Chapter 16

Biomes, Ecosystems, and Communities

16.1 Lesson 16.1: Biomes

Lesson Objectives

- Define biome and climate, and explain how biomes are related to climate.
- Outline how climate determines growing conditions for plants and affects the number and biodiversity of plants in a biome.
- Explain how climate is related to biodiversity of biomes and adaptations of organisms.

Introduction

If you look at the two pictures in **Figure 1** below, you will see very few similarities. The picture on the left shows a desert in Africa. The picture on the right shows a rainforest in Australia. What is the most obvious difference between the two places? It could be that the desert does not have any visible plants, whereas the rainforest is densely packed with trees. What causes these two places to be so different? The main reason is climate.

Biomes and Climate

The two pictures above represent two different types of biomes: deserts and rainforests. A **biome** is a group of similar ecosystems that cover a broad area. Biomes are major subdivisions of the biosphere. They can be classified into two major types:

- **Terrestrial biomes**: biomes on land
- **Aquatic biomes**: biomes in water

Figure 16.1: Sahara Desert in northern Africa (left). Rainforest in northeastern Australia (right). (8)

You will read about terrestrial biomes in Lesson 16.2 and aquatic biomes in Lesson 16.3. First, however, it is important to understand how climate influences biomes. Climate is the most important abiotic (non-living) factor affecting the distribution of terrestrial biomes of different types. Climate determines the growing conditions in an area, so it also determines what plants can grow there. Animals depend directly or indirectly on plants, so the type of animals that live in an area also depends on climate.

What Is Climate?

Climate is the average weather in an area over a long period of time, whereas weather is a day to day explanation. Weather and climate are described in terms of factors such as temperature and precipitation. The climate of a particular location depends, in turn, on its latitude (distance from the equator) and altitude (distance above sea level). Other factors that affect an area's climate include its location relative to the ocean or mountain ranges. Temperature and moisture are the two climatic factors that most affect terrestrial biomes.

Temperature

In general, temperature on Earth's surface falls from the equator to the poles. Based on temperature, climates can be classified as tropical, temperate, or arctic, as shown in **Figure 2**. Temperature also falls from lower to higher altitudes, for example, from the base of a mountain to its peak. This explains why the tops of high mountains in tropical climates may be snow-capped year-round.

The ocean may also play an important role in the temperature of an area. Coastal areas may have milder climates than areas farther inland at the same latitude. This is because the temperature of the ocean changes relatively little from season to season, and this affects the temperature on nearby coasts. As a result, many coastal areas have both warmer winters and cooler summers than inland areas.

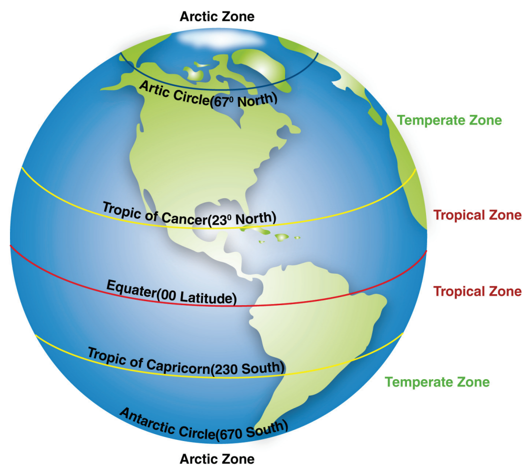


Figure 16.2: Major climate zones based on temperature include tropical, temperate, and arctic zones. The tropical zone extends from the Tropic of Capricorn to the Tropic of Cancer. The two temperate zones extend from the tropical zone to the arctic or antarctic circle. The two arctic zones extend from the arctic or antarctic circle to the north or south pole. (22)

Moisture

Based on the amount of water available to plants, climates can be classified as arid (dry), semi-arid, semi-humid, or humid (wet). The moisture of a biome is determined by both precipitation and evaporation. Evaporation, in turn, depends on heat from the sun. World-wide precipitation patterns result from global movements of air masses and winds, which are shown in **Figure 3**. For example, warm, humid air masses rise over the equator and are moved north and south by global air currents. The air masses cool and cannot hold as much water. As a result, they drop their moisture as precipitation. This explains why many tropical areas receive more precipitation than other areas of the world.

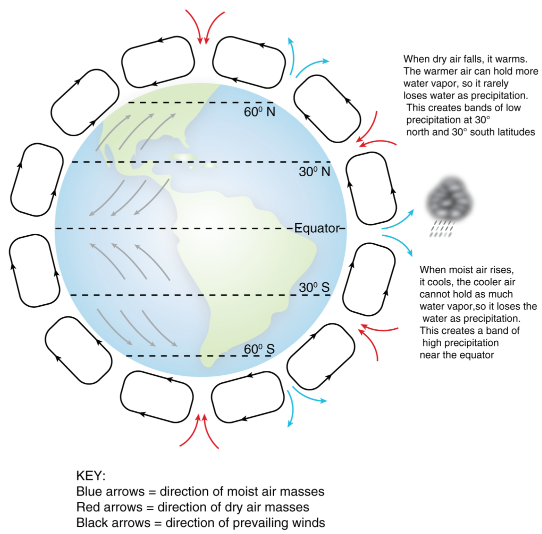


Figure 16.3: This model of Earth shows the direction in which air masses typically move and winds usually blow at different latitudes. These movements explain why some latitudes receive more precipitation than others. (9)

When the same air masses descend at about 30° north or south latitude (see **Figure 3**), they are much drier. This explains why dry climates are found at these latitudes. These latitudes are also warm and sunny, which increases evaporation and dryness. Dry climates are found near the poles, as well. Extremely cold air can hold very little moisture, so precipitation is low in arctic zones. However, these climates also have little evaporation because of the extreme cold. As a result, cold climates with low precipitation may not be as dry as warm climates with the same amount of precipitation.

Distance from the ocean and mountain ranges also influences precipitation. For example, one side of a mountain range near the ocean may receive a lot of precipitation because warm, moist air masses regularly move in from the water. As air masses begin to rise up over the mountain range, they cool and drop their moisture as precipitation. This is illustrated in **Figure 4**.

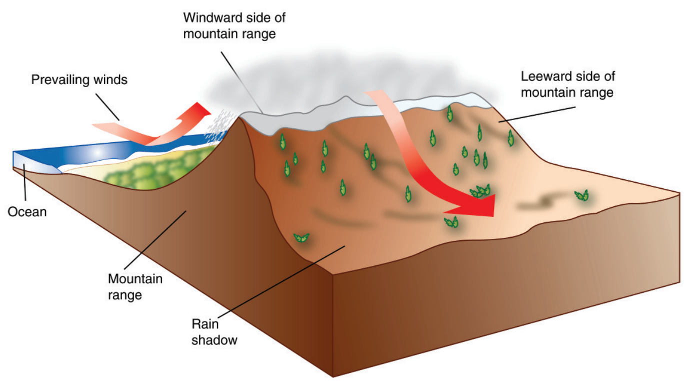


Figure 16.4: The windward side of this mountain range has a humid climate, whereas the leeward side has an arid climate. On the windward side, warm moist air comes in from the ocean, rises and cools, and drops its moisture as rain or snow. On the leeward side, the cool dry air falls, warms, and picks up moisture from the land. How has this affected plant growth on the two sides of the mountain range? (6)

By the time the air masses reach the other side of the mountain range, they no longer contain moisture. As a result, land on this side of the mountain range receives little precipitation. This land is in the **rain shadow** of the mountain range. Many inland areas far away from the ocean or mountain ranges are also dry. Air masses that have passed over a wide expanse of land to reach the interior of a continent usually no longer carry much moisture.

Climate and Plant Growth

Plants are the major producers in terrestrial biomes. Almost all other terrestrial organisms depend on them either directly or indirectly for food. Plants need air, warmth, sunlight, water, and nutrients to grow. Climate is the major factor affecting the number and diversity of plants that can grow in a terrestrial biome. Climate determines the average temperature and precipitation, the length of the growing season, and the quality of the soil, including levels of soil nutrients.

Growing Season

The **growing season** is the period of time each year when it is warm enough for plants to grow. The timing and length of the growing season determine what types of plants can grow in an area. For example, near the poles the growing season is very short. The temperature may rise above freezing for only a couple of months each year. Because of the cold temperatures and short growing season, trees and other slow-growing plants are unable to survive. The growing season gets longer from the poles to the equator. Near the equator, plants can grow year-round if they have enough moisture. A huge diversity of plants can grow in hot, wet climates.

The timing of precipitation also affects the growing season. In some areas, most of the precipitation falls during a single wet season (such as in California), rather than throughout the year (such as in New England). In these areas, the growing season lasts only as long as there is enough moisture for plants to grow.

Soil

Plants need soil that contains adequate nutrients and organic matter. Nutrients and organic matter are added to soil when plant litter and dead organisms decompose. In cold climates, decomposition occurs very slowly. As a result, soil in cold climates is thin and poor in nutrients. Soil is also thin and poor in hot, wet climates because the heat and humidity cause such rapid decomposition that little organic matter accumulates in the soil. The frequent rains also leach nutrients from the soil. Thin, poor soil is shown in the left drawing of **Figure 5**. The right drawing shows thick, rich soil. This type of soil is generally found in temperate climates and is best for most plants.

Biome Biodiversity and Adaptations

Because plants are the most important producers in terrestrial biomes, anything that affects their growth also influences the number and variety of other organisms that can be supported in a biome. Therefore, climate has a major impact on the biodiversity of biomes.

Biodiversity

Biodiversity refers to the number of different species of organisms in a biome (or ecosystem or other ecological unit). Biodiversity is usually greater in warmer biomes. Therefore, biodiversity generally decreases from the equator to the poles. Biodiversity is usually greater in wetter biomes, as well. Remember the desert and rainforest pictured in **Figure 1**? The biodiversity of these two biomes is vastly different. Both biomes have warm climates, but the desert is very dry, and the rainforest is very wet. The desert has very few organisms, so

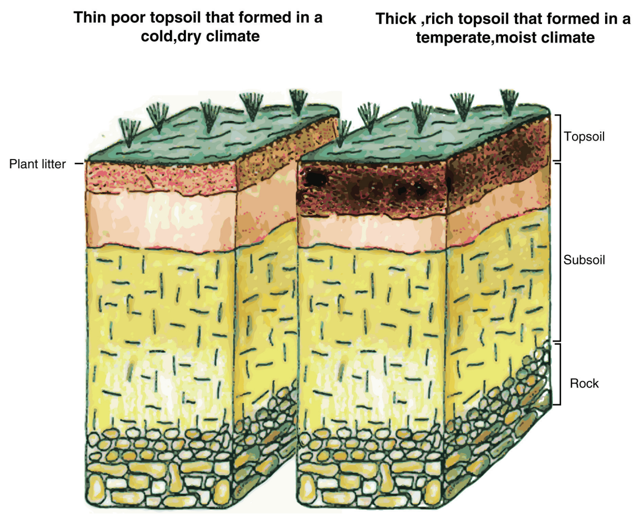


Figure 16.5: The soil on the left has a thin layer of topsoil, the part of soil where most plant roots obtain moisture and nutrients. The topsoil is light in color, which means that it is poor in nutrients and organic matter. The soil on the right has a thicker layer of topsoil. Its dark color indicates that the topsoil is rich in nutrients and organic matter. (7)

it has low biodiversity. Some parts of the desert may have no organisms, and therefore zero biodiversity. In contrast, the rainforest has the highest biodiversity of any biome on Earth.

Adaptations

Plants, animals, and other organisms evolve adaptations to suit them to the abiotic factors in their biome. Abiotic factors to which they adapt include temperature, moisture, growing season, and soil. This is why the same type of biome in different parts of the world has organisms with similar adaptations. For example, biomes with dry climates worldwide have plants with similar adaptations to aridity, such as special tissues for storing water (see **Figure 6**).

Figure 16.6: (left) The large hollow leaves of an African aloe plant store water and help the plant survive in its arid biome. (right) Cacti like these are found in arid biomes of North America. They store water in their thick, barrel-like stems. (18)

In biomes with a severe cold or dry season, plants may become dormant during that season of the year. In dormant plants, cellular activities temporarily slow down, so the plants need less sunlight and water. For example, many trees shed their leaves and become dormant during very cold or dry seasons. Animals in very cold or dry biomes also must adapt to these abiotic factors. For example, adaptations to cold include fur or fat, which insulates the body and helps retain body heat.

Lesson Summary

- A biome is a group of similar ecosystems that cover a broad area. Climate is the average weather in an area over a long period of time. Climate is the most important abiotic factor affecting the distribution of terrestrial biomes.

- Climate includes temperature and precipitation, and it determines growing season and soil quality. It is the major factor affecting the number and diversity of plants in terrestrial biomes.
- By affecting plants, which are the main producers, climate affects the biodiversity of terrestrial biomes. Plants and other organisms also evolve adaptations to climatic factors in their biomes, including adaptations to extreme cold and dryness.

Review Questions

1. Name three factors that help determine the climate of an ecosystem.
2. What is a rain shadow?
3. List some important factors related to climate that plants need in order to grow?
4. Compare the data for Seattle and Denver in the table below. What factors might explain why Seattle is warmer in the winter than Denver, even though Seattle is farther north?:

Table 16.1:

City	Latitude	Altitude	Location	Temperature[1]
Seattle, Washington	48°N	429 ft	Coastal	33°F
Denver, Colorado	41°N	5,183 ft	Interior	15°F

5.
6. [1]
7. Average low temperature in January
8. Explain how the quality of soil in an area is influenced by climate.
9. Why is biodiversity higher at the equator than it is near the poles?

Further Reading / Supplemental Links

- Harm J.de Blij, Peter O. Muller,and Richard S. Williams, Physical Geography: The Global Environment (3rd edition). Oxford University Press, 2004.
- Ross E. Koning,Climate and Biomes, Plant Physiology Information Website.
- Susan L. Woodward, Biomes of Earth: Terrestrial, Aquatic, and Human-Dominated. Greenwood Press, 2003.
- http://estrellamountain.edu/faculty/farabee/biobk/BioBookcommecosys.html
- http://ridge.icu.ac.jp/gen-ed/biomes.html
- http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/B/Biomes.html

Vocabulary

aquatic biome Biome in water.

biodiversity Number of different species of organisms in a biome (or ecosystem or other unit).

biome Group of similar ecosystems that cover a broad area.

climate Average weather in an area over a long period of time.

growing season Period of time each year when it is warm enough for plants to grow.

rain shadow Land on the leeward side of a mountain range that receives very little precipitation.

terrestrial biome Biome on land.

Points to Consider

Plants and the other organisms in terrestrial biomes are greatly influenced by climate.

- What is the climate like where you live?
- How hot or cold does it get, and how much precipitation usually falls?
- Discuss with your class the climate in your area and how it seems to affect plant growth.
- What plants and animals are naturally found in your part of the country?

16.2 Lesson 16.2: Terrestrial Biomes

Lesson Objectives

- State how terrestrial biomes are classified and distributed around the globe.
- Outline abiotic and biotic factors in tundra and boreal forest biomes.
- Describe climatic factors and organisms of temperate zone biomes.
- List abiotic factors in deserts and adaptations of desert organisms.
- Identify abiotic factors and organisms in tropical biomes.

Introduction

Terrestrial biomes include all land areas on Earth where organisms live. The major biomes cover large regions and are found on more than one continent. They are generally classified on the basis of climatic factors and the types of plants that are the primary producers.

Classification of Terrestrial Biomes

Scientists have created several different systems for classifying terrestrial biomes. Biomes in most classification systems include tundra, boreal forest, temperate forest, temperate grassland, chaparral, tropical forest, tropical grassland, and desert. The worldwide distribution of these biomes is shown in **Figure 1**.

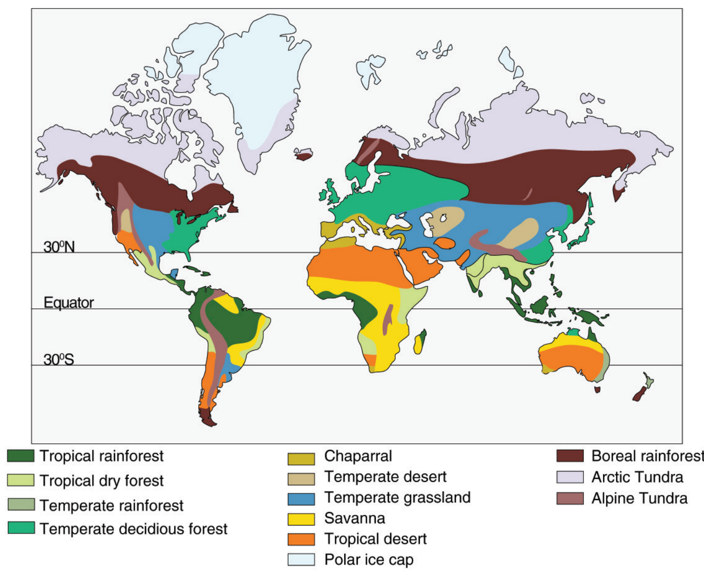


Figure 16.7: Distribution of Earth's major terrestrial biomes. (12)

The distribution of biomes shown in **Figure 1** reflects global patterns of temperature and moisture. It also reflects conditions in earlier times. Many areas have been disturbed by human actions, some more so than others. For example, most tundra biomes have been changed very little by human actions, but many forests have been completely cleared. Some biomes, including tropical rainforests, cannot be replaced once they have been destroyed. **Figure 2** summarizes important features of most of the biomes shown in **Figure 1**. Refer to both figures as you read about these terrestrial biomes throughout this lesson.

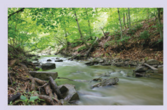
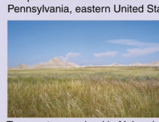
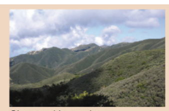
Biome: Other Name(s)	Type of Climate, Growing Season, Soil Quality	Biodiversity, Common Plants, Common Animals
Tundra: Artic tundra (high latitudes) Alpine tundra (high altitudes)	*Type of climate*: arctic, arid *Growing season:* very short *Soil quality:* Very poor	 Alpine tundra in the Alps Mountains of Switzerland in Europe  Arctic tundra on the northern coast of Alaska in the United States *Biodiversity:* very low *Plants*: mosses, grasses, and lichens; few herbaceous plants; no trees *Animals:* insects; birds (summer only); no amphibians or reptiles; mammals such as rodents, arctic hares, arctic foxes, polar bears; caribou (summer only); mountain goats and chinchillas (alpine tundra only)
Boreal Forest: Taiga Northern conifer forest	*Climate:* subarctic, semi-arid *Growing season:* short *Soil quality:* Poor	*Biodiversity:* low *Plants:* conifers such as cedar, spruce, pine, and fir; mosses and lichens *Animals:* insects; birds (mainly in summer); no amphibians or reptiles; mammals such as rodents, rabbits, minks, raccoons, bears, and moose; caribou (winter only)  Boreal forest in central (inland) Alaska, United States
Temperate Deciduous Forest: Temperate hardwood forest Temperate broadleaf forest	*Climate:* temperate, semi-humid *Growing season:* medium *Soil quality:* good *Climate:* temperate, semi-arid *Growing season:* medium *Soil quality:* excellent	 Temperate deciduous forest in Pennsylvania, eastern United States *Biodiversity*: high *Plants*: broadleaf deciduous trees such as beech, maple, oak, and hickory; ferns, mosses, and shrubs; many herbaceous plants *Animals*: insects, amphibians, reptiles, and birds; mammals such as mice, chipmunks, squirrels, raccoons, foxes, deer, black bears, bobcats, and wolves  Temperate grassland in Nebraska, midwestern United States *Biodiversity*: medium–high *Plants*: grasses; other herbaceous plants; no trees *Animals*: invertebrates such as worms and insects; amphibians, reptiles, and birds; mammals such as mice, prairie dogs, rabbits, foxes, wolves, coyotes, bison, and antelope; kangaroo (only in Australia)
Chaparral Mediterranean scrub forest	*Climate:* temperate, semi-arid *Growing season:* medium *Soil quality:* poor	*Biodiversity*: low–medium *Plants:* shrubs and small trees such as scrub oak and scrub pine *Animals:* insects, reptiles, and birds; mammals such as rodents and deer  Chaparral in southern California, United States
Desert	*Climate:* temperate or tropical, arid *Growing season:* varies *Soil quality:* very poor	*Biodiversity:* none–low *Plants:* plants adapted to dryness, such as cacti, sage-brush, and mesquite; virtually no plants if extremely arid *Animals*: insects, reptiles, and birds; mammals such as rodents and coyotes  Desert in southern California, United States
Tropical Rainforest	*Climate:* tropical, humid *Growing season:* year-round *Soil quality:* excellent	*Biodiversity*: very high *Plants*: tall flowering, broadleaf evergreen trees; vines and epiphytes; few plants on forest floor *Animals:* insects, amphibians, reptiles, and birds; mammals such as monkeys, sloths, leopards, jaguars, pigs, and tigers  Tropical rainforest in Ecuador, South America
Tropical Grassland Savanna	*Climate*: tropical, semi-arid *Growing season:* year-round *Soil quality:* poor	*Biodiversity*: low–medium *Plants*: grasses; scattered clumps of trees *Animals:* insects, reptiles, and birds; mammals such as zebras, giraffes, antelopes, lions, cheetahs, and hyenas  Elephant browsing on the leaves of an acacia tree in savanna in Kenya, eastern Africa

Figure 16.8: These biomes are described more fully in the text. Refer to **Figure 1** to see where each biome is found. (23)

Arctic and Subarctic Biomes

Artic and subarctic biomes are found near the north and south poles or at high altitudes in other climate zones. The biomes include tundra and boreal forests. Both have cold, dry climates and poor soil. They can support only limited plant growth and have low biodiversity.

Tundra

Tundra is an arctic biome where it is too cold for trees to grow. Outside of the polar ice caps, tundra has the coldest temperatures on Earth. There are two types of tundra: arctic tundra, which is also found in Antarctica, and alpine tundra, which is found only at high altitudes.

- **Arctic tundra** occurs north of the arctic circle and south of the antarctic circle. It covers much of Alaska and vast areas of northern Canada and Russia. It is also found along the northern coast of Antarctica.
- **Alpine tundra** occurs in mountains around the world at any latitude, but only above the tree line. The **tree line** is the edge of the zone at which trees are able to survive. Alpine tundra is found in the Rocky Mountains in the United States and in several other mountain ranges around the world.

Both types of tundra receive very low precipitation, but little of it evaporates because of the cold. Arctic tundra has **permafrost,** which is soil that is frozen year-round. The top layer of soil thaws in the summer, but deeper layers do not. As a result, water cannot soak into the ground. This leaves the soil soggy and creates many bogs, lakes, and streams. Alpine tundra does not have permafrost, except at very high altitudes. Therefore, alpine tundra soil tends to be dry rather than soggy.

Global warming poses a serious threat to Arctic tundra biomes because it is causing the permafrost to melt. When permafrost melts, it not only changes the tundra. It also releases large amounts of methane and carbon dioxide into the atmosphere. Both are greenhouse gases, which contribute to greater global warming.

The most common vegetation in tundra is mosses and lichens. They can grow in very little soil and become dormant during the winter. Tundra is too cold for amphibians or reptiles, which cannot regulate their own body heat. Insects such as mosquitoes can survive the winter as pupae and are very numerous in summer. In addition, many species of birds and large herds of caribou migrate to arctic tundra each summer. However, few birds and mammals live there year-round. Those that remain have adapted to the extreme cold. Polar bears are an example. They have very thick fur to insulate them from the cold. In alpine tundra, animals must adapt to rugged terrain as well as to cold. Alpine animals include mountain goats, which not only have wool to keep them warm but are also sure-footed and agile.

Boreal Forests

A **boreal forest** is a subarctic biome covered with conifers. Conifers are cone-bearing, needle-leaved evergreen trees such as spruces. Boreal forests are found only in the northern hemisphere. They occur just south of the arctic circle in Alaska, Canada, northern Europe, and Russia (where they are called taiga). They also occur in extreme northern regions of Minnesota, New York State, New Hampshire, and Maine.

Boreal forests have harsh continental climates, with very cold winters and relatively warm summers. The growing season is also short. Precipitation is quite low, but there is little evaporation. Most of the precipitation falls in the summer when plants are growing, so there is enough moisture for dense plant growth. A thick carpet of evergreen needles on the forest floor causes the soil to be too acidic for most other plants.

Conifers have adapted to the difficult conditions in several ways. They have shallow roots that suit them for the thin soil. They have needles instead of leaves, which reduce water loss during the long, dry winters. The needles are also very dark green in color, which maximizes absorption of sunlight for photosynthesis. Although boreal forests are dense with conifers, there are only a few different species of trees. Vegetation on the forest floor consists mostly of mosses and lichens. Animals found in boreal forests include insects, birds, and mammals such as rabbits, foxes, and brown bears. Caribou also spend their winters there. Like tundra, the boreal forest is too cold for amphibians or reptiles.

Temperate Biomes

Temperate biomes cover most of the continental United States and Europe. They also cover large parts of Asia. Types of temperate biomes include forests, grasslands, and chaparral.

Temperate Forests

There are two types of temperate forests: temperate deciduous forests and temperate rainforests. Both types have a temperate climate and good soil. A temperate climate is a moderate climate that is neither extremely hot nor extremely cold. A temperate climate can be either continental or coastal. Continental temperate climates are found inland, and they tend to have cold winters, hot summers, and moderate precipitation. Coastal temperate climates are found near the ocean, and they tend to have mild winters, cool summers, and high precipitation.

- **Temperate deciduous forests** are found in areas with continental temperate climates, such as the eastern United States and Canada and throughout much of Europe. These forests consist mainly of deciduous trees, such as maples and oaks, which lose their leaves in the fall. There are many other species of plants as well. Animals include insects, amphibians, reptiles, and birds. Mammals are also common, including rabbits and wolves.

- **Temperate rainforests** are found in areas with coastal temperate climates, such as the northwestern coast of North America and certain coastal regions of other continents. These forests consist mainly of evergreen trees, such as hemlocks and firs. Mosses, lichens, and ferns grow on the forest floor. There are also many epiphytic plants. Animals include insects, amphibians, reptiles, and birds. There are also many mammals, such as squirrels and deer.

Epiphytes are plants that grow on other plants. They use the other plants for support, not nutrients, and generally do not harm the plants they grow on. They grow high in the branches of trees where there is more sunlight available for photosynthesis.

Temperate Grasslands

Temperate grasslands are temperate biomes that consist mainly of grasses. They are found in the midwestern region of North America and in inland areas of most other continents. The climate is continental, and precipitation is relatively low. However, the majority of the precipitation falls during the growing season when plants need it the most.

Biomes are often referred to by local names. For example, a temperate grassland biome is known as prairie in North America, outback in Australia, pampa in South America, and steppe in central Asia. Can you find each of these temperate grasslands on the map in **Figure 1**?

The soil of temperate grasslands is the richest, deepest soil on Earth. It is densely covered with thick grasses that decompose to add large amounts of organic matter and nutrients to the soil. Grasses also have thick mats of roots that hold the soil in place and prevent erosion. The low rainfall does not leach many nutrients from the soil, but it does lead to frequent fires. The fires help prevent woody vegetation from moving in if a grassland is disturbed. This is because grasses can grow back after a fire, whereas most woody plants cannot.

The rich, deep soil supports high productivity. This is why the temperate grassland of the US midwest is known as the *Breadbasket of America.* Grass plants are closely spaced and can support many herbivore consumers. These range from grasshoppers to deer. Many worms and other invertebrates (animals without a backbone) consume organic matter in the soil. Grassland animals also include carnivores such as foxes and coyotes.

Chaparral

Chaparral is a shrub forest biome dominated by densely-growing evergreen shrubs or small trees, such as scrub oak. There are few other species of plants. Chaparral is found mainly in central and southern California and around the Mediterranean Sea. The climate, called a Mediterranean climate, has mild wet winters and hot dry summers. Fires are frequent because of the summer dryness, and the soil is relatively poor.

The majority of chaparral trees and plants are adapted to the dry summers. For example:

- Trees are short, which reduces their need for water.
- Many plants are dormant during the dry season, which also reduces water needs.
- The leaves of some plants have waxy coatings, which reduce water loss.

Most chaparral plants are adapted to frequent fires, as well. For example:

- Many plants can grow back quickly from the roots after burning to the ground.
- Some plants produce seeds that need fire in order to germinate.
- Many plants have thick underground stems that can survive fires.

The densely growing trees make it difficult for very large animals to penetrate the chaparral, so most chaparral animals are small. They include insects, birds, reptiles, and rodents. The largest animals are deer, which browse on the leaves of chaparral trees.

Deserts

A **desert** is a biome that receives no more than 25 centimeters (10 inches) of precipitation per year. Deserts are found in both temperate and tropical areas. The largest deserts are found at about 30° north or south latitude due to the dry air masses over these latitudes. Deserts also occur in rain shadows. A rain shadow is a dry region on the leeward side of a mountain range (see Lesson 16.1). Examples of rain shadow deserts include Death Valley and the Mojave Desert, both partly in California. The dry air in deserts leads to extreme temperature variations from day to night. Without water vapor in the air, there are no clouds to block sunlight during the day or hold in heat at night.

Desert soil is usually very poor. They tend to be sandy or rocky and lack organic content. Because of the low precipitation, minerals are not leached out and may become too concentrated for plants to tolerate. Plant cover is very sparse, so most of the soil is exposed and easily eroded by wind. The occasional rain tends to be brief but heavy, causing runoff and more erosion.

Most desert plants have evolved adaptations to the extreme dryness. For example:

- Many plants have special water-storing tissues in leaves, stems, or roots.
- Some plants have very long taproots that can reach down to the water table.
- Some plants have wide-spreading roots that can absorb water over a large area.
- Plants may have small, spiny leaves that help reduce water loss.

Most desert animals have adaptations to the extreme heat and bright sunlight. For example:

- Many small animals stay underground in burrows during the day and come out only at night.
- Most animals that are active in daytime spend as much time as possible in the shade of rocks or plants.
- Some animals have very large ears or other appendages, which help them lose heat to the environment, keeping them cooler.
- Many animals are light in color, which helps them reflect sunlight and stay cooler.

Tropical Biomes

Tropical biomes receive more sunlight than any other biomes on Earth. They also have high temperatures year-round. In addition to deserts, tropical biomes include forests and grasslands.

Tropical Forests

There are two types of tropical forests: tropical rainforests and tropical dry forests. Both occur near the equator, so they have plenty of sunlight and warmth year-round. However, they differ in the amount and timing of the precipitation they receive.

- **Tropical rainforests** receive more precipitation than any other biome. They are found near the equator in Central and South America and Africa. The soil is thin and poor, partly because the lush plant growth uses up nutrients before they can accumulate in the soil. Biodiversity of animals as well as plants is greater than in all other biomes combined. Most plants are tall, broadleaf evergreen trees. They form a dense canopy over the forest, so little sunlight reaches the forest floor. The many vines and epiphytes reach sunlight by growing on trees. Numerous animal species also live in trees, including monkeys, sloths, and leopards.
- **Tropical dry forests** occur in tropical areas where most of the precipitation falls during a single wet season. As a result, there is a pronounced dry season. Tropical dry forests are found in parts of Central and South America, Africa, and India. Trees and other plants are widely spaced because there is not enough water for denser growth. The plants also have adaptations to help them cope with seasonal drought. For example, many go dormant during the dry season, which reduces their need for water. Animals that live in tropical dry forests include arboreal animals such as monkeys and ground-dwelling animals such as rodents.

Tropical Grasslands

Tropical grasslands are tropical biomes with relatively low rainfall where the primary producers are grasses. Tropical grasslands are found mainly in Africa, where they are called savannas. They have high temperatures year-round, but relatively low precipitation. Moreover, most of the precipitation falls during a single wet season, leaving the rest of the year very dry. The soil is also poor.

In addition to grasses, there are scattered clumps of trees in most tropical grasslands. The trees are drought-adapted species such as acacia, which have narrow leaves that reduce water loss. Acacia trees also have thorns that discourage browsing by herbivores. Africa savannas are well known for their huge herds of herbivores, including zebra, giraffe, and wildebeest. They are also well known for their large carnivores—such as lions, cheetahs, and hyenas—that prey on the herbivores.

Lesson Summary

The concept map below shows how the terrestrial biomes described in this lesson are related.

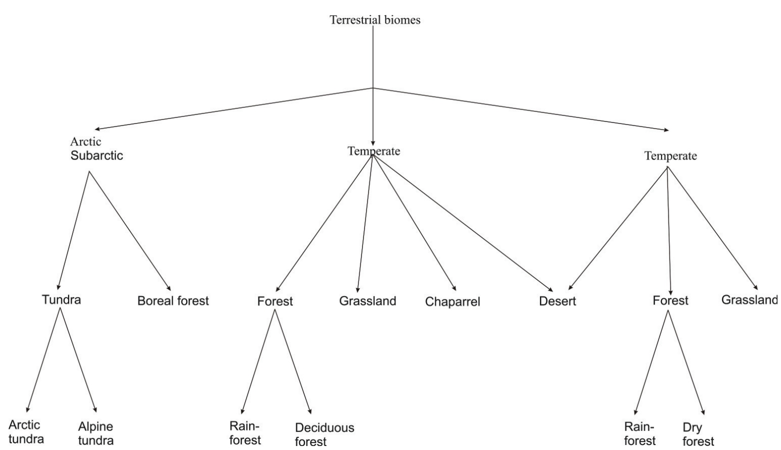


Figure 16.9: (14)

Review Questions

1. Identify the two types of tundra and where they are found.
2. Name two temperate biomes and the main type of plant found in each biome.
3. In which biome are you most likely to find grasses, zebras, and lions?
4. Assume a new species of lizard has been discovered in the northern hemisphere. It lives in an area of dense evergreen forest, where mosses and lichens grow on the forest floor. Identify the biome in which the lizard was found and explain your answer.

5. If you were to design a well-adapted desert animal, what traits would you give it to help it survive in its desert environment?
6. Compare and contrast two types of temperate forests.
7. If the tropics receive more sunlight year-round than any other biome, why are some plants in tropical rainforests adapted to low levels of sunlight?

Further Reading / Supplemental Links

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Vocabulary

alpine tundra Tundra biome that occurs in mountains around the world at any latitude, but only above the tree line.

arctic tundra Tundra biome that occurs north of the arctic circle and south of the antarctic circle.

boreal forest Subarctic biome covered with conifers.

chaparral Temperate biome with a Mediterranean climate that consists mainly of densely-growing evergreen shrubs such as scrub oak.

desert Temperate or tropical biome that receives no more than 25 centimeters of precipitation per year.

epiphyte Type of plant that grows on other plants for support.

permafrost Frozen soil year-round.

temperate deciduous forest Temperate biome that receives moderate rainfall and consists mainly of deciduous trees such as maples.

temperate grassland Temperate biome that receives relatively low precipitation and consists mainly of grasses.

temperate rainforest Temperate biome that receives heavy rainfall and consists mainly of evergreen trees such as hemlocks.

tree line Edge of the zone at which trees are able to survive.

tropical dry forest Tropical biome that receives relatively low rainfall, has a dry season, and consists mainly of widely spaced, drought-adapted trees.

tropical grassland Tropical biome that receives relatively low rainfall, has a dry season, and consists mainly of grasses.

tropical rainforest Tropical biome that receives heavy rainfall and consists mainly of tall, broadleaf evergreen trees.

tundra Arctic biome where it is too cold for trees to grow.

Points to Consider

The land areas where terrestrial biomes are found cover only 30 percent of Earth's surface. The rest of the surface is covered by water.

- What types of biomes do you think occur in water?
- How do you think water biomes might be classified?
- What do you think are some of the organisms that live in water biomes?

16.3 Lesson 16.3: Aquatic Biomes

Lesson Objectives

- Describe how aquatic biomes are divided into zones, and list types of aquatic organisms.
- Identify marine biomes, and state which biomes have the highest biodiversity.
- Name types of freshwater biomes, and describe how they differ from one another.

Introduction

Terrestrial organisms are generally limited by temperature and moisture. Therefore, terrestrial biomes are defined in terms of these abiotic factors. In contrast, most organisms that live in the water do not have to deal with extremes of temperature or moisture. Instead, their main limiting factors are the availability of sunlight and the concentration of dissolved nutrients in the water.

What Are Aquatic Biomes?

Aquatic biomes are biomes found in water. Water covers 70 percent of Earth's surface, so aquatic biomes are a major component of the biosphere. However, they have less total biomass than terrestrial biomes. Aquatic biomes can occur in either salt water or freshwater. About 98 percent of Earth's water is salty, and only 2 percent is fresh. The primary saltwater biome is the ocean. Major freshwater biomes include lakes and rivers.

Aquatic Zones

In large bodies of standing water (including the ocean and lakes), the water can be divided into zones based on the amount of sunlight it receives. There is enough sunlight for photosynthesis only in - at most - the top 200 meters of water. Water down to this depth is called the **photic zone**. Deeper water, where too little sunlight penetrates for photosynthesis, is called the **aphotic zone.**

Surface water dissolves oxygen from the air, so there is generally plenty of oxygen in the photic zone to support organisms. Water near shore usually contains more dissolved nutrients than water farther from the shore. This is because most dissolved nutrients enter a body of water from land, carried by runoff or rivers that empty into the body of water. When aquatic organisms die, they sink to the bottom, where decomposers release the nutrients they contain. As a result, deep water may contain more nutrients than surface water.

`Deep ocean water may be forced to the surface by currents in a process called '''upwelling.''' When this happens, dissolved nutrients are brought to the surface from the deep ocean. The nutrients can support large populations of producers and consumers, including many species of fish. As a result, areas of upwelling are important for commercial fishing.`With these variations in sunlight, oxygen, and nutrients, different parts of the ocean or a lake have different types and numbers of organisms. Therefore, life in a lake or the ocean is generally divided into zones. The zones correlate mainly with the amount of sunlight and nutrients available to producers. **Figure 1** shows ocean zones. Lakes have similar zones.

- The **littoral zone** is the shallow water near the shore. In the ocean, the littoral zone is also called the intertidal zone.

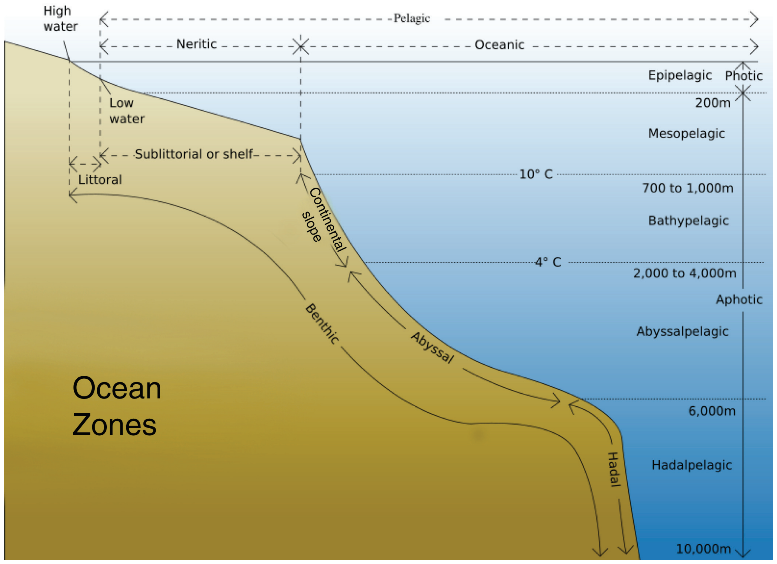

Figure 16.10: The ocean is divided into many different zones, depending on distance from shore and depth of water. The pelagic zone is divided into neritic and oceanic zones based on distance from shore. Into what additional zones is the pelagic zone divided on the basis of water depth? What additional zones make up the benthic zone? (17)

- The **pelagic zone** is the main body of open water farther out from shore. It is divided into additional zones based on water depth. In the ocean, the part of the pelagic zone over the continental shelf is called the **neritic zone,** and the rest of the pelagic zone is called the **oceanic zone.**
- The **benthic zone** is the bottom surface of a body of water. In the ocean, the benthic zone is divided into additional zones based on depth below sea level.

Aquatic Organisms

Aquatic organisms are classified into three basic categories: plankton, nekton, and benthos. Organisms in these three categories vary in where they live and how they move.

- **Plankton** are aquatic organisms that live in the water itself and cannot propel themselves through water. They include both phytoplankton and zooplankton. Phytoplankton are bacteria and algae that use sunlight to make food by photosynthesis. Zooplankton are tiny animals that feed on phytoplankton.
- **Nekton** are aquatic animals that live in the water and can propel themselves by swimming or other means. Nekton include invertebrates such as shrimp and vertebrates such as fish.
- **Benthos** are aquatic organisms that live on the surface below a body of water. They

live in or on the sediments at the bottom. Benthos include sponges, clams, and sea stars (see **Figure 2**).

Figure 16.11: This sea star, or starfish, is an example of a benthic organism. The tiny white projections on the bottom surface of the sea star allow it anchor to, or slowly crawl over, the bottom surface of the ocean. (16)

Marine Biomes

Marine biomes are aquatic biomes found in the salt water of the ocean. Major marine biomes are neritic, oceanic, and benthic biomes. Other marine biomes include intertidal zones, estuaries, and coral reefs.

Neritic Biomes

Neritic biomes occur in ocean water over the continental shelf (see **Figure 1**). They extend from the low-tide water line to the edge of the continental shelf. The water here is shallow, so there is enough sunlight for photosynthesis. The water is also rich in nutrients, which are washed into the water from the nearby land. Because of these favorable conditions, large populations of phytoplankton live in neritic biomes. They produce enough food to support many other organisms, including both zooplankton and nekton. As a result, neritic biomes have relatively great biomass and biodiversity. They are occupied by many species of invertebrates and fish. In fact, most of the world's major saltwater fishing areas are in neritic biomes.

Oceanic Biomes

Oceanic biomes occur in the open ocean beyond the continental shelf. There are lower concentrations of dissolved nutrients away from shore, so the oceanic zone has a lower density of organisms than the neritic zone. The oceanic zone is divided into additional zones based on water depth (see **Figure 1**).

- The **epipelagic zone** is the top 200 meters of water, or the depth to which enough sunlight can penetrate for photosynthesis. Most open ocean organisms are concentrated in this zone, including both plankton and nekton.
- The **mesopelagic zone** is between 200 and 1,000 meters below sea level. Some sunlight penetrates to this depth but not enough for photosynthesis. Organisms in this zone consume food drifting down from the epipelagic zone, or they prey upon other organisms in their own zone. Some organisms are detrivores, which consume dead organisms and organic debris that also drift down through the water.
- The **bathypelagic zone** is between 1,000 and 4,000 meters below sea level. No sunlight penetrates below 1,000 meters, so this zone is completely dark. Most organisms in this zone either consume dead organisms drifting down from above or prey upon other animals in their own zone. There are fewer organisms and less biomass here than in higher zones. Some animals are bioluminescent, which means they can give off light (see **Figure 3**). This is an adaptation to the total darkness.
- The **abyssopelagic zone** is between 4,000 and 6,000 meters below sea level. The **hadopelagic zone** is found in the water of deep ocean trenches below 6,000 meters. Both of these zones are similar to the bathypelagic zone in being completely dark. They have even lower biomass and species diversity.

Benthic Biomes

Benthic biomes occur on the bottom of the ocean where benthos live. Some benthos, including sponges, are sessile, or unable to move, and live attached to the ocean floor. Other benthos, including clams, burrow into sediments on the ocean floor. The benthic zone can be divided into additional zones based on how far below sea level the ocean floor is (see **Figure 1**).

- The **sublittoral zone** is the part of the ocean floor that makes up the continental shelf near the shoreline. The water is shallow enough for sunlight to penetrate down to the ocean floor. Therefore, photosynthetic producers such as seaweed can grow on the ocean floor in this zone. The littoral zone is rich in marine life.
- The **bathyal zone** is the part of the ocean floor that makes up the continental slope. It ranges from about 1,000 to 4,000 meters below sea level. The bathyal zone contains no producers because it is too far below the surface for sunlight to penetrate. Although

Figure 16.12: The anglerfish lives in the bathypelagic zone. The rod-like structure protruding from the anglerfish's face is tipped with bioluminescent microorganisms. The structure wiggles like a worm to attract prey. Only the "worm" is visible to prey in the total darkness of this zone. (26)

consumers and decomposers live in this zone, there are fewer organisms here than in the sublittoral zone.

- The **abyssal zone** is the part of the ocean floor in the deep open ocean. It varies from about 4,000 to 6,000 meters below sea level. Organisms that live on the ocean floor in this zone must be able to withstand extreme water pressure, continuous cold, and scarcity of nutrients. Many of the organisms sift through sediments on the ocean floor for food or dead organisms.
- The **hadal zone** is the ocean floor below 6,000 meters in deep ocean trenches. The only places where organisms are known to live in this zone are at hydrothermal vents, where invertebrates such as tubeworms and clams are found. They depend on microscopic archaea organisms for food. These tiny chemosynthetic producers obtain energy from chemicals leaving the vents (see the *Principles of Ecology* chapter).

Intertidal Zone

The **intertidal zone** is a narrow strip along the coastline that falls between high- and low-tide water lines. It is also called the littoral zone (see **Figure 1**). A dominant feature of this zone is the regular movement of the tides in and out. In most areas, this occurs twice a day. Due to the tides, this zone alternates between being under water at high tide and being exposed to the air at low tide. An intertidal zone is pictured in **Figure 4**.

Figure 16.13: These pictures show the Bay of Fundy off the northeastern coast of Maine in North America. The picture on the left shows the bay at high tide, and the picture on the right shows the bay at low tide. The area covered by water at high tide and exposed to air at low tide is the intertidal zone. (24)

The high tide repeatedly brings in coastal water with its rich load of dissolved nutrients. There is also plenty of sunlight for photosynthesis. In addition, the shallow water keeps large predators, such as whales and big fish, out of the intertidal zone. As a result, the intertidal zone has a high density of living things. Seaweeds and algae are numerous, and they support many consumer species, either directly or indirectly, including barnacles, sea stars, and crabs.

Other conditions in the intertidal zone are less favorable. For example, there are frequent shifts from a water to an air environment. There are also repeated changes in temperature and salinity (salt concentration). These changing conditions pose serious challenges to marine organisms. The moving water poses yet another challenge. Organisms must have some way to prevent being washed out to sea with the tides. Barnacles, like those in **Figure 5**, cement themselves to rocks. Seaweeds have rootlike structures, called holdfasts, which anchor them to rocks. Crabs burrow underground to avoid being washed out with the tides.

Figure 16.14: Barnacles secrete a cement-like substance that anchors them to rocks. (5)

Other Marine Biomes

The intertidal zone has high biodiversity. However, it is not the marine biome with the highest biodiversity. That distinction goes to estuaries and coral reefs. They have the highest biodiversity of all marine biomes.

- An **estuary** is a bay where a river empties into the ocean. It is usually semi-enclosed, making it a protected environment. The water is rich in dissolved nutrients from the river and shallow enough for sunlight to penetrate for photosynthesis. As a result, estuaries are full of marine life. **Figure 6** shows an estuary on the California coast near San Francisco.

Figure 16.15: This satellite photo shows the San Francisco Estuary on the California coast. This is the largest estuary on the lower west coast of North America. Two rivers, the Sacramento and the San Joaquin, flow into the estuary (upper right corner of photo). The estuary is almost completely enclosed by land but still connected to the ocean. (4)

- A **coral reef** is an underwater limestone structure produced by tiny invertebrate animals called corals. Coral reefs are found only in shallow, tropical ocean water. Corals secrete calcium carbonate (limestone) to form an external skeleton. Corals live in colonies, and the skeletal material gradually accumulates to form a reef. Coral reefs are rich with marine organisms, including more than 4,000 species of tropical fish. **Figure 7** shows a coral reef in the Hawaiian Islands.

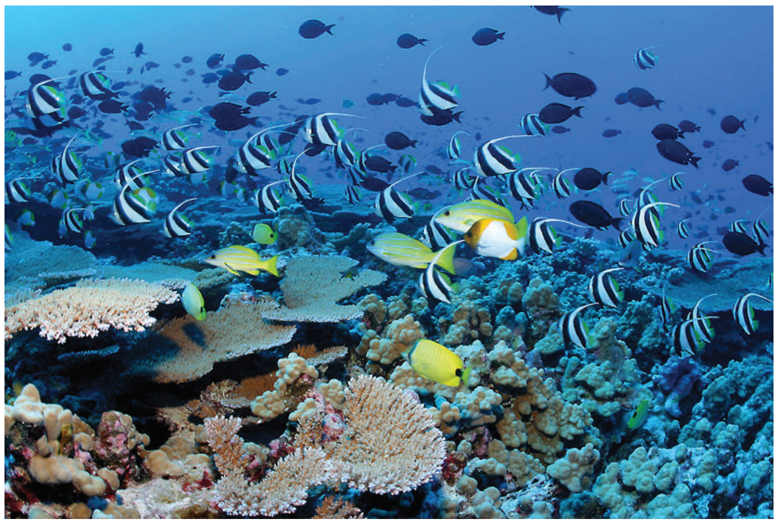

Figure 16.16: Colorful fish swim in warm, shallow ocean water near a coral reef off the Hawaiian Islands. (2)

Freshwater Biomes

Freshwater biomes occur in water that contains little or no salt. Freshwater biomes include standing water and running water biomes.

Standing Freshwater Biomes

Standing freshwater biomes include ponds and lakes. Ponds are generally smaller than lakes and shallow enough for sunlight to reach all the way to the bottom. In lakes, at least some of the water is too deep for sunlight to penetrate. As a result, like the ocean, lakes can be divided into zones based on availability of sunlight for producers.

- The littoral zone is the water closest to shore. The water in the littoral zone is generally shallow enough for sunlight to penetrate, allowing photosynthesis. Producers in this zone include both phytoplankton and plants that float in the water. They provide

food, oxygen, and habitat to other aquatic organisms. The littoral zone generally has high productivity and high biodiversity.
- The **limnetic zone** is the top layer of lake water away from shore. This zone covers much of the lake's surface, but it is only as deep as sunlight can penetrate. This is a maximum of 200 meters. If the water is muddy or cloudy, sunlight cannot penetrate as deeply. Photosynthesis occurs in this zone, and the primary producers are phytoplankton, which float suspended in the water. Zooplankton and nekton are also found in this zone. The limnetic zone is generally lower in productivity and biodiversity than the littoral zone.
- The **profundal zone** is the deep water near the bottom of a lake where no sunlight penetrates. Photosynthesis cannot take place, so there are no producers in this zone. Consumers eat food that drifts down from above, or they eat other organisms in the profundal zone. Decomposers break down dead organisms that drift down through the water. This zone has low biodiversity.
- The benthic zone is the bottom of a lake. Near the shore, where water is shallow, the bottom of the lake receives sunlight, and plants can grow in sediments there. Organisms such as crayfish, snails, and insects also live in and around the plants near shore. The plants provide shelter from predatory fish as well as food and oxygen. In deeper water, where the bottom of the lake is completely dark, there are no producers. Most organisms that live here are decomposers.

The surface water of a lake is heated by sunlight and becomes warmer than water near the bottom. Because warm water is less dense that cold water, it remains on the surface. When dead organisms sink to the bottom of a lake, they are broken down by decomposers that release the nutrients from the dead organism. As a result, nutrients accumulate at the lake's bottom. In spring and fall in temperate climates, the surface water of a lake reaches the same temperature as the deeper water. This gives the different water layers the same density, allowing them to intermix. This process, called **turnover,** brings nutrients from the bottom of the lake to the surface, where producers can use them.

Lakes can be categorized on the basis of their overall nutrient levels, as shown in **Table 1**. Oligotrophic lakes have low nutrient levels, so they also have low productivity. With few producers (or other aquatic organisms), the water remains clear and little oxygen is used up to support life. Biodiversity is low.

Table 16.2: **Trophic Classification of Freshwater Lakes**

Type of Lake	Nutrient Level	Productivity	Clarity of Water	Oxygen Level
Oligotrophic	Low	Low	High	High
Mesotrophic	Medium	Medium	Medium	Medium
Eutrophic	High	High	Low	Low
Hypertrophic	Very high	Very high	Very low	Very low

Acid rain is another cause of low productivity in lakes. Acid rain falling into a lake causes the lake water to become too acidic for many species to tolerate. This results in a decline in the number and diversity of lake organisms. This has happened to many lakes throughout the northeastern United States. The water in the lakes is very clear because it is virtually devoid of life.Lakes with high nutrient levels have higher productivity, cloudier water, lower oxygen levels, and higher biomass and biodiversity. Very high nutrient levels in lakes are generally caused by contamination with fertilizer or sewage. The high concentration of nutrients may cause a massive increase in phytoplankton, called a phytoplankton bloom (see **Figure 8**). The bloom blocks sunlight from submerged plants and other producers and negatively impacts most organisms in the lake.

Figure 16.17: The phytoplankton bloom on this lake blocks most sunlight from penetrating below the surface, creating a condition detrimental to many other aquatic organisms. (28)

Running Freshwater Biomes

Running freshwater biomes include streams and rivers. Streams are generally smaller than rivers. Streams may start with surface runoff, snowmelt from a glacier, or water seeping out of the ground from a spring. If the land is not flat, the water runs downhill. The water joins other streams and then rivers as it flows over the land. Eventually, the water empties into a pond, lake, or the ocean.

`Some species living in rivers that empty into the ocean may live in freshwater during some stages of their life cycle and in salt water during other stages. For example, salmon are born and develop in freshwater rivers and then move downstream to the ocean, where they live as adults. In contrast, some eels are born and develop in the ocean and then move into freshwater rivers to live as adults.`Compared with standing water, running water is better able to dissolve oxygen needed by producers and other aquatic organisms. When a river rushes over a waterfall, like the one in **Figure 9**, most of the water is exposed to the air, allowing it to dissolve a great deal of oxygen. Flowing water also provides a continuous supply of nutrients. Some nutrients come from the decomposition of dead aquatic organisms. Other nutrients come from the decomposition of dead terrestrial organisms, and other organic debris such as leaves, that fall into the water.

Figure 16.18: Flowing water forms a waterfall on the South Yuba River in Nevada County, California. As the water falls through the air, it dissolves oxygen needed by aquatic organisms. (3)

Algae are the main producers in running freshwater biomes. If water flows slowly, algae can float suspended in the water, and huge populations may form, like the phytoplankton bloom in **Figure 8** above. If water flows rapidly, algae must attach themselves to rocks or plants to avoid being washed away and generally cannot form very large populations.

Plants are also important producers in most running water biomes. Some plants, such as mosses, cling to rocks. Other plants, such as duckweed, float in the water. If nutrient levels are high, floating plants may form a thick mat on the surface of the water, like the one shown in **Figure 10** (left photo). Still other plants grow in sediments on the bottoms of streams and rivers. Many of these plants—like the cattails in **Figure 10** (right photo)—have long narrow leaves that offer little resistance to the current. In addition to serving as a food source, plants in running water provide aquatic animals with protection from the current and places to hide from predators.

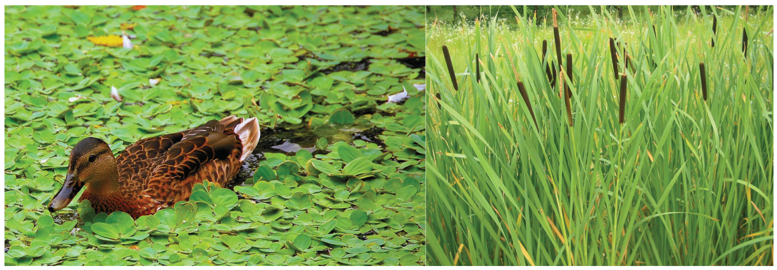

Figure 16.19: The picture on the left shows a thick mat of duckweed floating on a river. The picture on the right shows cattails growing in sediments at the edge of a stream bed. Notice the cattails' long, slender leaves, which reduce water resistance. (21)

Consumers in running water include both invertebrate and vertebrate animals. The most common invertebrates are insects. Others include snails, clams, and crayfish. Some invertebrates live on the water surface, others float suspended in the water, and still others cling to rocks on the bottom. All rely on the current to bring them food and dissolved oxygen. The invertebrates are important consumers as well as prey to the many vertebrates in running water. Vertebrate species include fish, amphibians, reptiles, birds, and mammals. However, only fish live in the water all the time. Other vertebrates spend part of their time on land.

`The movement of running water poses a challenge to aquatic organisms, which have adapted in various ways. Some organisms have hooks or threadlike filaments to anchor themselves to rocks or plants in the water. Other organisms, including fish, have fins and streamlined bodies that allow them to swim against the current.`The interface between running freshwater and land is called a **riparian zone.** It includes the vegetation that grows along the edge of a river and the animals that consume or take shelter in the vegetation. Riparian zones are very important natural areas for several reasons:

- They filter pollution from surface runoff before it enters a river.
- They help keep river water clear by trapping sediments.
- They protect river banks from erosion by running water.
- They help regulate the temperature of river water by providing shade.

Wetlands

A **wetland** is an area that is saturated or covered by water for at least one season of the year. Freshwater wetlands are also called swamps, marshes, or bogs. Saltwater wetlands include estuaries, which are described earlier in this lesson. Wetland vegetation must be adapted to water-logged soil, which contains little oxygen. Freshwater wetland plants include duckweed and cattails (see **Figure 10**, above). Some wetlands also have trees. Their roots may be partly above ground to allow gas exchange with the air. Wetlands are extremely important biomes for several reasons.

- They store excess water from floods and runoff.
- They absorb some of the energy of running water and help prevent erosion.
- They remove excess nutrients from runoff before it empties into rivers or lakes.
- They provide a unique habitat that certain communities of plants need to survive.
- They provide a safe, lush habitat for many species of animals.

Lesson Summary

- Aquatic biomes are divided into zones based on factors such as water depth and amount of sunlight available for photosynthesis. Aquatic organisms include plankton, nekton, and benthos.
- Marine biomes include neritic, oceanic, and benthic biomes. Intertidal zones, estuaries, and coral reefs are marine biomes with the highest biodiversity.
- Freshwater biomes may be standing water biomes, such as lakes, or running water biomes, such as rivers. Wetlands are biomes in which the ground is saturated or covered by water for at least part of the year.

Review Questions

1. In a large body of standing water, what is the photic zone?
2. State why the oceanic zone has a lower concentration of nutrients than the neritic zone.
3. Why is moving water a major challenge for organisms in the littoral zone of the ocean?
4. Why does the profundal zone of a lake have no producers?
5. A new species of bioluminescent fish has been discovered in the ocean. Which oceanic zone is most likely the home of this fish? Explain your answer.
6. A developer plans to extend a golf course into a riparian biome. Outline environmental arguments you could make against this plan.
7. Compare and contrast plankton, nekton, and benthos.
8. In the deep ocean far from shore, why might you find more dissolved nutrients at the bottom than at the surface?

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Vocabulary

abyssal zone Part of the ocean floor that is under the deep ocean.

abyssopelagic zone Water between 4,000 and 6,000 meters below sea level in the oceanic zone.

aphotic zone Deep water in a lake or the ocean where too little sunlight penetrates for photosynthesis to occur.

bathyal zone Part of the ocean floor that makes up the continental slope.

bathypelagic zone Water between 1,000 and 4,000 meters below sea level in the oceanic zone.

benthic biome Marine biome that occurs on the bottom of the ocean where benthos live.

benthic zone Bottom surface of the ocean or a lake.

benthos Aquatic organisms that live on the surface below a body of water.

coral reef Underwater limestone structure formed by tiny invertebrate animals called corals.

epipelagic zone Top 200 meters of water in the oceanic zone.

estuary Bay where a river empties into the ocean.

freshwater biome Biome such as a lake or river that has water with little or no salt.

hadal zone Part of the ocean floor that is in deep ocean trenches.

hadopelagic zone Water of deep ocean trenches below 6,000 meters in the oceanic zone.

intertidal zone Narrow strip along the coastline of the ocean that falls between high- and low-tide water lines.

limnetic zone Top layer of deep water in a lake, down to the depth that sunlight penetrates.

littoral zone Shallow water near the shore of a lake or the ocean.

marine biome Aquatic biome found in the salt water of the ocean.

mesopelagic zone Water between 200 and 1,000 meters below sea level in the oceanic zone.

nekton Aquatic animals that live in the water itself and can propel themselves by swimming or other means.

neritic biome Marine biome that occurs in ocean water over the continental shelf.

neritic zone Part of the pelagic zone over the continental shelf.

oceanic biome Marine biome that occurs in ocean water beyond the continental shelf.

oceanic zone Part of the pelagic zone beyond the continental shelf.

pelagic zone Main body of open water away from shore in a lake or the ocean.

photic zone Depth of water in a lake or the ocean to which sunlight can penetrate and photosynthesis can occur.

plankton Aquatic organisms that live in the water itself and cannot propel themselves through water.

profundal zone Deep water in a lake near the bottom where no sunlight penetrates.

riparian zone Interface between running freshwater and land.

sublittoral zone Part of the ocean floor that makes up the continental shelf.

turnover Process in which different layers of lake water intermix and bring nutrients from the bottom to the surface.

upwelling Process in which deep ocean water is forced to the surface by currents, bringing dissolved nutrients from the bottom to the surface.

wetland Area that is saturated or covered by water for at least one season of the year.

Points to Consider

Next we discuss community interactions. Abiotic factors such as water depth affect organisms in aquatic biomes. Organisms in all biomes are also affected by biotic factors, which include their interactions with other species.

- How do you think different species interact?
- What types of relationships do you think different species might have with eachother?
- How could these relationships affect the evolution of the species involved?

16.4 Lesson 16.4: Community Interactions

Lesson Objectives

- State the significance of the community in ecology, and list types of community interactions.
- Define predation, and explain how it affects population growth and evolution.
- Describe competition, and outline how it can lead to extinction or specialization of species.
- Define symbiosis, and identify major types of symbiotic relationships.
- Describe ecological succession, and explain how it relates to the concept of a climax community.

Introduction

Biomes as different as grasslands and estuaries share something extremely important. They have populations of interacting species. Moreover, species interact in the same basic ways in all biomes. For example, all biomes have some species that prey on other species for food. Species interactions are important biotic factors in ecological systems. The focus of study of species interactions is the community.

What Is a Community?

In ecology, a **community** is the biotic component of an ecosystem. It consists of populations of different species that live in the same area and interact with one another. Like abiotic factors, such as climate or water depth, species interactions in communities are important biotic factors in natural selection. The interactions help shape the evolution of the interacting species. Three major types of community interactions are predation, competition, and symbiosis.

Predation

Predation is a relationship in which members of one species (the predator) consume members of other species (the prey). The lions and cape buffalo in **Figure 1** are classic examples of predators and prey. In addition to the lions, there is another predator in this figure. Can you find it? The other predator is the cape buffalo. Like the lion, it consumes prey species, in this case species of grasses. Predator-prey relationships account for most energy transfers in food chains and webs (see the *Principles of Ecology* chapter).

Types of Predators

The lions in **Figure 1** are true predators. In **true predation,** the predator kills its prey. Some true predators, like lions, catch large prey and then dismember and chew the prey before eating it. Other true predators catch small prey and swallow it whole. For example, snakes swallow mice whole.

Some predators are not true predators because they do not kill their prey. Instead, they graze on their prey. In **grazing,** a predator eats part of its prey but rarely kills it. For example, deer graze on plants but do not usually kill them. Animals may also be "grazed" upon. For example, female mosquitoes suck tiny amounts of blood from animals but do not harm them, although they can transmit disease.

Figure 16.20: An adult male lion and a lion cub feed on the carcass of a South African cape buffalo. (19)

Predation and Populations

True predators help control the size of prey populations. This is especially true when a predator preys on just one species. Generally, the predator-prey relationship keeps the population size of both species in balance. This is shown in **Figure 2**. Every change in population size of one species is followed by a corresponding change in the population size of the other species. Generally, predator-prey populations keep fluctuating in this way as long as there is no outside interference.

Some predator species are known as **keystone species,** because they play such an important role in their community. Introduction or removal of a keystone species has a drastic effect on its prey population. This, in turn, affects populations of many other species in the community. For example, some sea star species are keystone species in coral reef communities. The sea stars prey on mussels and sea urchins, which have no other natural predators. If sea stars are removed from a coral reef community, mussel and sea urchin populations would have explosive growth, which in turn would drive out most other species and destroy the reef community.

Sometimes humans deliberately introduce predators into an area to control pests. This is called **biological pest control**. One of the earliest pests controlled in this way was a type of insect, called a scale insect. The scale insect was accidentally introduced into California from Australia in the late 1800s. It had no natural predators in California and was destroying the state's citrus trees. Then, its natural predator in Australia, a type of beetle, was introduced into California in an effort to control the scale insect. Within a few years, the insect was completely controlled by the predator. Unfortunately, biological pest control does not always work this well. Pest populations often rebound after a period of decline.

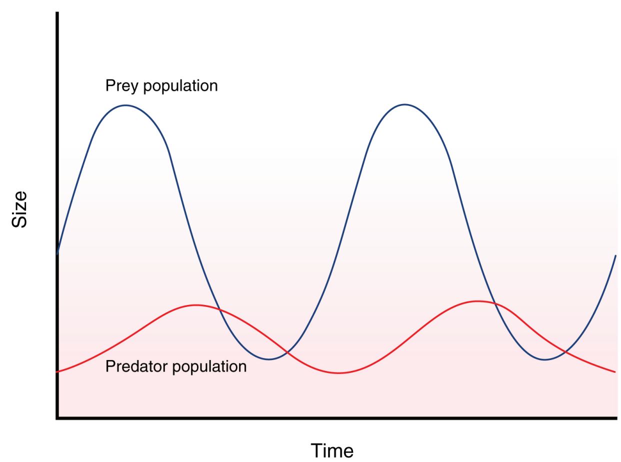

Figure 16.21: As the prey population increases, the predator population starts to rise. With more predators, the prey population starts to decrease, which, in turn, causes the predator population to decline. This pattern keeps repeating. There is always a slight lag between changes in one population and changes in the other population. (20)

Adaptations to Predation

Both predators and prey have adaptations to predation. Predator adaptations help them capture prey. Prey adaptations help them avoid predators. A common adaptation in both predator and prey species is **camouflage,** or disguise. One way of using camouflage is to blend in with the background. Several examples are shown in **Figure 3**.

Figure 16.22: Can you see the crab in the photo on the left? It is camouflaged with algae. The preying mantis in the middle photo looks just like the dead leaves in the background. The stripes on the zebras in the right photo blend the animals together, making it hard to see where one zebra ends and another begins. (13)

Another way of using camouflage is to look like a different, more dangerous animal. Using appearance to "mimic" another animal is called **mimicry. Figure 4** shows an example of mimicry. The moth in the figure has markings on its wings that look like the eyes of an owl. When a predator comes near, the moth suddenly displays the markings. This startles the predator and gives the moth time to fly away.

Figure 16.23: The moth on the left mimics the owl on the right. This "disguise" helps protect the moth from predators. (25)

Some prey species have adaptations that are the opposite of camouflage. They have bright colors or other highly noticeable traits that serve as a warning for their predators to stay away. For example, some of the most colorful butterflies are poisonous to birds, so birds have learned to avoid eating them. By being so colorful, the butterflies are more likely to be noticed—and avoided—by their predators.

Predation, Natural Selection, and Co-evolution

Adaptations to predation come about through natural selection (see the *Evolution in Populations* chapter). When a prey organism avoids a predator, it has higher fitness than members of the same species that were killed by the predator. The organism survives longer and may produce more offspring. As a result, traits that helped the prey organism avoid the predator gradually become more common in the prey population.

Evolution of traits in the prey species leads to evolution of corresponding traits in the predator species. This is called **co-evolution.** In co-evolution, each species is an important factor in the natural selection of the other species. Predator-prey co-evolution is illustrated by rough-skinned newts and common garter snakes, both shown in **Figure 5**. Through natural selection, newts evolved the ability to produce a strong toxin. In response, garter snakes evolved the ability to resist the toxin, so they could still safely prey upon newts. Then, newts evolved the ability to produce higher levels of toxin. This was followed by garter snakes evolving resistance to the higher levels. In short, the predator-prey relationship led to an evolutionary "arms race," resulting in extremely high levels of toxin in newts.

Figure 16.24: The rough-skinned newt on the left is highly toxic to other organisms. Common garter snakes, like the one on the right, have evolved resistance to the toxin. (15)

Competition

Competition is a relationship between organisms that strive for the same limited resources. The resources might be food, nesting sites, or territory. Two different types of competition are intraspecific and interspecific competition.

- **Intraspecific competition** occurs between members of the same species. For example, two male birds of the same species might compete for mates in the same territory. Intraspecific competition is a necessary factor in natural selection. It leads to adaptive changes in a species through time (see the *Evolution in Populations* chapter).
- **Interspecific competition** occurs between members of different species. For example, two predator species might compete for the same prey. Interspecific competition takes place in communities of interacting species. It is the type of competition referred to in the rest of this section.

Interspecific Competition and Extinction

When populations of different species in a community depend on the same resources, there may not be enough resources to go around. If one species has a disadvantage, such as more predators, it may get fewer of the necessary resources. As a result, members of that species are less likely to survive, and the species will have a higher death rate than the other species. Fewer offspring will be produced and the species may eventually die out in the area.

In nature, interspecific competition has often led to the extinction of species. Many other extinctions have occurred when humans introduced new species into areas where they had no predators. For example, rabbits were introduced into Australia in the mid-1800s for sport hunting. Rabbits had no predators in Australia and quickly spread throughout the continent. Many species of Australian mammals could not successfully compete with rabbits and went extinct.

Interspecific Competition and Specialization

Another possible outcome of interspecific competition is the evolution of traits that create distinct differences among the competing species. Through natural selection, competing species can become more specialized. This allows them to live together without competing for the same resources. An example is the anolis lizard. Many species of anolis live and prey on insects in tropical rainforests. Competition among the different species led to the evolution of specializations. Some anolis evolved specializations to prey on insects in leaf litter on the forest floor. Others evolved specializations to prey on insects on the branches of trees. This allowed the different species of anolis to co-exist without competing.

Symbiotic Relationships

Symbiosis is a close association between two species in which at least one species benefits. For the other species, the outcome of the association may be positive, negative, or neutral. There are three basic types of symbiotic relationships: mutualism, commensalism, and parasitism.

Mutualism

Mutualism is a symbiotic relationship in which both species benefit. Lichen is a good example. A lichen is not a single organism but a fungus and an alga. The fungus absorbs water from air and minerals from rock or soil. The alga uses the water and minerals to make food for itself and the fungus. Another example involves goby fish and shrimp (see **Figure 6**). The nearly blind shrimp and the fish spend most of their time together. The shrimp maintains a burrow in the sand in which both the goby and the shrimp live. When a predator comes near, the fish touches the shrimp with its tail as a warning. Then, both fish and shrimp retreat to the burrow until the predator is gone. Each gains from this mutualistic relationship: the shrimp gets a warning of approaching danger, and the fish gets a safe home and a place to lay its eggs.

Figure 16.25: The multicolored shrimp in the front and the green goby fish behind it have a mutualistic relationship. The shrimp shares its burrow with the fish, and the fish warns the shrimp when predators are near. Both species benefit from the relationship. (11)

Co-evolution often occurs in species involved in mutualistic relationships. Many examples are provided by flowering plants and the species that pollinate them. Plants have evolved flowers with traits that promote pollination by particular species. Pollinator species, in turn, have evolved traits that help them obtain pollen or nectar from certain species of flowers. For example, the plant with tube-shaped flowers shown in **Figure 7** co-evolved with hummingbirds. The birds evolved long, narrow beaks that allowed them to sip nectar from the tubular blooms.

Commensalism

Commensalism is a symbiotic relationship in which one species benefits while the other species is not affected. In commensalism, one animal typically uses another for a purpose other than food. For example, mites attach themselves to larger flying insects to get a "free ride," and hermit crabs use the shells of dead snails for shelter.

Co-evolution explains some commensal relationships. An example is the human species and some of the species of bacteria that live inside humans. Through natural selection, many species of bacteria have evolved the ability to live inside the human body without harming it.

Figure 16.26: This hummingbird's long slender beak and the large tubular flowers of the plant are a good match, which resulted from a long period of co-evolution. Their relationship is an example of mutualism. The hummingbird uses nectar from the flowers for food and pollinates the flowers in the process. (10)

Parasitism

Parasitism is a symbiotic relationship in which one species (the parasite) benefits while the other species (the host) is harmed. Some parasites live on the surface of their host. Others live inside their host, entering through a break in the skin or in food or water. For example, roundworms are parasites of the human intestine. The worms produce huge numbers of eggs, which are passed in the host's feces to the environment. Other humans may be infected by swallowing the eggs in contaminated food or water. This usually happens only in places with poor sanitation.

Some parasites eventually kill their host. However, most parasites do not. Parasitism in which the host is not killed is a successful way of life and very common in nature. About half of all animal species are parasitic in at least one stage of their lifecycle. Many plants and fungi are parasitic during some stages, as well. Not surprisingly, most animals are hosts to one or more parasites.

Species in parastic relationships are likely to undergo co-evolution. Host species evolve defenses against parasites, and parasites evolve ways to evade host defenses. For example, many plants have evolved toxins that poison plant parasites such as fungi and bacteria. The microscopic parasite that causes malaria in humans has evolved a way to evade the human immune system. It hides out in the host's blood cells or liver where the immune system cannot find it.

Ecological Succession

Ecological succession is the process by which a whole community of populations changes through time. It occurs following a disturbance that creates unoccupied areas for colonization. The first colonizer species are called **pioneer species.** They change the environment and pave the way for other species to move into the area. Succession occurs in two different ways, depending on the starting conditions: primary succession and secondary succession.

Primary Succession

Primary succession occurs in an area that has never been colonized before. Generally, the area is nothing but bare rock. This type of environment can come about in a number of ways, including:

- Lava can flow from a volcano and harden into rock.
- A glacier can retreat and leave behind bare rock.
- A landslide can uncover a large area of bare rock.

After the disturbance, pioneer species move in first. They include bacteria and lichens that can live on bare rock. Along with wind and water, these pioneer species help to weather the rock and form soil. Once soil begins to form, other plants can move in. At first, the plants include grasses and other species that can grow in thin, poor soil. As more plants grow and die, organic matter is added to the soil. This improves the soil and helps it hold water. The improved soil allows shrubs and trees to move into the area. An example of primary succession is shown in **Figure 8**.

Secondary Succession

Secondary succession occurs in a formerly inhabited area that was disturbed. The disturbance could be a fire, flood, or human action such as logging or farming. Secondary succession can occur faster than primary succession because the soil is already in place. In secondary succession, the pioneer species are plants that are adapted to exploit disturbances rather than bare rock. They typically include plants such as grasses, birch trees, and fireweed. Organic matter from the pioneer species improves the soil so other trees and plants can move into the area. An example of secondary succession is shown in **Figure 9**.

Climax Communities

Many early ecologists thought that a community always went through a predictable series of stages during succession. They also thought that the end result of succession was a final

Figure 16.27: On an island near New Zealand, bare rocks from a volcanic eruption are slowly being colonized by pioneer species. (27)

Figure 16.28: This formerly cultivated farm field in Poland is reverting to deciduous forest in the process of secondary succession. (1)

stage called a **climax community.** The type of climax community was believed to be determined mainly by climate. For example, in mild, wet temperate climates, evergreen rainforests were thought to be the predictable end result of succession. Climax communities were also thought to be very biodiverse. This characteristic, in turn, was believed to make them stable, or resistant to change.

Today, most ecologists think that change, rather than stability, is more characteristic of ecological systems. They argue that most communities are disturbed too often to reach a climax community stage. They also argue that high biodiversity does not always make a community stable. Some communities that have low biodiversity, such as salt marshes, are very resistant to change. On the other hand, some communities that have high biodiversity, such as coral reefs, are easily affected by disturbances. High biodiversity may increase species interactions. This, in turn, may make species more interdependent and communities more likely to change when they are disturbed.

Lesson Summary

- A community is the biotic component of an ecosystem. It consists of populations of interacting species. Types of community interactions are predation, competition, and symbiosis.
- Predation is a relationship in which members of one species consume members of other species. Predation influences population sizes and co-evolution of predator and prey species.
- Competition is a relationship between organisms that strive for the same limited resources. Interspecific competition often leads to extinction of one species. However, it may lead to greater specialization of the species, allowing them to co-exist without competing.
- Symbiosis is a close association between species in which at least one species benefits. Types of symbiotic relationships include mutualism, commensalism, and parasitism.
- Ecological succession is the process by which a whole community changes through time. It occurs following a disturbance. A stable climax community may or may not be the predictable end result of succession.

Review Questions

1. In ecology, what is a community?
2. Define predation and give an example of a predator and its prey.
3. What are two possible outcomes of interspecific competition?
4. List three basic types of symbiotic relationships.
5. What is ecological succession and when does it occur?
6. Assume that a destructive beetle was accidentally introduced to California from Europe. The beetle has no natural predators in California and is becoming a major pest.

Describe how biological pest control might be used to control this beetle.

7. A forest was recently disturbed, and several pioneer species have moved in. Which type of ecological succession is taking place? How do you know?
8. Why do species interactions often lead to co-evolution of the species involved? Give an example to illustrate your answer.
9. Summarize how ideas about ecological succession and climax communities have changed.

Further Reading / Supplemental Links

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Vocabulary

biological pest control Deliberate introduction of a predator species into an area in order to control a pest species.

camouflage Common adaptation in predator and prey species that involves disguise.

climax community Final stage of ecological succession.

co-evolution Evolution of interacting species in which each species is an important factor in the natural selection of the other species.

commensalism Symbiotic relationship in which one species benefits while the other species is not affected.

community Biotic component of an ecosystem.

competition Relationship between organisms that strive for the same limited resources.

ecological succession Process by which a whole community changes through time following a disturbance.

grazing Type of predation in which the predator eats part of its prey but rarely kills it.

intraspecific competition Competition between members of the same species.

interspecific competition Competition between members of different species.

keystone species Predator species that plays an important role in the community by controlling the prey population and, indirectly, the populations of many other species in the community.

mimicry Using appearance to "mimic" another animal.

mutualism Symbiotic relationship in which both species benefit.

parasitism Symbiotic relationship in which one species (the parasite) benefits while the other species (the host) is harmed.

pioneer species First colonizer species in an area undergoing ecological succession.

predation Relationship in which members of one species (the predator) consume members of other species (the prey).

primary succession Ecological succession that occurs in an area that has never been colonized before.

secondary succession Ecological succession that occurs in a formerly inhabited area that was disturbed.

symbiosis Close association between two species in which at least one species benefits.

true predation Type of predation in which the predator kills its prey.

Points to Consider

The size and growth of populations in a community is influenced by species interactions. For example, predator-prey relationships control the population growth of both predator and prey species.

- How would populations grow without these influences?
- What other factors do you think might affect population growth?
- What factors do you think may have affected the growth of the human population?

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