When you have completed this chapter, you should be able to:

**DESCRIBE** the basic structures and functions of the bivalves.

**DISTINGUISH** among the variety of gastropod forms and functions.

**DISCUSS** the unique shapes and adaptations of the cephalopods.

The recent improvement in water quality in coastal cities such as New York produced an unexpected result. Wood pilings that supported the piers began to collapse. The culprit was a marine invertebrate called the shipworm. Like a termite, the shipworm lives in wood and tunnels through it. Not surprisingly, shipworms prefer wood that is not soaked with pollutants. The return of the shipworm to cleaner harbors has prompted officials to use pilings made of recycled plastic.

The shipworm is really not a worm; it is a *mollusk*, a soft-bodied animal like other clams, snails, and mussels. These mollusks have an outer shell, which serves to protect the soft-bodied animal within. The whelk—a marine snail shown laying its eggs in the photo above—is a mollusk with an outer shell.

However, not all mollusks live in shells. The squid and the octopus are classified as mollusks because they are soft-bodied animals with structural and developmental characteristics similar to those of the shelled mollusks. There are more than 100,000 species of mollusks, all classified into several distinct groups within the phylum Mollusca. In this chapter, you will discover the diversity among the mollusks.
9.1 BIVALVES

The next time you go to the beach, observe the shells that are strewn along the shore. Many of them are the shells of clams, mussels, scallops, and oysters. What do the two mollusks shown in Figure 9-1 have in common? Notice that both mollusks have two shells. Mollusks with two shells are called bivalves (meaning “two shells”). All bivalves (also called pelecypods) are grouped together in the class Bivalvia.

Structures of a Typical Bivalve

All mollusks have soft, bilaterally symmetrical bodies composed of a head, foot, and coiled visceral mass (internal organs), and most have either an external or internal shell. They also have “advanced” features, first seen in the annelids, such as a coelom and a brain. The two shells of a bivalve are hinged together at one end and are kept closed by short, tough adductor muscles. There are two scars on the inside of bivalve shells where the adductor muscles are attached. The clam, oyster, and mussel have two adductor muscles, and the scallop has one. In fact, when you have scallops for dinner, you are eating the adductor muscle.

The clam (Mercenaria) is a common bivalve. There are more than 15,000 species of clams. Most clams live buried in sand in the intertidal and subtidal zones. Sea stars and predatory snails feed on them. After their soft bodies have been consumed, the clams’ empty shells are washed up on the beach by the incoming tide. (See Figure 9-2.)

Interestingly, you can often tell the age of a bivalve by looking at its shell. You may have noticed the lines on clamshells found on the beach. Each line is a new layer of shell that the clam produces as it grows. The lines form bands. Each band represents about a year’s growth, much like the growth rings in a tree. For example, a clam that has four bands would be about four years old. Some bands are wider than others. Can you explain why? Wider bands indicate more growth. In some years, conditions for growth are more favorable, so the clam grows more. (Note: You can examine a clamshell when you do the lab investigation at the end of this chapter.)
of the oldest living clam specimens known is a giant clam (*Tridacna gigas*) from the tropical waters of the South Pacific; it is over 60 years old and weighs more than half a ton.

Mollusk shells are hard due to the presence of the compound calcium carbonate (CaCO₃). How does a bivalve build its shell? A thin membrane called the mantle lines the insides of both shells and protects the internal organs. The mantle contains shell glands that secrete calcium carbonate, thereby producing the shell.

**Life Activities of Bivalves**

Normally, the shells of a bivalve are shut tight, with only a small gap between them. The bivalve cannot feed if its shells are completely closed. However, there are water flow passageways in a siphon tube, which protrudes through a gap between the clam’s shells. This tube can be extended for feeding and breathing, while the rest of the bivalve lies protected under the sand. The siphon has two openings, an **incurrent siphon** and an **excurrent siphon**. Water that contains food and oxygen enters through the incurrent siphon. Waste products of digestion and respiration are eliminated through the excurrent siphon. Since bivalves filter their food from the water, they are examples of filter feeders. As filter feeders, bivalves are responsible for filtering, and thereby cleansing, great quantities of seawater.

Bivalves are adapted to breathe underwater by using gill membranes. In function, gills are like your lungs. They are membranes
that take in oxygen and give off carbon dioxide. Water brought in
through the incumbent siphon flows to the gills. The surface of the
gills contains specialized cells with microscopic cilia. These ciliated
cells beat back and forth, creating the currents of water that enter
and exit the clam. Oxygen that is dissolved in the water flows over
the gills’ surface and diffuses through the gill membranes. Carbon
dioxide diffuses from the gills back into the water. Thus, gas
exchange at the gill surface is how a bivalve breathes. You can
observe the ciliated cells in a bivalve by doing the laboratory inves-
tigation at the end of this chapter.

How does a bivalve filter feed? During filter feeding, currents of
water that contain plankton and organic debris pass into the clam
through its siphon, propelled by the ciliary action of the gill sur-
faces. And how does the clam actually ingest its food? The food par-
ticles in the water get stuck in mucus that coats the surface of the
gills and mantle. The ciliated cells move the food along to the
clam’s mouth, which is located opposite its siphon. Food is digested
in a one-way digestive tract. Wastes exit through the excurrent
siphon. Bivalves have an open circulatory system. Nutrients and
oxygen are transported through their body by a colorless blood.

Bivalves have a variety of adaptations that, by securing them to
a substrate, enable them to filter feed more effectively. The mussel
(Mytilus), shown in Figure 9-1, lives in the turbulent intertidal zone,
where there is constant wave action. Tough byssal threads, which
are made of a fibrous protein, attach the mussel firmly to rocks and
other hard substrates. A gland inside the mussel’s foot secretes the
byssal threads, which extend out from the mussel. Sticky pads at
the end of the threads enable the mussels to cling to surfaces.

The oyster (Crassostrea), shown in Figure 9-1, also lives attached
to a substrate. The shells of the oyster are rough and uneven. The
flat upper shell fits like a lid on top of the more curved lower shell.
The lower shell secretes a cement that adheres to rocks and other
hard substrates. Dental scientists are interested in the chemical
properties of oyster cement, because it might be useful in develop-
ing a new type of filling for teeth.

Besides secreting their shells and cement, under the proper con-
ditions oysters and other bivalves can produce natural pearls. A
pearl is a small, round, shiny bead that has the same composition as
the smooth interior lining of a shell. A natural pearl starts to
develop when a sand grain gets into an oyster and lodges between the mantle and the shell. The mantle tissue reacts to the sand grain as a foreign body and secretes layers of shell around the grain, forming a pearl.

**Movement in Bivalves**

Not all bivalves adhere to substrates; some bivalves move. In fact, bivalves display a variety of adaptations for locomotion. The scallop is the fastest of the bivalves. This fan-shaped mollusk can scoot across the seafloor in sudden spurts. The quick movements are caused when a scallop repeatedly contracts and relaxes its large adductor muscle. The scallop’s shells then open and close, forcing water out from between them, which pushes the bivalve in the opposite direction. (See Figure 9-3.)

Bivalves can also move rapidly through substrates. The razor clam (*Ensis directus*) and the soft-shell clam (*Mya arenaria*) move quickly through the sand by using their muscular foot as a digging tool. (See Figure 9-4.) Burrowing quickly enables the clam to escape from its enemies, including clam diggers—people who dig for soft-shell clams in the intertidal zones at low tide. Clam diggers locate the buried clams by looking for holes in the sand made by the
extended siphon tubes. Some clams, such as the shipworm (*Teredo*), can even burrow through a solid substrate, such as the wood of a ship’s hull or wharf piling. (See Figure 9-5.)

**Reproduction in Bivalves**

The bivalves have separate sexes. Both fertilization and development are external. Females release their eggs into the water, where they are fertilized by sperm cells released by the males. During the early stages of development, the bivalves live as part of the plankton population. When they form their shells, the tiny bivalves sink to the seafloor, where they settle and mature into adults.

**9.1 Section Review**

1. How does a bivalve breathe?
2. Explain how a bivalve feeds.
3. Compare locomotion in the clam and the scallop.

**9.2 Gastropods**

Look at the mollusks illustrated in Figure 9-6. What do these two animals have in common? They both have a single shell and are marine snails, a type of gastropod. The **gastropods** are a diverse group, comprising about two thirds of all mollusk species. These mollusks are also referred to as univalves, meaning “one shell,” which is one of their distinguishing characteristics. All gastropods
are placed in the class Gastropoda (meaning “stomach-foot”). The snail is described below, as representative of a typical gastropod.

**Structures of a Typical Gastropod**

Snails, which are the most common gastropods, have a single coiled shell. (See Figure 9-7.) How does a gastropod carry out its life functions? Look at Figure 9-8, which shows the internal structures of a typical snail. The snail glides along the surface of a substrate on its large muscular foot. Food is ingested through the mouth and digested in a one-way digestive tract. Wastes are eliminated through the anus. Nutrients are transported through the body in an open circulatory system, consisting of a one-chambered heart and tiny blood vessels. Its colorless blood is pushed through tissue spaces by contractions of heart and body muscles. Kidneys excrete cellular (metabolic) wastes. When not feeding or moving about, a snail
retracts its soft body inside its shell. The shell’s opening is then covered by the snail’s **operculum**, a thick pad of tissue that closes like a trapdoor over its foot. The operculum is usually composed of a type of protein; in some snail species, it is calcified.

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**Life Activities of Snails**

The snail breathes by taking in oxygenated water through its siphon tube. Gills inside the snail take up the oxygen and give off carbon dioxide. The anterior tentacles in the head region are the receptors that the snail uses for sensations of touch. Two posterior tentacles, or eyestalks, are used for vision. Impulses from these receptors travel along sensory nerves to a small brain, made up of several pairs of ganglia. Movement is carried out by the nervous and muscular systems working together—impulses from the brain reach the muscles in the foot by way of the motor nerves.

Snails are adapted to crawl and climb in search of food. Most snails move along the seafloor, where they graze on tiny organisms. The periwinkle (*Littorina*), shown (shell only) in Figure 9-6, grazes on algae that grow on the surface of substrates such as rocks and marsh plants. Typical of all gastropods, the periwinkle has a ribbonlike, toothed structure called a **radula**, which it uses to scrape off and ingest the algae.

Other snails, such as the mud snail (*Ilyanassa*), shown in Figure 9-6, are scavengers—they feed on dead, or dying, organisms. If you put an open (dead or dying) clam or mussel into an aquarium with mud snails, they will quickly swarm all over the food. Mud snails feed by using their radula to tear and shred the dead matter into small pieces.

Some snails are predators; they actively hunt and kill their food. Two examples are shown in Figure 9-9. The moon snail (*Neverita*) feeds on live clams. Like many other predatory snails, it secretes chemicals from a gland in its foot to soften the shell of a clam. It then uses its radula to drill a small hole in the hinge area of the clamshell. The moon snail inserts its mouth through the hole and eats the soft-bodied animal inside. You can find clamshells that have these telltale holes washed up on the beach. (If you collect them, you can make a necklace.)

Another type of predatory snail, the cone snail (*Conus*), has
generated great interest for medical researchers around the world. This group of snails, numbering about 500 species, uses toxins to kill its prey. A harpoonlike radula at the end of the snail’s proboscis is used to spear prey, such as small fish, and deliver the poison. The potent toxins that cone snails produce are being studied because they show a variety of effects, such as pain relief, on vertebrate nervous systems.

Reproduction in Snails

Some snail species have separate sexes, while many others are hermaphrodites. Fertilization is internal, and development is external. Snails produce large numbers of offspring. In some species, the females deposit their fertilized eggs directly into the water. Others enclose the developing eggs in a protective covering. The whelk (*Busycon*), another type of predatory snail, produces an egg case composed of several capsules strung together, like beads on a string. (See Figure 9-10.) Each capsule contains one to two dozen embryos developing within it, making a total of several hundred embryos in the whole egg case. You may find the egg case of a whelk on the beach. You can carefully open up one of the capsules with sharp scissors and observe the contents with a hand lens or dissecting microscope. Young egg cases contain the embryos, whereas mature egg cases have “baby” whelks within their tiny shells.

In the moon snail, the eggs develop into larvae within a thin, leathery membrane called a sand collar, which is attached to the shell. The sand collar consists of sand grains cemented together by mucus that is secreted by the moon snail. Within three to five weeks, each larva produces a shell and then settles to the sea.
bottom, where it grows into an adult moon snail. Sexual maturity is reached in about three years.

The mud snail deposits flattened, transparent jelly capsules on substrates in the intertidal zones. Inside the capsules are 50 to 250 fertilized eggs. Within 6 to 7 days, each mud snail egg hatches into a swimming, ciliated larva called a **veliger**. The veligers join the plankton community, where they feed on tiny plankton and are, in turn, eaten by other animals. The production of so great a number of eggs by snails is important, since so many larvae are eaten while in the plankton community.

**Gastropod Diversity**

Look at the three gastropods shown in Figure 9-11. Compare them with the gastropods shown in Figures 9-6 through 9-10. As you can see, the shells in the previous figures are spiral in shape, whereas those in Figure 9-11 are more flat. The biggest of the flat-shelled gastropods is the abalone (**Haliotis**), which inhabits the rocky Pacific Coast, where it grazes on algae that grow on rocks. The inside of an abalone shell has a shiny rainbow pattern of colors referred to as iridescence. Just as the mantle tissue in an oyster can produce pearls, the abalone’s mantle secretes this pearly lustrous material, which is called **mother-of-pearl**. (This material is often used to make jewelry.)

A common gastropod of the intertidal zone is the slipper shell (**Crepidula**). The underside of the slipper shell resembles a slipper or shoe, hence its name. The slipper shell is a filter feeder that strains microorganisms and organic debris from the water. This mollusk lives attached to almost any hard substrate, including the backs of other snails, horseshoe crabs, even old tires and bottles. As the slipper shell grows, it changes its sex from male to female. The slipper shells are often found stacked, one on top of the other, with the
uppermost one being a male. Each level represents a different generation, with the oldest ones (females) on the bottom.

Another flat-shelled gastropod that inhabits the rocky coast in the intertidal zone is the limpet. Like snails, the limpets graze on algae that grow on the rocks. The limpet shell is shaped like a slightly flattened cone. Some species, such as the keyhole limpet (*Diodora*), have a hole at the top of the shell, which allows wastes to exit.

An unusual type of gastropod is shown in Figure 9-12, the sea slug (*Dendronotus*), also called a **nudibranch**. The sea slug and the sea hare (*Aplysia*) are gastropods that either lack shells or have reduced shells. These shy, membranous, beautiful creatures glide along the seafloor in the intertidal and subtidal zones. They breathe through their skin and through decorative tufts of gills on their backs. The sea slug feeds on hydroids and anemones; it uses their stinging cells as part of its own body’s defense by storing them in special projections on its skin. The slug’s dramatic coloration serves as a warning to would-be predators that it would be painful to eat! Sea hares graze on algae; some even turn green from the chlorophyll they consume. Like the cephalopods (see Section 9.3), some sea hares can release dark ink to confuse, and escape from, predators. The California sea hare, which can grow up to 75 cm in length and weigh up to 16 kg, is the biggest gastropod in the ocean.

**9.2 Section Review**

1. Describe two different feeding methods of snails.
2. Compare the feeding methods of slipper shells and limpets.
3. By what means do sea slugs and sea hares breathe?
Look at the two mollusks shown in Figure 9-13. What do these unusual-looking animals have in common with one another? Unlike the gastropods and bivalves, these mollusks are excellent swimmers. The swimming mollusks belong to the class Cephalopoda (meaning “head-foot”), with their prominent features being the head and the tentacles (the “foot”). Referred to as the cephalopods, they swim by a kind of jet propulsion. How are the cephalopods adapted for swimming? Most cephalopods have a streamlined body shape and lack an external shell. Water is drawn into the mantle cavity. When the mantle contracts, water is expelled through the siphon. The cephalopod is propelled in the opposite direction (much as a balloon flies around a room when its air escapes). By moving its siphon tube into different positions, the cephalopod can change directions suddenly. This mobility is coordinated by the cephalopod’s highly developed nervous system.

Figure 9-13 Two common cephalopods, the squid and the octopus.
The octopus is an animal that leads a largely solitary existence. Scientists in Naples, Italy, wanted to find out if octopuses can learn behaviors from one another. The scientists were interested because, even though octopuses are not social animals, they are known to be the most intelligent of the invertebrates.

The researchers set up an aquarium that contained one red ball and one white ball submerged in it. Several octopuses were placed in the tank. They were conditioned to attack the red ball by rewarding them with a fish if they did so. They were taught to avoid the white ball by giving them a mild electric shock if they approached it. After the octopuses were trained to attack the red ball and avoid the white ball, an untrained octopus was put into an adjacent tank to watch them. When the untrained octopus was later tested without being rewarded or shocked, it picked the red ball 129 times out of 150 trials. That’s about an 85 percent success rate!

Scientists were not too surprised by these findings. For its size, the octopus has the largest brain of any invertebrate and has shown signs of intelligence in other situations before. We now know that some of their brainpower is used for learning adaptive behaviors from others in new and challenging situations.

**QUESTIONS**

1. Calculate the failure rate of the untrained octopus. What can explain this outcome?
2. Why is the octopus considered to be so smart?
3. Why was electric shock used in this experiment? Why were fish used?
Structures of a Typical Cephalopod

The cephalopod captures prey, such as fish or crabs, with its tentacles—killing the animal with a bite from its parrotlike beak. In the case of the octopus (*Octopus*), paralyzing venom is often injected into the prey along with the bite. (The blue-ringed octopus is so venomous that it can cause death in humans.) Food is digested in a one-way digestive tract; wastes are eliminated through the anus. Nutrients are distributed through a closed circulatory system.

Compare the number of tentacles in the octopus with that of the squid (*Loligo*), shown in Figure 9-13. The octopus (meaning “eight feet”) has eight tentacles, whereas the squid has ten tentacles (two of which are longer than the others). Notice the numerous suction disks on the tentacles. The suction disks are used for grasping and holding onto prey. In the octopus, the suction disks are also used for climbing and crawling along the seafloor. One species of octopus even crawls onto land to search for food along the shore!

Life Activities of Cephalopods

How do the squid, octopus, and other cephalopods survive without the protection of an external shell? What they lack in external protection, these cephalopods have evolved to make up for in speed and other adaptations. The squid (which retains a long, thin internal shell called a “pen”) is the fastest of all cephalopods. It swims in large schools, which may also give it some protection. The octopus, cuttlefish (*Sepia*), and nautilus (*Nautilus*) are more solitary animals than the squid.

Besides being able to move quickly, these cephalopods use camouflage to avoid being detected. By using camouflage, an animal such as an octopus can change its appearance so that it blends in with the natural surroundings. Special pigmented cells in the skin, called chromatophores, expand and contract, causing changes in skin pattern and coloration that make the animal match its background. Another defense used by these cephalopods is the discharge of a thick cloud of ink into the water. This dark ink cloud can surprise and confuse would-be predators, enabling the cephalopod to escape. Recently, scientists have identified numerous species of drab-colored pygmy octopuses, which rely on their small size, rather than camouflage, to escape detection within coral reefs and kelp forests.
In addition, the octopus's brain and eye are both highly developed. The cephalopod's intelligence and acute vision enhance its ability to seek prey, avoid predators, and communicate.

**Elusive Cephalopods**

Two other types of cephalopods are illustrated in Figure 9-14. Notice that one of them, the nautilus, has an external shell. The **chambered nautilus**, which inhabits the deep waters of the South Pacific Ocean, has a spiral-shaped shell that is divided into compartments. The innermost compartments are gas-filled, which helps the animal regulate its buoyancy. The nautilus lives in the outermost compartment, slowly moving up and down in the water, with its sticky tentacles (approximately 40 to 90 of them) extended to capture crabs and other prey. However, it is not a very active hunter, since it swims more slowly than other cephalopods.

The **cuttlefish** is a bottom-dwelling cephalopod that feeds on invertebrates in the sand. An internal shell composed of calcium carbonate, known as the cuttlebone (which is either coiled or flat, depending on the species), adds support to the cuttlefish's soft, streamlined body. Like the squid, the cuttlefish has ten tentacles, two of which are long and slender with suckers on the end. (See Figure 9-14.)

The largest of the swimming mollusks, and also the largest invertebrate, is the giant squid *Architeuthis* (meaning “chief squid”). Over the years, fishermen have seen a few live giant squid, and dead ones have been netted and found washed up on the beach. However, an adult giant squid has never been captured alive. The giant squid...
squid, which resembles the common squid in structure, but which can grow to a length of about 20 meters (including tentacles), inhabits the deep parts of the ocean, between 300 and 600 meters. There, deep in the sea, the sperm whale (*Physeter*) hunts and eats it. What evidence shows that the sperm whale feeds on giant squid? Body parts, such as beaks, from giant squid have been found in sperm whale stomachs. Also, large circular marks made by giant squid suction disks have been seen on sperm whales, proving that these two giants do fight. Marine biologists are now using submersibles and robots to try to locate live giant squid in the deep. In addition, squid specialists are trying to capture and raise juvenile giant squid from the species’ breeding grounds off the coast of New Zealand. Unfortunately, the tiny squid are hard to find and even harder to keep alive in captivity.

**Reproduction in Cephalopods**

With the exception of the nautilus, cephalopods breed in shallow water. Males and females are separate. Fertilization is internal and development is external. The male cephalopod delivers a packet of sperm to the female, often using a tentacle to place it within her mantle cavity. The female squid deposits clusters of fertilized eggs that look like rice grains on rocks and shells. Most of the squid die after mating, leaving the eggs to develop on their own. Hatching occurs after two weeks, and the young emerge looking like miniature adult squid. The female octopus deposits clusters of thousands of fertilized eggs that look like grapes, attaching them to rocks and seaweed. The octopus protects and cleans her eggs, staying with them until they hatch, which may take as long as four months. After the eggs hatch, the mother usually dies of starvation, having not eaten during the incubation period.

**9.3 Section Review**

1. In what ways does the soft-bodied squid protect itself from predators?
2. Describe the unusual method of cephalopod locomotion. Why is it adaptive?
3. How does the octopus catch and subdue its prey?
9.4 OTHER MOLLUSKS

Chitons

So far you have studied three classes of mollusks: bivalves, gastropods, and cephalopods. How would you classify another mollusk, the chiton, shown in Figure 9-15? Unlike many mollusks, chitons have no eyes or tentacles on their heads. Also, notice the overlapping shells, a characteristic not found in any of the other mollusks. The chiton is assigned to its own class, Polyplacophora (meaning “many plates”). Chitons inhabit the rocky intertidal zones around the world. They vary in size from 1 to 40 cm in length. Chitons possess eight overlapping shells, which give the animal some flexibility. The shells cover a muscular foot that is used to grasp and glide over the surfaces of the rocky substrate. As the chiton moves along, it feeds (like a snail) by scraping algae off the rocks with its radula.

Scaphopods

Another small class of mollusks, called Scaphopoda, consists of the tusk shells, named for their tapering shell shape. (See Figure 9-16.) Most species of tusk shells, also called scaphopods, burrow in the sand of deep waters, while some live in the sediments of shallow tropical waters. Their long foot helps anchor them in the sand. Tusk shells have numerous long, thin tentacles with sticky ends, which they use to capture tiny worms and plankton found in the sand. The tentacles then push the food to the tusk shell’s mouth. Empty tusk shells are often found washed up on the beach; they are sometimes made into decorative ornaments. Native Americans used the tusk shells to make necklaces and valued them as a form of currency known as wampum.

9.4 Section Review

1. How is the chiton adapted to live in the rocky intertidal zone?
2. Describe the feeding method of the tusk shell.
3. In what kinds of environments do tusk shells live?
Laboratory Investigation 9

Feeding in a Bivalve

PROBLEM: How does a bivalve filter feed?

SKILL: Observing the action of ciliated cells under a microscope.

MATERIALS: Live clams or blue mussels, shallow bowls, seawater, medicine dropper, food coloring, hand lens, dissecting trays, newspapers, small rock, forceps, carmine powder, slides, coverslips, dissecting needles, microscope.

PROCEDURE

1. Put a live clam or mussel in a bowl and cover it with seawater. Using a medicine dropper, squeeze out a few drops of food coloring near the edge of its shell. Notice what happens. Enter your observations in your notebook. If the bivalve is alive (and it should be!), the dye should enter through the siphon. Observe the siphon with your hand lens. Make a sketch of the bivalve; draw and label its siphon. (See Figure 9-17.)

2. Remove the bivalve from the bowl and place it on a tray lined with newspapers or hold it in the palm of your hand. Open the bivalve by gently tapping one shell with a small rock until it cracks. Remove the pieces of shell with forceps. Try not to pull away the underlying tissues. (Note: It may work best to hold the bivalve in your hand, so that both shells do not crack.)

Figure 9-17 Internal structures of a clam.
3. Put the bivalve back in a bowl and cover it with seawater. The top layer of tissue is a thin membrane called the mantle. Parts of the mantle may be stuck to the shell fragments. Glands in the mantle secrete the shell.

4. Under the mantle lie several overlapping membranes coated with a thick fluid or mucus. These membranes are the gills. Sprinkle a few particles of carmine powder on the gills. Wait and see what happens. The particles are moved along by the action of special cells on the surface of the gills.

5. With your forceps, pull out a tiny piece of gill membrane and put it on a glass slide. Use dissecting needles to tease the piece of gill into even smaller pieces. Add a few drops of seawater to the teased pieces and put a coverslip over the slide.

6. Observe this wet mount under the low power of the microscope. Look for currents of moving water. Focus on the cells. Notice the tiny hairs beating back and forth. The hairs that are attached to the surface of these specialized cells are the cilia. The beating of the cilia causes the currents of water.

7. Turn to high power. Notice that each cell has a single hair, or cilium. Draw and label a row of ciliated cells.

OBSERVATIONS AND ANALYSES

1. How does a bivalve filter feed? What is the siphon’s role?
2. Describe the action of the cilia. Why are they so important?
3. Why was food coloring used in this experiment?
Chapter 9 Review

Answer the following questions on a separate sheet of paper.

Vocabulary
The following list contains all the boldface terms in this chapter.
adductor muscles, bivalves, byssal threads, cephalopods, chambered nautilus, chiton, chromatophores, cuttlefish, excurrent siphon, gastropods, incumbent siphon, mantle, mollusks, nudibranch, operculum, radula, scaphopods, siphon, tusk shells, veliger

Fill In
Use one of the vocabulary terms listed above to complete each sentence.

1. A membrane called the __________ lines the inside of bivalve shells.
2. Oxygen and food are taken in through a clam’s __________.
3. Gastropods use a toothed structure called a __________ to feed.
4. A mussel secretes __________ to attach its shell to a substrate.
5. Respiratory and digestive wastes exit from a clam’s __________.

Think and Write
Use the information in this chapter to respond to these items.

6. Describe the special adaptation that mussels have for surviving strong wave action along the shore.
7. Why do you think the squid and the octopus have camouflage, whereas the bivalves and gastropods do not?
8. Compare the feeding methods of bivalves and gastropods.

Inquiry
Base your answers to questions 9 through 12 on the following data and on your knowledge of marine science.

A marine science student learned in her biology class that the normal movement of cilia inside the human respiratory system helps rid the lungs of harmful airborne substances. Upon doing further
research, she also learned that tobacco smoke can slow down or even stop the beating of cilia (possibly leading to lung cancer). The student decided to test the effect of cigarette tobacco on the movement of cilia in the ribbed mussel, since its gills are lined with numerous cilia. She placed the gill tissue from a ribbed mussel in two Petri dishes: one containing seawater only (the control) and the other containing seawater and a tobacco extract (the experimental group). The gill tissue in the experimental group was exposed to the chemical extract for a period of 10 days. Observations were made on ciliary activity in both groups, recorded four times a day on each of the 10 days. Results are shown in the table below.

**EFFECT OF TOBACCO EXTRACT ON CILIARY ACTIVITY IN RIBBED MUSSELS (MODIOLUS DEMISSUS)**

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity Levels of Experimental Group (exposed to tobacco extract)</th>
<th>Activity Levels of Control Group (not exposed to tobacco extract)</th>
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*Key to activity levels: 6 = very active; 3 = moderately active; 1 = least active; 0 = no activity.

9. The results of this experiment show that ciliary activity
   a. stops in the control group after the fourth day  b. stops in the experimental group after the fourth day  c. increases in the control group after the fourth day  d. increases in the experimental group after the fourth day.
10. Which is an accurate statement regarding this experiment? 
   a. The experiment was done without prior research.   b. It was not carried out as a controlled experiment.   c. The student did not quantify her results.   d. The biology of the ribbed mussel was used as a model for understanding human biology.

11. Which statement represents a valid conclusion that can be drawn from this experiment?  
   a. Tobacco extract has no effect on ciliary activity.  
   b. Ciliary activity in gills cannot be studied outside the living animal.  
   c. Tobacco extract does have an effect on the level of ciliary activity in ribbed mussels.  
   d. There is not enough information to draw any tentative conclusions.

12. In a complete sentence or two, describe what effect, if any, the tobacco extract has on ciliary activity in gill tissue, and provide a reasonable scientific explanation for the results that were observed and recorded.

**Multiple Choice**

Choose the response that best completes the sentence or answers the question.

13. A snail closes its shell opening with a pad of tissue called the
   a. shell   b. foot   c. operculum   d. mantle.

14. Which of the following is a bivalve mollusk?  
   a. oyster  
   b. snail  
   c. whelk  
   d. nautilus

15. An example of a univalve mollusk is the  
   a. clam  
   b. mussel  
   c. scallop  
   d. snail.

16. The structure in a clam that secretes the shell is the  
   a. siphon  
   b. foot  
   c. gills  
   d. mantle.

17. A filter-feeding mollusk is the  
   a. moon snail  
   b. mussel  
   c. mud snail  
   d. whelk.

18. Of the following mollusks, which one is least related to the others?  
   a. snail  
   b. scallop  
   c. mussel  
   d. clam

19. All the following are cephalopods except the  
   a. octopus  
   b. chiton  
   c. squid  
   d. nautilus.
20. The gastropod that lacks a shell is the  
   a. cuttlefish  
   b. nudibranch  
   c. nautilus  
   d. squid.

21. All the following live mostly in or on a substrate except the  
   a. mussel  
   b. scaphopod  
   c. cephalopod  
   d. cone snail.

Refer to the following figure to answer questions 22 and 23.

22. The mollusk shown here would be  
    classified as a  
    a. univalve  
    b. bivalve  
    c. pelecypod  
    d. cephalopod.

23. What is the function of the structures  
    on top of its head?  
    a. vision  
    b. respiration  
    c. defense  
    d. food-getting

24. All of the following are gastropods except the  
    a. slipper shell  
    b. limpet  
    c. scallop  
    d. moon snail.

25. The class of mollusks that contains many species without  
    shells is  
    a. bivalves  
    b. scaphopods  
    c. chitons  
    d. cephalopods.

26. What characteristics do the two mollusks shown here have in common?  
    a. Both are filter feeders.  
    b. Both are soft-bodied animals.  
    c. Both have stinging tentacles.  
    d. Both have external shells.

Research/Activity

If you live near the coast, go to the beach and pick up a variety of shells. (Make sure they are no longer inhabited!) Try to include both bivalves and univalves in your collection. Identify the shells with their common and scientific names. Make a display of the shells and present your project to the class.