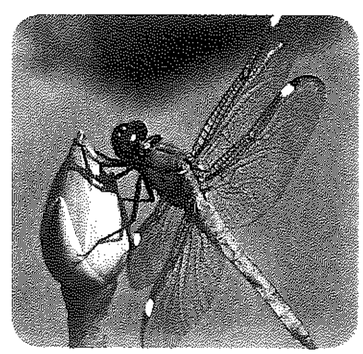
MAIN Idea Arthropods are classified based on the structure of their segments, types of appendages, and mouthparts.

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

Arthropod Groups

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

Table 1 Arthropod Characteristics — Interactive Table

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

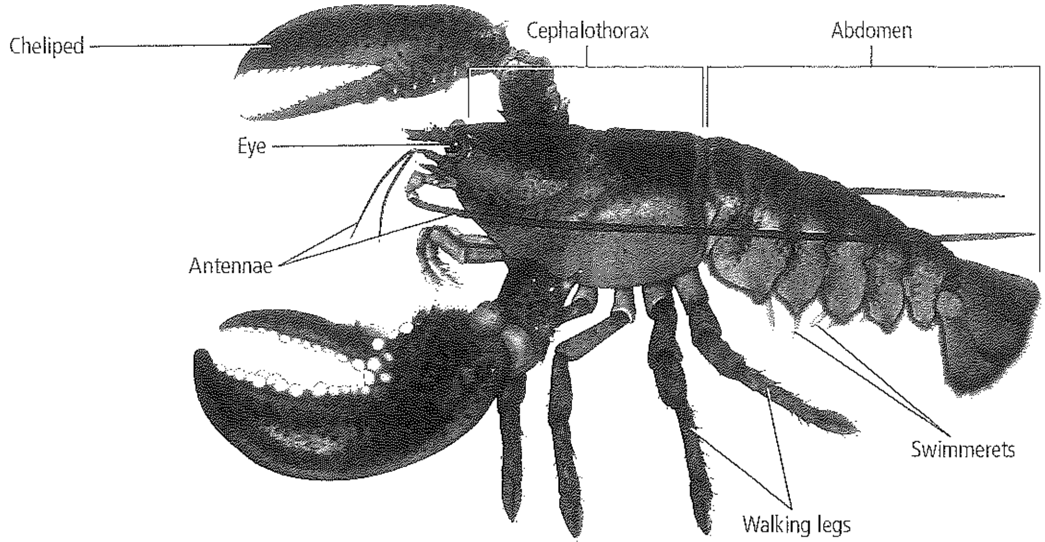


Figure 10 Lobsters are aquatic crustaceans. Note the chelipeds for catching and crushing food, the thick cephalothorax with attached walking legs, the antennae, and the abdomen with attached swimmerets.
Consider ***how else a lobster might use its chelipeds.***

Crustaceans

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

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

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

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

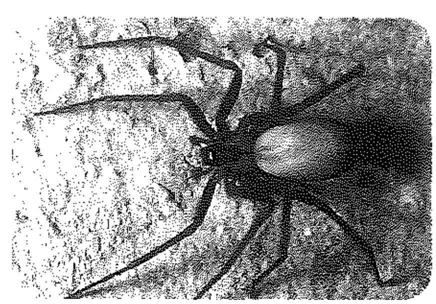
Virtual Lab

Spiders and Their Relatives

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

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

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



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

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

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

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

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

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

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

VOCABULARY

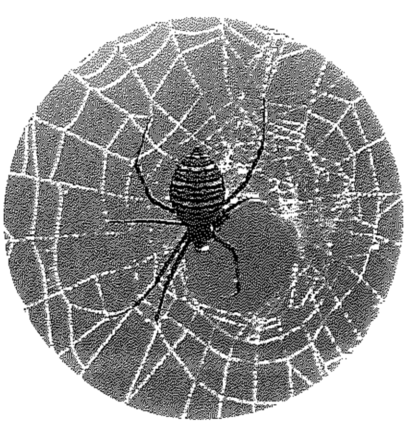
SCIENCE USAGE V. COMMON USAGE

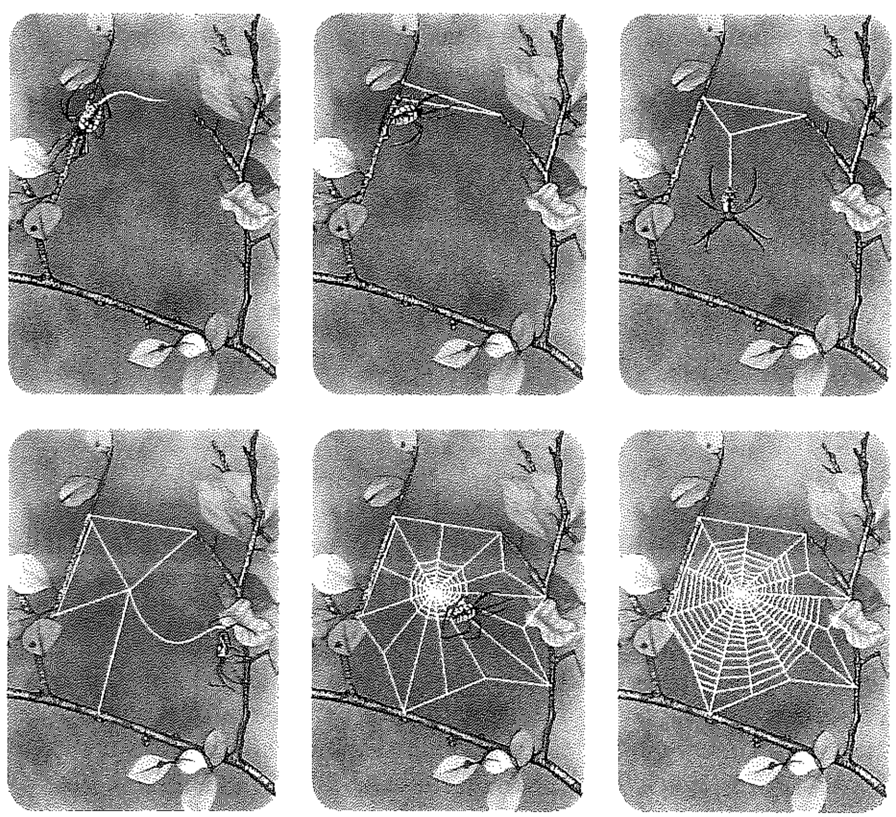
Weave

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

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

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





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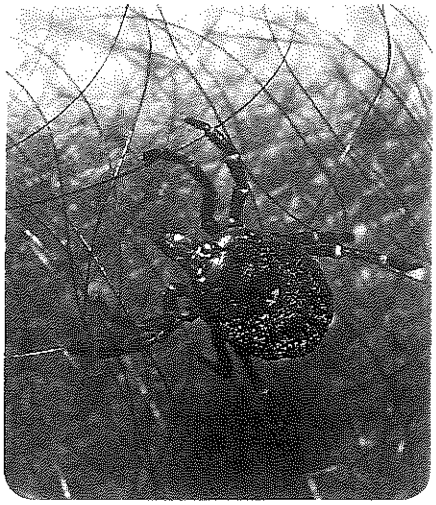
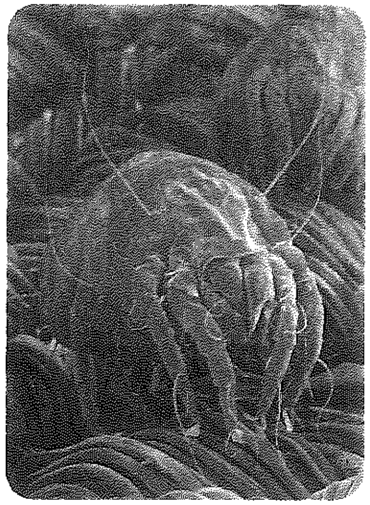


Tick



Mite

Scorpion

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

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

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

MiniLab 2

Compare Arthropod Characteristics

MiniLab

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

Procedure

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

Analysis

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

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

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

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

Section 2 Assessment

Section Summary

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

Understand Main Ideas

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

Think Critically

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

Online Quiz

Reading Preview

Essential Questions

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

Review Vocabulary

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

New Vocabulary

metamorphosis
pupa
nymph
caste

Multilingual eGlossary

Insects and Their Relatives

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

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

Diversity of Insects

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

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

External Features

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

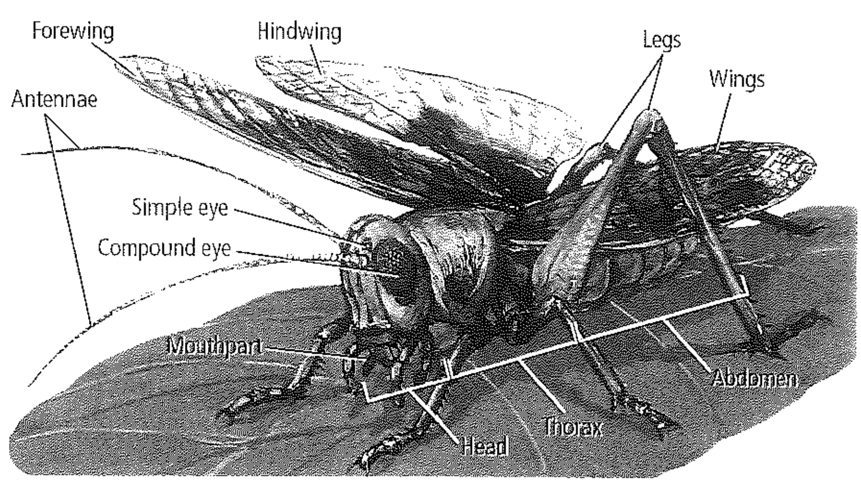


Figure 15 The head, thorax, and abdomen regions of this grasshopper are characteristic of insects.

Compare ***how the body regions of insects differ from those of crustaceans.***

Animation

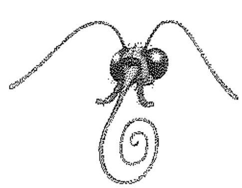
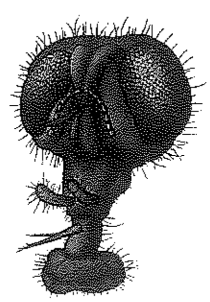
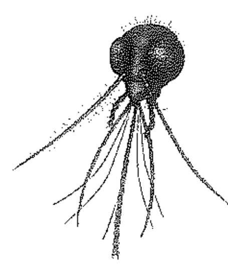
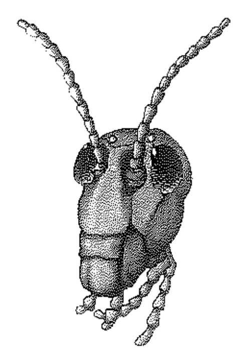
Insect Adaptations

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

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

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

Table 2 Insect Mouthparts — Interactive Table

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

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

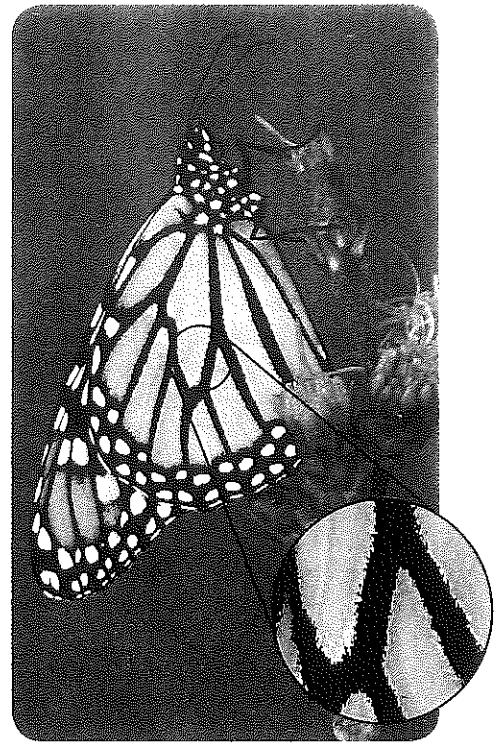


Figure 16 Butterfly wings are covered with fine scales.

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

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

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

DATA ANALYSIS LAB 1

Based on Real Data*

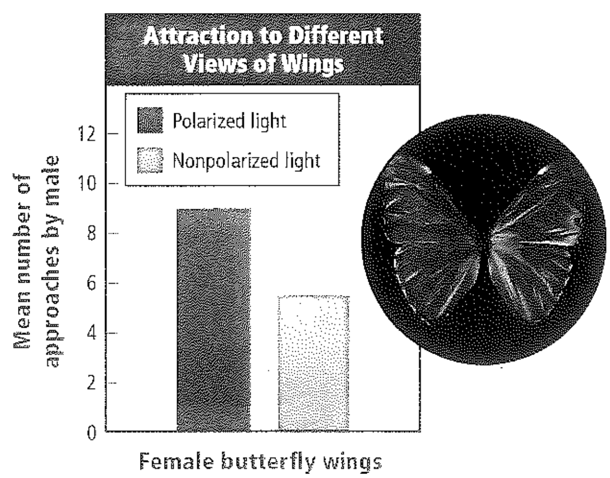
Interpret the Graph

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

Think Critically

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

Data and Observations



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

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

VOCABULARY

WORD ORIGIN

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

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

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

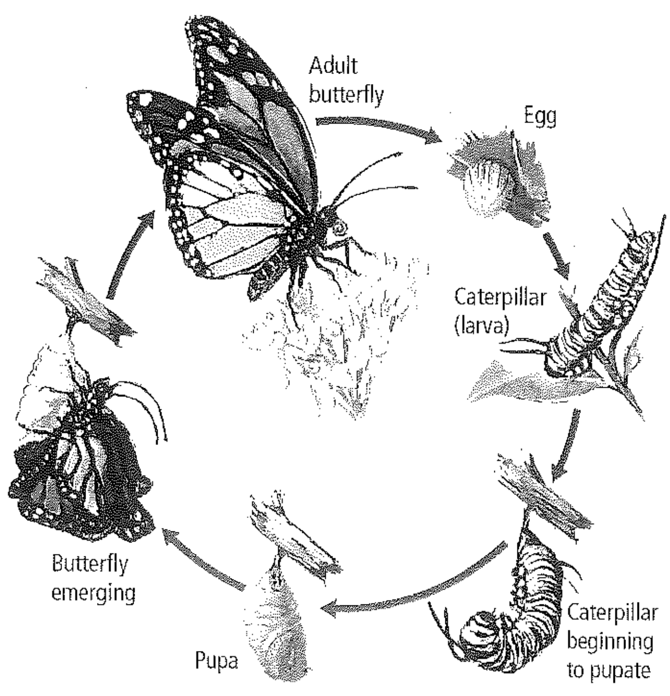
Reading Check **Summarize** the life cycle of an insect that undergoes complete metamorphosis.

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

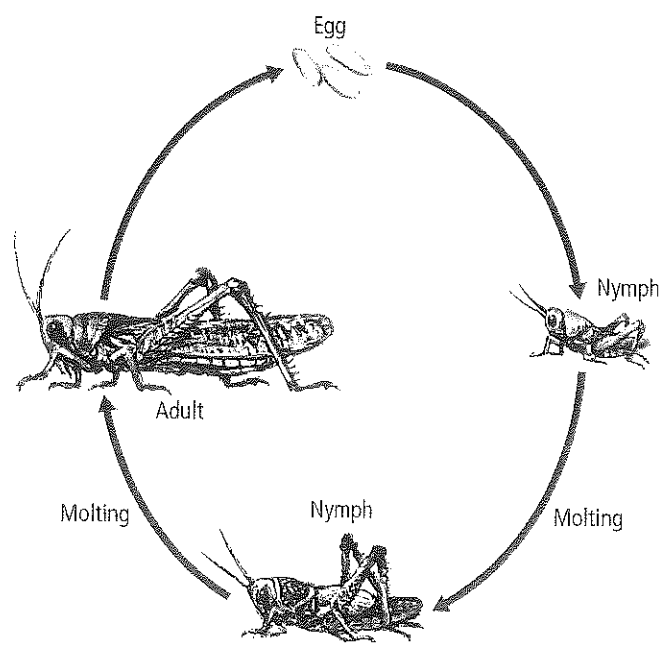
Figure 17 Insects that undergo complete metamorphosis have a resting stage called a pupa. This stage is absent in insects that undergo incomplete metamorphosis.

Animation

BrainPOP®



Complete metamorphosis



Incomplete metamorphosis

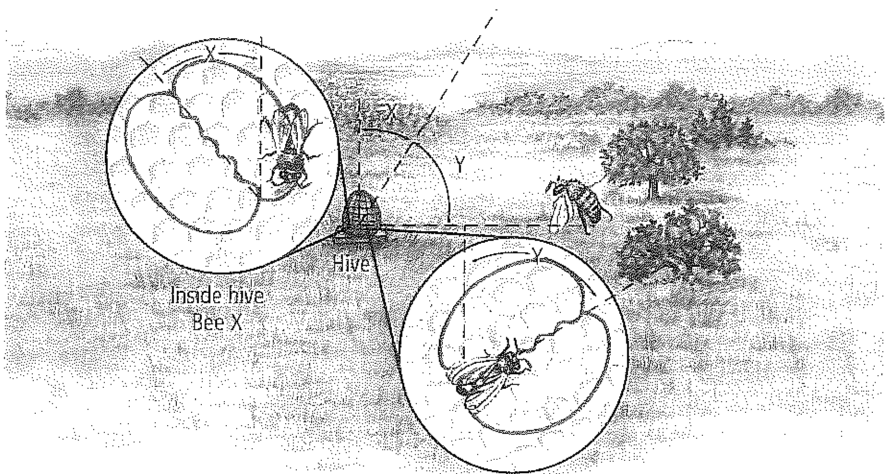


Figure 18 The honeybee's figure-eight waggle dance indicates the direction of the food in relation to the angle of the Sun.
Interpret *where Bee X has found food.*

Animation

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

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

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

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

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

CAREERS IN BIOLOGY

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

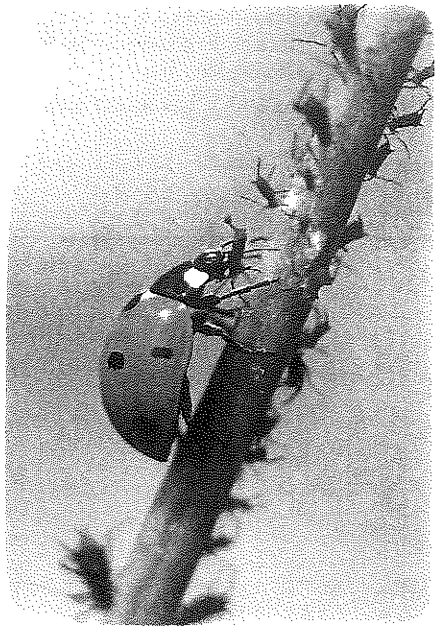


Figure 19 Not only are insects important in pollinating flowers, some are important in feeding on harmful insects. This ladybird beetle feeds on plant pests.

Explain ***how insects maintain stability in ecosystems.***

What's BIOLOGY Got To Do With It?

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

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

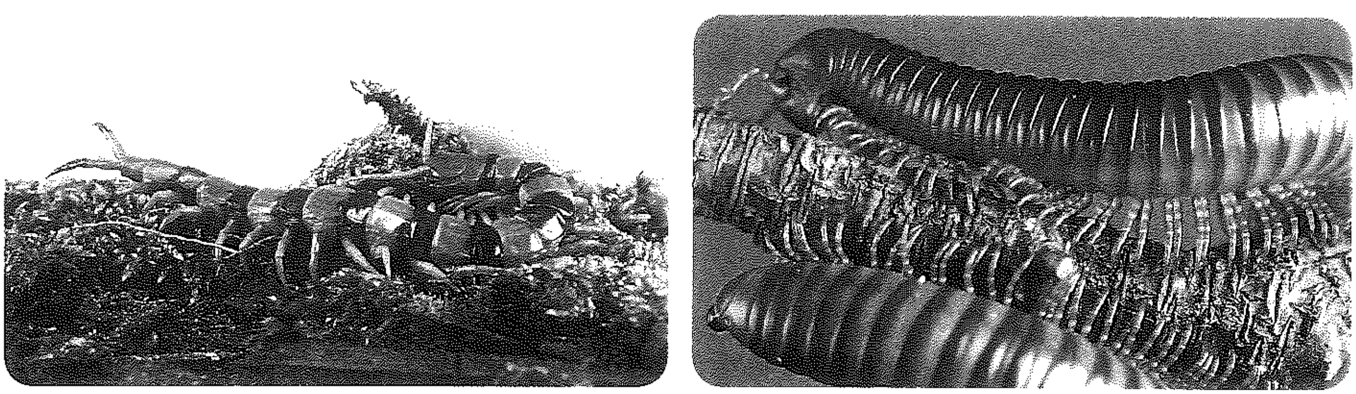
How is all this insect damage kept in check? In the past, chemicals were used indiscriminately to control insects. However, the overuse of chemicals disrupted food chains, reduced numbers of beneficial insects, and insects developed resistance to the insecticides. Use of biological controls has become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

Centipedes and Millipedes

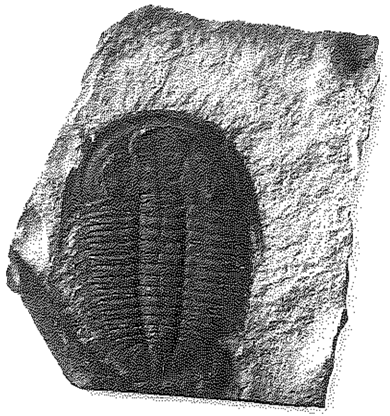
The centipedes of class Chilopoda and the millipedes of class Diplopoda are close relatives of insects. Centipedes move quickly and live in moist places under logs, bark, and stones. They have long, segmented bodies, and each segment has one pair of jointed legs. The first pair of appendages is modified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

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

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

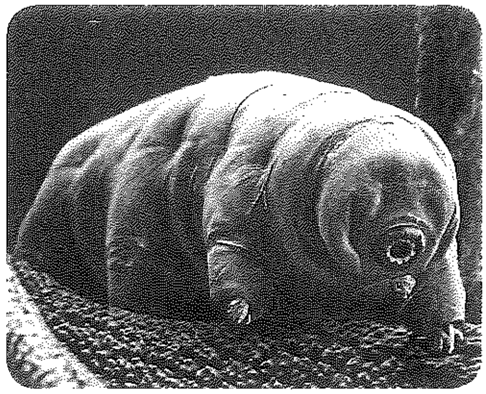


Centipede **Millipede**



Trilobite fossil

Color-Enhanced SEM Magnification: 400×



Tardigrade

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

Evolution of Arthropods

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

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

Section 3 Assessment

Section Summary

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

Understand Main Ideas

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

Think Critically

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

MATH in Biology

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

Online Quiz

In the Field

Career: Forensic Entomologist

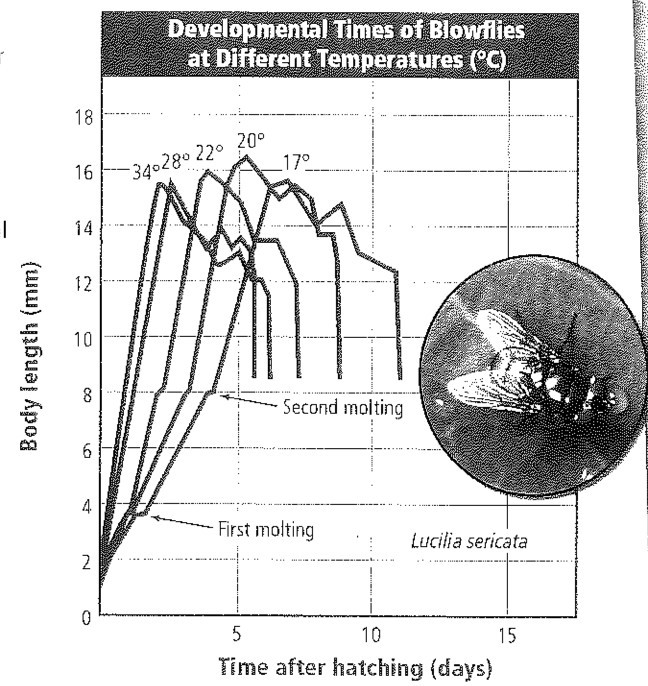
Insect Evidence

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

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

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

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



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

MATH in Biology

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

WebQuest

BIOLAB

WHERE ARE MICROARTHROPODS FOUND?

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

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

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

Safety Precautions

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

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

SHARE YOUR DATA

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

(t)Science Photo Library/Alamy; (b)Daisuke Morita/Getty Images

Chapter 26 Study Guide

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

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

Section 1 Arthropod Characteristics

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

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

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

Section 2 Arthropod Diversity

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

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

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

Section 3 Insects and Their Relatives

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

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

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

Section 1

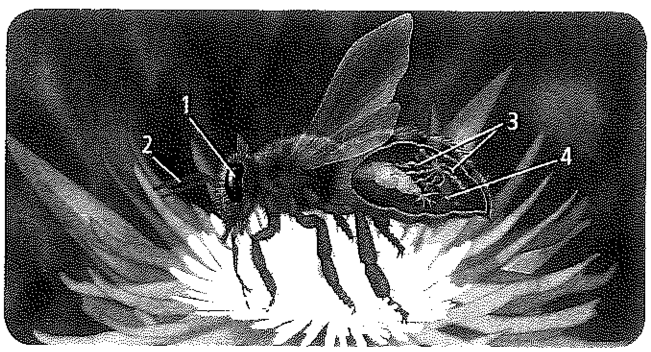
Vocabulary Review

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

1. Spiracles are to breathing as __________ are to excreting wastes.
2. Compound eye is to sense organ as mandible is to __________.
3. Head is to thorax as __________ is to abdomen.

Understand Main Ideas

Use the diagram below to answer questions 4 and 5.



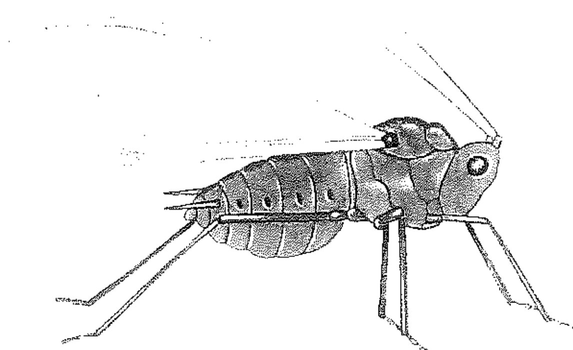
4. Which labeled structure helps terrestrial arthropods maintain water balance?
   A. 1
   B. 2
   C. 3
   D. 4
5. Which labeled structure would an arthropod use to sense odors in its environment?
   A. 1
   B. 2
   C. 3
   D. 4
6. Which group of words has one that does not belong?
   A. exoskeleton, chitin, molting, growth
   B. mandible, antennae, appendage, leg
   C. cephalothorax, thorax, head, abdomen
   D. simple eye, compound eye, tympanum, thorax
7. The relationship between muscle size and exoskeleton thickness limits which in an arthropod?
   A. diet C. motion
   B. habitat D. size

Constructed Response

8. BIG Idea Make a table that lists arthropod structures, their functions, and an analogy of what each structure is like in a world of human-made devices. For example, a particular bird's bill that pulls insects out of bark might be compared to tweezers that can pull a sliver out of skin. Use the following structures in your table: antennae, exoskeleton, mandibles, tracheal tubes, and tympanum.
9. **Open Ended** Katydids are members of the grasshopper family. Most katydids are green, but occasionally both pink and yellow katydids appear. Make a hypothesis to explain why pink and yellow katydids sometimes appear.

Think Critically

Use the diagram below to answer question 10.



10. CAREERS IN BIOLOGY Arborists, people who specialize in caring for trees, sometimes spray horticultural oils on fruit trees to control aphids, the plant pest shown in the diagram. Based on your knowledge of insect anatomy, analyze why oils are an effective treatment to control plant pests.
11. **Infer** Some species of flowers produce heat that attracts certain beetles to live inside the bloom. Infer how the plant and the beetle both benefit from this relationship.

Online Test Practice

Chapter 26 Assessment

Section 2

Vocabulary Review

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

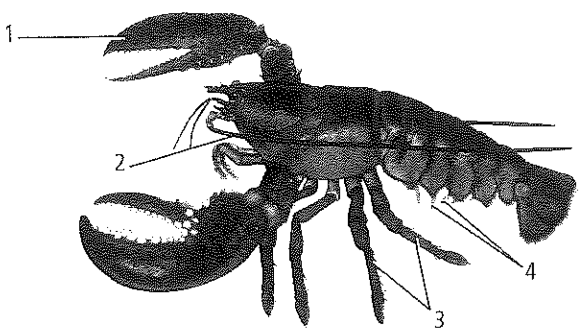
12. cheliped, swimmeret

13. chelicera, pedipalp

14. cheliped, chelicera

Understand Main Ideas

Use the diagram below to answer question 15.



15. Which structure would a lobster use to catch and crush food?
    A. 1 C. 3
    B. 2 D. 4

16. Which is not a characteristic of arachnids?
    A. chelicerae C. spinnerets
    B. pedipalps D. antennae

17. An animal you found on the forest soil has two body sections, no antennae, and large pincers as the second pair of appendages. What type of animal is it?
    A. tick C. spider
    B. scorpion D. lobster

18. In spiders, the spinnerets are involved in which activity?
    A. defense C. circulation
    B. getting rid of waste D. spinning silk

19. Which is not a characteristic of mites?
    A. one oval-shaped body section
    B. carry lyme disease bacteria
    C. less than 1 mm long
    D. animal parasite

Constructed Response

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

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

Think Critically

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

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

Section 3

Vocabulary Review

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

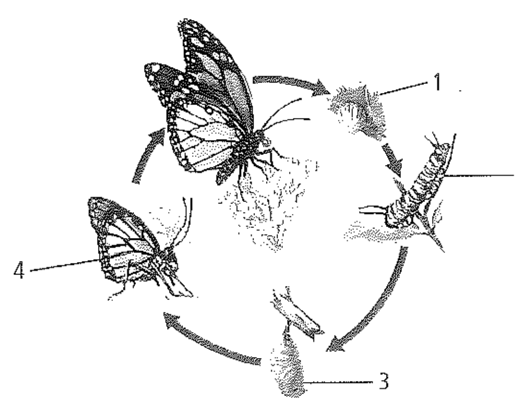
24. incomplete metamorphosis, pupa, larva, adult

25. complete metamorphosis, nymph, adult, molt

26. pupa, larva, nymph, caste, adult

Understand Main Ideas

Use the diagram below to answer question 27.



27. Which stage does not belong in the diagram of complete metamorphosis?
    A. 1 C. 3
    B. 2 D. 4

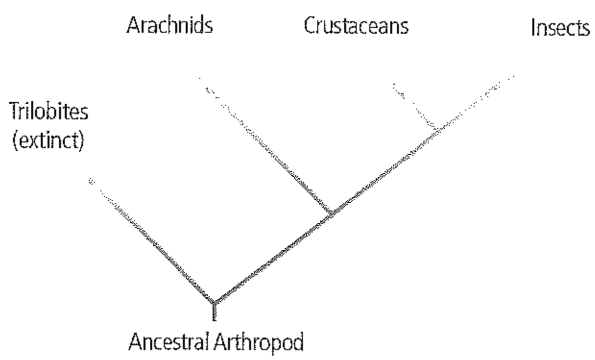
Online Test Practice

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

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

Constructed Response

Use the diagram below to answer questions 30 and 31.



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

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

Think Critically

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

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

Summative Assessment

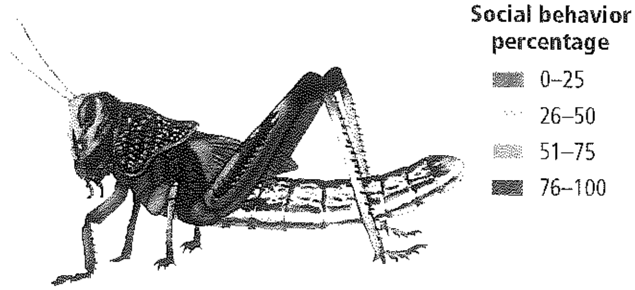
34. BIG Idea Select an arthropod from this chapter. Highlight its adaptations and explain how they help it thrive in its habitat.

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

DBQ Document-Based Questions

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

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



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

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

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

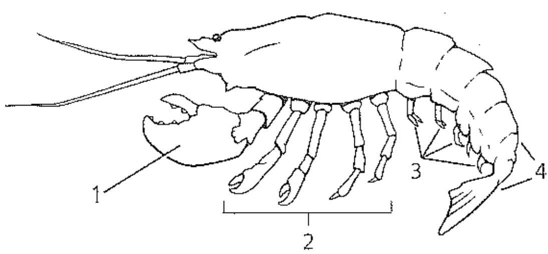
Standardized Test Practice

Cumulative

Multiple Choice

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

Use the diagram below to answer questions 2 and 3.



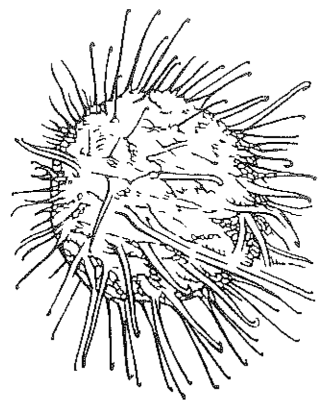
2. In which group does this animal belong?
   A. copepods
   B. crustaceans
   C. insects
   D. spiders

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

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

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

Use the drawing below to answer question 6.



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

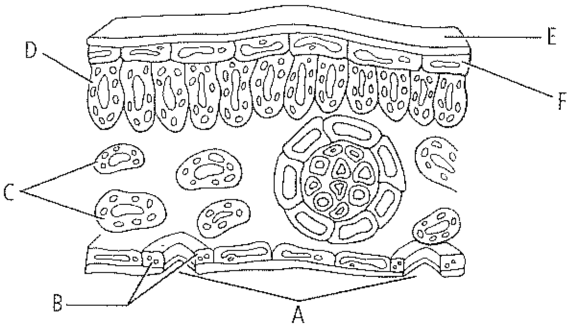
7. Which process is related to sexual reproduction in animals?
   A. budding
   B. fertilization
   C. fragmentation
   D. parthogenesis

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

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

Short Answer

Use the diagram below to answer question 10.



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

11. Which characteristics differentiate arthropods from other invertebrates?

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

13. What characteristics do all mollusks share?

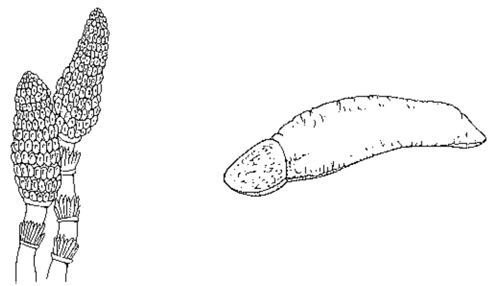
14. Compare and contrast how blood circulates through an insect with the circulation of blood in another kind of animal.

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

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

Extended Response

Use the illustrations below to answer question 17.



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

18. Evaluate the advantages and disadvantages of an exoskeleton.

Essay Question

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

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

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

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

NEED EXTRA HELP?

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