What You’ll Learn

- You will distinguish among the adaptations that have made arthropods the most abundant and diverse animal phylum on Earth.
- You will compare and contrast different classes of arthropods.

Why It’s Important

Arthropods are adapted to fill many important niches in every ecosystem in the world. Because arthropods occupy so many niches, they have an impact on all living things, including humans.

Reading Biology

Skim through the new vocabulary terms in the section previews, noting any unfamiliar words. As you read, make an outline of the chapter. Try to include the definition of each new vocabulary word in the outline.

To find out more about arthropods, visit the Glencoe Science Web site.

There are about 1 million known species of arthropods. How can we explain the enormous diversity of arthropods—a group that includes both spiders and lobsters?
What Is an Arthropod?

Arthropods pollinate many of the flowering plants on Earth. Some arthropods spread plant and animal diseases. Despite the enormous diversity of arthropods, they all share some common characteristics.

A typical arthropod is a segmented, coelomate invertebrate animal with bilateral symmetry, an exoskeleton, and jointed structures called appendages. An appendage is any structure, such as a leg or an antenna, that grows out of the body of an animal. In arthropods, appendages are adapted for a variety of purposes including sensing, walking, feeding, and mating. Figure 28.1 shows some of these adaptations.

Two out of every three animals living on Earth today are arthropods. You can find arthropods deep in the ocean and on high mountaintops. They live in polar regions and in the tropics. Arthropods are adapted to living in air, on land, and in freshwater and saltwater environments. Arthropods range in size from the 0.3-mm-long spider mite to the giant Japanese spider crab, which measures 4 m across. This water flea, Daphnia, lives in freshwater lakes and filters microscopic food from the water with its bristly legs.
Arthropods are the earliest known invertebrates to exhibit jointed appendages. Joints are advantageous because they allow more flexibility in animals that have hard, rigid exoskeletons. Joints also allow powerful movements of appendages, and enable an appendage to be used in many different ways. For example, the second pair of appendages in spiders is used for sensing and for mating. In scorpions, this pair of appendages is used for seizing prey.

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Arthropod exoskeletons provide protection

The success of arthropods as a group can be attributed in part to the presence of an exoskeleton. The exoskeleton is a hard, thick, outer covering made of protein and chitin (KITE un). Chitin is also found in the cell walls of fungi and in many other animals. In some species, the exoskeleton is a continuous covering over most of the body. In other species, the exoskeleton is made of separate plates held together by hinges. The exoskeleton protects and supports internal tissues and provides places for attachment of muscles. In many species that live on land, the exoskeleton is covered by a waxy layer that provides additional protection against water loss. In many aquatic species, the exoskeletons also contain calcium.

Why arthropods must molt

Exoskeletons are an important adaptation for arthropods, but they also have their disadvantages. First, they are relatively heavy structures. Many terrestrial and flying arthropods are adapted to their habitats by having a thinner, lighter-weight exoskeleton, which offers less protection but allows the animal more freedom to fly and jump.

More importantly, though, exoskeletons cannot grow, so arthropods must shed them periodically. Shedding the old exoskeleton is called molting. Before an arthropod molts, a new, soft exoskeleton is formed from chitin-secreting cells beneath the old one. When molting occurs, the animal contracts muscles in the rear part of its body, forcing blood forward. The forward part of the body swells, causing the old exoskeleton to split open, as Figure 28.2 shows. The animal then climbs out of its old exoskeleton. Before the new exoskeleton hardens, the animal swallows air or water to puff itself up in size. Thus, the new exoskeleton hardens in a larger size, allowing some room for the animal to continue to grow.

Most arthropods molt four to seven times in their lives, and during these periods, they are particularly vulnerable to predators. When the new exoskeleton is soft, arthropods cannot protect themselves or escape from danger because they move by bracing muscles against the rigid exoskeleton. Therefore, many species hide or remain motionless for a few hours or days until the new exoskeleton hardens.
Segmentation in arthropods

Most arthropods are segmented, but they do not have as many segments as you have seen in segmented worms. In most groups of arthropods, segments have become fused into three body sections—head, thorax, and abdomen. In other groups even these segments may be fused. Some arthropods show a head and a fused thorax and abdomen. In other groups, there is an abdomen and a fused head and thorax called a cephalothorax (sef uh luh THOR aks), as shown in Figure 28.3.

Fusion of the body segments is related to movement and protection. Species such as beetles that have separate head and thorax regions are more flexible than those with fused regions. Many species such as shrimps and lobsters have a cephalothorax, which protects the animal but which limits movement. Take a closer look at the fused body segments of an arthropod called a crayfish in the MiniLab on this page.

Crayfish Characteristics

There are more species of arthropods than all of the other animal species combined. This phylum includes a variety of adaptations that are not found in other animal phyla.

**Procedure**

1. Examine a preserved crayfish. CAUTION: Wear disposable latex gloves and use a forceps when handling preserved material.
2. Prepare a data table with the following arthropod traits listed: body segmentation, jointed appendages, exoskeleton, sense organs, jaws.
3. Observe the crayfish. Fill in your data table, indicating which of the arthropod traits you observed.
4. Gently lift the edge of the body covering where the legs attach to the body. Look for feathery structures. These are gills and are part of the animal's respiratory system. CAUTION: Wash hands with soap and water after handling preserved materials.

**Analysis**

1. Do crayfish have all of the traits listed above?
2. Make a hypothesis as to how crayfish locate food.

**Figure 28.3**

You can see the different body segments in these arthropods.

A. A stag beetle shows fusion of body segments into a distinct head, thorax, and abdomen.

B. In the camel-backed shrimp, the head and thorax are fused into a cephalothorax. The animal also has an abdomen.
Arthropods have efficient gas exchange

Arthropods are generally quick, active animals. They crawl, run, climb, dig, swim, and fly. In fact, some flies beat their wings 1000 times per second. As you would expect, arthropods have efficient respiratory structures that ensure rapid oxygen delivery to cells. This large oxygen demand is needed to sustain the high levels of metabolism required for rapid movements.

Three types of respiratory structures for taking oxygen into their bodies have evolved in arthropods: gills, tracheal tubes, and book lungs. In some arthropods, air diffuses right through the body wall. Aquatic arthropods exchange gases through gills, which extract oxygen from water and release carbon dioxide into the water. Land arthropods have either a system of tracheal tubes or book lungs. Most insects have tracheal tubes (TRAY kee ul), branching networks of hollow air passages that carry air throughout the body. Muscle activity helps pump the air through the tracheal tubes. Air enters and leaves the tracheal tubes through openings on the thorax and abdomen called spiracles (SPIHR ih kulz).

Most spiders and their relatives have book lungs, air-filled chambers that contain leaflike plates. The stacked plates of a book lung are arranged like pages of a book. All three types of respiration in arthropods are illustrated in Figure 28.4.

Arthropods have acute senses

Quick movements that are the result of strong muscular contractions enable arthropods to respond to a variety of stimuli. Movement, sound, and chemicals can be detected with great sensitivity by antennae, stalklike structures that detect changes in the environment.

Antennae are also used for communication among animals. Have you ever watched as a group of ants carried home a small piece of food? The ants were able to work together as a group because they were communicating with each other by pheromones (FER uh mohnz),
chemical odor signals given off by animals. Antennae sense the odors of pheromones, which signal animals to engage in a variety of behaviors. Some pheromones are used as scent trails, such as in the group-feeding behavior of ants, and many are important in the mating behavior of arthropods.

Accurate vision is also important to the active lives of arthropods. Most arthropods have one pair of large compound eyes and from three to eight simple eyes. A simple eye is a visual structure with only one lens that is used for detecting light. A compound eye is a visual structure with many lenses. Each lens registers light from a tiny portion of the field of view. The total image that is formed is made up of thousands of parts. The multiple lenses of a flying arthropod, such as the dragonfly shown in Figure 28.5, enable it to analyze a fast-changing landscape during flight. Compound eyes can detect the movements of prey, mates, or predators, and can also detect colors.

Arthropod nervous systems are well developed

Arthropods have well-developed nervous systems that process information coming in from the sense organs. The nervous system consists of a double ventral nerve cord, an anterior brain, and several ganglia. Arthropods have ganglia that have become fused. These ganglia act as control centers for the body section in which they are located.

Arthropods have other complex body systems

Arthropod blood is pumped by one or more hearts in an open circulatory system with vessels that carry blood away from the heart. The blood flows out of the vessels, bathes the tissues of the body, and returns to the heart through open body spaces.

Arthropods have a complete digestive system with a mouth, stomach, intestine, and anus, together with various glands that produce digestive enzymes. The mouthparts of most arthropod groups include a variety of jaws called mandibles (MAND uh bulz). Mouthparts are adapted for holding, chewing, sucking, or biting the various foods eaten by arthropods, illustrated in Figure 28.6.

Most terrestrial arthropods excrete wastes through Malpighian tubules (mal PIGH ee un). In arthropods, the
**Understanding Main Ideas**

1. Describe the pathway taken by the blood as it circulates through an arthropod’s body.
2. Describe two features that are unique to arthropods.
3. What are the advantages and disadvantages of an exoskeleton?
4. Compare how spiders and crabs protect themselves.

**Thinking Critically**

5. What characteristics of arthropods might explain why they are the most successful animals in terms of population sizes and numbers of species?

6. **Comparing and Contrasting** Compare the adaptations for gas exchange in aquatic and land arthropods. For more help, refer to *Thinking Critically* in the *Skill Handbook*. 

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**Problem-Solving Lab 28-1**

**Using Numbers**

**How many are there?** There are a lot of arthropod species on Earth. How do arthropods compare with other animals?

**Analysis**

Look over the circle graph. Determine the number of species in each phylum or class by noting that each degree on the circle represents about 3000 species. Note: You will need a protractor.

**Thinking Critically**

1. About how many species of arthropods are known? What percentage of all animal species are arthropods?
2. Which class of arthropods makes up the larger category? How many species are in this class? What percentage of all arthropods is in this class? What percentage of all animal species is in this class?
3. Which order (Diptera, Hymenoptera) makes up the largest category? How many species are in this order? What percentage of all arthropods is in this order?
4. Formulate a hypothesis that explains why there are so many arthropod species.

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**Arthropods reproduce sexually**

Most arthropod species have separate males and females and reproduce sexually. Fertilization is usually internal in land species but is often external in aquatic species. A few species, such as barnacles, are hermaphrodites, animals with both male and female reproductive organs. Some species, including bees, ants, and wasps, exhibit **parthenogenesis** (par thuh noh JEN uh sus), a form of asexual reproduction in which a new individual develops from an unfertilized egg.

There are more arthropod species than all other animal species combined. Find out how many species of arthropods there are by reading the Problem-Solving Lab on this page.
Female mosquitoes drink an average of 2.5 times their body weight in blood every day. Other arthropods feed on nectar, dead organic matter, oil, and just about every other substance you can imagine. The varied eating habits of arthropods reflect their huge diversity. The phylum Arthropoda includes these classes: Arachnida, spiders and their relatives; Crustacea, crabs and their relatives; Chilopoda, centipedes; Diplopoda, millipedes; Merostomata, horseshoe crabs; and Insecta, insects.

Arachnids

Do you remember the last time you saw a spider? Did you draw back with a quick, fearful breath, or did you move a little closer, curious to see what it would do next? Of the 30,000 species of spiders, only about a dozen are dangerous to humans. In North America, you need to watch out for only the two species illustrated in Figure 28.7—the black widow and the brown recluse.

What is an arachnid?

Spiders, scorpions, mites, and ticks belong to the class Arachnida (uh rakh nuh duh). Spiders are the largest group of arachnids. Spiders and other arachnids have only two
body regions—the cephalothorax and the abdomen. Arachnids have six pairs of jointed appendages. The first pair of appendages, called **chelicerae** (kih LIHS uh ree), is located near the mouth. Chelicerae are often modified into pincers or fangs. Pincers are used to hold food, and fangs inject prey with poison. Spiders have no mandibles for chewing. Using a process of extracellular digestion, digestive enzymes from the spider’s mouth liquefy the internal organs of the captured prey. The spider then sucks up the liquefied food.

The second pair of appendages, called the **pedipalps** (PED ih palpz), are adapted for handling food and for sensing. In male spiders, pedipalps are further modified to carry sperm during reproduction. The four remaining appendages in arachnids are modified as legs for locomotion. Arachnids have no antennae.

Most people know spiders for their ability to make elaborate webs. Although all spiders spin silk, not all make webs. Spider silk is secreted by silk glands in the abdomen. As silk is secreted, it is spun into thread by structures called **spinnerets**, located at the rear of the spider. How well can a spider see? Find out by reading the *Inside Story* on the next page.

**Ticks, mites, and scorpions: Spider relatives**

Spiders are not the only arthropods classified as arachnids. Ticks, mites, and scorpions are arachnids, too. Ticks and mites differ from spiders in that they have only one body section, as shown in *Figure 28.8*. The head, thorax, and abdomen are completely fused. Ticks feed on blood from reptiles, birds, and mammals. They are small but capable of expanding up to 1 cm or more after a blood meal. Ticks also can spread diseases. You can find out more about ticks and disease in the *Health Connection* at the end of this chapter.

Mites are so small that they often are not visible to the naked human eye. However, you can certainly feel the bite of mites called chiggers if they get under your clothing while you are camping.

Scorpions are easily recognized by their many abdominal body segments and enlarged pincers. They have a long tail with a venomous stinger at the tip. Scorpions live in warm, dry climates and eat insects and spiders. They use the poison in their stingers to paralyze large prey organisms.

**Crustaceans**

Most crustaceans (krus TAY shuns) are aquatic and exchange gases as water flows over feathery gills. Crustaceans are the only arthropods that have two pairs of antennae for sensing. All crustaceans have mandibles for crushing food, and two compound eyes, which are usually located on movable stalks. Unlike the up-and-down movement of your jaws, crustacean mandibles open and close from side to side.
A Spider

The garden spider weaves an intricate and beautiful web, dribbles sticky glue on the spiraling silk threads, and waits for insects to crash into them. Spiders are predatory animals, feeding almost exclusively on other arthropods. Many spiders build unique webs, which are effective in trapping flying insects.

Critical Thinking Explain how certain structures in spiders enable them to be effective predators.

1 Simple eyes Spiders have six or eight simple eyes that, in most species, detect light but do not form images. Spiders have no compound eyes.


3 Cocoon Female spiders wrap their eggs in a silken sac or cocoon, where the eggs remain until they hatch. Some spiders lay their eggs and never see their young. Others carry the sac around with them until the eggs hatch.

4 Silk glands Spiders have between two and six silk glands, which first release silk as a liquid. The silk then passes through as many as 100 small tubes before being spun into thread by the spinnerets.

5 Chelicerae Chelicerae are the two biting appendages of arachnids. In spiders, they are modified into fangs. Poison glands are located near the tips of the fangs.

6 Pedipalps A pair of pedipalps is used to hold and move food and also to function as sense organs. In males, pedipalps are bulbous and are used to carry sperm.

7 Legs The four pairs of walking legs are located on the cephalothorax of the spider.
Many crustaceans have five pairs of walking legs that are used for walking, for seizing prey, and for cleaning other appendages. The first pair of walking legs are often modified into strong claws for defense.

Crabs, lobsters, shrimps, crayfishes, barnacles, water fleas, and pill bugs are members of the class Crustacea, Figure 28.9. Some crustaceans have three body sections, and others have only two. Sow bugs and pill bugs, the only land crustaceans, must live where there is moisture, which aids in gas exchange. They are frequently found in damp areas around building foundations. You can observe crustaceans in the BioLab at the end of this chapter.

**Centipedes and Millipedes**

Centipedes, which belong to the class Chilopoda, and millipedes, members of the class Diplopoda, are shown in Figure 28.10. If you have ever turned over a rock on a damp forest floor, you may have seen the flattened bodies of centipedes wriggling along on their many tiny, jointed legs. Centipedes are carnivorous and eat soil arthropods, snails, slugs, and worms. The bite of a centipede is painful to humans. Like spiders, millipedes and centipedes have Malpighian tubules for excreting wastes. In contrast to spiders, centipedes and millipedes have tracheal tubes rather than book lungs for gas exchange.

A millipede eats mostly plants and dead material on damp forest floors. Millipedes do not bite, but they can spray obnoxious-smelling fluids from their defensive stink glands. You may have seen their cylindrical bodies walking with a slow, graceful motion.
Horseshoe Crabs: Living Fossils

Horseshoe crabs, members of the class Merostomata, are considered to be living fossils because they have remained relatively unchanged since the Cambrian period, about 500 million years ago. They are similar to trilobites in that they are heavily protected by an extensive exoskeleton. Shown in Figure 28.11, horseshoe crabs forage on sandy or muddy ocean bottoms for seaweed, worms, and mollusks. These arthropods migrate to shallow water during mating season, and the females lay their eggs on land, buried in sand above the high water mark. Newly hatched horseshoe crabs look like trilobites.

Insects

Have you ever launched an ambush on a fly with your rolled-up newspaper? You swat with great accuracy and speed, yet your prey is now firmly attached upside down on the kitchen ceiling. How does a fly do this?

The fly approaches the ceiling right-side up at a steep angle. Just before impact, it reaches up with its front legs. The forelegs grip the ceiling with tiny claws and sticky hairs, while the other legs swing up into position. The flight mechanism shuts off, and the fly is safely out of swatting distance. Adaptations that enable flies to land on ceilings are among the many that make insects the most successful arthropod group. How is the ability to fly an adaptive advantage to insects? Find out by reading the Inside Story on the next page.

Insect reproduction

Insects mate once, or at most only a few times, during their lifetimes. The eggs are fertilized internally, and, in some species, shells form around them. Most insects lay a large number of eggs, which increases the chances that some offspring will survive long enough to reproduce. Many female insects are equipped with an appendage that is modified for piercing through the surface of the ground or into wood. The female lays eggs in the hole.

Metamorphosis: Change in body shape and form

After eggs are laid, the insect embryo develops and the eggs hatch. In some wingless insects, such as springtails and silverfish, development is direct; the eggs hatch into miniature forms that look just like tiny adults. These insects go through
A Grasshopper

Grasshoppers make rasping sounds either by rubbing their wings together or by rubbing small projections on their legs across a scraper on their wings. Most calls are made by males. Some aggressive calls are made when other males are close. Other calls attract females, and still others serve as an alarm to warn nearby grasshoppers of a predator in the area.

Critical Thinking  Do grasshoppers have a well-developed nervous system?

1. **Ability to fly**  Insects are the only invertebrates that can fly. With the ability to fly, insects can find places to live, discover food sources, escape from predators, and find mates.

2. **Legs**  Insects have six legs. By looking at an insect’s legs, you can sometimes tell how it moves about and what it eats.

3. **Eyes**  Grasshoppers have two compound eyes and three simple eyes.

4. **Antennae**  Insects have one pair of antennae, which is used to sense vibrations, food, and pheromones in the environment.

5. **Spiracles**  The spiracles in the abdomen open into a series of tracheal tubes.

6. **Malpighian tubules**  Excretion takes place in Malpighian tubules. In the grasshopper, wastes are in the form of dry crystals of uric acid. Producing dry waste helps insects conserve water.

7. **Tympanum**  The structure insects use for hearing is a flat membrane called a tympanum.

8. **Nervous system**  Grasshoppers, like other insects, have a complex nervous system that includes several ganglia that act as nerve control centers for the body sections in which they are located.
successive molts until the adult size is reached. Many other species of insects undergo a series of major changes in body structure as they develop. In some cases, the adult insect bears little resemblance to its juvenile stage. This series of changes, controlled by chemical substances in the animal, is called **metamorphosis** (met uh MOR fuh sus).

Insects that undergo metamorphosis usually go through four stages on their way to adulthood: egg, larva, pupa, and adult. The **larva** is the free-living, wormlike stage of an insect, often called a caterpillar. As the larva eats and grows, it molts several times.

The **pupa** (pyew puh) stage of insects is a period of reorganization in which the tissues and organs of the larva are broken down and replaced by adult tissues. Usually the insect does not move or feed during the pupa stage. After a period of time, a fully formed adult emerges from the pupa.

The series of changes that occur as an insect goes through the egg, larva, pupa, and adult stages is known as complete metamorphosis. In winged insects that undergo complete metamorphosis, the wings do not appear until the adult stage. More than 90 percent of insects undergo complete metamorphosis. The complete metamorphosis of a butterfly is illustrated in **Figure 28.12**. Other insects that undergo complete metamorphosis include ants, beetles, flies, and wasps.

Complete metamorphosis is an advantage for arthropods because larvae do not compete with adults for the same food. For example, butterfly larvae (caterpillars) feed on leaves, but adult butterflies feed on nectar from flowers.

**Incomplete metamorphosis has three stages**

Many insect species, as well as other arthropods, undergo a gradual or incomplete metamorphosis, in which the insect goes through only three stages of development: egg, nymph, and adult, as shown in
A nymph, which hatches from an egg, has the same general appearance as the adult but is smaller. Nymphs may lack certain appendages, or have appendages not seen in adults, and they cannot reproduce. As the nymph eats and grows, it molts several times. With each molt, it comes to resemble the adult more and more. Wings begin to form, and an internal reproductive system develops. Gradually, the nymph becomes an adult. Grasshoppers and cockroaches are insects that undergo incomplete metamorphosis. You can compare the two types of metamorphosis in the MiniLab on this page.

**Origins of Arthropods**

Arthropods have been enormously successful in establishing themselves over the entire surface of Earth. Their ability to exploit just about every habitat is unequaled in the animal kingdom. The success of arthropods can be attributed in part to their varied life cycles, high reproductive output, and structural adaptations such as small size, a hard exoskeleton, and jointed appendages.
Arthropods most likely evolved from an ancestor of the annelids. As arthropods evolved, body segments fused and became adapted for certain functions such as locomotion, feeding, and sensing the environment. Segments in arthropods are more complex than in annelids, and arthropods have more developed nerve tissue and sensory organs such as eyes.

The exoskeleton of arthropods provides protection for their soft bodies. Muscles in arthropods are arranged in bands associated with particular segments and portions of appendages. The circular muscles of annelids do not exist in arthropods. Because arthropods have many hard parts, much is known about their evolutionary history. The trilobites shown in Figure 28.14 were once an important group of ancient arthropods, but they have been extinct for 250 million years.

**Section Assessment**

**Understanding Main Ideas**

1. How are centipedes different from millipedes?
2. How are insects different from spiders?
3. Describe three sensory adaptations of insects.
4. Compare the stages of complete and incomplete metamorphosis.

**Thinking Critically**

5. Why might complete metamorphosis have greater adaptive value for an insect than incomplete metamorphosis?

**6. Recognizing Cause and Effect** Some plants produce substances that prevent insect larvae from forming pupae. How might this chemical production be a disadvantage to the plant? For more help, refer to Thinking Critically in the Skill Handbook.
Without insects, life as we know it would be impossible. Two-thirds of all flowering plants depend on insects to pollinate them. Insects also digest and degrade carrion, animal wastes, and plant matter. Their actions help fungi, bacteria, and other decomposers recycle nutrients and enrich the soil on which plants and all terrestrial organisms depend.

CHARACTERISTICS
Insects have three body divisions—head, thorax, abdomen—and six legs attached to the thorax. The abdomen has multiple segments, the last ones often possessing external reproductive organs.

Most adult insects have wings, usually one or two pairs. An insect’s skin, or integument, is hard yet flexible, and waterproof. Many insects must molt in order to grow larger before metamorphosing into adult forms.

Because of their ability to fly, a rapid reproductive cycle, and a tough, external skeleton, insects are both resilient and successful.

SIZE AND DIVERSITY
Insects are members of the phylum Arthropoda and the class Insecta. The most diverse class in the animal kingdom, Insecta is also the largest—it contains more species than all other animal groups combined.
MOUTHPARTS
Insects get food by biting, lapping, and sucking. Some insects, such as grasshoppers and ants, have mouthparts for biting and chewing, with large mandibles for tearing into plant tissue or seizing prey. The powerful mandibles of bulldog ants, for example, are hinged at the sides of the head and bite inward—with great force—from side to side. Butterflies and honeybees have mouthparts shaped for lapping up nectar. Aphids and cicadas can pierce plant stems and then plant juices can be sucked like soda through a straw.

SENSE ORGANS
Insects gather information about their environment using a variety of sense organs that detect light, odors, sound, vibrations, temperature, and even humidity. Most adult insects have compound eyes, as well as two or three simple eyes on top of their heads. The compound eye of a large dragonfly contains a honeycomb of 28,000 lenses. The image from each lens is sent to the brain and somehow combined into a composite image, but we don’t know exactly what such insects see. Some insects navigate by using sound waves or following odor trails. Katydid and crickets have “ears” on their front legs; houseflies have taste receptors on their feet.

VERSATILITY
Some insects, such as the Arctic woolly bear caterpillar, can survive 10 months a year in subzero temperatures. Others, such as the monarch butterfly, migrate thousands of miles to warmer regions. Honeybees conserve heat in freezing temperatures by clumping into a ball that hums and churns all winter. Although some insects are plant pests, many others prey on their plant-munching relatives, and in so doing aid humans in the fight to control crop damage.
A SUPERLATIVE CRITTER

Some beetles can chew through lead or zinc or timber—not to mention whole fields of cotton. A leaf beetle in the Kalahari Desert produces a toxin powerful enough to fell an antelope. The American burying beetle can lift 200 times its weight. Among Earth’s most recognizable beetles, fireflies light up summer evenings, and ladybugs control garden pests.

HARMFUL VERSUS HELPFUL

Some beetles damage crops and spread disease. Spotted cucumber beetles, for example, devour leaves and flowers of cucumbers, melons, and squashes. They can also spread bacterial diseases to the plants they attack.

Many other beetles, such as ladybugs (also known as ladybirds), should be welcome visitors anywhere. Gardeners, farmers, and fruit-growers release thousands of ladybugs into gardens, fields, and orchards as a first line of defense against insect pests, especially aphids. The bright red-orange of ladybug beetles is an unmistakable warning to potential predators that the beetles are extremely distasteful.
BODY ARMOR
Many scientists consider beetles to be evolution’s biggest success story and think that thousands of additional species remain undiscovered. Beetles—all 350,000 described species—presently account for approximately 1 in 4 known animal species. Beetles thrive in deserts, under tropical forest canopies, and in water. One key to beetles’ adaptability is their “shell”—actually a pair of hardened wings called elytra. Elytra permit some beetles to live in deserts by sealing in moisture and other species to breathe underwater by trapping air. Many beetles are remarkably resistant to pesticides.

A SPECIAL NICHE
The Mesozoic era is often identified as the age of dinosaurs. But the truly colossal event during this period in Earth’s history was the proliferation of flowering plants. Primary pollinators of the era, beetles most likely fueled this explosion of color and fragrance. Beetles fill critical ecological niches as scavengers and as harvesters of caterpillars and other pests, which, left untended, would devour thousands of acres of crops and forest trees each year. When a beetle species faces extinction—as nine species in the United States currently do—scientists see it as an early warning system alerting us to significant environmental change.

1. THINKING CRITICALLY What are the advantages and disadvantages of an exoskeleton?

2. JOURNAL WRITING Research social behavior in insects and write a short essay to present to the class.
Will salt concentration affect brine shrimp hatching?

Brine shrimp (Artemia salina) belong to the class Crustacea. They are excellent experimental animals because their eggs hatch into visible swimming larvae within a very short time. Using the name as a clue, where might these animals normally be found?

**Problem**
How can you determine the optimum salt concentration for the hatching of brine shrimp eggs?

**Hypothesis**
Decide on one hypothesis that you will test. Your hypothesis might be that increased salt concentrations result in an increase in the number of eggs hatched.

**Objectives**
*In this BioLab, you will:*
- Analyze how salt concentration may affect brine shrimp hatching.
- Interpret your experimental findings.

**Possible Materials**
beakers or plastic bottles
labels or marking pencil
graduated cylinder
brine shrimp eggs
clear plastic trays
salt (noniodized)
balance
water

**Safety Precautions**
Wear protective eye goggles when preparing solutions.

**Skill Handbook**
Use the *Skill Handbook* if you need additional help with this lab.
**Plan the Experiment**

1. Decide on a way to test your group’s hypothesis. Keep the available materials in mind as you plan your procedure. Be sure to include a control. For example, you might place brine shrimp eggs in two trays—one with the salt concentration of the water brine shrimp normally inhabit, and one with a different salt concentration.

2. Decide how long you will make observations and how you will judge the extent of egg hatching.

3. Decide on the number of different salt water concentrations to use and what these concentrations will be. Review the steps needed to prepare solutions of different concentrations.

**Check the Plan**

Discuss the following points with other group members to decide on the final procedure for your experiment.

1. What is your one independent variable? Your dependent variable?

2. What will be your control?

3. How much water will you add to each tray and how will you measure the same number of eggs to be used in each tray?

4. Will it be necessary to control variables such as light and temperature?

5. What data will you collect and how will it be recorded?

6. Make sure your teacher has approved your experimental plan before you proceed further.

7. Carry out your experiment.

**Analyze and Conclude**

1. **Interpreting Data** Using specific numbers from your data, explain how salt concentration affects brine shrimp hatching.

2. **Drawing a Conclusion** Was your hypothesis supported? Explain.

3. **Identifying and Controlling Variables** What were the independent and dependent variables? What were some of the variables that had to be controlled?

4. **Hypothesizing** Formulate a hypothesis that explains why high salt concentrations may be harmful to brine shrimp hatching.

5. **Classifying** Classify brine shrimp. Identify their kingdom, phylum, class, order, family, genus, and species.

**Going Further**

**Project** Design an experiment that you could perform to investigate the role that temperature plays in brine shrimp hatching. If you have all of the materials you will need, you may want to carry out the experiment.

**Biology Online**

To find out more about brine shrimp and other crustaceans, visit the Glencoe Science Web site.

science.glencoe.com
Every American city, it seems, has its claim to fame. Chicago is recognized for its outstanding architecture. New York has long been thought of as the cultural center of the United States. Los Angeles is home to television production and to the nation’s legendary movie industry. One American city, however, would probably just as soon forget its claim to fame. Lyme, Connecticut, will forever be associated with Lyme disease, a crippling bacterial malaise that was first identified in this town in 1975.

Lyme disease manifests itself in humans in three distinct stages. First, a circular, bull's-eye rash appears. The rash is generally accompanied by chills, fever, and aching joints. These symptoms may resemble symptoms that result from an infection with an influenza virus. This is the mildest form of the disease. If left untreated, Lyme disease progresses to a second stage. The joint pains become more severe and may be joined by neurological symptoms, such as memory disturbances and vision impairment. Stage three is the most severe form of the disease. Crippling arthritis, facial paralysis, heart abnormalities, and memory loss may result.

Tick transmission
The cause of this debilitating disease is *Borrelia burgdorferi*, a corkscrew-shaped bacterium that is transmitted to humans through the bite of ticks. The bacterium infects mostly deer and white-footed mice. Ticks pick up the bacterium by sucking the blood from these animals. When the same ticks bite humans, the bacteria are passed on, and the result is Lyme disease.

Where Lyme disease strikes
Most cases of Lyme disease are reported in the Northeast, Mid-Atlantic, and North Central regions, as seen on the map. Lyme disease is also on the rise in many other areas.

Prevention and treatment
Ticks live in weedy areas, low shrubs, and tall grasses. If you are entering this type of habitat, it is advisable to wear light colored clothing to easily detect darker ticks, and to tuck pants legs into socks. In addition, insect repellents containing the chemical DEET can be applied to clothing (but not to skin). Careful examination of the body for ticks is also important.

Like most bacteria, *Borrelia burgdorferi* responds to antibiotics. Early treatment with antibiotics usually prevents the disease from progressing to its second or third stages. A new vaccine has been developed that is effective in 90 percent of adults exposed to Lyme disease, but this vaccine has not yet been proven to be safe for those under age 18.

Since the turn of the century, the deer population in the United States has been increasing steadily. How might this increase affect the incidence of Lyme disease? Why?
**Section 28.1**

**Characteristics of Arthropods**

**Main Ideas**
- Arthropods have jointed appendages, exoskeletons, varied life cycles, and body systems adapted to life on land, water, or air.
- Arthropods are members of the most successful animal phylum in terms of diversity. This can be attributed in part to their structural and behavioral adaptations.

**Vocabulary**
- appendage (p. 761)
- book lung (p. 764)
- cephalothorax (p. 763)
- compound eye (p. 765)
- mandible (p. 765)
- Malpighian tubule (p. 765)
- molting (p. 762)
- parthenogenesis (p. 766)
- pheromone (p. 764)
- simple eye (p. 765)
- spiracle (p. 764)
- tracheal tube (p. 764)

**Section 28.2**

**The Diversity of Arthropods**

**Main Ideas**
- Spiders have two body regions with four pairs of walking legs. They spin silk. Ticks and mites have one body section. Scorpions have many abdominal segments, enlarged pincers, and a stinger at the end of the tail.
- Most crustaceans are aquatic and exchange gases in their gills. They include crabs, lobsters, shrimps, crayfishes, barnacles, and water fleas.
- Centipedes are carnivores with flattened, worm-like bodies. Millipedes are herbivores with cylindrical, wormlike bodies.
- Insects are the most successful arthropod class in terms of diversity. They have many structural and behavioral adaptations that allow them to exploit all habitats.

**Vocabulary**
- chelicerae (p. 768)
- larva (p. 773)
- metamorphosis (p. 773)
- nymph (p. 774)
- pedipalp (p. 768)
- pupa (p. 773)
- spinneret (p. 768)

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**Understanding Main Ideas**

1. Crustaceans are different from other arthropods because they have two ________ used for sensing.
   a. jointed appendages  
   b. pairs of antennae  
   c. pedipalps  
   d. walking legs

2. Of the following, which are NOT appendages used by arthropods to obtain and eat food?
   a. chelicerae  
   b. pedipalps  
   c. mandibles  
   d. spiracles

3. Jointed appendages allow for greater ________ and more powerful movements.
   a. mobility  
   b. molting  
   c. flexibility  
   d. camouflage

4. ________ are arthropods with only one body section.
   a. Spiders  
   b. Ticks and mites  
   c. Scorpions  
   d. Crustaceans

5. ________ are used by arthropods for gas exchange.
   a. Pedipalps  
   b. Spiracles  
   c. Chelicerae  
   d. Spinnerets
6. What arthropod has many abdominal segments, enlarged pincers, and a stinger at the end of its tail?
   a. a spider   c. a scorpion
   b. a tick   d. a crab

7. Arthropods are so successful because of their ________.
   a. larvae   c. antennae
   b. book lungs   d. adaptations

8. Name an arthropod that is a carnivore and has a flattened, wormlike body.
   a. millipede   c. crustacean
   b. centipede   d. insect

9. Of the following, which is NOT an appendage of an arthropod?
   a. chelicerae   c. pedipalps
   b. antennae   d. cephalothorax

10. Arthropods with two body regions and four pairs of walking legs are called ________.
    a. spiders   c. scorpions
    b. ticks and mites   d. crustaceans

11. The most diverse group of arthropods is the ________ class.

12. Molting occurs when an arthropod sheds its old ________ and grows a new one.

13. The structure labeled b in the diagram below is used for what purpose by the grasshopper?

14. Spiders have a fused head and thorax region called a ________.

15. ________ are the hollow passages that carry air through the body of an arthropod.

16. Study the diagram below. The group most closely related to insects is the ________.

17. Evolutionary biologists have hypothesized that arthropods may have evolved from annelids because both have ________.

18. A butterfly excretes wastes through ________.

19. List in the correct order the stages of incomplete metamorphosis: ________, ________, adult.

20. When water passes over gills, ________ and ________ are exchanged.

21. Many insects are pests to humans when they are larvae but are beneficial when they are adults. Explain.

22. Why is it an adaptive advantage for barnacles to be hermaphrodites?

23. Relate differences in exoskeleton structure to the various modes of arthropod locomotion.

24. In what ways have wings been an adaptive advantage to the success of insects?

25. Of what advantage might movable, stalked eyes be to a crustacean that has a cephalothorax?
26. **Interpreting Scientific Illustrations**
Identify each of the arthropods at right as an arachnid, crustacean, or insect. What are their distinguishing features?

27. **Recognizing Cause and Effect**
What is the advantage to a plant of producing a chemical that is an effective insect repellent?

28. **Recognizing Cause and Effect**
What might be the effect on plant and animal life if all insects were suddenly to die?

29. **Observing and Inferring**
Evidence shows that deer, mice, and even household pets may harbor the bacteria that cause Lyme disease. How could pets become infected with these bacteria?

30. **Concept Mapping**
Complete the concept map by using the following vocabulary terms: appendages, mandibles, chelicerae, pedipalps.

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### Thinking Critically

**Assessing Knowledge & Skills**

The melting points of the waxy layers on certain insect exoskeletons are shown in the graph below. These melting points reflect the environments in which the insects were raised. Insects raised in warmer environments have wax that melts at higher temperatures than insects raised in cooler environments.

**Interpreting Data**
Study the graph and answer the following questions.

1. What is the melting point of the wax on insects in group B?
   - a. 15°C
   - b. 50°C
   - c. 35°C
   - d. 40°C

2. What is the melting point of the wax on insects in group C?
   - a. 15°C
   - b. 50°C
   - c. 35°C
   - d. 40°C

3. Which insects were raised at the lowest temperature?
   - a. A
   - b. B
   - c. C
   - d. D

4. **Making a Graph**
   Make a graph of these data: insect exoskeletons found by a stream melt at 15°C; in a forested area at 20°C; in a grassy meadow at 40°C; and on roadside soil at 50°C.

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**CD-ROM**
For additional review, use the assessment options for this chapter found on the *Biology: The Dynamics of Life* Interactive CD-ROM and on the Glencoe Science Web site. science.glencoe.com