CHAPTER 38

# ECHINODERMS AND INVERTEBRATE CHORDATES

This blue sea star, *Linckia laevigata,* shows the pentaradial symmetry of most echinoderms.

# SECTION 1

# ECHINODERMS

*The phylum Echinodermata (ee-KIE-noh-duhr-MAH-tuh) is a group of invertebrates that includes sea stars, sand dollars, sea urchins, and sea cucumbers. The members of this phylum, called* ***echinoderms,*** *inhabit marine environments ranging from shallow coastal waters to ocean trenches more than 10,000 m deep. They vary in diameter from 1 cm to 1 m and often are brilliantly colored.*

## OBJECTIVES

- **Discuss** four distinguishing characteristics of echinoderms.
- **Describe** representative species from each of the five classes of echinoderms.
- **Describe** the water-vascular system and other major body systems of echinoderms.
- **Compare** sexual and asexual reproduction in sea stars.

## VOCABULARY

**echinoderm**
**ossicle**
**water-vascular system**
**tube foot**
**test**
**pedicellaria**
**madreporite**
**stone canal**
**ring canal**
**radial canal**
**ampulla**
**cardiac stomach**
**pyloric stomach**
**bipinnaria**

## CHARACTERISTICS

Echinoderms are radially symmetrical animals. Like cnidarians and ctenophores, which are also radially symmetrical, echinoderms have no head or any other sign of cephalization. Unlike cnidarians and ctenophores, however, adult echinoderms develop from bilaterally symmetrical larvae. A few examples of echinoderm larvae are illustrated in Figure 38-1. This feature of development indicates that echinoderms probably evolved from bilaterally symmetrical ancestors.

The fossil record of echinoderms dates back to the Cambrian period, more than 500 million years ago. Early echinoderms from this period appear to have been sessile, and biologists believe these animals evolved radial symmetry as an adaptation to a sessile existence. Echinoderms later evolved the ability to move from place to place. Today, the vast majority of echinoderm species can move by crawling slowly along the ocean bottom, and only about 80 species are sessile.

Echinoderms are deuterostomes, which makes them different from the other invertebrates you have studied so far. Recall that *deuterostomes* are coelomates whose embryos have radial cleavage.

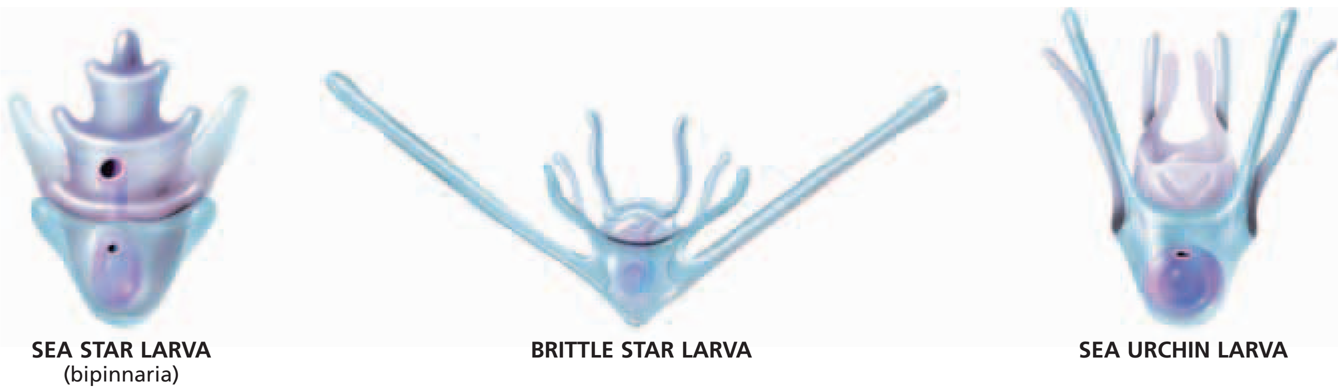


**FIGURE 38-1**
Notice the bilateral symmetry in these echinoderm larvae. The larvae develop into radially symmetrical adults.

**Word Roots and Origins**

***ossicle***

from the Latin *ossiculum,* meaning "little bone"

Also, in deuterostomes, the anus forms from the blastopore, and the mesoderm arises from outpockets of the endoderm. Because they develop as deuterostomes, echinoderms are more closely related to chordates than they are to other invertebrates. Chordates are also deuterostomes and are discussed in the second part of this chapter.

Echinoderms have four major characteristics that are not shared by any other phylum. (1) Most echinoderms have a type of radial symmetry called *pentaradial symmetry,* in which the body parts extend from the center along five spokes. (2) They have an endoskeleton composed of calcium carbonate plates known as **ossicles.** The ossicles may be attached to spines or spicules that protrude through the skin. The name *echinoderm* means "spiny skin." (3) They have a **water-vascular system,** which is a network of water-filled canals inside their body. (4) They have many small, movable extensions of the water-vascular system called **tube feet,** which aid in movement, feeding, respiration, and excretion. The water-vascular system and tube feet will be discussed in more detail.

## CLASSIFICATION

Taxonomists divide the 7,000 species of echinoderms into six classes, five of which will be described here: Crinoidea (kri-NOYD-ee-uh), Ophiuroidea (OH-fee-yoor-OYD-ee-uh), Echinoidea (EK-uh-NOYD-ee-uh), Holothuroidea (HOH-loh-thuh-ROYD-ee-uh), and Asteroidea (AS-tuh-ROYD-ee-uh).

### Class Crinoidea

Members of the class Crinoidea, called *crinoids* (KRI-NOYDZ), include the sea lilies and feather stars, which are shown in Figure 38-2. The name *crinoid* means "lily-like." Sea lilies most closely resemble the fossils of ancestral echinoderms from the Cambrian period. They are sessile as adults, remaining attached to rocks or the sea bottom by means of a long stalk. Feather stars, in contrast, can swim or crawl as adults, although they may stay in one place for long periods.

**FIGURE 38-2**

This sea lily, *Cenocrinus* (a), and these feather stars, *Oxycomanthus bennetti* (b), are members of the class Crinoidea. Notice their adaptations for filter feeding.

**(a)**

**(b)**

In both types of crinoids, five arms extend from the body and branch to form many more arms—up to 200 in some feather star species. Mucus-covered tube feet located on each arm filter small organisms from the water. The tube feet also serve as a respiratory surface across which crinoids exchange oxygen and carbon dioxide with the water. Cilia on the arms transport trapped food to the crinoid's mouth at the base of the arms. The mouth faces up in crinoids, but in most other echinoderms the mouth faces downward.

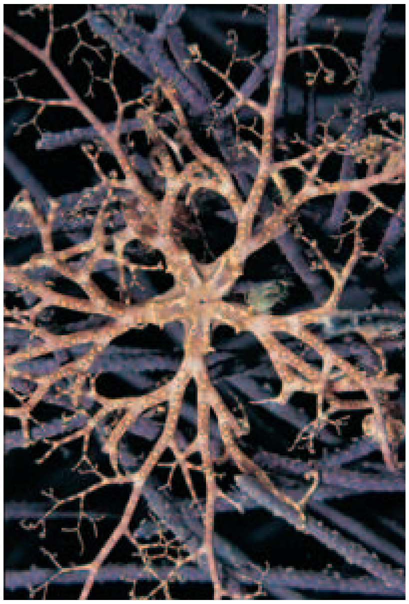

**FIGURE 38-3**

This basket star, *Astrophyton muricatum,* has long, flexible arms with many coiled branches.

## Class Ophiuroidea

The 2,000 species of basket stars and brittle stars make up the largest echinoderm class, Ophiuroidea, which means "snake-tail." Members of this class are distinguished by their long, narrow arms, which allow them to move more quickly than other echinoderms. As you can see in Figure 38-3, the thin, flexible arms of basket stars branch repeatedly to form numerous coils that look like tentacles. Brittle stars, so named because parts of their arms break off easily, can regenerate missing parts.

Basket stars and brittle stars live primarily on the bottom of the ocean, often beneath stones or in the crevices and holes of coral reefs. They are so numerous in some locations that they cover the sea floor. Some species feed by raking in food with their arms or gathering it from the ocean bottom with their tube feet. Others trap suspended particles with their tube feet or with mucous strands located between their spines.

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## Class Echinoidea

The class Echinoidea consists of about 900 species of sea urchins and sand dollars. *Echinoidea* means "spinelike," a description that applies especially well to many of the sea urchins, such as the ones shown in Figure 38-4. In both sea urchins and sand dollars, the internal organs are enclosed within a fused, rigid endoskeleton called a **test.**

The spherical sea urchins are well adapted to life on hard sea bottoms. They move by means of their tube feet and feed by scraping algae from hard surfaces with the five teeth that surround their mouth. The teeth and the muscles that move them are part of a complex jawlike mechanism called *Aristotle's lantern.* The spines that protrude from the test may be short and flat, long and thin, or wedge shaped, depending on the species. In some sea urchins, the spines are barbed, and in others, they are hollow and contain a venom that is dangerous to predators as well as swimmers.

**FIGURE 38-4**

The long, sharp spines that cover these sea urchins, *Strongylocentrotus,* provide protection against most predators.

Sand dollars live along seacoasts. As their name implies, they are usually found in sandy areas and have the flat, round shape of a silver dollar. Their shape is an adaptation for shallow burrowing. The short spines on a sand dollar are used in locomotion and burrowing, and they help clean the surface of the body. Sand dollars use their tube feet to capture food that settles on or passes over their body.

**FIGURE 38-5**

Tentacles around the mouth of this sea cucumber collect food and bring it to the animal's mouth. Five rows of tube feet that run along the body are evidence of the sea cucumber's pentaradial symmetry.

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## Class Holothuroidea

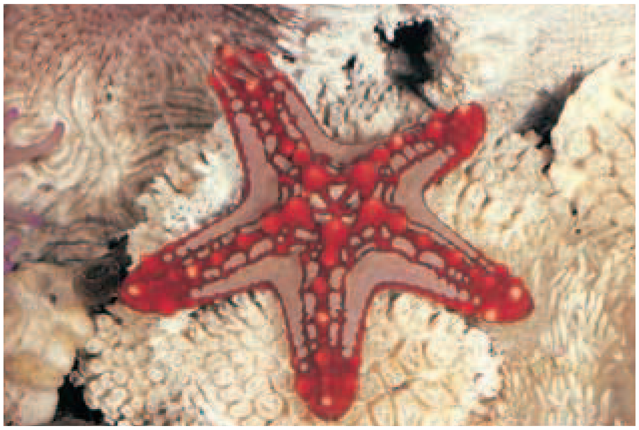
Sea cucumbers belong to the class Holothuroidea. Most of these armless echinoderms live on the sea bottom, where they crawl or burrow into soft sediment by using their tube feet. The ossicles that make up their endoskeleton are very small and are not connected to each other, so their bodies are soft. Modified tube feet form a fringe of tentacles around the mouth. When these tentacles are extended, as shown in Figure 38-5, the animals resemble the polyp form of some cnidarians. This resemblance explains the name of this class, which means "water polyp." A sea cucumber uses its tentacles to sweep up sediment and water. It then stuffs its tentacles into its mouth and cleans the food off them.

## Class Asteroidea

The sea stars, or starfish, belong to the class Asteroidea, which means "starlike." Sea stars live in coastal waters all over the world. They exist in a variety of colors and shapes, two of which are shown in Figure 38-6. Sea stars are economically important because they prey on oysters, clams, and other organisms that humans use as food.

**FIGURE 38-6**

Sea stars are found on rocky coastlines worldwide. One of the more colorful varieties is the African sea star, *Protoreaster linckii* (a). The sunflower star, *Pycnopodia helianthoides* (b), can have up to two dozen arms.



**(a)**

**(b)**

# STRUCTURE AND FUNCTION OF ECHINODERMS

The sea star will be used to demonstrate some of the details of echinoderm structure and function. As you read about how echinoderms carry out life functions, consider how they differ from the other groups of invertebrates you have studied.

## External Structure

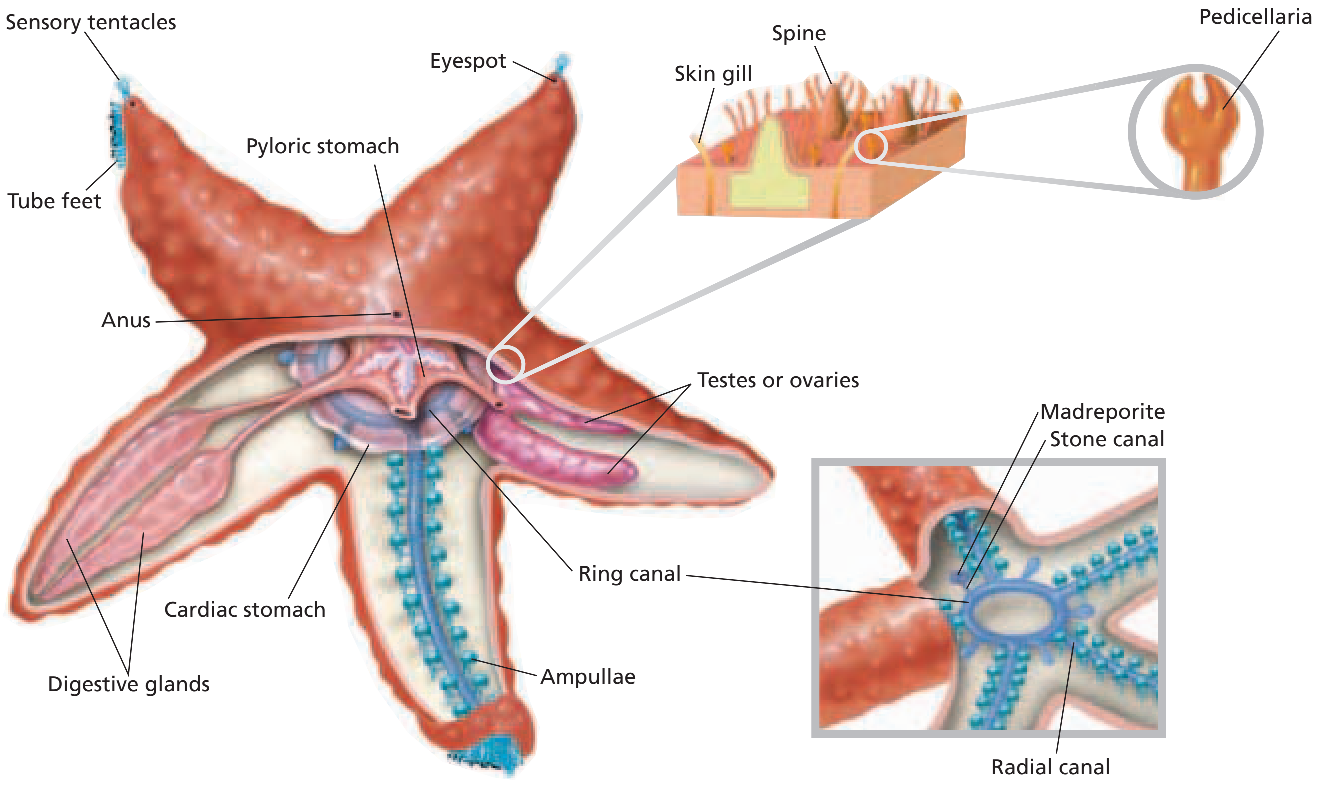
As you can see in Figure 38-7, the body of a sea star is composed of several arms that extend from a central region. Sea stars typically have five arms, but in some species, such as the one shown in Figure 38-6b, there may be as many as 24. Two rows of tube feet run along the underside of each arm. The body is often flattened.

In echinoderms, the side of the body where the mouth is located is referred to as the *oral surface.* The side of the body that is opposite from the mouth is called the *aboral* (A-BOHR-uhl) *surface.* In sea stars, the oral surface is on the underside of the body.

The body of a sea star is usually covered with short spines that give the animal a rough texture. Surrounding each spine in many sea stars are numerous tiny pincers called **pedicellariae** (PED-uh-suh-LAR-ee-ee), which are shown in Figure 38-7. Pedicellariae help keep the body surface free of foreign objects, including algae and small animals that might grow on the sea star or damage its soft tissues. Pedicellariae are found in sea stars and some sea urchins.

**FIGURE 38-7**

Sea stars have a number of structural features that are unique to the phylum Echinodermata. Their pentaradial symmetry is indicated by their five arms, each of which contains a division of their internal organ systems. The water-vascular system consists of a network of canals connected to hundreds of tube feet. The inset shows that the sea star's exterior is dotted with short spines, pincerlike pedicellariae, and skin gills.



## Water-Vascular System

The water-vascular system is a network of water-filled canals that are connected to the tube feet. Use Figure 38-7 to follow the path of water through the water-vascular system. Water enters the system through small pores in the **madreporite** (MA-druh-PAWR-IET), a sieve-like plate on the aboral surface. Water then passes down the **stone canal,** a tube that connects the madreporite to the **ring canal,** which encircles the mouth. Another tube, the **radial canal,** extends from the ring canal to the end of each arm. The radial canals carry water to the hundreds of hollow tube feet. Valves prevent water from flowing back into the radial canals from the tube feet.

The upper end of each tube foot is expanded to form a bulblike sac called an **ampulla** (am-PUHL-uh). Contraction of muscles surrounding the ampullae forces water into the tube feet, causing them to extend. Contraction of muscles lining the tube feet forces water back into the ampullae and shortens the tube feet. In this way, the sea star uses water pressure to extend and withdraw its tube feet. In many species, small muscles raise the center of each tube foot's disklike end, creating suction when the tube feet are pressed against a surface. These coordinated muscular contractions enable sea stars to climb slippery rocks and capture prey.

**Word Roots and Origins**

***ampulla***

form the Latin *ampulla,* meaning "flask"

## Feeding and Digestion

The sea star's mouth is connected by a short esophagus to the **cardiac stomach,** which the sea star can turn inside out through its mouth when it feeds. The cardiac stomach transfers food to the **pyloric stomach,** which connects to a pair of digestive glands in each arm. The cardiac stomach, pyloric stomach, and digestive glands break down food with the help of the enzymes they secrete. Nutrients are absorbed into the coelom through the walls of the digestive glands, and undigested material is expelled through the anus on the aboral surface.

Most sea stars are carnivorous, feeding on mollusks, worms, and other slow-moving animals. When a sea star captures a bivalve mollusk, such as a clam, it attaches its tube feet to both halves of the clamshell and exerts a steady pull, as Figure 38-8 shows. Eventually, the clam's muscles tire, and the shell opens slightly. The sea star then inserts its cardiac stomach into the clam and digests the clam's soft tissues while they are still in the shell. The sea star then withdraws the stomach, containing the partially digested food, back into its body, where the digestive process is completed.

**FIGURE 38-8**

This sea star, *Asterias rubens,* is prying open the shell of a clam to feed on the clam's soft tissues.

## Other Body Systems

Like other echinoderms, the sea star has no circulatory, excretory, or respiratory organ systems. Fluid in the coelom bathes the organs and distributes nutrients and oxygen. Gas exchange and waste excretion take place by diffusion through the thin walls of the tube feet and through the *skin gills,* hollow tubes that project from the coelom lining to the exterior. You can see the skin gills in the inset in Figure 38-7, on the previous page.

Because echinoderms have no head, they also have no brain. The nervous system consists mainly of a *nerve ring* that circles the mouth and a *radial nerve* that runs from the nerve ring along each arm. The nerve ring and radial nerves coordinate the movements of the tube feet. If the radial nerve in one arm is cut, the tube feet in that arm lose coordination. If the nerve ring is cut, the tube feet in all arms become uncoordinated, and the sea star cannot move.

Sea stars also have a nerve net near the body surface that controls the movements of the spines, pedicellariae, and skin gills. The end of each arm has an eyespot that responds to light and several tentacles that respond to touch. The tube feet also respond to touch, and other touch-sensitive and chemical-sensitive cells are scattered over the surface of the sea star's body.

## Reproduction and Development

Most sea star species have separate sexes, as do most other echinoderms. Each arm of the sea star contains a pair of ovaries or testes. Females produce up to 200 million eggs in one year. Fertilization occurs externally, when the eggs and sperm are shed into the water. Each fertilized egg develops into a bilaterally symmetrical, free-swimming larva called a **bipinnaria** (BIE-pin-AR-ee-uh). After about two months, the larva settles to the bottom, and begins metamorphosis into a pentaradially symmetrical adult.

Echinoderms have remarkable powers of regeneration. Sea stars can regenerate arms from the central region of their body, even if they lose all of their arms. The process of regeneration is very slow, taking as long as a year. Sea stars use their regenerative ability as a defensive mechanism, automatically shedding an arm at its base when the arm is captured by a predator. As you can see in Figure 38-9, some sea stars can even regenerate a complete, new individual from a detached arm, as long as the arm is attached to a portion of the central region. Certain species reproduce asexually when the body splits through the central region. The two parts that are formed then regenerate the missing structures.

**FIGURE 38-9**

As long as a sea star retains part of its central region, it can regenerate any arms it loses. The sea star shown here, a member of the genus *Echinaster,* is regenerating five new arms.

## SECTION 1 REVIEW

1. What are the characteristics that distinguish Echinodermata from other phyla?
2. Give the common names of members of each of the five classes of echinoderms.
3. How does a sea star extend and withdraw its tube feet?
4. Describe how sea stars are able to reproduce asexually.

**CRITICAL THINKING**

5. **Making Comparisons** Compare development in sea urchins with development in mollusks.
6. **Inferring Relationships** How would a sea star's ability to feed be affected by losing the water in its water-vascular system?
7. **Analyzing Concepts** Sea stars release millions of eggs during reproduction. How is this method of reproduction adaptive?

**SECTION 2**

## OBJECTIVES

- **List** the major characteristics of chordates.
- **Describe** the evolution and classification of invertebrate chordates.
- **Describe** the structure of lancelets.
- **Describe** the structure of tunicates.

## VOCABULARY

atriopore

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Keyword: HM60285
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# INVERTEBRATE CHORDATES

*The phylum Chordata (kawr-DAY-tuh) includes all of the vertebrates, or animals with backbones. It also includes two groups of invertebrates—animals that lack backbones.*

## CHARACTERISTICS

All animals with a backbone are vertebrates, and they make up one of the subphyla in the phylum Chordata, whose members are called *chordates.* Chordates are so named because they have a *notochord,* a stiff but flexible rod of cells that runs the length of the body near the dorsal surface. Figure 38-10 illustrates the notochord. The stiffness of the notochord provides a resistance against which the body muscles can exert force when they contract. The flexibility of the notochord allows the body to bend from side to side as well as up and down.

Some kinds of chordates retain the notochord throughout their life. In most vertebrates, however, the notochord is present in embryos but becomes greatly reduced when the vertebral column, or backbone, develops. In adult mammals, the notochord persists only as small patches of tissue between the bones of the vertebral column.

Recall that in addition to having a notochord, all chordates have the following three characteristics during some stage of their life: (1) a dorsal nerve cord, (2) pharyngeal pouches, and (3) a postanal tail. These characteristics are also illustrated in Figure 38-10. Unlike the ventral nerve cords of invertebrates such as annelids and arthropods, the dorsal nerve cord of a chordate is a hollow tube.

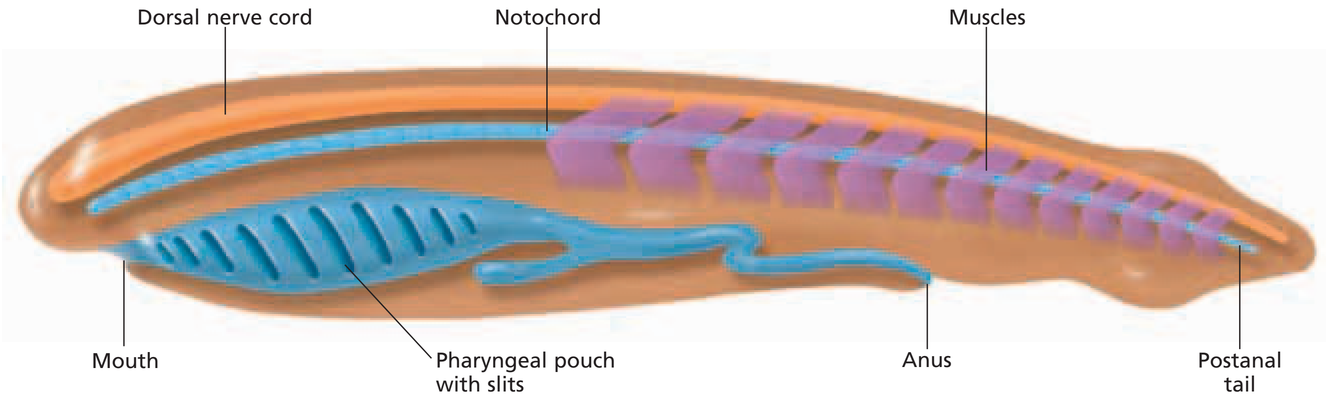



**FIGURE 38-10**
All chordates have a notochord, a dorsal nerve cord, pharyngeal pouches, and a postanal tail during at least some stage of their life.

In vertebrates, the anterior end of the nerve cord enlarges during development to form the brain, and the posterior end forms the spinal cord. The brain receives information from a variety of complex sensory organs, many of which are concentrated at the anterior end of the body.

The pharyngeal pouches are outpockets in the pharynx, the portion of the digestive tract between the mouth and the esophagus. In aquatic chordates, the pharyngeal pouches have slits and evolved first into filter-feeding structures and later into gill chambers. In terrestrial chordates, the pouches evolved into a variety of structures, including the jaws and inner ear.

The notochord extends into the postanal tail, and muscles in the tail can cause it to bend. The postanal tail provides much of the propulsion in many aquatic chordates. Invertebrates in other phyla lack this form of propulsion, and the anus, if present, is located at the end of the body.

## Quick Lab

### Modeling Chordate Characteristics

**Materials** several colors of clay, toothpicks, masking tape

**Procedure** Build clay models of a lancelet and an adult tunicate by using different colors of clay for the structures shown in Figures 38-11 and 38-12. Make flags using masking tape attached to toothpicks, and use them to identify any of the four major characteristics of chordates that are found in your models.

**Analysis** Which of the major characteristics of chordates are found in the lancelet? the adult tunicate? Which of the four characteristics is shared by both? Why is the tunicate classified as a chordate despite the fact that it has only three of the four chordate characteristics?

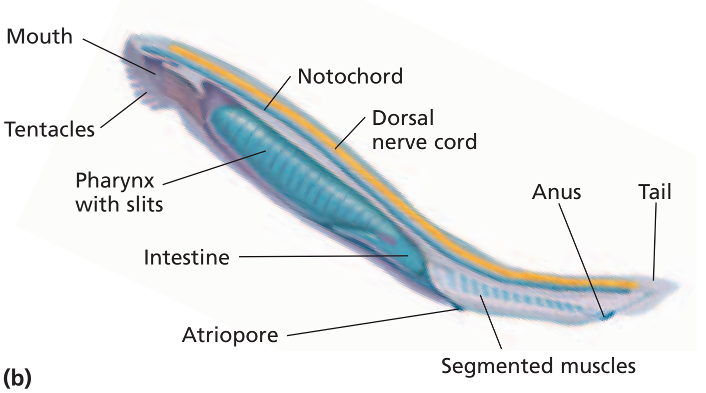
# EVOLUTION AND CLASSIFICATION

Like echinoderms, chordates are deuterostomes. This similarity provides evidence that echinoderms and chordates likely evolved from a common ancestor. The phylum Chordata is divided into three subphyla: Vertebrata, Cephalochordata (SEF-uh-loh-kawr-DAY-tuh), and Urochordata (YOOR-uh-kawr-DAY-tuh). Members of the subphylum Vertebrata, the vertebrates, constitute more than 95 percent of all chordate species. Members of the other two subphyla live only in the ocean. They are the closest living relatives of the early animals from which all chordates evolved.

## Subphylum Cephalochordata

The subphylum Cephalochordata contains about two dozen species of blade-shaped animals known as *lancelets*. Figure 38-11 shows that lancelets look much like the idealized chordate drawn in Figure 38-10. They retain their notochord, dorsal nerve cord, pharyngeal pouches, and postanal tail throughout their life.

(a)

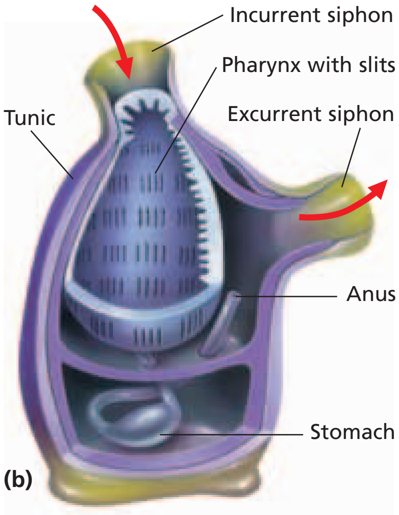



(b)

**FIGURE 38-11**

(a) The lancelet *Branchiostoma lanceolatum* lives with most of its body buried in the sand. (b) Even as adults, lancelets clearly show all four chordate characteristics.

(a)




(b)

**FIGURE 38-12**

Most adult tunicates, such as *Polycarpa aurata* (a), are sessile filter feeders. A drawing of a tunicate's internal structure (b) shows its enlarged pharynx with slits, the only chordate characteristic retained by adult tunicates.

Lancelets live in warm, shallow waters. They wriggle backward into the sand with a muscular tail. Only their anterior end protrudes from the sand. Lancelets have cilia that draw water into the pharynx through the mouth. Food particles in the water are trapped as the water passes through the slits in the pharynx. The food enters the intestine to be digested. The water leaves the body through an opening called the **atriopore** (AY-tree-oh-POHR).

Lancelets can swim weakly, powered by the coordinated contraction of muscles that run the length of their body. If you look closely at Figure 38-11, you can see that these muscles are arranged as a series of repeating segments. Body segmentation is another common feature of chordates. Recall that annelids and arthropods also have segmented bodies. However, animals in those phyla probably evolved body segmentation independently of chordates.

## Subphylum Urochordata

The 2,000 species in the subphylum Urochordata are commonly called *tunicates* because their bodies are covered by a tough covering, or tunic. Tunicates are also called *sea squirts* because they squirt out a stream of water when touched. As adults, most tunicates are sessile, barrel-shaped animals that live on the sea bottom. They may be solitary or colonial.

Figure 38-12 shows that tunicates are adapted for filter feeding. Propelled by the beating of cilia, water enters the body through an incurrent siphon, passes through slits in the pharynx, and exits through an excurrent siphon. Food that is filtered by the pharynx moves into the stomach. Undigested material leaves via the anus, which empties into the excurrent siphon.

Tunicates are hermaphrodites. Sperm and eggs are released through the excurrent siphon into the surrounding water, where fertilization occurs.

Adult tunicates bear little resemblance to the idealized chordate shown in Figure 38-10. Although they do have a pouchlike pharynx with slits, they have no notochord, dorsal nerve cord, or postanal tail. Larval tunicates, however, possess all four chordate characteristics, but they lose most of them during metamorphosis.

## SECTION 2 REVIEW

1. What are the four major characteristics of chordates?
2. What is the function of pharyngeal pouches in aquatic chordates?
3. What evidence of body segmentation do lancelets display?
4. Which of the chordate characteristics do tunicates retain as adults?

**CRITICAL THINKING**

5. **Making Comparisons** Compare the function of pharyngeal gill slits with that of gills in a crayfish.
6. **Inferring Relationships** How is burrowing backward, with the head out, adaptive in lancelets?
7. **Relating Concepts** In tunicates, the anus empties into the excurrent siphon. What is the advantage of this anatomical arrangement?

# CHAPTER HIGHLIGHTS

## SECTION 1 Echinoderms

- Most echinoderms develop from free-swimming, bilaterally symmetrical larvae into bottom-dwelling adults with pentaradial symmetry. The larval stage is evidence that echinoderms may have evolved from bilaterally symmetrical ancestors.
- Echinoderms have an endoskeleton made of ossicles and a water-vascular system, which includes many movable extensions called tube feet.
- The class Crinoidea includes sea lilies and feather stars, which are filter feeders that catch small organisms with their mucus-covered tube feet.
- The class Ophiuroidea consists of basket stars and brittle stars, fast-moving echinoderms with long, flexible arms.
- The class Echinoidea includes sea urchins and sand dollars, whose internal organs are enclosed inside a rigid endoskeleton called a test. Many sea urchins have long spines.
- The class Holothuroidea is made of sea cucumbers, armless echinoderms with soft bodies.
- The class Asteroidea consists of sea stars, which have from 5 to 24 arms. Two rows of tube feet run along the underside of each arm.
- The water-vascular system of a sea star consists of a network of canals that connect to bulblike ampullae. Contraction of muscles surrounding the ampullae extends the tube feet, and contraction of muscles lining the tube feet makes the tube feet retract.
- Sea stars can turn one of their stomachs inside out through their mouth to feed on prey they have captured. After the food is partially digested outside the body, it is brought inside, where digestion is completed.
- Sea stars lack circulatory, excretory, and respiratory organ systems, and they have no head or brain. They use skin gills for gas exchange and waste excretion.
- Most sea stars have separate sexes, and fertilization is external. Sea stars can also reproduce asexually by regeneration.

### Vocabulary

| | | | |
|---|---|---|---|
| **echinoderm** (p. 761) | **tube foot** (p. 762) | **stone canal** (p. 766) | **cardiac stomach** (p. 766) |
| **ossicle** (p. 762) | **test** (p. 763) | **ring canal** (p. 766) | **pyloric stomach** (p. 766) |
| **water-vascular system** (p. 762) | **pedicellaria** (p. 765) | **radial canal** (p. 766) | **bipinnaria** (p. 767) |
| | **madreporite** (p. 766) | **ampulla** (p. 766) | |

## SECTION 2 Invertebrate Chordates

- Chordates have a notochord, a stiff but flexible rod that runs the length of the body. In one group of chordates, the vertebrates, the notochord is largely replaced by the vertebral column, or backbone.
- Other common characteristics of chordates are a dorsal nerve cord, pharyngeal pouches, and a postanal tail. These characteristics are not present at all life stages in all chordates.
- Like echinoderms, chordates are deuterostomes, which suggests that echinoderms and chordates evolved from a common ancestor.
- Lancelets are animals in the subphylum Cephalochordata. These blade-shaped animals live partially buried in the sand, but they can swim from place to place. They retain all of the major chordate characteristics throughout their life.
- Tunicates are animals in the subphylum Urochordata. Tunicate larvae have all of the major chordate characteristics, but they lose most of them when they develop into adults. Most tunicate adults are sessile.

### Vocabulary

**atriopore** (p. 770)

# CHAPTER REVIEW

## USING VOCABULARY

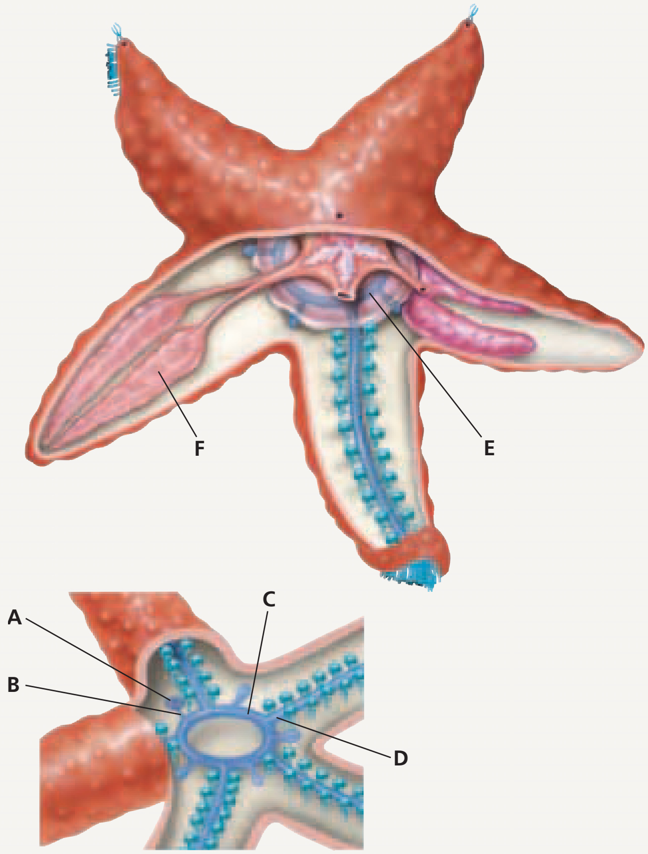
1. For each pair of terms, explain how the meanings of the terms differ.
   a. *ossicle* and *test*
   b. *tube foot* and *pedicellaria*
   c. *stone canal* and *ring canal*
   d. *madreporite* and *atriopore*
2. Explain the relationship between the *cardiac stomach* and the *pyloric stomach* in sea stars.
3. Choose the term that does not belong in the following group, and explain why it does not belong: *tube foot, bipinnaria, radial canal,* and *ampulla*.
4. **Word Roots and Origins** The word *pyloric* is derived from the Greek *pyloros,* which means "gatekeeper." Using this information, explain why the term *pyloric stomach* is a good name for the structure that the term describes.

## UNDERSTANDING KEY CONCEPTS

5. **Explain** why echinoderms are thought to have evolved from bilaterally symmetrical ancestors.
6. **Identify** the functions for which echinoderms use their tube feet.
7. **Compare** feeding in crinoids and basket stars.
8. **Compare** the ways that sea urchins and sand dollars are adapted to their environment.
9. **Describe** how the sea cucumber transports food to its mouth.
10. **Explain** why sea stars are of economic importance.
11. **Summarize** the process of feeding and digestion in the sea star.
12. **Compare** sexual and asexual reproduction in sea stars.
13. **Summarize** how pharyngeal pouches have become modified through evolution in aquatic chordates and in terrestrial chordates.
14. **Interpret** the significance of the notochord and the postanal tail to aquatic chordates, such as the lancelet.
15. **Explain** why members of the subphylum Urochordata are called tunicates.
16. **CONCEPT MAPPING** Use the following terms to create a concept map that sequences the path of water through the water-vascular system of a sea star: *water, radial canal, madreporite, ring canal, tube foot,* and *stone canal*.

## CRITICAL THINKING

17. **Forming Reasoned Opinions** Scientists have found many echinoderm fossils from the Cambrian period, but they have found few fossils of other species from this period. What might explain the large number of fossilized echinoderms?
18. **Analyzing Concepts** Sea lilies and sea cucumbers are mostly sessile animals as adults. Their larvae, however, can swim. What adaptive advantage do swimming larvae provide?
19. **Inferring Relationships** Basket stars are active at night. During the day, basket stars curl up their arms and become a compact mass. What are possible explanations for this behavior?
20. **Interpreting Graphics** Identify the structures labeled "A–F" in the diagram below.




21. **Applying Information** Commercial oyster farmers usually want to prevent sea stars from feeding in the oyster beds. In the past, the farmers would control the sea stars by chopping the sea stars in half and throwing them back into the water. Was this a good way to protect the oysters from predation by the sea stars? Why or why not? If not, describe a better method.

# Standardized Test Preparation

**DIRECTIONS:** Choose the letter of the answer choice that best answers the question.

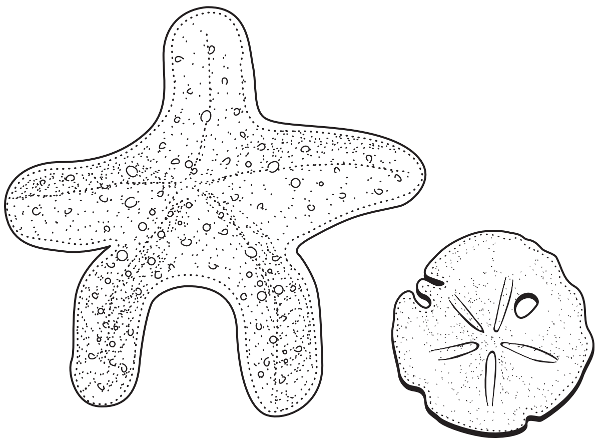
**1.** In a sea star, gas exchange and excretion of wastes take place by diffusion through which of the following structures?
**A.** pharynx
**B.** skin gills
**C.** atriopore
**D.** radial canals

**2.** Which of the following types of symmetry is characteristic of echinoderms?
**F.** biradial
**G.** bilateral
**H.** pentaradial
**J.** pentalateral

**3.** Which of the following classes of echinoderms most closely resembles the fossils of ancient echinoderms?
**A.** Crinoidea
**B.** Asteroidea
**C.** Echinoidea
**D.** Holothuroidea

**4.** Which of the following is found in adult tunicates, or sea squirts?
**F.** eyespot
**G.** notochord
**H.** spinal cord
**J.** pharynx with slits

**INTERPRETING GRAPHICS:** The illustration below shows a sea star and a sand dollar. Use the illustration to answer the question that follows.

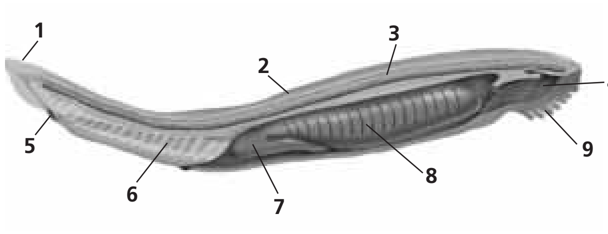


**5.** To which phylum do these animals belong?
**A.** Chordata
**B.** Vertebrata
**C.** Arthropoda
**D.** Echinodermata

**DIRECTIONS:** Complete the following analogy.

**6.** Cardiac stomach : digestion :: atriopore :
**F.** excretion
**G.** respiration
**H.** circulation
**J.** reproduction

**INTERPRETING GRAPHICS:** The diagram below shows a lancelet. Use the diagram to answer the question that follows.




**7.** Which four structures are the main distinguishing characteristics of chordates?
**A.** *1, 2, 3, 4*
**B.** *1, 2, 3, 8*
**C.** *2, 3, 4, 6*
**D.** *2, 3, 4, 9*

## SHORT RESPONSE

Echinoderms and chordates are believed to have evolved from a common ancestor.

Describe the evidence that supports this view.

## EXTENDED RESPONSE

The fossil record of echinoderms dates to the Cambrian period, more than 500 million years ago. Scientists have observed many well-preserved echinoderm species from this period.

*Part A* Based on the fossil evidence, which characteristics did the earliest adult echinoderms have, in terms of symmetry and ability to move?

*Part B* Based on your answer to Part A, describe the evolution of echinoderms.

**Test TIP** If you are unsure of the answers to particular questions, put a mark beside them (on your answer sheet or test booklet), and go on to other questions. If you have time, go back and reconsider the questions you skipped. (Do not write in this book.)

SKILLS PRACTICE LAB

# Comparing Echinoderms

## OBJECTIVES

- Compare the structure of two types of echinoderms.
- Infer function from the observation of structures.

## PROCESS SKILLS

- using dissection instruments and techniques
- observing

## MATERIALS

- preserved sea star
- preserved sea urchin
- sea urchin test
- dissection tray
- fine dissection scissors with pointed blades
- hand lens or dissecting microscope
- forceps
- blunt probe
- sharp probe
- dissection pins
- gloves (optional)
- 100 mL beaker
- household bleach
- Petri dish

## Background

1. List the major characteristics of echinoderms.
2. Which feature of echinoderms gives their phylum its name?
3. To which classes of echinoderms do sea stars and sea urchins belong?
4. What is pentaradial symmetry?

## PART A Observing the External Anatomy of a Sea Star

1. CAUTION **Put on safety goggles, gloves, and a lab apron.** Using forceps, hold a preserved sea star under running water to gently but thoroughly remove excess preservative. Then, place the sea star in a dissection tray.
2. What evidence can you find that indicates that the sea star has pentaradial symmetry?
3. Make a table in your lab report like the one shown on the next page. As you observe each of the structures listed in the table, fill in the function of that structure.
4. While referring to Figure 38-7, find the madreporite on the aboral surface of your sea star. Record the madreporite's position and appearance.
5. Use a hand lens to examine the sea star's spines. Describe their size and shape. Are they distributed in any recognizable pattern on the surface of the sea star? Are they covered by tissue or exposed? Are they movable or fixed?
6. Are pedicellariae present? What is their location and arrangement? Draw one as it appears under the hand lens or dissecting microscope.
7. Use the dissecting microscope to look for small skin gills. If any are present, describe their location and structure.
8. Now, examine the sea star's oral surface. Find the mouth, and describe its location and structure. Use forceps or a probe to gently move aside any soft tissues. What structures are found around the mouth?
9. Locate the tube feet. Describe their distribution. Using a dissecting microscope, observe and then draw a single tube foot.

## PART B Observing the Internal Anatomy of a Sea Star

10. Using scissors and forceps, carefully cut the body wall away from the aboral surface of one of the sea star's arms. Start near the end of the arm, and work toward the center. The internal

organs may stick to the inside of the body wall, so use a sharp probe to gently separate them from the body wall as you cut. Be careful not to damage the madreporite.

**11.** While referring to Figure 38-7, find the digestive glands in the arm you have opened. Describe their appearance. If you have dissected carefully, you should be able to find a short, branched tube that connects the digestive glands to the pyloric stomach. If you cannot find the digestive glands or this tube, repeat step 10 on one of the other arms, and look for them there.

**12.** Cut the tube that connects the digestive glands to the pyloric stomach, and move the digestive glands out of the arm. Look for the testes or ovaries. If your specimen is an immature animal, these organs may be small and difficult to find.

**13.** Locate the two rows of ampullae that run the length of the arm. What is the relationship between the ampullae and the tube feet, which you observed on the oral surface?

**14.** Carefully remove the body wall from the aboral surface of the central region of the sea star. Try to avoid damaging the underlying structures. Locate the pyloric stomach and the cardiac stomach. How does a sea star use its cardiac stomach during feeding?

**15.** Remove the stomachs, and find the canals of the water-vascular system: stone canal, ring canal, and radial canals. In which direction does water move through these canals?

**16.** CAUTION **Bleach is a highly corrosive agent. If you get it on your skin or clothing, wash it off at the sink while calling to your teacher. If you get it in your eyes, immediately flush it out at the eyewash station while calling to your teacher.** Cut a 1 cm cross section out of the middle of one of the arms. Using forceps, transfer the section to a small beaker containing enough bleach to cover it. The bleach will eat away the soft tissues, exposing the endoskeleton.

**17.** After about 10–15 minutes, use the forceps to carefully transfer the endoskeleton to a Petri dish containing tap water. Observe the endoskeleton under a dissecting microscope. Can you find individual ossicles?

### FUNCTION OF SEA STAR STRUCTURES

| Structure | Function |
|---|---|
| Madreporite | |
| Pedicellaria | |
| Skin gill | |
| Tube foot | |
| Digestive gland | |
| Ampulla | |
| Ossicle | |

## PART C Observing the Anatomy of a Sea Urchin

**18.** Using forceps, hold a preserved sea urchin under running water to remove excess preservative. Then, place the sea star in a dissection tray. What evidence can you find that indicates that the sea urchin has pentaradial symmetry?

**19.** Observe the sea urchin's spines. Answer the same questions for the sea urchin's spines that you answered for the sea star's spines in step 5.

**20.** Examine the sea urchin's oral surface. Find the mouth, and use a sharp probe to explore the structures around the mouth. How does the sea urchin's mouth differ from the sea star's?

**21.** Examine the sea urchin test. What might be the function of the rows of small pores on the test? What might be the function of the small bumps on the test?

**22.** Dispose of the specimens according to the directions from your teacher. Then, clean up your materials, and wash your hands before leaving the lab.

## Analysis and Conclusions

**1.** Which features are shared by sea stars and sea urchins?

**2.** What are some of the structural differences between sea stars and sea urchins?

## Further Inquiry

Observe how living sea stars move in a saltwater aquarium. Add some live mussels, and observe the feeding behavior of the sea stars.