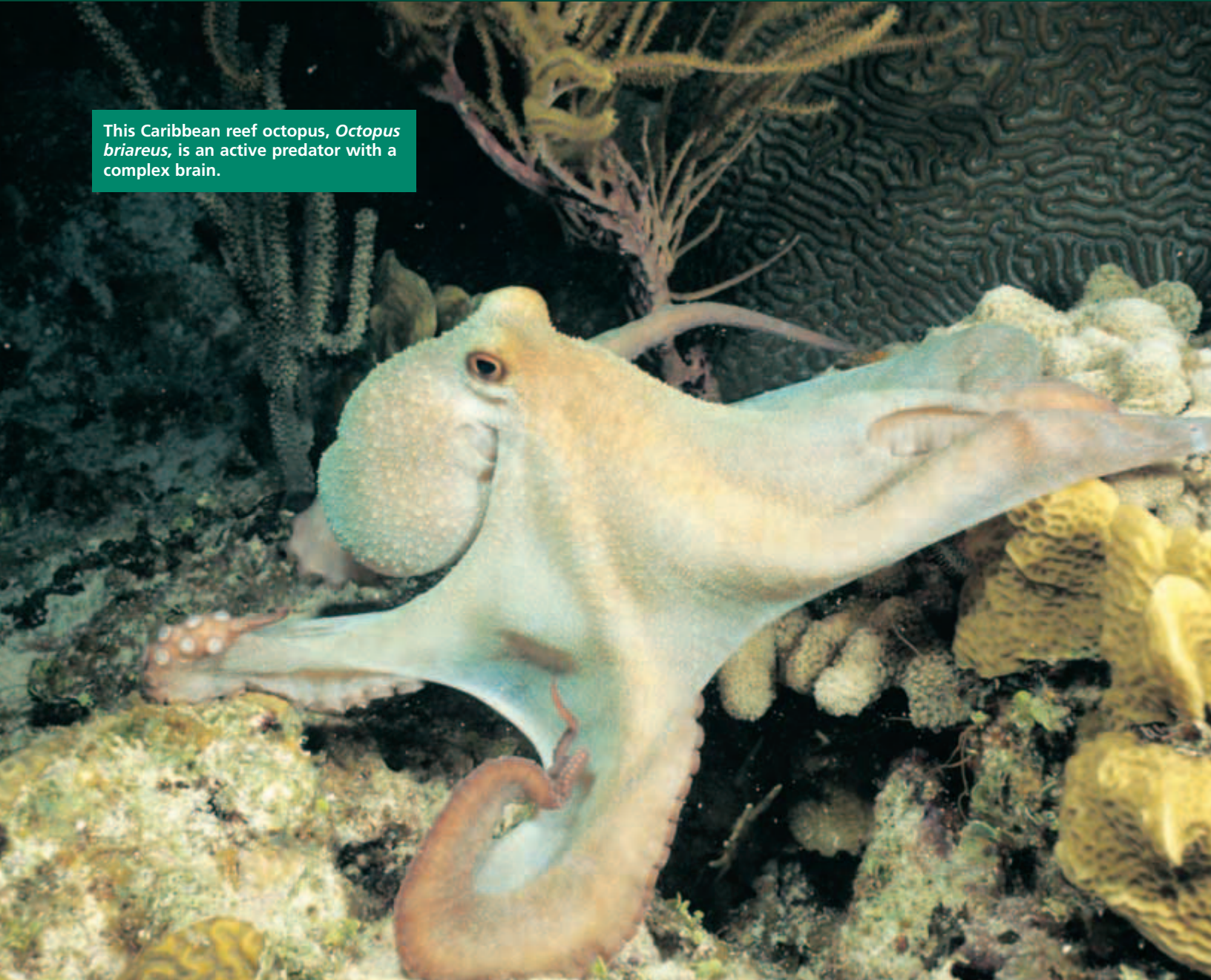


MOLLUSKS AND ANNELIDS

This Caribbean reef octopus, *Octopus briareus*, is an active predator with a complex brain.



SECTION 1 *Mollusca*

SECTION 2 *Annelida*

MOLLUSCA

Despite their very different appearances, invertebrates such as clams, snails, slugs, and octopuses belong to the same phylum, Mollusca (muh-LUHS-kuh). Members of this phylum are called mollusks, a name that comes from the Latin molluscus, which means “soft.” Although some mollusks have soft bodies, most have a hard shell that protects them.

CHARACTERISTICS OF MOLLUSKS

The phylum Mollusca is a diverse group of more than 112,000 species. Among animals, only the phylum Arthropoda has more species. Some mollusks are sedentary filter feeders, while others are fast-moving predators with complex nervous systems.

Mollusks are among several phyla of animals known as *coelomates*. Coelomates are so named because they have a true coelom, a hollow, fluid-filled cavity that is completely surrounded by mesoderm. Coelomates differ from pseudocoelomates, such as roundworms, which have a body cavity lined by mesoderm on the outside and endoderm on the inside.

A coelom has several advantages over a pseudocoelom. With a coelom, the muscles of the body wall are separated from those of the gut. Therefore, the body wall muscles can contract without hindering the movement of food through the gut. A coelom also provides a space where the circulatory system can transport blood without interference from other internal organs. The coelomate body plan is shared by annelids, which are discussed in the second half of this chapter, and by three other major phyla of animals: arthropods, echinoderms, and chordates, which include humans.

Another feature that is shared by most aquatic mollusks and annelids is a larval stage of development called a **trochophore** (TRAHK-oh-FAWR), illustrated in Figure 35-1. In some species, the trochophore hatches from the egg case and exists as a free-swimming larva. Cilia on the surface of a free-swimming trochophore propel the larva through the water and draw food into its mouth. As free-swimming trochophores are carried by ocean currents and tides, they contribute to the dispersal of their species. The presence of a trochophore in mollusks and annelids suggests that these two groups of animals may have evolved from a common ancestor.

OBJECTIVES

- Describe the key characteristics of mollusks.
- Describe the body plan of mollusks.
- Name the characteristics of three major classes of mollusks.
- Compare the body plans of gastropods, bivalves, and cephalopods.

VOCABULARY

trochophore
visceral mass
mantle
mantle cavity
ganglion
radula
gastropod
hemolymph
hemocoel
bivalve
incurrent siphon
excurrent siphon
cephalopod

FIGURE 35-1

A trochophore is a larva that develops from the fertilized egg of most mollusks and annelids. Cilia at both ends and in the middle propel free-swimming trochophores through the water.

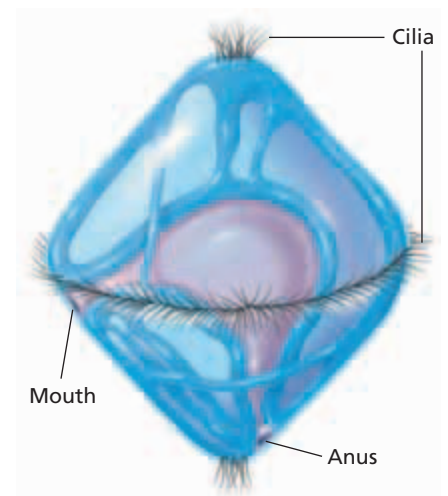


FIGURE 35-2

In the basic body plan of a mollusk, the body is divided into the head-foot and the visceral mass, which contains the internal organs. Covering the visceral mass is the mantle, which secretes the shell.

Visceral mass
Head-foot

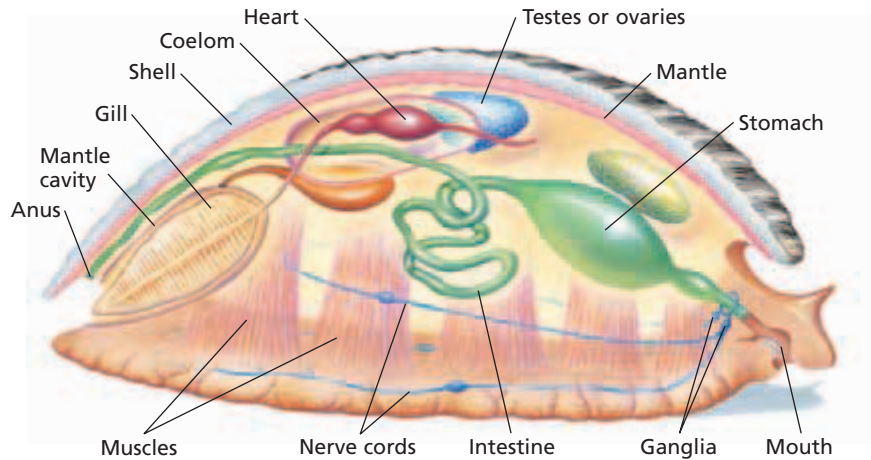
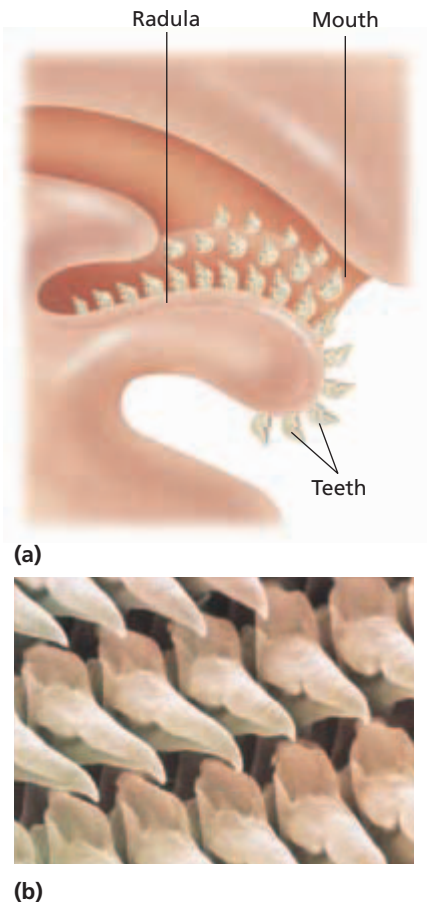


FIGURE 35-3

Inside the mouth (a), many mollusks have a radula, a band of tissue covered with teeth that can scrape food from other surfaces. The SEM in (b) shows the sharp edges of these teeth (600 \times).



BODY PLAN OF MOLLUSKS

Figure 35-2 shows that the body of a mollusk is generally divided into two main regions: the head-foot and the visceral mass. As its name suggests, the head-foot consists of the head, which contains the mouth and a variety of sensory structures, and the foot, a large, muscular organ usually used for locomotion. Above the head-foot is the **visceral (VIS-uh-uhl) mass**, which contains the heart and the organs of digestion, excretion, and reproduction. As shown in Figure 35-2, the coelom is limited to a space around the heart. Covering the visceral mass is a layer of epidermis called the **mantle**.

In most mollusks, the mantle secretes one or more hard shells containing calcium carbonate. Although shells protect the soft bodies of mollusks from predators, they also reduce the surface area available for gas exchange. This disadvantage is offset by another structural adaptation: gills. Gills provide a large surface area that is in contact with a rich supply of blood. In this way, gills are specialized for the exchange of gases. Figure 35-2 also shows that the delicate gills of mollusks are protected within the **mantle cavity**, a space between the mantle and the visceral mass.

Unlike many coelomates, mollusks do not have segmented bodies. Like flatworms and roundworms, most mollusks are bilaterally symmetrical. This symmetry is apparent in the nervous system, which consists of paired clusters of nerve cells called **ganglia**. The ganglia are situated in the head-foot and visceral mass and are connected by two pairs of long nerve cords. Nerve cells in the ganglia control the muscles involved in locomotion and feeding and process sensory information from specialized cells that respond to light, touch, and chemicals in the environment.

The main feeding adaptation of many mollusks is the **radula (RAJ-u-luh)**. As Figure 35-3 shows, in most species the radula is a flexible, tonguelike strip of tissue covered with tough, abrasive teeth that point backward. Through evolution, the radula has become adapted for a variety of functions in different mollusks.

TABLE 35-1 *Features of Three Classes of Mollusks*

Class	External shell	Head	Radula	Locomotion
Gastropoda	one (most species)	yes	yes	crawling (most)
Bivalvia	two	no	no	sessile (most)
Cephalopoda	none (most species)	yes	yes	rapid swimming

Terrestrial snails use the radula to cut through the leaves of garden plants, while aquatic snails use it to scrape up algae or to drill holes in the shells of other mollusks. The cone shell has a harpoon-shaped radula with which it captures fish and injects venom.

Most biologists use structural differences to divide mollusks into seven classes. Three of these classes are discussed below: class Gastropoda (gas-TRAHP-uh-duh), class Bivalvia (bie-VALV-ee-uh), and class Cephalopoda (SEF-uh-LAHP-uh-duh). Table 35-1 summarizes the major features of these three classes.

Word Roots and Origins

gastropod

from the Greek *gaster*, meaning "stomach," and *pous*, meaning "foot"

CLASS GASTROPODA

The largest and most diverse class of mollusks is Gastropoda, whose members are called **gastropods** (GAS-troh-PAHDZ). Most of the 40,000 species of gastropods, including snails, abalones, and conchs, have a single shell. Others, such as slugs and nudibranchs, have no shell at all.

Gastropods undergo a process called *torsion* during larval development. During torsion, the visceral mass twists around 180 degrees in relation to the head. This twisting brings the mantle cavity, gills, and anus to the front of the animal, as shown in Figure 35-4. Because of torsion, a gastropod can withdraw its head into its mantle cavity when threatened. Coiling of the shell is unrelated to torsion.

Wavelike muscular contractions of the foot move gastropods smoothly over surfaces. You can see these contractions if you look closely at the underside of a snail or slug as it crawls across a windowpane or the side of an aquarium.

Gastropods have an open circulatory system, meaning that the circulatory fluid, called **hemolymph**, does not remain entirely within vessels. Instead, it is collected from the gills or lungs, pumped through the heart, and released directly into spaces in the tissues. These fluid-filled spaces compose what is known as a **hemocoel** (HEE-moh-SEEL), or blood cavity. From the hemocoel, the hemolymph returns via the gills or lungs to the heart.

FIGURE 35-4

In a gastropod, such as this snail, the mantle cavity, anus, and gills are near the head as a result of torsion during development.

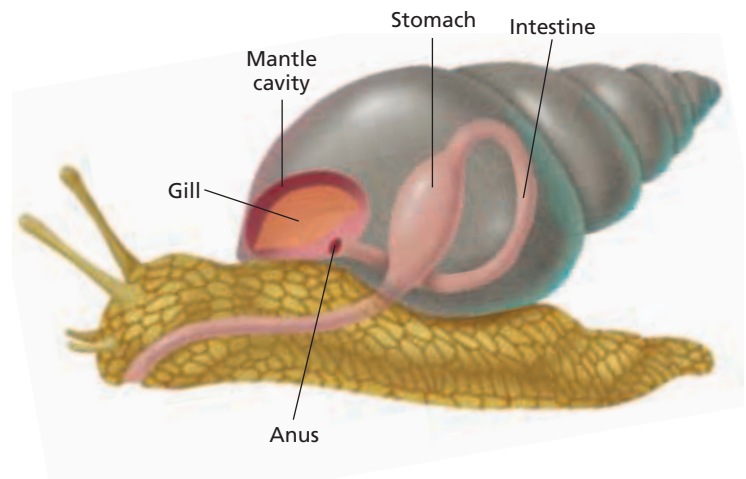




FIGURE 35-5

The extensions on the back of this horned nudibranch, *Hermisenda crassicornia*, provide a large surface area for gas exchange.

Snails

Snails are gastropods that live on land, in fresh water, and in the ocean. Two eyes at the end of delicate tentacles on the head help most snails locate food. If danger arises, the tentacles retract into the head. Aquatic snails respire through gills in the mantle cavity. In land snails, the mantle cavity acts as a modified lung that exchanges oxygen and carbon dioxide with the air. The thin membrane lining the mantle cavity must be kept moist to allow gases to diffuse through it. For this reason, land snails are most active when the air has a high moisture content. Snails survive dry periods by becoming inactive and retreating into their shells. They seal the opening to their shell with a mucous plug, which keeps them from drying out.

Other Gastropods

Slugs are terrestrial gastropods that look like snails without shells. Like land snails, slugs respire through the lining of their mantle cavity. They avoid drying out by hiding in moist, shady places by day and feeding at night.

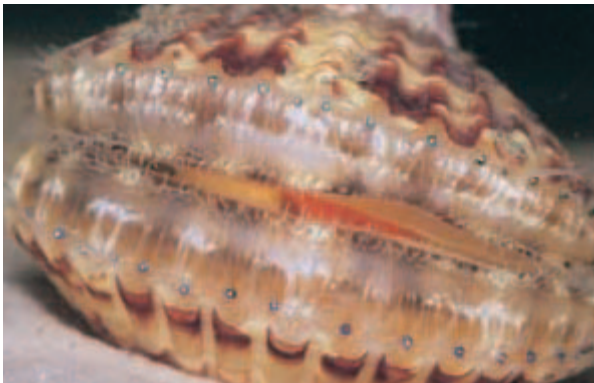
Nudibranchs (NOO-di-BRANGKS), such as the one in Figure 35-5, are marine gastropods that lack shells. *Nudibranch* means “naked gill,” which refers to the fact that gas exchange occurs across the entire body surface of these animals. The surface of most nudibranchs is covered with numerous ruffles or delicate, fingerlike extensions that increase the total area available for gas exchange.

Some gastropods show unusual adaptations of the foot. In pteropods, or “sea butterflies,” for example, the foot is modified into a winglike flap that is used for swimming rather than crawling.

Gastropods show great diversity in their reproduction. Many species have separate sexes, but hermaphrodites are common among aquatic and terrestrial gastropods.

FIGURE 35-6

The two valves that make up the hinged shell of a bivalve can separate, allowing water to circulate through the animal. Some bivalves, such as this scallop, of the genus *Argopecten*, have a row of eyes near the outer margin of each valve.



CLASS BIVALVIA

Members of the class Bivalvia include aquatic mollusks, such as clams, oysters, and scallops. These mollusks are called **bivalves** because, as Figure 35-6 shows, their shell is divided into two halves, or valves, connected by a hinge. A bivalve can close its shell by contracting the powerful adductor muscles that are attached to the inside surface of each valve. When the adductor muscles relax, the valves open.

Each valve consists of three layers that are secreted by the mantle. The thin outer layer protects the shell against acidic conditions in the water. The thick middle layer of calcium carbonate strengthens the shell. The smooth, shiny inner layer protects the animal’s soft body.

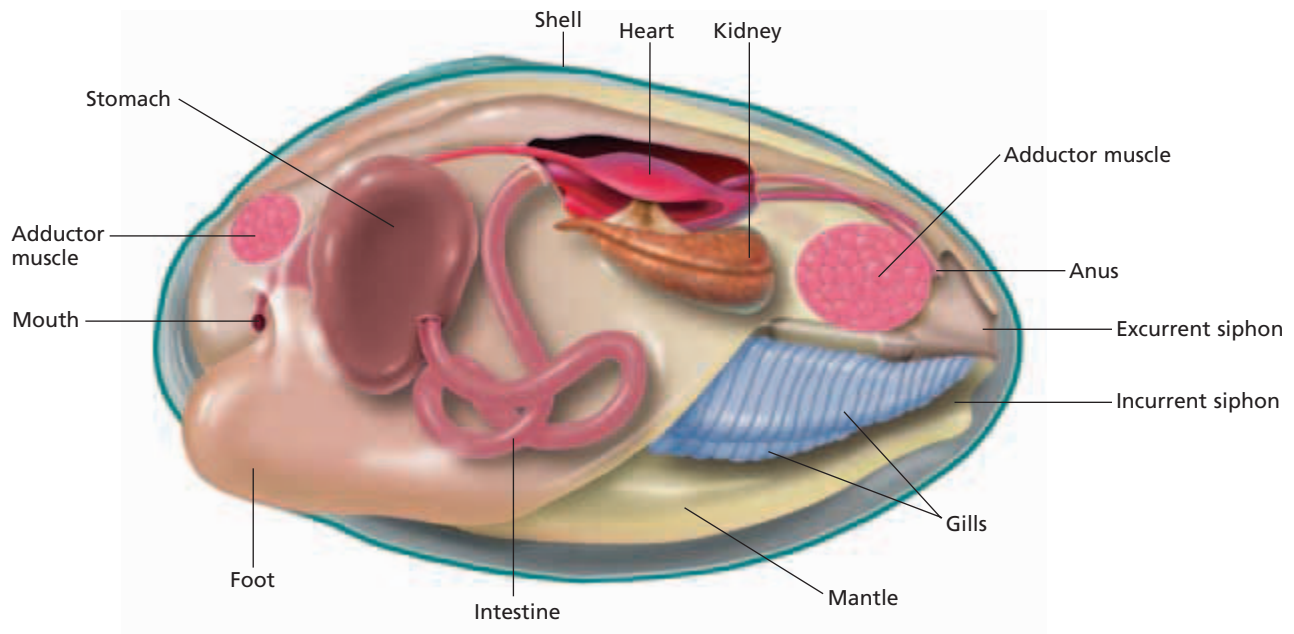


FIGURE 35-7

In this illustration, one valve has been omitted to show a clam's anatomy. The internal structure of a clam is typical of most bivalves.

In contrast with gastropods, which move about in search of food, most bivalves are sessile. Some species extend their muscular foot into the sand and fill the foot with hemolymph to form a hatchet-shaped anchor. The muscles of the foot then contract, pulling the animal down into the sand. As an adaptation for a sessile existence, bivalves usually are filter feeders. They are the only mollusks without a radula.

Bivalves lack a distinct head. Their nervous system consists of three pairs of ganglia: one pair near the mouth, another pair in the digestive system, and the third pair in the foot. The ganglia are connected by nerve cords. Nerve cells in the ganglia receive information from sensory cells in the edge of the mantle that respond to touch or to chemicals in the water. Some bivalves also have a row of small eyes along each mantle edge. Stimuli detected by these sensory structures can trigger nerve impulses that cause the foot to withdraw and the shell to close.

Clams

Clams are bivalves that live buried in mud or sand. The mantle cavity of a clam is sealed except for a pair of hollow, fleshy tubes called *siphons*, which you can see in Figure 35-7. Cilia beating on the gills set up a current of water that enters through the **incurrent siphon** and leaves through the **excurrent siphon**. As the water circulates inside the clam, the gills filter small organisms and organic debris from the water. The filtered material becomes trapped on the gills in a sticky mucus that moves in a continuous stream toward the mouth. Water passing over the gills also exchanges oxygen and carbon dioxide with the hemolymph.

Most species of clams have separate sexes. Marine clams reproduce by shedding sperm and eggs into the water, and fertilization occurs externally. The fertilized egg becomes a trochophore that eventually settles to the bottom and develops into an adult.



Quick Lab

Describing a Mollusk

Materials 2–3 bivalve shells, colored pencils, paper

Procedure

1. Using colored pencils, draw a bivalve shell on a sheet of paper.
2. Use Figure 35-7 to help you locate and label the adductor muscle scars, the mantle cavity, and the hinge area on the bivalve.

Analysis Describe the shell of the bivalve, including its color, its ridges, the appearance and texture of the mantle, and the location of the hinge area.

In some clam species, adults may weigh 200 kg (440 lb) and be more than 1 m (3.3 ft) across. In most freshwater clams, eggs are fertilized internally by sperm that enter through the incurrent siphon. The larvae that develop are discharged into the water through the excurrent siphon. If they contact a passing fish, they may live as parasites on its gills or skin for several weeks before settling to the bottom.

Other Bivalves

Oysters are bivalves that become permanently attached to a hard surface early in their development. Some are grown commercially as food or as sources of cultured pearls. Scallops can move through the water by repeatedly opening their valves and snapping them shut. This motion expels bursts of water, creating a form of jet propulsion. The teredo, or shipworm, is one of the few bivalves that does not filter-feed. Instead, it bores into driftwood or ship timbers and ingests the particles that are produced by the drilling. The wood cellulose is broken down by symbiotic bacteria that live in the shipworm's intestine.

CLASS CEPHALOPODA

Members of the class Cephalopoda include octopuses, squids, cuttlefishes, and chambered nautilus. These marine mollusks are called **cephalopods** (SEF-uh-loh-PAHDZ), a term that means “head-foot.” Cephalopods are specialized for a free-swimming, predatory existence. Extending from the head is a circle of tentacles, as you can see in Figure 35-8. The tentacles’ powerful suction cups allow cephalopods to grasp objects and capture prey. Cephalopods kill and eat their prey with the help of a pair of jaws that resemble a parrot’s beak.

The nervous system is more advanced in cephalopods than in any other group of mollusks. The cephalopod brain, which is the largest of any invertebrate brain, is divided into several lobes and contains millions of nerve cells. Octopuses, for example, can learn to perform tasks and discriminate between objects on the basis of their shape or texture. The sensory systems of cephalopods are also well developed. Most cephalopods have complex eyes that form images. The tentacles contain numerous cells that sense chemicals in the water.

Cephalopods have a closed circulatory system. Closed circulatory systems transport fluid more rapidly than open circulatory systems do. Thus, nutrients, oxygen, and carbon dioxide are carried quickly through the body of these highly active animals. Cephalopods also have separate sexes. The male uses a specialized tentacle to transfer packets of sperm from his mantle cavity to the mantle cavity of the female, where fertilization occurs. The female lays a mass of fertilized eggs and guards the eggs until they hatch. Unlike other mollusks, cephalopods develop from an egg into a juvenile without becoming a trochophore.

FIGURE 35-8

Most of the body of cephalopods is made up of a large head attached to tentacles. The tentacles of cephalopods, such as this cuttlefish, *Sepia latimanus*, surround their mouth. The streamlined body of many cephalopods enables them to swim rapidly in pursuit of prey.



Many cephalopods can release a dark fluid into the water to temporarily distract predators. They also have pigment cells called *chromatophores* (kroh-MAT-uh-FAWHRZ), which are located in the outer layer of the mantle. Chromatophores can produce a sudden change in the color of a cephalopod, allowing the animal to blend in with its surroundings.

Squids

Squids are cephalopods with ten tentacles. The longest two tentacles are used for capturing prey, and the other eight tentacles force the prey into the squid's mouth. The muscular mantle propels the squid swiftly through the water by pumping jets of water through an excurrent siphon. Most squids grow to about 30 cm (1 ft) in length, but a few species can be much longer. The giant squid, *Architeuthis*, may reach a length of 18 m (about 60 ft) and a weight of more than 900 kg (about 1 ton). *Architeuthis* is the world's largest known invertebrate.

Octopuses

Octopuses have eight tentacles and share many characteristics with squids, including their methods of escaping from predators. Instead of using jet propulsion to chase prey, however, octopuses are more likely to crawl along the ocean bottom with their tentacles or lie in wait in caves and rock crevices. Octopuses average 1 m (3.3 ft) or less in length, although the giant Pacific octopus may grow to a length of 9 m (about 30 ft).

Chambered Nautilus

Squids and cuttlefish have small internal shells. The chambered nautilus, shown in Figure 35-9, is the only existing cephalopod that has retained its external shell. The nautilus shell is coiled and divided into a series of gas-filled chambers separated by partitions. The soft body of the nautilus is confined to the outermost chamber. As the nautilus grows, it moves forward in its shell, makes a new partition, and fills the chamber behind the partition with gas. The gas makes the nautilus buoyant.

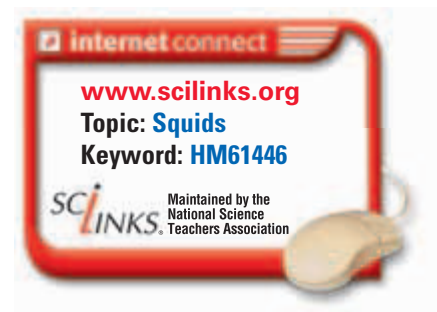


FIGURE 35-9

Although cephalopods evolved from shelled ancestors, the chambered nautilus is the only living cephalopod species with an external shell.

SECTION 1 REVIEW

1. What is one advantage of a true coelom over a pseudocoelom?
2. In which phyla of animals is the larval trochophore stage found?
3. For what purpose is a radula used?
4. Why are land snails more active when the air around them is moist?
5. Compare the circulatory systems of each of the three major classes of mollusks.

CRITICAL THINKING

6. **Analyzing Concepts** Suggest why an open circulatory system is sufficient to meet the needs of a gastropod.
7. **Making Comparisons** Compare the adaptations of clams and squids and relate them to lifestyle.
8. **Inferring Relationships** Which features of bivalves indicate that they are bilaterally symmetrical?

LEECHES: New Uses for an Old Remedy

Why are leeches called *bloodsuckers*? Do they really suck blood? Yes, they do, and their role as blood-suckers could help save your life.

For centuries, leeches were used in medical practice. In the second century C.E., the Greek physician Galen described the use of leeches in removing blood from patients in a procedure called *bloodletting*. An excess of blood in the body was believed to be responsible for a variety of illnesses, from headaches and fevers to heart disease. Physicians used the leeches to remove this “bad blood” from a patient’s body.

Bloodletting was common in Europe through the early 1800s. During the late 19th century, however, medical science discredited the idea that excess blood causes disease, and bloodletting fell out of favor.

Uses in Microsurgery

Leeches are making a comeback in medicine, although with new purposes. One of these purposes is to increase the success rate of surgical operations to reattach severed limbs, fingers, ears, or toes. Such operations involve microsurgery, a process in which surgeons reconnect tendons, blood vessels, and nerves by using tiny instruments and powerful microscopes. However, in some microsurgery, physicians cannot reconnect tiny, delicate blood vessels. As a result, circulation in the reattached limb, finger, or toe is impaired.

The tissues may become congested with blood. If congestion occurs, the tissues of the reattached part will not heal and will eventually die.

One solution to this congestion problem is to place leeches on the reattached body part. Once attached to the wound site, the leeches begin to suck out the accumulated blood, relieving congestion and allowing the tissues to remain healthy until the veins can grow back. At about \$10 each, leeches are a relatively inexpensive treatment for a serious problem.

Uses as Anticoagulants

Leeches have medical uses that go beyond their ability to remove blood. Scientists have known since the 1800s that leech saliva contains a powerful anticoagulant, a substance that inhibits blood clotting. The leech’s anticoagulant, called *hirudin*, can cause four hours or more of steady bleeding.



Leeches have been applied to this patient's sutures across his upper back to reduce blood congestion. Each leech can remove up to 5 mL of blood.

The steady bleeding helps prevent blood from clotting so the leech can feed freely.

New Applications

Today, *hirudin* is made through genetic engineering, without the aid of leeches. It has proven useful in the treatment of some heart patients, particularly those who have had heart attacks, who suffer from angina, or who have undergone angioplasty, a procedure to open blocked arteries. One research study even indicated that *hirudin* may be effective against the spread of cancer.

The amazing uses that have been found for a substance in leech saliva are encouraging to medical researchers, who continue to explore how knowledge of invertebrate organisms can be beneficially combined with medical technology.

REVIEW

1. Outline how leeches help surgeons in microsurgery.
2. Identify three potential new applications of *hirudin*.
3. **Critical Thinking** Why is *hirudin* now made by genetic engineering instead of being taken directly from leeches?



ANNELIDA

Colorful feather-duster worms, common earthworms, and bloodsucking leeches are all members of the phylum *Annelida* (uh-NEL-i-duh). An animal in this phylum is called an annelid (AN-uh-LID), a term that means “little rings.” The name refers to the many body segments that make an annelid look as if it is composed of a series of rings.

CHARACTERISTICS OF ANNELIDS

The phylum *Annelida* consists of about 15,000 species of bilaterally symmetrical, segmented worms. Segmentation is the most distinctive feature of annelids. Like mollusks, annelids have a true coelom, but the coelom in annelids is divided into separate compartments by partitions. Division of the coelom represents an evolutionary advance over the earliest wormlike coelomates. In an undivided coelom, the force of muscle contraction in one part of the body is transmitted to other parts by the fluid in the coelom. A segmented coelom enables different parts of the body to contract or expand independently. In addition, duplication of some of the organ systems in each segment provides a form of insurance against injury. If one segment becomes disabled, the others can still function.

Most annelids have external bristles called **setae** (SEET-ee) (singular, *seta*), and some have fleshy protrusions called **parapodia** (PAR-uh-POH-dee-uh) (singular, *parapodium*). Both of these structures are visible in Figure 35-10. The number of setae and the presence or absence of parapodia provide the basis for dividing annelids into three classes: Oligochaeta (AHL-uh-goh-KEET-uh), Polychaeta (PAHL-i-KEE-tuh), and Hirudinea (HIR-yoo-DIN-ee-uh). All organ systems are well developed in most members of each class.

CLASS OLIGOCHAETA

Annelids of the class Oligochaeta generally live in the soil or in fresh water and have no parapodia. *Oligochaeta* means “few bristles,” and as the name suggests, these annelids have a few setae on each segment. The most familiar member of the class Oligochaeta is the earthworm. As you read about the earthworm, look for adaptations that enable this animal to lead a burrowing life.

OBJECTIVES

- **Identify** the structures that provide the basis for dividing annelids into three classes.
- **List** the advantages of body segmentation.
- **Describe** the structural adaptations of earthworms.
- **Compare** the three classes of annelids.

VOCABULARY

seta
parapodium
crop
gizzard
typhlosole
aortic arch
nephridium
clitellum
seminal receptacle
chitin

FIGURE 35-10

Numerous setae help this bearded fireworm, *Hermodice carunculata*, move through its environment. The setae extend from fleshy flaps called *parapodia*. Also known as bristle worms, bearded fireworms are members of the class Polychaeta.



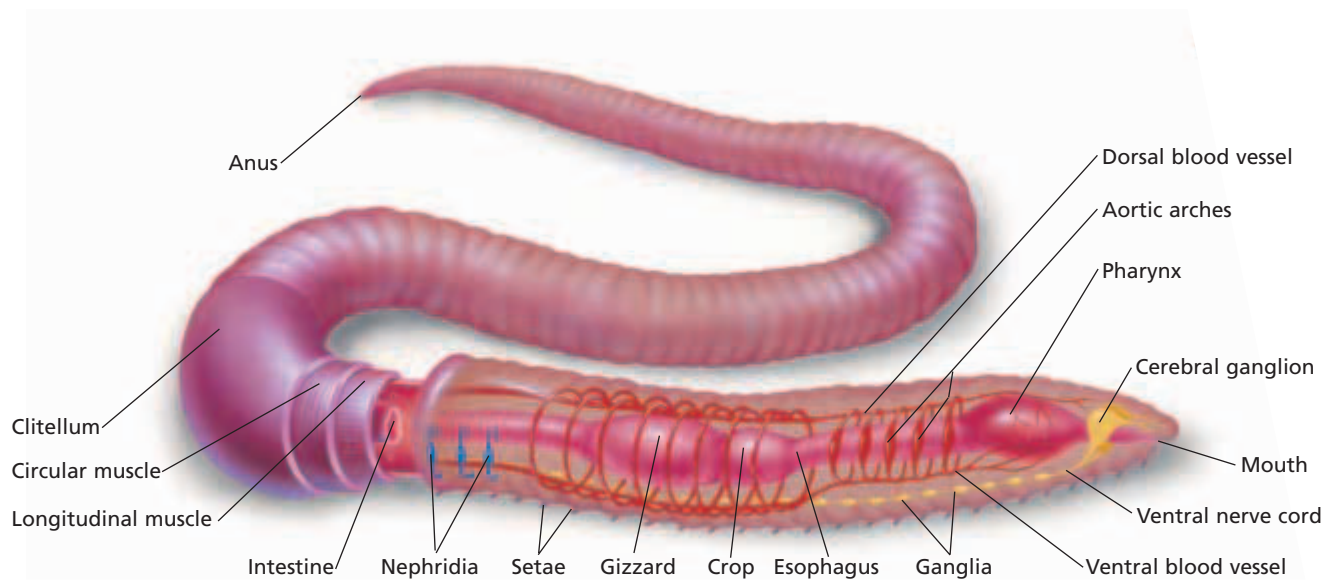


FIGURE 35-11

The segmentation of annelids, such as this earthworm, is visible both externally and internally. Some of the internal structures, such as ganglia and nephridia, are repeated in each segment.

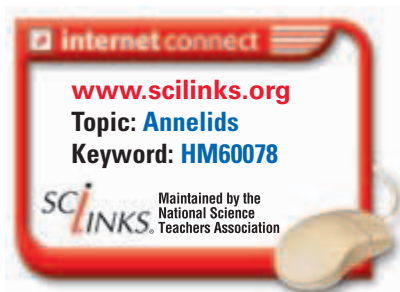
Structure and Movement

An earthworm's body is divided into more than 100 segments, most of which are virtually identical. Figure 35-11 shows that circular and longitudinal muscles line the interior body wall of an earthworm. To move, the worm anchors some of the middle segments by their setae and contracts the circular muscles in front of those segments. Contraction of the circular muscles increases the pressure of the coelomic fluid in those segments. This increased pressure elongates the animal and pushes the anterior end forward. Setae in the anterior segments then grip the ground as the longitudinal muscles contract, pulling the posterior segments forward. This method of locomotion in earthworms is an example of the kind of movement made possible by segmentation.

Feeding and Digestion

Earthworms ingest soil as they burrow through it. Soil is sucked into the mouth by the muscular pharynx. The soil then passes through a tube called the *esophagus* (ee-SAHF-uh-guhs) to a temporary storage area known as the **crop**. From the crop, the soil moves to a thick, muscular part of the gut called the **gizzard**. Find these parts of the digestive tract in Figure 35-11. The gizzard grinds the soil, releasing and breaking up organic matter. As the soil passes through the long intestine, digested organic compounds and nutrients in the soil are absorbed by the blood. An infolding of the intestinal wall called the **typhlosome** (TIF-luh-SOHL) increases the surface area available for digestion and absorption. Undigested material is eliminated from the earthworm's body through the anus.

Earthworms play an important role in maintaining the fertility of soil. By decomposing dead leaves and other organic materials, earthworms help release nutrients into the soil. The burrows made by earthworms allow air to penetrate into the soil, bringing oxygen to plant roots and soil microorganisms. Earthworms also loosen the soil, making it easier for roots to grow and for water to seep into the soil.



Circulation

A closed circulatory system transports oxygen, carbon dioxide, nutrients, and wastes through the body of an earthworm. The blood travels toward the posterior end through a ventral blood vessel and then returns to the anterior end through a dorsal blood vessel. As you can see in Figure 35-11, five pairs of muscular tubes, the **aortic** (ay-AWR-tik) **arches**, link the dorsal and ventral blood vessels near the anterior end of the worm. Contractions of the dorsal blood vessel and the aortic arches force blood through the circulatory system.

Respiration and Excretion

Oxygen and carbon dioxide diffuse directly through the skin, which contains many small blood vessels. This exchange of gases can take place only if the skin is moist. Therefore, earthworms avoid dry ground and extreme heat. Secretions of mucus and the presence of a thin cuticle also help keep an earthworm's skin moist.

Earthworms eliminate cellular wastes and excess water through excretory tubules called **nephridia** (nee-FRID-ee-uh), some of which are shown in Figure 35-11. Each segment, except the first three and the last one, contains a pair of nephridia. As coelomic fluid passes through the nephridia, some of the water is reabsorbed by blood vessels. The remaining fluid and the wastes dissolved in it are released from the body through pores on the ventral surface.

Neural Control

The nervous system of an earthworm consists of a chain of ganglia connected by a ventral nerve cord. Most body segments contain a single ganglion. Nerves branching from each ganglion carry impulses to the muscles and from the sensory cells in that segment. In the most anterior segments, several ganglia are fused to form the cerebral ganglia, or brain, as you can see in Figure 35-11. One of the main functions of the cerebral ganglia is to process information from sensory structures that respond to light, touch, chemicals, moisture, temperature, and vibrations. Although these sensory structures are found in all segments, they are concentrated at the anterior end.

Reproduction

Earthworms are hermaphrodites, but an individual worm cannot fertilize its own eggs. Mating occurs when two earthworms press their ventral surfaces together with their anterior ends pointing in opposite directions. The worms are held together by their setae and by a film of mucus secreted by each worm's **clitellum** (klie-TEL-uhm). The clitellum, also shown in Figure 35-11, is a thickened section of the body. Each earthworm injects sperm into the mucus. The sperm from each worm move through the mucus to the **seminal receptacle** of the other, where the sperm are stored. The worms then separate. After several days, the clitellum of each worm secretes a tube of mucus and a tough carbohydrate known as **chitin** (KIE-tin).

Word Roots and Origins

nephridium

from the Greek *nephros*, meaning "kidney," and *idion*, meaning "small"

As this tube slides forward, it picks up the worm's eggs and the stored sperm from the other worm. Fertilization occurs inside the tube, which closes up to form a protective case. The young worms develop inside the case for 2–3 weeks before hatching.

CLASSES POLYCHAETA AND HIRUDINEA

About two-thirds of all annelids are members of the class Polychaeta. *Polychaeta* means “many bristles,” which refers to the numerous setae that help polychaetes move. The setae project from parapodia, some of which function in gas exchange. Polychaetes differ from other annelids in that they have antennae and specialized mouthparts. They are also the only annelids that have a trochophore stage. Most polychaetes live in marine habitats. Some are free-swimming predators that use their strong jaws to feed on small animals. Others feed on sediment as they burrow through it or use their tentacles to scour the ocean bottom for food.

Hirudinea is the smallest class of annelids, consisting of about 500 species of leeches. Most leeches live in calm bodies of fresh water, but some species live among moist vegetation on land. Leeches have no setae or parapodia. At each end of a leech's body is a sucker that can attach to surfaces. By attaching the anterior sucker and then pulling the rest of the body forward, leeches can crawl along solid objects. Aquatic leeches can also swim with an undulating movement of their body. Many leeches are carnivores that prey on small invertebrates, but some species, including the one shown in Figure 35-12, are parasites that suck blood from other animals. After attaching themselves to the skin of their host, parasitic leeches secrete an anaesthetic that prevents the host from feeling their presence. They also secrete a substance that prevents blood from clotting. If undisturbed, a leech can ingest 10 times its own weight in blood.

FIGURE 35-12

The leech *Haemadipsa* sp. is a parasite that sucks blood from animals, including humans. Other leeches are free-living carnivores.



SECTION 2 REVIEW

1. What are the advantages of a segmented body?
2. How are an earthworm's circular and longitudinal muscles used in locomotion?
3. How does an earthworm exchange oxygen and carbon dioxide with its environment?
4. How do polychaetes differ from earthworms?
5. Describe how some leeches are adapted to a parasitic lifestyle.

CRITICAL THINKING

6. **Analyzing Patterns** In earthworms, blood flows in opposite directions in the dorsal and ventral vessels. How is this helpful to the animal?
7. **Applying Information** Why do you see so many earthworms after a long rainy period?
8. **Recognizing Differences** How is the form of parasitism shown in some leeches different from that of a tapeworm or a liver fluke?

CHAPTER HIGHLIGHTS

SECTION 1

Mollusca

- Mollusks and annelids have true coeloms. Most aquatic mollusks and annelids develop from a trochophore.
- A mollusk's body is divided into the head-foot and the visceral mass, which contains the internal organs. Most mollusks have at least one shell, which is secreted by a layer of epidermis called the mantle. Aquatic mollusks have gills through which gas exchange takes place.
- The main feeding adaptation of most mollusks is the radula, a tonguelike structure that is modified in different species for scraping, drilling, or harpooning.
- Gastropods undergo torsion—the visceral mass twists during larval development. Snails and most other gastropods have a single shell, while some gastropods, such as slugs and nudibranchs, lack shells. Gastropods move by means of wavelike, muscular contractions of the foot and have an open circulatory system.
- Bivalves have a shell that is divided into two valves, which can be pulled together by contracting powerful adductor muscles. Bivalves lack a distinct head and have no radula. Most are sessile and filter food from the water. In clams, water enters through an incurrent siphon and exits through an excurrent siphon. Food is strained from the water as it passes through the gills.
- Cephalopods, including octopuses and squids, are free-swimming, predatory mollusks with numerous tentacles. They have an advanced nervous system with a large brain and well-developed sensory organs. Cephalopods have a closed circulatory system and do not pass through a trochophore stage during development.

Vocabulary

trochophore (p. 705)
visceral mass (p. 706)
mantle (p. 706)
mantle cavity (p. 706)

ganglion (p. 706)
radula (p. 706)
gastropod (p. 707)
hemolymph (p. 707)

hemocoel (p. 707)
bivalve (p. 708)
incurrent siphon (p. 709)
excurrent siphon (p. 709)

cephalopod (p. 710)

SECTION 2

Annelida

- Annelids have a true coelom and a body that is divided into many segments. Most annelids have external bristles called *setae*, and some have fleshy protrusions called *parapodia*.
- The number of setae and the presence or absence of parapodia provide the basis for dividing annelids into three classes: Oligochaeta, Polychaeta, and Hirudinea.
- Segmentation enables the different parts of the body to carry out various functions independently. It also protects the organism in case of injury because uninjured segments can continue to function.
- Members of the class Oligochaeta generally live in the soil or in fresh water. They have no parapodia and relatively few setae.
- The most familiar member of the class Oligochaeta is the earthworm, which feeds on organic matter as it burrows through the soil. Earthworms have a closed circulatory system. They exchange gases through their skin and eliminate cellular wastes and excess water through excretory tubules called *nephridia*.
- Polychaetes have numerous setae that project from parapodia. They also have antennae and specialized mouthparts, and they pass through a trochophore stage during their development. Most polychaetes live in the ocean.
- Members of the class Hirudinea, leeches live in fresh water or on land. They have no setae or parapodia. Many leeches are carnivores that prey on small invertebrates, but some are bloodsucking parasites.

Vocabulary

seta (p. 713)
parapodium (p. 713)
crop (p. 714)

gizzard (p. 714)
typhlosole (p. 714)
aortic arch (p. 715)

nephridium (p. 715)
clitellum (p. 715)
seminal receptacle (p. 715)

chitin (p. 715)

CHAPTER REVIEW

USING VOCABULARY

- For each pair of terms, explain how the meanings of the terms differ.
 - crop* and *gizzard*
 - gastropod* and *cephalopod*
 - setae* and *parapodia*
 - clitellum* and *seminal receptacle*
 - incurrent siphon* and *excurrent siphon*
- Explain the relationship between *hemolymph* and *hemocoel*.
- Choose the term that does not belong in the following group, and explain why it does not belong: *incurrent siphon*, *excurrent siphon*, *trochophore*, and *crop*.
- Word Roots and Origins** The word *chitin* is derived from the Greek *chiton*, meaning “tunic.” Using this information, explain why the term *chitin* is a good name to describe this compound.

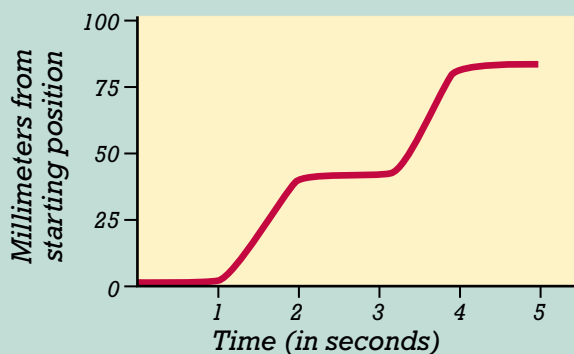
UNDERSTANDING KEY CONCEPTS

- Identify** the functions performed by the cilia on a free-swimming trochophore.
 - List** the main parts in the basic body plan of a mollusk.
 - Describe** the main feeding adaptation of mollusks.
 - Identify** whether or not each of the following mollusks has a shell: nudibranch, clam, snail, and slug.
 - Compare** the body structure of a cephalopod to that of a gastropod.
 - Distinguish** between polychaetes and other annelids. Which characteristics set polychaetes apart?
 - Explain** how segmentation aids movement in earthworms.
 - Summarize** why earthworms require a moist environment to survive.
 - Describe** the organization of an earthworm’s nervous system.
 - Identify** a typical environment in which one member of each of the three classes of annelids may be found.
 - Summarize** the characteristics shared by mollusks and annelids.
- CONCEPT MAPPING** Use the following terms to create a concept map that shows the major characteristics of the phylum Annelida: *annelids*, *segmented worms*, *coelomates*, *setae*, *parapodia*, *Oligochaeta*, *Polychaeta*, *Hirudinea*, *earthworm*, *bearded fireworm*, and *leech*.

CRITICAL THINKING

- Applying Information** If a grain of sand or other irritant gets inside the shell of a bivalve, the mantle coats the irritant with the material that lines the inner layer of the shell. Many layers of this material form a pearl. However, making a pearl consumes resources that an oyster could use for other purposes, such as strengthening its shell. Of what advantage is it to an oyster to make a pearl?
- Inferring Relationships** Clams reproduce by releasing sperm and eggs into the water. How might this process affect the reproductive success of these mollusks? Would you expect clams to release many sperm and eggs or only a few?
- Making Comparisons** Clams are aquatic, and earthworms are terrestrial. Nevertheless, the feeding methods of clams and earthworms are somewhat similar. Explain how they are similar.
- Interpreting Graphics** The graph below plots the movement of the anterior end of an earthworm over time. Was the anterior end moving or stationary during the periods represented by the horizontal sections of the graph? Which of the earthworm’s sets of muscles were contracting during the periods represented by the horizontal sections? Explain.

Earthworm Movement



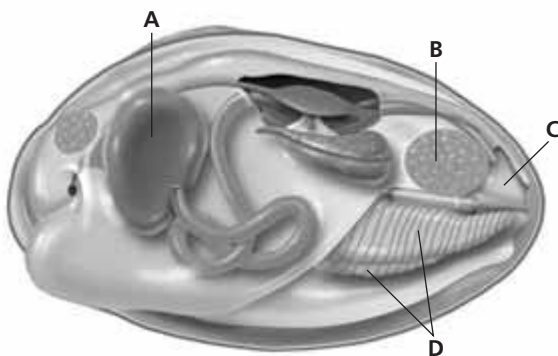


Standardized Test Preparation

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

- Why do terrestrial snails and slugs need an environment with a high moisture content?
 - to avoid drying out
 - to see and hear better
 - to swim more efficiently
 - to avoid being eaten by birds
- Which of the following are the only mollusks with a closed circulatory system?
 - snails
 - bivalves
 - gastropods
 - cephalopods
- Annelids are divided into three classes based partly on the number of which of the following?
 - setae
 - segments
 - nephridia
 - aortic arches
- Parapodia are a distinguishing characteristic of which class of annelids?
 - Bivalvia
 - Hirudinea
 - Polychaeta
 - Oligochaeta

INTERPRETING GRAPHICS: The diagram below shows the internal structure of a bivalve. Use the diagram to answer the questions that follow.

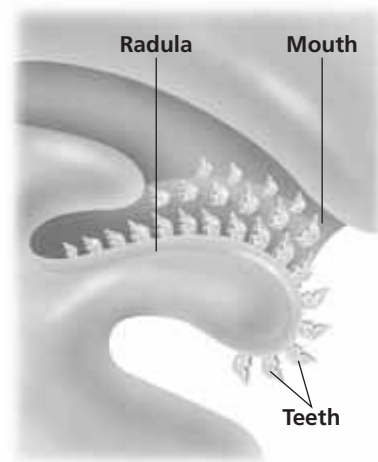


- Which of the structures is involved in respiration and feeding?
 - A
 - B
 - C
 - D
- What is structure B?
 - a gill
 - a siphon
 - the mantle
 - an adductor muscle

DIRECTIONS: Complete the following analogy.

7. Nephridium : excretion :: clitellum :
- digestion
 - circulation
 - respiration
 - reproduction

INTERPRETING GRAPHICS: The diagram below shows the mouth structure of a class of organisms. Use the diagram to answer the question that follows.



8. In which class of organisms is the mouth structure shown above most likely to be found?
- bivalves
 - hirudines
 - gastropods
 - polychaetes

SHORT RESPONSE

During larval development, gastropods undergo a process called *torsion*.

Describe the outcome of torsion.

EXTENDED RESPONSE

Earthworms have three main structural features that enable movement.

Part A Describe these features.

Part B Explain how they work together to enable movement.

Test TIP

In tests, analogies compare pairs of items, such as *kitten : cat :: puppy : ?* Before looking at the possible answers, identify how the first pair of terms is related. For example, since a kitten is a young cat, the relationship is baby : adult, so the correct answer would be *puppy : dog*.

Testing Earthworm Behavior

OBJECTIVES

- Observe a live earthworm.
- Test how an earthworm responds to light, moisture, and ammonia.
- Test the effect of temperature on heart rate.

PROCESS SKILLS

- observing
- hypothesizing
- experimenting
- collecting data
- analyzing data


MATERIALS

- safety goggles
- live earthworm
- shallow pan
- paper towels
- medicine dropper
- hand lens
- black paper or piece of cardboard
- fluorescent lamp
- 2 cotton swabs
- 3% aqueous ammonia solution
- 15 cm Petri dish
- thermometer
- stopwatch or clock with second hand
- 2 plastic tubs for water baths
- warm tap water
- ice cubes

Background

1. How does an earthworm benefit from cephalization?
2. Describe how gases enter and exit an earthworm's body.

PART A Observing an Earthworm

1.  **CAUTION** You will be working with a live animal. Be sure to treat it gently and to follow directions carefully. Place a moist paper towel in a pan, and place an earthworm on the paper towel.

CAUTION Rinse the earthworm frequently with

water from a medicine dropper to prevent the worm from drying out.



2. Observe the behavior of the earthworm for a few minutes. Identify the earthworm's anterior and posterior ends by watching it move in the pan. As the worm crawls around in the pan, it will lead with its anterior end.
3. Locate the earthworm's clitellum. Is the clitellum closer to the anterior end or the posterior end? What is the function of the clitellum?
4. Identify the earthworm's dorsal and ventral surfaces by gently rolling the worm over. The dorsal surface will be on top after the worm rights itself.
5. Pick up the earthworm, and feel its skin with your fingers. One surface of the earthworm should feel slightly rougher than the other. The roughness is due to the hairlike setae that project from the earthworm's skin. On which surface are the setae located? Use a hand lens to examine the setae up close.
6. Return the earthworm to the pan, and use the hand lens to find a thick purple line running along the dorsal surface of the worm. This line is the dorsal blood vessel. Does the earthworm have an open or a closed circulatory system?
7. Draw a picture of the earthworm, and label its anterior and posterior ends, dorsal and ventral surfaces, clitellum, setae, and dorsal blood vessel.

PART B Earthworm Responses to Stimuli


8. In this part of the laboratory investigation, you will test the earthworm's responses to three different stimuli. With your lab partners, develop three separate hypotheses that describe an earthworm's responses to light, moisture, and a base. In your lab report, make a data table like the one on the next page.
9. To test the earthworm's response to light, cover half of the pan with black paper or cardboard. Check the lighting in the room. The light must be low and even during this test. Position the fluorescent lamp over the uncovered portion of the pan. Place the earthworm in the center of the pan, and observe its movements. Record your observations in your data table.




OBSERVATIONS OF EARTHWORM BEHAVIOR

Behavior	Observations
Response to light	
Response to moisture	
Response to water on a swab	
Response to ammonia	

10. To test the earthworm's response to moisture, turn off the fluorescent lamp, move it away from the pan, and remove the paper covering half of the pan. Place a piece of dry paper towel on one side of the pan and a piece of wet paper towel on the other side of the pan. Lay the earthworm across the two paper towels. Observe the earthworm's response to the two environments, and record your observations in your data table.
11. To test the earthworm's response to ammonia, make sure the paper towels on both sides of the pan are wet. Moisten a cotton swab with water. Hold the cotton swab first near the earthworm's anterior end and then near its posterior end. Do not touch the earthworm with the swab. Record your observations in your data table.
12.   **CAUTION** Wear safety goggles at all times during the following procedure. If you get ammonia on your skin or clothing, wash it off at the sink while calling to your teacher. If you get ammonia in your eyes, immediately flush it out at the eyewash station while calling to your teacher. Moisten a different cotton swab with ammonia solution, and repeat step 11. Do not touch the earthworm with the swab or the ammonia solution. Record your observations in your data table.

PART C Effect of Temperature on Heart Rate

13.  In this part of the laboratory investigation, you will examine how an earthworm's heart rate changes as its body temperature changes. Add enough tap water to a Petri dish to barely cover the bottom of the dish. Place an earthworm in the dish.

14. Using a hand lens, look for rhythmic contractions of the dorsal blood vessel. Each contraction represents a single heartbeat. Calculate the worm's heart rate by counting the number of contractions that occur in exactly one minute. This is easiest to do if one person counts contractions while another person watches a stopwatch or clock.
15.  **CAUTION** Glassware is fragile. Notify the teacher of broken glass or cuts. Do not clean up broken glass or spills involving broken glass unless the teacher tells you to do so. Place a thermometer next to the worm in the Petri dish, and measure the temperature. Record the worm's heart rate and the temperature in a table on the chalkboard.
16. Float the Petri dish containing the worm on top of either a warm-water bath or a cold-water bath. Place the thermometer next to the worm in the Petri dish, and watch the temperature until it reaches either 30°C (for the warm-water bath) or 10°C (for the cold-water bath).
17. Remove the Petri dish from the water bath, and immediately begin counting heartbeats for exactly one minute. After one minute, measure the temperature in the dish again. Calculate the average temperature to the nearest degree. Record the worm's heart rate and the average temperature in the table on the chalkboard.
18. Using data from the whole class, graph heart rate as a function of temperature. Draw the best-fit curve through the points.
19.   Return the earthworm to the container from which you obtained it. Clean up your materials, and wash your hands before leaving the lab.

Analysis and Conclusions

1. State whether your hypotheses in Part B were supported by your observations. Explain.
2. What is the adaptive advantage of the earthworm's responses to light and moisture?
3. List variables that, if not controlled, might have affected the results in Part B.
4. Describe the relationship between the earthworm's heart rate and temperature as shown by your graph.

Further Inquiry

Design an experiment to determine which colors of light an earthworm is sensitive to or which areas on an earthworm are sensitive to light.