CHAPTER 27

# Echinoderms and Invertebrate Chordates

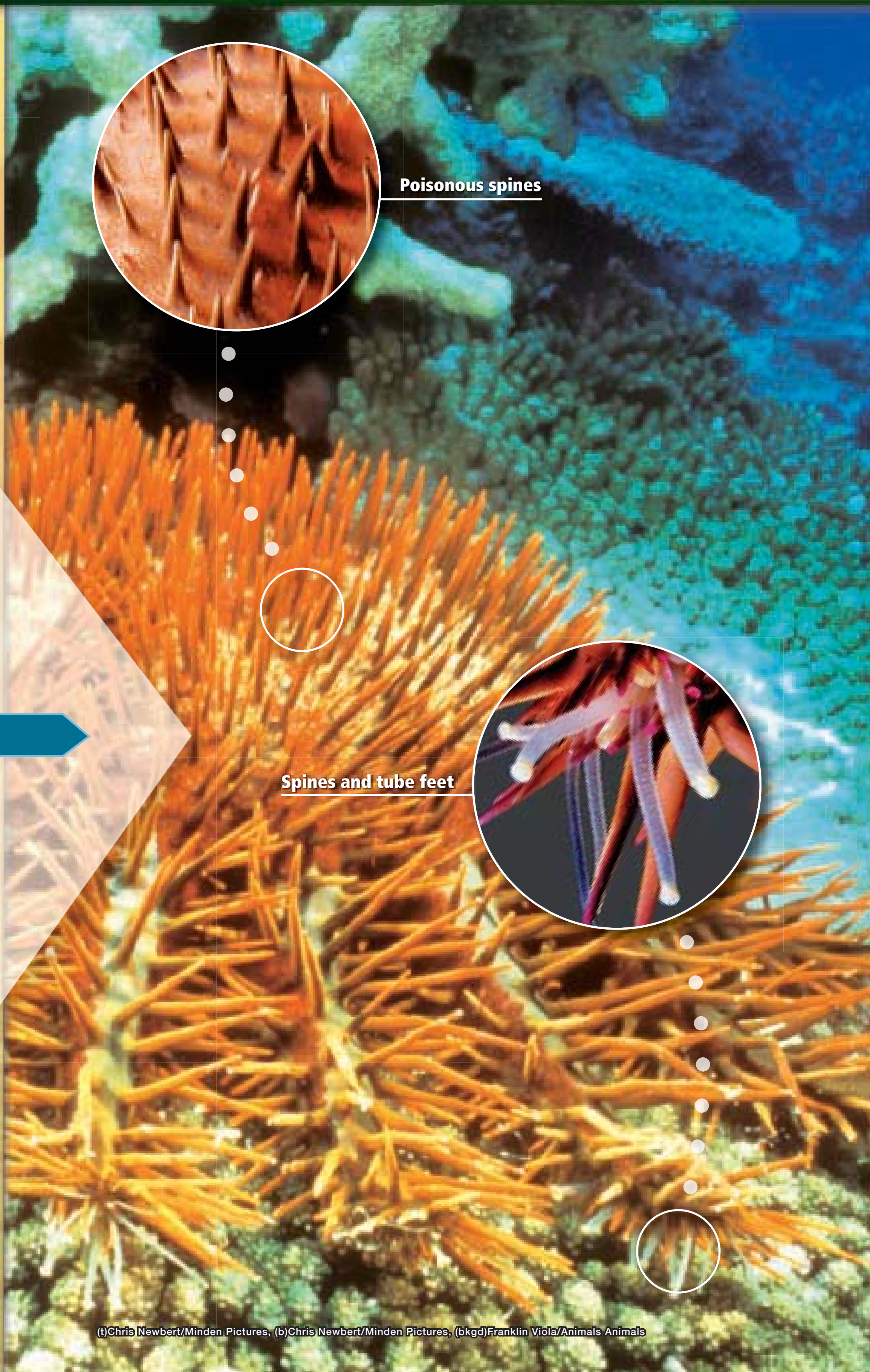
**BIG Idea** Echinoderms and invertebrate chordates have features that connect them to the chordates that evolved after them.

## Section 1
### Echinoderm Characteristics
**MAIN Idea** Echinoderms are marine animals with spiny endoskeletons, water-vascular systems, and tube feet; they have radial symmetry as adults.

## Section 2
### Invertebrate Chordates
**MAIN Idea** Invertebrate chordates have features linking them to vertebrate chordates.

## BioFacts

- A single crown-of-thorns sea star eats 2–6 $m^2$ of coral per year.
- Crown-of-thorns sea stars have spines that are covered with poison-filled skin.
- Another echinoderm, the sea cucumber, protects itself by changing the consistency of its skin from near liquid to solid and back again.




(t)Chris Newbert/Minden Pictures, (b)Chris Newbert/Minden Pictures, (bkgd)Franklin Viola/Animals Animals

CLE 3210.Inq.3; CLE 3210.Inq.4; CLE 3210.5.2

# LAUNCH Lab

## Why are tube feet important?

Like all echinoderms, the crown-of-thorns sea star in the opening photo has structures called tube feet. In this lab, you will observe tube feet and determine their function.

### Procedure

1. Read and complete the lab safety form.
2. Place a **live sea star** in a **petri dish** filled with **water from a saltwater aquarium.** **WARNING:** ***Treat the sea star in a humane manner at all times.***
3. Observe the ventral side of the sea star under a **dissecting microscope.** Look for the rows of tube feet that run down the middle of each arm, and draw a diagram of the structures.
4. Gently touch the end of a tube foot with a **glass probe.** Record your observations.
5. Return the sea star and water to the aquarium.

### Analysis

1. **Describe** the structure of the sea star's tube feet.
2. **Infer** Based on your observations, what is the function of an echinoderm's tube feet?

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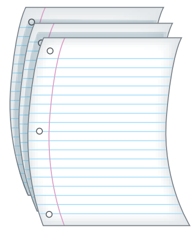
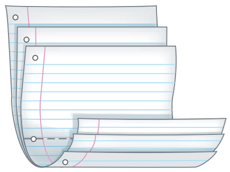
**FOLDABLES™ Study Organizer**

**Describing Invertebrate Chordates** Make the following Foldable to help you understand the physical features that link invertebrate chordates to vertebrate chordates.

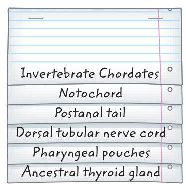
**STEP 1** Collect three sheets of paper and layer them about 1.5 cm apart vertically. Keep the edges level.



**STEP 2** Fold up the bottom edges of the paper to form six tabs.



**STEP 3** Crease well along the fold to hold the tabs in place. Staple along the fold. Rotate the paper so the fold is at the top, and label each tab as shown.




**FOLDABLES** **Use this Foldable with Section 27.2.** As you read the section, record information about the physical features of invertebrate chordates that link them to vertebrate chordates.

**CLE 3210.5.6:** Explore the evolutionary basis of modern classification systems. **ALSO COVERS:** CLE 3210.5.1; CLE 3210.5.2; CLE 3210.5.5; SPI 3210.2.1; SPI 3210.5.1; SPI 3210.5.2; SPI 3210.5.5

# Echinoderm Characteristics

**MAIN Idea Echinoderms are marine animals with spiny endoskeletons, water-vascular systems, and tube feet; they have radial symmetry as adults.**

**Real-World Reading Link** To take a blood-pressure reading, a health care professional squeezes a bulb that forces air through a tube and into the blood-pressure cuff around your arm. The cuff remains tight around your arm until the pressure is released when the air is let out. Some animals use this same kind of system to obtain food and move.

## Reading Preview

### Objectives

- **Summarize** the characteristics common to echinoderms.
- **Evaluate** how the water-vascular system and tube feet are adaptations that enable echinoderms to be successful.
- **Distinguish** between the classes of echinoderms.

### Review Vocabulary

**endoskeleton:** an internal skeleton that provides support and protection and can act as a brace for muscles to pull against

### New Vocabulary

pedicellaria
water-vascular system
madreporite
tube foot
ampulla

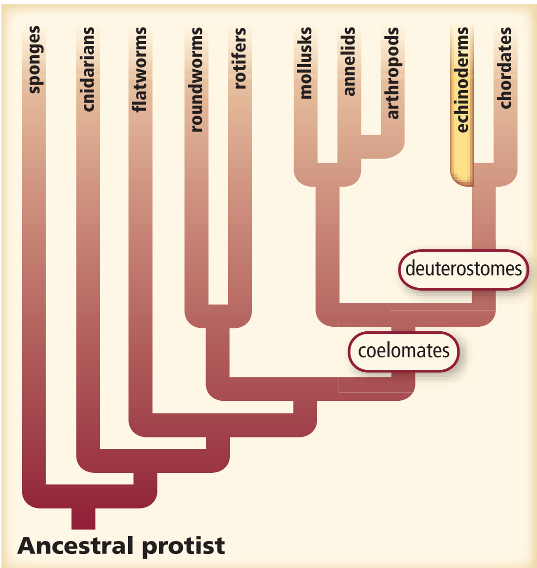
## Echinoderms Are Deuterostomes

As shown in the evolutionary tree in **Figure 27.1,** echinoderms (ih KI nuh durmz) are deuterostomes—a major transition in the phylogeny of animals. Notice how the evolutionary tree branches at deuterostome development.

The mollusks, annelids, and arthropods you studied in previous chapters are protostomes. Recall that during development, a protostome's mouth develops from the opening on the gastrula, while a deuterostome's mouth develops from elsewhere on the gastrula. This might not seem important, but consider that only echinoderms and the chordates that evolved after echinoderms have this kind of development. Echinoderms and chordates are related more closely than groups that do not develop in this way. Animals with spinal cords, including humans, are chordates.

The approximately 6000 living species of echinoderms are marine animals and include sea stars, sea urchins and sand dollars, sea cucumbers, brittle stars, sea lilies and feather stars, and sea daisies. Two echinoderms are shown in **Figure 27.1.**

**Figure 27.1** Echinoderms are marine animals and are the first animals in evolutionary history to have deuterostome development and an endoskeleton.




Purple sea urchin

Feather star

## Body Structure

The brittle star is an example of an echinoderm with the spiny endoskeleton that is characteristic of the organisms in this phylum. Echinoderms are the first group of animals in evolutionary history to have endoskeletons. In echinoderms, the endoskeleton consists of calcium carbonate plates, often with spines attached, and is covered by a thin layer of skin. On the skin are **pedicellariae** (PEH dih sih LAH ree ee) (singular, pedicellaria) small pincers that aid in catching food and in removing foreign materials from the skin.

All echinoderms have radial symmetry as adults. In **Figure 27.2,** you can see this feature in the five arms of the brittle star radiating out from a central disk. However, echinoderm larvae have bilateral symmetry, as shown in **Figure 27.2.** In the next chapter, you will learn how bilateral symmetry shows an embryonic link to the vertebrate animals that evolved later.

No other animals with the complex organ systems of echinoderms have radial symmetry. Scientists theorize that the ancestors of echinoderms did not have radial symmetry. Primitive echinoderms might have been sessile, and radial symmetry developed, to enable them to carry on a successful stationary existence. Free-moving echinoderms might have evolved from the sessile animals. Investigate the features of echinoderms in **MiniLab 27.1.**

**Reading Check** **Infer** how radial symmetry is important to animals that cannot move quickly.



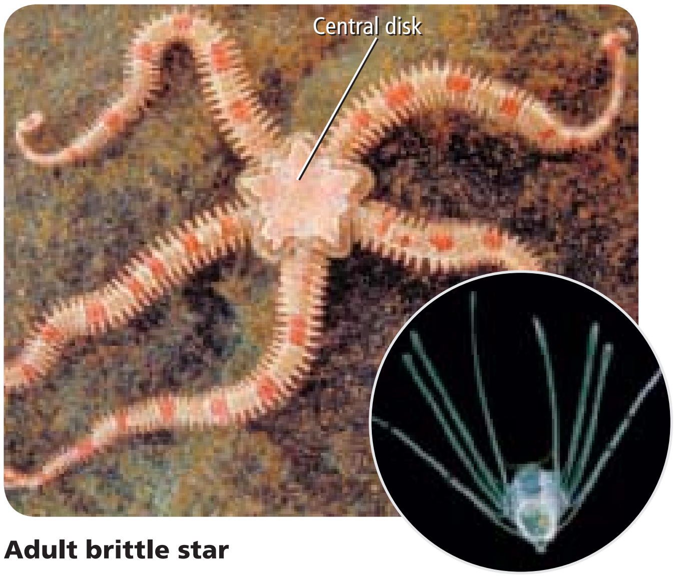



**Figure 27.2** Brittle star larvae have bilateral symmetry and can be divided along only one plane into mirror-image halves. Adult brittle stars have radial symmetry and can be divided through a central axis, along any plane, into equal halves.

CLE 3210.Inq.3; CLE 3210.Inq.4; CLE 3210.5.2; SPI 3210.5.5

## MiniLab 27.1

### Observe Echinoderm Anatomy

**What are the characteristics of echinoderms?** Although they have many shapes and sizes, all echinoderms have some features in common.

**Procedure**

1. Read and complete the lab safety form.
2. Study preserved specimens of **a sand dollar, a sea cucumber, a sea star,** and **a sea urchin.**
3. Create a data table to record your observations. Complete the table by describing the major features of each specimen. Include a sketch of each specimen.
4. Label any external features you can identify.
5. Clean all equipment and return it to the appropriate place. Wash your hands thoroughly after handling preserved specimens.

**Analysis**

1. **Compare** the external features of the echinoderms you studied. Can your observations completely justify why these four organisms are classified in the same phylum? Explain.
2. **Observe and Infer** What features are most important in helping echinoderms avoid being eaten by predators?

# Visualizing an Echinoderm

**Figure 27.3**
Sea urchins can be found in tidal areas of the sea. They burrow into crevices in rocks to hide, and they scrape algae with a hard five-plated structure, called Aristotle's lantern, in their mouths. Imagine that these plates are like teeth that move.

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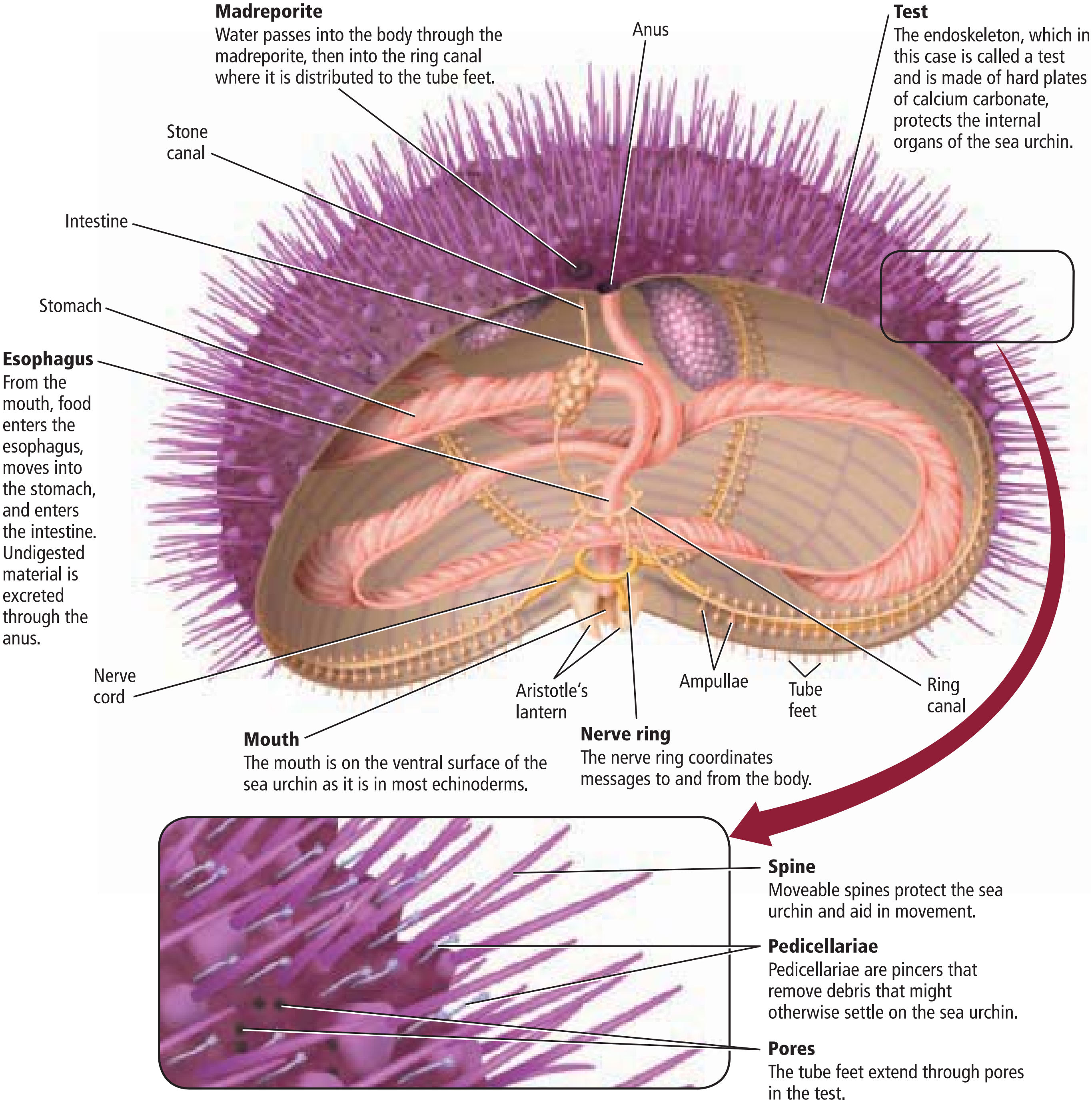



Concepts in Motion **Interactive Figure** To see an animation of echinoderm features, visit biologygmh.com.
Biology Online

Nancy Rotenberg/Animals Animals

**Water-vascular system** Another feature of echinoderms is their **water-vascular system**—a system of fluid-filled, closed tubes that work together to enable echinoderms to move and get food. The strainerlike opening to the water-vascular system, shown in **Figure 27.3,** is called the **madreporite** (MA druh pohr it). Water is drawn into the madreporite, then moves through the stone canal to the ring canal. From there, the water moves to the radial canals and eventually to the tube feet.

**Tube feet** are small, muscular, fluid-filled tubes that end in suction-cuplike structures and are used in movement, food collection, and respiration. The opposite end of the tube foot is a muscular sac, called the **ampulla** (AM pyew luh). When muscles contract in the ampulla, water is forced into the tube foot and it extends. Imagine holding a small, partly inflated balloon in your hand and squeezing it. The balloon will extend from between your thumb and forefinger, which is similar to the way the tube foot extends. The suction-cuplike structure on the end of the tube foot attaches it to the surface. This hydraulic suction enables all echinoderms to move and some, such as sea stars, to apply a force strong enough to open the shells of mollusks, as illustrated in **Figure 27.4.**

**Feeding and digestion** Echinoderms use a great variety of feeding strategies in addition to tube feet. Sea lilies and feather stars extend their arms and trap food. Sea stars prey on a variety of mollusks, coral, and other invertebrates. Many species of sea stars can push their stomachs out of their mouths and onto their prey. They then spread digestive enzymes over the food and use cilia to bring the digested material to their mouths. Brittle stars can be active predators or scavengers, and they can trap organic materials in mucus on their arms. Most sea urchins use teethlike plates, shown in **Figure 27.3,** to scrape algae off surfaces or feed on other animals. Many sea cucumbers extend their branched, mucous-covered tentacles to trap floating food.

**Respiration, circulation, and excretion** Echinoderms also use their tube feet in respiration. Oxygen diffuses from the water through the thin membranes of the tube feet. Some echinoderms carry out diffusion of oxygen through all thin body membranes in contact with water. Others have thin-walled skin gills that are small pouches extending from the body. Many sea cucumbers have branched tubes, called respiratory trees, through which water passes and oxygen moves into the body.

Circulation takes place in the body coelom and the water-vascular system, while excretion of cellular wastes occurs by diffusion through thin body membranes. Cilia move water and body fluids throughout these systems aided by pumping action in some echinoderms. In spite of the simplicity of these organs and systems, echinoderms maintain homeostasis effectively with adaptations that are suited to their way of life.

**Reading Check** **Summarize** the functions of an echinoderm's tube feet.

**Figure 27.4** A sea star uses its tube feet to open the two shells of a clam.
**Describe** *the sea star's feeding method.*

**LAUNCH Lab**
**Review** Based on what you've read about the water-vascular system, how would you now answer the analysis questions?


■ **Figure 27.5** A sea star lifts the end of an arm to sense light and movement.

**Response to stimuli** Echinoderms have both sensory and motor neurons with varying degrees of complexity in different species. In general, a nerve ring surrounds the mouth with branching nerve cords connecting to other body areas.

Sensory neurons respond to touch, chemicals dissolved in the water, water currents, and light. At the tips of the arms of sea stars are eyespots, clusters of light-sensitive cells, illustrated in **Figure 27.5.** Many echinoderms also sense the direction of gravity. For example, a sea star will return to an upright position after being overturned by a wave or current.

**Movement** Echinoderm locomotion is as varied as echinoderm body shapes. The structure of the endoskeleton is important for determining the type of movement an echinoderm can undertake. The movable bony plates in the endoskeletons of echinoderms enable them to move easily. Feather stars move by grasping the soft sediments of the ocean bottom with their cirri—long, thin appendages on their ventral sides—or by swimming with up-and-down movements of their arms. Brittle stars use their tube feet and their arms in snakelike movements for locomotion. Sea stars use their arms and tube feet for crawling. Sea urchins move by using tube feet and burrowing with their movable spines. Sea cucumbers crawl using their tube feet and body wall muscles.

**Reading Check** **Summarize** In addition to using their tube feet, in what other ways do echinoderms move?

**VOCABULARY**

**SCIENCE USAGE V. COMMON USAGE**

**Structure**

***Science usage:*** the arrangement of parts of an organism.
*The structure of an insect's mouth determines how it functions.*

***Common usage:*** something that is constructed, such as a building.
*The workers built the structure in three months.*

**Reproduction and development** Most echinoderms reproduce sexually. The females shed eggs and the males shed sperm into the water where fertilization takes place. The fertilized eggs develop into free-swimming larvae with bilateral symmetry. After going through a series of changes, the larvae develop into adults with radial symmetry. Recall that echinoderms have deuterostome development, making them an important evolutionary connection to vertebrates.

The sea star in **Figure 27.6** illustrates an echinoderm regenerating a lost body part. Many echinoderms can drop off an arm when they are attacked, enabling them to flee while the predator is distracted. Others can expel part of their internal organ systems when threatened, an action that might surprise and deter predators. All of these body parts can be regenerated.

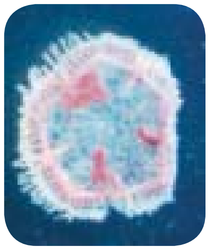
■ **Figure 27.6** This sea star is regenerating one of its arms, a process that can take up to one year.
**Explain** ***how regenerating body parts helps echinoderms survive.***

Zigmund Leszczynski/Animals Animals

Concepts In Motion

**Interactive Table** To explore more about echinoderms, visit biologygmh.com.

## Table 27.1 Classes of Echinoderms

| Class | Asteroidea | Ophiuroidea | Echinoidea | Crinoidea | Holothuroidea | Concentricycloidea |
|---|---|---|---|---|---|---|
| Examples |  |  |  |  |  |  |
| Class Members | Sea stars | Brittle stars | Sea urchins, Sand dollars | Sea lilies, Feather stars | Sea cucumbers | Sea daisies |
| Distinctive Features | • Often five-armed<br>• Tube feet used for feeding and movement | • Often five-armed<br>• Arms break off easily and can be regenerated<br>• Move by arm movement<br>• Tube feet have no suction cups | • Body encased in a test with spines<br>• Sea urchins burrow in rocky areas.<br>• Sand dollars burrow in sand. | • Sessile for some part of life<br>• Sea lilies have long stalks.<br>• Feather stars have long branching arms. | • Cucumber shape<br>• Leathery outer body<br>• Tube feet modified to tentacles near mouth | • Less than 1 cm in diameter<br>• No arms<br>• Tube feet located around a central disk |

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## Echinoderm Diversity

The major classes of living echinoderms include Asteroidea (AS tuh ROY dee uh), the sea stars; Ophiuroidea (OH fee uh ROY dee uh), the brittle stars; Echinoidea (ih kihn OY dee uh), the sea urchins and sand dollars; Crinoidea (kri NOY dee uh), the sea lilies and feather stars; Holothuroidea (HOH loh thuh ROY dee uh), the sea cucumbers; and Concentricycloidea (kahn sen tri sy CLOY dee uh), the sea daisies. Recall that they all are marine animals with radial symmetry as adults, a water-vascular system with tube feet, endoskeletons often bearing spines, and larvae with bilateral symmetry. The classes of echinoderms are summarized in **Table 27.1.**

**Sea stars** If you ever have seen an echinoderm, it probably was a sea star. Most species of sea stars have five arms arranged around a central disk. Some, such as the one in **Figure 27.7,** have more than five arms. Sea stars can be found in shallow water near the shore and in tide pools when the tide recedes. They can be found in groups clinging to rocks by means of their tube feet. A single tube foot can exert a pull of 0.25–0.30 N. This is equal to the force required to lift 25–30 large paper clips. Because a sea star might have as many as 2000 tube feet, it can exert quite a large force as it crawls or opens mollusks for food. Sea stars are important predators in marine ecosystems, feeding on clams and other bivalves. Because of their spiny skin, sea stars usually are not food for other marine predators.

**Figure 27.7** Sunflower stars can have twenty or more arms.



(b)Stuart Westmorland/Photo Researchers, (l to r, t to b)Zigmund Leszczynski/Animals Animals, (2)Joyce & Frank Burek/Animals Animals, (3)C.C. Lockwood/Animals Animals, (4)Fred McConnaughey/Photo Researchers, (5)Gustav Verderber/Visuals Unlimited, (6)Science VU/Alan Baker/Visuals Unlimited

■ **Figure 27.8** One type of brittle star, the basket star, extends its branched arms into the current to filter feed.

**Analyze** ***How are brittle stars different from sea stars?***

**Brittle stars** Like sea stars, most brittle stars have five arms, but the brittle star's arms are thin and very flexible, as shown in **Figure 27.8.** They do not have suckers on their tube feet, so they cannot use them for movement as sea stars do. Brittle stars move by rowing themselves quickly over the bottom rocks and sediments or by snakelike movements of their arms. When attacked by a predator, a brittle star can release an arm and make a quick getaway. The missing arm will be regenerated later. Brittle stars hide in the crevices of rocks by day and feed at night. They feed on small particles suspended in the water or catch suspended materials on mucous strands between their spines.

Some brittle stars respond to light. The spherical structures covering the body of these brittle stars might function as light-gathering lenses. Brittle stars are more abundant and have more numbers of species than any other class of echinoderm.

**Reading Check** **Compare and contrast** the locomotion of sea stars and brittle stars.

**Sea urchins and sand dollars** Burrowing is a key characteristic of sea urchins and sand dollars. Sand dollars can be found in shallow water burrowing into the sand, while sea urchins burrow into rocky areas. These echinoderms each have a compact body enclosed in a hard endoskeleton, called a test, that looks like a shell. The tube feet extend through pores in the test. Closely fitting plates of calcium carbonate make up the test. Sea urchins and sand dollars lack arms, but their tests reflect the five-part pattern of arms in sea stars and brittle stars. Spines also are an important feature of this class, as seen in **Figure 27.9.** Some sea urchin spines and pedicellariae contain venom and are used for fending off predators. The poison in pedicellariae can paralyze prey. Sea urchins also can be herbivorous grazers, scraping algae from rocks, while sand dollars filter organic particles from the sand in which they are partially buried.

■ **Figure 27.9** Sea urchins burrow themselves into rocky crevices with their sharp, movable spines. Sand dollars burrow themselves into the sand, where they filter out small food particles.

**Sea urchins**

**Sand dollar**

**Aristotle's lantern**

**Five-sided lantern**

■ **Figure 27.10** Aristotle's lantern is a five-sided mouthpart similar in shape to a five-sided lantern. The force of a sea urchin's chewing plates is so strong that it has been known to chew through concrete.

**Connection to History** Most sea urchins have a chewing apparatus inside their mouths consisting of five hard plates, similar to teeth. This structure, shown in **Figure 27.10,** is called Aristotle's lantern. It was named after a description written by Aristotle, a Greek philosopher, in his book *Historia Animalium* (The History of Animals). In the fourth century B.C., which is when Aristotle lived, people used five-sided lanterns with side panels made of thin, translucent horn, called horn lanterns. Aristotle thought the mouth of a sea urchin looked like a horn lantern without the panels.

**Sea lilies and feather stars** Fossil records show that sea lilies and feather stars are the most ancient of the echinoderms and were abundant before other echinoderms evolved. They are different from other echinoderms in that they are sessile for part of their lives. As shown in **Figure 27.11,** sea lilies have a flower-shaped body at the top of a long stalk, while the long-branched arms of feather stars radiate upward from a central area. Though they might stay in one place for a long time, sea lilies and feather stars can detach themselves and move elsewhere. Both sea lilies and feather stars capture food by extending their tube feet and arms into the water, where they catch suspended organic materials.

**Reading Check** **Compare** How are feather stars and sea lilies similar?

■ **Figure 27.11** This fossil illustrates how a sea lily's body is flower-shaped at the tip of a long stalk. A feather star extends its arms from a central point where they are attached.
**Infer** ***How is the shape of the arms of feather stars adapted to a lifestyle that includes little movement?***

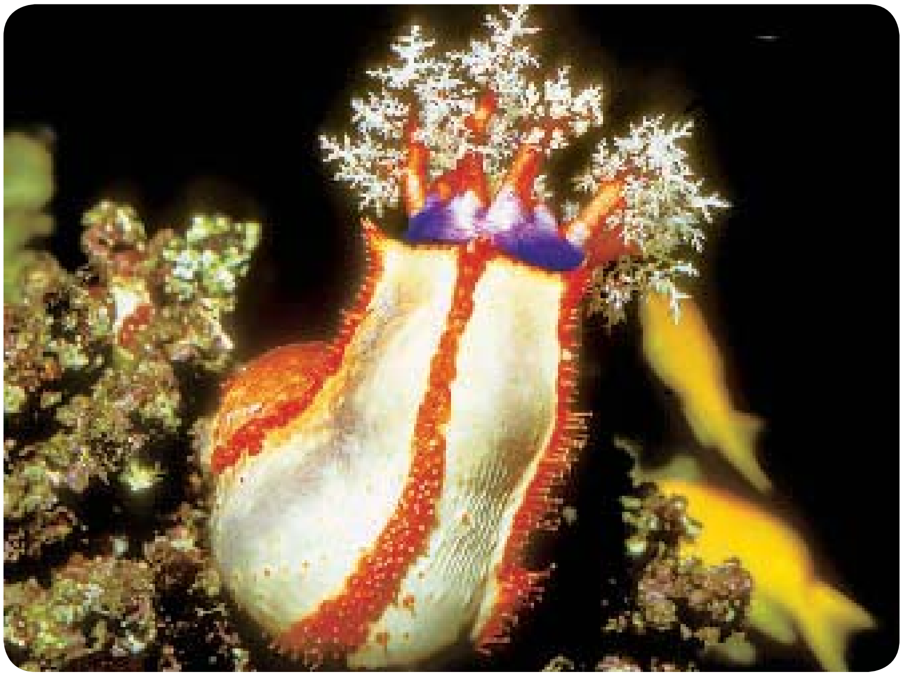
**Sea lily**

**Feather star**



(t)Ken Lucas/Visuals Unlimited, (bl)James L. Amos/Photo Researchers, (br)Norbert Wu/Minden Pictures

**Figure 27.12** Some of the sea cucumber's tube feet are modified into tentacles that trap food particles from the water.
**Identify** *What substance coats the tentacles and helps trap food particles?*



**CAREERS IN BIOLOGY**

**Marine Biologist** Scientists in this field study plants and animals, such as echinoderms, that live in the ocean. They also study how pollution affects the marine environment. For more information on biology careers, visit biologygmh.com.

**Sea cucumbers** Sea cucumbers don't look like other echinoderms. Some might say they don't even look like animals. Can you guess why they are called sea cucumbers? They look like cartoon cucumbers creeping over the ocean floor. Their elongated bodies move sluggishly by means of tube feet assisted by contractions in their muscular body wall. Their calcium carbonate plates are reduced in size and do not connect as they do in other echinoderms, so their outer bodies generally appear leathery. Some of their tube feet are modified to form tentacles which extend from around their mouths to trap suspended food particles, as shown in **Figure 27.12.** The tentacles are covered with mucus, which increases their ability to trap food. Once food has been trapped on a tentacle, it is drawn into the mouth where the food is sucked off. This process is similar to licking your finger after putting it in a bowl of pudding.

Sea cucumbers are the only echinoderms to have respiratory organs in the form of respiratory trees. These many-branched tubes pump in seawater through the anus for oxygen extraction. The respiratory tree also functions in excretion by removing cellular wastes.

When a sea cucumber is threatened, it can cast out some of its internal organs through its anus. A potential predator might be confused by this action and move on. The sea cucumber can regenerate its lost parts. Even though the sea cucumber's adaptations might seem odd, it is important to remember that this animal maintains homeostasis with adaptations that fit its way of life in its particular habitat.

**Figure 27.13** Sea daisies are tiny disc-shaped echinoderms.

**Sea daisies** Discovered in 1986 off the coast of New Zealand, sea daisies have been difficult to classify and study, because so few have been found. They are less than 1 cm in diameter and are disc-shaped with no arms. Their tube feet are located around the edge of the disc. **Figure 27.13** shows that they have five-part radial symmetry, as do other echinoderms. Notice the daisy pattern of petals, or tube feet, around the edges of the disc.

**Reading Check** **Infer** What characteristics place sea daisies in the phylum Echinodermata?

Norbert Wu/Minden Pictures

## Ecology of Echinoderms

Sea cucumbers and sea urchins are sources of food for people in some Asian countries. The muscles of certain sea cucumbers are eaten as sushi, and dried sea cucumbers are added to flavor soups, vegetables, and meat. The egg masses of sea urchins are eaten raw or slightly cooked.

Commensal relationships exist between some echinoderms and other marine animals. Recall from Chapter 2 that commensalism is a relationship in which one organism benefits and the other organism is neither helped nor harmed. For example, some species of brittle stars live inside sponges. The brittle star leaves the protective interior of the sponge and feeds on materials that have settled on the sponge.

**Echinoderm benefits** Marine ecosystems also depend on some echinoderms. When populations of echinoderms decline, a change in the ecosystem is often noted. For example, a sea urchin species that lives in the Caribbean and the Florida keys declined in numbers by more than 95 percent in 1983 due to disease. After this, algae increased greatly on the coral reefs and virtually destroyed the reefs in many areas. Sea urchins and sea cucumbers are bioturbinators—organisms that stir up sediment on the ocean floor. This action is important to the entire marine ecosystem, as it makes nutrients in the seafloor available to other organisms.

**Echinoderm harm** Some echinoderms can harm marine ecosystems. The crown-of-thorns sea star shown in the photo at the beginning of this chapter feeds on coral polyps. When these sea stars increase in numbers, coral reefs are destroyed. Although the causes of the population explosions of these sea stars continue to be debated, the numbers seem to decline on their own. At a later time, they might increase again with no apparent explanation. Sea urchins are a favorite food of sea otters, as shown in **Figure 27.14.** The number of sea otters in California has declined in recent years, leading to an increase in the number of sea urchins. The sea urchins are eating the kelp forests, destroying the habitat of fish, snails, and crabs.

**Figure 27.14** Without enough sea otters to keep the sea urchin population under control, sea urchins will continue to increase in number, threatening the kelp forests on which they feed.

## Section 27.1 Assessment

CLE 3210.5.2; CLE 3210.5.6; SPI 3210.5.2

### Section Summary

- Adult echinoderms can be identified by four main structural features.
- Larval echinoderms have features that link them to relatives that evolved after them.
- Echinoderms have a water-vascular system and tube feet.
- Echinoderms have a variety of adaptations for feeding and movement.
- There are six major classes of living echinoderms.

### Understand Main Ideas

1. MAIN Idea **Identify** the four main features that distinguish adult echinoderms.
2. **Explain** how a water-vascular system works.
3. **Sketch** line drawings that represent each of the six classes of echinoderms.
4. **Suggest** how feeding and movement are related to each other in echinoderms.

### Think Critically

5. **Hypothesize** A certain species of red-and-white-striped shrimp is often found on a species of colorful brittle stars. Form a hypothesis about the relationship between the shrimp and the brittle stars.

MATH in Biology

6. If it takes a force of 20 N to pull apart a bivalve's shells, how many tube feet will it take to pull apart a bivalve if each tube foot has a pull of 0.25 N?

Section 27.2

CLE 3210.5.5: Explain how evolution contributes to the amount of biodiversity. ALSO COVERS: CLE 3210.5.1; CLE 3210.5.2; CLE 3210.5.6; SPI 3210.5.1; SPI 3210.5.2; SPI 3210.5.5

## Reading Preview

### Objectives

- **Interpret** the features of invertebrate chordates that place them in the phylum Chordata.
- **Analyze** the features of invertebrate chordates that place them with invertebrates.
- **Compare** the adaptations of lancelets with those of sea squirts.

### Review Vocabulary

**deuterostome:** an animal whose mouth develops from cells other than those at the opening of the gastrula

### New Vocabulary

chordate
invertebrate chordate
notochord
postanal tail
dorsal tubular nerve cord
pharyngeal pouch

# Invertebrate Chordates

**MAIN Idea Invertebrate chordates have features linking them to vertebrate chordates.**

**Real-World Reading Link** Worms, snails, bees, fishes, birds, and dogs are all animals because they share common characteristics. Think about the features these animals have in common and the features that make them different from each other. The animals that share the most features are related more closely than the animals that share only a few features.

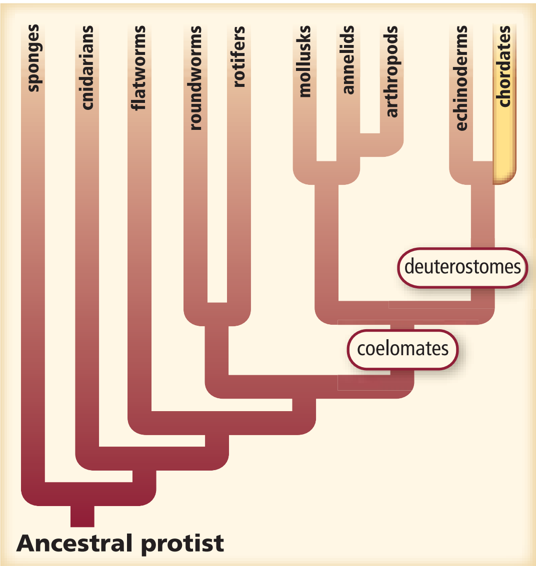
## Invertebrate Chordate Features

Look at **Figure 27.15,** the evolutionary tree of animal phylogeny. Notice that invertebrate chordates, such as lancelets and tunicates, are deuterostomes like echinoderms but they have additional chordate features that echinoderms do not have.

Fossil evidence suggests animals such as the lancelet, shown in **Figure 27.15,** separated from the echinoderms during the Cambrian. This group of animals is known as the invertebrate chordates. It has become a diverse group over the last 500 million years. The lancelet is also called an amphioxus (am fee AHK sus).

The lancelet is a small eel-like animal that spends most of its life buried in the sand filtering the water for food. They are tiny, headless creatures with translucent, fish-shaped bodies. Fossil and molecular data show that the lancelet is one of the closest living relatives of vertebrates. In 2007, genetic studies showed that tunicates, shown in **Figure 27.15,** are the closest invertebrate relative to vertebrates. You are more closely related to the lancelet and tunicate than you are to any other invertebrate—yet related very distantly compared to other vertebrates.

**Figure 27.15** Like echinoderms, invertebrate chordates, such as lancelets and tunicates, show deuterostome development.





**Lancelet**


**Tunicate**

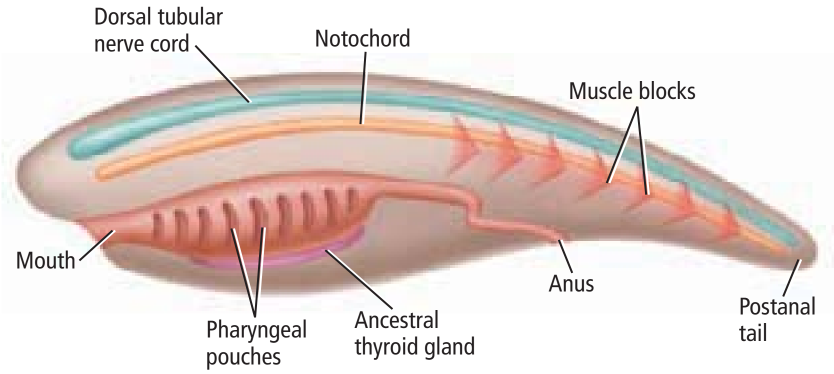



**Figure 27.16** Chordates have a dorsal tubular nerve cord, a notochord, pharyngeal pouches, a postanal tail, and, possibly, some form of a thyroid gland.
**Infer** ***Which of these features did you have when you were an embryo?***

**Chordates** are animals belonging to the phylum Chordata (kor DAH tuh) that have four distinctive features—a dorsal tubular nerve cord, a notochord, pharyngeal pouches, and a postanal tail—at some point during their development. Recent evidence suggests that all chordates also might have some form of a thyroid gland. In addition, they have a coelom and segmentation. Study **Figure 27.16** to see the main features of chordates. Recall that vertebrates are animals with backbones. Most chordates are vertebrates. **Invertebrate chordates,** which belong to two of the subphyla of chordates—Cephalochordata and Urochordata, also have a dorsal tubular nerve cord, a notochord, pharyngeal pouches, a postanal tail, and, possibly, an ancestral thyroid gland. They have no backbone, however.

**Notochord** The **notochord** (NOH tuh kord) is a flexible, rodlike structure that extends the length of the body. It is located just below the dorsal tubular nerve cord. In most vertebrates, the notochord eventually is replaced by bone or cartilage. In invertebrate chordates, the notochord remains. The flexibility of the notochord enables the body to bend, rather than shorten, during contractions of the muscle segments. An animal with a notochord can make side-to-side movements of the body and tail, the first time in the course of evolution that fishlike swimming is made possible.

**Postanal tail** A free-swimming animal moves efficiently by using a postanal tail. A **postanal tail** is a structure used primarily for locomotion and is located behind the digestive system and anus. In most chordates, the postanal tail extends beyond the anus. Tails in nonchordates have parts of the digestive system inside and the anus is located at the end of the tail. The postanal tail with its muscle segments can propel an animal with more powerful movements than the body structure of invertebrates without a postanal tail.

**Dorsal tubular nerve cord** In nonchordates, the nerve cords are ventral to, or below, the digestive system and are solid. Chordates have a **dorsal tubular nerve cord** that is located dorsal to, or above, the digestive organs and is a tube shape. The anterior end of this cord becomes the brain and the posterior end becomes the spinal cord during development of most chordates.

**Reading Check** **Analyze** How is a notochord important to invertebrate chordates?

**VOCABULARY**
**WORD ORIGIN**
**Notochord**
***noto-*** prefix; from Greek, meaning *back.*
***-chord*** from Greek, meaning *chord* or *string.*

**FOLDABLES**
Incorporate information from this section into your Foldable.

## Study Tip

**Cooperation** Form a group with four other students. Each group member should pick one of the five boldfaced headings under the heading *Invertebrate Chordate Features.* Each group member should read the selected section and then teach the rest of the group the material presented in that section of text.

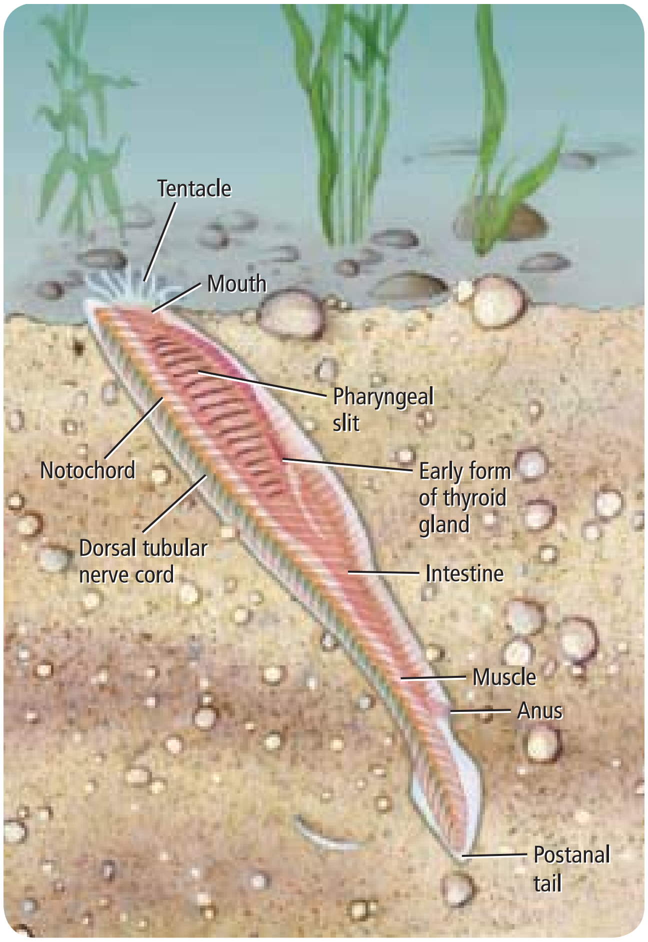



**Figure 27.17** The lancelet is an invertebrate chordate that has the main features of chordates.
**Infer** *How might the short tentacles surrounding the lancelet's mouth function?*

**Pharyngeal pouches** In all embryos, paired structures called **pharyngeal pouches** connect the muscular tube that links the mouth cavity and the esophagus. In aquatic chordates, the pouches contain slits that lead to the outside. These structures were used first for filter feeding and later evolved into gills for gas exchange in water. In terrestrial chordates, the pharyngeal pouches do not contain slits and develop into other structures, such as the tonsils and the thymus gland. Pharyngeal pouches are thought to be evidence of the aquatic ancestry of all vertebrates.

**Ancestral thyroid gland** The thyroid gland is a structure that regulates metabolism, growth, and development. An early form of a thyroid gland had its origins in cells of early chordates that secreted mucus as an aid in filter feeding. Invertebrate chordates have an endostyle—cells in this same area that secrete proteins similar to those secreted by the thyroid gland. Only vertebrate chordates have a thyroid gland.

**Connection to Health** Iodine is concentrated in the endostyle and plays an important role in thyroid gland function. It is essential for the production of thyroid hormones. In the United States, iodine is added to salt to prevent iodine deficiency. Other sources of iodine include fish, dairy products, and vegetables grown in iodine-rich soil.

**Reading Check** **Explain** why an endostyle might be considered an early form of a thyroid gland.

## Diversity of Invertebrate Chordates

Like echinoderms, all invertebrate chordates are marine animals. There are about 23 species of lancelets belonging to subphylum Cephalochordata. Tunicates, in subphylum Urochordata, consist of about 1250 species.

**Lancelets** Recall the amphioxus at the beginning of this section. Most lancelets belong to the genus *Branchiostoma* (formerly *Amphioxus*). They are small, fishlike animals without scales. As shown in **Figure 27.17,** lancelets burrow their bodies into the sand in shallow seas.

Lancelets lack color in their skin, which is only one cell layer deep, enabling an observer to view some body functions and structures. Water flowing through the body can be observed as a lancelet filter feeds. To get food, water enters the mouth of the lancelet and passes through pharyngeal gill slits. Food is trapped and passed on to a stomachlike structure to be digested. Water exits through the gill slits.

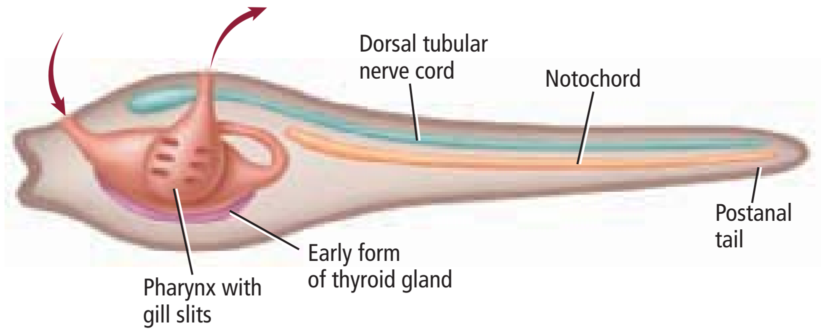



**Figure 27.18** Larval tunicates look like tadpoles and have all of the chordate features. The arrows indicate where water flows into and out of the body.

Just as filter feeding can be observed in the lancelet, its muscles can also be seen. Observe the internal structures of a lancelet in **Figure 27.17.** The arrangement of segmented muscle blocks is similar to that in vertebrates, enabling lancelets to swim with a fishlike motion. Unlike vertebrates, they have no heads or sensory structures other than light receptors and small sensory tentacles near the mouth. The nervous system consists of main branching nerves and a simple brain at the anterior end of the animal. Blood passes through the body by the action of pumping blood vessels, as there is no true heart. Lancelets have separate sexes, and fertilization is external.

**Tunicates** Often called sea squirts, tunicates (TEW nuh kayts) are named for the thick outer covering, called a tunic, that covers their small, saclike bodies. Most tunicates live in shallow water; some live in masses on the ocean floor. In general, tunicates are sessile, and only in the larval stages do they show typical chordate features. Locate the notochord, postanal tail, dorsal tubular nerve cord, pharyngeal pouches, and ancestral thyroid gland on the tunicate larva in **Figure 27.18.**

Water is drawn into the saclike body of an adult tunicate through the incurrent siphon, as shown in **Figure 27.19,** by the action of beating cilia. Food particles are trapped in a mucous net and moved into the stomach where digestion takes place. In the meantime, water leaves the body, first through gill slits in the pharynx and then out through the excurrent siphon.

Circulation in the body of the tunicate is performed by a heart and blood vessels that deliver nutrients and oxygen to body organs. The nervous system consists of a main nerve complex and branching neurons. Tunicates are hermaphrodites—they produce both eggs and sperm—with external fertilization.

Why are tunicates called sea squirts? When they are threatened, they can eject a stream of water with force through the excurrent siphon, possibly distracting a potential predator.

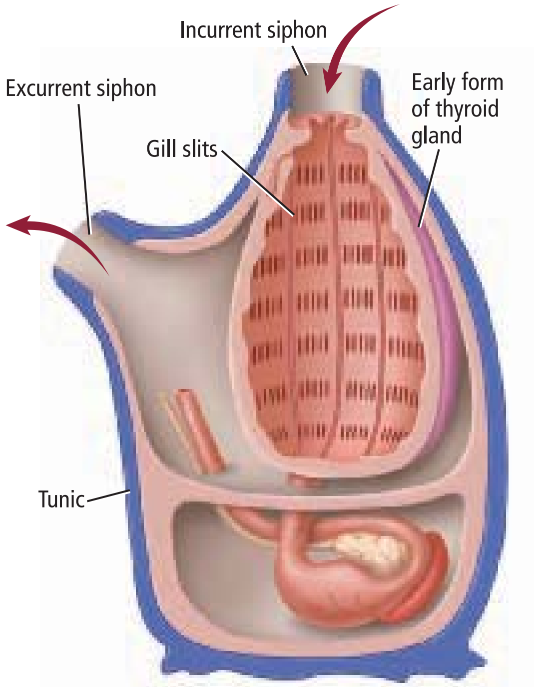
**Reading Check** **Compare** tunicates and lancelets.

CLICK HERE

**Figure 27.19** Adult tunicates look like sacs. The only chordate features that remains in the adult is pharyngeal gill slits and the thyroid gland. The arrows indicate water flow in and out of the body.
**Compare** ***What other invertebrates have you studied that are filter feeders?***

Concepts In Motion

**Interactive Figure** To see an animation of a tunicate's anatomy, visit biologygmh.com.



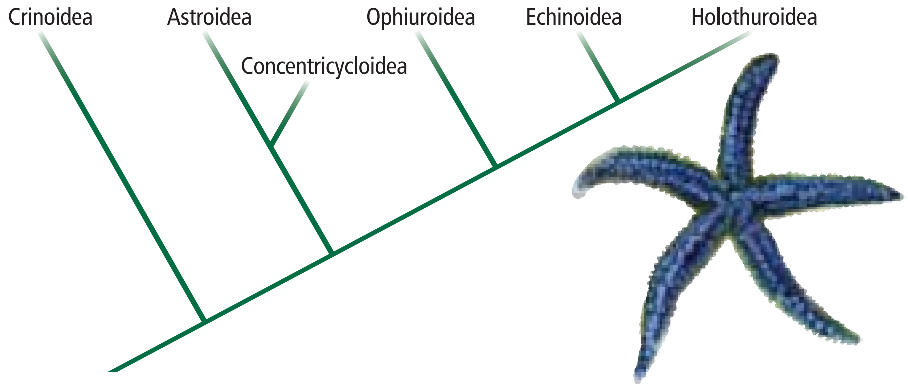



**Figure 27.20** This cladogram shows the phylogeny of echinoderms.
**Interpret** *Which is the most recent class of echinoderms to evolve?*

## Evolution of Echinoderms and Invertebrate Chordates

Biologists are studying fossil and molecular evidence to learn how echinoderms and invertebrate chordates are related to the vertebrates that evolved later.

**Phylogeny of echinoderms** The fossil record of echinoderms extends back to the Cambrian. Scientists think that they evolved from ancestors with bilateral symmetry because echinoderms have bilaterally symmetrical larvae. Their radial symmetry develops later in the adult stage. Many biologists think that ancient echinoderms were sessile and attached to the ocean floor by a long stalk, just as the sea lily does today.

Echinoderms also undergo deuterostome development. Recall that this type of development links them phylogenetically to chordates, which also have deuterostome development. The cladogram in **Figure 27.20** shows one interpretation of the evolution of echinoderms.

**CAREERS IN BIOLOGY**

**Evolutionary Biologist** Scientists in this field study how organisms have changed over time. For more information on biology careers, visit biologygmh.com.

# DATA ANALYSIS LAB 27.1

CLE 3210.Inq.4; ✓3210.5.4; SPI 3210.5.5

**Based on Real Data***

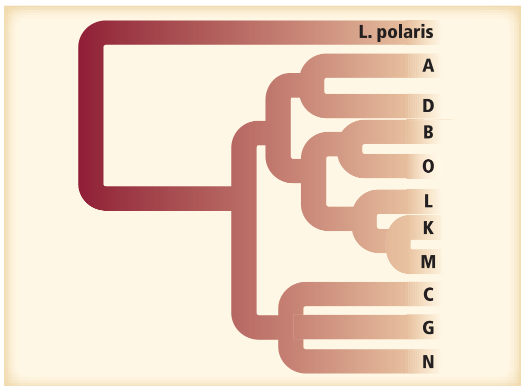
## Interpret Scientific Illustrations

**How does an evolutionary tree show relationships among sea stars?** This evolutionary tree is a representation of various species of sea stars and their phylogenetic history based on molecular data. Each letter represents a specific sea star species.

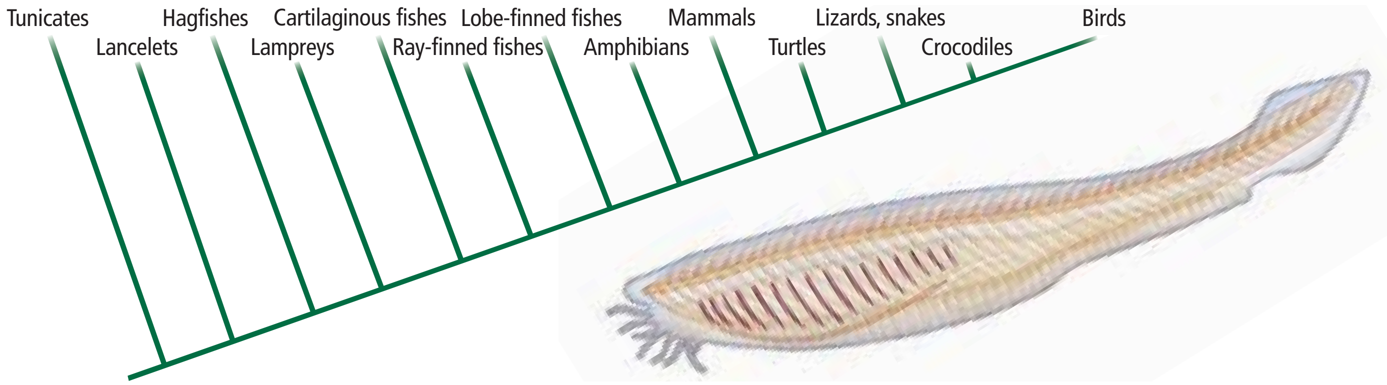
### Think Critically

1. **Identify** Which sea star is most closely related to sea star A?
2. **Interpret** Which is the oldest sea star?
3. **Analyze** Which group of sea stars has the most diversity—C,G,N or L,K,M? How did you decide?

### Data and Observations




*Data obtained from: Hrincevich, A.W., et al. 2000. Phylogenetic analysis of molecular lineages in a species-rich subgenus of sea stars (*Leptasterias* subgenus *Hexasterias*). *American Zoologist* 40: 365-374.




■ **Figure 27.21** This cladogram shows a possible phylogeny of invertebrate chordates and other chordates that evolved later.

**Phylogeny of invertebrate chordates** How could sleek, burrowing, fishlike lancelets be close relatives of saclike, sessile sea squirts? They are related because of their dorsal tubular nerve cords, notochords, pharyngeal gill slits, and postanal tails, even if sea squirts have all these features only in their larvae. Beyond this answer, scientists debate about the evolution of these animals and raise still unanswered questions. For example, from which invertebrate chordate did the fishlike tadpole larvae arise? What was the original form of that first fishlike animal?

One thing is certain: the notochord, that flexible tough rod, provided support for the animal, and it also provided a place for muscles to attach. With this arrangement, chordates could swing their backs from side to side and swim through the water, a key development in the evolution of chordates. This advance also led to the first large animals. Examine the cladogram in **Figure 27.21** to see one interpretation of how chordates are related.

## Section 27.2 Assessment

CLE 3210.5.2; CLE 3210.5.6; SPI 3210.5.1

### Section Summary

- Chordates have four main features that make them different from animals that are not chordates.
- Invertebrate chordates have all the features of chordates, except they do not have the main feature of vertebrate chordates.
- The notochord is an adaptation that enabled animals to move in ways they had never moved before.
- Lancelets are fish-shaped invertebrate chordates that, as adults, have all the main features of chordates.
- Tunicates are sac-shaped invertebrate chordates that have chordate features as larvae.

### Understand Main Ideas

1. MAIN Idea **Summarize** the main features of invertebrate chordates that show their close relationship to vertebrate chordates.
2. **Describe** the characteristic of invertebrate chordates that places them with other invertebrates rather than with vertebrates.
3. **Model** Make models of a lancelet and a sea squirt from clay or salt dough. Identify features that place these animals in the phylum Chordata.
4. **Compare** the adaptations of sea squirts with those of lancelets that enable them to live in their environments.

### Think Critically

5. **Design an experiment** to determine if lancelets prefer a light environment or a dark environment.
6. **Interpret** Use **Figure 27.21** to determine which subphylum of chordates evolved next after the cephalochordates.

*WRITING in* **Biology**

7. Write a paragraph describing how sponges and tunicates are alike. Write another paragraph describing how they are different from each other.

# CUTTING-EDGE BIOLOGY

## Echinoderms Aid Medical Research

Because the collagen in a sea cucumber's connective tissue is not fixed, its body can change from the consistency of liquid gelatin to a rigid structure and back again in seconds.

**How did the comic book character the Incredible Hulk increase his body size without ripping his body to pieces?**

Believe it or not, producers consulted an expert on echinoderms before creating a film about this character because they wondered if any living creature could perform such feats. Sea cucumbers, specifically, can stretch and then shrink back to their normal size, much like the Incredible Hulk does in the film.

**Connective tissue** When Greg Szulgit was a graduate student in biology, he discovered the amazing power of sea cucumbers to increase their body size and then shrink back to their normal size. How do sea cucumbers change their body size? It's all due to their connective tissue—the tissue that connects, supports, and surrounds other tissues and organs in the body.

A sea cucumber's connective tissue is similar to a human's connective tissue. Connective tissue fibers contain a protein called collagen. In humans, collagen is a fixed part of the tissue. Szulgit and other researchers found that the collagen in the connective tissue of echinoderms is not fixed, but instead slides back and forth. When the collagen particles in the endoskeleton are sliding past each other, a sea cucumber's body is soft and flexible. A sea cucumber's cells can release a substance that locks the collagen and stops it from sliding. This stiffens its endoskeleton, making it immobile.

**Connective-tissue disorders** Szulgit studies the sea cucumber's body-stretching abilities with the hope of someday being able to treat connective-tissue disorders in humans. These disorders include Ehlers-Danlos syndrome, osteogenesis imperfecta, and Marfan syndrome.

People with Ehlers-Danlos syndrome have abnormally fragile connective tissue, resulting in joint problems and weakened internal organs. In osteogenesis imperfecta, the body doesn't produce enough collagen or it produces poor quality collagen, leading to fragile bones that break easily. People with Marfan syndrome have connective tissue that isn't as stiff as it should be, causing skeletal abnormalities and weakened blood vessels.

By studying the connective tissue in echinoderms such as the sea cucumber, researchers are moving closer to successfully treating debilitating illnesses that prevent people from having freedom of movement in their joints due to connective tissue diseases.

### WRITING in Biology

**Journal** Visit biologygmh.com to learn more about scientific research involving echinoderms. Create a biologist's research journal describing his or her work with an echinoderm. The journal should include thorough descriptions, charts, graphs, and sketches of echinoderms.

# BIOLAB

CLE 3210.5.1; ✓3210.Inq.3; SPI 3210.Inq.4

## INTERNET: HOW DO ECHINODERMS SURVIVE WITHOUT A HEAD, EYES, OR A BRAIN?

**Background:** Echinoderms have evolved unlike any other animals on Earth. Lacking eyes and a brain, they also have no heart, and pump seawater through their bodies rather than blood. Some echinoderms can change their endoskeletons from rock hard to nearly liquid within seconds. Some can break off an arm to distract a predator. Sound unusual? Not for echinoderms.

**Question:** *How do echinoderms survive in the competitive marine environment?*

These sea stars, basket stars, and sea urchins are from the Gulf of Maine.

### Materials

internet access
echinoderm reference book
field journal

### Procedure

1. Read and complete the lab safety form.
2. Design and construct a data table for recording the species; physical characteristics; food sources/strategies for obtaining food; predators; defense strategies; reproduction and development; and other interesting facts about six animals.
3. Choose one species from each of the six major classes of echinoderms to study. List the species in your data table.
4. Research the species you chose and fill in information in your data table. Observe the echinoderms in their natural habitat by visiting a local zoo or aquarium. If you cannot observe the animals in their natural habitats, obtain information about the echinoderms from a reference book or visit biologygmh.com.
5. Record your observations in your field journal. Transfer the information to your data table.
6. Post your results at biologygmh.com. Use data posted by other students to complete missing portions of your table.

### Analyze and Conclude

1. **Describe** some basic physical characteristics shared by echinoderms.
2. **Compare** sexual and asexual reproductive strategies used by echinoderm species.
3. **Think Critically** Echinoderm larvae and mature echinoderms differ in several important ways. Describe the differences, and infer the advantages they provide.
4. **Interpret Data** What are the major food sources of the echinoderms you studied?
5. **Draw Conclusions** Are echinoderms well-adapted to survive in the marine environment? Justify your answer.
6. **Error Analysis** Describe advantages and disadvantages of obtaining information about echinoderms from the Internet.

### WRITING in Biology

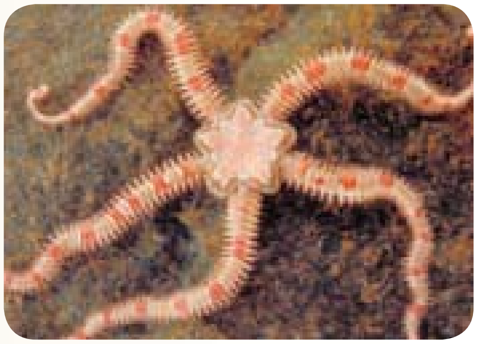
**Resource Book** Use the data you gathered to create a fact sheet including photos and interesting information about each echinoderm you studied. Combine your fact sheets with those developed by other students to create an echinoderm resource book for your school's media center. To find out more about echinoderms, visit Biolabs at biologygmh.com.

# Study Guide

Download quizzes, key terms, and flash cards from biologygmh.com.

FOLDABLES **Analyze** Use what you have learned in this chapter to debate the placement of invertebrate chordates in the phylum Chordata.

| Vocabulary | Key Concepts |
|---|---|
| **Section 27.1 Echinoderm Characteristics** | |
| • ampulla (p. 795)<br>• madreporite (p. 795)<br>• pedicellaria (p. 793)<br>• tube foot (p. 795)<br>• water-vascular system (p. 795) | **MAIN Idea** Echinoderms are marine animals with spiny endoskeletons, water-vascular systems, and tube feet; they have radial symmetry as adults.<br>• Adult echinoderms can be identified by four main structural features.<br>• Larval echinoderms have features that link them to relatives that evolved after them.<br>• Echinoderms have a water-vascular system and tube feet.<br>• Echinoderms have a variety of adaptations for feeding and movement.<br>• There are six major classes of living echinoderms. |



| Vocabulary | Key Concepts |
|---|---|
| **Section 27.2 Invertebrate Chordates** | |
| • chordate (p. 803)<br>• dorsal tubular nerve cord (p. 803)<br>• invertebrate chordate (p. 803)<br>• notochord (p. 803)<br>• pharyngeal pouches (p. 804)<br>• postanal tail (p. 803) | **MAIN Idea** Invertebrate chordates have features linking them to vertebrate chordates.<br>• Chordates have four main features that make them different from animals that are not chordates.<br>• Invertebrate chordates have all the features of chordates, except they do not have the main feature of vertebrate chordates.<br>• The notochord is an adaptation that enabled animals to move in ways they had never moved before.<br>• Lancelets are fish-shaped invertebrate chordates that, as adults, have all the main features of chordates.<br>• Tunicates are sac-shaped invertebrate chordates that have chordate features as larvae. |



Biology Online Vocabulary PuzzleMaker biologygmh.com

(t)Robert L. Dunne/Photo Researchers, (b)G.I. Bernard/OSF/Animals Animals

CHAPTER 27 # Assessment

Questions are correlated to the Tennessee Science Curriculum for Biology I.

## Section 27.1

### Vocabulary Review

*Distinguish between the terms in each of the following pairs.*

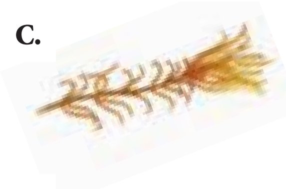
1. tube foot, ampulla SPI 3210.5.2
2. madreporite, water-vascular system SPI 3210.5.2

### Understand Key Concepts

3. Which is not an echinoderm? ✓3210.5.4

**A.**

**C.**



**B.**

**D.**

**A.** A **C.** C
**B.** B **D.** D

4. Which echinoderm is sessile for part of its life?
**A.** sea cucumber **C.** brittle star
**B.** sea lily **D.** sea urchin

SPI 3210.5.1

5. What three functions do tube feet perform?
**A.** reproduction, feeding, respiration
**B.** feeding, respiration, neural control
**C.** feeding, respiration, movement
**D.** development, reproduction, respiration

CLE 3210.5.2

6. Which is not associated with deuterostomes?
**A.** a pattern of development CLE 3210.5.2
**B.** mouth develops from somewhere on the gastrula away from the opening
**C.** echinoderms
**D.** arthropods

7. Which are involved in protecting an echinoderm?
**A.** endoskeleton, pedicellariae, spines
**B.** madreporite, tentacles, endoskeleton
**C.** water-vascular system, ampulla, pedicellariae
**D.** exoskeleton, pedicellariae, spines

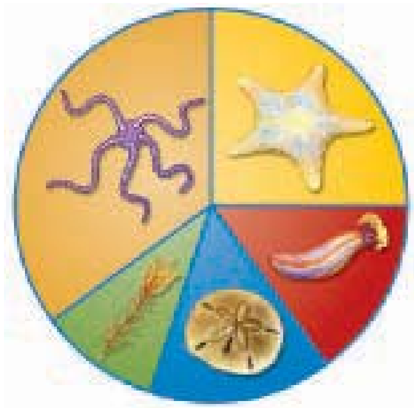
CLE 3210.5.2

8. What is the main difference between echinoderm larvae and adults? CLE 3210.5.1
**A.** Larvae are protostomes and adults are deuterostomes.
**B.** Larvae are deuterostomes and adults are protostomes.
**C.** Larvae have bilateral symmetry and adults have radial symmetry.
**D.** Larvae have radial symmetry and adults have bilateral symmetry.

9. Which group of echinoderms has respiratory trees with many branches? SPI 3210.5.2
**A.** sea cucumbers
**B.** sea stars
**C.** sea lilies and feather stars
**D.** sea urchins and sand dollars

### Constructed Response

*Use the diagram below to answer questions 10 and 11.*



10. **Short Answer** Examine the circle graph and estimate the percentage of echinoderms that are sea cucumbers. ✓3210.Math.2

11. **Open Ended** Examine the circle graph and explain why class Concentricycloidea does not appear with the other classes of living echinoderms. CLE 3210.Inq.4

12. **Open Ended** Scientists have discovered a fossil that has the following characteristics: an endoskeleton similar to that of echinoderms, a tail-like structure with an anus at the end of the tail, a structure that might be a gill, and symmetry similar to echinoderms. How might scientists explain this animal in terms of echinoderm classification? SPI 3210.5.5

**13. Open Ended** Tidal animals suffer when water and air temperatures rise beyond the limits of tolerance of the animals. The temperature of sea stars remain about 18 degrees cooler than those of the surrounding mussels on a hot day. Make a hypothesis about why sea stars have a lower body temperature. SPI 3210.5.1

## Think Critically

**14. Observe and Infer** You are walking on the beach and find an animal that has many feathery arms and tube feet. What kind of animal might this be? ✓3210.5.4

**15. Hypothesize** Some sea urchins seem to have relatively long lifespans. Make a hypothesis about why they live so long. SPI 3210.Inq.2

# Section 27.2

## Vocabulary Review

*Using the vocabulary terms from the Study Guide page, replace the underlined words with the correct term.*

**16.** Animals that are chordates, but do not have backbones are the close relatives of chordates. SPI 3210.5.6

**17.** Located just below the nerve cord is a structure in chordates that enables invertebrate chordates to swim by moving their tails back and forth. CLE 3210.5.2

**18.** The connections between the muscular tube that links the mouth cavity and the esophagus develop slits and are used for filter feeding in some invertebrate chordates. CLE 3210.5.2

## Understand Key Concepts

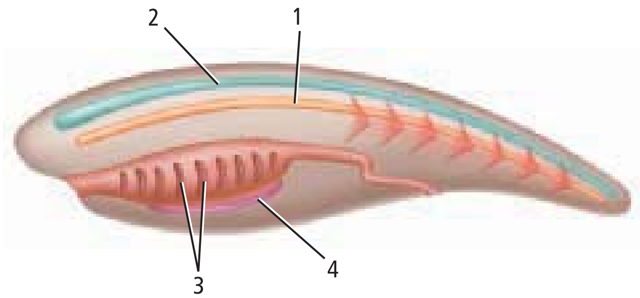
**19.** Chordates have which features at some time in their lives? CLE 3210.5.2

**A.** water-vascular system, notochord, pharyngeal pouches, postanal tail
**B.** tunic, pharyngeal pouches, dorsal tubular nerve cord, postanal tail
**C.** tube feet, notochord, pharyngeal pouches, postanal tail
**D.** dorsal tubular nerve cord, notochord, pharyngeal pouches, postanal tail

**20.** Which is the main function of a postanal tail? CLE 3210.5.2

**A.** circulation
**B.** digestion
**C.** flexibility
**D.** locomotion

*Use the diagram below to answer questions 21 and 22.*




**21.** Fishlike swimming is made possible by which labeled structure above? CLE 3210.5.2

**A.** 1 **C.** 3
**B.** 2 **D.** 4

**22.** Which structure develops into the brain and spinal cord in most chordates? CLE 3210.5.2

**A.** 1 **C.** 3
**B.** 2 **D.** 4

**23.** Which describes adult sea squirts? SPI 3210.5.2

**A.** They are bilaterally symmetrical.
**B.** They have the same adult features as lancelets.
**C.** As adults, they have only two chordate features.
**D.** They are actively swimming predators.

**24.** In invertebrate chordates, what does the endostyle secrete? CLE 3210.5.2

**A.** proteins similar to thyroid hormone
**B.** mucus
**C.** the notochord
**D.** pharyngeal pouches

**25.** The phylogeny of echinoderms indicates that echinoderms are related to chordates because they both have which feature? SPI 3210.5.6

**A.** pharyngeal pouches
**B.** deuterostome development
**C.** protostome development
**D.** pseudocoeloms

26. Which structure might be an early form of the thyroid gland? CLE 3210.5.4
   **A.** dorsal tubular nerve cord
   **B.** endostyle
   **C.** notochord
   **D.** pharyngeal pouches

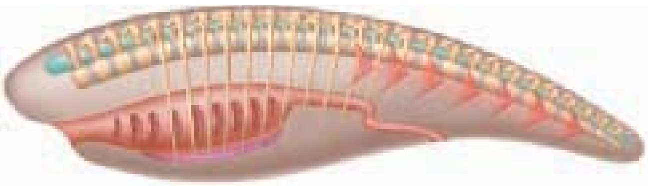
27. Which chordate feature enabled large animals to develop? CLE 3210.5.1
   **A.** dorsal tubular nerve cord
   **B.** notochord
   **C.** pharyngeal pouches
   **D.** postanal tail

## Constructed Response

28. **Open Ended** Infer why there are no freshwater invertebrate chordates. ✓ 3210.Inq.4

29. **Open Ended** What would happen if all lancelets disappeared? SPI 3210.2.1

*Use the diagram below to answer questions 30 and 31.*



30. **Short Answer** Examine the diagram and explain why this animal could not be an invertebrate chordate. ✓ 3210.5.4

31. **Short Answer** What features does this animal share with invertebrate chordates? ✓ 3210.5.4

## Think Critically

32. **Analyze** How do the larvae of organisms help scientists classify and determine the phylogeny of animals? SPI 3210.5.5

33. **Use the Internet** Make a visual report of the newest information, both molecular and fossil evidence, gathered by scientists on the origins of chordates. CLE 3210.5.4

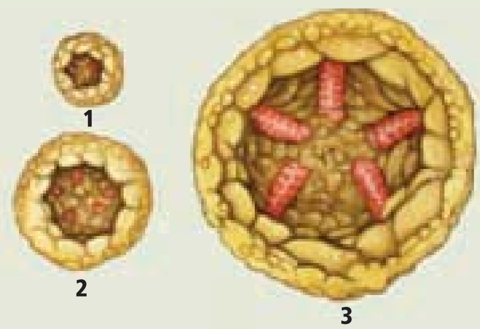
## Additional Assessment

34. WRITING in Biology **Create** a poem that describes your favorite echinoderm. Make sure you point out the actual features of the echinoderm. SPI 3210.5.2

### DBQ Document-Based Questions

*Study the illustration of the progression of development of arms in a specific sea star.*

Diagram based on examples from: Sumrall, Colin D., 2005. Unpublished research on the growth stages of *Neoisorophusella lanei*. The University of Tennessee. http://web.eps.utk.edu/Faculty/sumrall/research2.htm




35. What kind of symmetry is shown in the diagram labeled 1? SPI 3210.5.2

36. Infer how additional arms might develop. SPI 3210.Inq.2

37. How does the number of arms in diagram 3 reflect the characteristics of all echinoderms? CLE 3210.5.2

## Cumulative Review

38. Compare Neanderthals and modern humans. **(Chapter 16)** CLE 3210.5.4

39. Compare and contrast the animal-like, plantlike, and funguslike protists. **(Chapter 19)** CLE 3210.5.1

40. Prepare a list of vocabulary words that describe general fungal structures, and sketch illustrations of each one. **(Chapter 20)** SPI 3210.5.2

41. Name three hormones and the effects they can have on plants. **(Chapter 22)** CLE 3210.5.1

42. Sequence the steps involved in the production of the pollen grain and egg in anthophytes. **(Chapter 23)** CLE 3210.4.6

# Assessment Practice

**Cumulative**

All questions are correlated to the Tennessee Biology I Curriculum on the next page.

## Multiple Choice

1. In which structure of a flowering plant do eggs develop?
   **A.** anther
   **B.** ovule
   **C.** seed
   **D.** stigma

*Use the diagram below to answer question 2.*

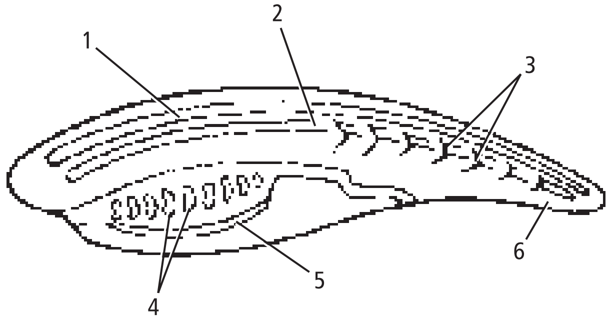
2. Arthropods have specialized mouthparts for feeding. For which type of feeding method is this mouthpart specialized?
   **A.** getting nectar from flowers
   **B.** sponging liquids from a surface
   **C.** sucking blood from a host
   **D.** tearing and shredding leaves

3. Which statement about a group of invertebrates is correct?
   **A.** Cnidarians have collar cells.
   **B.** Flatworms have flame cells.
   **C.** Flatworms have nematocysts.
   **D.** Sponges have a nervous system.

4. Echinoderms have which characteristic that is an evolutionary connection to vertebrates?
   **A.** bilateral symmetry as adults
   **B.** free-swimming larvae
   **C.** deuterostome development
   **D.** radial symmetry as larvae

5. Which special adaptation would be essential for an insect that swims in water?
   **A.** compound eyes
   **B.** modified legs
   **C.** sticky foot pads
   **D.** sharp mouth parts

*Use the diagram below to answer questions 6 and 7.*




6. Which structure is replaced by bone or cartilage in vertebrate chordates?
   **A.** 1
   **B.** 2
   **C.** 4
   **D.** 5

7. Which structure is a bundle of nerves protected by fluid?
   **A.** 1
   **B.** 3
   **C.** 5
   **D.** 6

8. What kind of body organization or body structure first appeared with the evolution of flatworms?
   **A.** bilateral symmetry
   **B.** coelomic cavity
   **C.** nervous system
   **D.** radial symmetry

9. Suppose a cell from the frond of a fern contains 24 chromosomes. How many chromosomes would you expect to find in the spores?
   **A.** 6
   **B.** 12
   **C.** 24
   **D.** 48



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## Short Answer

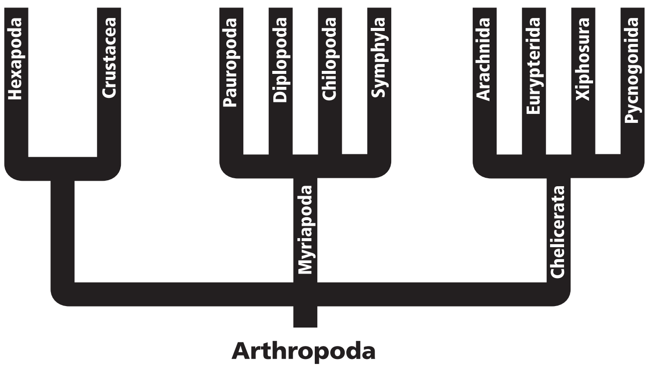
**10.** Use what you know about the body structure of a sponge to explain how it obtains food.

**11.** Sea stars are echinoderms that feed on oysters. Justify why oyster farmers should not cut up sea stars and toss the parts back into the water.

**12.** Evaluate the defense adaptations of the two groups of invertebrate chordates.

**13.** Contrast the main characteristics of echinoderms with the characteristics of the organisms in another phylum that you already know.

*Use the diagram below to answer questions 14 and 15.*




**14.** Write a hypothesis about why horseshoe crabs (in class Xiphosura) are more closely related to spiders than to regular crabs and lobsters.

**15.** Write a hypothesis about where trilobites would fit into this phylogenetic tree.

## Extended Response

**16.** Explain how echinoderms and annelids are similar, and how they are different.

**17.** In animals, how are mitosis and meiosis different?

**18.** Evaluate the idea that it was not a large evolutionary jump for aquatic arthropods to move onto land.

**19.** Suppose that one crow in an area's population is born with longer claws on its feet than other crows in the same population. According to Darwin's theory of natural selection, under what circumstances would this trait become common in the area's crow population?

## Essay Question

In the past, many horror movies have featured giant arthropods attacking major cities. These giant arthropods have included ants, grasshoppers, crabs, and spiders. Actually, the largest living insects are not very big. The longest insect, a walking stick, is about 40 cm long. Some marine arthropods grow larger. The largest arthropod is the Japanese spider crab that can grow up to 4 m wide. Some fossil marine arthropods are even larger. However, none of these are nearly as large as the size of the giant arthropod villains in the movies.

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

**20.** Write an essay about why real-life arthropods cannot become as large as the giant arthropods shown in horror movies.

| If You Missed Question . . . | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Review Section . . . | 23.3 | 26.1 | 25.1 | 27.1 | 26.3 | 27.2 | 27.2 | 25.1 | 21.3 | 24.3 | 27.1 | 27.2 | 27.2 | 26.2 | 26.3 | 24.2 | 10.1 | 26.2 | 15.1 | 26.1 |
| Tennessee Correlations | CLE 3210.5.1 | CLE 3210.5.2 | SPI 3210.5.5 | CLE 3210.5.6 | CLE 3210.5.2 | CLE 3120.5.5 | SPI 3210.5.2 | CLE 3210.5.6 | ✓3210.4.4 | CLE 3120.5.2 | SPI 310.2.4 | CLE 3210.5.1 | SPI 3210.5.5 | SPI 3210.5.6 | SPI 3210.5.6 | SPI 3210.5.5 | CLE 3210.1.4 | SPI 3210.5.3 | CLE 3210.5.3 | CLE 3210.5.1 |