Before beginning this section review with your students the objectives listed in the Student Edition. Section 1 describes the common characteristics of arthropods. The arthropod family tree shows that this phylum of organisms is divided into two groups: those with jaws and those with fangs or pincers.

Tell students that one of the characteristics of arthropods is an exoskeleton, or “outer skeleton,” constructed of the strong, chemically-resistant material called chitin. Ask students to brainstorm a list of advantages and disadvantages of an exoskeleton.

(Advantages: protection, muscle attachment, and reduction of water loss. Disadvantages: Does not “stretch” for growth, can be heavy, and can be vulnerable to breaking or cracking.)

Jointed Appendages

Whether you are looking at a scorpion or a leaf-footed bug, as shown in Figure 1, when you see an arthropod, you will probably notice its appendages. An appendage is a structure that extends from the arthropod’s body wall. Unlike the parapodia and setae of annelids, arthropod appendages have joints that bend. The phylum name, Arthropoda, literally means “joint foot.” A variety of jointed appendages are found in arthropods, including legs for walking, antennae for sensing the environment, and mouthparts for sucking, ripping, and chewing food.

Arthropods almost certainly share a distant common ancestor with the annelid worms. Like annelids, arthropods have a coelom and a segmented body. Arthropod fossils, some as much as 600 million years old, are among the oldest, best-preserved fossils of multicellular animals. Among the most numerous of the early arthropods were the now-extinct trilobites, which lived in the sea. Like modern arthropods, trilobites had segmented bodies and jointed appendages, and they were the first animals to have eyes capable of forming images. Trilobites became extinct about 250 million years ago. The first terrestrial arthropods were probably scorpions similar to the modern scorpion shown in Figure 1.
Arthropod Diversity

If a prize were given for sheer numbers, it would go to the arthropods. The total number of arthropod species exceeds that of all other kinds of animals combined. About 900,000 species of arthropods have been recorded, and probably at least as many remain to be classified. There are more species of beetles alone than there are of vertebrates. Scientists estimate that 10^{18} arthropods are alive at any one moment! The great majority of arthropods are small, about 1 mm (0.04 in.) in length. The very smallest are parasitic mites only 80 µm (0.003 in.) long. The largest arthropods are gigantic crabs 3.6 m (12 ft) across, found in the sea near Japan.

Living arthropods are traditionally divided into two groups, arthropods with jaws and arthropods with fangs or pincers. As shown in Figure 2, arthropods with jaws belong to either subphylum Uniramia (yoo nuh RAY mee uh) or to subphylum Crustacea (kruhs TAY shuhs). Arthropods with fangs or pincers belong to subphylum Chelicerata (chuh LIS uh rahd uh). Each of these three subphyla represents a distinct evolutionary line.

Figure 2  Phyllogenetic tree
This phyllogenetic tree shows the relationships among the three arthropod subphyla which form two groups: those with jaws and those with fangs or pincers.

---

**Teach**

**Reading Organizer** As students read this section, have them put the various classes of arthropods and their descriptions on index cards. The class name should be placed on one side and the description on the other. In addition, students could make cards with the class name on one side and examples on the other. Have students use the cards as flash cards to review the section.

**Interpreting Visuals** Explain to students that the phylogenetic tree in Figure 2 “reads” like a graph up the Y axis, but not from left to right across the X axis. Explain further: Time progresses up the Y axis. That is, points on the tree closer to the bottom of the page denote time longer ago, and points on the tree closer to the top of the figure denote more recent time. However, organismal change does not progress from left to right along the X axis. Organismal change is shown whether moving to the left or right.

**Teaching Tip** Jointed Appendages Have students read the Evolutionary Milestone on page 664. Remind them that jointed appendages were a major evolutionary development. Have students point out the joints in the appendages shown in Figure 1.

**did you know?**

“Jointed Foot” The prefix “arthro” comes from a Greek word meaning “joint,” and the prefix “pod” comes from another Greek word meaning “foot.” The word arthritis refers to an inflammation of the joints. A podiatrist is a doctor who treats conditions of the feet and a pseudopod is also known as a “false foot.”
Interactive Reading Assign Chapter 30 of the Holt Biology Guided Audio CD Program to help students achieve greater success in reading the chapter. Auditory

Teaching Tip Arthropod Segmentation Have students look through this chapter and find examples of trends in arthropod body plans. Ask: Which are more segmented, larvae or adults? (larvae) Which types of arthropods show more segmentation? (Answers will vary. Millipedes and centipedes are highly segmented.)

Using the Figure Have students discuss which characteristics from the list can be seen in the two arthropods pictured in Figure 3. (Students can see the external structures on the list, but not the internal structures.)

Compound Eyes Many arthropods have compound eyes, shown in Figure 4. A compound eye is an eye composed of thousands of individual visual units, each with its own lens and retina. The brain receives input from each of the units, and then composes an image of an object. While the image formed is not as clear as what you see, arthropods see motion much more quickly. This is why it is so difficult to sneak up on a fly. Some arthropods also have simple, single-lens eyes that do not form images, but simply distinguish light from dark. Most insects have both compound and simple eyes. In dragonflies and locusts, these simple eyes function as horizon detectors. The ability to see the horizon helps the insect stabilize its position during flight.

Arthropod Body Plan
While arthropods may be quite different in appearance, they share a number of internal and external features, which are summarized in Figure 3. There is great variation in appearance among arthropod species, and not every species has every feature listed. However, these features are characteristic of the phylum as a whole.

Segmentation
In arthropods, individual body segments often exist only during the larval stage. For example, when you look at a butterfly larva (a caterpillar), you can easily see that it has many segments. However, if you look closely at an adult butterfly, you will see only three body regions. In most arthropods the many body segments fuse during development to form three distinct regions—the head, the thorax (midbody region), and the abdomen. In some arthropods, such as the crab shown at the top in Figure 3, the head is fused with the thorax to form a body region called the cephalothorax.

Figure 3 Arthropod characteristics. These eight characteristics are typical of arthropods, although not all arthropods show each characteristic.

Characteristics of Arthropods
- Jointed appendages
- Segmentation
- Distinct head, often with compound eyes
- Exoskeleton
- Respiration by gills, tracheae, or book lungs
- Open circulatory system
- Excretion through Malpighian tubules
- Wings on many arthropods

Figure 4 Compound eyes. The compound eye of this house fly is made of thousands of individual units. Magnification: 22×
Exoskeleton
The outer layer of the arthropod body is a rigid exoskeleton (often called a shell) composed primarily of chitin. The exoskeleton is thin and flexible where the joints of the appendages are located. Muscles attached to the interior surfaces of the exoskeleton can pull against it, causing the animal's joints to bend. As shown in Figure 5, many arthropods can use their jointed appendages to perform complex movements. While chitin is tough, it is brittle and breaks easily. As arthropods increase in size, their exoskeletons must become thicker to withstand the pull of larger muscles without breaking. However, an increase in thickness of the exoskeleton adds weight, restricting the size arthropods can reach. 1 2 3

The exoskeleton of the different arthropod groups varies greatly in thickness. If you have ever attempted to swat a large insect, you know that its exoskeleton can be difficult to crush. Crustaceans, for example, have a thick, relatively inflexible exoskeleton. In comparison, the exoskeleton of other insects and some arachnids is fairly soft and flexible. Regardless of the nature of an arthropod's exoskeleton, it provides protection from injury and helps to prevent water loss. 1

**Evaluating Jointed Appendages**

To understand the importance of jointed appendages, test your range of movement without and with bending your joints.

**Materials**
meterstick, paper, and pencil

**Procedure**

1. Work in pairs, and assign one person to be the test subject and one person to record the data.
2. The test subject extends one arm straight out in front of the body. The subject then places a meterstick along the inside of the arm, as shown in the illustration. The elbow should not be bent.
3. The recorder measures and records the distance along the meterstick that the test subject can reach with extended (not bent) fingers.
4. The test subject now tries to increase the range of movement by bending the fingers only. The recorder measures and records the closest and farthest distance along the meterstick that can be reached.
5. The test subject now tries to increase the range of motion by bending the elbow. The recorder measures and records the closest and farthest distance along the meterstick that can be reached.

**Analysis**

1. **Describe** how eating breakfast might be different if you did not have joints on your fingers and at your elbows.
2. **Predict** the advantages an animal with jointed appendages has over an animal without jointed appendages when capturing and consuming food.
3. **Predict** the advantages for an arthropod that has sense organs (eyes and odor detectors) on the ends of jointed appendages.

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Cultural Awareness

**Crickets**
To the Japanese, crickets are considered pets and a delightful source of musical and artistic pleasure. Favorite pet crickets are often given elaborate cages and beautiful porcelain water dishes. Japanese cricket owners even “tickle” their crickets with delicate hand-carved brushes to encourage them to sing. To the British, a cricket on the hearth is a sign of good luck. Bio/IPC 3C
Teaching Tip —— Basic

Molting

Ask students to brainstorm some of the problems inherent in molting. (Emerging from an exoskeleton can be hazardous to an arthropod. For about two hours after emerging from an outgrown exoskeleton, an arthropod is vulnerable to predators and the environment because its new exoskeleton has not yet hardened.) Ask students how arthropods can protect themselves during molting. (Arthropods usually hide until their new exoskeletons have hardened.)

TAKS 3 Bio 10A

Teaching Tip —— General

Arthropod Respiratory Organs

Insects have hollow branching tubes called tracheae that carry air into the body's tissues. Spiders have leaflike plates called book lungs that have a large surface area to exchange oxygen and carbon dioxide. Lobsters have gills that also have a large surface area for gas exchange.

TAKS 2 Bio 10A

Real Life

Answer Bio 3B

Topical products for head lice contain the insecticide permethrin. Most products are shampoos or creams used to treat the scalp. After such treatments, health care practitioners suggest combing the hair with a fine-toothed comb to remove the eggs. Creams are also available to treat the skin all over the body. The spread of lice can usually be prevented if people avoid sharing combs, brushes, hats, towels, and other items that may transfer lice or eggs from one person to another.

Real Life

Head lice often infect entire schools.

Head lice are notoriously difficult to control. Having clean hair will not prevent a head lice infection, and anti-lice shampoos often fail to kill immature head lice.

Finding Information

Research the latest remedies for treating head lice, and find out how to avoid infection.

Molting

A tough exoskeleton protects an arthropod from predators and helps prevent water loss. But an exoskeleton cannot grow larger, so an arthropod cannot simply grow bigger, as many other animals do. Imagine blowing up a balloon inside a soft drink can—after a certain point, the balloon cannot get any bigger. Arthropods have the same problem. In a process called molting, or ecdysis (EHK duh sis), they shed and discard their exoskeletons periodically. Molting is triggered by the release of certain hormones. Just before molting, a new exoskeleton forms beneath the old one. When the new exoskeleton is fully formed, the old one breaks open. The arthropod emerges in its new, still-soft exoskeleton, as shown in Figure 6. The new exoskeleton hardens within a few hours or a few days, depending on the species.

Respiration

The majority of terrestrial arthropods respire through a network of fine tubes called tracheae (TRAY kee ee), as shown in Figure 7. Air enters the arthropod's body through structures called spiracles and passes into the tracheae, delivering oxygen throughout the body. Valves that control the flow of air through the spiracles and prevent water loss were a key adaptation for the first arthropods that invaded land more than 400 million years ago.

Albino Roaches? People often see what they think are “albino” insects, such as roaches. These white insects are not really albinos. They have just shed their exoskeletons recently and full coloration has not yet returned.
Excretion
Terrestrial arthropods have a unique excretory system that efficiently conserves water and eliminates metabolic wastes. This system is composed of excretery units called Malpighian tubes. Malpighian tubes are slender, fingerlike extensions from the arthropod’s gut that are bathed by blood. Water and small dissolved particles in the blood move through the tubules and into the arthropod’s gut. As this fluid moves through the gut, most of the water, valuable ions, and metabolites from the fluid are reabsorbed into the arthropod’s body tissues by osmosis. Metabolic wastes remain in the gut and eventually leave the body through the anus. You can see the Malpighian tubes on the grasshopper in Up Close: Grasshopper, in Section 2 of this chapter.

An Arthropod on the Move

TAKS 3 Bio 7B

The monarch butterfly, Danaus plexippus, is a long-distance traveler. Each year, millions of these insects migrate from sites across the United States and Canada to their wintering grounds in central Mexico. Some monarchs fly up to 4,000 km on their journey. Four to five generations of monarchs are born each year. In central Mexico, some monarchs wait until the following March. Generations of Migrants Four to five generations of monarchs are born each year. In spring, most monarchs are found in the southern United States. The offspring of each successive generation move farther north to breed. Monarchs born in early fall postpone breeding until the next year. They respond to the shorter days and lower temperatures by beginning their long migration to Mexico, where they remain until the following March.

Monarchs funnel through Texas during both the spring and the fall migrations. In the fall, they use two main flyways. One, which passes through the center of the state, is about 300 km wide and is used by most monarchs. The other flyway follows the coastline. Finding Their Way Scientists at the University of Texas at El Paso have shown that monarchs use at least two methods to chart their course. Under clear skies, the butterflies note the direction of the sun with respect to north. On cloudy days, they find their way by detecting Earth’s magnetic field. The researchers demonstrated the latter method by collecting monarchs in the fall and placing them in a chamber where the magnetic field could be blocked or reversed. In the absence of a magnetic field, the butterflies flew in random directions. When the magnetic field was reversed, they flew to the northeast, the opposite of their normal migratory direction.

BIOWatch

An Arthropod on the Move

TAKS 2 Bio 8C

The Devil’s River and Frio River. Good places to observe include Seminole Canyon State Historic Park and most locations along the Devil’s River and Frio River. Discussion

- For monarchs born in the fall, what are the advantages of waiting until the following spring to breed? (Larvae born in the spring will be more likely to survive due to warmer climate and greater availability of food/vegetation.)

Close

Reteaching

Have students write the characteristics of arthropods on index cards and quiz one another with them. Interpersonal TAKS 2 Bio 8C

Quiz

True or False:
1. One characteristic of arthropods is a closed circulatory system. (False. Arthropods have open circulatory systems.) TAKS 2 Bio 8C
2. When an arthropod molts, it sheds its exoskeleton. (True) TAKS 2 Bio 8C

Alternative Assessment

Have students write review questions and answers for a trivia-type game. Pair each student with a partner, and have the students in each pair take turns asking their partner the questions. Interpersonal
Section 2

Overview
Before beginning this section review with your students the objectives listed in the Student Edition. Section 2 describes the characteristics of arachnids: spiders, scorpions, ticks, mites, and daddy longlegs.

Bellringer
Ask students to list what comes to mind when they hear the word “spider.” For homework, have students determine whether their preconceptions are accurate. For example, if students list “poisonous” have them research which spiders are poisonous. Are there poisonous spiders in your state? If students list words like “scary,” have them clarify what characteristics of spiders make them scary and have them determine the accuracy of these characteristics.

TAKS 1 Bio/IPC 2C, 2D

Motivate

Activity — Advanced
Poisonous Spiders Have students search the library or an on-line database for information about poisonous spiders around the world, such as the Australian funnel-web spider, whose bite can be lethal if left untreated. Have students make a pamphlet describing the spider and its habitat, the symptoms caused by the spider’s bite, and the measures a person should take if bitten.

Verbal TAKS 1 Bio/IPC 2C, 2D

Objectives

- Summarize the characteristics of arachnids. TAKS 2
- Identify the internal and external characteristics of brown recluse spiders. TAKS 3
- Compare spiders, ticks, and mites. TAKS 8C
- Identify the health threats posed by some arachnids. TAKS 4D, 11D

Key Terms

- chelicera
- pedipalp
- spinneret

Arachnid Modifications

Perhaps no other group of animals is more disliked and feared by humans than the arachnids—spiders, scorpions, ticks, mites, and daddy longlegs. While it is true that some spiders and scorpions are highly venomous, in general these creatures do more good than harm. For example, many spiders are major predators of insect pests, and gardeners usually welcome them. Arachnids (uh RAK nihdz) form the largest class in subphylum Chelicerata. Two minor classes, marine horseshoe crabs and sea spiders, also belong to this subphylum. The members of subphylum Chelicerata have mouthparts called chelicerae (kah LIZ ah ree) that are modified into pincers or fangs, as shown in Figure 8.

The arachnid body is made up of a cephalothorax and an abdomen. There are no antennae, and the first pair of appendages are chelicerae. The second pair of appendages are pedipalps, which are modified to catch and handle prey. (The pedipalps are sometimes specialized for sensory or even reproductive functions.) Following the pedipalps are four pairs of appendages called walking legs.

All arachnids except some mites are carnivores, and most are terrestrial. Since arachnids do not have jaws, they are able to consume only liquid food. To do so, the arachnid first injects its prey with powerful enzymes that cause the prey's tissues to liquefy. Then the arachnid sucks the liquid food into its stomach.

Spiders

The chelicerae of spiders are modified into fangs. Poison glands located in the spider's anterior end secrete a toxin through these fangs. The toxin kills or paralyzes the prey. The spider then injects enzymes into the prey that digest its tissues, and the spider sucks up the liquid food. Spiders are important predators of insects in almost every terrestrial ecosystem. Only two species of spiders living in the United States, the black widow and brown recluse, are dangerous to humans. Not all spiders build beautiful webs as the orb-builders do. Most spiders can secrete sticky strands of silk from appendages called spinnerets located at the end of the abdomen. Tubes located on some spinnerets do not produce silk. Instead, they excrete a sticky substance that the spider can use to make some silk strands adhesive.

Figure 8 Chelicerae. The baboon spider's pointed black chelicerae (fangs) and its two pair of pedipalps are clearly seen in this close-up of its head region.

Chapter Resource File

- Lesson Plan
- Directed Reading
- Active Reading

TEKS/TAKS

Student Edition
TAKS Obj 2 Bio 8C
TAKS Obj 2 Bio 10A
TAKS Obj 3 Bio 4D
TAKS Obj 3 Bio 7B
TEKS Bio 4D, 7B, 8C, 10A, 11D

Teacher Edition
TAKS Obj 1 Bio/IPC 2C, 2D
TAKS Obj 2 Bio 8C, 10A
TAKS Obj 3 Bio 4D, 7B
TEKS Bio 4D, 7B, 8C, 10A, 11D
TEKS Bio/IPC 2C, 2D

Transparencies

- Bellringer
- Anatomy of a Spider

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Chapter 30 • Arthropods
**did you know?**

**Spider Silk**  All spiders have silk glands and organs called spinnerets that spin the silk. Some spiders spin webs that are used to catch prey. Others may use webs to protect their eggs and young. Spiders do not discard their old webs but eat them to recycle the protein in them. Spiders also use silk to wrap up prey, or they spin sticky balls to throw at prey. Burrow-dwellers line their underground homes with silk.  *Bio 12C*
Teach, continued

SKILL BUILDER—GENERAL

Vocabulary Arachnids are named for Arachne, a weaver in Greek mythology. Arachne boastfully challenged the goddess Athena to a weaving contest. Arachne produced a beautiful tapestry. Athena was so enraged by Arachne’s skill that she changed Arachne into a spider.

Close

Reteaching—BASIC

Have students create crossword puzzles using the vocabulary terms in this section. Then have them trade puzzles and try to solve them. LS Verbal TAKS 1 Bio/IPC 2D

Quiz—GENERAL

1. Define the term “chelicerae.” (Chelicerae are arachnid mouthparts that are modified into fangs or pincers.) Bio 5A

2. Explain the meaning of the following statement: All arachnids except some mites are carnivores. (The statement means that most arachnids feed on animals, not on plants.) TAKS 1 Bio/IPC 2C, 2D

Alternative Assessment—ADVANCED

Have students write an essay on arachnids, highlighting the organism they think is the most fascinating and explaining why. LS Verbal TAKS 1 Bio/IPC 2C, 2D

Section 2 Review

1. Compare the body plan of spiders, scorpions, and mites, including differences in appendages. 8C

2. Describe the body and coloring of a brown recluse spider. 8C

3. Critical Thinking Summarizing Information

   Explain why a tick bite is more a cause for concern than the bite of most spiders. 8D 11D

4. Critical Thinking Evaluating Conclusions

   Is an animal that has grasping pincers, a segmented body, and two antennae correctly identified as a scorpion? Why or why not? 8C

5. *TAKS Test Prep*

   The relationship between a tick and a dog is an example of
   A. homeostasis.
   B. parasitism.
   C. commensalism.
   D. mutualism.

Answers to Section Review

1. Spider—fangs modified from chelicerae; pedipalps; two segments (cephalothorax and abdomen). Scorpion—stinger; pedipalps modified into pincers; head, thorax, and abdomen fused into one. Mite—chelicerae and pedipalps; head, thorax, and abdomen fused into one. TAKS 2 Bio 8C

2. They are up to 10 mm in length, dark brown, with a violin shape on their cephalothorax. TAKS 2 Bio 8C

3. Only two spiders in the United States are poisonous to humans. In contrast, many ticks transmit diseases, such as Lyme disease and Rocky Mountain spotted fever. TAKS 3 Bio 4D; Bio 11D

4. The identification is not correct. Scorpions have no antennae. TAKS 2 Bio 8C

5. *TAKS Doctor*

   A. Incorrect. Homeostasis is the maintenance of stable internal conditions in spite of changes in the external environment.
   B. Correct. Parasitism is a relationship in which one organism feeds on another.
   C. Incorrect. Commensalism is a relationship in which one organism benefits and the other is neither harmed nor helped.
   D. Incorrect. Mutualism is a relationship in which both organisms benefit. TAKS 3 Bio 12B
Section 3
Overview
Before beginning this section review with your students the objectives listed in the Student Edition. Section 3 describes the general body plan and life cycles of insects. Then, after discussing insect flight and the social insects, Section 3 includes the centipedes and millipedes, members (with the insects) of the Subphylum Uniramia.

TAKS 2 Bio/IPC 2C, 2D; TAKS 2 Bio 8C

Bellringer
Prepare a handout for students with the following facts:
There are more arthropod species than all other animal species combined.
Eighty-five percent of all animals are arthropods. Arthropods are our main competitors for food. If left unchecked (by nature), they could take over the world.
There are 200 million insects for every human on Earth. Insects destroy 10–15 percent of the world’s food supply each year. Insects have been on Earth for approximately 300 million years. Bush crickets have ears on their knees.

Have the students read the facts while you take attendance, then ask students which fact was the most interesting to them and why.

KEY TERMS
mandible
metamorphosis
chrysalis
pupa
nymph
caste

Preconceptions
People use the terms “insects” and “bugs” freely to refer to many organisms, some of which are not insects. Ask students to list 5 organisms that they think are insects. Then have students compare the characteristics of the organisms they listed with those of insects. Have students determine whether or not the organisms on their lists are truly insects.

TAKS 1 Bio/IPC 2C, 2D; TAKS 2 Bio 8C

Chapter Resource File
- Lesson Plan
- Directed Reading
- Active Reading
- Data Sheet for Data Lab

One-Step Planner CD-ROM
- Reading Organizers
- Reading Strategies
- Supplemental Reading

Identifying Preconceptions
The predominance of insects, especially beetles (Coleoptera), in the living world is illustrated by the blue section of this pie chart.

Table 1 Four Orders of Insects

<table>
<thead>
<tr>
<th>Order</th>
<th>Examples</th>
<th>Number of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coleoptera “shield winged”</td>
<td>Beetles, weevils</td>
<td>350,000</td>
</tr>
<tr>
<td>Diptera “two winged”</td>
<td>Flies, mosquitoes</td>
<td>120,000</td>
</tr>
<tr>
<td>Lepidoptera “scale winged”</td>
<td>Butterflies, moths</td>
<td>120,000</td>
</tr>
<tr>
<td>Hymenoptera “membrane winged”</td>
<td>Ants, wasps, bees</td>
<td>100,000</td>
</tr>
</tbody>
</table>

Insect Diversity
Anyone who has ever been on a picnic in a wooded area does not have to be told that insects are numerous. Ants, mosquitoes, gnats, flies, bees, crickets—they all want to join in while the cicadas sing in the background. These animals all belong to the arthropod subphylum Uniramia, an enormous group of mostly terrestrial arthropods that have chewing mouthparts called mandibles (jaws). Uniramians consist of three classes: Insecta (insects), Diplopoda (millipedes), and Chilopoda (centipedes).

The insects are by far the largest group of organisms on Earth, with more than 700,000 named species. Most scientists agree that there may be several million insect species in existence, with most of the undiscovered species living in the tropics. As shown in Figure 10, more than 50 percent of all named animal species are insects. More than 90 percent of these species belong to one of the four orders shown in Table 1. To read about other orders of insects, see “A Six-Kingdom System of Classification” in the Appendix of this book.

Figure 10 Species of insects

Table 1 Four Orders of Insects

- Coleoptera “shield winged”
- Diptera “two winged”
- Lepidoptera “scale winged”
- Hymenoptera “membrane winged”

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Demonstration

Bring examples of live or preserved insects to class for display, or bring detailed photographs of insects from a nature magazine. Allow students to compare the animals. Ask them to point out examples of the arthropod characteristics. (jointed appendages, segmentation, exoskeleton, wings, spiracles, etc.)

Visual

Using the Figure

Use Figure 12 to point out how the mouthparts of different insects are adapted for different functions. Grasshoppers cut and chew their food, mosquitoes puncture skin to draw out blood, and flies soak up fluids with their mouthparts.

Teaching Tip

Jumping Fleas

Dr. Miriam Rothschild is a world-class entomologist and the world's expert on fleas. In 1977 she published a paper giving the first description of the flea's jumping mechanism. Using high-speed photography that records 10,000 frames per second, Dr. Rothschild concluded that a flea's ability to leap is equivalent to a human jumping over a tower 30,000 times before exhaustion sets in. She also found that a jumping rabbit flea has 230 times more acceleration than a spacecraft reentering the Earth's atmosphere after a trip to the moon.

Insect Body Plan

Insects are primarily a terrestrial group, and aquatic insects probably had terrestrial ancestors. Although the great majority of insects are small (some are only a few centimeters in length), others are much larger. The African Goliath beetle, for example, exceeds 10 cm (4 in.) in length. Generally, the larger insects live in tropical areas. Despite great variation in their size, all insects share the same general body plan, made up of three body sections.

1. Head. Located on an insect's head are mandibles, specialized mouthparts, and one pair of antennae. The mandibles and mouthparts of different insect species are adapted for eating different foods, as shown in Figure 11. In addition, an insect's head usually has a relatively large pair of compound eyes and a pair of antennae. Like the mouthparts, antennae vary greatly in size and shape.

2. Thorax. The thorax is composed of three fused segments. Attached to the thorax are three pairs of jointed walking legs. Some insects, such as fleas, lice, and silverfish, lack wings, but other adult insects have one or two pairs attached to the thorax.

3. Abdomen. The abdomen is composed of 9 to 11 segments. In adult insects, there are no wings or legs attached to the abdomen.

Turn the facing page to learn more about one particular insect, the grasshopper, in Up Close: Eastern Lubber Grasshopper.

Career

Forensic Entomologist

Maggots crawling out of eye sockets are usually the stuff of horror films. But to forensic entomologists, insects and cadavers are part of their work. Forensic entomology is the science of using insect evidence to determine information related to a crime. By using insect evidence gathered from and around a corpse, a forensic entomologist can determine approximate time and location of death and may help provide information in investigations of sudden death, traffic accidents with no obvious cause, and possible criminal misuse of insects. Most forensic entomologists hold the Ph.D. degree. However, a student with a BS degree and a major in entomology would be qualified for a position as a research assistant, technician, or staff member in a research laboratory.
Insect Life Cycle

The life cycles of most insects are complex, and often several molts are required before the adult stage is reached. During the last molt, the young insect undergoes a dramatic physical change called metamorphosis.

**Complete Metamorphosis** Almost all insect species undergo "complete" metamorphosis, as shown in Figure 12. In complete metamorphosis, the wingless, wormlike larva encloses itself within a protective capsule called a chrysalis (KRIHS uh lihs). Here, it passes through a pupa stage, in which it changes into an adult.

A complete metamorphosis is a complex life cycle. The larvae can, however, exploit different habitats and food sources than adults. For example, the larvae of nectar-drinking butterflies are caterpillars that eat leaves! This ecological separation of young from adults eliminates competition. This increases the chance of survival for each phase of the life cycle.

**Incomplete Metamorphosis** A smaller number of species develop into adults in a much less dramatic incomplete metamorphosis, as shown in Figure 13. In these species, the egg hatches into a juvenile, or nymph (NIHMF), that looks like a small, wingless adult. After several molts, the nymph develops into an adult.

---

**Teaching Tip**

**Silk** Encourage students to research the history of the discovery of silk. The Chinese were the first to produce silk fabrics, and for about 3,000 years, they were the only people who knew how to cultivate silkworms. Chinese legends colorfully tell of the discovery of silk by Emperor Huangdi’s wife in about 2700 B.C. Have students create a poster or diorama of the history of silk.

**Teaching Tip**

**Metamorphosis** Ask students to compare complete and incomplete metamorphosis in a Graphic Organizer similar to the one at the bottom of this page. Students may use either generalizations or specific insects in their comparisons.

**Visual TAKS 1 Bio/IPC 2C, 2D**

**Interpreting Visuals** Tell students that each visual in Figures 12 and 13 depicts a cycle. Since there is no beginning or end in a cycle, the student may choose any point to begin analyzing the cycle. However, when comparing two cycles, tell students to choose an equivalent point in each to begin, such as the adult, to make the comparison easier.

**TAKS 1 Bio/IPC 2C, 2D**

---

**Graphic Organizer**

Use this graphic organizer with *Teaching Tip: Metamorphosis* on this page.

<table>
<thead>
<tr>
<th>Complete metamorphosis</th>
<th>Egg → Larva → Pupa → Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incomplete metamorphosis</td>
<td>Egg → Nymph → Adult</td>
</tr>
</tbody>
</table>
Almost everyone knows that grasshoppers produce sounds that resemble chirping “songs.” But most people don’t know that it is generally male grasshoppers that play these songs as part of their courtship behavior. They generally have a repertoire of three. The male grasshopper’s initial song attracts the female, and when a female comes close, the male plays a more “intimate” melody. However, when another male is close by and competing for the female, the male plays the rivalry song. Some females play no songs in response, while the females of some species respond with short bursts of song.

**Extern Structures**

- **Thorax** The thorax is composed of three fused segments, each with a pair of legs. The front two pairs are walking legs. The rear pair is larger jumping legs. During mating season, males “sing” to potential mates by rubbing a row of pegs on a jumping leg against ridges on a forewing.
- **Wings** Grasshoppers have a pair of leathery forewings that protect the more delicate flying wings.
- **Head** Two antennae contain sense organs for touch and smell. On each side of the head is a very large compound eye. Located high on the forehead are three light-detecting ocelli.
- **Mouthparts** The stiff upper labrum and lower labium (lips) hold a leaf or blade of grass in place while the mandibles (jaws), assisted by maxillas (graspers), tear off pieces of the plant.

**Spiracles** Spiracles admit air to the extensively branching system of tracheae that deliver oxygen throughout the body.
develop into a pupa and from which they will emerge as a moth. Silk farmers do not allow most pupas to become moths, because a moth will shatter the silk cocoon as it leaves. Instead, farmers kill most pupae and process the silk cocoons. First the cocoon is unwound. Then several processes strengthen the threads. Finally, the thread is dyed and woven into fabric.

Bio 3F, 5A; IPC 8E

**did you know?**

**Silk is an agricultural product.** Today, silk is made with cultivated silkworms, usually caterpillars of the species *Bombyx mori*. The silk-making process begins as the female lays 300 to 500 eggs on special paper provided by silk farmers. The eggs develop into larvae. When the silkworm larvae are ready to begin metamorphosis, they spin a cocoon made of one continuous silk thread, in which they will develop into a pupa and from which they will emerge as a moth. Silk farmers do not allow most pupas to become moths, because a moth will shatter the silk cocoon as it leaves. Instead, farmers kill most pupae and process the silk cocoons. First the cocoon is unwound. Then several processes strengthen the threads. Finally, the thread is dyed and woven into fabric.

Bio 3F, 5A; IPC 8E

**Eastern Lubber Grasshopper**

**Discussion**

- How do grasshopper eyes make it almost impossible to sneak up on this insect? (Grasshoppers have compound eyes on each side of their head and three light-detecting ocelli on their forehead.)
- How can you tell that this grasshopper is a female from its external structures? (This grasshopper has ovipositors, which are used to deposit fertilized eggs.)
- What structures do grasshoppers use to move slowly? How do they make quick escapes? (Grasshoppers use their walking legs to move slowly. When they need to escape quickly, they use their jumping legs or wings.)
- What are the three main sections of a grasshopper’s body, and what is a major body function that occurs in each section? (The grasshopper has a head, thorax, and abdomen. Touching, smelling, seeing, and chewing occur in the head; walking and jumping occur in the thorax; and respiration, reproduction, and excretion occur in the abdomen.)
- What would happen if every grasshopper were to freeze during a cold winter? (The species would continue to survive because grasshopper eggs stay dormant in winter and hatch in the spring.)

**Up Close**

**Internal Structures**

**Reproductive system** The female collects the male’s sperm in a storage pouch called a seminal receptacle. Later, the female digs a hole using two pairs of pointed ovipositors. As she releases the eggs into the hole, they are fertilized by the stored sperm.

**Circulatory system** A long blood vessel with a series of muscular “hearts” runs along the grasshopper’s back. Blood is pumped out of the open system and bathes the body tissues directly before returning to the heart.

**Nervous system** The nervous system is composed of a major ventral nerve cord with ganglia located in each body segment. Three fused ganglia in the head serve as the brain.

**Digestive system** Chewed food enters a storage pouch called a crop and passes to the gizzard, where it is shredded and crushed. Food is digested in the midgut, and food molecules pass through the midgut wall into the fluid of the coelom. This fluid eventually enters the circulatory system.
Answers to Analysis

1. Populations were stable during the first 4 years. Both populations cycled between the same high and low values each year.
2. As the population of the beneficial species increases, pest numbers decrease, and vice versa.
3. The number of beneficial species and insect pests decreased. The pest population eventually recovered and further increased. The beneficial species population did not recover.
4. Before the application of pesticide, the pest population reached an annual maximum of about 6,000 per hectare. After the pesticide application, the pest population rose to 10,000 per hectare.
5. Answers will vary.

**Flight**

Insects were the first animals to have wings. For more than 100 million years, until flying reptiles appeared, insects were the only flying organisms. Flight, illustrated in **Figure 14**, was a great evolutionary innovation. Flying insects were able to reach previously inaccessible food sources and to escape quickly from danger.

An insect’s wings develop from saclike outgrowths of the body wall of the thorax. The wings of adult insects are composed entirely of chitin, strengthened by a network of tubes called veins (which carry air, not blood). In most insects, the power stroke of the wing during flight is downward, and it is produced by strong flight muscles. When at rest, most insects fold their wings over their abdomen, but a few insects are unable to do this. Dragonflies, for example, keep their wings outstretched when they rest beside a pond. Most insects have two pairs of wings. A few groups of insects, such as fleas and lice, are wingless.

In most insects only one pair of wings is functional for flight. In some species, the second pair of wings serves another purpose. For example, in grasshoppers and beetles, the forewings act as protective wing covers. In flies, the hindwings are modified into knoblike structures that help control stability during flight.

**Analyzing the Effects of Pesticide Use**

**Background**

In nature, insect pests are usually kept in balance by the presence of predators, including other insects. The use of some pesticides can upset this balance, as shown in the graph below. Examine the graph, and answer the analysis questions.

**Analysis**

1. Identify the years during which the two insect populations appear to maintain stability in relation to each other. Justify your answer with data from the graph.
2. Describe the relationship between the two insect species before year 4.
3. Describe the changes in the two populations after the use of a pesticide.
4. Compare the annual changes in population size of the pest species before and after the use of a pesticide.
5. Critical Thinking Developing Hypotheses. Propose a hypothesis that might explain the dramatic changes that occur in the insect populations after the use of pesticides.

---

**REAL WORLD**

**Pest control** Invite a pest-control authority to class to discuss the problems and risks associated with termites and other common household pests, such as ants and cockroaches. Ask the visitor to explain when such insects are considered a hazard. Have students ask questions about new methods used to control pests and about how to avoid infestations.

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**TAKS Benchmark Fact**

Review the concepts of work (work = force \times distance) and power (power = work/time) by having students calculate and compare the work and power done in flight by two imaginary lacewings. For example, assume that during its flight lacewing A exerted a force of 2 N over a distance of 10 m in 4 s while lacewing B exerted a force of 3 N over a distance of 15 m in 10 s. Remind students that the joule (N-m) is the work unit and watt (J/s) is the power unit. Ask students which lacewing did the most work and which one had the highest power output.
Social Insects

Two orders of insects, Hymenoptera (ants, bees, and wasps) and Isoptera (termites), have elaborate social systems. These insects often live in highly organized societies of genetically related individuals. Within these insect societies, there is a marked division of labor; with different kinds of individuals performing specific functions. The role played by an individual in a colony is called its **caste**. Caste is determined by a combination of heredity; diet, especially as a larva; hormones; and **pheromones**, chemical substances used for communication. In the termite colony shown in Figure 15, for example, small, active members called workers gather the food, raise the young, and excavate tunnels. Other, larger termites, called soldiers, defend the colony with their immense jaws. Both workers and soldiers are sterile. Reproduction is a function of only the queen and king. 1 2

Insect Relatives

Centipedes and millipedes, shown in Figure 16, have similar bodies. Each has a head region followed by numerous similar segments. Each segment bears one or two pairs of legs. Centipedes have one pair of legs per segment and can have up to 173 segments. Modern millipedes have from 11 to 100 or more body segments, and most millipede segments have two pairs of legs. While centipedes are carnivores, most millipedes are herbivores. 1 2

---

**Section 3 Review**

1. **Relate** the Eastern Lubber grasshopper’s body plan to that of a typical insect.  
2. **Compare** the life cycles of grasshoppers and butterflies.  
3. **Identify** the distinguishing characteristics of insects, millipedes, and centipedes.  
4. **Critical Thinking** Forming Hypotheses  
   Based on the information given in Table 1, what characteristic is key to determining an insect’s classification? Support your answer.  
5. **TAKS Test Prep** A grasshopper’s antennae contain sense organs for  
   A. touch and smell.  
   B. smell and hearing.  
   C. hearing and vision.  
   D. vision and touch.

---

**Answers to Section review**

1. The Eastern Lubber grasshopper has a body plan like that of a typical insect. It has a head, a thorax, and an abdomen; three pairs of jointed legs; an antenna; and an exoskeleton.  
   **TAKS** 2 Biol/IPC 2C; Biol/IPC 8B  
2. Grasshoppers go through several nymph stages during incomplete metamorphosis. Butterflies go through complete metamorphosis, with egg, larva, pupa, and adult stages.  
   **Bio** 8B  
3. Insects have three body sections, three pairs of legs, and antenna; millipedes have many body segments with two pairs of legs per segment, and are herbivores; centipedes have many body segments with one pair of legs per segment, and are carnivores.  
   **TAKS** 2 Biol/IPC 8C  
4. Wings are the key characteristic in classification. They are described for each class.  
   **TAKS** 2 Biol 8C  
5. **TAKS Doctor**  
   A. Correct. Two antennae contain sense organs for touch and smell.  
   B. Incorrect. Grasshopper’s antennae contain sense organs for touch but not hearing.  
   C. Incorrect. Grasshoppers see with compound eyes, not their antennae.  
   D. Incorrect. Grasshoppers’ antennae contain sense organs for touch, but they see with their compound eyes.  
   **TAKS** 2 Biol 10A; Biol 11B

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**Quiz**

1. List the structures usually found on the insect head. (mandibles, specialized mouth parts, and antennae)  
   **TAKS** 2 Biol 10A  
2. What is the relationship between insects and centipedes? (Insects and centipedes are both arthropods in the Subphylum Uniramia. However, they belong to different Classes.)  
   **TAKS** 2 Biol 8C  

---

**Alternative Assessment**

Collect a variety of images of insects, centipedes, and millipedes from nature magazines, the Web, or other resources you may have. Have students work in groups of three and distribute the images equally among the groups. Have students develop twenty questions (and answers) about their images. Using their images and the questions they developed, have groups quiz each other.  
**TAKS** 1 Biol/IPC 2C, 2D;  
**TAKS** 3 Biol 7B; Biol 8B

---

**Close**

Divide the class into four groups. Write the name of each of the four insect orders listed in **Table 1** on slips of paper. Have a representative from each group pick one of the folded slips out of a bowl or beaker, making sure they cannot see the writing on the slips. Then have each group ask questions of the other groups about insects in their order. The questions should be phrased so that they can be answered “yes” or “no.”

**Interpersonal**  
**TAKS** 1 Biol/IPC 2C, 2D;  
**TAKS** 3 Biol 7B; Biol 8B

---

**Teaching Tip**

**Bees in Agriculture** Tell students that the widespread use of pesticide sprays has resulted in the loss of beehives. Have students discuss the effects the loss of these hives might have on consumers. (Because bees are needed to pollinate many crops, reduced agricultural production and higher prices would result.) Tell students that some farmers have to rent mobile beehives to pollinate their crops.  
**TAKS** 1 Biol/IPC 2D; Biol/IPC 3C
Crustacean Habitats

Just as insect species dominate on land, crustaceans abound in the world’s oceans. Their great numbers have earned them the nickname “the insects of the sea.” Many are microscopic creatures that drift as plankton in the ocean currents. While primarily marine, members of subphylum Crustacea are also found in fresh water and in a few terrestrial habitats. Crustaceans include crabs, lobsters, crayfish, shrimps, barnacles, water fleas (*Daphnia*), and pill bugs.

Almost all crustaceans have a distinctive larval form called a nauplius (*NAW plee uhs*). The nauplius, shown in Figure 17, has three pairs of branched appendages. Like insects, the nauplius undergoes a series of molts before it takes on its adult form.

Adult crustaceans also have mandibles, as insects do. But crustaceans differ from insects in a number of important respects, as summarized in Table 2.

### Terrestrial Crustaceans

Only a few crustacean groups have successfully invaded terrestrial habitats. The most widespread group of terrestrial crustaceans is composed of the pill bugs and sow bugs. They live among leafy ground litter found in gardens and woods. Pill bugs and sow bugs belong to a group called isopods and are the only crustaceans that are truly terrestrial. Another group, the sand fleas, includes several thousand species typically found along beaches. In addition, a few species of land crabs live in damp areas. Land crabs are only partly adapted to terrestrial living. They are active primarily at night, when the air is more moist. Their life cycle is tied to the ocean, where the larvae live until maturity.

<table>
<thead>
<tr>
<th>Table 2 Comparison of Crustaceans and Insects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Nature of appendages</td>
</tr>
<tr>
<td>Antennae</td>
</tr>
<tr>
<td>Chewing appendages</td>
</tr>
<tr>
<td>Location of appendages</td>
</tr>
<tr>
<td>Respiration</td>
</tr>
</tbody>
</table>
**Aquatic Crustaceans**

Crustaceans are a major food source for humans and some animals. The members of some orders of crustaceans are quite small. Common are fairy shrimps, water fleas, ostracods, and tiny copepods (KOH puh pahds). Copepods are among the most abundant multicellular organisms on Earth and are a key food source in the marine food chain. Another small marine crustacean, *Euphausia superba*, swarms in huge groups and is known by its common name, krill. Krill, shown in Figure 18, are the chief food for many marine species.

**Decapods**

Large marine crustaceans such as shrimps, lobsters, and crabs, along with the freshwater crayfish shown in Figure 19, have five pairs of legs and are often referred to as decapods. Almost one quarter of all crustaceans are decapods. The head and thorax of decapods are fused into a single cephalothorax, which is covered on top by a protective shield called a carapace.

In crayfish and lobsters, the anterior pair of legs are modified into large pincers called chelipeds (KEE luh pehdz). Appendages called swimmerets are attached to the underside of the abdomen and are used in swimming and in reproduction. Flattened, paddle-like appendages called uropods are at the end of the abdomen. Many decapods have a telson, or tail spine. Decapods can propel themselves through the water by forcefully flexing their abdomen.

![Figure 18](image_url) **Krill.** Found in icy Antarctic waters, krill are the chief food for many marine animals.

**Figure 19** **Crayfish**

Like all decapods, the crayfish has five pairs of legs.

---

**MISCONCEPTION ALERT**

**Pill Bugs**

Although their name implies otherwise, pill bugs or potato bugs are actually terrestrial crustaceans, not insects. Pill bugs belong to the Order Isopoda (the isopods). Whereas insects have three pairs of legs and breathe with a system of tracheae, pill bugs have seven pairs of legs and breathe with gills.

**Answers to Analysis**

1. Most crabs die in April, May, and June.
2. Most crabs molt in April, May, and June.
3. During their molting season, many crabs fall prey to predators and disease.
4. When the crabs molt, more will die due to disease and predation.
5. Answers will vary. Crabs are fragile after molting and are more susceptible to disease.

**Appendix**

- **Antennules**
- **Cheliped**
- **Antennae**
- **Cephalothorax**
- **Abdomen**
- **Telson**
- **Uropod**
- **Swimmerets**
- **Walking legs**

---

**Educator Tips**

**Health**

Some crabs have been found to carry human parasites. In Asia, freshwater crabs can carry lung flukes, which can then be transmitted to humans who eat the crabs. In Africa, onchocerciasis, an eye disease that is transmitted by flies, is also carried on the backs of river crabs, where the fly larvae live. However, most decapods are not harmful to people when they are cooked properly. Students in the United States are often unaware of diseases that afflict people in countries that do not have effective public health systems. Encourage students to find out more about these parasitic diseases.

**TAKS 1 Bio/IPC 2D; IPC 3A; Bio 3A, 11D**
Reteaching

Show photographs of a lobster and a water flea, and ask students to identify the similarities and differences.

Visual Quiz

True or False:
1. Pill bugs and sow bugs are terrestrial crustaceans, not insects. (True) TAKS 2 Bio 8C
2. Lobsters and crabs are called decapods because they have five pairs of legs. (True) TAKS 2 Bio 8C

Quiz

Relating Molting to Mortality Rates

**Background**
During the soft-shell stage that follows molting, many crustaceans die of disease or are eaten by predators. The bar graph below shows the percent mortality for crabs over a 9-month period. Study the data, and answer the analysis questions.

**Analysis**
1. Summarize what the data in the graph tell you about crab mortality.
2. Summarize what the graph shows about molting in crabs.
3. Describe the relationship between the mortality rates and molting periods of crabs.

**Critical Thinking**

- Developing Hypotheses
  Propose a hypothesis that explains the relationship between the percent of crabs molting and mortality rates.

- Making Predictions
  Most states have laws that require crab fishers to return molting crabs to the water. How might the length of time a molting crab is exposed to air or how roughly a crab is handled affect whether the crab survives being caught and released?

Sessile Crustaceans

Barnacles are a group of crustaceans that are sessile as adults. Free-swimming larvae attach themselves to a rock, post, or some other submerged object, where they remain. Hard plates that can open and close protect the barnacle's body. When feeding, barnacles extend their jointed feeding appendages (legs) through the open plates. Their feathery legs stir food from the water into the barnacles' mouth. Unlike most crustaceans, barnacles are hermaphrodites. However, they do not usually fertilize their own eggs.

Answers to Section Review

1. Answers should summarize the information given in Table 2 of this section. TAKS 2 Bio 8C
2. Decapods have antennae, pincers, a cephalothorax with walking legs, and a segmented abdomen. TAKS 2 Bio 8C
3. You would most likely find pill bugs only in moist environments. Bio 11B
Alternative Assessment

Have students construct concept maps that show the similarities and differences among the following arthropods: arachnids, insects, millipedes and centipedes, and crustaceans.  

Key Concepts

1. **Features of Arthropods**
   - All arthropods have a coelom, a segmented body, and jointed appendages that are modified to perform different functions.
   - Arthropods have an exoskeleton made of chitin, which they discard periodically in a process called molting.
   - Arthropods are grouped into three subphyla: Chelicerata, Uniramia, and Crustacea.

2. **Spiders and Other Arachnids**
   - Members of subphylum Chelicerata have mouthparts, called chelicerae, that are modified into fangs or pincers.
   - Spiders have a head and a cephalothorax, no antennae, six or eight pairs of simple eyes, a pair of fangs and pedipalps, and four pairs of walking legs.
   - Scorpions have pedipalps modified into large, grasping pincers. A stinger is located at the end of their abdomen.
   - Mites have body parts that are fused to form an unsegmented body. Many mites transmit diseases.

3. **Insects and Their Relatives**
   - Insects make up more than half of all named animal species.
   - All insects have a body plan with three body sections (head, thorax, and abdomen), three pairs of legs (all attached to the thorax), and one pair of antennae.
   - The life cycles of insects are complex and involve a process of change called metamorphosis, during which larvae change into the adult insects.

4. **Crustaceans**
   - Crustaceans have a distinctive larval form called a nauplius.
   - Copepods and krill, which are tiny marine crustaceans, are the chief food of many marine species.
   - Most crustaceans have branched appendages, two pairs of antennae, three chewing appendages, walking legs attached to the thorax, and gills. Like insects, crustaceans have jaws called mandibles.

**Key Terms**

**Section 1**
- appendage (664)
- thorax (666)
- cephalothorax (666)
- compound eye (666)
- molting (668)
- trachea (668)
- spiracle (668)
- Malpighian tubule (669)

**Section 2**
- chelicera (670)
- pedipalp (670)
- spinneret (670)

**Section 3**
- mandible (673)
- metamorphosis (675)
- chrysalis (675)
- pupa (675)
- nymph (675)
- caste (679)

**Section 4**
- nauplius (680)
- krill (681)

Answer to Concept Map

The following is one possible answer to Performance Zone item 15.
Using Key Terms

1. The chief organ of excretion in insects is the [ch. 10A]
   a. Malpighian tubule.
   b. pedipalp.
   c. nephridium.
   d. spiracle.

2. In spiders, chelicerae are modified into [ch. 7B]
   a. spinnersets.
   b. legs.
   c. antennae.
   d. pedipalps.

3. Spinnnersets are located on the spider's [ch. 8C]
   a. thorax.
   b. abdomen.
   c. cephalothorax.
   d. pedipalps.

4. Insects respire through structures called [ch. 10A]
   a. book lungs.
   b. spiracles.
   c. gills.
   d. ganglia.

5. For each pair of terms, explain the differences in their meanings.
   a. cephalothorax, exoskeleton
   b. chelicerae, pedipalps
   c. spinnersets, pedipalps
   d. mandible, cephalothorax

6. What evidence suggests that arthropods are closely related to annelids? [ch. 8B]
   a. Arthropods and annelids have gills.
   b. Both groups have marine species.
   c. Segmentation is present in both groups.
   d. Arthropods have vestigial parapodia.

7. Which is a feature of the arthropod body plan? [ch. 8C]
   a. a hydrostatic support system
   b. pharyngeal slits
   c. an exoskeleton
   d. a nonsegmented body

8. Arthropods molt because [ch. 7B]
   a. their body grows faster than their shell.
   b. of damage to their exoskeleton.
   c. their exoskeleton cracks and lets in water.
   d. their hard exoskeleton cannot grow larger.

9. In adult insects [ch. 8C]
   a. the abdomen has wings.
   b. there are two pairs of antennae.
   c. the legs are attached to the thorax.
   d. the first appendages are chelicerae.

10. Which of the following sequences shows a complete metamorphosis? [ch. 8C]
    a. egg → larva → pupa → adult
    b. egg → larva → mature pupa
    c. egg → young juvenile → older juvenile
    d. egg → pupa → winged juvenile → adult

11. Millipedes and centipedes differ in that [ch. 8B, 8C]
     a. are terrestrial and segmented.
     b. have one pair of legs on each segment.
     c. have poisonous fangs.
     d. are herbivores.

12. Which of the following is not a crustacean? [ch. 8C]
    a. lobster
    b. scorpion
    c. copepod
    d. water flea

13. Copepods are said to be the most important animals on Earth because they are a critical link in the marine food chain.
    b. found in both the ocean and fresh water.
    c. accomplished predators.
    d. easier to collect and study than other arthropods.

14. BIOWatch Why is Earth's magnetic field important to Monarch butterflies? [ch. 11B]

15. Concept Mapping Construct a concept map that outlines the three major groups of arthropods and that gives the characteristics for each group. Try to include the following terms in your concept map: appendages, cephalothorax, tracheae, spiracles, chelicerae, pedipalps, complete metamorphosis, chrysalis, pupa, and nauplius. [ch. 8C, 3E]

Assignment Guide

<table>
<thead>
<tr>
<th>Section</th>
<th>Questions</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>5a, 6, 7, 8, 21</td>
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<tr>
<td>2</td>
<td>2, 3, 5, 7, 15, 17, 20</td>
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<td>3</td>
<td>1, 4, 5, 9, 10, 11, 14, 15, 16, 17, 18, 19, 20, 22</td>
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<tr>
<td>4</td>
<td>12, 13, 15, 18, 21</td>
</tr>
</tbody>
</table>
Critical Thinking

16. Applying Information  If levels of vegetation were reduced, which arthropod species would likely have a greater advantage—an arthropod species that undergoes complete metamorphosis or one that undergoes incomplete metamorphosis? Explain your answer.  

17. Recognizing Logical Inconsistencies  A neighbor commented that there was an increased number of insects around her house and that she was killing every spider she saw. How might these actions affect the number of insects around a house?  

18. Inferring Conclusions  An unknown arthropod has three body segments, one pair of antennae, and three pairs of jointed legs. What kind of arthropod is it? Explain how you arrived at this conclusion.  

19. Recognizing Relationships  The wings of the atlas moth, Attacus atlas, look much like the head of a snake. Why might it benefit a flying insect to look like a snake?  

Alternative Assessment

20. Forming a Model  Using papier mâché or some other material, make a model of a grasshopper or a spider. Decide in advance how many features of insects you must show to make an adequate model. Present your model to the class, and describe the structures that you modeled.  

21. Communicating Information  Use the media center or Internet sources to learn more about diseases transmitted by arthropods. Develop a brochure that presents your findings. The brochure should discuss the species that transmit the disease, as well as the symptoms and treatment of the disease.  

22. Career Connection  Agricultural Insect Inspector  Research the field of inspecting field crops for the presence of harmful insects, and write a report on your findings. Your report should include a job description, training required, kinds of employers, growth prospects, and starting salary.  

TAKS Test Prep

Use the illustration below and your knowledge of science to answer questions 1–3.

1. What type of environmental stimulus is structure A sensitive to?  
   A. touch  C. light  
   B. sound  D. odor  

2. Structures B and C are specialized for  
   F. inhaling and exhaling air.  
   G. biting and chewing leaves.  
   H. sponging and lapping liquids.  
   J. catching and handling prey.  

3. This animal's exoskeleton is adapted to  
   A. prevent movement at the joints.  
   B. withstand pressure in deep water.  
   C. help prevent water loss.  
   D. grow as the animal grows.  

Test Tip  
If points are not deducted for guessing, answer every question.  

TAKS Doctor

1. A. Incorrect. Touch is detected by the grasshopper’s antennae.  
   B. Incorrect. Sound is not detected in the grasshopper by structure A.  
   C. Correct. Structure A is an ocellus, a light-detecting organ of the grasshopper.  
   D. Incorrect. Smell is detected by the grasshopper’s antennae.  

2. F. Incorrect. Air enters and leaves the grasshopper through the spiracles.  
   G. Correct. The mandibles and the maxillae are used to bite and chew leaves.  
   H. Incorrect. The grasshopper has no structures for sponging and lapping liquids.  
   J. Incorrect. Grasshoppers are herbivores and do not catch and handle prey.  

3. A. Incorrect. The exoskeleton is hinged at the joints for movement.  
   B. Incorrect. Grasshoppers do not inhabit deep water. They are terrestrial.  
   C. Correct. The exoskeleton is efficient in conserving body moisture.  
   D. Incorrect. The exoskeleton does not grow; grasshoppers molt to allow for growth.  

Critical Thinking

16. A species that undergoes complete metamorphosis would probably have the advantage. In complete metamorphosis, the larvae have different food sources from the adults, and this difference might help one or the other survive. Also, during complete metamorphosis, the pupa is within a protective chrysalis and would likely survive the drought. In incomplete metamorphosis, the nymph is similar to the adult, and both nymphs and adults would likely be affected.  

17. Spiders eat insects. When spiders are removed, insects have fewer predators. Killing the spiders probably led to an increase in the insect population.  

18. It is an insect because it has three common insect characteristics.  

19. Predators might think the moth is a snake and therefore not attack it.  

Alternative Assessment

20. Models will vary but should show the external structures illustrated in the drawings of the spider or grasshopper depicted in the Up Close features in this chapter.  

21. Answers will vary, but brochures should be well organized and present the group’s findings accurately.  

22. Answers will vary. Agricultural insect inspectors work for crop producers to identify harmful and helpful insects. A college degree in entomology may be required. Employers include agricultural stations, universities, and government agencies. Growth prospects are good. Starting salary will vary by region.