Climate and the distribution of land and water play a role in shaping ecosystems and influencing the distribution of organisms on Earth.

15.1 Life in the Earth System

15.2 Climate

Data Analysis
CONSTRUCTING COMBINATION GRAPHS

15.3 Biomes

15.4 Marine Ecosystems

15.5 Estuaries and Freshwater Ecosystems

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ONLINE Labs
- QuickLab  Microclimates
- Winter Water Chemistry
- Modeling Biomes
- Heating and Cooling Rates of Water and Soil
- Modeling the Water Cycle
- Open Inquiry Lab  Aquatic Primary Productivity
USING LANGUAGE

Hypothesis or Theory? To scientists, a theory is a well-supported scientific explanation that makes useful predictions. The main difference between a theory and hypothesis is that a hypothesis has not been tested, and a theory has been tested repeatedly and seems to correctly explain all the available data.

YOUR TURN

Use information from the chapter to complete the following tasks.

1. Is the greenhouse effect a hypothesis? Explain.
2. Write your own hypothesis that explains the increase in global temperatures.

What species would you expect to find in a rain forest?

Not all rain forests are teeming with monkeys and macaws. The temperate rain forest of the Pacific Northwest is inhabited by an entirely different community of plants and animals than is found in tropical rain forests. Location, climatic conditions, and other abiotic factors determine what species you will find in a particular area.
The biosphere is the portion of Earth that is inhabited by life. The biosphere is the part of Earth where life exists. All of Earth's ecosystems, taken together, form the biosphere. If you could remove all the nonliving parts of the biosphere— all the water, air, rocks, and so on—you would be left with the biota. The biota are the living things within the biosphere.

The biosphere includes living organisms and the land, air, and water on Earth where living things reside. The biosphere also may be called the biota.

You need to look at how all four Earth systems interact to really understand how an ecosystem works. For example, a plant growing in a swamp depends on the soil in which it grows just as much as on the water in the swamp. It uses carbon dioxide from the atmosphere to make sugars, and it gives off excess oxygen, slightly changing the air around it. One plant growing in one swamp has a small effect on the Earth system as a whole. But all living things together throughout the planet's history have had a vast effect.

**Connect** Is the air in your classroom part of the biosphere or the biota? Explain.
Biotic and abiotic factors interact in the biosphere.

Just as one ecosystem is connected to another, all four Earth systems are also connected. A change in one sphere can affect the others. If plants are removed from a riverbank, for example, rain may flow more easily from the land to the water. This increased flow would likely carry more sediment and therefore make the river water murkier, as shown in FIGURE 1.1. The murky water might block sunlight, affecting the growth of aquatic plants. This change might in turn prevent these plants from taking up carbon dioxide and releasing oxygen.

James Lovelock, an atmospheric scientist from the United Kingdom, proposed the Gaia hypothesis to explain how biotic and abiotic factors interact in the biosphere. This hypothesis considers Earth itself a kind of living organism. Its atmosphere, geosphere, and hydrosphere are cooperating systems that yield a biosphere full of life. He called this living planet Gaia after the Greek goddess of Earth. In the early 1970s, Lynn Margulis, a microbiologist from the United States, added to the hypothesis, specifically noting the ties between the biosphere and other Earth systems. For example, when carbon dioxide levels increase in the atmosphere, plants grow more quickly. As their growth continues, they remove more and more carbon dioxide from the atmosphere. The atmospheric carbon dioxide level drops, and plant growth slows. This give-and-take, known as a feedback loop, helps maintain a fairly constant level of carbon dioxide in the atmosphere.

Sometimes, people mistakenly believe that the Gaia hypothesis suggests that Earth is a thinking being that regulates the geosphere, the atmosphere, and the hydrosphere. This is obviously not the case. Rather, the Gaia hypothesis recognizes the extensive connections and feedback loops between the living and nonliving parts of the planet. Many scientists are now devoting their careers to organizing new fields of study, such as geobiology and geomicrobiology, to examine these intriguing relationships.

Summarize Explain the Gaia hypothesis in your own words. **TEKS 3F**

**FIGURE 1.1** Deforestation, or the removal of forests, along the Mahajamba Bay in Madagascar has led to erosion along the waterway, clogging the water with silt and soil.
Climate is a key abiotic factor that affects the biosphere.

Main Ideas
- Climate is the prevailing weather of a region.
- Earth has three main climate zones.

Connect to Your World
Although you might sometimes check the local weather report to see if you'll need an umbrella, you are already familiar with the general climate where you live. If you live in the Midwest, you know that winter means cold temperatures, while in the Southwest, winter temperatures are much milder. The long-term weather patterns of an area help determine which plants and animals you will find living there.

Climate is the prevailing weather of a region.

The weather of an area may change from day to day, and even from hour to hour. In contrast, the climate is the long-term pattern of weather conditions in a region. Climate includes factors such as average temperature and precipitation and relative humidity. It also includes the seasonal variations an area experiences, such as rainy or dry seasons, cold winters, or hot summers.

The key factors that shape an area's climate include temperature, sunlight, water, and wind. Among these abiotic factors, temperature and moisture play a large role in the shaping of ecosystems. Descriptions of a specific region's climate take these abiotic factors into consideration. For example, a specific region such as a desert may be described as hot and dry, while a rain forest may be described as warm and moist.

Even within a specific region, climate conditions may vary dramatically. A microclimate is the climate of a small specific place within a larger area. A microclimate may be as small as a hole in a decaying log where mushrooms grow, as pictured in Figure 2.1, or as large as a city neighborhood. San Francisco, for example, is characterized by frequent fog and cool temperatures. However, not far beyond the city limits, and even within other sections of the city itself, the weather may be quite different.

Microclimates can be very important to living things. The same grassy meadow, for example, may be home to both frogs and grasshoppers. The frogs may tend toward areas that are moist, often at the base of the grasses, while the grasshoppers may prefer drier sites and cling to the tops of the grass blades. Each of these locations is a microclimate.

Analyze Where in a forest might you find different microclimates?
Earth has three main climate zones.

Scientists use average temperature and precipitation levels to categorize a region’s climate. Using this system, Earth can be divided into three main climate zones, as shown in **Figure 2.2**. These three zones are the polar, tropical, and temperate climates. The polar climate is found at the far northern and southern regions of Earth. The tropical zone surrounds the equator. The temperate zone is the wide area in between the polar and tropical zones.

**Influence of Sunlight**

What determines an area’s climate? The answer begins with the sun. The sun’s rays are most intense, and therefore hottest, on the portion of the planet that sunlight strikes most directly. Earth’s surface is heated unevenly due to its curved shape. The area of Earth that receives the most direct radiation from the sun all year is the region at and around the equator, where the tropical climate zone is found. Near the North and South poles, or polar climate zones, the sun’s rays strike Earth’s surface at a lower angle, diffusing their heat over a larger area.

Earth’s tilt on its axis also plays a role in seasonal change. As Earth orbits the sun, different regions of the planet receive higher or lower amounts of sunlight. When the North Pole is at its maximum tilt away from the sun, it is winter in the Northern Hemisphere and summer in the Southern Hemisphere. When the North Pole reaches its maximum tilt toward the sun, the opposite is true.

**Figure 2.2 Climate Zones**

The uneven heating of Earth by the sun results in three different climate zones.

- **Polar Climate**: The polar climate zone is located in far northern and far southern reaches of the planet, where the temperature is typically cold and often below freezing.
- **Tropical Climate**: The tropical climate zone, which surrounds the equator, runs from the Tropic of Cancer to the Tropic of Capricorn and is characterized by warm, moist conditions.
- **Temperate Climate**: The temperate climate zone is located in the broad area lying between the polar and tropical climate zones. This zone experiences summer and winter seasons of about equal length.

Apply What is the relationship between sunlight and climate zone?
Air and Water Movement

When the sun heats Earth, it warms not only the land and the rocks but also the water and the air. This heating causes movements in both water and air. Warm air and warm water are less dense than cooler air and water, and therefore they rise. Because the tropics near the equator are especially warm, the warm air here rises and the cooler air from areas to the north or south moves in to take its place. As the warm air rises, it cools. Since cold air holds less moisture than warm air does, a large amount of precipitation drops as rain. This large amount of precipitation, along with warm temperatures, defines the tropical rain forest regions found near the equator. The movement of air also leads to movement in water, forming currents. The rotation of Earth, water temperatures, and salinity levels also interact to form currents.

Landmasses

Landmasses also shape climates. For example, areas closer to bodies of water have a different climate from areas farther away because land tends to heat and cool more quickly than water. Thus, coastal areas tend to have smaller changes in temperature than areas farther inland. Farther inland, areas experience a much larger range of seasonal high and low temperatures.

Water evaporates from open bodies such as lakes or oceans faster than it does from soil or through plant transpiration. As a result, coastal sites in general have higher humidity and receive more precipitation than inland areas.

Mountains may also have a large effect on an area’s climate. As warm, moist air nears a mountain, it rises and cools. This cooling of air results in precipitation on the side of the mountain range facing the wind. On the downwind side of the mountain, drier and cooler air produces a rain shadow, or area of decreased precipitation. The Sierra Nevada mountain range in California, shown in Figure 2.3, is one example of this phenomenon. While the western slope receives a large amount of precipitation, the Great Basin to the east of the mountains is dry.

**Figure 2.3** The western slope of the Sierra Nevada, which faces the prevailing winds, receives precipitation throughout the year. Due to the rain shadow, the eastern slope of the Sierras is much drier.

**Quick Lab: Observing Microclimates**

**Determine the temperature of inside and outside areas of your school to identify different microclimates.**

**Problem** Where are different microclimates in and around your school grounds?

**Procedure**

1. Identify one place inside and one place outside your school where microclimates may exist.
2. Place a thermometer at each location. Wait at least five minutes before recording the temperature.

**Analyze and Conclude**

Compare the temperatures you collected with those recorded by your classmates at different locations.

**Materials**

- thermometer
- stopwatch
Adaptations to Climate

Many organisms have adaptations that allow them to survive in a specific climate. The water-holding frog shown in FIGURE 2.4 is a dramatic example. It lives in the dry grasslands and deserts of inland Australia, where the rainy season comes only once a year. Dry periods can last 10 months or more. The frog survives the dry season by burrowing underground, where water evaporates more slowly. Moisture loss is further reduced by a cocoonlike structure formed from the frog’s shed skin. When rains soak the ground, the frogs crawl out of their burrows to mate, and the females lay eggs in water puddles that form in depressions along the ground. Within a matter of weeks, the eggs hatch into tadpoles, and the tadpoles develop into frogs. This frog must move through its life cycle very quickly because the water evaporates quickly once the rains end. If the tadpoles are not ready to leave the ponds, they will die.

Connect Describe the climate where you live.

TABLE 1. AVERAGE CLIMATE IN ALBUQUERQUE, NM

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation (mm)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>12.4</td>
<td>2.1</td>
</tr>
<tr>
<td>February</td>
<td>11.2</td>
<td>5.2</td>
</tr>
<tr>
<td>March</td>
<td>15.5</td>
<td>8.9</td>
</tr>
<tr>
<td>April</td>
<td>12.7</td>
<td>13.1</td>
</tr>
<tr>
<td>May</td>
<td>15.2</td>
<td>18.2</td>
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<tr>
<td>June</td>
<td>16.5</td>
<td>23.8</td>
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<td>32.3</td>
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<tr>
<td>August</td>
<td>43.9</td>
<td>24.5</td>
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<td>September</td>
<td>27.2</td>
<td>20.6</td>
</tr>
<tr>
<td>October</td>
<td>25.4</td>
<td>14.1</td>
</tr>
<tr>
<td>November</td>
<td>15.7</td>
<td>6.9</td>
</tr>
<tr>
<td>December</td>
<td>12.4</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Source: National Oceanic and Atmospheric Administration

FIGURE 2.4 Water-holding frogs crawl out of their burrows to mate during the rainy season.

15.2 Formative Assessment

REVIEWING MAIN IDEAS
1. What is the difference between climate and weather?
2. What are the three different climate zones, and where are they located?

CRITICAL THINKING
3. Connect Where might there be microclimates in your area?
4. Infer Would areas along the shores of the Great Lakes have warmer summers and colder winters than other inland areas? Explain.

5. Would you expect an area with several microclimates to have more or fewer ecological niches? Explain your answer.
Biomes

**KEY CONCEPT** Biomes are land-based, global communities of organisms.

**MAIN IDEAS**
- Earth has six major biomes.
- Polar ice caps and mountains are not considered biomes.

**Connect to Your World**
Have you ever seen a cactus in a tropical rain forest or a penguin in a desert? Individual plant and animal species have adaptations that let them thrive only in certain biomes. In this section, you will learn about the major biomes of the world and the characteristics of each.

**MAIN IDEA** Earth has six major biomes.

The global distribution of biomes is shown in **FIGURE 3.1**. Characteristics of each biome are given in **FIGURE 3.2**. As you will see, these broad biome types can be divided into even more specific zones. For example, the grassland biome can be further separated into zones of temperate and tropical grassland.

A variety of ecosystems are found within a biome. However, because a biome is characterized by a certain set of abiotic factors, ecosystems located across the globe in the same biome—the tropical rain forest of Brazil or Madagascar, for example—tend to have similar plant and animal species.

**FIGURE 3.1 World Biomes**

A biome is defined by its climate and by the plant communities that live there.

**Identify** Which biomes are found in North America?
### FIGURE 3.2 Biomes

<table>
<thead>
<tr>
<th>Biome</th>
<th>Characteristics</th>
</tr>
</thead>
</table>
| **Tropical**     | • Warm temperatures and abundant rainfall occur all year.  
                   • Vegetation includes lush thick forests.  
                   • Animals that live within the thick cover of the uppermost branches of rain forest trees use loud vocalizations to defend their territory and attract mates. |
| **Grassland**    | • Temperatures are warm throughout the year, with definite dry and rainy seasons.  
                   • Vegetation includes tall grasses with scattered trees and shrubs.  
                   • Hoofed animals, such as gazelles and other herbivores, dominate this biome. |
| **Desert**       | • This biome has a very dry climate.  
                   • Plants, such as cacti, store water or have deep root systems.  
                   • Many animals are nocturnal; they limit their activities during the day. |
| **Temperate**    | • Temperatures are hot in the summer and cold in the winter; precipitation is spaced evenly over the year.  
                   • Broadleaf forest dominates this biome, and deciduous trees lose their leaves in the winter. |
| **Temperate rain forest** | • This biome has one long wet season and a relatively dry summer.  
                   • Evergreen conifers, which retain their leaves (needles) year-round, dominate this biome.  
                   • While some species remain active in the winter, others migrate to warmer climates or hibernate. |
| **Taiga**        | • This biome has long, cold winters and short, warm, humid summers.  
                   • Coniferous trees dominate this biome.  
                   • Mammals have heavy fur coats to withstand the cold winters. |
| **Tundra**       | • Subzero temperatures are the norm during the long winter, and there is little precipitation.  
                   • The ground is permanently frozen; only mosses and other low-lying plants survive.  
                   • Animal diversity is low. |
Tropical Rain Forest Biome

A tropical rain forest has warm temperatures and abundant precipitation throughout most, if not all, of the year. This climate typically produces lush, thick forests that can completely shade the forest floor. The limiting factor for plants that live on the forest floor is sunlight. In fact, as little as 1 percent of the sunlight that strikes the uppermost branches of the trees, called the canopy, may make it through to the ground. The soil is very thin and low in nutrients. Most organisms that live in this biome inhabit branches of the upper canopy. Some plants, called epiphytes, grow above the ground on the branches of trees. A few of these, such as some figs, sprout and develop on branches and then send down long lengths of roots that grow into the ground below.

Grassland Biomes

Grassland biomes occur in a variety of climates. A grassland is an area where the primary plant life is grass. Tropical grasslands are found in the tropical climate zones of South America, Africa, and Australia. Temperate grasslands are found in the temperate climate zones of South Africa, eastern Europe, and central North America.

Tropical grasslands, also called savannas, are covered with grass plants that may stand 1–2 meters (3–7 ft) in height. Some grasslands have scattered trees or shrubs, but the trees are never as thick and lush as in the tropical rain forests. The limiting factor in the savanna is rainfall. For five months or more each year, precipitation averages at most 10 centimeters (4 in.) a month; often there is much less. During the rainy season, however, water can replenish lakes, rivers, streams, and wetlands and form temporary ponds. This biome is home to plants and animals that have adapted to the extreme shifts in moisture.

Temperate grasslands receive 50–90 centimeters (20–35 in.) of annual precipitation, most occurring as rain in the late spring and early summer. Summers may be warm or quite hot, depending on the latitude of the grassland. Under such arid conditions, fast-spreading fires are common. Some plants in temperate grasslands have adapted to fire by producing fire-resistant seeds that require the fire’s heat to start germination.

Desert Biome

Desert biomes receive less than 25 centimeters (10 in.) of precipitation annually, and are always characterized by a very dry, or arid, climate. There are four types of deserts: hot, semiarid, coastal, and cold.

In hot deserts, such as the Sonoran Desert in Arizona, the daily summer temperature may easily top 38°C (100°F). At night, however, the temperature can drop by 10 degrees Celsius or more. During the winter, the temperature may be as low as 0°C (32°F). The precipitation falls as rain in hot deserts.
Semiarid deserts, like hot deserts, have long and dry summers and low amounts of rain in the winter. In comparison with hot deserts, however, temperatures are cooler and rarely exceed 38°C. Coastal deserts are characterized by cool winters followed by relatively long, warm summers. Temperatures range from a maximum of 35°C (95°F) in the summer to −4°C (25°F) in the winter. In cold deserts, such as the Great Basin of the western United States, precipitation falls evenly throughout the year and often occurs as snow in the winter. Summer temperatures range between 10°C (50°F) at night to 24°C (75°F) during the day, and winter temperatures can drop below freezing.

Plants use a variety of strategies to survive a desert’s heat and lack of moisture. The reduced surface area of a cactus’s spines helps it to retain more water by avoiding moisture loss from transpiration. Many desert plants have the ability to conserve or store water over a long period of time. Some desert plants, such as mesquite, have extremely long root systems that absorb water by reaching down to the water table. Desert plants also have heat- and drought-resistant seeds.

**Contrast** How do rainfall amounts differ in deserts and in tropical rain forests?

### Temperate Forest Biomes
A key feature of temperate biomes is their distinguishable seasons. The growing season occurs during the warmer temperatures from mid-spring to mid-fall and depends upon the availability of water.

The **temperate deciduous forest** typically receives about 75–150 centimeters (30–59 in.) of precipitation spread over the entire year as rain or snow. This biome is characterized by hot summers and cold winters. Deciduous trees have adapted to winter temperatures by dropping their leaves and going dormant during the cold season. Trees, such as oaks, beeches, and maples, along with shrubs, lichens, and mosses, make up the main vegetation.

The **temperate rain forest** does not receive precipitation evenly spaced across the year. Instead, it has one long wet season and a relatively dry summer, during which fog and low-lying clouds provide the needed moisture. Precipitation in the temperate rain forest averages over 250 centimeters (98 in.) per year. Evergreen conifers, such as spruces, Douglas firs, and redwoods, dominate this biome. Coniferous trees retain their needles all year. Mosses, lichens, and ferns are plant species found on the forest floor.

### Taiga Biome
The **taiga** (TY-guh), also known as the boreal forest, is located in cooler climates. Winters are long and cold, often lasting six months or more. The average winter temperature is below freezing. Summers are short, typically with only two to three months of frost-free days. However, they may be quite humid and warm, sometimes reaching 21°C (70°F). Precipitation in the taiga is 30–85 centimeters (12–33 in.) per year, which is similar to that in the arid temperate grasslands. Coniferous forest is dominant in the taiga.
Tundra Biome

Often described as bleak, the tundra is located beyond the taiga in far northern latitudes. Winter lasts as long as 10 months a year. The average winter temperature is below freezing. The ground below the surface is always frozen. This frozen ground is known as permafrost. Summers last just 6 to 10 weeks. Precipitation is meager, averaging less than 13 centimeters (5 in.) annually.

In addition to limited precipitation, permafrost captures and holds moisture, making very little available to plants. Therefore, the tundra is quite barren. Only mosses, other tiny, low-lying plants, and a few scattered shrubs are able to survive. Trees and most flowering plants do not grow here.

Minor Biomes

In addition to the six major biomes, there are also some other biomes that occur globally, but on a smaller scale. One example is chaparral, shown in Figure 3.3. Chaparral (shap-uh-RAL), also called Mediterranean shrubland, is characterized by its hot, dry summers and cool, moist winters. Over the year, temperatures in the chaparral range from 10°C (50°F) to 40°C (104°F). Annual precipitation ranges from 38–102 centimeters (15–40 in.), and occurs mostly during the winter as rain. The dominant plants in the chaparral are small-leaved evergreen shrubs. This biome is found in small areas across the globe, including the central and southern coast of California in the western United States, the coast of Chile in South America, the Mediterranean Sea coast in Europe, the southern and western coasts of Australia, and the southwestern tip of South Africa. Because of the fairly hot climate, the plants in this biome exhibit some of the same adaptations to heat as those found in the desert biome. Many plants have shallow root systems that let them take in as much water as possible when it rains. The leaves of shrubs have thick cuticles that help in water retention. Many plant species, such as sage and rosemary, give off a strong smell. These aromatic oils are also highly flammable, and promote fire. As in temperate grasslands, chaparral plants have adapted to the presence of fire, and some plants need fire in order for their seeds to germinate.

Connect What biome includes the area where you live?
Polar ice caps and mountains are not considered biomes.

Polar ice caps are ice-covered areas that have no soil and do not have a specific plant community. In mountains, the climate and the animal and plant communities change depending on elevation. Because of these characteristics, polar caps and mountains are not categorized as biomes.

Polar ice caps occur around the poles at the top and bottom of Earth. In the Northern Hemisphere, the polar ice cap includes parts of Greenland and permanently frozen portions of the Arctic Ocean and surrounding islands. In the Southern Hemisphere, the polar ice cap includes the glacier-covered continent of Antarctica. At the ice caps, ice and snow cover the surface all year. Very few plants or fungi are able to survive the harsh conditions found in the polar regions. Some species found in Antarctica include mosses and lichens. Most animals in this region depend on the sea for their food. Animals such as polar bears, shown in Figure 3.4, have layers of fat that keep them warm in the cold polar conditions. Different animals are found in the northern and southern polar regions. For example, polar bears are found only in the north, while penguins are found only in the south.

Mountains are often rich with life. Different communities of species have adapted to the variety of ecosystems found at different mountain elevations. As you move up a mountain, the different communities that you see are similar to the biomes found in different latitudes across the globe. For example, you may begin a hike in a grassland at the base of the mountain, continue upward through a coniferous forest, and finally reach a desolate tundralike zone at the mountain’s top. While the life zones found on mountains are similar across biomes, their species of plants and animals differ as a result of the different abiotic factors that shape each biome.

**Summarize** Explain why neither polar ice caps nor mountains are considered biomes.

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**15.3 Formative Assessment**

**REVIEWING MAIN IDEAS**

1. List and describe the six major biome types.
2. What are some characteristics of mountains and polar ice caps?
3. Compare variations and adaptations of desert organisms with organisms in the tundra. **TEKS 12B**

**CRITICAL THINKING**

4. **Predict** How might stopping fires change a temperate **grassland**?
5. **Infer** Polar bears have white fur but black skin underneath. Consider the climate in which the bears live. What might be the adaptive advantage of the bears’ black skin? **TEKS 12B**

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**ANIMAL BEHAVIOR**

6. Male birds that migrate the earliest to their summer nesting sites can usually secure the best territories. What limiting factor keeps birds from arriving too early in the **taiga**? **TEKS 12B**
Marine Ecosystems

**KEY CONCEPT** Marine ecosystems are global.

**MAIN IDEAS**
- The ocean can be divided into zones.
- Coastal waters contain unique habitats.

**Connect to Your World**
If you've ever been to the ocean, you are already familiar with some ocean zones. If you walked on the beach at the edge of the surf, you were in the intertidal zone. If you went into the water, you were swimming in the neritic zone. In this section, you will learn about these and other zones that divide the ocean. You will also read about the unique habitats found along the ocean's coasts.

**The ocean can be divided into zones.**

The oceans are a global expanse of water containing a large variety of living things that dwell from coastal shallows to the great depths of the deep-sea vents.

**Ocean Zones**
Scientists use several systems to divide the ocean into different zones. The simplest division of the ocean separates the water of the open sea, or pelagic zone, from the ocean floor, which is called the benthic zone.

The presence of light is also used to differentiate between areas of the ocean. The photic zone is the portion of the ocean that receives plentiful sunlight. In contrast, the aphotic zone refers to the depths of the ocean where sunlight does not reach.

In a third system, as shown in **Figure 4.2**, the ocean is separated into zones using distance from the shoreline and water depth as dividing factors.

The **intertidal zone** is the strip of land between the high and low tide lines. Organisms in this zone, such as those that inhabit tidal pools, must tolerate a variety of conditions that result from changing water levels. Organisms must contend with changes in temperature, amount of moisture, and salinity. The sea anemone, for example, opens up when underwater during high tide. It avoids drying out during low tide by closing up.

The **neritic zone** (nuh-RIHT-ihk) extends from the intertidal zone out to the edge of the continental shelf. The depth of the neritic zone may range from a few centimeters at low tide to more than 200 meters deep.
The **bathyal zone** (BATH-ee-uhl) extends from the edge of the neritic zone to the base of the continental shelf. The bathyal zone lies between the depths of 200 and 2000 meters. This zone is characterized by water that is turbid, or murky, due to the accumulation of silt. Fish that have adapted to living in areas of high pressure live in the bathyal zone. Burrowing animals thrive in this zone.

The **abyssal zone** (uh-BIHS-uhl) lies below 2000 meters and is in complete darkness. While deep-sea vents support a large number of organisms, the total number of species found in this zone is much smaller than the number found in the neritic zone. Because there is no light, photosynthetic organisms do not exist. Chemosynthetic organisms are the base of the food webs at the deep-sea vents. Many organisms that live in the abyssal zone make their own light, much as a firefly produces its glow. This light is often used to attract mates and prey.

**Life in the Neritic Zone**

Although the neritic zone represents less than one-tenth of the total ocean area, it contains 40 times more biomass than the rest of the ocean. Much of the biomass consists of organisms called plankton. **Plankton** are tiny free-floating organisms that live in the water. These organisms include both animals and protists. **Zooplankton** is another term for animal plankton. **Phytoplankton** are photosynthetic plankton, which include microscopic protists such as algae.

Marine phytoplankton, especially blue-green algae and other types of algae, are critical to life on the planet. These organisms carry out the bulk of photosynthesis on Earth, and therefore provide most of the oxygen. According to many estimates, 70 percent or more of the oxygen in every breath you take can be traced back to marine phytoplankton. In addition to their role in oxygen production, phytoplankton also form the base of the oceanic food web.

**Hypothesize** What other adaptations might organisms have in the abyssal zone?
Coastal waters contain unique habitats.

The shallow, coastal waters that make up the neritic zone contain much more than plankton. Two highly diverse habitats found within these coastal waters are coral reefs and kelp forests.

Coral reefs are found within the tropical climate zone. In this area, water temperatures remain warm all year. A single coral reef may be home to 50 to 400 species of corals, along with hundreds of other species, including fishes, sponges, and sea urchins. Studies indicate that the biomass in coral reefs may be up to 1000 times greater than the biomass in a similar area of ocean that does not contain a reef.

Corals are animals that have a mutualistic relationship with algae. The coral provides a home for the algae, and algae provide nutrients for the coral as a byproduct of photosynthesis. Coral reefs are made mostly of coral skeletal material, which packs together over thousands of years into solid structures. Coral reefs are delicate. A change in conditions, such as increased water temperature or pollution, can kill the algae, which then starves the coral. With global ocean temperatures on the rise, coral reefs are in decline around the world.

Ecologists are trying to reintroduce these diverse communities in some areas by making artificial reefs, shown in Figure 4.3, where organisms can find shelter. In addition, some shipwrecks and sunken oil rigs have become artificial reefs that can support fishes and other species associated with coral reefs.

In contrast to coral reefs, kelp forests exist in cold, nutrient-rich waters, such as those found in California’s Monterey Bay. These forests are composed of large communities of kelp, a seaweed. Kelp grows from the ocean floor up to the water’s surface, sometimes extending up to a height of over 30 meters (about 100 ft). Kelp forests are areas of high productivity that provide habitat and food sources to many marine species ranging from tiny invertebrates to large mammals, such as sea lions.

Compare What are the similarities between coral reefs and kelp forests? TEKS 12B
**15.5 Estuaries and Freshwater Ecosystems**

**KEY CONCEPT** Freshwater ecosystems include estuaries as well as flowing and standing water.

**MAIN IDEAS**
- Estuaries are dynamic environments where rivers flow into the ocean.
- Freshwater ecosystems include moving and standing water.
- Ponds and lakes share common features.

**Connect to Your World**
You rely on aquatic ecosystems more than you might realize. Many of the fish and shellfish that you might eat depend, at least for a part of their lives, on estuaries. But more importantly for you, freshwater ecosystems provide the water that you need to survive.

**TEKS 12B, 12F**
compare variations and adaptations of organisms in different ecosystems and describe how environmental change can impact ecosystem stability

**VOCABULARY**
estuary
watershed
littoral zone
limnetic zone
benthic zone

**Main Idea**
Estuaries are dynamic environments where rivers flow into the ocean.

An **estuary** is a partially enclosed body of water formed where a river flows into an ocean. The San Francisco and Chesapeake bays are estuaries. So are the Louisiana bayous, Florida Bay in the Everglades, and many other harbors, sounds, and inlets around the world.

The distinctive feature of an estuary is the mixture of fresh water from a river with salt water from the ocean. The river carries high levels of nutrients from inland areas. The tidal movements of water in the ocean also bring in large volumes of organic matter and a variety of marine species from the ocean. Large numbers of species thrive in this rich mixture of fresh water and salt water.

Estuaries are highly productive ecosystems, on a level comparable to tropical rain forests and coral reefs. Photosynthetic organisms thrive in estuaries throughout the year, providing the basis for the aquatic food web. Estuaries also have thriving detritivore communities that decompose the enormous amounts of dead plant and animal matter that build up in the estuary’s waters. These decomposers return vital nutrients back to the ecosystem. Estuaries also provide the necessary habitat for a number of endangered and threatened species. For example, the brown pelican, the Morro Bay kangaroo rat, and a plant called the Morro manzanita are all threatened or endangered species that depend on the Morro Bay estuary in California, shown in **Figure 5.1**.

**Figure 5.1** An estuary occurs where a river flows into the ocean. Estuaries are high in biodiversity and provide habitat for a number of species.
Estuary Characteristics

The large number of phytoplankton and zooplankton in an estuary support a variety of species. Populations of fish and crustaceans depend on plankton as their primary food source. In turn, birds and other secondary consumers eat fish and crustaceans. Humans also rely on estuaries as a food source. In fact, 75 percent of the fish we eat depend on estuary ecosystems, making estuaries an important resource for the commercial fishing industry.

Estuaries provide a protected refuge for many species. Reefs and barrier islands along an estuary’s boundary with the ocean protect estuary species from storms and the ocean’s strong currents and waves. In an estuary’s calm waters, many aquatic species lay eggs, and their young mature there before venturing into the ocean. The use of estuaries as spawning grounds explains why these areas are often called nurseries of the sea. Estuaries are also a key part of the migration paths of many bird species, as shown in Figure 5.2. Birds rely on estuaries as a refuge from the cold weather that occurs in the northern parts of their range during certain parts of the year.

Changing conditions in estuaries present challenges for species that live there. For example, in order to withstand changing salinities, some organisms have glands that remove the excess salt that builds up in their bodies. This adaptation helps organisms cope with an estuary’s changing salinity level. Salt levels may lower with the tide and during periods of drought or heavy rainfall.

Threats to Estuary Ecosystems

Estuaries are made up of a variety of ecosystems, including salt marshes, mud flats, open water, mangrove forests, and tidal pools. When estuaries are lost to land development and other human activities, these ecosystems and the organisms that live within them are also lost.

The removal of estuaries also makes coastal areas more vulnerable to flood damage from catastrophic storms such as hurricanes. Estuaries act as a buffer between the ocean and coastal land. In some coastal areas of the United States, over 80 percent of the original estuary habitat has been lost to land development.

Analyze What characteristics make an estuary such a productive ecosystem?
Freshwater ecosystems include moving and standing water.

Rivers and streams are the flowing bodies of fresh water that serve as paths through many kinds of ecosystems. Rivers and streams, along with lakes and ponds, originate from watersheds. A watershed is a region of land that drains into a river, a river system, or another body of water.

**Freshwater Ecosystems**

If you have ever paddled down a river in a canoe, you have probably witnessed the change in shoreline ecosystems, perhaps with a forest along one stretch and sand dunes along another. Along its course, a river may vary in many ways. For example, the speed of its flow is greater in narrow areas than in wide ones. The river bottom may be alternately sandy, gravel-covered, or rock-strewn. The water level may differ across seasons. In some areas, spring brings about the melting of snow and causes river water levels to rise. Humans also affect water levels by damming rivers or by draining water for irrigation or drinking water.

Unlike rivers and streams, wetlands have very little water flowing through them. A wetland is an area of land that is saturated by ground or surface water for at least part of the year. Bogs, marshes, and swamps are different types of wetlands that are identified by their plant communities. Common wetland plants include cattails, duckweed, and sedges.

Like estuaries, wetlands are among the most productive ecosystems on Earth. They provide a home for a large number of species, some of which are only found in wetlands. Wetlands also help maintain a clean water supply. A wetland filters dirty water and renews underground stores of water.

**Adaptations of Freshwater Organisms**

The particular variety of freshwater organisms found in a body of water depends on a number of factors. These factors include water temperature, oxygen levels, pH, and the water flow rate. Each type of freshwater ecosystem is home to species with adaptations suited to its conditions. In fast-moving rivers, for example, trout are adapted to swim against the current. They have streamlined bodies that can slice through the water easily. Some aquatic insects, such as the stonefly, have hooks on their bodies. The stonefly uses the hooks to attach itself to a solid surface in fast-running water to avoid being swept away. Similarly, tadpoles that live in fast-running water often have sucker mouths that they use to attach to a surface while feeding. These tadpoles also have streamlined bodies with long tails and low fins that help them to move in the fast water. Tadpoles that live in pools or in slower moving water often lack sucker mouths and have more rounded bodies and higher fins.

**Predict** What effect would the construction of a dam have on a river ecosystem?

**TEKS 12F**
Although they are much smaller in size than oceans, freshwater ponds and lakes are also divided into zones. Scientists use the terms littoral, limnetic, and benthic to identify and separate these zones.

- The freshwater littoral zone is similar to the oceanic intertidal zone, and it is located between the high and low water marks along the shoreline. The waters of the littoral zone are well-lit, warm, and shallow. A diverse set of organisms, including water lilies, dragonflies, and snails, live in this zone.
- The limnetic zone (also called the pelagic zone) refers to the open water located farther out from shore. This zone is characterized by an abundance of plankton communities, which support populations of fish.
- The benthic zone is the lake or pond bottom, where less sunlight reaches. Decomposers, such as bacteria, live in the mud and sand of the benthic zone.

During the summer and the winter, the water temperature within a lake is stratified, which means that different layers of the lake have different temperatures. In the summer, water is warmer near the surface and colder at the bottom of the lake. These warm and cold regions are separated by a thin zone called the thermocline.

All of the water within a lake “turns over” periodically. This happens because water is most dense at 4°C (39°F). When water reaches this temperature, it will sink beneath water that is either warmer or cooler. In autumn, colder air temperatures cool the surface layer of water to 4°C, causing it to sink and mix with the water underneath. During the winter, the surface layer of water cools to less than 4°C. In the spring, when the surface water warms to 4°C, it sinks and mixes with the layers of water below. In both autumn and spring, the underlying water flows upward and switches places with the surface water. This upwelling brings nutrients such as bits of decaying plants and animals from the benthic zone to the surface, where they are eaten by surface-dwelling organisms.

Analyze  What is the significance of lake turnover to the lake ecosystem?
Amphibian Distribution
Graph the number of known amphibian species by region and analyze the distribution. Find out how amphibians are distributed all over the world.

Where Do They Live?
Use the adaptations of marine organisms to place them in the appropriate ocean environments.

Explore an Ecosystem
Dig further to explore the organisms, geology, soils, climate, and other characteristics of one major ecosystem.
15.3 Biomes

Biomes are land-based, global communities of organisms. Earth has six major biomes. These biomes include tropical rain forest, grassland, desert, temperate forest, taiga, and tundra. Polar ice caps and mountains are not considered biomes.

15.4 Marine Ecosystems

Marine ecosystems are global. Scientists use different criteria to separate the ocean into different zones. One system separates the ocean into zones using distance from the shoreline and water depth as dividing factors. The neritic zone contains 40 times more biomass than the open ocean. Coral reefs are found in the warm, shallow waters of the tropical climate zone. Kelp forests thrive in cold, nutrient-rich waters.

15.5 Estuaries and Freshwater Ecosystems

Freshwater ecosystems include estuaries as well as flowing and standing water. An estuary is a partially enclosed body of water that exists where a river flows into an ocean. A variety of organisms are adapted to the constant change in salinity found in an estuarine ecosystem. Freshwater ecosystems include rivers and streams, wetlands, and lakes and ponds.

**BIG IDEA**
Climate and the distribution of land and water play a role in shaping ecosystems and influencing the distribution of organisms on Earth.

**KEY CONCEPTS**

15.1 Life in the Earth System
The biosphere is one of Earth’s four interconnected systems. The biosphere includes living organisms, called the biota, and the land, air, and water on Earth where the biota live. Biotic and abiotic factors interact in the biosphere, and a change in one Earth system can affect the others.

15.2 Climate
Climate is a key abiotic factor that affects the biosphere. Factors that influence an area’s climate include temperature, sunlight, water, and wind. The three main climate zones on Earth are polar, tropical, and temperate. The polar zone is located at the far northern and far southern reaches of the planet. The tropical zone surrounds the equator. The temperate zone is located in the broad area between the polar and tropical zones.

**READING TOOLBOX**

**Concept Map** Use a concept map to summarize what you know about climate zones.

**Supporting Main Ideas** Use a diagram like the one below to summarize what you know about biomes.

- Tropical rain forests are warm and have abundant precipitation year-round.
- [ ]
- [ ]
- [ ]

**SYNTHESIZE YOUR NOTES**

- Earth has six major biomes.
- [ ]
CHAPTER 15 Review

INTERACTIVE Review
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CHAPTER VOCABULARY

15.1 biosphere
biota
hydrosphere
atmosphere
gerosphere
15.2 climate
microclimate
15.3 canopy
grassland
desert

deciduous
coniferous
taiga
tundra
chaparral
15.4 intertidal zone
neritic zone
bathyal zone
abyssal zone
plankton
15.5 estuary
watershed
littoral zone
limnetic zone
benthic zone
zooplankton
phytoplankton
coral reef
kelp forest

Reviewing Vocabulary

Compare and Contrast

Describe one similarity and one difference between the two terms in each of the following pairs.

1. biosphere, biota
2. zooplankton, phytoplankton
3. hydrosphere, atmosphere
4. climate, microclimate
5. taiga, tundra
6. neritic, intertidal
7. kelp forest, coral reef

Reviewing MAIN IDEAS

13. Explain the difference between the terms biota, biosphere, and biome.
14. After a forest fire wipes out plants growing on a hill, rainwater washes soil down into a stream, and the stream fills with silt. In this example, what are the interactions between biotic and abiotic factors? TEKS 12F
15. If the temperature in an area drops five degrees between one day and the next, has the climate of the area changed? Explain.
16. What is the connection between sunlight, the curved shape of Earth, and Earth’s three main climate zones?
17. Why are two different deserts, each on a separate continent, considered to be the same biome?
18. Why are polar caps and mountains not considered biomes?
19. Briefly compare the four ocean zones—intertidal, neritic, bathyal, and abyssal—based on their distance from the shoreline and their water depth.
20. Where, in terms of water depth, would you expect to find a coral reef? a kelp forest? TEKS 12B
21. Estuaries occur where rivers flow into the ocean. What conditions in estuaries make them suitable as nurseries for organisms that live out in the open ocean as adults? TEKS 12B
22. The ecosystem of a river upstream in the mountains and downstream in a valley can be very different. Describe the adaptations of an upstream organism and an organism that lives downstream in the same river. TEKS 12B

READING TOOLBOX GREEK AND LATIN WORD ORIGINS

8. The term plankton comes from the Greek word planktos, which means “wandering.” Explain how this meaning relates to plankton.
9. The term climate comes from the Greek word klima, which means “surface of the earth.” Explain how this meaning relates to the definition of climate.
10. The term estuary comes from the Latin word aestus, which means “tide” or “surges.” Using this meaning, explain how it relates to what an estuary is.
11. The term littoral comes from the Latin word litoralis, meaning “shore.” Explain how this meaning relates to the definition of littoral zone.
12. The term deciduous comes from the Latin word decidere, which means “to fall off.” How is this meaning related to the definition of deciduous?
Critical Thinking

23. **Apply** A deer drinks water from a stream, and then later it breathes out some of the water as vapor into the air. Through which three Earth spheres has this water moved? **TEKS 10C**

24. **Infer** How would Earth's three main climate zones be different if Earth's axis were not tilted in relation to the Sun? (Hint: The tropical climate zone would likely be the most similar to how it is now.) **TEKS 10C**

25. **Infer** Do you think it is possible for a biome to change from one type into another? Explain a situation in which this might happen.

26. **Connect** Why does the health of an entire coral reef ecosystem depend on algae? **TEKS 10C, 12F**

27. **Analyze** Describe two reasons why it is critical to protect estuary ecosystems. **TEKS 12F**

Interpreting Visuals

Use the diagram of a rocky intertidal zone to answer the next three questions.

28. **Predict** How do you think the organisms above the high-tide mark are able to obtain the water they need to survive? **TEKS 12B**

29. **Compare** What adaptations are necessary for a species to survive in the spray zone compared with a species in the low-tide zone? **TEKS 12B**

30. **Hypothesize** Why do you think there aren’t any fish shown in the diagram? Why wouldn’t fish be a major part of the rocky intertidal zone? **TEKS 12B**

Analyzing Data  **Construct a Combination Graph**

Below is a climatogram for the city of Portland, Oregon. Use the graph to answer the next four questions.

### AVERAGE CLIMATE OF PORTLAND, OREGON

<table>
<thead>
<tr>
<th>Month</th>
<th>Precipitation (cm)</th>
<th>Temperature (°C)</th>
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</table>

Source: National Oceanic Atmospheric Administration

31. **Analyze** Which month receives the highest amount of rain? the highest temperature?

32. **Summarize** Describe in one or two sentences the climate of Portland throughout the year.

33. **Analyze** A family is planning to vacation in Portland. Many of their planned activities occur outdoors. If they wish to avoid rain, in which month should they travel?

34. **Connect** Based on the data in the graph, which biome is Portland a part of? Explain your choice.

Making Connections

35. **Write a Policy** The majority of the wetlands in the United States have been drained and used for development. A company has submitted a proposal to purchase an area of 100 acres of wetland that it plans to develop. If you were an official in the area, how would you respond to this proposal? What would you say to a local environmental group that opposes the proposal? What might be a possible compromise? Use information from the chapter to convince your fellow elected officials to take your position. **TEKS 12F**

36. **Synthesize** Reread the information about the temperate rain forest at the beginning of the chapter. Using your knowledge of climate, biomes, and evolution, explain why different species are found in temperate and tropical rain forests. **TEKS 12B**
Record your answers on a separate piece of paper.

MULTIPLE CHOICE

1. *Sylvilagus auduboni* is a rabbit species that lives in dry desert regions, while the species *Sylvilagus palustris* lives in marshes. Which variation in behavior would most likely benefit *S. palustris*, but not *S. auduboni*?
   A. an ability to swim
   B. being active at night
   C. building a nest immediately after mating
   D. burrowing to avoid predators

2. The graph above shows how the average temperature and precipitation for a given environment change over the course of a year. Which of these most likely describes an organism that is adapted to living in this environment?
   A. low growing mosses
   B. epiphytes that grow on tree branches
   C. a cactus that is able to store water
   D. a teak tree that blocks out most of the sunlight from reaching the ground

3. Over thousands of years, the plants in a region change from plants with lush foliage to deep-rooted plants adapted to dry conditions. This shift is most likely the result of a change in —
   A. predators
   B. climate
   C. sunlight
   D. weather

4. Tropical rain forests have the greatest number of species of any biome. However, the alteration of rain forest habitats into farmland threatens to most likely —
   A. increase biomass
   B. increase species diversity
   C. cause a mass extinction
   D. decrease biodiversity

5. The diagram above shows the zones that exist in freshwater lakes. In the benthic zone, dead organic material is converted into nutrients that can be used by other organisms. What type of organisms carry out this conversion?
   A. decomposers
   B. consumers
   C. carnivores
   D. producers

6. High concentrations of sediment in the water can block out sunlight needed by aquatic plants for photosynthesis. This condition will most likely result in —
   A. increased concentrations of nitrogen
   B. decreased concentrations of nitrogen
   C. increased concentrations of oxygen
   D. decreased concentrations of oxygen

THINK THROUGH THE QUESTION

Think about what is produced and what is consumed during photosynthesis. If rates of photosynthesis decrease, the products of photosynthesis will decrease in the ecosystem.