Sustaining Earth's Ecosystems

This dry, shrubby landscape ▶ in the South Okanagan Valley is called the antelope brush grassland, after the dark-stemmed shrubs and clumps of grasses that grow here. This grassland has provided some Okanagan First Nations with plants such as bitterroot, known as speetlum, which is harvested for both food and medicine. Less than 40 percent of the antelope brush grassland still exists, making it one of the most threatened areas in Canada. Changes in land use and an expanding human population may result in the loss of many species, including the burrowing owl, prairie falcon, pallid bat, and Great Basin pocket mouse. Many people are working to protect this area, such as members of the Nk'Mip First Nation and groups such as the Desert Society and the Nature Conservancy of Canada. Volunteers, government workers, and scientists are also helping to restore plants and animals that once thrived here and to educate people about this region.

Key Ideas

1 **Biomes and ecosystems are divisions of the biosphere.**

1.1 Biomes

1.2 Ecosystems

2 **Energy flow and nutrient cycles support life in ecosystems.**

2.1 Energy Flow in Ecosystems

2.2 Nutrient Cycles in Ecosystems

2.3 Effects of Bioaccumulation on Ecosystems

3 **Ecosystems continually change over time.**

3.1 How Changes Occur Naturally in Ecosystems

3.2 How Humans Influence Ecosystems

3.3 How Introduced Species Affect Ecosystems

Imagine an abandoned mining site, a huge, lifeless hole in the ground the size of 30 football fields. Now, imagine the same area transformed into giant domed greenhouses containing more than 1 million plants from around the world. This is the Eden Project, which has become one of the most popular tourist sites in the United Kingdom, attracting thousands of visitors each day.

Opened in 2001, the Eden Project is not just a green theme park. The purpose of the project is to educate people about the important relationship of plants to humans. Eden shows its visitors how much humans depend on plants for oxygen, food, shelter, and products such as medicine, clothing, and paper. Eden also demonstrates the importance of managing and protecting the variety of plant life for future generations. There are 4500 different species, or types, of plants growing in Eden. These plants are just a sample of the biodiversity of Earth's 270 000 known plant species. **Biodiversity** is a term used to describe the variety of life on Earth. By gaining a better understanding of biodiversity, we can better understand which species are more likely to be affected by changes that occur on Earth. With this knowledge, we can learn how to better protect those species.

Educating people about biodiversity extends beyond the domes and outdoor gardens of Eden. Funds generated by the project are used to educate people in countries where there is much deforestation. In places such as northern Argentina, where a vast forest once grew, people are learning about the importance of plant life in their community. They are also learning how they can benefit from the remaining forest and still protect it for future generations. The Eden Foundation, which directs the scientific, research, and education programs at Eden, also works with the mining industry to encourage investment in mine reclamation. Mine reclamation is a process in which old mine sites are transformed into healthy, productive areas, which support both local communities and the natural environment.

Biodiversity in Canada

Find Out ACTIVITY

The Eden Project encourages people to be aware of the variety of plants and their importance in the world. You have been hired to educate people about protecting the biodiversity of both plant and animal life in Canada by helping them to appreciate the number of living things in our country. In this activity, you will design a model to demonstrate the number of known species of different organisms in Canada.

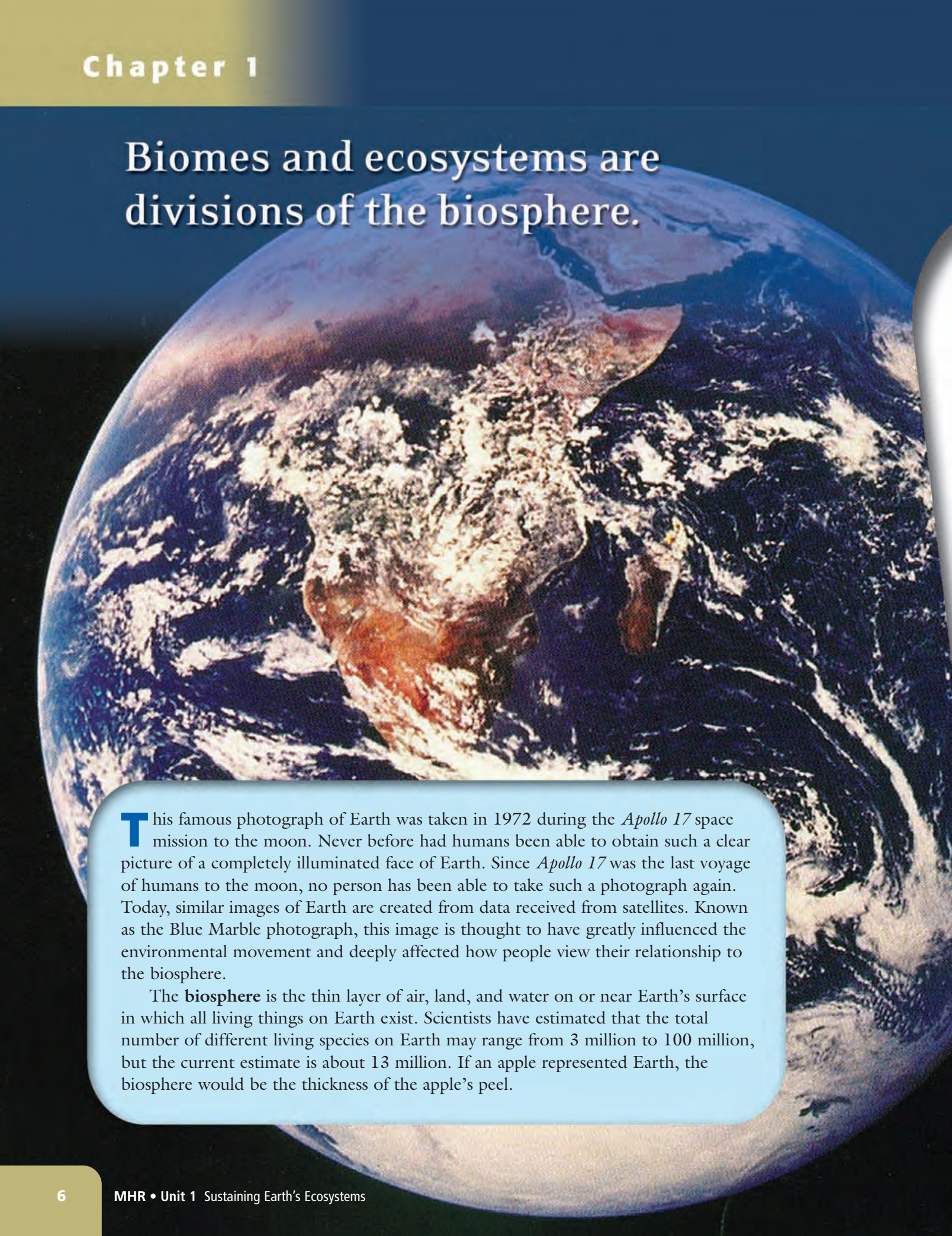| Group of Organisms	Number of Known Species in Canada
Fungi (e.g., mushrooms)	11 800
Flowering plants (e.g., dogwood trees)	3 800
Coniferous plants (e.g., fir trees)	34
Other plants (e.g., mosses)	1 100
Sponges (e.g., glass sponges)	490
Molluscs (e.g., snails)	1 500
Arachnids (e.g., spiders)	3 275
Crustaceans (e.g., shrimp)	3 139
Insects (e.g., bees)	18 530
Fish (e.g., salmon)	1 100
Amphibians (e.g., frogs)	42
Reptiles (e.g., snakes)	42
Birds (e.g., robins)	426
Mammals (e.g., bears)	194

What to Do

1. Work with a partner or in a small group. Examine the data in the table of known species in Canada. Decide how you could create a model for this information (for example, a three-dimensional model). Your model should accurately reflect the correct proportions of different species in relation to one another. Your model should be clear, visually interesting, and easy for people to understand.

2. Plan your model. It can be two-dimensional or three-dimensional, and you may use your computer.

3. Write down all the steps you will follow to create your model.

4. Create your model.

What Did You Find Out?

1. Did any of the numbers of known species surprise you? If so, identify which ones and explain why you were surprised.

2. Compare your model with another group's model.

    (a) Describe any similarities and differences between the two models.

    (b) Describe the best features of each model.

3. If you were to redesign your model, how would you change it and why?

Biomes and ecosystems are divisions of the biosphere.

This famous photograph of Earth was taken in 1972 during the *Apollo 17* space mission to the moon. Never before had humans been able to obtain such a clear picture of a completely illuminated face of Earth. Since *Apollo 17* was the last voyage of humans to the moon, no person has been able to take such a photograph again. Today, similar images of Earth are created from data received from satellites. Known as the Blue Marble photograph, this image is thought to have greatly influenced the environmental movement and deeply affected how people view their relationship to the biosphere.

The **biosphere** is the thin layer of air, land, and water on or near Earth's surface in which all living things on Earth exist. Scientists have estimated that the total number of different living species on Earth may range from 3 million to 100 million, but the current estimate is about 13 million. If an apple represented Earth, the biosphere would be the thickness of the apple's peel.

What You Will Learn

In this chapter, you will
- **describe** the factors that influence the characteristics and distribution of biomes on Earth
- **identify** biotic and abiotic characteristics of biomes and ecosystems
- **explain** the interaction of biotic and abiotic components in biomes and ecosystems
- **relate** plant and animal adaptations to environmental conditions in biomes and ecosystems
- **understand** the biotic interactions among populations and communities in ecosystems

Why It Is Important

The interaction of biotic and abiotic components in the environment determines the distribution of life on Earth and the health of ecosystems. Biotic interactions between organisms influence the survival rates of populations. Understanding these relationships gives us a better understanding of the impact of human activities and natural events on ecosystems.

## Skills You Will Use

In this chapter, you will
- **construct** a climatograph
- **graph** predator-prey relationships

FOLDABLES™
Reading & Study Skills

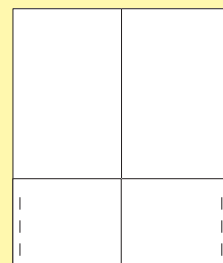**Make the following Foldable and use it to take notes on what you learn in Chapter 1.**

**STEP 1** Using an 28 cm by 43 cm piece of paper, **make** a hotdog fold. **Crease** the edge.

STEP 2 **Open** the paper and **fold** the short side of the paper upward to create a 10 cm tab. **Crease** this edge.
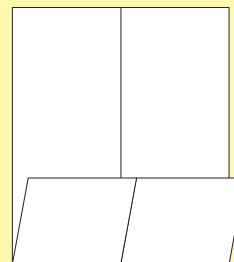
STEP 3 **Staple** or glue the outer edges of the 10 cm tab to create a pocket.

STEP 4 **Fold** the top edge of the paper down by 5 cm, **crease**, and **unfold** to create a heading space for the two-column chart. **Label as shown**.

| 1.1 Biomes | 1.2 Ecosystems |
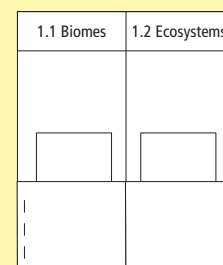
Organize As you read this chapter, use your Foldable to store work and notes. In the columns, list biotic and abiotic components found in biomes and ecosystems. Use index cards or quarter sheets of notebook paper to record information, define terms, describe specific biomes, and explain different relationships and interactions found within ecosystems.

1.1 Biomes

Biomes are the largest divisions of the biosphere. The large regions within biomes have similar biotic and abiotic components. The interaction of these components determines the characteristics of biomes. Temperature and precipitation are the main abiotic factors that influence the distribution of biomes and the organisms within them. Organisms have adaptations for survival in the specific environmental conditions of their biome.

Words to Know

abiotic
adaptation
biome
biotic
climate
climatograph

If you were to walk in the forest shown in Figure 1.1, you might think you were walking in a rainforest on Vancouver Island. The winters here are warm and have large amounts of rainfall. This forest has many tall evergreen trees under which a variety of ferns and mosses grow in the shade.

If you were on this bridge, you would actually be walking in a rainforest on New Zealand's South Island. If you were walking on the bridge in Figure 1.2 on the next page, you would be walking in a rainforest on Vancouver Island.
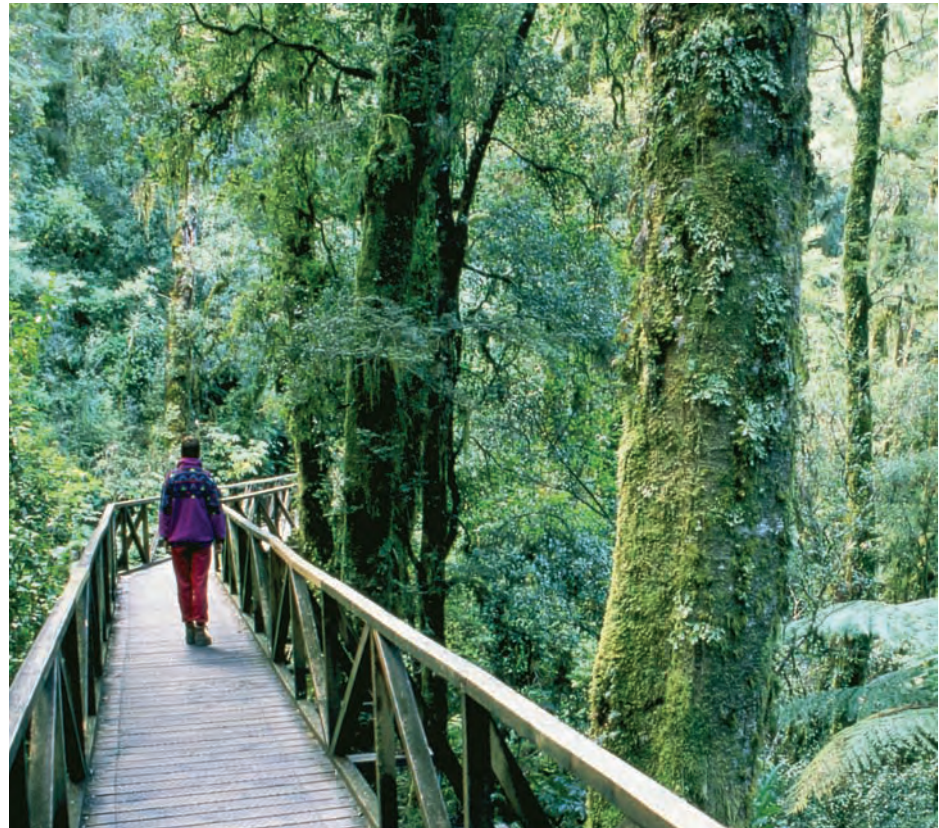

Figure 1.1 Hiking in Fiordland National Park, South Island, New Zealand

Figure 1.2 Hiking in Pacific Rim National Park, Vancouver Island

Every environment, such as a rainforest, has living (**biotic**) and non-living (**abiotic**) components. Biotic components are the living organisms in an environment. Plants, animals, fungi, and bacteria are all examples of biotic components of an ecosystem. They interact with each other and with the physical and chemical environment in which they live. Abiotic components are the non-living parts of an environment such as sunlight, soil, moisture, and temperature.

Scientists study the biosphere by breaking it down into smaller divisions (Figure 1.3). The largest of these divisions is called a biome. (You will learn more about ecosystems and habitats in section 1.2.) A **biome** includes large regions that have similar biotic components, such as similar plants and animals, and similar abiotic components, such as similar temperature and amount of rainfall.
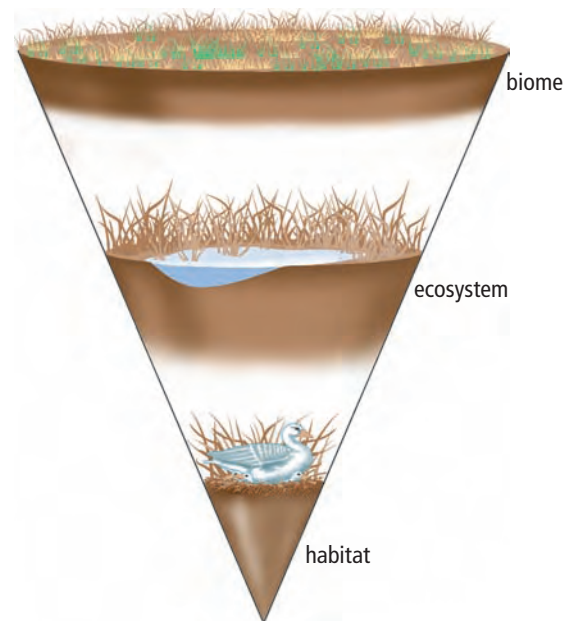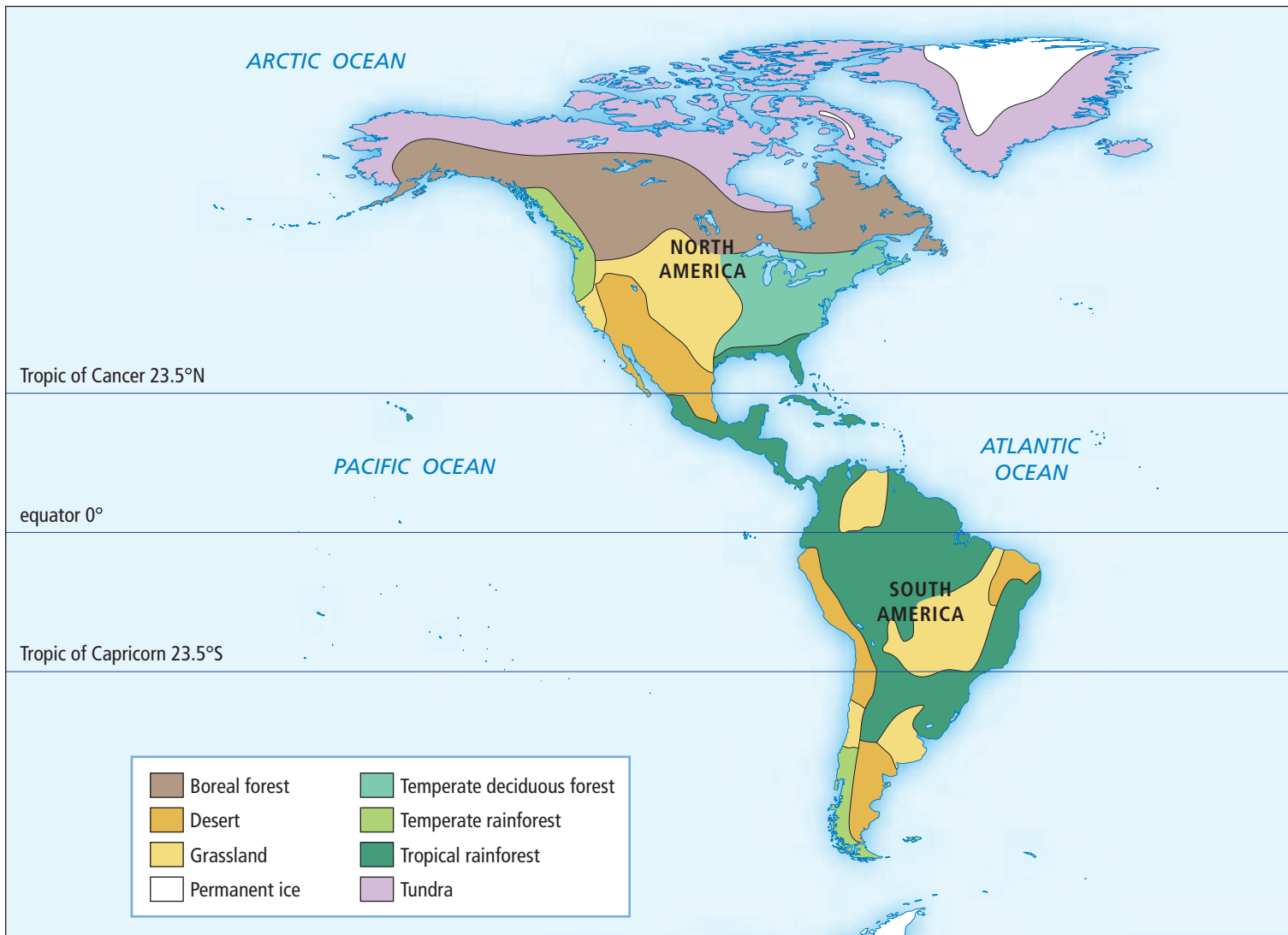

Figure 1.3 The biosphere consists of biomes. Each biome contains many ecosystems. Each ecosystem contains habitats in which a variety of organisms live.

Introducing the Biomes of the World

Much of Earth's biosphere consists of fresh water and oceans. These aquatic biomes are essential for life on land. Marine algae supply at least 75 percent of the world's oxygen and take in huge amounts of carbon dioxide from the atmosphere. In addition, seawater that evaporates produces rainwater for life on land. In this section, however, you will focus on the eight **terrestrial**, or land-based, biomes shown in Figure 1.4.

As you learn about terrestrial biomes, you may see different maps with 11 or even 16 different biomes. Some scientists classify biomes according to their temperature and the amount of moisture they receive. Other scientists classify biomes according to the type of plants that grow in them. Biomes are complex because of the many interactions that take place between abiotic factors, such as climate and soil, and biotic factors, such as plants and animals. Understanding how the biotic and abiotic components of a biome interact will help you understand how biomes are distributed across Earth and how changes in a biome may affect the organisms living in them.

Figure 1.4 Biomes of the world

Legend:
- Boreal forest
- Desert
- Grassland
- Permanent ice
- Temperate deciduous forest
- Temperate rainforest
- Tropical rainforest
- Tundra

A quick look at the world biome map (Figure 1.4) shows eight areas in eight different colours distributed across Earth. Some areas are the same colour and are in similar locations. Some areas are the same colour but are in very different locations. In this activity, you will identify some patterns about the distribution of biomes.

What to Do

1. Work with a partner. Study the map, using the key to familiarize yourself with the location of each biome.
2. Describe two patterns you see in the distribution of the biomes.

3. Compare your patterns with the patterns identified by another pair of students.
4. Record a class list that includes all the distribution patterns identified. Indicate which ones were identified by more than one pair of students.

What Did You Find Out?

1. Which distribution patterns were identified more than once? List the three most frequently identified patterns.
2. In a paragraph, provide an explanation for each of these three patterns based on your general knowledge.
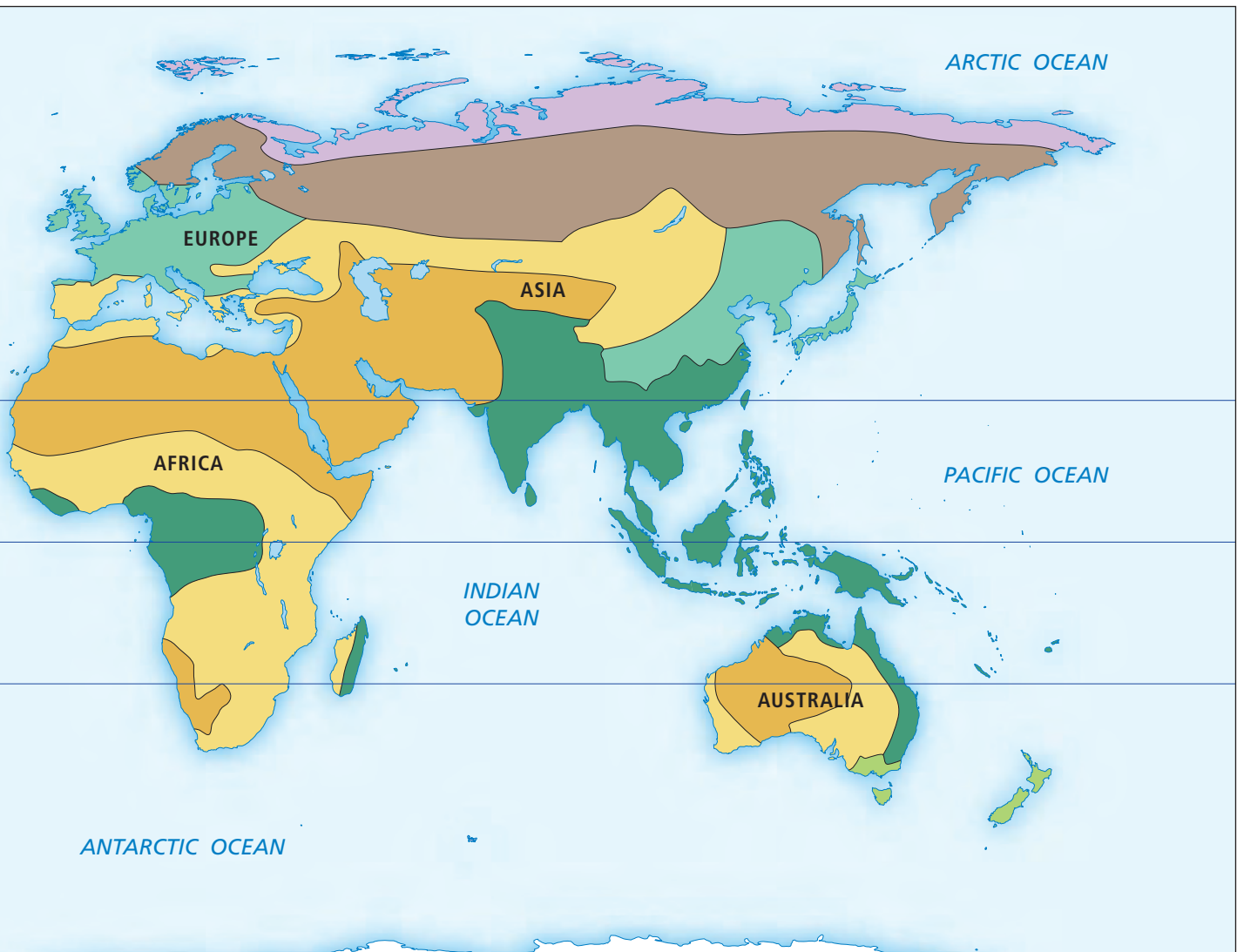
1. What is a biome?
2. What are the biotic components of a biome?
3. What are the abiotic components of a biome?
4. Name the major biomes that are in Canada.

Factors That Influence the Characteristics and Distribution of Biomes

The rainforests in Figure 1.1 on page 8 and Figure 1.2 on page 9 are in the temperate rainforest biome. However, if you look again at the world biome map in Figure 1.4 on pages 10 and 11, you will see that the temperate rainforest biome is located in very different parts of the world. These temperate rainforests are considered to be in the same biome because they have similar characteristics. Both rainforests have similar temperatures, receive large amounts of rainfall, and have plants and animals that have adaptations for survival in cool, wet environments.

Temperature and precipitation

Temperature and precipitation (which includes rainfall, snow, mist, and fog) are two of the most important abiotic factors that influence the characteristics of biomes and the distribution of biomes on Earth. The slugs, ferns, mosses, and large trees that you would find in the rainforests of New Zealand and British Columbia would not survive in a hot, dry desert biome because they can survive only in environments that are cool and wet (Figure 1.5).

Figure 1.5 Ferns (A) and slugs (B) are characteristic of the cool, wet temperate rainforest biome.

Figure 1.6 shows world biomes in relation to average annual precipitation and average annual temperature. Notice also that the biomes overlap, which indicates that other factors influence precipitation and temperature. These factors include latitude, elevation, and ocean currents. Wind also plays a role, which you will learn more about in Chapter 11.

How to use the graph

Suppose you knew the average annual temperature and average annual precipitation of a region. To determine the type of biome of the region, you would locate the intersection point of these data on the graph. For example, if the average annual temperature is 15°C, locate 15°C on the *x*-axis. Then move up the graph in a line from 15°C until you reach 25 cm of average annual precipitation on the *y*-axis. This intersection point indicates that the region is in the grassland biome. You could also begin with the average annual precipitation on the *y*-axis and then find the intersection with the average annual temperature on the *x*-axis.
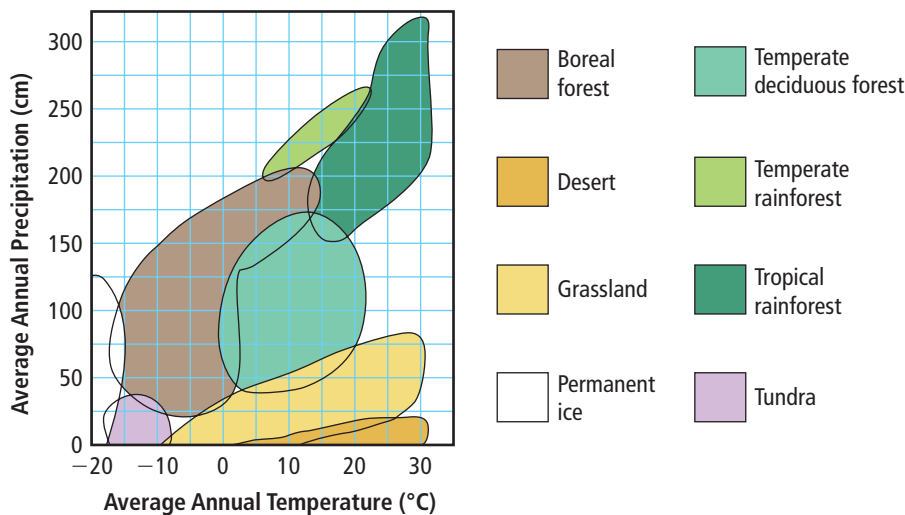

Figure 1.6 Average annual temperature and average annual precipitation of biomes

Practice Problems

Try the following biome identification problems yourself. Identify the biome of each region using the data provided.
1. The region has an average annual precipitation of about 175 cm and an average annual temperature of 5°C.
2. The region ranges in temperature between 0°C and 20°C and receives about 100 cm of rain.
3. The region has low average annual precipitation and an average annual temperature that ranges between −18°C and −8°C.
4. The region has high average annual precipitation and an average annual temperature of 15°C.

Answers provided on page 591

Latitude

Latitude is another abiotic factor that can influence the characteristics and distribution of biomes because it affects temperature and precipitation. **Latitude** is the distance measured in degrees north or south from the equator. The equator, which is at 0° latitude, divides Earth into the northern and southern hemispheres. At the equator, the rays of the sun shine down from almost directly overhead. As a result, the equator receives 12 hours of sunlight each day year-round and experiences little annual fluctuation in temperature.

If you look at the map in Figure 1.7, you will see that the Tropic of Cancer is located above the equator and the Tropic of Capricorn is below the equator. Since the zone between these lines of latitude, called the tropical zone, is close to the equator, it receives more direct sunlight and has warm temperatures. North of the Tropic of Cancer and south of the Tropic of Capricorn, the sun's rays hit Earth at an angle, due to the tilt of Earth. As a result, the sun's rays spread out over the larger surface area between these latitudes and the poles. Since the sun's rays are less intense farther away from the equator, the temperatures in these zones (the temperate zones) are lower than they are at the equator.

Latitude also affects precipitation. At the equator, the direct sunlight heats moist air, which quickly rises, cools in the upper atmosphere, and falls back to Earth as rain. The land and ocean that are on the equator receive the greatest amount of rainfall on Earth. In polar regions, little moisture can be picked up and carried in cold air, so clouds do not form readily and there is little precipitation. Temperate regions experience the collision of cold air masses from the poles and warm, moist air masses from the tropics that results in seasonal rainfall patterns.

Connection

Section 11.1 has more information on the relationship between Earth's tilt and solar energy.
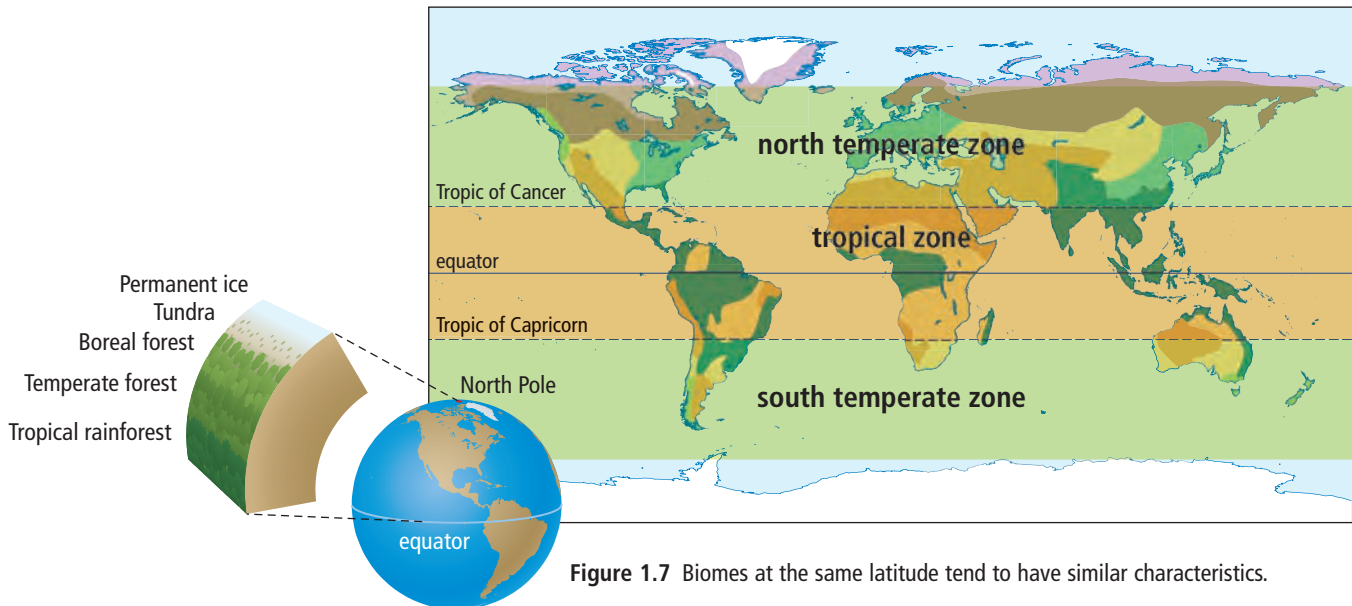

Permanent ice
Tundra
Boreal forest
Temperate forest
Tropical rainforest

north temperate zone
Tropic of Cancer
equator
tropical zone
Tropic of Capricorn
North Pole
south temperate zone
equator

Figure 1.7 Biomes at the same latitude tend to have similar characteristics.

Elevation

Elevation also has an effect on temperature. **Elevation** is the height of a land mass above sea level. Temperature changes occur because the atmosphere becomes thinner at higher elevations, and a thinner atmosphere retains less heat. Elevation also has an effect on precipitation patterns. On the windward side of a mountain, clouds filled with moisture rise and cool, then release rain or snow. On the leeward side of a mountain, which is the side sheltered from the wind, the air warms again, which allows it to absorb water, creating a dry land area. Since elevation affects both temperature and precipitation, the type of biome found at a high altitude can be different from the type of biome found at a lower elevation. You may have noticed how changes in elevation can influence the type of biome if you have ever hiked up a mountain or looked at mountains while driving along the Coquihalla highway. Figure 1.8 shows an example of how biomes can change as elevation increases.
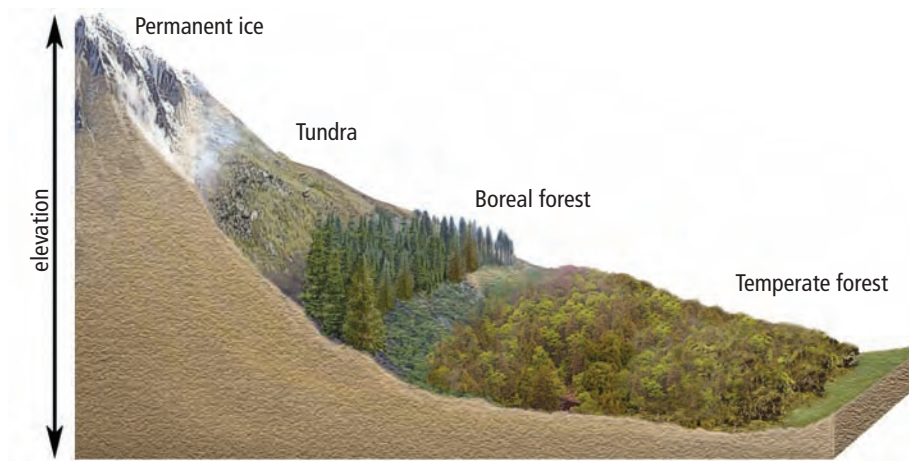

Permanent ice

Tundra

Boreal forest

Temperate forest

elevation

Figure 1.8 The effects of elevation

Ocean currents

Ocean currents are another abiotic factor that affects temperature and precipitation and therefore influences the characteristics of biomes. Canada's temperate rainforest biome is located along the coast of British Columbia. Both Canada's and New Zealand's temperate rainforest biomes are influenced by ocean currents, making them warmer and wetter than other temperate biomes.

Reading Check

1. Name two abiotic factors that influence the characteristics of biomes.
2. How does temperature change with latitude?
3. How does precipitation change with latitude?
4. How can the temperate rainforest biome be located in two very different parts of the world?
5. Explain why you might find a permanent ice biome at the top of a mountain and a temperate forest biome at the bottom.

Climatographs

Temperature and precipitation are two important factors that determine climate. **Climate** is the average pattern of weather conditions that occur in a region, which are observed and recorded over a period of years. (You will learn more about climate in Unit 4.)

A **climatograph** is a graph of climate data for a specific region and is generated from data usually obtained over 30 years from local weather observation stations. A climatograph includes average monthly temperature and an average of the total monthly precipitation for each
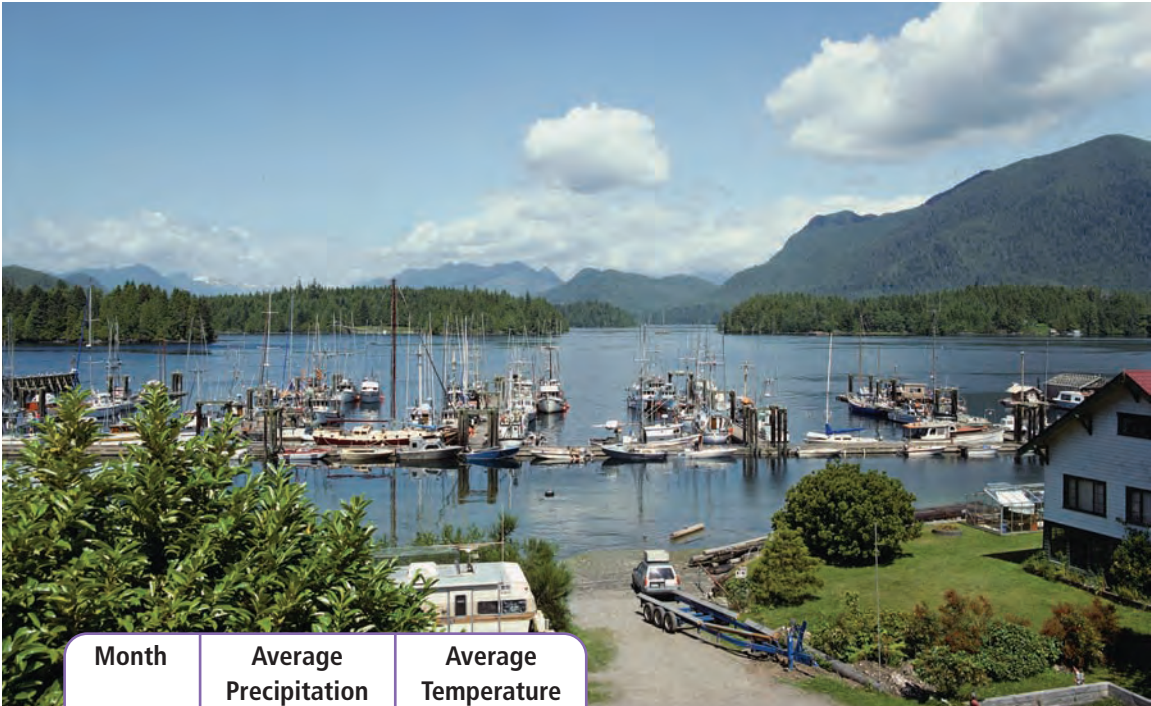
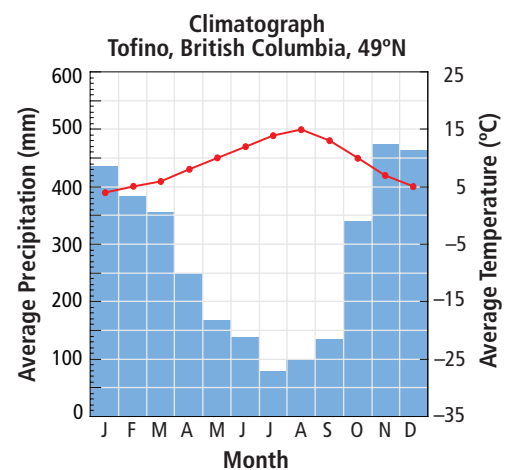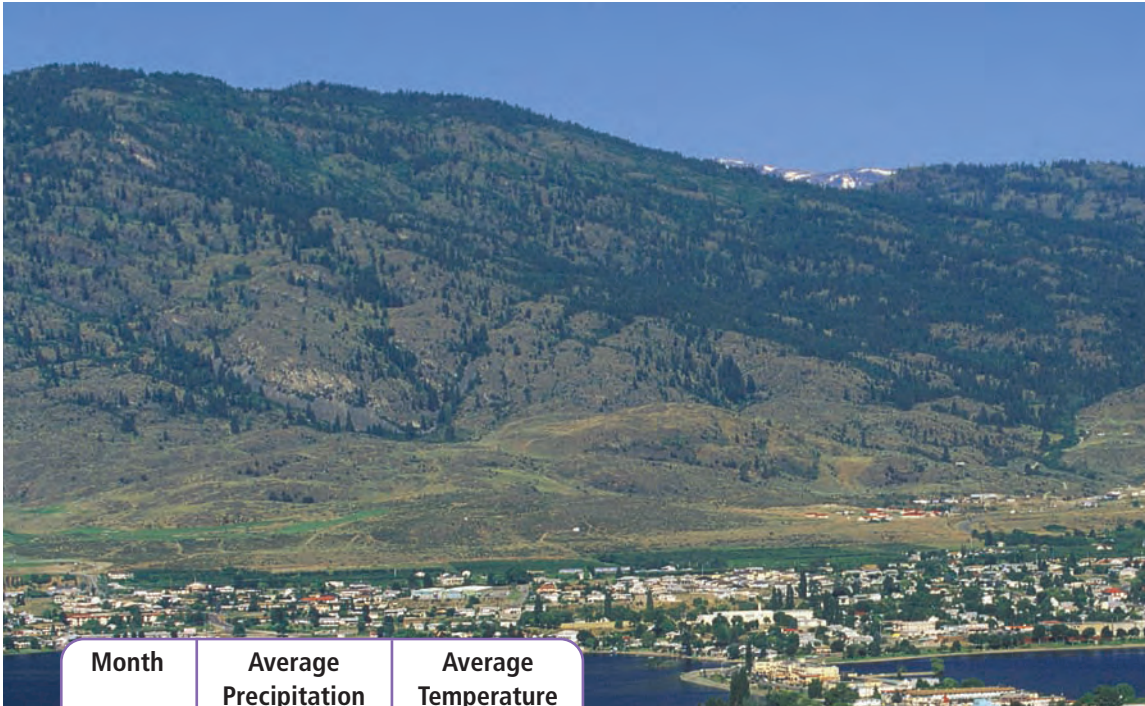| Month	Average Precipitation (mm)	Average Temperature (°C)
J	436	4
F	382	5
M	355	6
A	249	8
M	165	10
J	138	12
J	77	14
A	94	15
S	134	13
O	340	10
N	475	7
D	462	5

Figure 1.9 The statistics for this graph came from Tofino, British Columbia, which is in the temperate rainforest biome.

month. Comparing climatographs can give you a greater understanding of the temperature and precipitation patterns in regions within a biome. You can also use climatographs to compare temperature and precipitation patterns in regions that are in different biomes, as shown in Figure 1.9 on the previous page and Figure 1.10 below. On a climatograph, the month of the year is shown on the horizontal axis. Average temperature is shown on the right vertical axis, and average precipitation is shown on the left vertical axis.

Month	Average Precipitation (mm)	Average Temperature (°C)
J	12	−2
F	18	1
M	20	6
A	23	11
M	37	15
J	36	19
J	24	22
A	21	21
S	16	16
O	17	10
N	26	4
D	17	−1

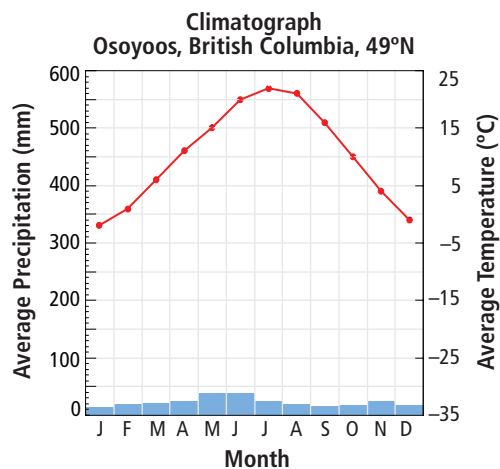**Climatograph Osoyoos, British Columbia, 49°N**

Figure 1.10 The statistics for this graph came from Osoyoos, British Columbia, which is in the desert biome.

Figure 1.11 The cone shape of pine trees is a structural adaptation. As a result, the branches do not break with the weight of the snow.

Adaptations and Biomes

When you think of a polar bear, you may think of northern Canada. When you think of a monkey, you may think of a tropical jungle. When you think of a cactus, you may think of a desert. Certain types of plants and animals are characteristic of certain biomes because they are better adapted for survival in the environmental conditions in those locations. **Adaptations** are characteristics that enable organisms to better survive and reproduce. There are three types of adaptations: structural, physiological, and behavioural.

A **structural adaptation** is a physical feature of an organism's body having a specific function that contributes to the survival of the organism. For example, pine trees are cone-shaped and therefore shed snow easily (Figure 1.11). Porcupines have sharp, stiff quills that function to defend against the attacks of other animals. The arctic fox has a thick, white coat in the winter and a brownish-grey coat in the summer. A change of coat colour provides camouflage for arctic foxes and improves their ability to hunt successfully. All these are examples of structural adaptations that enable the survival of plants and animals.

A **physiological adaptation** is a physical or chemical event that occurs within the body of an organism that enables survival. For example, wolves can maintain a constant body temperature regardless of weather conditions (Figure 1.12). This adaptation enables wolves to survive harsh Canadian winters. The process for converting solar energy into chemical energy (photosynthesis) in cacti (Figure 1.13) is different from photosynthesis in trees and ferns of temperate regions. This adaptation means that cacti require only half as much water for photosynthesis as trees and ferns do.

Figure 1.12 A physiological adaptation enables wolves to maintain a constant body temperature even in cold weather.
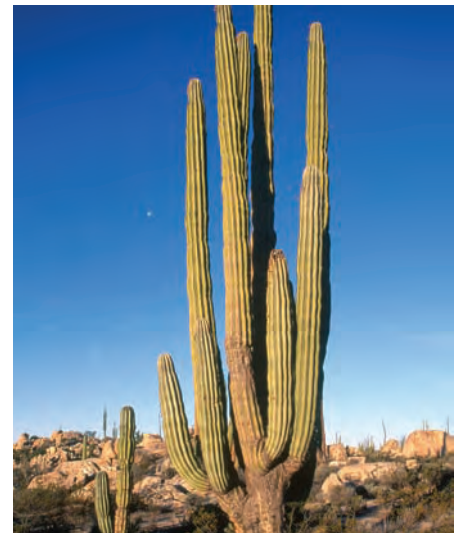

Figure 1.13 Photosynthesis in cacti requires a smaller amount of water than in plants from other biomes as a result of a physiological adaptation.

A **behavioural adaptation** refers to what an organism does to survive in the unique conditions of its environment. These adaptations may include how the organism feeds, mates, cares for its young, migrates, hibernates, or burrows to escape predators. (A predator eats all or part of another organism—its prey). For example, the burrowing owl (which is also a predator) builds its nest in abandoned prairie dog burrows in grassland areas (Figure 1.14). The owl lines the nest with grass, which keeps it cool during the day and warm at night. Cow dung placed at the entrance to the burrow hides the scent of the owl from other predators, such as snakes, skunks, and foxes, which prey on eggs, young, and adults.

Figure 1.14 Another behavioural adaptation of the burrowing owl is that it hisses like a rattlesnake to scare off predators.

Reading Check

1. What is an adaptation?
2. Name three types of adaptations.
3. Describe an adaptation that benefits an animal.
4. Describe an adaptation that benefits a plant.

A Survey of Biomes

So far in this chapter, you have learned that a biome has regions with similar biotic components, such as similar plants and animals and similar abiotic components, such as similar temperature and precipitation. Biomes are often named for their dominant vegetation or for a geographical or physical characteristic. Seven of the following biomes are found in Canada: tundra, boreal forest, temperate deciduous forest, temperate rainforest, grassland, desert, and permanent ice.

Word Connect

"Forest canopy," "understorey," and "forest floor" are three terms ecologists frequently use to describe the layers of forests in biomes. The forest canopy is formed by the tallest trees in the forest. The understorey is formed by the plants and shrubs that grow beneath the canopy. The forest floor is the bottom layer of the forest, which includes roots, fallen leaves, and soil.

Tundra

Caribou

Climatograph
Alert, Nunavut, 82.5°N
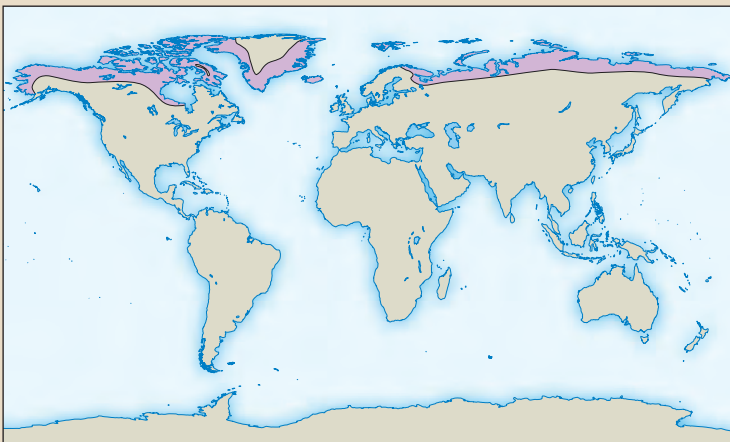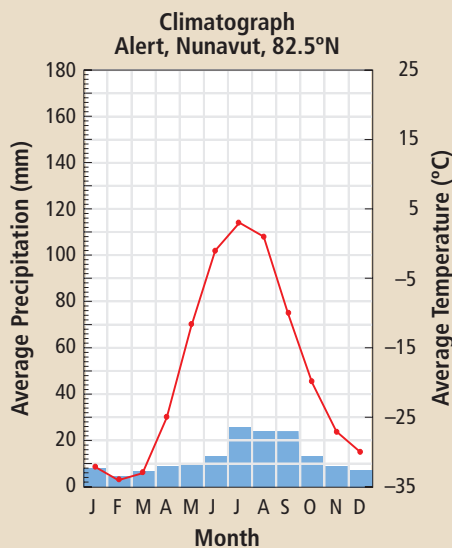
Location: The tundra biome is in the upper northern hemisphere, just below the ice-covered polar seas, at 60° to 70° north latitude.
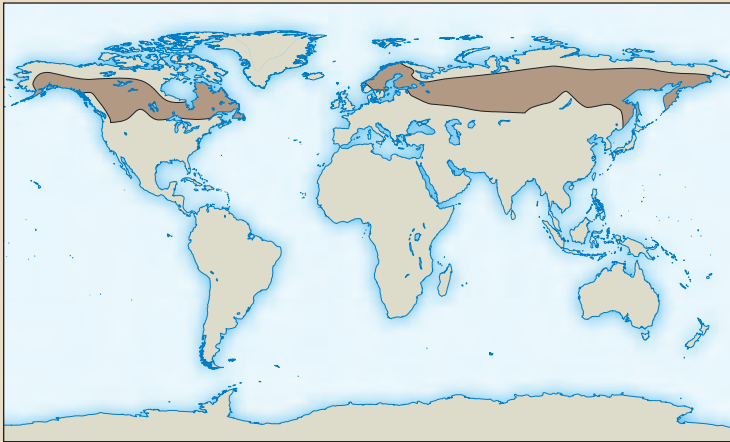
Climate: Precipitation is less than 25 cm annually. Annual summer average temperatures range from 3°C to 12°C. Winter temperatures range from −20°C to −30°C.

Physical features: The tundra biome always has a layer of permanently frozen soil called permafrost. Its flat terrain (the physical features of its land area) results in poor drainage. In summer, a thin layer of topsoil thaws, creating many pools and marshes. The tundra is cold and dark much of the year but has 24 hours of daylight each day during its brief summer.

Plant adaptations: No trees grow here since the growing season is too short. Roots cannot penetrate permafrost. Many plants grow close to the ground, where they absorb the warmth that has been trapped by the dark soil and are sheltered from the fierce winds. Short grasses, lichens, and mosses survive here. Some flowering plants, such as the arctic crocus, have fuzzy coverings on their stems, leaves, and buds that provide protection from the wind. Shrubs flower quickly during the long, sunlit summer days. The Labrador tea bush keeps its old leaves rather than dropping them, which conserves nutrients and helps protect the plant from cold, wind, and drying out.

Animal adaptations: Arctic foxes and hares have compact bodies and shorter legs and ears, which reduce heat loss. Many tundra animals grow more slowly and reproduce less frequently than animals in temperate biomes, therefore requiring less energy. The Greenland sulfur butterfly has a long life cycle, taking up to 14 years to become an adult. Caribou migrate to food sources in winter. In winter, the white feathers of the snowy owl prevent its prey from seeing it against the snow. Many birds migrate here in summer to eat insects that reproduce in great numbers in the marshy conditions.

Boreal Forest

Location: Boreal forests are found in the northern hemisphere between 45° and 65° north latitude across Canada (shown above) and between 55° and 65° north latitude in Russia, Finland, and Scandinavia.

Climate: Precipitation is 30 cm to 85 cm annually, much of it falling as snow. Temperatures are below freezing half of the year and often drop to −40°C.

Physical features: There is a short summer growing season of an average of 50 days. The terrain is often rough. Many marshes, shallow lakes, and wetlands hold vast amounts of water. The soil is also very wet.
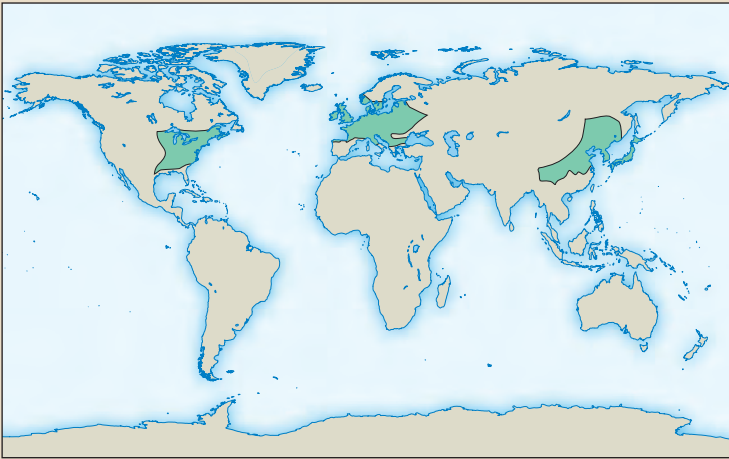
Plant adaptations: Trees are mainly coniferous (cone-bearing), such as black spruce and white spruce, with small, pointed, waxy needles that resist water loss and allow snow to slide off easily. In a balsam fir–white spruce forest, little light reaches the forest floor, so there are few understorey plants.

Animal adaptations: Insect-eating birds such as warblers migrate south in the fall. Seed eaters such as the finch stay year-round. Small mammals such as chipmunks and shrews burrow in winter to stay warm. Mammals such as moose have thick insulating coats and tend to be large. Large bodies enable moose to retain their body heat. The fur of snowshoe hares changes from summer brown to winter white, which camouflages them from predators. Insects multiply rapidly and in large quantities in the summer. Reptiles and amphibians are rare since they are not adapted to survive low temperatures.

**Climatograph
Fort Nelson, British Columbia, 59°N**
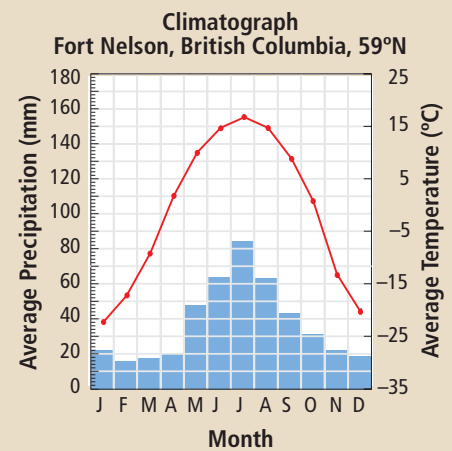
Snowshoe hare

Temperate Deciduous Forest

Canada goose

**Climatograph**
Toronto, Ontario, 44°N

Location: These forests are found mainly in eastern Canada (shown above), the eastern United States, eastern Asia, and western Europe. Southern Australia and New Zealand also have areas of deciduous forest. They occur above 23.5° north latitude and between 23.5° and 38° south latitude.

Climate: The annual rainfall is about 75 cm to 180 cm, with precipitation equally distributed throughout the year. Temperatures range from −30°C in winter to 30°C in summer.

Physical features: Seasonal changes between summer and winter are very large. Temperature changes during a day can also be large. This biome has four distinct seasons and a long, warm growing season. The soil is enriched by fallen leaves that break down and provide nutrients.

Plant adaptations: Plants grow in four to five layers, with tall maple, oak, and birch trees in the canopy layer. Light penetrates the layers, resulting in an understorey that has great biodiversity. Shorter trees occupy the second layer, with shrubs in the third layer, berries in the fourth layer, and ferns, herbs, and mosses on the forest floor. Deciduous trees shed their large, broad leaves in winter, which prevents water loss and reduces breakage of limbs with heavy snow. Thick bark limits moisture loss from the trees.

Animal adaptations: The many layers in the forest provide many habitats for squirrels, rabbits, skunks, cougars, deer, wolves, bears, and amphibians. Squirrels, chipmunks, and blue jays store nuts and seeds in tree hollows. Some mammals hibernate. Many birds migrate to warmer areas in winter.
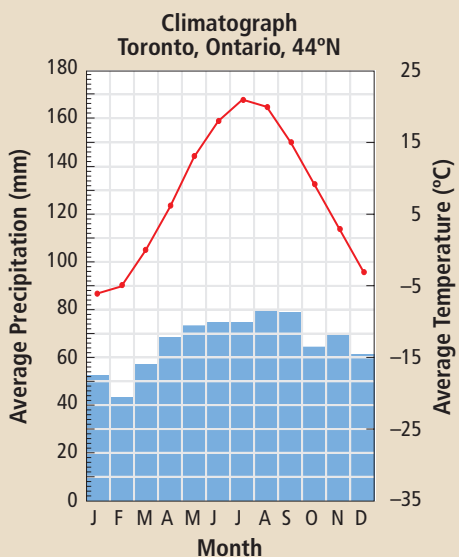
Temperate Rainforest

Location: Temperate rainforests run from about 38° to 56° south latitude along the coast of Chile in South America and from 38° to 61° north latitude along the northwest coast of North America, including coastal British Columbia (shown above). New Zealand and part of southern Australia also have temperate rainforests.

Climate: Rainfall exceeds 200 cm a year with average temperatures ranging from 5°C to 25°C. Coastal fog supplies additional moisture.

Physical features: Temperate rainforests occur in narrow strips along coastlines that are backed by mountains, where the ocean winds drop large amounts of moisture on the windward side of the mountains.

Plant adaptations: Trees can grow very tall because of high precipitation and include large evergreens such as the Sitka spruce (up to 48 m tall) and the Douglas fir (up to 60 m tall). Mosses are draped on trees, and lichens cling on tree trunks, where they receive more light than on the forest floor. Ferns, mosses, and fungi that survive in the shade blanket the forest floor.

Animal adaptations: Most animals live on or near the forest floor, where they are protected from the wind and rain. Many birds and small mammals, such as chipmunks, eat seeds that fall on the forest floor. Many insects live in the tree bark and decomposing plant matter. Birds with long beaks and amphibians with sticky tongues eat these insects.

Climatograph
Pachena Point, British Columbia, 48°N
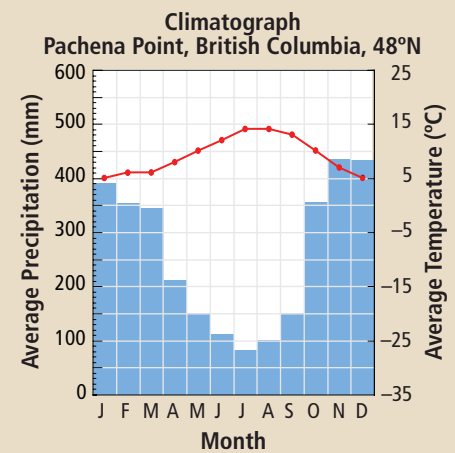
Long-toed salamander
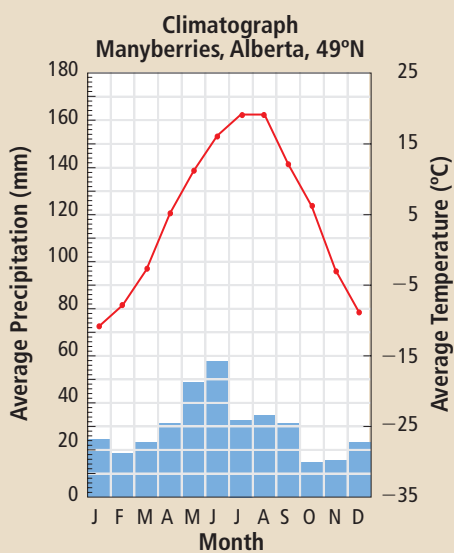
Grassland (Temperate and Tropical)
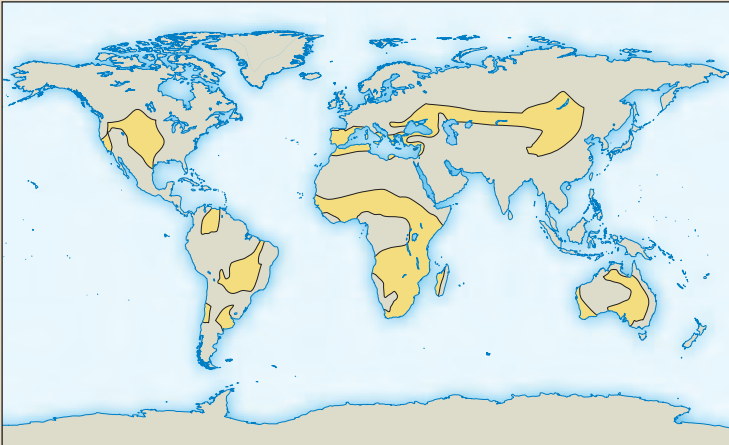
Location: The grassland found in Canada is referred to as the temperate grassland or prairies (shown above). They are also called prairies in other locations in North America and steppes in Russia. Temperate grasslands are found above 23.5° north latitude and below 23.5° south latitude. Tropical grasslands or savannas are found from 5° to 20° north and south of the equator in Africa, South America, and northern Australia.

Climate: In temperate grasslands, the precipitation is 25 cm to 100 cm annually, with hot summers of 30°C and cold winters below −10°C. In tropical grasslands, precipitation is 50 to 130 cm annually, with daily temperatures ranging from 20°C to 30°C.

Physical features: In both temperate and tropical grasslands, the land is mainly flat. The soil is very rich and fertile in the temperate grassland created by the growth and decay of deep grass roots. The tropical grassland is less rich because nutrients are removed by occasional heavy rain. In both grasslands, strong winds may cause soil erosion. Precipitation usually occurs in late spring or early summer and is followed by an extended dry period. Grass fires are common in hot tropical grasslands but occur less frequently in temperate grasslands.

Plant adaptations: In both temperate and tropical grasslands, trees are scarce because of limited rainfall. Fire and grazing animals also kill seedlings. In temperate grasslands, grasses such as blue grama and buffalo grass are well adapted for drought as their roots are deep and form dense mats that collect water when it is available. Because of their well-developed root systems, plants can regrow after a fire. Flexible stalks enable these grasses to bend without breaking in the wind.

Climatograph Manyberries, Alberta, 49°N

Grassland (Temperate and Tropical)

Many wind- and insect-pollinated wildflowers, such as asters, goldenrod, and clover, grow between the grasses. In tropical grasslands, grasses also have deep roots. Some trees, such as acacia, have thorns that deter animals from eating them. Some grasses have sharp edges or are too bitter for grazing.

Animal adaptations: Many large grazing mammals are present in large numbers because there is plentiful grass. Animals such as antelope are found in both biomes and have flat teeth that grind plant materials. In tropical grasslands, herds of antelope, giraffes, and zebras are found with predators such as lions, cheetahs, and leopards. In temperate grasslands, large mammals include antelope, wild horses, kangaroos, and predators such as wolves and coyotes. Animals such as mice, rabbits, gophers, and snakes are common to both grassland types. These animals burrow to escape fire, predators, and extreme weather.


Pronghorn antelope (temperate grassland)


Zebra (tropical grassland)

Reading Check

1. List three characteristics of the tundra biome.
2. List two characteristics of the boreal forest biome.
3. Describe the plant life of a temperate rainforest.
4. Identify the two types of grassland.
5. Explain why grassland plants can survive drought and prairie fires.

Tropical Rainforest

Toucan
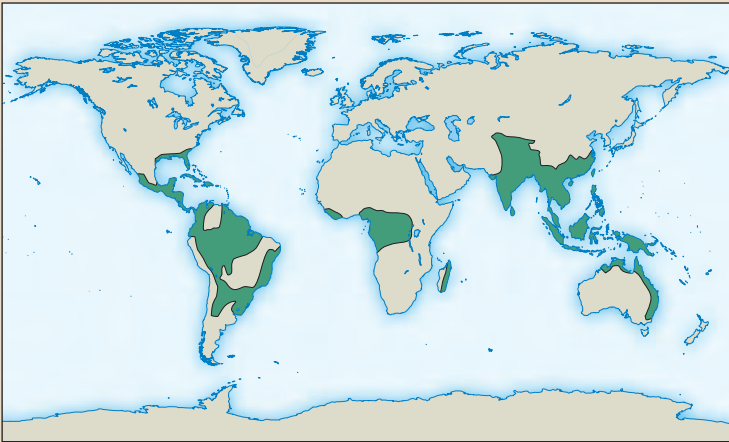
Climatograph
Manokwari, Indonesia, 1°N
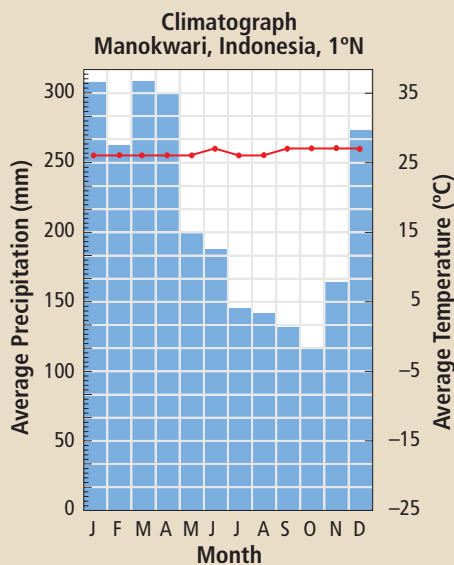
Location: Tropical rainforests are located in a band 4800 km wide around the equator, mostly in the area between the Tropic of Cancer (23.5° north latitude) and the Tropic of Capricorn (23.5° south latitude). These forests cover much of northern South America (shown above), Central America, central Africa, and southeast Asia.

Climate: Rainfall is about 250 cm per year. Temperature is 20°C to 25°C year-round.

Physical features: The soil is poor as nutrients are quickly recycled and not retained. The soil is also poor because heavy rain washes minerals away. The forest floor is very dark, which limits plant growth.

Plant adaptations: This biome has the largest number of different plant species. Plants grow in many layers. Tall trees form a dense canopy that absorbs most of the sunlight. Only shrubs adapted to shade thrive in the understorey. Vines climb tree trunks into the canopy where there is more light. Many plants, such as orchids, reach sunlight by growing on tall trees. Leaves have narrow tips that allow rain to run off quickly, which reduces weight on the branches.

Animal adaptations: This biome has the greatest diversity of animals on Earth but has few large mammals. Most animals are adapted to live in trees since there is little vegetation on the forest floor. Many are specialists, adapted to a particular food or habitat, which reduces competition. Nut eaters like parrots and toucans have big, strong beaks that cut nuts from the trees and crack open the tough shells. Some rainforest animals secrete poisons that protect them from predators. The slow movement of the South American three-toed sloth, an adaptation to its low-calorie diet of leaves, also makes it less noticeable to predators such as jaguars.

Desert (Hot and Cold)

Scorpion
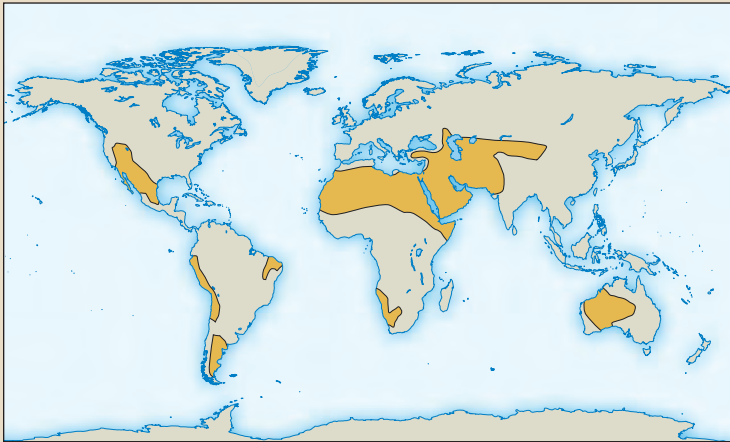
Location: Hot deserts are found on every continent around latitudes about 30° north and south and include the Kalahari and Sahara of Africa, the Simpson of Australia, the Atacama of South America, and the Sonoran (shown above) in the United States. Cold deserts are found in dry regions in the interior of continents above 30° north latitude and below 30° south latitude and in the rain shadows of mountains. Cold deserts include the Great Basin Desert of North America (which includes Canada's Pocket Desert), the Patagonian Desert of Argentina, and the Gobi Desert of central Asia.

Climate: In hot deserts, the rainfall is less than 25 cm annually, with hot days averaging 38°C and cold nights averaging 7°C. In cold deserts, the rainfall is also less than 25 cm annually, with summer days averaging 21°C to 26°C and winter days averaging −2°C to 4°C.

Physical features: In hot deserts, there is either very little rainfall or there is a lot of rain in a very short period. The soils are often salty because minerals do not get washed away. In cold deserts, most precipitation falls as snow, but there is rain in the spring. The soil is often salty and little water erosion occurs.

Plant adaptations: In hot deserts, there are few plant species. Spiny cacti that have thick, fleshy stems that conserve water are common. Their roots extend metres away from the plant to absorb water. Other plants have small, thick, waxy leaves that also store water. Many plants have spines or produce chemicals that protect them from being eaten. In cold deserts, there are few plant species and most are less than 1 m tall. Many plants, such as sagebrush, are deciduous and have spiny leaves. Sagebrush roots can extend 30 m and absorb water when available.

Animal adaptations: In the hot desert, reptiles are common and have thick skin and scales that prevent water loss. Animals such as desert spadefoot toads and scorpions bury themselves in the ground and sleep during times of heat and drought. Animals are active mainly at night when temperatures are lower. In the cold desert, fan-throated lizards, small mammals, such as foxes, coyotes, jackrabbits, and pocket mice burrow to escape the cold.

**Climatograph
Yuma, Arizona, 32.5°N**
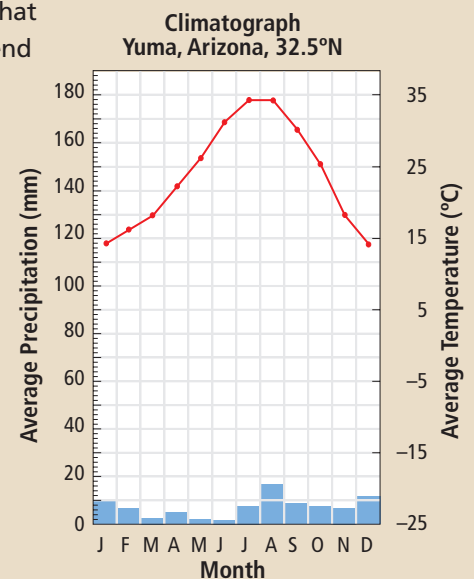
Permanent Ice (Polar Ice)
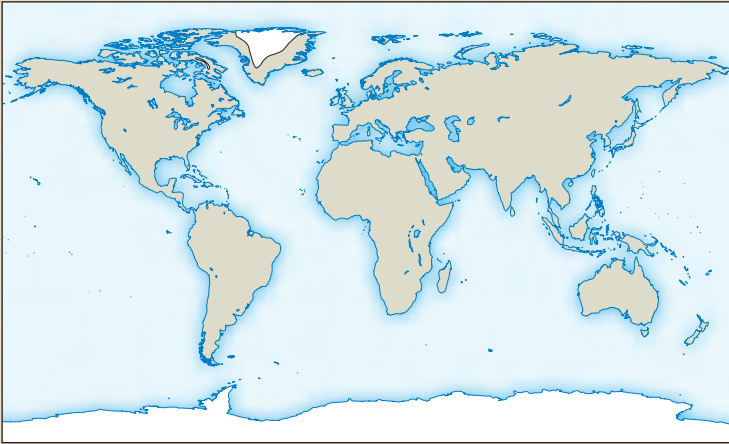

King penguins of Antarctica

Location: This biome includes the polar land masses and large polar ice caps of the Arctic, Greenland, and Antarctica (shown above).

Climate: Annual precipitation is less than 50 cm, most falling as snow. Antarctica has recorded a temperature as low as −89°C. Average Arctic winter temperatures are −30°C. Average Antarctic summer temperatures range from 9°C on the coast to −30°C inland. Average Arctic summer temperatures range from 3°C to 14°C.

Physical features: This biome has very strong winds and little soil. Little fresh water is available because of freezing conditions. Antarctica is very cold almost all year-round.

Plant adaptations: Lichens (organisms that consist of fungi and algae) can tolerate drought and cold and are dark-coloured, thus absorbing more sunlight. Many species of moss survive in the Arctic, but few species of moss grow in Antarctica. There are only two flowering plants in Antarctica, but there are more than 100 species of flowering plants in the Arctic because of its brief growing season.

Animal adaptations: The Arctic has polar bears, walruses, seals, arctic foxes, and some insects. Antarctica has mostly penguins and marine mammals, such as leopard seals. Penguins have fat layers and tightly packed feathers that retain heat. Polar bears, seals, and walruses have thick coats and fat layers for warmth. Walruses have no external ear, which reduces heat loss, and they lie close together in herds of over a thousand animals, thus retaining heat.

Climatograph
McMurdo Sound, Antarctica, 77°S
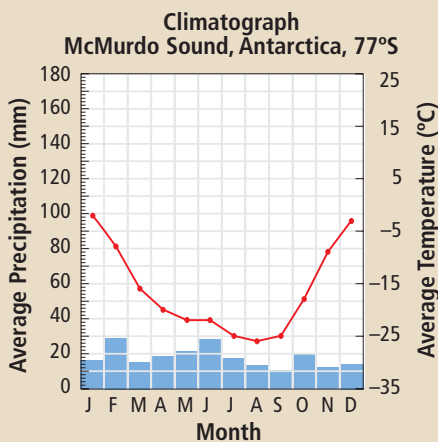
Reading Check

1. Which biome has the greatest variety of plant and animal species?
2. Identify the two types of desert.
3. Give two examples of desert plant adaptations.
4. What limits the variety and numbers of living things that can survive in the permanent ice biome?
5. Give two examples of animal adaptations for life in Antarctica.

Explore More

If you ever go to Deception Island, be sure to pack your bathing suit. Find out why this island off the coast of Antarctica has quite a different climate than icy McMurdo Sound. Begin your search at **www.bcscience10.ca**.

1-1B Biotic and Abiotic Components of Biomes

Think About It

Biomes have both living and non-living components that affect the organisms living in them. In this activity, you will compare and contrast the biotic and abiotic components of two biomes.

What to Do

1. Your teacher will give you photographs of a variety of biomes. Work with a partner to identify which biomes are shown in the photographs.
2. Make a list of all the living components shown in each biome.
3. Make another list of all the non-living components of each biome.
4. Your teacher will give you photographs of a variety of organisms. Study the plant and animal photographs carefully.
5. Work with your partner to sort the photographs into groups of plants and animals that you would find in the biomes you have identified.
6. Brainstorm a list of plant characteristics you observe for each biome.
7. Brainstorm a list of animal characteristics you observe for each biome.
8. Consider other plant and animal characteristics that would be beneficial to organisms in these biomes, and add them to your lists.

9. Choose two biomes. Construct a full-page Venn diagram to compare and contrast the biotic and abiotic components of these biomes. Include animal and plant characteristics in the biotic section of the diagram.
10. Compare your results with those of your classmates.

Science Skills

Go to Science Skill 11 for information on making Venn diagrams.

What Did You Find Out?

1. What similarities in biotic components did you find between the biomes you compared in your Venn diagram?
2. What differences in abiotic components did you find between these two biomes?
3. How can you explain the differences in the biotic factors between these two biomes?
4. How can you explain the differences in the abiotic factors between these two biomes?

Materials

- ruler
- red and blue pencils
- graph paper

You have learned that temperature and precipitation are two abiotic factors that influence the climate and the types of plants and animals in a biome. You have also learned that you can use climatographs to compare the climates of different biomes. In this activity, you will practise interpreting and graphing climatographs. Then, you will make an inference about which biomes are represented by the climatographs.

Question

How can you use the information in climatographs to infer which biomes are represented?

Procedure

Part 1 Analyze a Climatograph

1. Working with a partner, study Climatograph A below and then answer the following questions.

    (a) What information is represented on the left-hand vertical y-axis ?

    (b) What information is represented by the letters along the horizontal *x*-axis?

    (c) What are the units of measurement for precipitation?

    (d) What are the units of measurement for temperature?

    (e) What is the total amount of precipitation in July?

    (f) What is the average temperature in December?
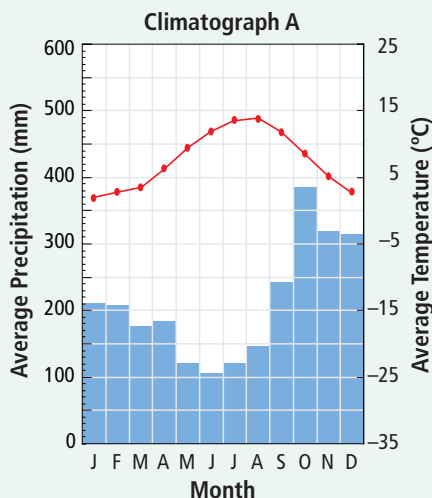
Climatograph A

Part 2 Graph a Climatograph

2. Construct a climatograph for the following climate data. Follow the directions in steps 3 to 7.

Month	Average Precipitation (mm)	Average Temperature (°C)
J	64	−10
F	51	−8
M	64	−2
A	67	6
M	81	13
J	91	18
J	88	21
A	87	19
S	86	14
O	79	8
N	77	1
D	74	−6

3. On the graph paper, mark 12 intervals on the horizontal axis. Label each interval with the first letter of the month, starting with "J" for January.

4. On the left vertical axis, mark 10 intervals beginning at 0 and extending to 100. Each interval has a value of 10. Label this axis "Average Precipitation (mm)."

5. Draw a second vertical axis for temperature on the right. On this axis, mark seven intervals beginning with −10°C and extending to 25°C. Label this axis "Average Temperature (°C)."

6. Present the data for each month's average precipitation as a bar graph. Use a blue pencil to shade in the bar graph.

7. Enter the data for each month's average temperature in the middle of the space allocated for that month. Use a red pencil to draw a curve between the points.

8. Add the title "Climatograph B."

Part 3 Compare Climatographs and Make an Inference

9. Compare Climatograph A to Climatograph B.

   (a) How do the monthly precipitation patterns in the two climatographs compare?

   (b) How do the monthly temperature patterns in each climatograph compare?

   (c) Infer which biome is represented by Climatograph A.

   (d) Infer which biome is represented by Climatograph B.

Analyze

1. How would you describe the climate represented by Climatograph A?

2. How would you describe the climate represented by Climatograph B?

3. Which biome do you think is represented by Climatograph A? How do you know?

4. Which biome do you think is represented by Climatograph B? How do you know?

5. If temperatures above 5°C are required for plant growth, which biome has the longer growing season: the biome represented by Climatograph A or the biome represented by Climatograph B? Explain.

Conclude and Apply

1. One of the climatographs in this activity represents the climate of a city in British Columbia and one represents a city from another province in Canada. Which cities do you think are represented by these climatographs?

2. Some scientists predict that, due to global warming, Earth's average monthly temperatures will rise by 4°C by 2100. What effect might this have on the growing season in these two Canadian cities?

Science Watch

Dust on the Move
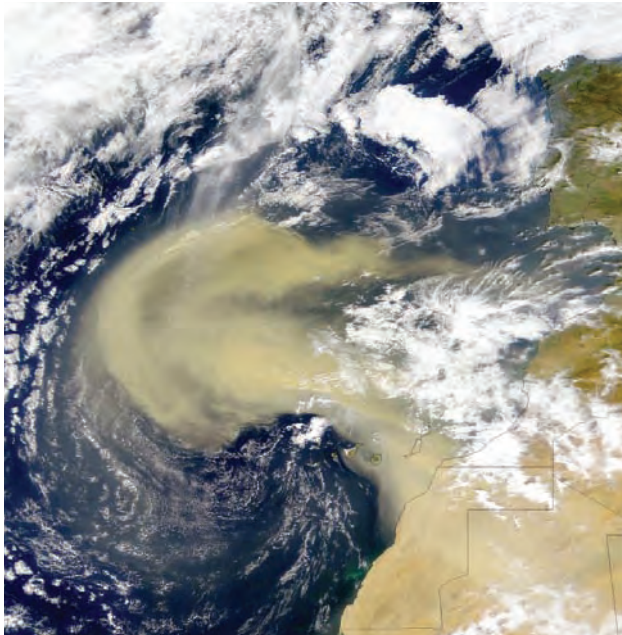
You may think the ground under your feet does not go anywhere, but soil and dust are constantly on the move, reshuffling particles around the biosphere. Fine particles of arid soil from the Sahara Desert are carried by winds across the Atlantic Ocean and reach the Americas within days. Soil, part of the abiotic environment, has an impact on the biotic environments in other areas of the world. While scientists have long known that soil can be transported vast distances, only recently have they begun to understand the full environmental impact of this movement.

Scientists estimate that the quantity of soil that moves large distances in Earth's atmosphere is approximately 3 billion tonnes annually. Plants in the Amazon rainforest have evolved in ways that take advantage of particles rich in iron, phosphorus, and organic matter that are carried in the wind from the African Sahara desert. In the South Atlantic Ocean and the Caribbean Sea, seaweed and algae flourish after dust storms.

It is believed that global warming is increasing the intensity of dust storms. Scientists are now hypothesizing that the increased amount of Saharan dust is also causing environmental distress. Some dust particles in clouds can stop rain droplets from falling, reducing precipitation in some areas.

Of great concern is the devastation caused by the microbial hitchhikers (micro-organisms) in windborne soil. Concentrations of bacteria carried across the globe have been calculated to be from 10^6 to 10^9 bacteria per gram of soil. It is estimated that 30 percent of these dust micro-organisms can cause disease. Also along for the ride in soil are viruses and spores from fungi that are affecting many animal species. Evidence shows that the death of Caribbean staghorn corals and sea urchins is directly related to African dust deposits. The fungus *Aspergillus*, which is carried in the windborne soil, has also caused the death of coral sea fans. Disease caused by fungi has been found to affect Caribbean sugar cane and banana crops after dust storms. While African dust in the atmosphere is not new, huge amounts of dust blowing off Asia is a recent occurrence. Increased desertification (the creation of deserts) due to less precipitation and increased land use in Asia is also producing millions of tonnes of windborne dust. Although Hawaiian Island plants may gain nutrients from the dust of Asian deserts, the full extent of the negative effects of this increased soil movement has yet to be determined.

Questions

1. Explain how the Amazon rainforest biome has benefited from the Sahara Desert biome.
2. Give two damaging environmental effects caused by the Saharan dust.
3. How have microbial hitchhikers affected organisms in the Caribbean?

Check Your Understanding

Checking Concepts

1. What is the biosphere?
2. List three abiotic components of a biome.
3. What factors influence the characteristics and distribution of life in a terrestrial biome?
4. Explain the importance of adaptations to the survival of plants and animals in their biome.
5. How are plants adapted to survive a short growing season?
6. List two boreal forest animals, and describe their adaptations.
7. Explain why temperate rainforest biomes are found along coastlines.
8. Explain why there is little vegetation on the floor of the tropical rainforest.
9. (a) Identify the biomes shown in the climatographs below.

Climatograph A

Climatograph B
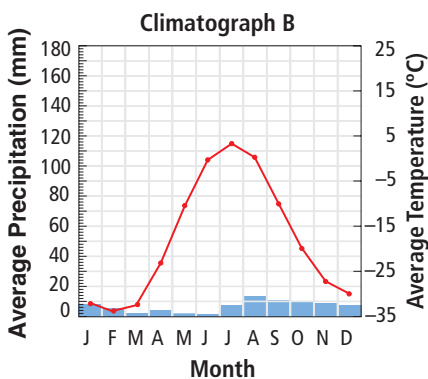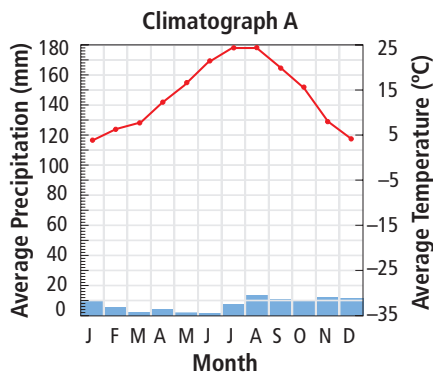
(b) Explain how you identified each biome.

10. Match the following biomes to the descriptions in parts (a) to (g).
    (i) tundra
    (ii) boreal forest
    (iii) temperate deciduous forest
    (iv) grassland
    (v) tropical rainforest
    (vi) desert
    (vii) temperate rainforest
    (a) distinct seasons, moderate climate
    (b) permafrost
    (c) Douglas fir, moss, lichen
    (d) many layers of trees and plants, but light gets through
    (e) great biodiversity, many layers of trees and plants, but light does not get through
    (f) fleshy, spiny cacti
    (g) coniferous forest

Understanding Key Ideas

11. Explain how latitude influences temperature and precipitation.
12. Explain how temperature affects the biotic component of biomes.
13. Explain why the plants and animals of eastern Canada are similar to the plants and animals of eastern Asia.
14. Distinguish among the three types of adaptations, and provide an example of each type.
15. Imagine that you were travelling directly north from Venezuela near the equator to the North Pole.
    (a) List the terrestrial biomes that you would travel through.
    (b) Identify one plant and one animal that is typical of each biome.

Pause and Reflect

"The greatest biodiversity is found closest to the equator." Support or refute (argue against) this statement based on what you have learned in this section.