Section 1 Echinoderms

Objectives

- **Compare** the developmental pattern found in protostomes with that found in deuterostomes. 8B
- **Describe** the major characteristics of echinoderms. 8C TAKS 2
- **Summarize** how the sea star's water vascular system functions. 7B TAKS 3

Key Terms

blastopore
protostome
deuterostome
ossicle
water-vascular system
skin gill

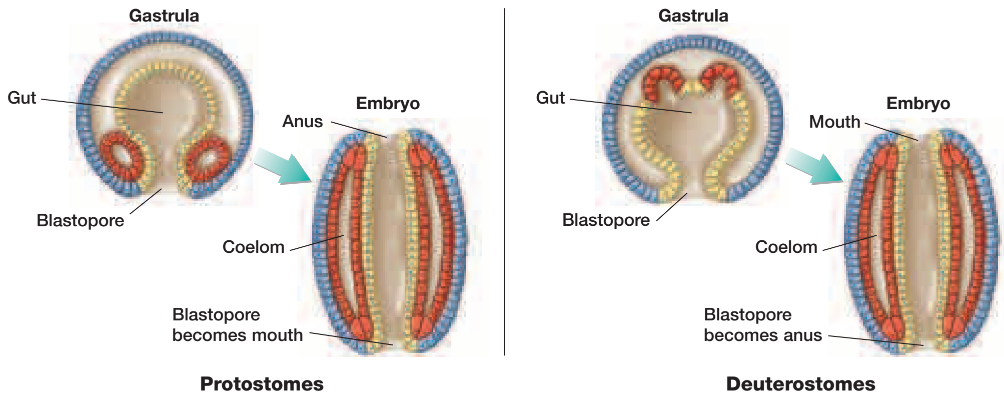
Animal Development

If you have been to a saltwater aquarium, you're sure to have seen echinoderms, which are spiny invertebrates that live on the ocean bottom. How could echinoderms like the brittle star shown on the first page of this chapter be related to animals such as chordates, which are primarily vertebrates? The answer lies in their early development. As an embryo develops, it goes through a gastrula stage. As shown in **Figure 1,** a gastrula has an opening to the outside called the **blastopore.** In acoelomate animals, the mouth develops from or near the blastopore. This pattern of development also occurs in some coelomate animals, such as annelids, mollusks, and arthropods. Animals with mouths that develop from or near the blastopore are called **protostomes.** 1

Some animals follow a different pattern of development. In phylums Echinodermata and Chordata, the anus—not the mouth—develops from or near the blastopore. (The mouth forms later, on another part of the embryo.) Animals with this pattern of development are called **deuterostomes,** also shown in Figure 1. If you know the origin of these two terms, it's easy to remember the differences between the two developmental patterns. The term *protostome* is from the Greek *protos,* meaning "first," and *stoma,* meaning "mouth." The prefix *deutero-* is from the Greek *deuteros,* meaning "second." In deuterostomes, the anus develops first and the mouth develops second. 1 2

Figure 1 Embryonic development

The development of an animal embryo follows one of two patterns.



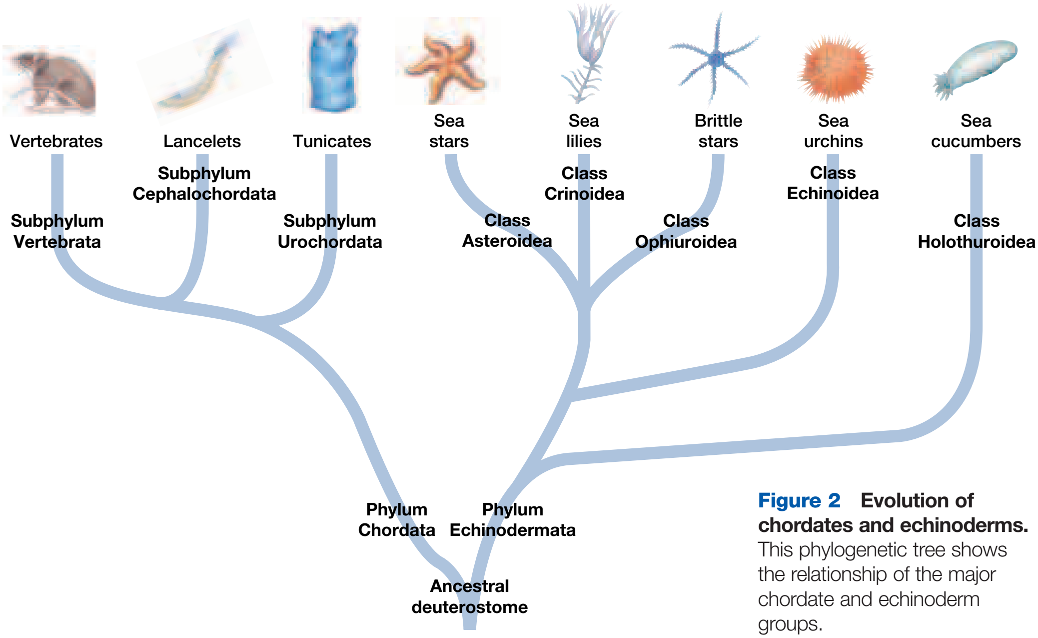


Figure 2 **Evolution of chordates and echinoderms.** This phylogenetic tree shows the relationship of the major chordate and echinoderm groups.

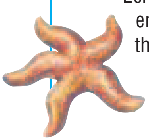
The first deuterostomes were marine echinoderms that evolved more than 650 million years ago. They were also the first animals to develop an endoskeleton. Today, most people are familiar with echinoderms known as "starfish," which are not really fish and are more properly called sea stars. In addition to sea stars, many other animals commonly seen along the sea shore—sea urchins, sand dollars, and sea cucumbers—are echinoderms. All are marine, and all are radially symmetrical as adults.

Chordates, as well as a few other small phyla, are also deuterostomes. (Humans and all other vertebrates are chordates.) Like the echinoderms, chordates have an internal skeleton. This developmental similarity unites these seemingly dissimilar animal phyla. It also leads scientists to believe that chordates and echinoderms derived from a common ancestor, as shown in the phylogenetic tree in **Figure 2.** The identity of the ancestral deuterostome is not known. The fossil record indicates that echinoderms, such as the sea lily in **Figure 3,** were abundant in the ancient seas. 1 2 3

Figure 3 **Fossil sea lily.** Sea lilies such as the one preserved by this fossil were plentiful in the ancient oceans.

Evolutionary Milestone

8 Deuterostomes



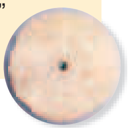
Echinoderms are coelomates that have a deuterostome pattern of embryo development. The same pattern of development occurs in the chordates.

Modern Echinoderms

Real Life

Do sand dollars resemble the sun?

To the Chumash Indians of southern California, the lines radiating from a sand dollar's mouth resemble the sun's rays. Sand dollars, once plentiful in the Pacific Ocean, became the Chumash's symbol for the "newborn" sun of the winter solstice.



Many of the most familiar animals seen along the seashore—sea stars, sea urchins, sand dollars—are echinoderms. Echinoderms are also common in the deep ocean. While all echinoderms are marine, the different classes of echinoderms vary considerably in the details of their body design. Despite their apparent differences, all echinoderms share four fundamental characteristics.

1. **Endoskeleton.** Echinoderms have a calcium-rich endoskeleton composed of individual plates called **ossicles**. When ossicles first form in young echinoderms, they are enclosed in living tissue, so they are a true endoskeleton. Even though the ossicles of adult echinoderms appear to be external, they are covered by a thin layer of skin (although sometimes the skin is worn away). In adult sea stars and in many other echinoderms, a large number of these plates are fused together. The fused plates function much like an arthropod exoskeleton. They provide sites for muscle attachment and shell-like protection. In most echinoderms, the plates of the endoskeleton bear spines that project upward through their skin.
2. **Five-part radial symmetry.** All echinoderms are bilaterally symmetrical as larvae. During their development into adults, the larvae's body plan becomes radially symmetrical. Most adult echinoderms, such as the one shown on the left in **Figure 4,** have a five-part body plan with arms that radiate from a central point. However, the number of arms can vary. Echinoderms have no head or brain. Instead, the nervous system consists of a central ring of nerves with branches extending into each of the arms. Although echinoderms are capable of complex response patterns, each arm acts more or less independently. Many species, including sea stars, can regenerate a new arm if a portion of an arm is lost. In some species of sea stars, a complete animal can regenerate from an arm connected to a portion of the central disk. However, a complete sea star cannot regenerate from an arm alone.

WORD Origins

The term *echinoderm* is from the Greek *echinos,* meaning "spiny," and *derma,* meaning "skin."

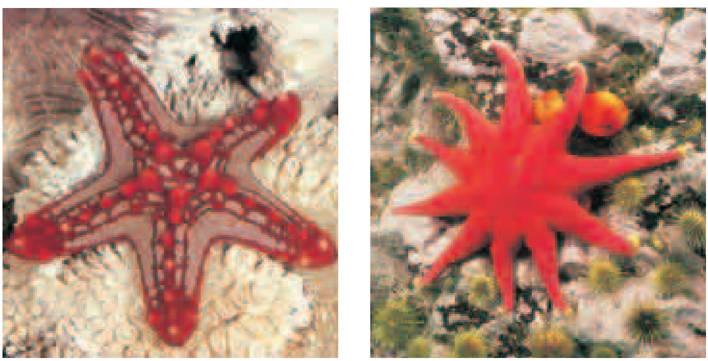


Figure 4 Five-part body plan. The echinoderm five-part body plan is easily seen in this colorful African species. Other sea stars, such as the sunstar, have more than five arms.

3. **Water-vascular system.** Echinoderms have a water-filled system of interconnected canals and thousands of tiny hollow tube feet called a **water-vascular system.** In some echinoderms, such as the sea star, the tube feet extend outward through openings in the ossicles. In some species, each tube foot has a sucker at its tip. Many echinoderms use their tube feet to crawl across the sea floor. The water-vascular system also functions in feeding and gas exchange. A sea star can use the hundreds of tube feet on its arms to pull the valves of a bivalve open. Some gas exchange and waste excretion takes place through the thin walls of the tube feet. 2 3

4. **Coelomic circulation and respiration.** The echinoderm body cavity functions as a simple circulatory and respiratory system. Particles, including respiratory gases, move freely throughout the large, fluid-filled coelom. Many echinoderms have skin gills that aid respiration and waste removal. **Skin gills,** shown in **Figure 5,** are small, fingerlike projections that grow among the echinoderm's spines. These projections create an increased surface area through which respiratory gases can be exchanged. Skin gills also function as excretory structures, and wastes that accumulate in them are released into the surrounding water. 2 3

You can learn more about the structure of one particular echinoderm, the sea star, in *Up Close: Sea Star,* on the following page.

Figure 5 **Skin gills.** An echinoderm's skin gills function as both respiratory and excretory organs.

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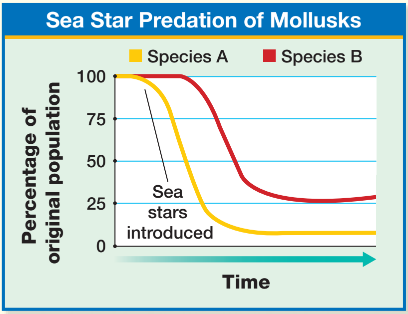
DATA LAB

Determining How Predators Affect Prey

Background 2C 12B TAKS 1, TAKS 3

Sea stars can be very effective predators, and they frequently eat mollusks. The chart at right shows the relative number of two species of mollusks before and after the introduction of a predatory sea star. Study the chart, and answer the Analysis questions.



Analysis

1. **Compare** the relative sizes of the two mollusk populations before the introduction of the sea star.

2. **Identify** the preferred prey of the sea star, and use the data presented in the graph to support your answer.

3. **Critical Thinking** **Analyzing Data** When the sea star began preying on the nonpreferred species, the preferred species had dropped to what percent of its original population?

4. **Critical Thinking** **Inferring Relationships** What factors might cause the sea star to begin consuming a nonpreferred species, even when its preferred prey is still present?

5. **Critical Thinking** **Predicting Outcomes** Predict the relative abundance of the two species of mollusks if the sea star remains in the area indefinitely.

Up Close

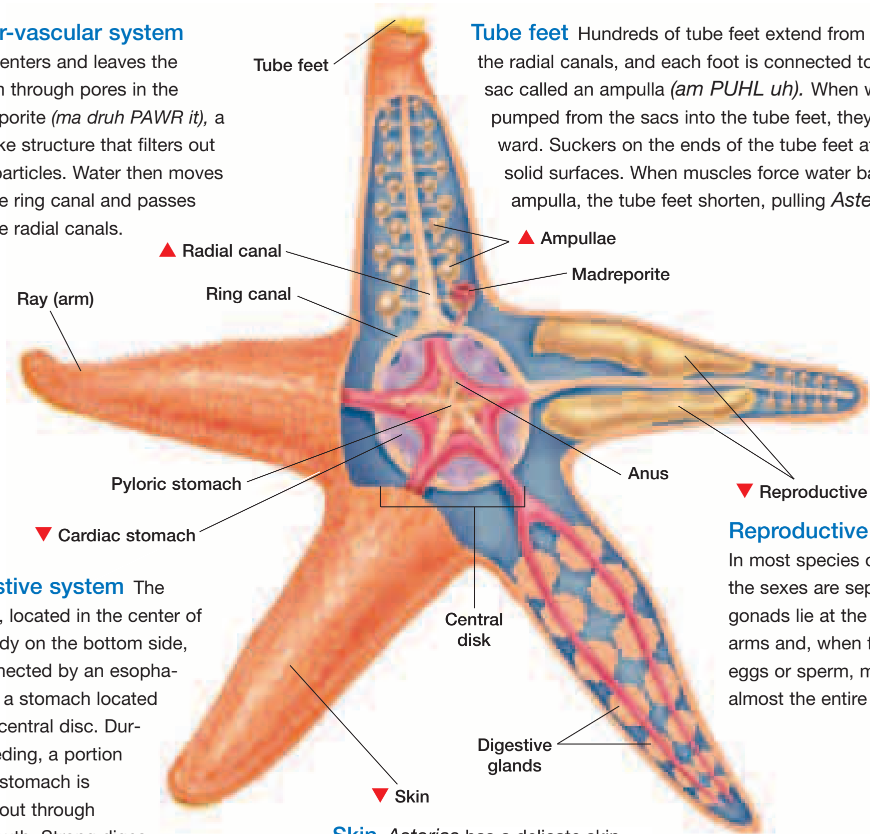
Sea Star TAKS 2, TAKS 3

- **Scientific name:** *Asterias vulgaris*
- **Size:** Typically from 15 to 30 cm (6 to 12 in.) in diameter
- **Range:** East coast of North America
- **Habitat:** Intertidal; often on hard, rocky surfaces
- **Diet:** Slow-moving or sessile species, including mollusks, crustaceans, polychaetes, and corals

Characteristics

Water-vascular system
Water enters and leaves the system through pores in the madreporite *(ma druh PAWR it),* a sievelike structure that filters out large particles. Water then moves into the ring canal and passes into the radial canals.

Tube feet
Hundreds of tube feet extend from the bottom of the radial canals, and each foot is connected to a waterfilled sac called an ampulla *(am PUHL uh).* When water is pumped from the sacs into the tube feet, they expand outward. Suckers on the ends of the tube feet attach firmly to solid surfaces. When muscles force water back into the ampulla, the tube feet shorten, pulling *Asterias* forward.



Reproductive system
In most species of *Asterias* the sexes are separate. The gonads lie at the base of the arms and, when filled with eggs or sperm, may occupy almost the entire arm.

Digestive system
The mouth, located in the center of the body on the bottom side, is connected by an esophagus to a stomach located in the central disc. During feeding, a portion of the stomach is thrust out through the mouth. Strong digestive juices liquefy the prey, which is then ingested.

Skin
Asterias has a delicate skin stretched over an endoskeleton of spiny plates.

Echinoderm Diversity

Echinoderms are one of the most numerous of all marine phyla. In the past, they were even more plentiful than they are now. There are more than 20 extinct classes of echinoderms and an additional six classes of living members. As you saw on the phylogenetic tree that appeared earlier in this section, the living classes include sea stars, sea lilies, brittle stars, sea urchins, and sea cucumbers. The recently discovered sea daisy does not appear on the phylogenetic tree because its relationship to the other echinoderms is not fully understood.

Figure 6 **Sea star.** This sea star is using its tube feet to pry open the shell of a clam. Then it will feed on the clam's soft tissues.

Sea Stars

Sea stars are the echinoderms most familiar to people. Almost all species of sea stars are carnivores, and they are among the most important predators in many marine ecosystems. For example, the crown-of-thorns sea star eats coral polyps. In 1 year, a single crown-of-thorns can consume up to 6 m^2 of a reef. Over time, this sea star can destroy an entire coral reef ecosystem. Other sea stars prey on bivalve mollusks, whose shells they pull open with their powerful tube feet, as shown in **Figure 6.**

The ossicles of many species of sea stars produce pincerlike structures called pedicellaria *(ped uh suh LAH ree uh)*. Pedicellaria contain their own muscles and nerves, and they snap at anything that touches them. This action prevents small organisms from attaching themselves to the surface of the sea star.

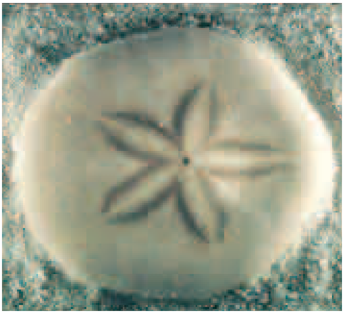
Brittle Stars

The sea star's relatives, the brittle stars and sea baskets, make up the largest class of echinoderms. Brittle stars have slender branched arms that they move in pairs to row along the ocean floor. Their arms break off easily, a fact that gives brittle stars their name. Brittle stars and sea baskets live primarily on the ocean bottom, and they usually hide under rocks or within crevices in coral reefs. Although a few species are predators, most brittle stars are filter feeders or feed on food in the ocean sediment.

Sea Lilies and Feather Stars

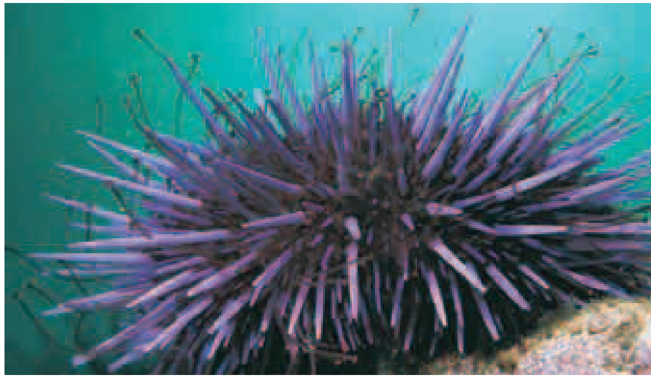
The sea lilies and feather stars are the most ancient and primitive living echinoderms. They differ from all other living echinoderms because their mouth is located on their upper, rather than lower, surface. Sea lilies are sessile and are attached to the ocean floor by a stalk that is about 60 cm (23 in.) long. Feather stars, shown in **Figure 7,** use hooklike projections to attach themselves directly to the ocean bottom or a coral reef. They sometimes crawl or swim for short distances.

Figure 7 **Feather star.** The feathery arms of these feather stars are adapted for filter feeding.



Sand dollar

Figure 8 **Sea urchin and sand dollar.** Sea urchins usually live on rocky ocean bottoms, while sand dollars live on sandy ocean bottoms.



Sea urchin

Sea Urchins and Sand Dollars

The sea urchins and sand dollars, shown in **Figure 8,** lack distinct arms but have the basic five-part body plan seen in other echinoderms. Both sea urchins and sand dollars have a hard, somewhat flattened endoskeleton of fused plates covered with spines protruding from it. The spines provide protection and, in some species of sea urchins, contain a venom that causes a severe burning sensation. In some other species of sea urchin, a specialized type of pedicellarium contains a toxin used to paralyze prey. Sea urchins are found on the ocean bottoms while sand dollars live in sandy areas along the sea coast. 1 2

Sea Cucumbers

Sea cucumbers are soft-bodied, sluglike animals without arms. They differ from other echinoderms in that their ossicles are small and are not fused together. Because of this, the sea cucumber's long, cylindrical body is soft. Often the body has a tough, leathery exterior. The sexes of most sea cucumbers are separate, but some species are hermaphrodites. 1 2 3

Sea cucumbers feed by trapping tiny organisms present in the sea water. Their mouth, located at one end of the body, is surrounded by several dozen tube feet modified into tentacles. The tentacles are covered with a sticky mucus that entraps plankton. Periodically, the sea cucumber draws its tentacles into its mouth and cleans off the plankton and mucus. The tentacles are then coated with a fresh supply of mucus. When threatened, a sea cumber has an unusual means of defending itself. As shown in **Figure 9,** the sea cucumber can release a number of sticky threads from its anus to entrap its attacker. 4

Figure 9 **Sea cucumber.** When threatened, a sea cucumber releases sticky threads that entrap its attacker.

Sea Daisies

In 1986, a new class of echinoderm was discovered: strange disk-shaped little animals called sea daisies. Less than 1 cm (0.39 in.) in diameter, these creatures were first found in deep waters off the coast of New Zealand. Only a few species are known. Sea daisies have five-part radial symmetry but no arms. Their tube feet are located around the edges of the disk rather than along the radial lines, like they are in other echinoderms. 1 2 3

BIOWatch

Monitoring Water Quality

If you were swimming or fishing in coastal waters, you likely would not be able to detect the presence of toxic chemicals in the water, the sediments, or the sea life. To help protect humans and marine organisms, scientists have developed several tests to monitor marine environments for potential health hazards. Since sea urchin sperm and eggs are very sensitive to many pollutants, they are used in one of these tests, known as the sea urchin fertilization bioassay. (A bioassay is the use of a living organism or cell culture to test for the presence of a substance.)

Using Sea Urchins

Samples of ocean water, sediment, and industrial wastes that are discharged into the ocean are collected regularly from different sites. Then they are tested under controlled conditions in a lab. In this bioassay, sea urchin sperm and eggs are mixed together with the collected samples. After a short waiting period, scientists compare the fertilization success rate in the collected water samples with the fertilization success rate found in control water samples. If the test samples show a lower fertilization rate, scientists conclude that toxic contaminants are present.

Taking Action

What happens when the test indicates the presence of contaminants? More specific tests may be run to determine exactly what contaminants are present. If the toxicity can be traced to runoff from a factory or sewage treatment plant, the plant may be forced to clean its waste before discharging it. Sediments may have to be removed or decontaminated. In the future, it may be possible to clean up some pollutants by using plants that have the ability to remove toxic chemicals from the water they are growing in. The use of this process, known as phytoremediation, in marine environments is an exciting new area of research.

Recording water temperature in a bioassay tank

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Section 1 Review

1. **Summarize** why echinoderms are considered to be more closely related to tunicates, lancelets, and vertebrates than to other animals. 8B 8C

2. **Summarize** the four major echinoderm characteristics. 8C

3. **Describe** how the sea stars use their water-vascular system to move along the sea floor. 7B

4. TAKS Test Prep In an echinoderm, the functions of a circulatory system are carried out by the 10A
   - **A** ossicles.
   - **B** pedicellariae.
   - **C** coelom.
   - **D** madreporite.