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

DISTINGUISH between the different life zones along a shore.
DISCUSS the characteristics of a variety of marine environments.
DESCRIBE the typical inhabitants of these marine environments.

We all need a place to live. The place, or “home,” in which an organism is typically found is called its habitat. The total surroundings of a living thing are called the environment. The ocean contains various kinds of environments; some are located along the coast, while others are found far out at sea.

Environments have living (biological) and nonliving (physical and chemical) components. The living (biotic) things in an environment are called the biota. A coral reef’s biota, for example, includes algae, fish, crustaceans, cnidarians, sponges, bacteria, and any other forms of life that inhabit the area. The nonliving (abiotic) parts of a coral reef environment include the water chemistry, light, temperature, salinity, and water pressure, to name a few. Interactions among the biotic and abiotic factors characterize all environments. In this chapter, you will learn about important marine environments in order to understand how each provides a home for living things.
3.1 MARINE LIFE ZONES

Where in the vastness of the ocean can marine organisms be found? Fortunately, you don’t have to travel very far. Many marine plants and animals live along the coast. Look at the profile of a coast shown in Figure 3-1 on page 62, which illustrates some life zones on a sandy beach. A life zone is a region that contains characteristic organisms that interact with one another and with their environment. One important coastal life zone is the intertidal zone.

The Intertidal Zone

The intertidal zone is the area located between high tide and low tide. At high tide the ocean reaches its highest point along a beach, and at low tide the ocean is at its lowest level. High tide is marked by the strandline, a long line of seaweed and debris deposited on the beach during each high tide. (See Figure 3-2 on page 63.) If you were to turn the seaweed over, tiny crustaceans called beach hoppers, or beach fleas, would dart and jump about. When the tide is low, you can walk in the intertidal zone and find a variety of marine invertebrates, including other crustaceans, worms, and mollusks. Organisms that live in the intertidal zone are well adapted to meeting the challenges of living in an area that has alternating periods of wet and dry, as the tides come in and go out each day.

The Supratidal Zone

When you go to the beach, you put your blanket or towel down in a life zone called the supratidal zone, which is the area above the intertidal zone, up to the sand dunes. Even though you may be a good distance from the ocean, you can smell it because the supratidal zone gets a fine mist of salt spray from the crashing waves. However, the salt spray limits the growth of plants in the lower supratidal zone. In the upper supratidal zone, where there is less salt spray, many species of grasses, shrubs, and trees grow. (Refer to Figure 3-1 on page 62.)
Below the low tide line is the subtidal zone, the coastal life zone that remains underwater. The **subtidal zone** includes an area of heavy wave impact, and the sandy area beyond that, which is affected by underwater turbulence. Some organisms in this zone have structures that help them cling to hard substrates; this pre-
vents their being swept away by waves and currents. (Refer to Figure 3-1.) For example, encrusting sponges secrete an acid that enables them to bore into rocks and shells. These shells are often found on the beach, pockmarked with holes from the sponges. Another clinging animal is the sea star. Sea stars cling to hard surfaces by means of suction from their tube feet. Pounding waves cannot dislodge marine snails or sea anemones, which cling to hard surfaces using their muscular feet. Mussels and barnacles receive the full force of wave impact along sandy and rocky shores, but they manage to stay put. Mussels cling to the rocks by secreting tough, fibrous byssal threads that stick to hard substrates. The barnacle has the strongest attachment, because it literally cements itself with glue to rocks and other hard substrates. Clinging organisms also include marine algae, such as kelp and rockweed, which are anchored to rocky surfaces by a fibrous pad of tissue called a holdfast. (Organisms in the intertidal zone also experience the stress of wave impact; read about the surf zone below.)

Many organisms that live in the subtidal zone possess flattened bodies. A flat body minimizes exposure to wave impact. Flat fish such as the flounder avoid turbulence, as well as their enemies, by burying themselves in the sand. Only their gill cover and eyes poke through the sand. While buried, the flounder might happen to see its prey, the sand dollar, another flat inhabitant of the subtidal zone. The sand dollar uses its tube feet to move slowly along the sandy...
seafloor, where it feeds on algae and dead organic matter. Other inhabitants of the subtidal zone are crabs, shrimp, clams, snails, and worms, which are eaten by fish swimming above the sandy bottom.

The Pelagic Zone

The largest life zone in the ocean is the pelagic zone. (See Figure 3-3.) The pelagic zone covers the entire ocean of water above the sea bottom—that vast region where large schools of fish and pods of marine mammals swim freely. The pelagic zone includes the neritic zone (fewer than 200 meters in depth) and the oceanic zone (more than 200 meters in depth).

The Neritic Zone

Beyond the subtidal zone is a life zone called the neritic zone. The neritic zone is the region of water that lies above the continental shelf, the relatively shallow part of the seafloor that adjoins the continents. When people go deep-sea fishing, they are actually in the neritic zone. In fact, most of the world’s commercial fishing takes place within the neritic zone.
place in the neritic zone. Why is the neritic zone so productive? Rivers that contain runoff from the land flow into the neritic zone, thus providing nutrients for plankton. In addition, much of the neritic zone’s depths are sunlit, so algae, phytoplankton, and marine plants can carry on photosynthesis, the food-making process on which most living things depend.

The Oceanic Zone

The oceanic zone is the life zone that extends beyond the neritic zone and includes most of the open ocean. The upper part of the oceanic zone receives light, whereas the lower part (most of the ocean) is in darkness. The part of the ocean that light penetrates is called the photic (meaning “light”) zone, which is the area most suitable for supporting life. (This is also called the euphotic zone.) Most light penetrates to an average depth of about 100 meters, and to a maximum depth of about 200 meters, within the photic zone. Ninety-nine percent of all sunlight that enters the water is absorbed within the photic zone. The vast area below, which is dark, is called the aphotic (meaning “no light”) zone. There is more life in the photic zone, because light promotes the growth of algae and plants, which provide a source of food for marine animals. As a result, more communities of organisms develop in the photic zone than in the aphotic zone. Communities are made up of populations of different species of organisms that interact with one another and with their environment.

Although there are fewer communities of organisms in the aphotic zone, numerous life-forms, such as fish, worms, squid, and crustaceans, have been observed and photographed in the great depths of the ocean. Deep-sea organisms are specially adapted to live in the depths of the ocean. An adaptation is any characteristic of an organism that enables it to live successfully in its environment. The anglerfish, for example, is adapted to live in the deep ocean because it possesses a huge mouth and long sharp teeth to help it catch prey in the darkness. It even has a lure over its mouth that glows in the dark, making it possible for the fish to see and attract prey. (See Chapter 12.) Other deep-sea fishes have mouths that are pointed upward, which helps them catch the scraps of food that fall from shallower waters.
Marine biologists who specialize in deep-sea organisms are having a field day—they have recently discovered an oasis of life in the deep ocean, an area that had previously been thought to be a biological wasteland. The scientists have probed deep down in the Atlantic and Pacific oceans and found a surprising diversity of life among the benthos, or bottom-dwelling organisms. This biodiversity was unexpected because biologists did not think the seafloor had the features and conditions necessary to promote the evolution of so many different, yet closely related, organisms.

A great variety of benthos were collected by use of new sampling equipment controlled by ships at the surface. One piece of equipment consisted of a box corer (a device that looks like a cookie cutter), which sampled bottom sediments. A more typical tool, a fine mesh net, scooped up specimens from along the seafloor. Marine biologists can collect specimens in this manner from as far down as 1.3 km. One sample contained nearly 1600 different species, including various slugs, snails, crabs, worms, sea stars, and anemones. Many samples were collected that contained species never seen before. Scientists now estimate that the deep ocean may contain ten million or more species of invertebrates—much more than the number of invertebrate species known to live on land.

Many questions remain about the evolution and adaptations of deep-sea benthos. How do so many different types of organisms survive in this pitch-black region of near-freezing temperatures and crushing pressure? How does the environment provide nourishment to support the high numbers? These questions have even given rise to some speculation that much larger animals may exist in the deep that are still unknown to science. We may never know for certain. But it is likely that, in light of the recent findings, more comprehensive explorations of the deep seafloor will continue to be undertaken.

**QUESTIONS**

1. Why were marine scientists surprised by the biodiversity among the benthos?
2. What kinds of organisms have been found in the samples that were collected?
3. How do scientists collect invertebrates that live more than 1 km deep?
The deepest part of the ocean floor is the ocean basin, or abyssal plain, which is also home to a variety of organisms. Many fish and invertebrates inhabit the bottom and rarely swim near the surface. Bottom-dwelling organisms that live on the seafloor inhabit an area called the benthic zone. The benthic zone actually includes the entire ocean floor, from the shallow intertidal zone to the deep ocean basin. Organisms that inhabit the benthic zone are called benthos. The benthos that live in the ocean basin are adapted to regions of very low temperatures and very high pressure.

3.1 Section Review

1. Which life zone is more productive, the neritic or the oceanic? Explain.

2. How are some benthic organisms adapted to live in turbulent waters?

3. Why might it be hard for deep-sea fish to find food? What adaptations do they have for this?

3.2 The Sandy Beach Environment

One of the most familiar environments along the shore is the sandy beach. Sandy beaches are composed of sand, a loose sediment that is easily shifted and moved about by wind and water. This battering by wind and water makes the sandy beach a rather harsh environment, yet it provides a variety of habitats for living things. If you were to walk from the upper beach area down to the shore, you would pass through some of the life zones described in Section 3.1. Each zone contains a particular group of organisms that share the habitat. This pattern of marine life, which forms distinct bands, or life zones, along the shore is called zonation. The upper beach contains a zone of beach plants that includes trees, shrubs, and grasses. The roots of these plants hold onto the sand and prevent its erosion by wind and water. The sand collects in small hills, or dunes. The trees occupy the highest elevations in the dunes, followed by shrubs growing along the slopes of the dunes and beach grasses at the lower levels. (See Figure 3-4 on page 68.)
If you continued your walk down the beach to the water, you would pass through the area of wet sand called the intertidal zone. When covered with water, the intertidal zone harbors a variety of marine animals. When the tide goes out, some of these animals, such as fish and crabs, retreat to deeper waters, while others, such as marine worms and the mud snail and other mollusks, stay behind and burrow in the moist sand.

The Surf Zone

The typical sandy beach has a region of crashing waves called the surf zone, which is white with foam as a result of air mixing with water as waves pound on the shore. The surf zone is not a fixed zone. Instead it moves with the tide as it advances and retreats on the slope of the beach, from the subtidal to the intertidal zones. Since the water in this zone is in constant motion, the sand is pushed and moved about by wave action. For creatures that live in the surf zone, life is like always being in a storm. (See Figure 3-5.)

Some small marine animals, such as the mole crab (Emertia) and the surf clam (Spisula), have managed to adapt to the turbulence of the surf zone. The mole crab avoids the waves by using its paddlelike appendages to dig into the sand. From there, it feeds on microscopic organisms by sticking its feathery appendages up into the water. Its smooth jelly-bean shape helps the mole crab swim with minimal resistance through swirling mixtures of sand and water. (See Figure
The thick shell of the surf clam protects it against wave impact and erosion from moving sand; and the surf clam’s large muscular foot enables it to dig quickly into the sand to avoid predators.

When the tide is out and you are walking in shallow water, you are in the subtidal zone. You would have to be careful where you stepped—you could be pinched by the sharp claws of a sand crab, such as the lady crab (*Ovalipes ocellatus*) or the blue claw crab (*Callinectes sapidus*). Like the mole crab, they swim and dig in the sand by means of their paddlelike appendages; and they hide from predators by burrowing in the sand, with only their eyestalks sticking up. These crabs usually feed on scraps of food, but occasionally they catch small fish such as silversides (*Menidia*), which swim in schools in the oxygenated waters of the surf zone. The silversides feed on invertebrates and crab eggs, and are, in turn, preyed on by larger fish such as the striped bass (*Morone saxatilis*), which swim into the shallows from the deeper sea.

**3.2 Section Review**

1. What factors influence the zonation along a sandy beach?
2. Compare the habitat of the upper beach with that of the intertidal zone. What kinds of plants or animals are typical of each zone?
3. How are conditions for life in a sandy beach’s intertidal zone different from those in its subtidal zone?
3.3 THE ROCKY COAST ENVIRONMENT

Many coastal states, such as Maine, California, Oregon, Washington, Alaska, and Hawaii, have shores composed of solid rock. Shores made up of solid rock are called rocky coasts. What kind of environment for living things is provided by a rocky coast? Look at the typical rocky coast shown in Figure 3-7. Rocks provide a surface on which marine organisms can attach themselves. When the tide is out, you can see seaweeds clinging to the rocks. Similar to that of a sandy beach, the rocky coast shows zones of habitats, with each made up of different communities of living things. Typically, four major bands, or zones, of life can be observed: the upper intertidal, mid-intertidal, lower intertidal, and subtidal zones. (See Figure 3-8.)

The Upper Intertidal Zone

The upper intertidal zone, or wave splash zone, is the area above the high-tide mark that gets moisture from the ocean spray of crashing waves. The moist rocks provide an environment for the growth of blue-green bacteria (formerly called blue-green algae), which form a thin film on the rocks. These photosynthetic organisms absorb water from the splashing waves and take in CO₂ from

Figure 3-7 The rocky coast shows distinct bands of different seaweeds.
the air to produce food and oxygen. When the bacteria die, they stain the rocks black, causing a discoloration that is often mistaken for an oil spill.

The periwinkle snail (*Littorina littorea*) feeds on algae in the upper intertidal zone. The snails scrape the algae off the rocks with their rasping mouthpart, called a radula. The limpet, which is another mollusk, also grazes on algae in this zone.
The Mid-Intertidal Zone

Below the upper intertidal zone lies the mid-intertidal zone, which is occupied largely by barnacles, mussels, and seaweeds. Two common species of barnacles, the rock barnacle (*Balanus balanoides*) and the bay barnacle (*B. improvisus*), can be found glued to the rocks. Barnacles adhere to the rocks so strongly that the most powerful wave cannot dislodge them.

At high tide, barnacles are covered by water. During this time, they filter feed on plankton and organic debris by rhythmically whipping their feathery cirri to capture food. (You can observe filter feeding in the barnacle by doing the investigation at the end of this chapter.) When the tide goes out, the barnacles are exposed to air for several hours, so they shut their shells tight to keep from drying. The barnacle's sharp, overlapping shells also help to protect it from predators. However, a marine snail called the dog whelk (*Nucella lapilli*) can drill a hole through the shell and eat the barnacle. (The whelk produces an acidic secretion from its foot gland, which softens the barnacle shell before the whelk drills into it with its radula.) Along the rocky coast of the Pacific Northwest, the giant acorn barnacle (*B. nubilis*) grows up to 100 millimeters (mm) in size; this barnacle is traditionally harvested and eaten by Native Americans.

Below the layer of barnacles lie seaweeds and a densely packed bed of mussels. As mentioned above, mussels attach to the rocks by means of byssal threads. The threads prevent the mussels from being dislodged by waves. Like barnacles, mussels are filter feeders. The beating of the mussels' tiny cilia (on the surface of their gill membranes) creates currents that carry food and oxygen into, and wastes out of, their shells.

This bed of mussels attracts several predators. The dog whelk that eats barnacles also eats mussels. Sea stars raid the mussel beds and consume large numbers of these bivalves. The blackfish, or tautog (*Tautoga onitis*), has well-developed front teeth that can crush mussels. (A popular food fish caught by anglers from rock jetties and piers, it inhabits Atlantic waters from Nova Scotia to the Carolinas.) The blue mussel (*Mytilus edulis*) is found along the Atlantic and Pacific coasts and is harvested and eaten by humans.

The brown seaweed called rockweed (*Fucus*) also lives in the mid-intertidal zone. When the tide is low, thick mats of rockweed
can be seen draped over the rocks. The seaweed clings to the rocks by means of its holdfast pad. Rockweed provides cover for a variety of marine animals that live in and among the rocks, such as snails, limpets, small crabs, and worms. When the tide is high, rockweed floats near the surface, buoyed up by its gas-filled bladders.

The Lower Intertidal Zone

Below the bed of mussels lies the lower intertidal zone, which is dominated by seaweeds. The red seaweed commonly known as Irish moss (*Chondrus crispus*) grows like a thick carpet over the rocks in this zone. When the tide is low, spaces between the rocks retain water, forming small habitats known as tide pools. (See Figure 3-9.) Tide pools are like natural aquarium tanks that contain algae, invertebrates (such as snails and crabs), and small fish.

The Subtidal Zone

Below the lower intertidal zone is the underwater subtidal zone. The rocky coast subtidal zone has an abundance of life. The best way to observe life in the subtidal zone is by snorkeling. You can observe sea urchins and snails grazing on algae. Sea urchins eat giant kelp,
the biggest seaweed in the ocean, by feeding on its holdfasts. Sea stars cling to the rocks. The movement of the sea stars is dictated by the tides. When the tide comes in, the sea stars move from the subtidal zone to the intertidal zone to feed on the mussels. There is also a variety of sea anemones, as well as crabs and lobsters, hiding in the rock crevices. Lobsters come out of their hiding places at night to feed. Predatory fish that swim in from the open ocean prey on the abundant invertebrates.

### 3.3 Section Review

1. How do the rocky coast life zones differ from those of the sandy beach?
2. Compare the types of organisms found in the upper intertidal zone with those found in the lower intertidal zone.
3. Describe the organisms that are typical of the rocky coast mid-intertidal zone.

### 3.4 The Estuary Environment

Along many coasts, freshwater rivers drain into the ocean. At the mouth of a river, where it enters the ocean, salt water and freshwater mix, forming the type of environment known as an *estuary*. Along the shores of an estuary, there are many inland bays and creeks. (See Figure 3-10.) The varied terrain of an estuary, along with its *brackish* water (the mixture of freshwater and seawater), provides diverse habitats for marine life. In fact, an estuary is one of...
the most productive environments found along any coast. Many types of organisms lay their eggs in an estuary, and the young of many species develop in this nutrient-rich environment.

Many estuaries were formed at the end of the last Ice Age, about 10,000 to 15,000 years ago, when glaciers melted and the sea level rose. The ocean invaded low-lying coastal areas, flooding the mouths of rivers and streams. Sediments carried in by the ocean were deposited offshore, forming long ridges of sand called barrier beaches. On one side of a barrier beach is the bay and on the other side is the open ocean. The estuary lies on the bay side of a barrier beach. (See Figure 3-11.)

Estuaries have calm waters because they are protected from heavy wave impact by the barrier beaches. The estuaries have become natural sanctuaries for a wide variety of marine plants and animals. As a result, several different natural communities have been identified in the estuary environment.

The Salt Marsh Community

In many estuaries along the Atlantic, Pacific, and Gulf coasts, grasses grow abundantly in the shallow water, forming a salt marsh community, or wetlands. Look at a typical salt marsh community,
shown in Figure 3-12. Marsh grasses are the dominant species in the salt marsh. One type of grass, called cordgrass (*Spartina*), is tough, coarse, and resistant to the killing effects of salt; special glands in its leaves secrete salt crystals. Few animals eat cordgrass because it is tough and has a high salt content. However, since it is a producer, cordgrass is high in nutrients. After cordgrass dies, its dead organic matter is acted on by decay bacteria. Such decaying organic matter is referred to as *detritus*. During the process of decay, nutrients from cordgrass, and other forms of detritus, are released into the estuary's waters. (See Figure 3-13.)

The nutrients, which include phosphates (used for energy) and nitrates (used for growth), are taken up by plankton. The plankton flourish and become a food source for a variety of filter feeders. One of the filter feeders is the ribbed mussel (*Modiolus demissus*), which lives half buried in the mud. The water currents created by the mussel's cilia also benefit the cordgrass by increasing water circulation around its roots. Attached to the mussels are barnacles, which also filter feed. The tangle of cordgrass roots acts as a net to trap organic debris, which is consumed by another inhabitant of the salt marsh, the common shore shrimp (*Palaemonetes vulgaris*).

The lives of many inhabitants of the salt marsh are controlled by the tides. When the tide is low, small fiddler crabs (*Uca*) emerge from their holes in the sand to feed on bits of organic matter left
behind by the outgoing tide. If approached, they make a quick retreat into the nearest hole. Before the tide comes in, the fiddler crabs return to their tunnels and plug up the entrances.

Another crustacean that feeds on organic debris in the salt marsh is the hermit crab (*Pagarus*). You can see hermit crabs scurrying about in the shallow tidal creeks, feeding on food particles in the sand. Since they have soft, unprotected abdomens, hermit crabs live inside empty snail shells to protect themselves from predators. When hermit crabs outgrow their snail shells, they look for larger ones to inhabit.

The calm and nutrient-rich waters of the salt marsh provide an ideal environment for marine animals to produce offspring. In fact, these wetlands, which are home to a great variety of fish, are often described as the important “nurseries” for many species of ocean fish. Young flounders are among these fish. The flounders feed on killifish (*Fundulus*), which are regular inhabitants of the salt marsh. The killifish, in turn, feed on insect larvae.

The fish and invertebrates that inhabit the salt marsh are a food source for the many bird, reptile, and mammal species that live in and around the marsh. Many migratory birds also depend on the wetlands for food as they fly both north and south each year.
The Mud Flat Community

The part of the estuary environment that is characterized by dark, muddy sand and no marsh grasses is called the tidal mud flat community. The mud flat has a slightly sloping beach touched by gentle waves. (See Figure 3-14.) There is very little aeration of the muddy sands because of the slight wave impact. Flushing action by the outgoing tide is minimal. As a result, organic debris carried in by the incoming tide tends to accumulate in the sand. (See Figure 3-15.)

Just as the wetland is the estuary’s nursery, the mud flat is its graveyard. Bacteria decompose the wastes and turn the sand into a dark mud. If you were to dig a hole in the sand, you would see that under the surface the sand is black and gives off a foul odor, like rotting eggs. The smell is caused by the presence of hydrogen sulfide (H₂S), a compound that is the product of decay and that accumulates in sediments deficient in oxygen. Microscopic organisms are abundant in the mud flats. Decomposers, like the decay bacteria

Figure 3-14 Characteristic organisms of a mud flat community.
that live in the dark, moist sand and play an important role in the well-being of the mud flat community, convert wastes into useful nutrients. Tidal action transports the nutrients to other parts of the estuary and out to sea. Nutrients from the estuary are a major food source for the oceanic plankton.

Within the mud flat, a variety of invertebrates scavenge for food. At low tide, large numbers of mud snails (*Ilyanassa obsoleta*) feed on debris in shallow tide pools. These tiny “garbage eaters” do an efficient job of getting rid of excess wastes in the mud flat. Sandworms and bloodworms tunnel through the sand, feeding on organic debris. Clams also live in the sand. The soft-shell clam (*Mya arenaria*) has a long siphon tube that it uses to take in water that contains plankton. When the tide is out, the clam retracts its siphon, leaving a hole in the sand. You can locate soft-shell clams by looking for these telltale holes in the sand. The slightest movement causes the soft-shell clams to squirt water up through the holes.

The mud flat is also home to another mollusk, the razor clam (*Ensis directus*). The razor clam has a well-developed muscular foot that it uses to dig quickly through the sand. The burrowing action of mollusks, worms, and other invertebrates in the mud flats helps to bring some much-needed air to the oxygen-deficient sediments.

The invertebrates also burrow in the mud and sand to escape predators, such as shorebirds. The bills of the various shorebirds are of different shapes and lengths, depending on the birds' feeding
habits. The short bill of the plover and sandpiper is used to feed on invertebrates that live near the surface in the mud. Shorebirds with longer bills can reach invertebrates that burrow deeper into the mud.

**The Mangrove Community**

In regions with a tropical climate, such as Florida, the shores of some bays and inlets are covered by a thick growth of mangrove trees, and the coastal marsh takes the form of a **mangrove community**, or mangrove swamp. (See Figure 3-16.) The dominant plant species that grows in the water of the mangrove swamp is the red mangrove tree (*Rhizophora mangle*). At low tide, the arching roots, which anchor the mangrove trees in the muddy sand, are visible. At high tide, the water covers the roots, but the tree trunks and leaves remain above water. (See Figure 3-17.)
The incoming tide brings in organic debris that gets trapped in the tangle of mangrove roots. Dead leaves from the mangrove trees decay in the water. The products of decay enrich the mangrove swamp with nutrients, a food source for plankton. Filter-feeding animals such as barnacles and oysters consume the plankton. The outgoing tide flushes nutrients back out to sea, providing oceanic life with an important food source.

The mangrove swamp is like a natural wildlife sanctuary. Like the tangled roots of the mangrove trees, life in the mangrove swamp is a diverse web of interrelationships. A variety of marine animals, including snails, land crabs, and fiddler crabs, scavenge for food at low tide. In the evenings, raccoons search for crabs among the mangrove roots. When the tide is in, the crown conch (*Melongea corona*) preys on oysters; and fish, such as the mangrove snapper (*Lutjanus griseus*), feed on the smaller fish and invertebrates swimming among the roots. Nesting in the leafy trees are the brown pelican (*Pelecanus occidentalis*) and the osprey (*Pandion haliaetus*), which hunt and scavenge on the abundant marine life.

Mangrove swamps also protect the shore from erosion. The roots of the mangrove tree hold the sand and prevent it from being carried away by waves and currents. During storms, the mangrove swamp acts like a giant sponge, absorbing the water and impact of the storm. Mangrove communities are natural barriers that protect other habitats farther inland.
3.4 **SECTION REVIEW**

1. Why is an estuary such a productive aquatic environment?
2. How are organic wastes recycled in the mud flat community?
3. Briefly describe life around the tree roots in a mangrove swamp.

3.5 **THE CORAL REEF ENVIRONMENT**

The **coral reef** is among the most spectacular of marine environments. Look at the coral reef animals shown in Figure 3-18. As you can see, the coral reef contains a fantastic assortment of marine life. The foundation for this diverse community is the coral animal itself. The coral reef is a stony formation that is built up from the seafloor by a living organism called the coral polyp. (See Chapter 7 for more information on the coral polyp.)

The reef begins to form when microscopic coral larvae settle on a hard substrate in the sand and develop into coral polyps. The coral animals live in colonies, with each tiny polyp sitting in its own limestone home, which it builds. Each new generation of polyps lays down a new layer of limestone, causing the reef to expand upward (at about 2.5 cm per year) and outward. Some massive reefs are more than 40 meters high and more than 1000 km long. Corals can grow right up to the ocean surface but cannot grow out of the water.

![Figure 3-18 Characteristic organisms of a coral reef community.](image-url)
Coral Features

Coral reefs are found in the tropical and subtropical regions of the world, between 30 degrees north and 30 degrees south latitude. They are located in the Atlantic, Pacific, and Indian oceans. Why are coral reefs found only in the mid-latitudes? In these latitudes, the ocean’s water is warm and clear, and there is plenty of sunlight. These are the conditions that are needed to promote the growth of symbiotic algae within the coral polyps that build the reefs.

Look at a world map and locate Australia’s Great Barrier Reef, the longest reef system in the world; it is approximately 2000 km long. Large reefs are also found in the Caribbean, the Florida Keys, and off the coast of Belize in Central America. Living among the Great Barrier Reef’s corals are more than 1500 species of fish, among other organisms.

Why do so many different organisms inhabit the coral reef? A reef consists of different types of coral growing together. The many kinds and shapes of corals create an irregular pattern of crevices, depressions, and caves in which organisms can live and hide. This great variety of life, or biodiversity, is typically found in habitats that provide many areas for hiding and surfaces for attachment.

Each type of coral has its own unique shape, size, color, and texture. Corals are classified into two types, hard corals and soft corals. Many corals are named after familiar objects, for example, hard corals such as elk horn (Acropora palmata), staghorn (Acropora cervicornis), and brain (Diploria labyrinthiformis), and soft corals such as fan (Gorgonia ventalina) and sea rod (Plexaura flexuosa), which are more flexible and sway in the currents. (See Figures 3-19 and 3-20.)
The coral reef is a very productive environment. However, coral reefs are fragile. Pieces of coral can be broken off easily; even touching coral can damage the thin membrane that protects its surface. Unfortunately, many coral reefs around the world are in danger. Development along coasts has clouded offshore waters and caused reefs to die. The unrestricted use of reefs for fishing and diving has contributed to their degradation.

**Reef Inhabitants**

When you dive along a coral reef, you encounter an oasis of colorful living things. Typical reef inhabitants include the butterfly fish with its elongated snout to feed on food particles on the reef surface, the barracuda with its needlelike teeth to grab and eat other reef fish, and the parrot fish with its beaklike mouth to nibble off chunks of reef. (See Figure 3-21.) The parrot fish eats the coral polyps and eliminates the indigestible limestone. (The egested particles of limestone trickle down to the seafloor to form coral sand.) Various sponges, worms, shrimps, anemones, sea stars, mollusks, and other fish also live in and around the reef.

How do the inhabitants of the coral reef avoid predators? The reef provides ideal hiding places for its inhabitants, as mentioned above. In a coral crevice, you might see a spiny lobster (*Panulirus argus*), which retreats farther back into its hole if it detects danger. Predators also hide; for example, the moray eel (*Gymnothorax*) stays hidden in crevices and rarely ventures out during the day. In fact, many reef animals emerge only at night to feed.

Some fish depend on **camouflage**, the ability to match or blend in with their natural background, to avoid being detected. To hide, the sticklike trumpetfish (*Aulostomus*) floats motionless, with its head facing down, alongside branching corals and sponges. Such camouflage helps the trumpetfish escape detection by other fish, including those it may want to eat. In contrast, the spotted trunkfish (*Lactophrys bicaudalis*) lives at the bottom of the reef, where it is difficult to spot against the background of coral and speckled sand. (See Figure 3-22.) Fish can also gain some protection against predators by swimming in a large group, or school, of their own species. Schools of fish may stay in one location, or they may swim over long distances. Stationary schools of fish, such as that of the grunt
(Haemulon), are common around coral reefs. There is security in numbers; the chances of any fish in particular being caught by a predator is reduced by its being within a school of hundreds of fish. (See Figure 3-23.)

Reef fish are well known for being very colorful. The black-and-yellow coloration of the rock beauty (Holocanthus tricolor) stands out in stark contrast to the background colors of the reef. The queen angelfish (Holocanthus ciliaris) and the butterfly fish (Chaetodon) also exhibit different, bold colors in a pattern known as color contrast. What is the adaptive value of color contrast in fish? Fish use color as a means of identifying members of their own species. This is a very important ability in the coral reef environment, where there are numerous species of fish, many of them closely related. Color is also used to confuse predators. For example, the four-eyed butterfly fish has two fake eyespots at the base of its tail fin, which trick predators into thinking that the back of the fish is its front. (See Figure 3-24.) Spots, bars, and stripes (such as on the banded butterfly fish), which obscure the outline of a fish, are called disruptive coloration. Such coloration makes it harder for a predator to see and catch the fish.

The reef is like an apartment building, with inhabitants living close to one another and at different levels. However, in the reef environment...
there are no walls to separate one neighbor from another. Living so close together, the different types of fish need to establish a home area or turf. A home area with well-defined boundaries is called a territory. Within its territory, a fish may need to defend important resources such as food, a mate, or a nesting site. The damselfish (Microspethodon chrysurus), for example, will attack a much larger fish such as a parrot fish, or even a scuba diver, in an attempt to defend its territory. Such behavior by an organism in defending its home area is called territoriality. Larger fish, such as the barracuda and the black-tipped and white-tipped reef sharks, are also territorial. They swim along the reef and patrol their home area, threatening or even attacking perceived intruders, including divers. (See Figure 3-25.)

3.5 Section Review

1. How is a coral reef built? What substance is it made up of?
2. What conditions are required for the growth of a coral reef?
3. What are some ways the inhabitants of a coral reef avoid detection?
PROBLEM: What are the physical properties of beach sand?

SKILLS: Using a dissecting microscope; measuring tiny sand grains.

MATERIALS: Transparent metric ruler, dissecting microscope (or compound microscope), sand samples, dissecting needle, petri dish, magnet.

PROCEDURE

1. Place the transparent metric ruler on the stage of the microscope.

2. Sprinkle some sand in the petri dish and put the dish on top of the ruler.

3. Observe the sand grains under the microscope. In your notebook, record the size of a single grain, in mm, on a copy of Table 3-1. If the grains vary widely in size, measure several and record the average size. Notice if there are any tiny shells or fragments that may be the remains of foraminifers.

4. Observe the physical properties of color, texture, luster, and shape in the grains. Use a dissecting needle to separate the grains into different piles, each representing a different property. Record your observations in the table. Make a sketch of a sand grain from each sample pile.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Size</th>
<th>Color</th>
<th>Texture</th>
<th>Luster</th>
<th>Shape</th>
<th>Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td>B</td>
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</tr>
</tbody>
</table>
TABLE 3-2 MINERALS AND THEIR PHYSICAL PROPERTIES

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Physical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>Clear, glassy, resembles salt crystals, eroded from granite</td>
</tr>
<tr>
<td>Feldspar</td>
<td>Clear, tan or gray, usually square, eroded from granite</td>
</tr>
<tr>
<td>Hornblende</td>
<td>Dark gray to black, glassy</td>
</tr>
<tr>
<td>Mica</td>
<td>Thin shiny flakes, silver gray to black</td>
</tr>
<tr>
<td>Magnetite</td>
<td>Dark shiny triangles, clings to magnet, contains iron</td>
</tr>
<tr>
<td>Garnet</td>
<td>Purple to red, angular, abrasive, used in sandpaper</td>
</tr>
<tr>
<td>Olivine</td>
<td>Olive-green, glassy</td>
</tr>
<tr>
<td>Basalt</td>
<td>Gray to black, resembles lumps of coal</td>
</tr>
<tr>
<td>Pyrite</td>
<td>Pale orange to yellow, metallic luster (like gold)</td>
</tr>
<tr>
<td>Calcite</td>
<td>Opaque, glassy, composed of calcium carbonate, reacts with dilute HCl to produce bubbles of CO₂</td>
</tr>
</tbody>
</table>

5. Place a small magnet in contact with the sand. Do the sand grains cling to the magnet? If the sand clings, iron is present. Identify the mineral in Table 3-2 that contains the element iron. Use this table to identify the minerals that match the physical properties of the samples you observed. Record the information in your copy of Table 3-1.

OBSERVATIONS AND ANALYSES

1. Which type of sand would be a good source for magnetite—coral sand or volcanic sand? Explain.

2. What are the four physical properties of beach sand that are important for identification?

3. In what ways do you think the texture and shape of a sand grain are related to its source (where the sand is from; wave action; activities of organisms)?
Chapter 3 Review

Answer the following questions on a separate sheet of paper.

Vocabulary
The following list contains all the boldface terms in this chapter.

adaptation, aphotic zone, barrier beaches, benthic zone, benthos, biodiversity, brackish, camouflage, color contrast, continental shelf, coral reef, disruptive coloration, estuary, intertidal zone, life zone, mangrove community, mud flat community, neritic zone, ocean basin, oceanic zone, pelagic zone, photic zone, photosynthesis, rocky coasts, salt marsh community, sandy beach, strandline, subtidal zone, supratidal zone, surf zone, territoriality, tide pools, wetlands, zonation

Fill In

1. The __________ is dominated by trees that live in salt water.
2. Organisms that live on the seafloor inhabit the __________.
3. The __________ includes the waters above the continental shelf.
4. The area between high tide and low tide is the __________.
5. Salt water and freshwater form an __________ at a river mouth.

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

6. Compare the intertidal zone of a rocky beach with that of a sandy beach.
7. What are two important differences between the neritic and oceanic zones?
8. Compare the main traits of a salt marsh with those of a mud flat community.
Inquiry

Base your answers to questions 9 through 12 on Figure 3-3 on page 64, which shows a cross section of the major life zones of the ocean, and on your knowledge of marine science.

9. Identify, by name, the zone in which most of the world’s commercial fishing takes place. Give two reasons why this zone is so biologically productive.

10. Identify, by name, the vast area of the oceanic zone that receives very little sunlight. Give an example of an organism that is adapted to live in this zone. Below which oceanic zone is it located (identify by name)?

11. Identify, by name, the largest marine life zone. What kinds of large marine animals swim freely here? What are the names of the two life zones that it includes?

12. Identify, by name, the zone in which marine organisms live that are specially adapted to survive alternating periods of high tides and low tides. How do barnacles survive there?

Multiple Choice

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

13. The arching roots of the mangrove tree serve all the following functions except   a. they anchor the trees in the muddy sand   b. they provide a habitat for small fish and invertebrates   c. they serve as a food source for the mangrove snapper   d. they hold the sand and prevent its erosion.

14. Which of the following organisms would be found in a rocky coast intertidal zone?   a. sea anemones, flounder, blue-green bacteria, barnacles   b. barnacles, snails, mussels, seaweeds   c. mussels, sea stars, cordgrass, seaweeds   d. sea stars, cordgrass, shore shrimp, fiddler crabs

15. Of the following marine organisms, which would probably not be found in a rocky tide pool?   a. crab   b. grazing snail   c. flounder   d. barnacle
16. A barrier beach is located between  
   (a) a bay and an atoll  
   (b) a bay and a river  
   (c) a river and an atoll  
   (d) a bay and the ocean.

17. The marine environment that is characterized by a shifting, unstable sediment is the  
   (a) rocky coast  
   (b) coral reef  
   (c) sandy beach  
   (d) tide pool.

18. The dominant plant life in the salt marsh is the  
   (a) sea lettuce  
   (b) cordgrass  
   (c) mangrove tree  
   (d) red algae.

19. The salt marsh is more productive than the mud flat because it  
   (a) lies in deeper waters  
   (b) has more salt  
   (c) has more producer organisms  
   (d) lies in calmer waters.

20. In which geographic area would a mangrove swamp be located?  
   (a) Gulf of Maine  
   (b) Puget Sound  
   (c) San Francisco  
   (d) Florida Keys.

21. Coral reefs are found in latitudes where the ocean’s waters are  
   (a) warm and clear  
   (b) warm and murky  
   (c) cold and clear  
   (d) cold and murky.

22. The cordgrass *Spartina* has adapted to salt water by  
   (a) growing deep roots  
   (b) conserving freshwater in its leaves  
   (c) secreting excess salt from its leaves  
   (d) not taking in salt through its roots.

23. The mud flat community has all of the following characteristics except  
   (a) dark, muddy sand  
   (b) invertebrates that burrow  
   (c) a high rate of decomposition  
   (d) turbulent wave action.

24. All the following factors contribute to the coral reef’s biodiversity except  
   (a) the growth of algae within the coral polyps  
   (b) many crevices in which animals can live and hide  
   (c) plenty of sunlight  
   (d) coastal development.

25. The ability of a fish to blend in with its surroundings is called  
   (a) color contrast  
   (b) camouflage  
   (c) disruptive coloration  
   (d) territoriality.

**Research/Activity**

Many wetlands are being lost to coastal development. Report on recent efforts to protect vanishing wetlands in the United States.