What You’ll Learn

- You will compare and contrast the adaptations of echinoderms.
- You will distinguish the features of chordates by examining invertebrate chordates.

Why It’s Important

By studying how echinoderms and invertebrate chordates function, you will enhance your understanding of evolutionary relationships between these two groups.

**READING BIOLOGY**

Scan the chapter, examining the illustrations and reading the captions. As you read, write down the key idea illustrated in each figure.

**BIOLOGY Online**

To find out more about echinoderms and invertebrate chordates, visit the Glencoe Science Web site.

[science.glencoe.com](http://science.glencoe.com)

A sea star extends its stomach from its mouth and engulfs a sea urchin. Hours later, the sea star draws its stomach back in and moves away. All that’s left of the urchin is the bumpy globe you see here. Even its spines are gone.
29.1 Echinoderms

Think about what the best defense might be for a small animal that moves slowly in tide pools on the seashore. Did you think of armor, spines, or perhaps poison as methods of protection? Sea urchins are masters of defense—some use all three methods. The sea urchin looks different from the feather star and from the sea star on the facing page, yet all three belong to the same phylum. What characteristics do they have in common? What features determine whether an animal is an echinoderm?

What Is an Echinoderm?

Members of the phylum Echinodermata have a number of unusual characteristics that easily distinguish them from members of any other animal phylum. Echinoderms move by means of hundreds of hydraulic, suction cup-tipped appendages and have skin covered with tiny, jawlike pincers. Echinoderms (ih kī nūh durmz) are found in all the oceans of the world.

Echinoderms have endoskeletons

If you were to examine the skin of several different echinoderms, you would find that they all have a hard, spiny, or bumpy endoskeleton covered by a thin epidermis. The long, pointed spines on a sea urchin are obvious. Sea stars, sometimes called starfishes, may not appear spiny at first glance, but a close look reveals that their long, tapering arms, called rays, are covered with short, rounded spines. The spiny skin of a sea cucumber consists of soft tissue embedded with small, platelike structures that barely resemble spines. The endoskeleton of all echinoderms is made primarily of calcium carbonate, the compound that makes up limestone.

Some of the spines found on sea stars and sea urchins have become modified into pincerlike appendages called pedicellariae (PED ih sīhl AHR ee āy). An echinoderm uses its jawlike pedicellariae for protection and for cleaning the surface of its body. You can examine these structures in the MiniLab on the following page.

Word Origin

**echinoderm**

From the Greek words *echinos*, meaning “spiny,” and *derma*, meaning “skin.” Echinoderms are spiny-skinned animals.

**pedicellariae**

From the Latin word *pediculus*, meaning “little foot.” Pedicellariae resemble little feet.
Examining Pedicellariae

Echinoderms move by tube feet. They also have tiny pincers on their skin called pedicellariae.

Procedure

1. Observe a slide of sea star pedicellariae under low-power magnification. **CAUTION: Use caution when working with a microscope and slides.**
2. Record the general appearance of one pedicellaria. What does it look like?
3. Make a diagram of one pedicellaria under low-power magnification.
4. Record the size of one pedicellaria in micrometers.

Analysis

1. Describe the general appearance of one pedicellaria.
2. What is the function of this structure?
3. Explain how the structure of pedicellariae assists in their function.

**Echinoderms have radial symmetry**

You may remember that radial symmetry is an advantage to animals that are stationary or move slowly. Radial symmetry enables these animals to sense potential food, predators, and other aspects of their environment from all directions. Observe the radial symmetry, as well as the various sizes and shapes of spines, of each echinoderm pictured in Figure 29.1.

**The water vascular system**

Another characteristic unique to echinoderms is the water vascular system that enables them to move, exchange gases, capture food, and excrete wastes. Look at the close-up of the underside of a sea star in Figure 29.2. You can see that grooves filled with tube feet run from the area of the sea star’s mouth to the tip of each ray. **Tube feet** are hollow, thin-walled tubes that end in a suction cup. Tube feet look somewhat like miniature droppers. The round, muscular structure called the **ampulla** (AM puh lah) works something like the bulb of a dropper. The end of a tube foot works like a tiny suction cup. Each tube foot works independently of the others, and the animal moves along slowly by alternately pushing out and pulling in its tube feet. You can learn more about the operation of the water vascular system in the Physics...
The water vascular system is a hydraulic system that operates under water pressure. Water enters and leaves the water vascular system of a sea star through the madreporite (MAH dray pohr ite), a sievelike, disk-shaped opening on the upper surface of the echinoderm’s body. You can think of this disk as being like the little strainer that fits into the drain in a sink and keeps large particles out of the pipes. You can find out how a sea star eliminates wastes by reading the Inside Story on the next page.

Finally, tube feet function in gas exchange and excretion. Gases are exchanged and wastes are eliminated by diffusion through the thin walls of the tube feet.

**Echinoderms have varied nutrition**

All echinoderms have a mouth, stomach, and intestines, but their methods of obtaining food vary. Sea stars are carnivorous and prey on worms or on mollusks such as clams. Most sea urchins are herbivores and graze on algae. Brittle stars, sea lilies, and sea cucumbers feed on dead and decaying matter that drifts down to the ocean floor. Sea lilies capture this suspended organic matter with their tentaclelike tube feet and move it to their mouths.

**Echinoderms have a simple nervous system**

Echinoderms have no head or brain, but they do have a central nerve ring that surrounds the mouth. Nerves extend from the nerve ring down each ray. Each radial nerve then branches into a nerve net that provides sensory information to the animal. Echinoderms have cells that detect light and touch, but most do not have sensory organs. Sea stars are an exception. A sea star’s body consists of long, tapering rays that extend from the animal’s central disk. At the tip of each ray, on the underside, is an eyespot, a sensory organ consisting of a cluster of light-detecting cells. When walking, sea stars curve up the tips of their rays so that the eyespots are turned up and outward. This enables a sea star to detect the intensity of light coming from every direction.

**Echinoderms have bilaterally symmetrical larvae**

If you examine the larval stages of echinoderms, you will find that they have bilateral symmetry, a feature more common to chordates. The ciliated larva that develops from the fertilized egg of an echinoderm is shown in Figure 29.3. Through metamorphosis, the free-swimming larvae make dramatic changes in both body parts and in symmetry. The bilateral symmetry of echinoderm larvae indicates that echinoderm ancestors also may have had bilateral symmetry, suggesting a close relationship to the chordates. You can observe sea urchin development in the BioLab at the end of this chapter.
A Sea Star

If you ever tried to pull a sea star from a rock where it is attached, you would be impressed by how unyielding and rigid the animal seems to be. Yet at other times, the animal shows great flexibility, such as when it rights itself after being turned upside down.

Critical Thinking  How is radial symmetry useful to a sea star?

1. **Endoskeleton**  A sea star can maintain a rigid structure or be flexible because it has an endoskeleton in the form of calcium carbonate plates just under its epidermis. The plates are connected by bands of soft tissue and muscle. When the muscles are contracted, the body becomes firm and rigid. When the muscles are relaxed, the body becomes flexible.

2. **Madreporite**  Water flows in and out of the water vascular system through the madreporite.

3. **Tube feet**  The suction action of tube feet, caused by the contraction and relaxation of the ampulla, is so strong that the sea star’s muscles can open a clam or oyster shell.

4. **Eyespots**  When moving, a sea star curves up the tips of its rays so that the eyespots are turned up and outward. Echinoderm eyespots distinguish between light and dark but do not form images.

5. **Digestive gland**  The digestive gland gives off chemicals for digestion.

6. **Stomach**  To eat, a sea star pushes its stomach out of its mouth and spreads the stomach over the food. Powerful enzymes secreted by the digestive gland turn solid food into a soupy liquid that the stomach can easily absorb. Then the sea star pulls the stomach back into its body.

7. **Anus**  Waste products of digestion are eliminated through the anus.

8. **Pedicellariae**  The pincerlike pedicellariae on the rays of the sea star will pinch any animal that tries to crawl over it.
Diversity of Echinoderms

Approximately 6000 species of echinoderms exist today. More than one-third of these species are in the class Asteroidea (AS tuh royd ee uh), to which the sea stars belong. The four other classes of living echinoderms are Ophiuroidea (OH fee uh royd ee uh), the brittle stars; Echinoidea (eh kihn OYD ee uh), the sea urchins and sand dollars; Holothuroidea (HOH loh thuh royd ee uh), the sea cucumbers; and Crinoidea (cry NOYD ee uh), the sea lilies and feather stars.

Sea stars

Most species of sea stars have five rays, but some have more. Some species may have more than 40 rays. The rays are tapered and extend from the central disk. You have already read about the characteristics of sea stars that make them a typical example of echinoderms.

Brittle stars

As their name implies, brittle stars are extremely fragile, Figure 29.4. If you try to pick up a brittle star, parts of its rays will break off in your hand. This is an adaptation that helps the brittle star survive an attack by a predator. While the predator is busy with the broken-off ray, the brittle star can escape. A new ray will regenerate within weeks.

Brittle stars do not use their tube feet for locomotion. Instead, they propel themselves with the snakelike, slithering motion of their flexible rays. They use their tube feet to pass particles of food along the rays and into the mouth in the central disk.

Sea urchins and sand dollars

Sea urchins and sand dollars are globe- or disk-shaped animals covered with spines, as Figure 29.4 shows. They do not have rays. The circular, flat skeletons of sand dollars have a five-petaled flower pattern on the surface. A living sand dollar is covered with minute, hairlike spines that are lost when the animal dies. A sand dollar has tube feet that protrude from the petal-like markings on its upper surface. These tube feet are modified into gills. Tube feet on the animal’s bottom surface aid in bringing food particles to the mouth.

Sea urchins look like living pin-cushions, bristling with long, usually
What makes sea cucumbers release gametes? The orange sea cucumber lives in groups of 100 or more per square meter. In the spring, these sea cucumbers produce large numbers of gametes (eggs and sperm), which they shed in the water all at the same time. The adaptive value of such behavior is that fertilization of many eggs is assured. When one male releases sperm, the other sea cucumbers in the population, both male and female, also release their gametes. Biologists do not know whether the sea cucumbers release their gametes in response to a seasonal cue, such as increasing day length or increasing water temperature, or whether they do this in response to the release of sperm by one sea cucumber.

Analysis
Design an experiment that will help to determine whether sea cucumbers release eggs and sperm in response to the release of sperm from one individual or in response to a seasonal cue.

Thinking Critically
If you find that female sea cucumbers release 200 eggs in the presence of male sperm and ten eggs in the presence of water that is warmer than the surrounding water, what would you do in your next experiment?

Sea cucumbers
Sea cucumbers are so called because of their vegetable-like appearance, shown in Figure 29.5. Their leathery covering allows them to be more flexible than other echinoderms; they pull themselves along the ocean floor using tentacles and tube feet. When sea cucumbers are threatened, they exhibit a curious behavior. They may expel a tangled, sticky mass of tubes through the anus, or they may rupture, releasing some internal organs that are regenerated in a few weeks. These actions confuse their predators, giving the sea cucumber an opportunity to move away. Sea cucumbers reproduce by shedding eggs and sperm into the water, where fertilization occurs. You can find out more about sea cucumber reproduction in the Problem-Solving Lab on this page.

Sea lilies and feather stars
Sea lilies and feather stars resemble plants in some ways. Sea lilies are the only sessile echinoderms. Feather stars are sessile only in larval form. The adult feather star uses its feathery arms to swim from place to place.
**Origins of Echinoderms**

The earliest echinoderms may have been bilaterally symmetrical as adults, and probably were attached to the ocean floor by stalks. Another view of the earliest echinoderms is that they were bilateral and free-swimming. The development of bilateral larvae is one piece of evidence biologists have for placing echinoderms as the closest invertebrate relatives of the chordates.

Recall that most invertebrates show protostome development, whereas deuterostome development appears mainly in chordates. The echinoderms represent the only major group of deuterostome invertebrates.

Because the endoskeletons of echinoderms easily fossilize, there is a good record of this phylum. Echinoderms, as a group, date from the Paleozoic era, as shown in Figure 29.6. More than 13,000 fossil species have been identified.

---

**Section Assessment**

**Understanding Main Ideas**

1. How does a sea star move? Explain in terms of the water vascular system of echinoderms.
2. Describe the differences in symmetry between larval echinoderms and adult echinoderms.
3. How are sea cucumbers different from other echinoderms?
4. Compare how sea urchins and sea cucumbers obtain food.

**Thinking Critically**

5. How do the various defense mechanisms among the echinoderm classes help deter predators?
6. **Classifying** Prepare a key that distinguishes among classes of echinoderms. Include information on features you may find significant. For more help, refer to Organizing Information in the Skill Handbook.
What Is an Invertebrate Chordate?

The chordates most familiar to you are the vertebrate chordates—chordates that have backbones, such as birds, fishes, and mammals, including humans. But the phylum Chordata (kor DAHT uh) includes three subphyla: Urochordata, the tunicates (sea squirts); Cephalochordata, the lancelets; and Vertebrata, the vertebrates. In this section you will examine the tunicates and lancelets—invertebrate chordates that have no backbones. You will study the vertebrate chordates in the next unit.

Invertebrate chordates may not look much like fishes, reptiles, or humans, but like all other chordates, they have a notochord, a dorsal hollow nerve cord, gill slits, and muscle blocks at some time during their development. In addition, all chordates have bilateral symmetry, a well-developed coelom, and segmentation. The features shared by invertebrate and vertebrate chordates are illustrated in Figure 29.7.

You can observe these features in invertebrate chordates in the Problem-Solving Lab later in this section.
All chordates have a notochord

All chordate embryos have a notochord (NOHT uh kord)—a long, semirigid, rodlike structure located between the digestive system and the dorsal hollow nerve cord. The notochord is made up of large, fluid-filled cells held within stiff, fibrous tissues. In invertebrate chordates, the notochord is retained into adulthood. But in vertebrate chordates, this structure is replaced by a backbone. Invertebrate chordates do not develop a backbone.

The notochord develops just after the formation of a gastrula from mesoderm on what will be the dorsal side of the embryo. The physical support provided by a notochord enables invertebrate chordates to make powerful side-to-side movements of the body. These movements propel the animal through the water at a great speed.

All chordates have a dorsal hollow nerve cord

The dorsal hollow nerve cord in chordates develops from a plate of ectoderm that rolls into a hollow tube. This occurs at the same time as the development of the notochord. The sequence of development of the dorsal hollow nerve cord is illustrated in Figure 29.8. This tube is composed of cells surrounding a fluid-filled canal that lies above the notochord. In most adult chordates, the cells in the posterior portion of the dorsal hollow nerve cord develop into the spinal cord. The cells in the anterior portion develop into a brain. A pair of
of nerves connects the nerve cord to each block of muscles.

**All chordates have gill slits**

The **gill slits** of a chordate are paired openings located in the pharynx, behind the mouth. Many chordates have several pairs of gill slits only during embryonic development. Invertebrate chordates that have gill slits as adults use these structures to strain food from the water. In some vertebrates, especially the fishes, the gill slits develop into internal gills that are adapted to exchange gases during respiration.

**All chordates have muscle blocks**

Muscle blocks are modified body segments that consist of stacked muscle layers. You have probably seen muscle blocks when you ate a cooked fish. The blocks of muscle cause the meat to separate easily into flakes. Muscle blocks are anchored by the notochord, which gives the muscles a firm structure to pull against. As a result, chordates tend to be more muscular than members of other phyla.

Muscle blocks also aid in movement of the tail. At some point in development, all chordates have a muscular tail. As you know, humans are chordates, and during the early development of the human embryo, there is a muscular tail that disappears as development continues. In most animals that have tails, the digestive system extends to the tip of the tail, where the anus is located. Chordates, however, usually have a tail that extends beyond the anus. You can observe many of the chordate traits in a lancelet in the *MiniLab* on the next page.

**Figure 29.9**

Tunicate larvae are about 1 cm long and are able to swim freely through the water (a). As adults, tunicates become sessile filter feeders enclosed in a tough, baglike layer of tissue called a tunic (b).

---

**Diversity of Invertebrate Chordates**

The invertebrate chordates belong to two subphyla of the phylum chordata: subphylum Urochordata, the tunicates (*tew nuh kaytz*), also called sea squirts, and subphylum Cephalochordata, the lancelets.

**Tunicates are sea squirts**

Members of the subphylum Urochordata are commonly called tunicates, or sea squirts. Although adult tunicates do not appear to have any shared chordate features, the larval stage, as shown in *Figure 29.9*, has a tail that makes it look similar to a tadpole. Tunicate larvae do not feed, and are free swimming only for a few days after hatching. Then they settle and attach themselves with a sucker to boats, rocks, and the ocean bottom. Many adult tunicates secrete a
Examining a Lancelet  *Branchiostoma californiense* is a small, sea-dwelling lancelet. At first glance, it appears to be a fish. However, its structural parts and appearance are quite different.

**Procedure**

1. Place the lancelet onto a glass slide. **CAUTION:** Wear disposable latex gloves and handle preserved material with forceps.
2. Use a dissecting microscope to examine the animal. **CAUTION:** Use care when working with a microscope and slides.
3. Prepare a data table that will allow you to record the following: General body shape, Length in mm, Head region present, Fins and tail present, Nature of body covering, Sense organs such as eyes present, Habitat, Segmented body.
4. Indicate on your data table if the following can easily be observed: gill slits, notochord, dorsal hollow nerve cord.

**Analysis**

1. How does *Branchiostoma* differ structurally from a fish? How are its general appearance and habitat similar to those of a fish?
2. Explain why you were not able to see gills, notochord, and a dorsal hollow nerve cord.
3. Using its scientific name as a guide, where might the habitat of this species be located?

**Figure 29.10**

Lancelets usually spend most of their time buried in the sand with only their heads sticking out so they can filter tiny morsels of food from the water (a). The lancelet's body looks very much like a typical chordate embryo (b).

---

tunic, a tough sac made of cellulose, around their bodies. Colonies of tunicates sometimes secrete just one big tunic that has a common opening to the outside. You can find out how tunicates eat in the *Inside Story* on the next page.

Only the gill slits in adult tunicates indicate their chordate relationship. Adult tunicates are small, tubular animals that range in size from microscopic to several centimeters long, about as big as a large potato. If you remove a tunicate from its sea home, it might squirt out a jet of water for protection—hence the name *sea squirt*.

**Lancelets are similar to fishes**

Lancelets belong to the subphylum Cephalochordata. They are small, streamlined, and common marine animals, usually about 5 cm long, as Figure 29.10 shows. They spend most of their time buried in the sand with only their heads sticking out. Like tunicates, lancelets are filter feeders. Unlike tunicates, however, lancelets retain all their chordate features throughout life.
**A Tunicate**

*Tunicates, or sea squirts, are a group of about 1250 species that live in the ocean. They may live near the shore or at great depths. They may live individually, or several animals may share a tunic to form a colony.*

**Critical Thinking** *In what ways are sponges and tunicates alike?*

---

**1. Excurrent siphon** Water leaves the body of the animal through the excurrent siphon. When a tunicate is disturbed, it may forcefully spout water from its mouth and excurrent siphon simultaneously.

**2. Incurrent siphon** Water comes into the animal through the incurrent siphon, the animal’s mouth.

**3. Ciliated groove** During filter feeding, food is trapped by mucus secreted in a ciliated groove. The food and mucus are digested in the animal’s intestine.

**4. Heart** The heart of the tunicate is unusual because it pumps blood in one direction for several minutes and then reverses direction.

**5. Tunic** Tunicates are covered with a layer of tissue called a tunic. Some tunics are thick and tough, and others are thin and translucent. All protect the animal from predators.

**6. Pharynx** The pharynx is lined with gill slits and cilia. The beating of the cilia causes a current of water to move through the animal. Food is filtered out, and dissolved oxygen is removed from the water in the pharynx.
Although lancelets look somewhat similar to fishes, they have only one layer of skin, with no pigment and no scales. Lancelets do not have a distinct head, but they do have light sensitive cells on the anterior end. They also have a hood that covers the mouth and the sensory tentacles surrounding it. The tentacles direct the water current and food particles toward the animal’s mouth.

**Origins of Invertebrate Chordates**

Because sea squirts and lancelets have no bones, shells, or other hard parts, their fossil record is incomplete. Biologists are not sure where sea squirts and lancelets fit in the phylogeny of chordates. According to one hypothesis, echinoderms, invertebrate chordates, and vertebrates all arose from ancestral sessile animals that fed by capturing food in tentacles. Modern vertebrates probably arose from the free-swimming larval stages of ancestral invertebrate chordates. Recent discoveries of fossil forms of organisms that are similar to living lancelets in rocks 550 million years old show that invertebrate chordates probably existed before vertebrate chordates.

**Section Assessment**

**Understanding Main Ideas**

1. Describe the four features of chordates.
2. How are invertebrate chordates different from vertebrates?
3. Compare the physical features of sea squirts and lancelets.
4. How do sea squirts and lancelets protect themselves?

**Thinking Critically**

5. What features of chordates suggest that you are more closely related to invertebrate chordates than to echinoderms?

**Skill Review**

6. **Designing an Experiment**

   Assume that you have found some tadpolelike animals in the water near the seashore and that you can raise them in a laboratory. Design an experiment in which you will determine whether the animals are larvae or adults. For more help, refer to *Practicing Scientific Methods* in the Skill Handbook.
Sea urchins are typical of most echinoderms in that their sexes are separate, fertilization is external, and development of a fertilized egg is quite rapid. Thus, these animals are excellent choices for studying gametes, watching fertilization, and observing changes occurring in a fertilized egg.

**Problem**
How can you induce a sea urchin to release its gametes?

**Objectives**
*In this BioLab, you will:*
- **Induce** sea urchins to release their gamete cells.
- **Observe** living sperm and egg cells under the microscope.
- **Observe** developmental changes in a fertilized sea urchin egg.

**Materials**
- live sea urchins
- sea water
- glass slides and cover slips
- syringe filled with potassium chloride
- beakers
- petri dish
- dropper
- microscope
- test tube

**Safety Precautions**
Always wear goggles in the lab.

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

**PREPARATION**

1. Fill a small beaker (250 mL) with sea water.
2. Obtain a live sea urchin from your teacher and locate an area of soft tissue next to its mouth.
3. Using a syringe, your teacher will insert the needle into this soft tissue and inject the syringe contents into the sea urchin.
4. Turn your animal so that its mouth is facing up and place it in a petri dish. **CAUTION: Use care in handling live animals.**
5. Wait a minute or two, then check the petri dish. If the sea urchin is male, a milky white mass of sperm will be present in the dish. If it is female, a yellow orange mass of eggs will be seen.
6. If you have a female sea urchin, hold her upside down directly over the seawater-filled beaker and allow the eggs to fall directly into the water.
7. If your urchin is male, use a dropper to add several drops of sperm from the petri dish to your beaker of sea water.
8. Check with your classmates to see who has a male and who has a
1. **Compare and Contrast** Compare eggs and sperm, noting numbers released, numbers observed under low power, size, and ability to move.

2. **Predicting** Based on the pattern of fertilization, predict the reason for the large number of gametes released in nature.

3. **Observing** Describe the behavior of sperm when they first come in contact with an egg.

4. **Observing** How does an unfertilized egg differ in appearance from a fertilized egg? Draw both eggs in your data table.

**Going Further**

**Project** Continue to observe fertilized eggs and note the stages of development. Keep a record of time after fertilization and corresponding changes in development.

**Biology Online** To find out more about echinoderm development, visit the Glencoe Science Web site. science.glencoe.com

**ANALYZE AND CONCLUDE**

**1.** Compare and Contrast

**2.** Predicting

**3.** Observing

**4.** Observing

**CAUTION:** Wash your hands immediately after working with animals.
Many organisms use hydraulic systems to supply food and oxygen to, and remove wastes from, cells lying deep within the body. Hydraulics is a branch of science that is concerned with the practical applications of liquids in motion. In living systems, hydraulics is usually concerned with the use of water to operate systems that help organisms find food and move from place to place.

The sea star uses a unique hydraulic mechanism called the water vascular system for movement and for obtaining food. The water vascular system provides the water pressure that operates the tube feet of sea stars and other echinoderms.

The water vascular system On the upper surface of a sea star is a sievelike disk, the madreporite, which opens into a fluid-filled ring. Extending from the ring are long radial canals running along a groove on the underside of each of the sea star’s rays. Many small lateral canals branch off from the sides of the radial canals. Each lateral canal ends in a hollow tube foot. The tube foot has a small muscular bulb at one end, the ampulla, and a short, thin-walled tube at the other end that is usually flattened into a sucker. Each ray of the sea star has many tube feet arranged in two or four rows on the bottom side of the ray. The tube feet are extended or retracted by hydraulic pressure in the water vascular system.

Mechanics of the water vascular system The entire water vascular system is filled with water and acts as a hydraulic system, allowing the sea star to move. The muscular ampulla contracts and relaxes with an action similar to the squeezing of a dropper bulb. When the muscles in the wall of the ampulla contract, a valve between the lateral canal and the ampulla closes so that water does not flow backwards into the radial canal. The pressure from the walls of the ampulla acts on the water, forcing it into the tube foot’s sucker end, causing it to extend.

When the extended tube foot touches a rock or a mollusk shell, the center of the foot is retracted slightly. This creates a vacuum, enabling the tube foot to adhere to the rock or shell. The tip of the tube foot also secretes a sticky substance that helps it adhere. To move forward, muscles in the ampulla relax, and muscles in the tube foot wall contract. These actions shorten the tube foot and pull the sea star forward. Water is forced back into the relaxed ampulla. When the muscles in the ampulla contract, the tube foot extends again. This pattern of extension and retraction of tube feet results in continuous movement. It is the coordinated movement of many tube feet that enable the sea star to move slowly along the ocean floor.

Connection to Biology

In what way do scallops and earthworms also use hydraulic pressure for locomotion?

To find out more about hydraulic pressure systems, visit the Glencoe Science Web site. science.glencoe.com
**Chapter 29 Assessment**

**SUMMARY**

**Section 29.1**

**Echinoderms**

**Main Ideas**

- Echinoderms have spines or bumps on their endoskeletons, radial symmetry, and water vascular systems. Most move by means of the suction action of tube feet.
- Echinoderms include sea stars, sea urchins, sand dollars, sea cucumbers, sea lilies, and feather stars.
- Deuterostome development, an internal skeleton, and bilaterally symmetrical larvae are indicators of the close phylogenetic relationship between echinoderms and chordates.

**Vocabulary**

- ampulla (p. 788)
- madreporite (p. 789)
- pedicellaria (p. 787)
- ray (p. 787)
- tube feet (p. 788)
- water vascular system (p. 789)

**Section 29.2**

**Invertebrate Chordates**

**Main Ideas**

- Chordates have a dorsal hollow nerve cord, a notochord, muscle blocks, gill slits, and a tail at some stage during development.
- Sea squirts and lancelets are invertebrate chordates.
- Vertebrate chordates may have evolved from larval stages of ancestral invertebrate chordates.

**Vocabulary**

- dorsal hollow nerve cord (p. 795)
- gill slit (p. 796)
- notochord (p. 795)

**UNDERSTANDING MAIN IDEAS**

1. Sea stars, sea urchins, sand dollars, sea cucumbers, sea lilies, and feather stars are examples of echinoderms that all have ________.
   - a. exoskeletons
   - b. jointed appendages
   - c. tube feet
   - d. larvae with radial symmetry

2. Of the following, which is NOT a characteristic of chordates?
   - a. dorsal hollow nerve cord
   - b. notochord
   - c. pedicellariae
   - d. muscle blocks

3. When a sea star loses a ray, it is replaced by the process of ________.
   - a. regeneration
   - b. reproduction
   - c. metamorphosis
   - d. parthenogenesis

4. Animals that have spines or bumps on their endoskeletons, radial symmetry, and water vascular systems are ________.
   - a. invertebrate chordates
   - b. chordates
   - c. vertebrates
   - d. echinoderms

5. A close phylogenetic relationship between echinoderms and some chordates is indicated by the fact that both have similar ________.
   - a. habitats
   - b. larvae
   - c. sizes
   - d. gills
6. Spines on sea stars and sea urchins are modified into pedicellariae used for ________.
   a. feeding  
   b. protection  
   c. breathing  
   d. reproduction

7. The water vascular system operates the tube feet of sea stars and other echinoderms by means of ________.
   a. water pressure  
   b. water exchange  
   c. water pumps  
   d. water filtering

8. Tube feet, in addition to functioning in locomotion, also function in ________.
   a. gas exchange and digestion  
   b. digestion and circulation  
   c. gas exchange and excretion  
   d. excretion and digestion

9. Water enters and leaves the water vascular system of a sea star through the ________.
   a. radial canal  
   b. ampulla  
   c. tube feet  
   d. madreporite

10. Sea squirts and lancelets are invertebrate chordates that have ________.
    a. pedicellariae  
    b. exoskeletons  
    c. tube feet  
    d. larvae with bilateral symmetry

11. When a sea cucumber is threatened, it can ________ its internal organs.

12. The ________ is a semirigid, rodlike structure common to all members of the phylum Chordata.

13. When a sea star lifts up the tips of its rays, it is detecting ________.

14. Muscle blocks attached to the notochord enable chordates to be more ________.

15. Examine the diagram below. From which group did brittle stars most likely evolve?

16. Tunicates and lancelets get food by ________.

17. Most echinoderms flourished in the Paleozoic era. Brittle stars require habitat similar to other echinoderms, but they did not flourish during the Paleozoic because they most likely ________.

18. A ________ is a flat, disc-shaped echinoderm without rays, and only minute hairlike spines.

19. Sea stars are more likely to leave a fossil record than ________ such as tunicates and lancelets.

20. The ________ of this larva shows its close relationship to chordates.

21. If you were an oyster farmer, why would you be advised not to break apart and throw back any sea stars that were destroying the oyster beds?

22. How does a sessile animal such as a sea squirt protect itself?
23. Relate the various functions of the water vascular system to the environment in which echinoderms live.

24. How is the ability of echinoderms to regenerate an adaptive advantage to these animals?

25. Explain how a sea squirt maintains homeostasis.

26. Observing and Inferring Explain why the tube feet of a sand dollar are located on its upper surface as well as on its bottom surface.

27. Comparing and Contrasting Compare the pedicellariae of echinoderms with the nematocysts of cnidarians.

28. Concept Mapping Complete the concept map by using the following vocabulary terms: ampulla, madreporite, tube feet, water vascular system.

ASSESSING KNOWLEDGE & SKILLS

The diagrams below represent cross sections of larvae. The intestines are shown in red and the nerve cords are shown in blue.

Interpreting Scientific Illustrations Use the diagram to answer the following questions.

1. Which of the diagrams shows a cross section of a lancelet?
   a. A  
   b. B  
   c. C  
   d. none of the diagrams

2. Which of the diagrams would represent segmented worms and echinoderms?
   a. A  
   b. B  
   c. C  
   d. none of the diagrams

3. What does the yellow, solid area represent?
   a. nerve cord  
   b. intestines  
   c. notochord  
   d. spinal cord

4. What is wrong with diagram C if it represents an invertebrate chordate?
   a. The notochord is ventral.  
   b. The nerve cord is ventral and there is no notochord.  
   c. It is too flat.  
   d. The intestine should be round.

5. Interpreting Scientific Illustrations Using the same color code and the same three organs, draw a diagram of a cross section of a larval sea squirt, sea star, and earthworm.

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
Invertebrates

How are jellyfishes, earthworms, sea stars, and butterflies alike? All of these animals are invertebrates—animals without backbones. The ancestors of all modern invertebrates had simple body plans. They lived in water and obtained food, oxygen, and other materials directly from their surroundings, just like present-day sponges, jellyfishes, and worms. Some invertebrates have external coverings such as shells and exoskeletons that provide protection and support.

Sponges

Sponges, phylum Porifera, are invertebrates made up of two cell layers. Most sponges are asymmetrical. They have no tissues, organs, or organ systems. Most adult sponges do not move from place to place.

Cnidarians

Like sponges, cnidarians are made up of two cell layers and have only one body opening. The cell layers of a cnidarian, however, are organized into tissues with different functions. Cnidarians are named for stinging cells that contain nematocysts that are used to capture food. Jellyfishes, corals, sea anemones, and hydras belong to phylum Cnidaria.

VITAL STATISTICS

Cnidarians

Size ranges: Smallest: Haliclystus salpinx, jellyfish, diameter, 25 mm; largest: giant jellyfish medusa, diameter, 2 m; largest coral colony: Great Barrier Reef, length, 2027 km
Most poisonous: The sting of an Australian box jelly can kill a human within minutes.
Distribution: Worldwide in marine, brackish, and freshwater habitats.
Numbers of species:
Phylum Cnidaria
Class Hydrozoa—hydroids, 2700 species
Class Scyphozoa—jellyfishes, 200 species
Class Anthozoa—sea anemones and corals, 6200 species

Sponges are filter feeders. A sponge takes in water through pores in the sides of its body, filters out food, and releases the water through the opening at the top.
Roundworms

Roundworms, phylum Nematoda, have a pseudocoelom and a tubelike digestive system with two body openings. Most roundworms are free-living, but many plants and animals are affected by parasitic roundworms.

Flatworms

Flatworms, phylum Platyhelminthes, include free-living planarians, parasitic tapeworms, and parasitic flukes. Flatworms are bilaterally symmetrical animals with flattened solid bodies and no body cavities. Flatworms have one body opening through which food enters and wastes leave.

Free-living flatworms have a head end with organs that sense the environment. Flatworms can detect light, chemicals, food, and movements in their surroundings.

VITAL STATISTICS

**Flatworms**

- **Size ranges:** Largest, beef tapeworm, length, 30 m
- **Distribution:** Worldwide in soil, marine, brackish, and freshwater habitats
- **Numbers of species:**
  - Phylum Platyhelminthes:
    - Class Turbellaria—free-living planarians, 3000 species
    - Class Cestoda—parasitic tapeworms, 3500 species
    - Class Trematoda—parasitic flukes, 8000 species

Parasitic roundworms such as this *Trichinella* are contracted by eating undercooked pork. Other roundworms can be contracted by walking barefoot on contaminated soil.


**Mollusks**

Slugs, snails, clams, squids, and octopuses are members of phylum Mollusca. All mollusks are bilaterally symmetrical and have a coelom, two body openings, a muscular foot for movement, and a mantle, which is a thin membrane that surrounds the internal organs. In shelled mollusks, the mantle secretes the shell.

**Classes of Mollusks**

The three major classes of mollusks are gastropods with one shell or no shell; bivalves with two hinged shells; and cephalopods. Cephalopods include octopuses, squids, and shelled nautiluses that all have muscular tentacles and are capable of swimming by jet propulsion. All mollusks, except bivalves, have a rough, tongue-like organ called a radula used for obtaining food.

**Focus on Adaptations**

The type of body cavity an animal has determines how large it can grow and how it takes in food and eliminates wastes. Acoelomate animals, such as planarians, have no body cavity. Water and digested food particles travel through a solid body by the process of diffusion.

**Body Cavities**

Marine flatworm

Animals such as roundworms have a fluid-filled body cavity called a pseudocoelom that is partly lined with mesoderm. Mesoderm is a layer of cells between the ectoderm and endoderm that differentiates into muscles, circulatory vessels, and reproductive organs. The pseudocoelom provides support for the

**Vital Statistics**

**Mollusks**

**Size ranges:** Largest: tropical giant clam, length, 1.5 m; North Atlantic giant squid, length, 18 m; Pacific giant octopus, length, 10 m; smallest: seed clam, length, less than 1 mm

**Distribution:** Worldwide in salt-, fresh-, and brackish water, and on land in moist temperate and tropical habitats.

**Numbers of species:**

- Phylum Mollusca
  - Class Gastropoda—snails and slugs, 80,000 species
  - Class Bivalvia—bivalves, 10,000 species
  - Class Cephalopoda—octopuses, squids, and nautiluses, 600 species

**Cephalopods, such as octopuses, are predators. They capture prey using the suckers on their long tentacles.**

**Gastropods, such as snails, use their radulas to scrape algae from rock surfaces.**

**Bivalves, such as clams, strain food from water by filtering it through their gills.**
Segmented Worms

Bristleworms, earthworms, and leeches are members of phylum Annelida, the segmented worms. Segmented worms are bilaterally symmetrical, coelomate animals that have segmented, cylindrical bodies with two body openings. Most annelids have setae, bristlelike hairs that extend from body segments, that help the worms move.

Segmentation is an adaptation that provides these animals with great flexibility. Each segment has its own muscles. Groups of segments have different functions, such as digestion or reproduction.

Classes of Segmented Worms

Phylum Annelida has three classes: Hirudinidae, the leeches; Oligochaeta, the earthworms; and Polychaeta, the bristleworms.

Leeches have flattened bodies with no setae. Most species are parasites that suck blood and body fluids from ducks, turtles, fishes, and mammals.

VITAL STATISTICS

Segmented Worms

Size ranges: Largest: giant tropical earthworm, length, 4 m; smallest: freshwater worm, Aeolosoma, length, 0.5 mm

Distribution: Terrestrial and marine, brackish, and freshwater habitats worldwide, except polar regions and deserts.

Numbers of species:
Phylum Annelida
   Class Hirudinea—leeches, 500 species
   Class Oligochaeta—earthworms, 3100 species
   Class Polychaeta—bristleworms, 8000 species

Most bristleworms have a distinct head and a body with many setae.
Arthropods

Arthropods are bilaterally symmetrical, coelomate invertebrates with tough outer coverings called exoskeletons and jointed appendages that are used for walking, sensing, feeding, and mating. Exoskeletons protect and support their soft internal tissues and organs. Jointed appendages allow for powerful and efficient movements.

Arthropod Diversity

Two out of three animals on Earth today are arthropods. The success of arthropods can be attributed to adaptations that provide efficient gas exchange, acute senses, and varied types of mouthparts for feeding. Arthropods include organisms such as spiders, crabs, lobsters, shrimps, crayfishes, centipedes, millipedes, and the enormously diverse group of insects.

Focus on Adaptations

Insects

Insects have many adaptations that have led to their success in the air, on land, in freshwater, and in salt water. For example, insects have complex mouthparts that are well adapted for chewing, sucking, piercing, biting, or lapping. Different species have mouthparts adapted to eating a variety of foods.

If you have ever been bitten by a mosquito, you know that mosquitoes have piercing mouthparts that cut through your skin to suck up blood. In contrast, butterflies and moths have long, coiled tongues that they extend deep into tubular flowers to sip nectar. Grasshoppers and many beetles have hard, sharp mandibles they use to cut off and chew leaves. But the heavy mandibles of staghorn beetles no longer function as jaws; instead, they have become defensive weapons used for competition and mating purposes.
**Arthropod Origins**

Arthropods most likely evolved from segmented worms; they both show segmentation. However, an arthropod's segments are fused and have a greater complexity of structure than those of segmented worms. Because arthropods have exoskeletons, fossil arthropods are frequently found, and consequently more is known about their origins than about the phylogeny of worms.

Members of class Insecta, the insects, such as this luna moth, have three pairs of jointed legs and one pair of antennae for sensing their environments.

**Different Foods for Different Stages**

Because insects undergo metamorphosis, they often utilize different food sources at different times of the year. For example, monarch butterfly larvae feed on milkweed leaves, whereas the adults feed on milkweed flower nectar. Apple blossom weevil larvae feed on the stamens and pistils of unopened flower buds, but the adult weevils eat apple leaves. Some adult insects, such as mayflies, do not eat at all! Instead, they rely on food stored in the larval stage for energy to mate and lay eggs.

**VITAL STATISTICS**

**Arthropods**

- **Size ranges**: Largest insects: tropical stick insect, length, 33 cm; Goliath beetle, mass, 100 g; smallest insect: fairyfly wasp, length, 0.21 mm
- **Distribution**: All habitats worldwide.
- **Numbers of species**:
  - Phylum Arthropoda
    - Class Arachnida—spiders and their relatives, 57,000 species
    - Class Crustacea—crabs, shrimps, lobsters, crayfishes, 35,000 species
    - Class Merostomata—horseshoe crabs, 4 species
    - Class Chilopoda—centipedes, 2,500 species
    - Class Diplopoda—millipedes, 10,000 species
    - Class Insecta—insects, 750,000 species

Millipedes, class Diplopoda, are herbivores. Millipedes have up to 100 body segments, and each segment has two pairs of legs.
**Echinoderms**

Echinoderms, phylum Echinodermata, are radially symmetrical, coelomate animals with hard, bumpy, spiny endoskeletons covered by a thin epidermis. The endoskeleton is comprised of calcium carbonate. Echinoderms move using a unique water vascular system with tiny, suction-cuplike tube feet. Some echinoderms have long spines also used in locomotion.

The tube feet of a sea star operate by means of a hydraulic water vascular system. Sea stars move along slowly by alternately pushing out and pulling in their tube feet.

**Echinoderm Diversity**

There are five major classes of echinoderms. They include sea stars, brittle stars, sea urchins, sea cucumbers, sand dollars, sea lilies, and feather stars.

Echinoderms have bilaterally symmetrical larvae, a feature that suggests a close relationship to the chordates.

**Invertebrate Chordates**

All chordates have, at one stage of their life cycles, a notochord, a dorsal hollow nerve cord, gill slits, and muscle blocks. A notochord is a long, semirigid, rodlike structure along the dorsal side of these animals. The dorsal hollow nerve cord is

Sea cucumbers have a leathery skin and are flexible. Like most echinoderms, they move using tube feet.

**VITAL STATISTICS**

**Echinoderms**

- **Size ranges:** Largest: sea urchin, diameter, 19 cm; longest: sea cucumber, length, 60 cm
- **Distribution:** Marine habitats worldwide.
- **Numbers of species:**
  - Phylum Echinodermata
    - Class Asteroidea—sea stars, 1500 species
    - Class Crinoidea—sea lilies and feather stars, 600 species
    - Class Ophiuroidea—brittle stars, 2000 species
    - Class Echinoidea—sea urchins and sand dollars, 950 species
    - Class Holothuroidea—sea cucumbers, 1500 species

The long, thin arms of brittle stars are fragile and break easily, but they grow back. Brittle stars use their arms to walk along the ocean bottom.
Invertebrates

The lancelet is an example of an invertebrate chordate. Notice that the lancelet’s body is shaped like that of a fish even though it is a burrowing filter feeder.

<table>
<thead>
<tr>
<th>Understanding Main Ideas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. An animal that is a filter feeder, takes in water through pores in the sides of its body, and releases water from the top is a __________.</td>
</tr>
<tr>
<td>a. roundworm</td>
</tr>
<tr>
<td>b. gastropod</td>
</tr>
<tr>
<td>2. Nematocysts are unique to __________.</td>
</tr>
<tr>
<td>a. sponges</td>
</tr>
<tr>
<td>b. mollusks</td>
</tr>
<tr>
<td>3. An example of a free-living flatworm is a __________.</td>
</tr>
<tr>
<td>a. planarian</td>
</tr>
<tr>
<td>b. tapeworm</td>
</tr>
<tr>
<td>4. Which of the following is used by segmented worms for movement?</td>
</tr>
<tr>
<td>a. chelicerae</td>
</tr>
<tr>
<td>c. setae</td>
</tr>
<tr>
<td>5. Which of the following are invertebrate chordates?</td>
</tr>
<tr>
<td>a. sea anemones</td>
</tr>
<tr>
<td>b. lancelets</td>
</tr>
<tr>
<td>6. Parasitism is a way of life for most __________.</td>
</tr>
<tr>
<td>a. flukes</td>
</tr>
<tr>
<td>b. sponges</td>
</tr>
<tr>
<td>7. An example of an animal with no body cavity is a(n) __________.</td>
</tr>
<tr>
<td>a. sea star</td>
</tr>
<tr>
<td>b. flatworm</td>
</tr>
<tr>
<td>8. An octopus belongs to phylum Mollusca because it has a mantle, bilateral symmetry, two body openings, and __________.</td>
</tr>
<tr>
<td>a. an external shell</td>
</tr>
<tr>
<td>b. a muscular foot</td>
</tr>
<tr>
<td>c. a pseudocoelom</td>
</tr>
<tr>
<td>d. segmentation</td>
</tr>
<tr>
<td>9. Leeches feed by __________.</td>
</tr>
<tr>
<td>a. grazing on aquatic plants</td>
</tr>
<tr>
<td>b. stinging prey</td>
</tr>
<tr>
<td>c. filter feeding</td>
</tr>
<tr>
<td>d. sucking blood</td>
</tr>
<tr>
<td>10. Which of the following characteristics is unique to arthropods?</td>
</tr>
<tr>
<td>a. nematocysts</td>
</tr>
<tr>
<td>b. jointed appendages</td>
</tr>
</tbody>
</table>

Thinking Critically

1. A radula is to a snail as a(n) __________ is to a jellyfish. Explain your answer.

2. Why is more known about animals with hard parts than is known about animals with only soft parts?

3. In what ways are echinoderms more similar to vertebrates than to other invertebrates?

4. You are examining a free-living animal that had a thin, solid body with two surfaces. Into what phylum is this organism classified? Explain.

5. In what two ways are spiders different from insects?