Key Questions and Concepts

7-1 What factors influence climate?

CONCEPT 7-1 An area's climate is determined mostly by solar radiation, the earth's rotation, global patterns of air and water movement, gases in the atmosphere, and the earth's surface features.

7-2 How does climate affect the nature and locations of biomes?

CONCEPT 7-2 Differences in average annual precipitation and temperature lead to the formation of tropical, temperate, and cold deserts, grasslands, and forests, and largely determine their locations.

7-3 How have we affected the world's terrestrial ecosystems?

CONCEPT 7-3 In many areas, human activities are impairing ecological and economic services provided by the earth's deserts, grasslands, forests, and mountains.

Note: Supplements 2 (p. S4), 4 (p. S20), 5 (p. S31), 8 (p. 47), 10 (p. S59), and 13 (p. S78) can be used with this chapter.

To do science is to search for repeated patterns,
not simply to accumulate facts,
and to do the science of geographical ecology
is to search for patterns of plant and animal life
that can be put on a map.

ROBERT H. MACARTHUR

7-1 What Factors Influence Climate?

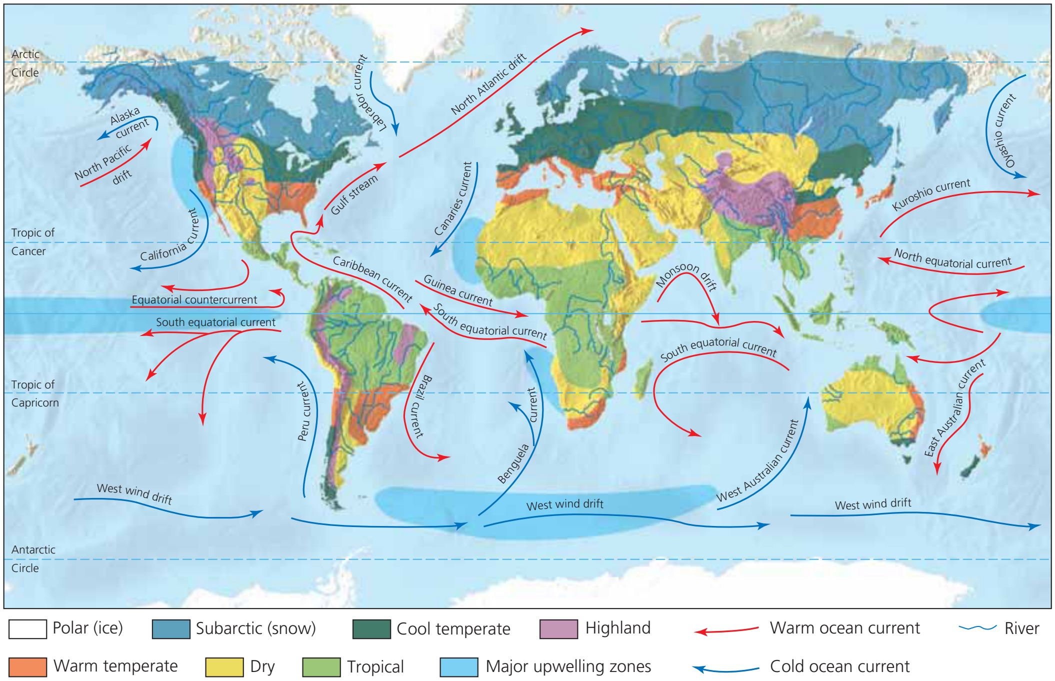
CONCEPT 7-1 An area's climate is determined mostly by solar radiation, the earth's rotation, global patterns of air and water movement, gases in the atmosphere, and the earth's surface features.

The Earth Has Many Different Climates

Weather is a local area's short-term temperature, precipitation, humidity, wind speed, cloud cover, and other physical conditions of the lower atmosphere as measured over hours or days. (Supplement 8, p. S47, introduces you to weather basics.) **Climate** is an area's general pattern of atmospheric or weather conditions measured over long periods of time ranging from decades to thousands of years. As American writer and humorist Mark Twain once said, "Climate is what we expect, weather is what we get." Figure 7-2 (p. 142), depicts the earth's major climate zones, an important component of the earth's natural capital (Figure 1-3, p. 8).

Climate varies in different parts of the earth mostly because patterns of global air circulation and ocean currents distribute heat and precipitation unevenly (Figure 7-3, p. 142). Three major factors determine how air circulates in the lower atmosphere, which helps to distribute heat and moisture from the tropics to other parts of the world:

- *Uneven heating of the earth's surface by the sun.* Air is heated much more at the equator, where the sun's rays strike directly, than at the poles, where sunlight strikes at a slanted angle and spreads out over a much greater area (Figure 7-3, right). These differences in the distribution of incoming solar energy help to explain why tropical regions near the equator are hot, why polar regions are cold, and why temperate regions in between generally have intermediate average temperatures.
- *Rotation of the earth on its axis.* As the earth rotates around its axis, its equator spins faster than its polar regions. As a result, heated air masses rising above the equator and moving north and south to cooler areas are deflected to the west or east over different parts of the planet's surface (Figure 7-3). The atmosphere over these different areas is divided into huge regions called *cells,* distinguished by direction of air movement. And the differing directions of air movement are called *prevailing winds*—major surface winds that blow almost continuously



CENGAGENOW™ **Active Figure 7-2** **Natural capital:** generalized map of the earth's current climate zones, showing the major contributing ocean currents and drifts and upwelling areas (where currents bring nutrients from the ocean bottom to the surface). Winds play an important role in distributing heat and moisture in the atmosphere, which leads to such climate zones. Winds also cause currents that help distribute heat throughout the world's oceans. *See an animation based on this figure at* CengageNOW™. **Question:** Based on this map what is the general type of climate where you live?

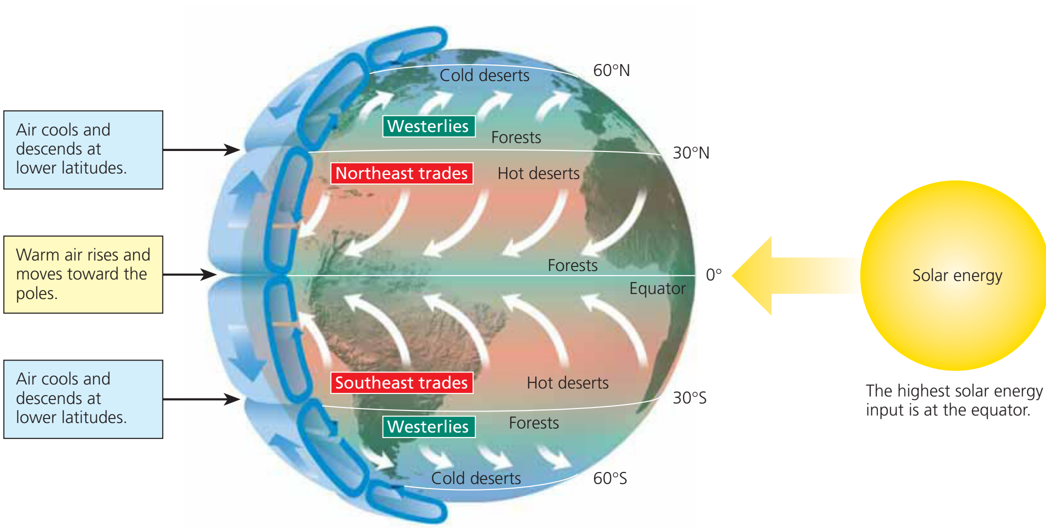


Figure 7-3 *Global air circulation.* The largest input of solar energy occurs at the equator. As this air is heated it rises and moves toward the poles. However, the earth's rotation deflects the movement of the air over different parts of the earth. This creates global patterns of prevailing winds that help distribute heat and moisture in the atmosphere.

and help distribute air, heat, moisture, and dust over the earth's surface (**Core Case Study**).

- *Properties of air, water, and land.* Heat from the sun evaporates ocean water and transfers heat from the oceans to the atmosphere, especially near the hot equator. This evaporation of water creates giant cyclical convection cells that circulate air, heat, and moisture both vertically and from place to place in the atmosphere, as shown in Figure 7-4.

Prevailing winds (Figure 7-3) blowing over the oceans produce mass movements of surface water called **currents.** Driven by prevailing winds and the earth's rotation, the earth's major ocean currents (Figure 7-2) redistribute heat from the sun from place to place, thereby influencing climate and vegetation, especially near coastal areas.

The oceans absorb heat from the earth's air circulation patterns; most of this heat is absorbed in tropical waters, which receive most of the sun's heat. This heat and differences in water *density* (mass per unit volume) create warm and cold ocean currents. Prevailing winds and irregularly shaped continents interrupt these currents and cause them to flow in roughly circular patterns between the continents, clockwise in the northern hemisphere and counterclockwise in the southern hemisphere.

Heat is also distributed to the different parts of the ocean and the world when ocean water mixes vertically in shallow and deep ocean currents, mostly as a result of differences in the density of seawater. Because it has a higher density, colder seawater sinks and flows beneath warmer and less dense seawater. This creates a connected loop of deep and shallow ocean currents, which act like a giant conveyer belt that moves heat to and from the deep sea and transfers warm and cold water between the tropics and the poles (Figure 7-5).

The ocean and the atmosphere are strongly linked in two ways: ocean currents are affected by winds in the atmosphere (**Core Case Study**), and heat from the ocean affects atmospheric circulation (Figure 7-4). One example of the interactions between the ocean and the atmosphere is the *El Niño–Southern Oscillation,* or *ENSO,* as discussed on pp. S48–S49 in Supplement 8 and in *The Habitable Planet,* Video 3, at **www.learner.org/resources/series209.html**. This large-scale weather phenomenon occurs every few years when prevailing winds in the tropical Pacific Ocean weaken and change direction. The resulting above-average warming of Pacific waters can affect populations of marine species by changing the distribution of plant nutrients. It also alters the weather of at least two-thirds of the earth for one or two years (see Figure 5, p. S49, in Supplement 8).

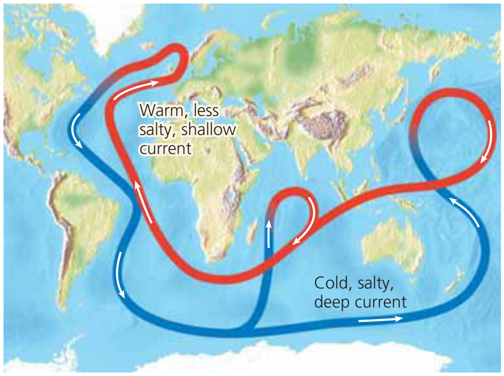


Figure 7-5 *Connected deep and shallow ocean currents.* A connected loop of shallow and deep ocean currents transports warm and cool water to various parts of the earth. This loop, which rises in some areas and falls in others, results when ocean water in the North Atlantic near Iceland is dense enough (because of its salt content and cold temperature) to sink to the ocean bottom, flow southward, and then move eastward to well up in the warmer Pacific. A shallower return current aided by winds then brings warmer, less salty—and thus less dense—water to the Atlantic. This water can cool and sink to begin this extremely slow cycle again. **Question:** How do you think this loop affects the climates of the coastal areas around it?

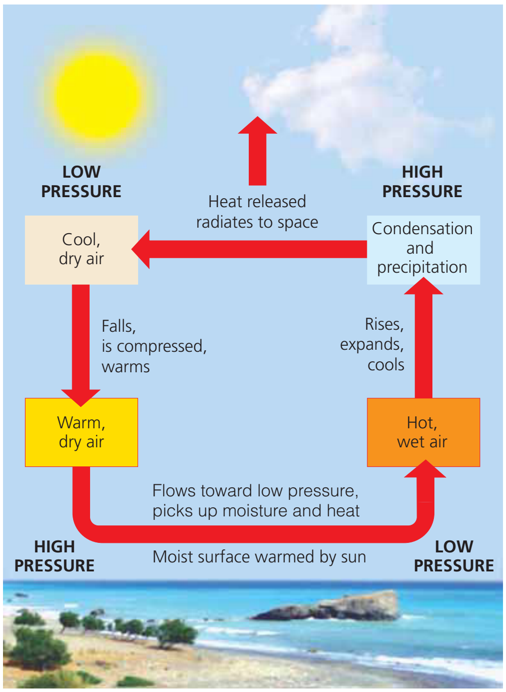


Figure 7-4 Energy transfer by convection in the atmosphere. *Convection* occurs when hot and wet warm air rises, cools, and releases heat and moisture as precipitation (right side). Then the denser cool, dry air sinks, gets warmer, and picks up moisture as it flows across the earth's surface to begin the cycle again.

CENGAGENOW™ Learn more about how oceans affect air movements where you live and all over the world at CengageNOW™.

The earth's air circulation patterns, prevailing winds, and configuration of continents and oceans result in six giant convection cells (like the one shown in Figure 7-4) in which warm, moist air rises and cools, and cool, dry air sinks. Three of these cells are found north of the equator and three are south of the equator. These cells lead to an irregular distribution of climates and deserts, grasslands, and forests, as shown in Figure 7-6 (**Concept 7-1**).

CENGAGENOW™ Watch the formation of six giant convection cells and learn more about how they affect climates at CengageNOW.

THINKING ABOUT
Winds and Biomes

CORE CASE STUDY

How might the distribution of the world's forests, grasslands, and deserts shown in Figure 7-6 differ if the prevailing winds shown in Figure 7-3 did not exist?

Greenhouse Gases Warm the Lower Atmosphere

Figure 3-8 (p. 56) shows how energy flows to and from the earth. Small amounts of certain gases, including water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), in the atmosphere play a role in determining the earth's average temperatures and its climates. These **greenhouse gases** allow mostly visible light and some infrared radiation and ultraviolet (UV) radiation from the sun to pass through the atmosphere. The earth's surface absorbs much of this solar energy and transforms it to longer-wavelength infrared radiation (heat), which then rises into the lower atmosphere.

Some of this heat escapes into space, but some is absorbed by molecules of greenhouse gases and emitted into the lower atmosphere as even longer-wavelength infrared radiation. Some of this released energy radiates into space, and some warms the lower atmosphere and the earth's surface. This natural warming effect of the troposphere is called the **greenhouse effect** (see Figure 3-8, p. 56, and *The Habitable Planet,* Video 2, at **www.learner.org/resources/series209.html**). Without the warming caused by these greenhouse gases, the earth would be a cold and mostly lifeless planet.

Human activities such as burning fossil fuels, clearing forests, and growing crops release carbon dioxide, methane, and nitrous oxide into the atmosphere. Considerable evidence and climate models indicate that there is a 90–99% chance that the large inputs of greenhouse gases into the atmosphere from human activities are enhancing the earth's natural greenhouse effect. This *human-enhanced global warming* (Science Focus, p. 33) could cause climate changes in various places on the earth that could last for centuries to thousands of years. As this warming intensifies during this century, climate scientists expect it to alter precipitation patterns, shift areas where we can grow crops, raise average sea levels, and shift habitats for some types of plants and animals, as discussed more fully in Chapter 19.

CENGAGENOW™ Witness the natural greenhouse effect and see how human activities have affected it at CengageNOW.

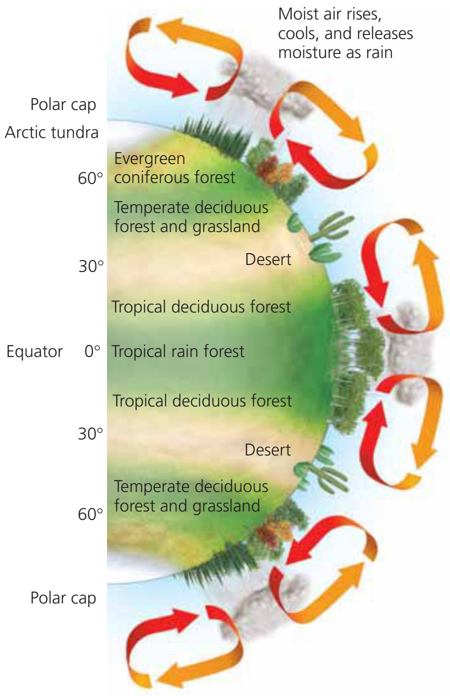


Figure 7-6 *Global air circulation, ocean currents, and biomes.* Heat and moisture are distributed over the earth's surface via six giant convection cells (like the one in Figure 7-4) at different latitudes. The resulting uneven distribution of heat and moisture over the planet's surface leads to the forests, grasslands, and deserts that make up the earth's terrestrial biomes.

The Earth's Surface Features Affect Local Climates

Heat is absorbed and released more slowly by water than by land. This difference creates land and sea breezes. As a result, the world's oceans and large lakes moderate the weather and climates of nearby lands.

Various topographic features of the earth's surface create local and regional weather and climatic conditions that differ from the general climate of a region. For example, mountains interrupt the flow of prevailing surface winds and the movement of storms. When moist air blowing inland from an ocean reaches a mountain range, it is forced upward. As it rises, it cools and expands and then loses most of its moisture as rain and snow on the windward slope of the mountain (the side from which the wind is blowing).

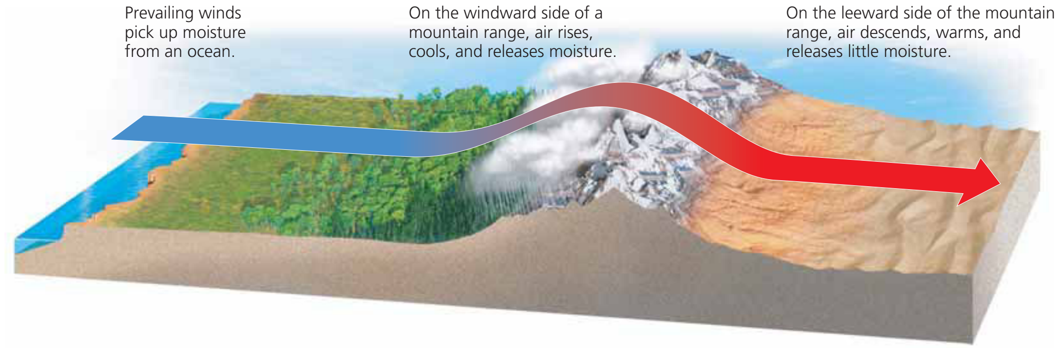


Figure 7-7 The *rain shadow effect* is a reduction of rainfall and loss of moisture from the landscape on the side of a mountain facing away from prevailing surface winds. Warm, moist air in onshore winds loses most of its moisture as rain and snow on the windward slopes of a mountain range. This leads to semiarid and arid conditions on the leeward side of the mountain range and the land beyond. The Mojave Desert in the U.S. state of California and Asia's Gobi Desert are both produced by this effect.

As the drier air mass passes over the mountaintops it flows down the leeward (away from the wind) slopes, warms up (which increases its ability to hold moisture), and sucks up moisture from the plants and soil below. The loss of moisture from the landscape and the resulting semiarid or arid conditions on the leeward side of high mountains create the **rain shadow effect** (Figure 7-7). Sometimes this leads to the formation of deserts such as Death Valley in the United States, which is in the rain shadow of Mount Whitney, the highest mountain in the Sierra Nevadas. In this way, winds (**Core Case Study**) play a key role in forming some of the earth's deserts. CORE CASE STUDY

Cities also create distinct microclimates. Bricks, concrete, asphalt, and other building materials absorb and hold heat, and buildings block wind flow. Motor vehicles and the climate control systems of buildings release large quantities of heat and pollutants. As a result, cities tend to have more haze and smog, higher temperatures, and lower wind speeds than the surrounding countryside.

THINKING ABOUT
Winds and Your Life

CORE CASE STUDY

What are three changes in your lifestyle that would take place if there were no winds where you live?

RESEARCH FRONTIER

Modeling and other research to learn more about how human activities affect climate. See **academic.cengage.com/biology/miller**.

7-2 How Does Climate Affect the Nature and Locations of Biomes?

CONCEPT 7-2 Differences in average annual precipitation and temperature lead to the formation of tropical, temperate, and cold deserts, grasslands, and forests, and largely determine their locations.

Climate Affects Where Organisms Can Live

Different climates (Figure 7-2) explain why one area of the earth's land surface is a desert, another a grassland, and another a forest (Figure 7-6) and why global air circulation (Figure 7-3) accounts for different types of deserts, grasslands, and forests (**Concept 7-2**).

Figure 7-8 (p. 146) shows how scientists have divided the world into several major **biomes**—large terrestrial regions characterized by similar climate, soil, plants, and animals, regardless of where they are found in the world. The variety of terrestrial biomes and aquatic systems is one of the four components of the earth's biodiversity (Figure 4-2, p. 79, and **Concept 4-1A**, p. 78)—a vital part of the earth's natural capital. CONCEPT LINK

By comparing Figure 7-8 with Figure 7-2 and Figure 1 on pp. S20–S21 in Supplement 4, you can see how the world's major biomes vary with climate.