47

Echinoderms

Concept Outline

47.1 The embryos of deuterostomes develop quite differently from those of protostomes.

Protostomes and Deuterostomes. Deuterostomes—the echinoderms, chordates, and a few other groups—share a mode of development that is quite different from other animals.

47.2 Echinoderms are deuterostomes with an endoskeleton.

Deuterostomes. Echinoderms are bilaterally symmetrical as larvae but metamorphose to radially symmetrical adults.

Echinoderm Body Plan. Echinoderms have an endoskeleton and a unique water-vascular system seen in no other phylum.

47.3 The six classes of echinoderms are all radially symmetrical as adults.

Class Crinoidea: The Sea Lilies and Feather Stars. Crinoids are the only echinoderms that are attached to the sea bottom for much of their lives.

Class Asteroidea: The Sea Stars. Sea stars, also called starfish, are five-armed mobile predators.

Class Ophiuroidea: The Brittle Stars. Brittle stars are quite different from the sea stars for whom they are sometimes mistaken.

Class Echinoidea: The Sea Urchins and Sand Dollars. Sea urchins and sand dollars have five-part radial symmetry but lack arms.

Classes Holothuroidea and Concentricycloidea: Sea Cucumbers and Sea Daisies. Sea cucumbers are soft-bodied echinoderms without arms. The most recently discovered class of echinoderms, sea daisies are tiny, primitive echinoderms that live at great depths.

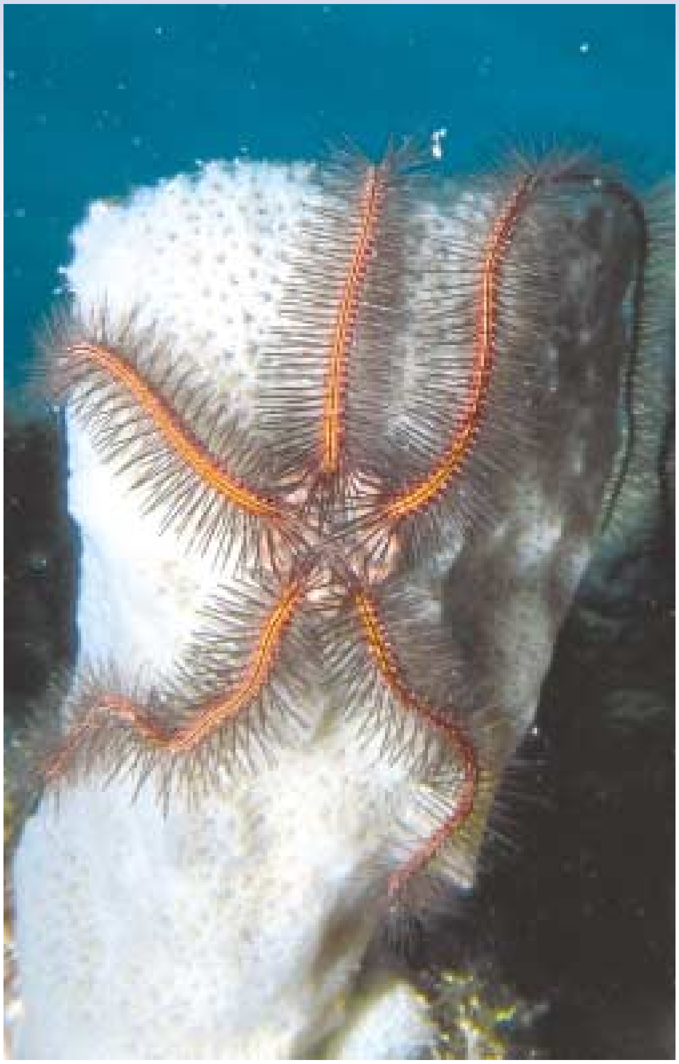


FIGURE 47.1
An echinoderm. Brittle star, *Ophiothrix*, a member of the largest group of echinoderms.

Echinoderms, which include the familiar starfish, have been described as a "noble group especially designed to puzzle the zoologist." They are bilaterally symmetrical as larvae, but undergo a bizarre metamorphosis to a radially symmetrical adult (figure 47.1). A compartment of the coelom is transformed into a unique water-vascular system that uses hydraulic power to operate a multitude of tiny tube feet that are used in locomotion and food capture. Some echinoderms have an endoskeleton of dermal plates beneath the skin, fused together like body armor. Many have miniature jawlike pincers scattered over their body surface, often on stalks and sometimes bearing poison glands. This collection of characteristics is unique in the animal kingdom.

47.1 The embryos of deuterostomes develop quite differently from those of protostomes.

Protostomes and Deuterostomes

The coelomates we have met so far—the mollusks, annelids, and arthropods—exhibit essentially the same kind of embryological development, starting as a hollow ball of cells, a blastula, which indents to form a two-layer-thick ball with a blastopore opening to the outside. Also in this group, the mouth (stoma) develops from or near the blastopore (figure 47.2). This same pattern of development, in a general sense, is seen in all noncoelomate animals. An animal whose mouth develops in this way is called a **protostome** (from the Greek words *protos*, "first," and *stoma*, "mouth"). If such an animal has a distinct anus or anal pore, it develops later in another region of the embryo. The fact that this kind of developmental pattern is so widespread in diverse phyla suggests that it is the original pattern for animals as a whole and that it was characteristic of the common ancestor of all eumetazoan animals.

A second distinct pattern of embryological development occurs in the echinoderms, the chordates, and a few other smaller related phyla. The consistency of this pattern of development, and its distinctiveness from that of the protostomes suggests that it evolved once, in a common ancestor to all of the phyla that exhibit it. In **deuterostome** (Greek, *deuteros*, "second," and *stoma*, "mouth") development, the blastopore gives rise to the organism's anus, and the mouth develops from a second pore that arises in the blastula later in development.

Deuterostomes represent a revolution in embryonic development. In addition to the pattern of blastopore formation, deuterostomes differ from protostomes in a number of other fundamental embryological features:

1. The progressive division of cells during embryonic growth is called *cleavage.* The cleavage pattern relative to the embryo's polar axis determines how the cells will array. In nearly all protostomes, each new cell buds off at an angle oblique to the polar axis. As a result, a new cell nestles into the space between the older ones in a closely packed array. This pattern is called **spiral cleavage** because a line drawn through a sequence of dividing cells spirals outward from the polar axis (figure 47.2).

   In deuterostomes, the cells divide parallel to and at right angles to the polar axis. As a result, the pairs of cells from each division are positioned directly above

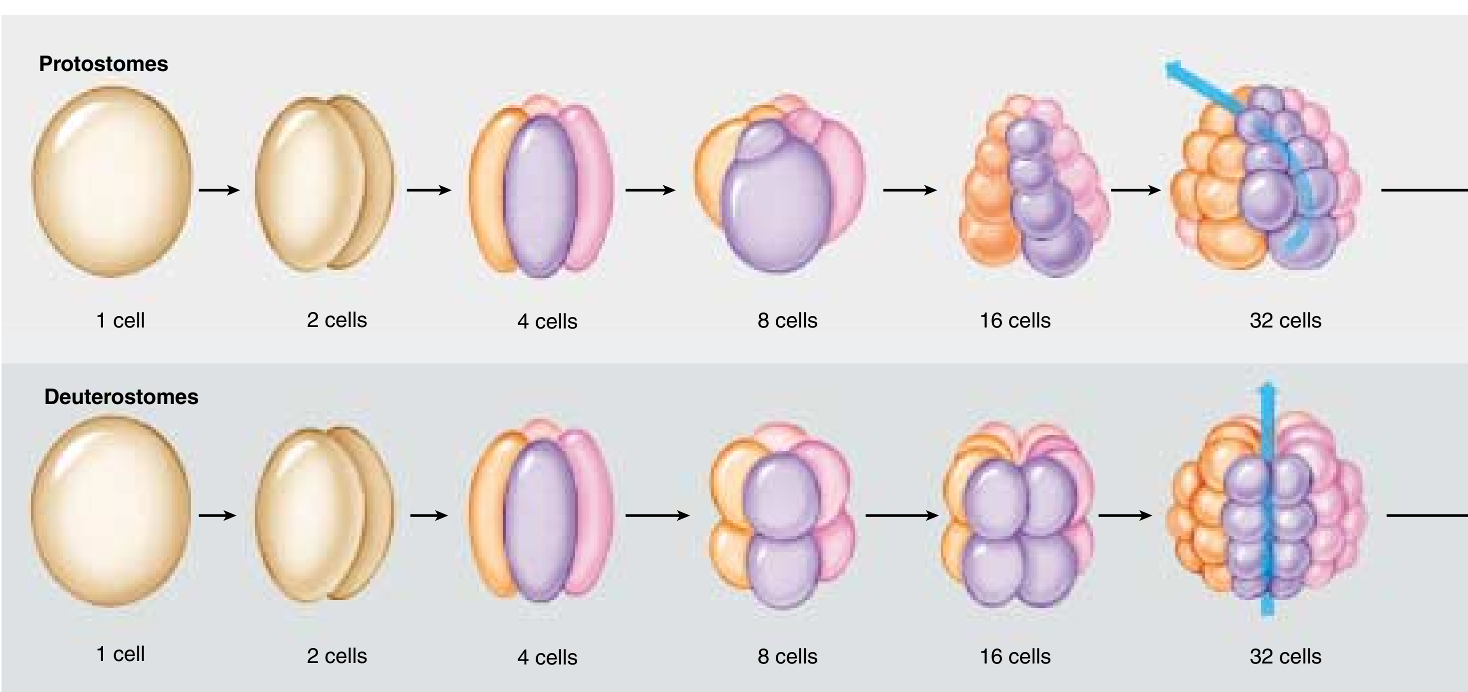


FIGURE 47.2
Embryonic development in protostomes and deuterostomes. Cleavage of the egg produces a hollow ball of cells called the blastula. Invagination of the blastula produces the blastopore and archenteron. In protostomes, embryonic cells cleave in a spiral pattern and become tightly packed. The blastopore becomes the animal's mouth, and the coelom originates from a mesodermal split.

and below one another; this process gives rise to a loosely packed array of cells. This pattern is called **radial cleavage** because a line drawn through a sequence of dividing cells describes a radius outward from the polar axis.

2. Protostomes exhibit **determinate** development. In this type of development, each embryonic cell has a predetermined fate in terms of what kind of tissue it will form in the adult. Before cleavage begins, the chemicals that act as developmental signals are localized in different parts of the egg. Consequently, the cell divisions that occur after fertilization separate different signals into different daughter cells. This process specifies the fate of even the very earliest embryonic cells. Deuterostomes, on the other hand, display **indeterminate** development. The first few cell divisions of the egg produce identical daughter cells. Any one of these cells, if separated from the others, can develop into a complete organism. This is possible because the chemicals that signal the embryonic cells to develop differently are not localized until later in the animal's development.
3. In all coelomates, the coelom originates from mesoderm. In protostomes, this occurs simply and directly: the cells simply move away from one another as the coelomic cavity expands within the mesoderm. However, in deuterostomes, whole groups of cells usually move around to form new tissue associations. The coelom is normally produced by an evagination of the **archenteron**—the central tube within the gastrula, also called the primitive gut. This tube, lined with endoderm, opens to the outside via the blastopore and eventually becomes the gut cavity.

The first abundant and well-preserved animal fossils are nearly 600 million years old; they occur in the Ediacara series of Australia and similar formations elsewhere. Among these fossils, many represent groups of animals that no longer exist. In addition, these ancient rocks bear evidence of the coelomates, the most advanced evolutionary line of animals, and it is remarkable that their two major subdivisions were differentiated so early. In the coelomates, it seems likely that all deuterostomes share a common protostome ancestor—a theory that is supported by evidence from comparison of rRNA and other molecular studies. The event, however, occurred very long ago and presumably did not involve groups of organisms that closely resemble any that are living now.

In deuterostomes, the egg cleaves radially, and the blastopore becomes the anus. In protostomes, the egg cleaves spirally, and the blastopore becomes the mouth.

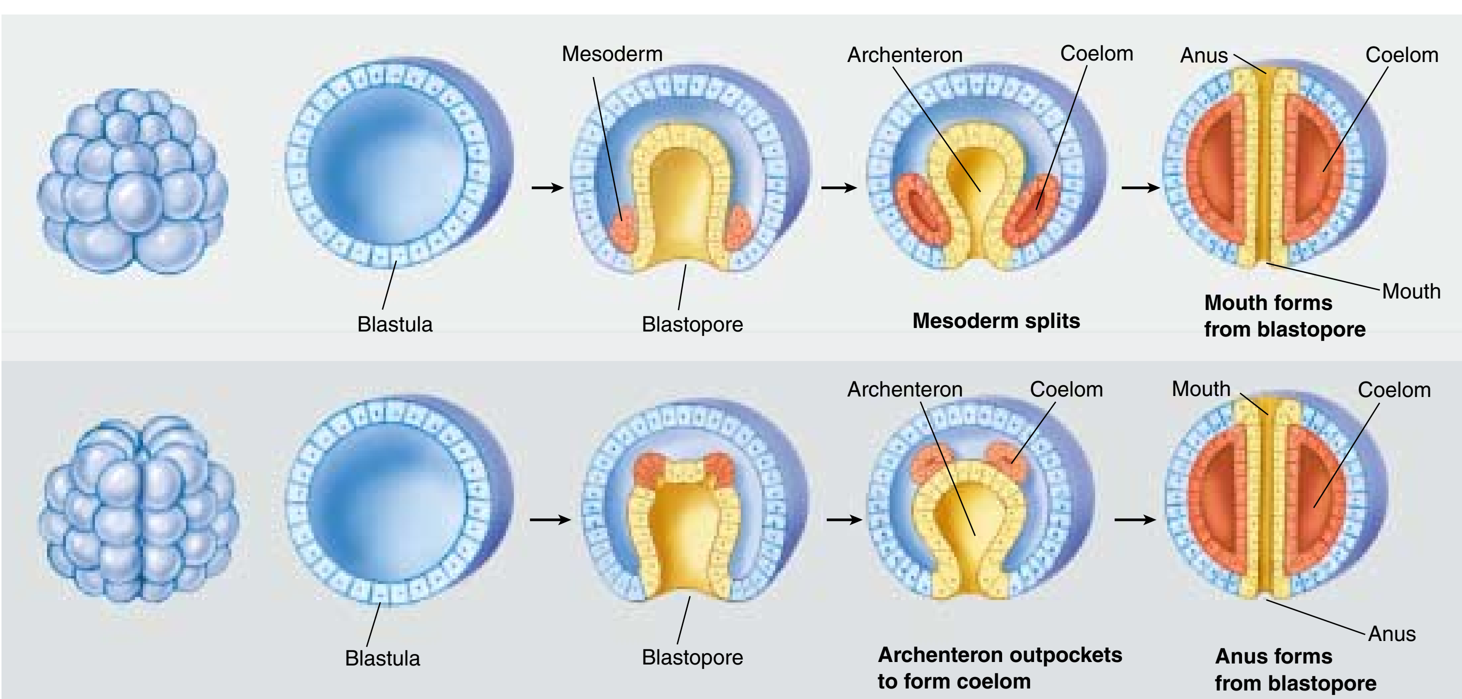
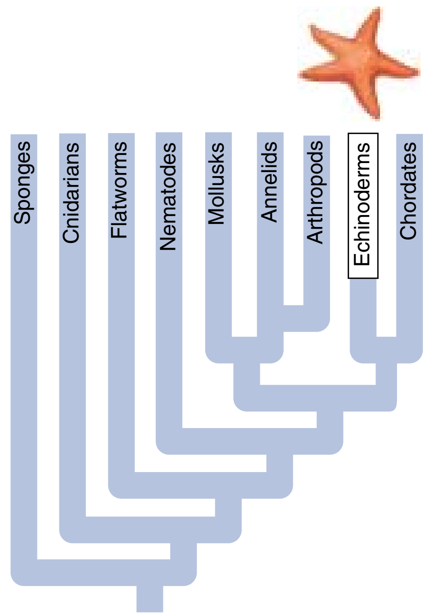


FIGURE 47.2 (continued)
In deuterostomes, embryonic cells cleave radially and form a loosely packed array. The blastopore becomes the animal's anus, and the mouth develops at the other end. The coelom originates from an evagination, or outpouching, of the archenteron in deuterostomes.

47.2 Echinoderms are deuterostomes with an endoskeleton.

Deuterostomes

Mollusks, annelids, and arthropods are protostomes. However, the echinoderms are characterized by *deuterostome development*, a key evolutionary advance. The *endoskeleton* makes its first appearance in the echinoderms also.



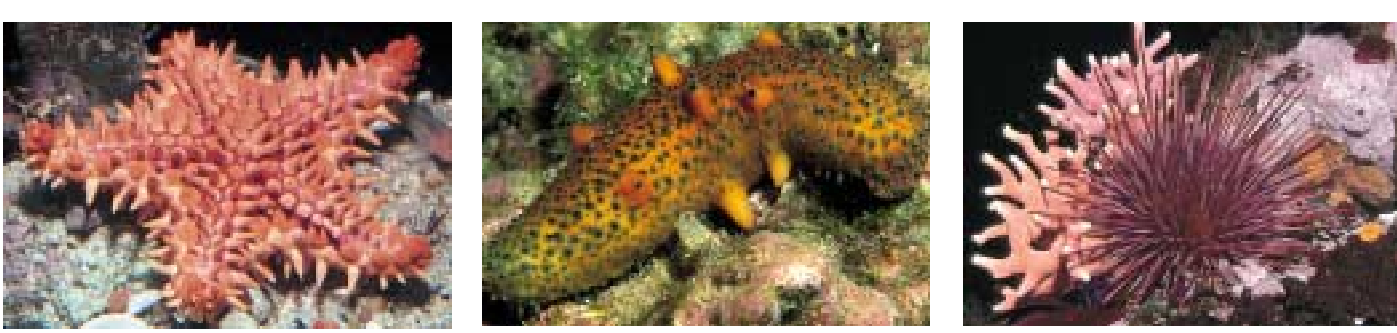
The Echinoderms

Deuterostomate marine animals called **echinoderms** appeared nearly 600 million years ago (figure 47.3). Echinoderms (phylum Echinodermata) are an ancient group of marine animals consisting of about 6000 living species and are also well represented in the fossil record. The term *echinoderm* means "spiny skin" and refers to an **endoskeleton** composed of hard calcium-rich plates just beneath the delicate skin (figure 47.4). When they first form, the plates are enclosed in living tissue and so are truly an endoskeleton, although in adults they frequently fuse, forming a hard shell. Another innovation in echinoderms is the development of a hydraulic system to aid in movement or feeding. Called a **water-vascular system,** this fluid-filled system is composed of a central ring canal from which five radial canals extend out into the body and arms.

Many of the most familiar animals seen along the seashore, sea stars (starfish), brittle stars, sea urchins, sand dollars, and sea cucumbers, are echinoderms. All are radially symmetrical as adults. While some other kinds of animals are radially symmetrical, none have the complex organ systems of adult echinoderms. Echinoderms are well represented not only in the shallow waters of the sea but also in its abyssal depths. In the oceanic trenches, which are the deepest regions of the oceans, sea cucumbers account for more than 90% of the biomass! All of them are bottom-dwellers except for a few swimming sea cucumbers. The adults range from a few millimeters to more than a meter in diameter (for one species of sea star) or in length (for a species of sea cucumber).

There is an excellent fossil record of the echinoderms, extending back into the Cambrian. However, despite this wealth of information, the origin of echinoderms remains unclear. They are thought to have evolved from bilaterally symmetrical ancestors because echinoderm larvae are bilateral. The radial symmetry that is the hallmark of echinoderms develops later, in the adult body. Many biologists believe that early echinoderms were sessile and evolved radiality as an adaptation to the sessile existence. Bilaterality is of adaptive value to an animal that travels through its environment, while radiality is of value to an animal whose environment meets it on all sides. Echinoderms attached to the sea bottom by a central stalk were once common, but only about 80 such species survive today.

Echinoderms are a unique, exclusively marine group of organisms in which deuterostome development and an endoskeleton are seen for the first time.



(a) (b) (c)

FIGURE 47.3
Diversity in echinoderms. (*a*) Sea star, *Oreaster occidentalis* (class Asteroidea), in the Gulf of California, Mexico. (*b*) Warty sea cucumber, *Parastichopus parvimensis* (class Holothuroidea), Philippines. (*c*) Sea urchin (class Echinoidea).

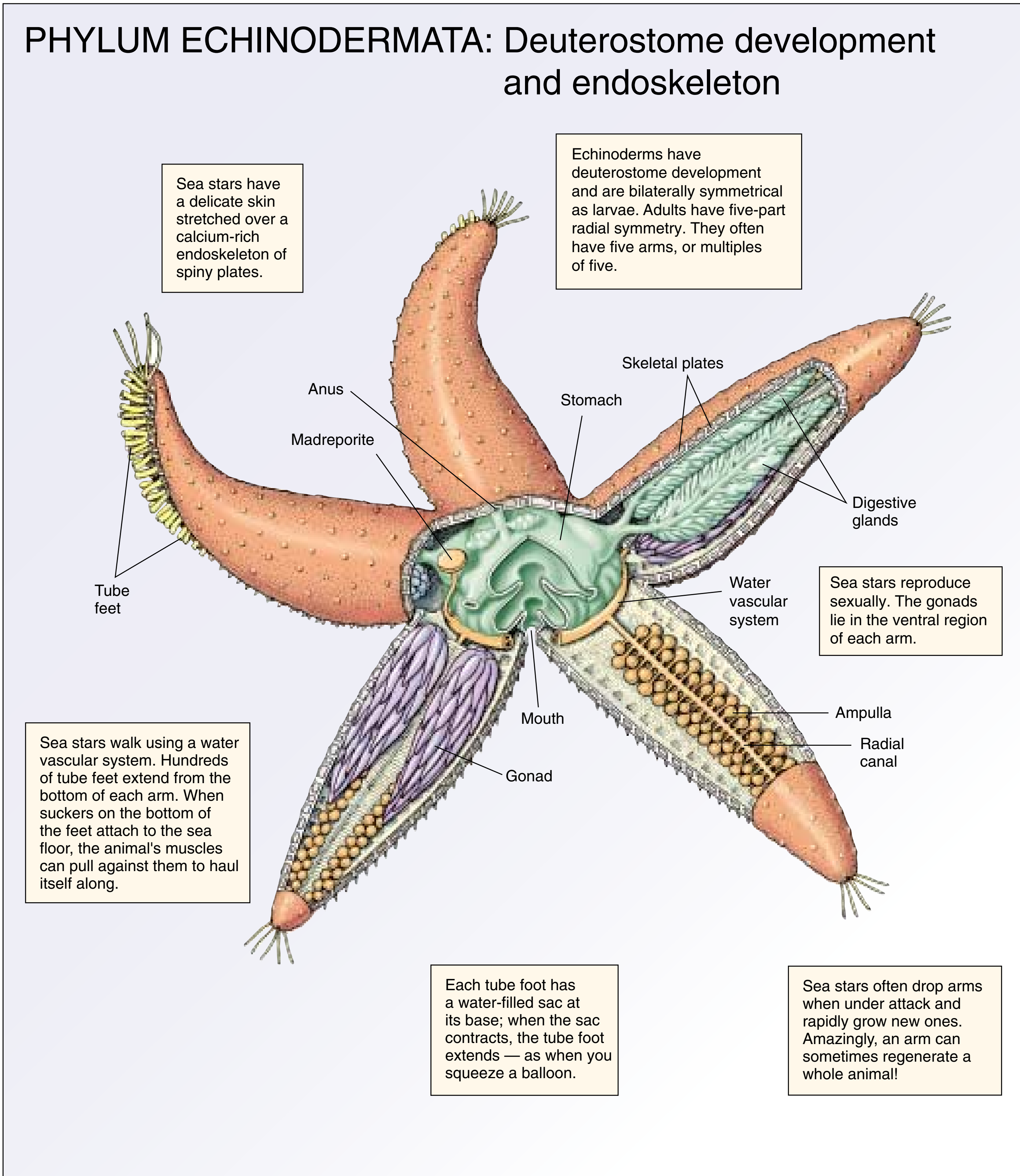


FIGURE 47.4
The evolution of deuterostome development and an endoskeleton. Echinoderms, such as sea stars (phylum Echinodermata), are coelomates with a deuterostome pattern of development. A delicate skin stretches over an endoskeleton made of calcium-rich plates, often fused into a continuous, tough, spiny layer.

Echinoderm Body Plan

The body plan of echinoderms undergoes a fundamental shift during development. All echinoderms have **secondary radial symmetry,** that is, they are bilaterally symmetrical during larval development but become radially symmetrical as adults. Because of their radially symmetrical bodies, the usual terms used to describe an animal's body are not applicable: dorsal, ventral, anterior, and posterior have no meaning without a head or tail. Instead, the body structure of echinoderms is discussed in reference to their mouths which are located on the oral surface. Most echinoderms crawl along on their oral surfaces, although in sea cucumbers and some other echinoderms, the animal's axis lies horizontally and they crawl with the oral surface in front.

Echinoderms have a five-part body plan corresponding to the arms of a sea star or the design on the "shell" of a sand dollar. These animals have no head or brain. Their nervous systems consist of a central **nerve ring** from which branches arise. The animals are capable of complex response patterns, but there is no centralization of function.

Endoskeleton

Echinoderms have a delicate epidermis, containing thousands of neurosensory cells, stretched over an endoskeleton composed of either movable or fixed calcium-rich (calcite) plates called ossicles. The animals grow more or less continuously, but their growth slows down with age. When the plates first form, they are enclosed in living tissue. In some echinoderms, such as asteroids and holothuroids, the ossicles are widely scattered and the body wall is flexible. In others, especially the echinoids, the ossicles become fused and form a rigid shell. In many cases, these plates bear spines. In nearly all species of echinoderms, the entire skeleton, even the long spines of sea urchins, is covered by a layer of skin. Another important feature of this phylum is the presence of mutable collagenous tissue which can range from being tough and rubbery to weak and fluid. This amazing tissue accounts for many of the special attributes of echinoderms, such as the ability to rapidly autotomize body parts. The plates in certain portions of the body of some echinoderms are perforated by pores. Through these pores extend **tube feet,** part of the water-vascular system that is a unique feature of this phylum.

The Water-Vascular System

The water-vascular system of an echinoderm radiates from a **ring canal** that encircles the animal's esophagus. Five **radial canals,** their positions determined early in the development of the embryo, extend into each of the five parts of the body and determine its basic symmetry (figure 47.5). Water enters the water-vascular system through a **madreporite,** a sievelike plate on the animal's surface, and flows to the ring canal through a tube, or stone canal, so named because of

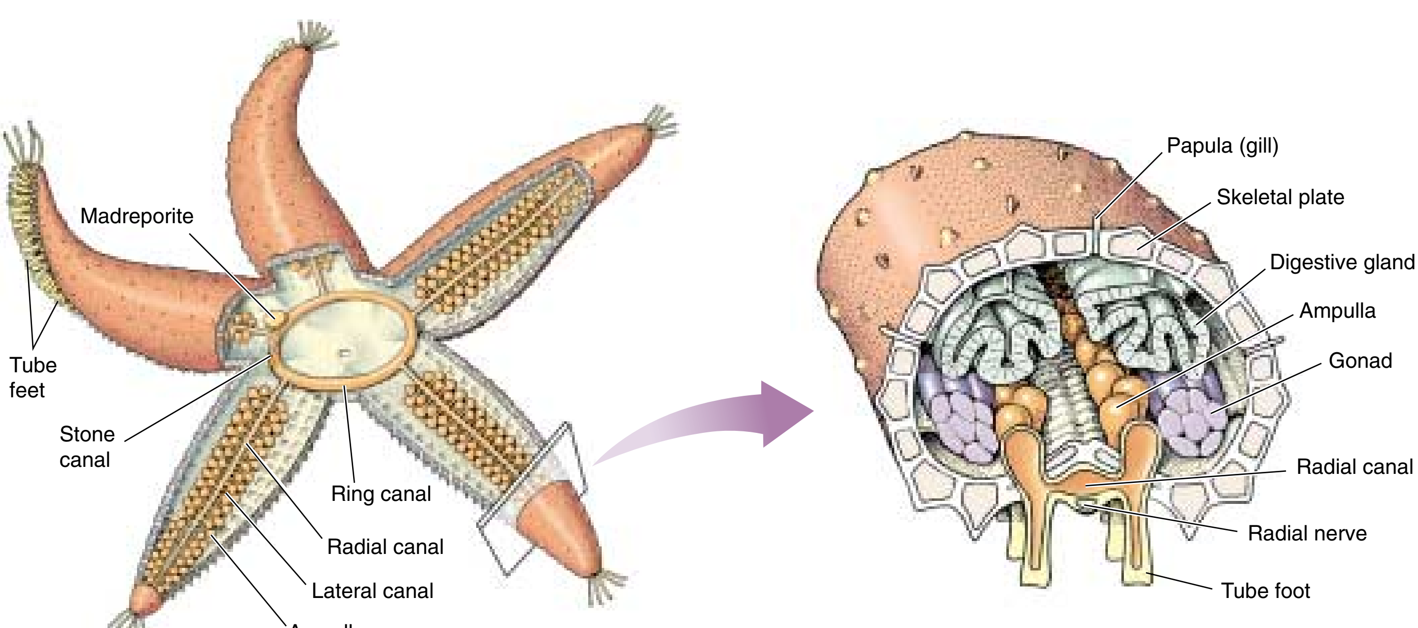


FIGURE 47.5
The water-vascular system of an echinoderm. Radial canals allow water to flow into the tube feet. As the ampulla in each tube foot contracts, the tube extends and can attach to the substrate. Subsequently, muscles in the tube feet contract bending the tube foot and pulling the animal forward.

FIGURE 47.6
Tube feet. The nonsuckered tube feet of the sea star, *Ludia magnifica*, are extended.

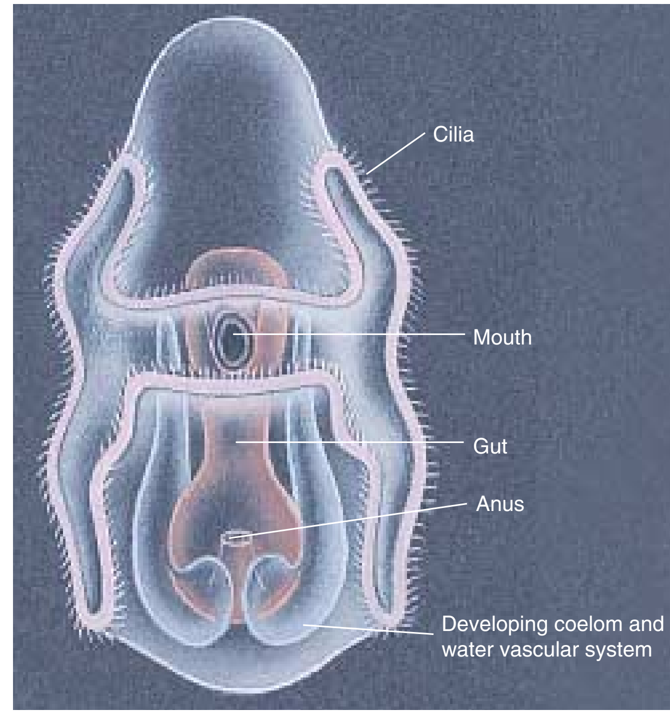


FIGURE 47.7
The free-swimming larva of an echinoderm. The bands of cilia by which the larva moves are prominent in this drawing. Such bilaterally symmetrical larvae suggest that the ancestors of the echinoderms were not radially symmetrical, like the living members of the phylum.

the surrounding rings of calcium carbonate. The five radial canals in turn extend out through short side branches into the hollow tube feet (figure 47.6). In some echinoderms, each tube foot has a sucker at its end; in others, suckers are absent. At the base of each tube foot is a muscular sac, the **ampulla,** which contains fluid. When the ampulla contracts, the fluid is prevented from entering the radial canal by a one-way valve and is forced into the tube foot, thus extending it. When extended, the foot can attach itself to the substrate. Longitudinal muscles in the tube foot wall then contract causing the tube feet to bend. Relaxation of the muscles in the ampulla allows the fluid to flow back into the ampulla which moves the foot. By the concerted action of a very large number of small individually weak tube feet, the animal can move across the sea floor.

Sea cucumbers (see figure 47.3*b*) usually have five rows of tube feet on the body surface that are used in locomotion. They also have modified tube feet around their mouth cavity that are used in feeding. In sea lilies, the tube feet arise from the branches of the arms, which extend from the margins of an upward-directed cup. With these tube feet, the animals take food from the surrounding water. In brittle stars (see figure 47.1), the tube feet are pointed and specialized for feeding.

Body Cavity

In echinoderms, the coelom, which is proportionately large, connects with a complicated system of tubes and helps provide circulation and respiration. In many echinoderms, respiration and waste removal occurs across the skin through small, fingerlike extensions of the coelom called papulae (see figure 47.5). They are covered with a thin layer of skin and protrude through the body wall to function as gills.

Reproduction

Many echinoderms are able to regenerate lost parts, and some, especially sea stars and brittle stars, drop various parts when under attack. In a few echinoderms, asexual reproduction takes place by splitting, and the broken parts of sea stars can sometimes regenerate whole animals. Some of the smaller brittle stars, especially tropical species, regularly reproduce by breaking into two equal parts; each half then regenerates a whole animal.

Despite the ability of many echinoderms to break into parts and regenerate new animals from them, most reproduction in the phylum is sexual and external. The sexes in most echinoderms are separate, although there are few external differences. Fertilized eggs of echinoderms usually develop into free-swimming, bilaterally symmetrical larvae (figure 47.7), which differ from the trochophore larvae of mollusks and annelids. These larvae form a part of the plankton until they metamorphose through a series of stages into the more sedentary adults.

Echinoderms are characterized by a secondary radial symmetry and a five-part body plan. They have characteristic calcium-rich plates called ossicles and a unique water-vascular system that includes hollow tube feet.

47.3 The six classes of echinoderms are all radially symmetrical as adults.

There are more than 20 extinct classes of echinoderms and an additional 6 with living members: (1) Crinoidea, sea lilies and feather stars; (2) Asteroidea, sea stars, or starfish; (3) Ophiuroidea, brittle stars; (4) Echinoidea, sea urchins and sand dollars; (5) Holothuroidea, sea cucumbers, and (6) Concentricycloidea, sea daisies. Sea daisies were recently discovered living on submerged wood in the deep sea.

Class Crinoidea: The Sea Lilies and Feather Stars

Sea lilies and feather stars, or crinoids (class Crinoidea) differ from all other living echinoderms in that the mouth and anus are located on their upper surface in an open disc. The two structures are connected by a simple gut. These animals have simple excretory and reproductive systems and an extensive water-vascular system. The arms, which are the food-gathering structures of crinoids, are located around the margins of the disc. Different species of crinoids may have from 5 to more than 200 arms extending upward from their bodies, with smaller structures called pinnules branching from the arms. In all crinoids, the number of arms is initially small. Species with more than 10 arms add additional arms progressively during growth. Crinoids are filter feeders, capturing the microscopic organisms on which they feed by means of the mucus that coats their tube feet, which are abundant on the animals' pinnules.

Scientists that study echinoderms believe that the common ancestors of this phylum were sessile, sedentary, radially symmetrical animals that resembled crinoids. Crinoids were abundant in ancient seas, and were present when the Burgess Shale was deposited about 515 million years ago. More than 6000 fossil species of this class are known, in comparison with the approximately 600 living species.

FIGURE 47.8
Sea lilies, *Cenocrinus asterius*. Two specimens showing a typical parabola of arms forming a "feeding net." The water current is flowing from right to left, carrying small organisms to the stalked crinoid's arms. Prey, when captured, are passed down the arms to the central mouth. This photograph was taken at a depth of about 400 meters in the Bahamas from the Johnson-Sea-Link Submersible of the Harbor Branch Foundation, Inc.

FIGURE 47.9
Feather star. This feather star is on the Great Barrier Reef in Australia.

Sea Lilies

There are two basic crinoid body plans. In sea lilies, the flower-shaped body is attached to its substrate by a stalk that is from 15 to 30 cm long, although in some species the stalk may be as much as a meter long (figure 47.8). Some fossil species had stalks up to 20 meters long. If they are detached from the substrate, some sea lilies can move slowly by means of their feather-like arms. All of the approximately 80 living species of sea lilies are found below a depth of 100 meters in the ocean. Sea lilies are the only living echinoderms that are fully sessile.

Feather Stars

In the second group of crinoids, the 520 or so species of feather stars, the disc detaches from the stalk at an early stage of development (figure 47.9). Adult feather stars have long, many-branched arms and usually anchor themselves to their substrate by claw-like structures. However, some feather stars are able to swim for short distances, and many of them can move along the substrate. Feather stars range into shallower water than do sea lilies, and only a few species of either group are found at depths greater than 500 meters. Along with sea cucumbers, crinoids are the most abundant and conspicuous large invertebrates in the warm waters and among the coral reefs of the western Pacific Ocean. They have separate sexes, with the sex organs simple masses of cells in special cavities of the arms and pinnules. Fertilization is usually external, with the male and female gametes shed into the water, but brooding—in which the female shelters the young—occurs occasionally.

Crinoids, the sea lilies and feather stars, were once far more numerous. Crinoids are the only echinoderms attached for much of their lives to the sea bottom.

Class Asteroidea: The Sea Stars

Sea stars, or starfish (class Asteroidea; figure 47.10), are perhaps the most familiar echinoderms. Among the most important predators in many marine ecosystems, they range in size from a centimeter to a meter across. They are abundant in the intertidal zone, but they also occur at depths as great as 10,000 meters. Around 1500 species of sea stars occur throughout the world.

The body of a sea star is composed of a central disc that merges gradually with the arms. Although most sea stars have five arms, the basic symmetry of the phylum, members of some families have many more, typically in multiples of five. The body is somewhat flattened, flexible, and covered with a pigmented epidermis.

Endoskeleton

Beneath the epidermis is an endoskeleton of small calcium-rich plates called ossicles, bound together with connective tissue. From these ossicles project spines that make up the spiny upper surface. Around the base of the spines are minute, pincerlike *pedicellariae*, bearing tiny jaws manipulated by muscles. These keep the body surface free of debris and may aid in food capture.

The Water-Vascular System

A deep groove runs along the oral (bottom) surface of each arm from the central mouth out to the tip of the arm. This groove is bordered by rows of tube feet, which the animal uses to move about. Within each arm, there is a radial canal that connects the tube feet to a ring canal in the central body. This system of piping is used by sea stars to power a unique hydraulic system. Contraction of small chambers called ampullae attached to the tube feet forces water into the podium of the feet, extending them. Conversely, contraction of muscles in the tube foot retracts the podium, forcing fluid back into the ampulla. Small muscles at the end of each tube foot can raise the center of the disclike end, creating suction when the foot is pressed against a substrate. Hundreds of tube feet, moving in unison, pull the arm along the surface.

Feeding

The mouth of a sea star is located in the center of its oral surface. Some sea stars have an extraordinary way of feeding on bivalve mollusks. They can open a small gape between the shells of bivalves by exerting a muscular pull on the shells (figure 47.11). Eventually, muscular fatigue in the bivalve results in a very narrow gape, sufficient enough for the sea star to insert its stomach out through its mouth into the bivalve. Within the mollusk, the sea star secretes its digestive enzymes and digests the soft tissues of its prey, retracting its stomach when the process is complete.

FIGURE 47.10
Class Asteroidea. This class includes the familiar starfish, or sea stars.

FIGURE 47.11
A sea star attacking a clam. The tube feet, each of which ends in a suction cup, are located along grooves on the underside of the arms.

Reproduction

Most sea stars have separate sexes, with a pair of gonads lying in the ventral region inside each arm. Eggs and sperm are shed into the water so that fertilization is external. In some species, fertilized eggs are brooded in special cavities or simply under the animal. They mature into larvae that swim by means of conspicuous bands of cilia.

Sea stars, also called starfish, are five-armed, mobile predators.

Class Ophiuroidea: The Brittle Stars

Brittle stars (class Ophiuroidea; figure 47.12) are the largest class of echinoderms in numbers of species (about 2000) and they are probably the most abundant also. Secretive, they avoid light and are more active at night.

Brittle stars have slender, branched arms. The most mobile of echinoderms, brittle stars move by pulling themselves along, "rowing" over the substrate by moving their arms, often in pairs or groups, from side to side. Some brittle stars use their arms to swim, a very unusual habit among echinoderms.

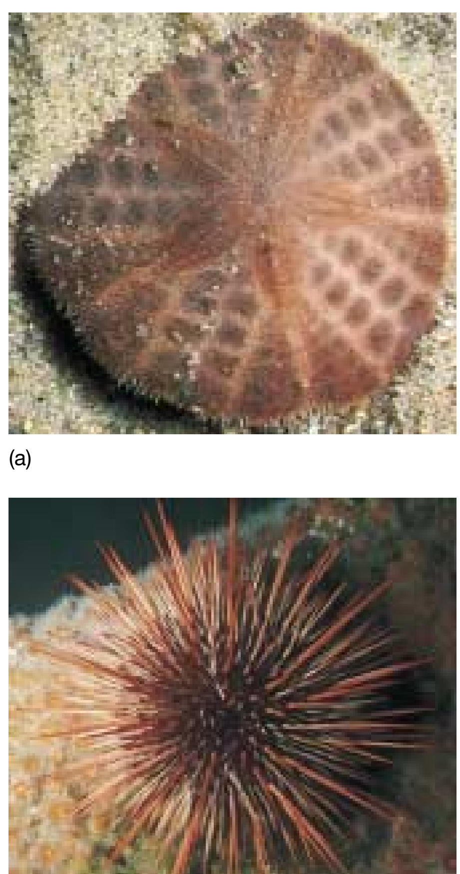
Brittle stars feed by capturing suspended microplankton and organic detritus with their tube feet, climbing over objects on the ocean floor. In addition, the tube feet are important sensory organs and assist in directing food into the mouth once the animal has captured it. As implied by their common name, the arms of brittle stars detach easily, a characteristic that helps to protect the brittle stars from their predators.

Like sea stars, brittle stars have five arms. More closely related to the sea stars than to the other classes of the phylum, on closer inspection they are surprisingly different. They have no pedicellariae, as sea stars have, and the groove running down the length of each arm is closed over and covered with ossicles. Their tube feet lack ampullae, have no suckers, and are used for feeding, not locomotion.

Brittle stars usually have separate sexes, with the male and female gametes in most species being released into the water and fusing there. Development takes place in the plankton and the larvae swim and feed using elaborate bands of cilia. Some species brood their young in special cavities and fully developed juvenile brittle stars emerge at the end of development.

Brittle stars, very secretive, pull themselves along with their arms.

FIGURE 47.12
Class Ophiuroidea. Brittle stars crawl actively across their marine substrates.



(a)

(b)

FIGURE 47.13
Class Echinoidea. (*a*) Sand dollar, *Echinarachnius parma*. (*b*) Giant red sea urchin, *Strongylocentrotus franciscanus*.

Class Echinoidea: The Sea Urchins and Sand Dollars

The members of the class Echinoidea, sand dollars and sea urchins, lack distinct arms but have the same five-part body plan as all other echinoderms (figure 47.13). Five rows of tube feet protrude through the plates of the calcareous skeleton, and there are also openings for the mouth and anus. These different openings can be seen in the globular skeletons of sea urchins and in the flat skeletons of sand dollars. Both types of endoskeleton, often common along the seashore, consist of fused calcareous plates. About 950 living species constitute the class Echinoidea.

Echinoids walk by means of their tube feet or their movable spines, which are hinged to the skeleton by a joint that makes free rotation possible. Sea urchins and sand dollars move along the sea bottom, feeding on algae and small fragments of organic material. They scrape these off the substrate with the large, triangular teeth that ring their mouths. The gonads of sea urchins are considered a great delicacy by people in different parts of the world. Because of their calcareous plates, sea urchins and sand dollars are well preserved in the fossil record, with more than 5000 additional species described.

As with most other echinoderms, the sexes of sea urchins and sand dollars are separate. The eggs and sperm are shed separately into the water, where they fuse. Some brood their young, and others have free-swimming larvae, with bands of cilia extending onto their long, graceful arms.

Sand dollars and sea urchins lack arms but have a five-part symmetry.

Classes Holothuroidea and Concentricycloidea: Sea Cucumbers and Sea Daisies

Sea Cucumbers

Sea cucumbers (class Holothuroidea) are shaped somewhat like their plant namesakes. They differ from the preceding classes in that they are soft, sluglike organisms, often with a tough, leathery outside skin (figure 47.14). The class consists of about 1500 species found worldwide. Except for a few forms that swim, sea cucumbers lie on their sides at the bottom of the ocean. Their mouth is located at one end and is surrounded by eight to 30 modified tube feet called tentacles; the anus is at the other end. The tentacles around the mouth may secrete mucus, used to capture the small planktonic organisms on which the animals feed. Each tentacle is periodically wiped off within the esophagus and then brought out again, covered with a new supply of mucus.

Sea cucumbers are soft because their calcareous skeletons are reduced to widely separated microscopic plates. These animals have extensive internal branching systems, called respiratory trees, which arise from the **cloaca,** or anal cavity. Water is pulled into and expelled from the respiratory tree by contractions of the cloaca; gas exchange takes place as this process occurs. The sexes of most cucumbers are separate, but some of them are hermaphroditic.

Most kinds of sea cucumbers have tube feet on the body in addition to tentacles. These additional tube feet, which might be restricted to five radial grooves or scattered over the surface of the body, may enable the animals to move about slowly. On the other hand, sea cucumbers may simply wriggle along whether or not they have additional tube feet. Most sea cucumbers are quite sluggish, but some, especially among the deep-sea forms, swim actively. Sea cucumbers, when irritated, sometimes eject a portion of their intestines by a strong muscular contraction that may send the intestinal fragments through the anus or even rupture the body wall.

Sea Daisies

The most recently described class of echinoderms (1986), sea daisies are strange little disc-shaped animals, less than 1 cm in diameter, discovered in waters over 1000 m deep off New Zealand (figure 47.15). Only two species are known so far. They have five-part radial symmetry, but no arms. Their tube feet are located around the periphery of the disc, rather than along radial lines, as in other echinoderms. One species has a shallow, saclike stomach but no intestine or anus; the other species has no digestive tract at all—the surface of its mouth is covered by a membrane through which it apparently absorbs nutrients.

FIGURE 47.14
Class Holothuroidea. Sea cucumber.

FIGURE 47.15
Class Concentricycloidea. Sea daisy.

Sea cucumbers are soft-bodied, sluglike animals without arms. The newly discovered sea daisies are the most mysterious echinoderms. Tiny and simple in form, they live at great depths, absorbing food from their surroundings.

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Chapter 47

Summary | Questions | Media Resources

47.1 The embryos of deuterostomes develop quite differently from those of protostomes.

- The two major evolutionary lines of coelomate animals—the protostomes and the deuterostomes—are both represented among the oldest known fossils of multicellular animals, dating back some 650 million years.
- In the protostomes, the mouth develops from or near the blastopore, and the early divisions of the embryo are spiral. At early stages of development, the fate of the individual cells is already determined, and they cannot develop individually into a whole animal.
- In the deuterostomes, the anus develops from or near the blastopore, and the mouth forms subsequently on another part of the gastrula. The early divisions of the embryo are radial. At early stages of development, each cell of the embryo can differentiate into a whole animal.

1. What patterns of embryonic development related to cleavage and the blastopore occur in protostome coelomates? What patterns occur in deuterostome coelomates?

2. Which major coelomate phyla are protostomes and which are deuterostomes? How does the early developmental fate of cells differ between the two groups? How is the development of the coelom from mesodermal tissue different between them?

47.2 Echinoderms are deuterostomes with an endoskeleton.

- Echinoderms are exclusively marine deuterostomes that are radially symmetrical as adults.
- The epidermis of an echinoderm stretches over an endoskeleton made of separate or fused calcium-rich plates.
- Echinoderms use a unique water-vascular system that includes tube feet for locomotion and feeding.

3. What type of symmetry and body plan do adult echinoderms exhibit?

4. What is the composition and location of the echinoderm skeleton?

5. How do echinoderms respire? How developed is their digestive system?

- Echinoderms

47.3 The six classes of echinoderms are all radially symmetrical as adults.

- Crinoids are sessile for some or all of their lives and have a mouth and anus located on the upper surface of the animal.
- Sea stars are active predators that move about on their tube feet.
- Brittle stars use their tube feet for feeding and move about using two arms at a time.
- The endoskeletons of sea urchins and sand dollars consist of fused calcareous plates that have been well preserved in the fossil record.
- The endoskeletons of sea cucumbers are drastically reduced and separated, making them soft-bodied.
- Sea daisies are a newly described class of echinoderms with disc-shaped bodies.

6. In what two ways do members of the phylum Echinodermata reproduce? What type of larva do they possess?

7. How do sea cucumbers superficially differ from other echinoderms? How are some of their tube feet specially modified? What is the extent of their skeleton? What is the function of their unique respiratory tree? How is their reproduction different from that of other echinoderms?