reaching a size that would have allowed them the capacity for gliding or actual flapping flight. Even modern insects with broadly attached wings, such as butterflies, use the basal one-third of their wings (the area next to the thorax) for thermoregulation, and the outer two-thirds for flight, camouflage, and mate selection.

Many of the common insects we encounter on a daily basis—including ants, beetles, cockroaches, butterflies, crickets and flies—are examples of Hexapoda. Among these, adult ants, beetles, flies, and butterflies develop by complete metamorphosis from grub-like or caterpillar-like larvae, whereas adult cockroaches and crickets develop through a gradual or incomplete metamorphosis from wingless immatures. All growth occurs during the juvenile stages. Adults do not grow further (but may become larger) after their final molt. Variations in wing, leg, and mouthpart morphology all contribute to the enormous variety seen in the insects. Insect variability was also encouraged by their activity as pollinators and their coevolution with flowering plants. Some insects, especially termites, ants, bees, and wasps, are eusocial, meaning that they live in large groups with individuals assigned to specific roles or castes, like queen, drone, and worker. Social insects use **pheromones**—external chemical signals—to communicate and maintain group structure as well as a cohesive colony.

VISUAL CONNECTION

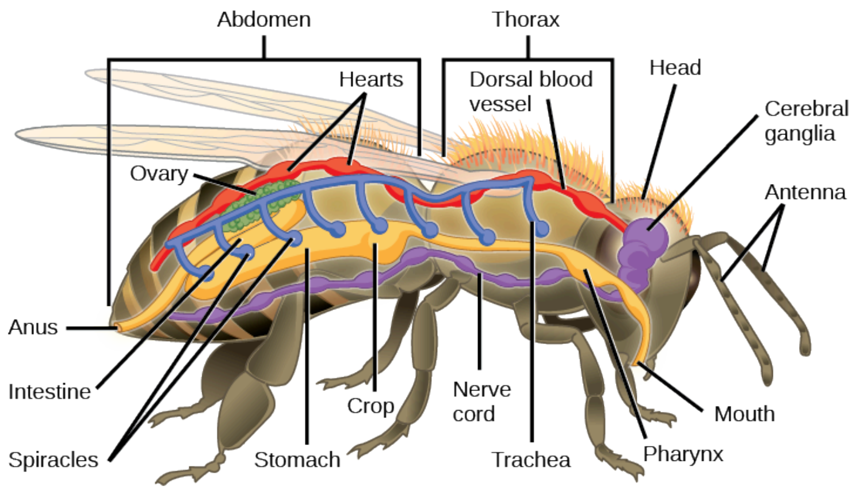


Figure 28.45 Insect anatomy. In this basic anatomy of a hexapod insect, note that insects have a well-developed digestive system (yellow), a respiratory system (blue), a circulatory system (red), and a nervous system (purple). Note the multiple "hearts" and the segmental ganglia.

Which of the following statements about insects is false?

a. Insects have both dorsal and ventral blood vessels.
b. Insects have spiracles, openings that allow air to enter into the tracheal system.
c. The trachea is part of the digestive system.
d. Most insects have a well-developed digestive system with a mouth, crop, and intestine.

28.7 Superphylum Deuterostomia

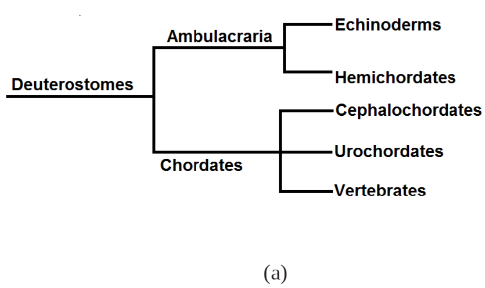
By the end of this section, you will be able to do the following:

- Describe the distinguishing characteristics of echinoderms
- Describe the distinguishing characteristics of chordates

The phyla Echinodermata and Chordata (the phylum that includes humans) both belong to the superphylum Deuterostomia. Recall that protostomes and deuterostomes differ in certain aspects of their embryonic development, and they are named based on which opening of the **archenteron** (primitive gut tube) develops first. The word deuterostome comes from the Greek word meaning “mouth second,” indicating that the mouth develops as a secondary structure opposite the location of the blastopore, which becomes the anus. In protostomes (“mouth first”), the first embryonic opening becomes the mouth, and the second opening becomes the anus.

There are a series of other developmental characteristics that differ between protostomes and deuterostomes, including the type of early cleavage (embryonic cell division) and the mode of formation of the coelom of the embryo: Protosomes typically exhibit spiral mosaic cleavage whereas deuterostomes exhibit radial regulative cleavage. In deuterostomes, the endodermal lining of the archenteron usually forms buds called **coelomic pouches** that expand and ultimately obliterate the embryonic blastocoel (the cavity within the blastula and early gastrula) to become the **embryonic mesoderm**, the third germ layer. This happens when the mesodermal pouches become separated from the invaginating endodermal layer forming the archenteron, then expand and fuse to form the coelomic cavity. The resulting coelom is termed an **enterocoelom**. The archenteron develops into the alimentary canal, and a mouth opening is formed by invagination of ectoderm at the pole opposite the blastopore of the gastrula. The blastopore forms the anus of the alimentary system in the juvenile and adult forms. Cleavage in most deuterostomes is also *indeterminant*, meaning that the developmental fates of early embryonic cells are not decided at that point of embryonic development (this is why we could potentially clone most deuterostomes, including ourselves).

The deuterostomes consist of two major clades—the Chordata and the Ambulacraria. The Chordata include the vertebrates and two invertebrate subphyla, the urochordates and the cephalochordates. The Ambulacraria include the echinoderms and the hemichordates, which were once considered to be a chordate subphylum (Figure 28.46). The two clades, in addition to being deuterostomes, have some other interesting features in common. As we have seen, the vast majority of invertebrate animals do *not* possess a defined bony vertebral endoskeleton, or a bony cranium. However, one of the most ancestral groups of deuterostome invertebrates, the Echinodermata, do produce tiny skeletal "bones" called *ossicles* that make up a true **endoskeleton**, or internal skeleton, covered by an epidermis. The Hemichordata (acorn worms and pterobranchs) will not be covered here, but share with the echinoderms a three-part (tripartite) coelom, similar larval forms, and a derived metanephridium that rids the animals of nitrogenous wastes. They also share pharyngeal slits with the chordates (Figure 28.46). In addition, hemichordates have a dorsal nerve cord in the midline of the epidermis, but lack a neural tube, a true notochord and the endostyle and post-anal tail characteristic of chordates.



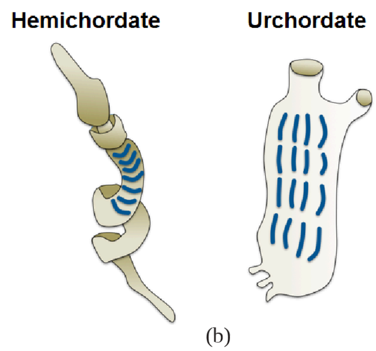


Figure 28.46 Ambulacraria and Chordata. (a) The major deuterostome taxa. (b) pharyngeal slits in hemichordates and urochordates. (credit a MAC; credit b modification of Gill Slits By Own work by Zebra.element [Public domain], via Wikimedia Commons)

Phylum Echinodermata

Echinodermata are named after their "prickly skin" (from the Greek "echinos" meaning "prickly" and "dermos" meaning "skin"). This phylum is a collection of about 7,000 described living species of exclusively marine, bottom-dwelling organisms. Sea stars (Figure 28.47), sea cucumbers, sea urchins, sand dollars, and brittle stars are all examples of echinoderms.

Morphology and Anatomy

Despite the adaptive value of bilaterality for most free-living cephalized animals, adult echinoderms exhibit pentaradial symmetry (with "arms" typically arrayed in multiples of five around a central axis). Echinoderms have an endoskeleton made of calcareous ossicles (small bony plates), covered by the epidermis. For this reason, it is an endoskeleton like our own, not an exoskeleton like that of arthropods. The ossicles may be fused together, embedded separately in the connective tissue of the dermis, or be reduced to minute spicules of bone as in sea cucumbers. The spines for which the echinoderms are named are connected to some of the plates. The spines may be moved by small muscles, but they can also be locked into place for defense. In some species, the spines are surrounded by tiny stalked claws called **pedicellaria**, which help keep the animal's surface clean of debris, protect *papulae* used in respiration, and sometimes aid in food capture.

The endoskeleton is produced by dermal cells, which also produce several kinds of pigments, imparting vivid colors to these animals. In sea stars, fingerlike projections (papillae) of dermal tissue extend through the endoskeleton and function as gills.

Some cells are glandular, and may produce toxins. Each arm or section of the animal contains several different structures: for example, digestive glands, gonads, and the tube feet that are unique to the echinoderms. In echinoderms like sea stars, every arm bears two rows of *tube feet* on the oral side, running along an external ambulacral groove. These tube feet assist in locomotion, feeding, and chemical sensations, as well as serve to attach some species to the substratum.

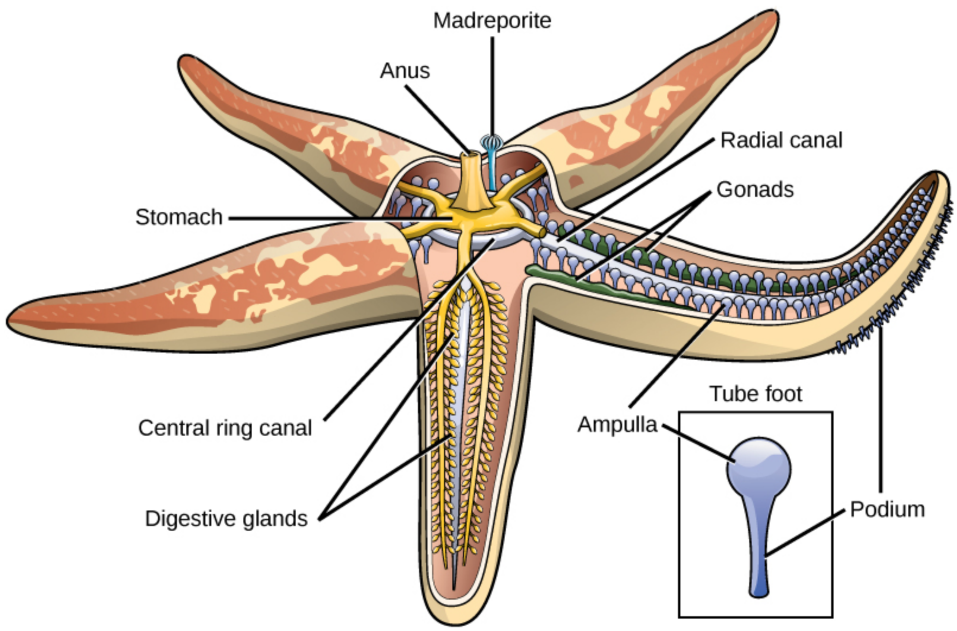


Figure 28.47 Anatomy of a sea star. This diagram of a sea star shows the pentaradial pattern typical of adult echinoderms, and the water vascular system that is their defining characteristic.

Water Vascular and Hemal Systems

Echinoderms have a unique **ambulacral (water vascular) system**, derived from part of the **coelom**, or "body cavity." The water vascular system consists of a central ring canal and radial canals that extend along each arm. Each radial canal is connected to a double row of **tube feet**, which project through holes in the endoskeleton, and function as tactile and ambulatory structures. These tube feet can extend or retract based on the volume of water present in the system of that arm, allowing the animal to move and also allowing it to capture prey with their suckerlike action. Individual tube feet are controlled by bulblike **ampullae**. Seawater enters the system through an **aboral madreporite** (opposite the oral area where the mouth is located) and passes to the ring canal through a short **stone canal**. Water circulating through these structures facilitates gaseous exchange and provides a hydrostatic source for locomotion and prey manipulation. A **hemal system**, consisting of oral, gastric, and aboral rings, as well as other vessels running roughly parallel to the water vascular system, circulates nutrients. Transport of nutrients and gases is shared by the water vascular and hemal systems in addition to the visceral body cavity that surrounds the major organs.

Nervous System

The nervous system in these animals is a relatively simple, comprising a circumoral nerve ring at the center and five radial nerves extending outward along the arms. In addition, several networks of nerves are located in different parts of the body. However, structures analogous to a brain or large ganglia are not present in these animals. Depending on the group, echinoderms may have well-developed sensory organs for touch and chemoreception (e.g., within the tube feet and on tentacles at the tips of the arms), as well as photoreceptors and statocysts.

Digestive and Excretory Systems

A mouth, located on the oral (ventral) side, opens through a short esophagus to a large, baglike stomach. The so-called "cardiac" stomach can be everted through the mouth during feeding (for example, when a starfish everts its stomach into a bivalve prey item to digest the animal—*alive*—within its own shell!) There are masses of digestive glands (**pyloric caeca**) in each arm, running dorsally along the arms and overlying the reproductive glands below them. After passing through the pyloric caeca in each arm, the digested food is channeled to a small anus, if one exists.

Podocytes—cells specialized for ultrafiltration of bodily fluids—are present near the center of the echinoderm disc, at the junction of the water vascular and hemal systems. These podocytes are connected by an internal system of canals to the

madreporite, where water enters the stone canal. The adult echinoderm typically has a spacious and fluid-filled coelom. Cilia aid in circulating the fluid within the body cavity, and lead to the fluid-filled **papulae**, where the exchange of oxygen and carbon dioxide takes place, as well as the secretion of nitrogenous waste such as ammonia, by diffusion.

Reproduction

Echinoderms are dioecious, but males and females are indistinguishable apart from their gametes. Males and females release their gametes into water at the same time and fertilization is external. The early larval stages of all echinoderms (e.g., the *bipinnaria* of asteroid echinoderms such as sea stars) have bilateral symmetry, although each class of echinoderms has its own larval form. The radially symmetrical adult forms from a cluster of cells in the larva. Sea stars, brittle stars, and sea cucumbers may also reproduce asexually by **fragmentation**, as well as regenerate body parts lost in trauma, even when over 75 percent of their body mass is lost!

Classes of Echinoderms

This phylum is divided into five extant classes: Asteroidea (sea stars), Ophiuroidea (brittle stars), Echinoidea (sea urchins and sand dollars), Crinoidea (sea lilies or feather stars), and Holothuroidea (sea cucumbers) (Figure 28.48).

The most well-known echinoderms are members of class Asteroidea, or sea stars. They come in a large variety of shapes, colors, and sizes, with more than 1,800 species known so far. The key characteristic of sea stars that distinguishes them from other echinoderm classes includes thick arms that extend from a central disk from which various body organs branch into the arms. At the end of each arm are simple eye spots and tentacles that serve as touch receptors. Sea stars use their rows of tube feet not only for gripping surfaces but also for grasping prey. Most sea stars are carnivores and their major prey are in the phylum Mollusca. By manipulating its tube feet, a sea star can open molluscan shells. Sea stars have two stomachs, one of which can protrude through their mouths and secrete digestive juices into or onto prey, even before ingestion. A sea star eating a clam can partially open the shell, and then evert its stomach into the shell, introducing digestive enzymes into the interior of the mollusk. This process can both weaken the strong adductor (closing) muscles of a bivalve and begin the process of digestion.

LINK TO LEARNING

Explore the sea star's body plan (http://openstax.org/l/sea_star) up close, watch one move across the sea floor, and see it devour a mussel.

Brittle stars belong to the class Ophiuroidea ("snake-tails"). Unlike sea stars, which have plump arms, brittle stars have long, thin, flexible arms that are sharply demarcated from the central disk. Brittle stars move by lashing out their arms or wrapping them around objects and pulling themselves forward. Their arms are also used for grasping prey. The water vascular system in ophiuroids is not used for locomotion.

Sea urchins and sand dollars are examples of Echinoidea ("prickly"). These echinoderms do not have arms, but are hemispherical or flattened with five rows of tube feet that extend through five rows of pores in a continuous internal shell called a *test.* Their tube feet are used to keep the body surface clean. Skeletal plates around the mouth are organized into a complex multipart feeding structure called *"Aristotle's lantern.*" Most echinoids graze on algae, but some are suspension feeders, and others may feed on small animals or organic *detritus*—the fragmentary remains of plants or animals.

Sea lilies and feather stars are examples of Crinoidea. Sea lilies are *sessile*, with the body attached to a stalk, but the feather stars can actively move about using leglike *cirri* that emerge from the aboral surface. Both types of crinoid are suspension feeders, collecting small food organisms along the ambulacral grooves of their feather-like arms. The "feathers" consisted of branched arms lined with tube feet. The tube feet are used to move captured food toward the mouth. There are only about 600 extant species of crinoids, but they were far more numerous and abundant in ancient oceans. Many crinoids are deep-water species, but feather stars typically inhabit shallow areas, especially in substropical and tropical waters.

Sea cucumbers of class Holothuroidea exhibit an extended oral-aboral axis. These are the only echinoderms that demonstrate “functional” bilateral symmetry as adults, because the extended oral-aboral axis compels the animal to lie horizontally rather than stand vertically. The tube feet are reduced or absent, except on the side on which the animal lies. They have a single gonad and the digestive tract is more typical of a bilaterally symmetrical animal. A pair of gill-like structures called **respiratory trees** branch from the posterior gut; muscles around the cloaca pump water in and out of these trees. There are clusters of tentacles around the mouth. Some sea cucumbers feed on detritus, while others are suspension feeders, sifting out small organisms with their oral tentacles. Some species of sea cucumbers are unique among the echinoderms in that cells containing *hemoglobin* circulate in the coelomic fluid, the water vascular system and/or the hemal system.

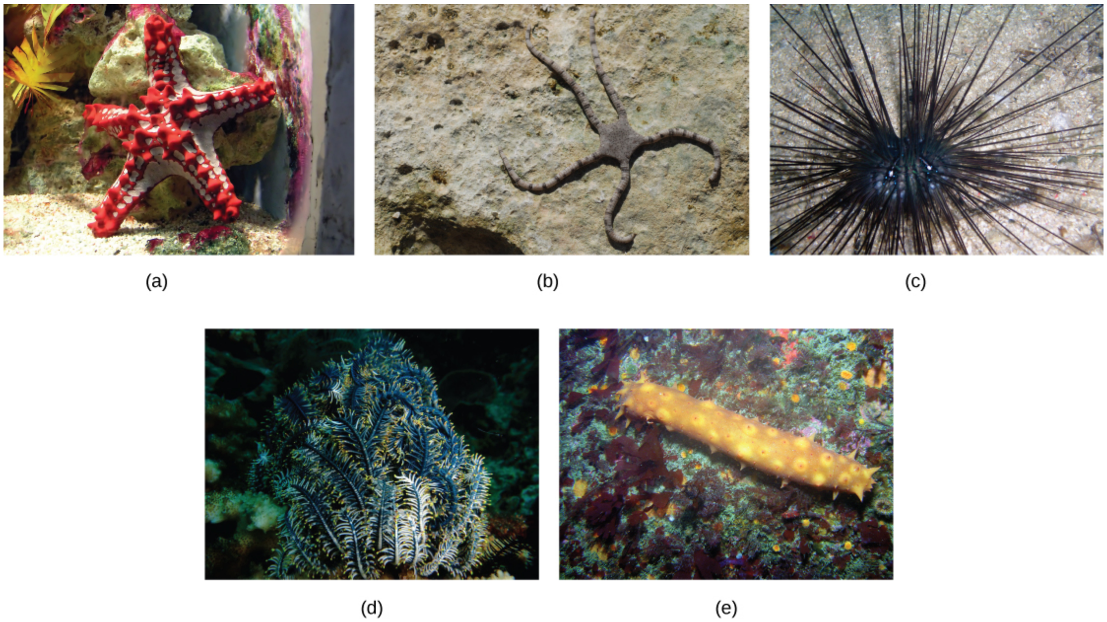


Figure 28.48 Classes of echinoderms. Different members of Echinodermata include the (a) sea star of class Asteroidea, (b) the brittle star of class Ophiuroidea, (c) the sea urchins of class Echinoidea, (d) the sea lilies belonging to class Crinoidea, and (e) sea cucumbers, representing class Holothuroidea. (credit a: modification of work by Adrian Pingstone; credit b: modification of work by Joshua Ganderson; credit c: modification of work by Samuel Chow; credit d: modification of work by Sarah Depper; credit e: modification of work by Ed Bierman)

Phylum Chordata

Animals in the phylum Chordata share five key features that appear at some stage of their development: a notochord, a dorsal hollow nerve cord, pharyngeal slits, a post-anal tail, and an endostyle/thyroid gland that secretes iodinated hormones. In some groups, some of these traits are present only during embryonic development. In addition to containing vertebrate classes, the phylum Chordata contains two clades of "invertebrates": Urochordata (tunicates, salps, and larvaceans) and Cephalochordata (lancelets). Most tunicates live on the ocean floor and are suspension feeders. Lancelets are suspension feeders that feed on phytoplankton and other microorganisms. The invertebrate chordates will be discussed more extensively in the following chapter.

KEY TERMS

amoebocyte sponge cell with multiple functions, including nutrient delivery, egg formation, sperm delivery, and cell differentiation

Annelida phylum of vermiform animals with metamerism

archenteron primitive gut cavity within the gastrula that opens outward via the blastopore

Arthropoda phylum of animals with jointed appendages

biramous referring to two branches per appendage

captacula tentacle-like projection that is present in tusks shells to catch prey

cephalothorax fused head and thorax in some species

chelicera modified first pair of appendages in subphylum Chelicerata

choanocyte (also, collar cell) sponge cell that functions to generate a water current and to trap and ingest food particles via phagocytosis

Chordata phylum of animals distinguished by their possession of a notochord, a dorsal, hollow nerve cord, an endostyle, pharyngeal slits, and a post-anal tail at some point in their development

clitellum specialized band of fused segments, which aids in reproduction

Cnidaria phylum of animals that are diploblastic and have radial symmetry

cnidocyte specialized stinging cell found in Cnidaria

conispiral shell shape coiled around a horizontal axis

corona wheel-like structure on the anterior portion of the rotifer that contains cilia and moves food and water toward the mouth

ctenidium specialized gill structure in mollusks

cuticle (animal) the tough, external layer possessed by members of the invertebrate class Ecdysozoa that is periodically molted and replaced

cypris larval stage in the early development of crustaceans

Echinodermata phylum of deuterostomes with spiny skin; exclusively marine organisms

enterocoelom coelom formed by fusion of coelomic pouches budded from the endodermal lining of the archenteron

epidermis outer layer (from ectoderm) that lines the outside of the animal

extracellular digestion food is taken into the gastrovascular cavity, enzymes are secreted into the cavity, and the cells lining the cavity absorb nutrients

gastrodermis inner layer (from endoderm) that lines the digestive cavity

gastrovascular cavity opening that serves as both a mouth and an anus, which is termed an incomplete digestive system

gemmule structure produced by asexual reproduction in freshwater sponges where the morphology is inverted

hemocoel internal body cavity seen in arthropods

hermaphrodite referring to an animal where both male and female gonads are present in the same individual

invertebrata (also, invertebrates) category of animals that do not possess a cranium or vertebral column

madreporite pore for regulating entry and exit of water into the water vascular system

mantle (also, pallium) specialized epidermis that encloses all visceral organs and secretes shells

mastax jawed pharynx unique to the rotifers

medusa free-floating cnidarian body plan with mouth on underside and tentacles hanging down from a bell

mesoglea non-living, gel-like matrix present between ectoderm and endoderm in cnidarians

mesohyl collagen-like gel containing suspended cells that perform various functions in the sponge

metamerism series of body structures that are similar internally and externally, such as segments

Mollusca phylum of protostomes with soft bodies and no segmentation

nacre calcareous secretion produced by bivalves to line the inner side of shells as well as to coat intruding particulate matter

nauplius larval stage in the early development of crustaceans

nematocyst harpoon-like organelle within cnidocyte with pointed projectile and poison to stun and entangle prey

Nematoda phylum of worm-like animals that are triploblastic, pseudocoelomates that can be free-living or parasitic

Nemertea phylum of dorsoventrally flattened protostomes known as ribbon worms

osculum large opening in the sponge's body through which water leaves

ostium pore present on the sponge's body through which water enters

oviger additional pair of appendages present on some arthropods between the chelicerae and pedipalps

parapodium fleshy, flat, appendage that protrudes in pairs from each segment of polychaetes

pedipalp second pair of appendages in Chelicerata

pilidium larval form found in some nemertine species

pinacocyte epithelial-like cell that forms the outermost layer of sponges and encloses a jelly-like substance called mesohyl

planospiral shell shape coiled around a vertical axis

planuliform larval form found in phylum Nemertea

polymorphic possessing multiple body plans within the lifecycle of a group of organisms

polyp stalk-like sessile life form of a cnidarians with mouth and tentacles facing upward, usually sessile but may be able to glide along surface

Porifera phylum of animals with no true tissues, but a

porous body with rudimentary endoskeleton
radula tongue-like organ with chitinous ornamentation
rhynchocoel cavity present above the mouth that houses the proboscis
schizocoelom coelom formed by groups of cells that split from the endodermal layer
sclerocyte cell that secretes silica spicules into the mesohyl
seta/chaeta chitinous projection from the cuticle
siphon tubular structure that serves as an inlet for water into the mantle cavity
spicule structure made of silica or calcium carbonate that provides structural support for sponges
spongocoel central cavity within the body of some sponges
trochophore first of the two larval stages in mollusks
uniramous referring to one branch per appendage
veliger second of the two larval stages in mollusks
water vascular system system in echinoderms where water is the circulatory fluid
zoea larval stage in the early development of crustaceans

CHAPTER SUMMARY

28.1 Phylum Porifera

Animals included in phylum Porifera are parazoans because they do not show the formation of true embryonically derived tissues, although they have a number of specific cell types and "functional" tissues such as pinacoderm. These organisms show very simple organization, with a rudimentary endoskeleton of spicules and spongin fibers. Glass sponge cells are connected together in a multinucleated syncytium. Although sponges are very simple in organization, they perform most of the physiological functions typical of more complex animals.

28.2 Phylum Cnidaria

Cnidarians represent a more complex level of organization than Porifera. They possess outer and inner tissue layers that sandwich a noncellular mesoglea between them. Cnidarians possess a well-formed digestive system and carry out extracellular digestion in a digestive cavity that extends through much of the animal. The mouth is surrounded by tentacles that contain large numbers of cnidocytes—specialized cells bearing nematocysts used for stinging and capturing prey as well as discouraging predators. Cnidarians have separate sexes and many have a lifecycle that involves two distinct morphological forms—medusoid and polypoid—at various stages in their life cycles. In species with both forms, the medusa is the sexual, gamete-producing stage and the polyp is the asexual stage. Cnidarian species include individual or colonial polypoid forms, floating colonies, or large individual medusa forms (sea jellies).

28.3 Superphylum Lophotrochozoa: Flatworms, Rotifers, and Nemerteans

This section describes three phyla of relatively simple invertebrates: one acoelomate, one pseudocoelomate, and one eucoelomate. Flatworms are acoelomate, triploblastic animals. They lack circulatory and respiratory systems, and have a rudimentary excretory system. This digestive system is incomplete in most species, and absent in tapeworms. There are four traditional groups of flatworms, the largely free-living turbellarians, which include polycladid marine worms and tricladid freshwater species, the ectoparasitic monogeneans, and the endoparasitic trematodes and cestodes. Trematodes have complex life cycles involving a molluscan secondary host and a primary host in which sexual reproduction takes place. Cestodes, or tapeworms, infect the digestive systems of their primary vertebrate hosts.

Rotifers are microscopic, multicellular, mostly aquatic organisms that are currently under taxonomic revision. The group is characterized by the ciliated, wheel-like corona, located on their head. Food collected by the corona is passed to another structure unique to this group of organisms—the mastax or jawed pharynx.

The nemerteans are probably simple eucoelomates. These ribbon-shaped animals also bear a specialized proboscis enclosed within a rhynchocoel. The development of a closed circulatory system derived from the coelom is a significant difference seen in this species compared to other phyla described here. Alimentary, nervous, and excretory systems are more developed in the nemerteans than in the flatworms or rotifers. Embryonic development of nemertean worms proceeds via a planuliform or trochophore-like larval stage.

28.4 Superphylum Lophotrochozoa: Molluscs and Annelids

Phylum Mollusca is a large, group of protostome schizocoelous invertebrates that occupy marine, freshwater, and terrestrial habitats. Mollusks can be divided into seven classes, each of which exhibits variations on the basic molluscan body plan. Two defining features are the mantle, which secretes a protective calcareous shell in many species, and the radula, a rasping feeding organ found in most classes. Some mollusks have evolved a reduced shell, and others have no radula. The mantle also covers the body and forms a mantle cavity, which is quite distinct from the coelomic cavity—typically reduced to the area surrounding the heart, kidneys, and intestine. In aquatic mollusks, respiration is facilitated by gills (ctenidia) in the mantle cavity. In terrestrial mollusks, the mantle cavity itself serves as an organ of gas exchange. Mollusks also have a muscular foot, which is modified in various ways for locomotion or food capture. Most mollusks have separate sexes. Early development in aquatic species occurs via one or more larval stages, including a trochophore larva, that precedes a veliger larva in some groups.

Phylum Annelida includes vermiform, segmented animals. Segmentation is metameric (i.e., each segment is partitioned internally as well as externally, with various structures repeated in each segment). These animals have well-developed neuronal, circulatory, and digestive systems. The two major groups of annelids are the polychaetes, which have parapodia with multiple bristles, and oligochaetes, which have no parapodia and fewer bristles or no bristles. Oligochaetes, which include earthworms and leeches, have a specialized band of segments known as a clitellum, which secretes a cocoon and protects gametes during reproduction. The leeches do not have full internal segmentation. Reproductive strategies include separate sexes, hermaphroditism, and serial hermaphroditism. Polychaetes typically have trochophore larvae, while the oligochaetes develop more directly.

28.5 Superphylum Ecdysozoa: Nematodes and Tardigrades

The defining feature of the Ecdysozoa is a collagenous/chitinous cuticle that covers the body, and the necessity to molt the cuticle periodically during growth. Nematodes are roundworms, with a pseudocoel body cavity. They have a complete digestive system, a differentiated nervous system, and a rudimentory excretory system. The phylum includes free-living species like *Caenorhabditis elegans* as well as many species of endoparasitic organisms such as *Ascaris* spp. They include dioeceous as well as hermaphroditic species. Embryonic development proceeds via several larval stages, and most adults have a fixed number of cells.

The tardigrades, sometimes called "water bears," are a widespread group of tiny animals with a segmented cuticle covering the epidermis and four pairs of clawed legs. Like the nematodes, they are pseudocoelomates and have a fixed number of cells as adults. Specialized proteins enable them to enter cryptobiosis, a kind of suspended animation during which they can resist a number of adverse environmental conditions.

28.6 Superphylum Ecdysozoa: Arthropods

Arthropods represent the most successful animal phylum on Earth, both in terms of the number of species and the number of individuals. As members of the Ecdysozoa, all arthropods have a protective chitinous cuticle that must be periodically molted and shed during development or growth. Arthropods are characterized by a segmented body as well as the presence of jointed appendages. In the basic body plan, a pair of appendages is present per body segment. Within the phylum, traditional classification is based on mouthparts, body subdivisions, number of appendages, and modifications of appendages present. In aquatic arthropods, the chitinous exoskeleton may be calcified. Gills, tracheae, and book lungs facilitate respiration. Unique larval stages are commonly seen in both aquatic and terrestrial groups of arthropods.

28.7 Superphylum Deuterostomia

Echinoderms are deuterostome marine organisms, whose adults show five-fold symmetry. This phylum of animals has a calcareous endoskeleton composed of ossicles, or body plates. Epidermal spines are attached to some ossicles and serve in a protective capacity. Echinoderms possess a water-vascular system that serves both for respiration and for locomotion, although other respiratory structures such as papulae and respiratory trees are found in some species. A large aboral madreporite is the point of entry and exit for sea water pumped into the water vascular system. Echinoderms have a variety of feeding techniques ranging from predation to suspension feeding. Osmoregulation is carried out by specialized cells known as podocytes associated with the hemal system.

The characteristic features of the Chordata are a notochord, a dorsal hollow nerve cord, pharyngeal slits, a post-anal tail, and an endostyle/thyroid that secretes iodinated hormones. The phylum Chordata contains two clades of invertebrates: Urochordata (tunicates, salps, and larvaceans) and Cephalochordata (lancelets), together with the vertebrates in the Vertebrata. Most tunicates live on the ocean floor and are suspension feeders. Lancelets are suspension feeders that feed on phytoplankton and other microorganisms. The sister taxon of the Chordates is the Ambulacraria, which includes both the Echinoderms and the hemichordates, which share pharyngeal slits with the chordates.

VISUAL CONNECTION QUESTIONS

1. Figure 28.3 Which of the following statements is false?
   a. Choanocytes have flagella that propel water through the body.
   b. Pinacocytes can transform into any cell type.
   c. Lophocytes secrete collagen.
   d. Porocytes control the flow of water through pores in the sponge body.

2. Figure 28.21 Which of the following statements about the anatomy of a mollusk is false?
   a. Mollusks have a radula for grinding food.
   b. A digestive gland is connected to the stomach.
   c. The tissue beneath the shell is called the mantle.
   d. The digestive system includes a gizzard, a stomach, a digestive gland, and the intestine.

3. Figure 28.45 Which of the following statements about insects is false?
   a. Insects have both dorsal and ventral blood vessels.
   b. Insects have spiracles, openings that allow air to enter into the tracheal system.
   c. The trachea is part of the digestive system.
   d. Most insects have a well-developed digestive system with a mouth, crop, and intestine.

REVIEW QUESTIONS

4. Mesohyl contains:
   a. a polysaccharide gel and dead cells.
   b. a collagen-like gel and suspended cells for various functions.
   c. spicules composed of silica or calcium carbonate.
   d. multiple pores.

5. The large central opening in the parazoan body is called the:
   a. gemmule.
   b. spicule.
   c. ostia.
   d. osculum.

6. Most sponge body plans are slight variations on a simple tube-within-a-tube design. Which of the following is a key limitation of sponge body plans?
   a. Sponges lack the specialized cell types needed to produce more complex body plans.
   b. The reliance on osmosis/diffusion requires a design that maximizes the surface area to volume ratio of the sponge.
   c. Choanocytes must be protected from the hostile exterior environment.
   d. Spongin cannot support heavy bodies.

7. Cnidocytes are found in _____.
   a. phylum Porifera
   b. phylum Nemertea
   c. phylum Nematoda
   d. phylum Cnidaria

8. Cubozoans are ________.
   a. polyps
   b. medusoids
   c. polymorphs
   d. sponges

9. While collecting specimens, a marine biologist finds a sessile Cnidarian. The medusas that bud from it swim by contracting a ring of muscle in their bells. To which class does this specimen belong?
   a. Class Hydrozoa
   b. Class Cubozoa
   c. Class Scyphozoa
   d. Class Anthozoa

10. Which group of flatworms are primarily ectoparasites of fish?
    a. monogeneans
    b. trematodes
    c. cestodes
    d. turbellarians

11. The rhynchocoel is a ________.
    a. circulatory system
    b. fluid-filled cavity
    c. primitive excretory system
    d. proboscis

12. Annelids have (a):
    a. pseudocoelom.
    b. true coelom.
    c. no coelom.
    d. none of the above

13. A mantle and mantle cavity are present in:
    a. phylum Echinodermata.
    b. phylum Adversoidea.
    c. phylum Mollusca.
    d. phylum Nemertea.
14. How does segmentation enhance annelid locomotion?
    a. Segmentation creates repeating body structures so the entire organism functions in synchrony.
    b. Segmentation allows specialization of different body regions.
    c. Neural segmentation allows annelids to localize sensations.
    d. Muscle contractions can be localized to specific regions of the body to coordinate movement.
15. The embryonic development in nematodes can have up to __________ larval stages.
    a. one
    b. two
    c. three
    d. four
16. The nematode cuticle contains _____.
    a. glucose
    b. skin cells
    c. chitin
    d. nerve cells
17. Crustaceans are _____.
    a. ecdysozoans
    b. nematodes
    c. arachnids
    d. parazoans
18. Flies are_______.
    a. chelicerates
    b. hexapods
    c. arachnids
    d. crustaceans
19. Which of the following is **not** a key advantage provided by the exoskeleton of terrestrial arthropods?
    a. Prevents dessication
    b. Protects internal tissue
    c. Provides mechanical support
    d. Grows with the arthropod throughout its life
20. Echinoderms have _____.
    a. triangular symmetry
    b. radial symmetry
    c. hexagonal symmetry
    d. pentaradial symmetry
21. The circulatory fluid in echinoderms is _____.
    a. blood
    b. mesohyl
    c. water
    d. saline
22. Which of the following features does not distinguish humans as a member of phylum Chordata?
    a. Human embryos undergo indeterminate cleavage.
    b. A spinal cord runs along an adult human's dorsal side.
    c. Human embryos exhibit pharyngeal arches and gill slits.
    d. The human coccyx forms from an embryonic tail.
23. The sister taxon of the Chordata is the _____.
    a. Mollusca
    b. Arthropoda
    c. Ambulacraria
    d. Rotifera

CRITICAL THINKING QUESTIONS

24. Describe the different cell types and their functions in sponges.
25. Describe the feeding mechanism of sponges and identify how it is different from other animals.
26. Explain the function of nematocysts in cnidarians.
27. Compare the structural differences between Porifera and Cnidaria.
28. Compare the differences in sexual reproduction between Porifera and Cubozoans. How does the difference in fertilization provide an evolutionary advantage to the Cubozoans?
29. How does the tapeworm body plan support widespread dissemination of the parasite?
30. Describe the morphology and anatomy of mollusks.
31. What are the anatomical differences between nemertines and mollusks?
32. How does a change in the circulatory system organization support the body designs in cephalopods compared to other mollusks?
33. Enumerate features of *Caenorhabditis elegans* that make it a valuable model system for biologists.
34. What are the different ways in which nematodes can reproduce?

35. Why are tardigrades essential to recolonizing habits following destruction or mass extinction?
36. Describe the various superclasses that phylum Arthropoda can be divided into.
37. Compare and contrast the segmentation seen in phylum Annelida with that seen in phylum Arthropoda.
38. How do terrestrial arthropods of the subphylum Hexapoda impact the world's food supply? Provide at least two positive and two negative effects.
39. Describe the different classes of echinoderms using examples.