UNIT 2

Ecology

American crocodile, Everglades National Park, Florida

Crosscutting Concepts Ecology deals with life at all scales, from microscopic to planetary. Organisms interact with each other and with their environments, forming global systems driven by energy. Those systems are rarely stable; causes of global change produce measurable effects on all living things, including humans.

BOUNCE TO ACTIVATE **VIDEO**

Author Joe Levine talks about stability and change, using succession as an example.

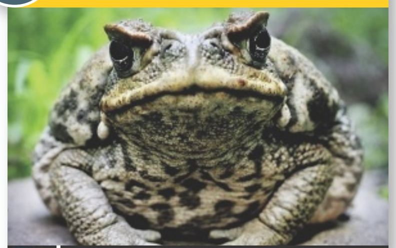
UNIT 2 PROBLEM-BASED LEARNING

Invasives
IN YOUR NEIGHBORHOOD

It was just a little snake when you bought it. But, a year later, your Burmese python was as long as you are tall and weighed more than you do. This was not the kind of pet you had in mind. Unfortunately, some Burmese python owners have reached the same conclusion and have abandoned their enormous pets in Florida's Everglades National Park. These pythons have flourished in their new home and are causing large declines in small mammal populations in the Everglades. Burmese pythons are an invasive species . . . and they are not alone. In fact, invasives are all around us.

PROBLEM LAUNCH
Choose an invasive species in your local ecosystem to focus on.

VIDEO



BOUNCE TO ACTIVATE

Watch a video about Australia's battle with the poisonous cane toad.

PROBLEM: How can you reduce the impact of an invasive species on your local ecosystem?

TO SOLVE THIS PROBLEM, perform these activities as they come up in the unit and record your findings in your Explorer's Journal.

INTERACTIVITY

Investigate how invasive species can disrupt a native food web.

INTERACTIVITY

Conduct a virtual investigation to see the effect of the introduced Burmese pythons on the Everglades ecosystem.

STEM PROJECT

Design a solution to help control the population of the local invasive species you chose.

AUTHENTIC READING

Read about how an invasive species is changing hemlock forests in the Smoky Mountains.

INTERACTIVITY

Virtually test different strategies for controlling an invasive frog in the American southwest.

PROBLEM WRAP-UP

Present your findings, and propose a solution for reducing the impact of a local invasive species.

CHAPTER 3

The Biosphere

Go Online to access your digital course.

- VIDEO
- AUDIO
- INTERACTIVITY
- eTEXT
- ANIMATION
- VIRTUAL LAB
- ASSESSMENT

Biosphere 2

HS-LS2-2, HS-ESS2-4, HS-ESS3-6, HS-ETS1-3

CASE STUDY

Can we make a working model of our living planet?

Rising like a mirage in the desert 30 miles north of Tucson, Arizona, a huge greenhouse shaped like an Aztec pyramid towers over smaller greenhouses, domes, and oddly-shaped buildings. It would be easy to think that this place was built as a set for a science fiction movie on Mars. As it turns out, that impression wouldn't be far from the truth.

This is "Biosphere 2"—built in the late 1980s in hopes of providing a model for human space colonies. Its builders knew that colonists would need to produce food to eat, oxygen to breathe, and clean water to drink. Recycling waste products was essential. But how could they mange all this?

"Biosphere 1" is Earth, whose living and physical global systems support life through complex processes that we only partly understand. So a team of biologists and engineers set out to design and build a "biosphere in miniature" that could support human life sealed off from the outside world. Biosphere 2 included three acres of greenhouses in which to grow food, and, in miniature, a tropical rain forest, an ocean with a coral reef, a desert, a grassland, and a mangrove forest. These artificial environments contained roughly 3000 documented species, and many species of undocumented microorganisms. A crew of eight "biosphereans" sealed themselves inside.

Was Biosphere 2 a success? That depends on how you define "success." Almost as soon as Biosphere 2 was sealed, the composition of its atmosphere started changing. Oxygen concentrations dropped so dramatically that supplemental oxygen had to be piped in. Meanwhile, carbon dioxide levels rose steadily. Many desirable plant and animal species died—including all pollinating insects. Nuisance insects and weeds grew exponentially.

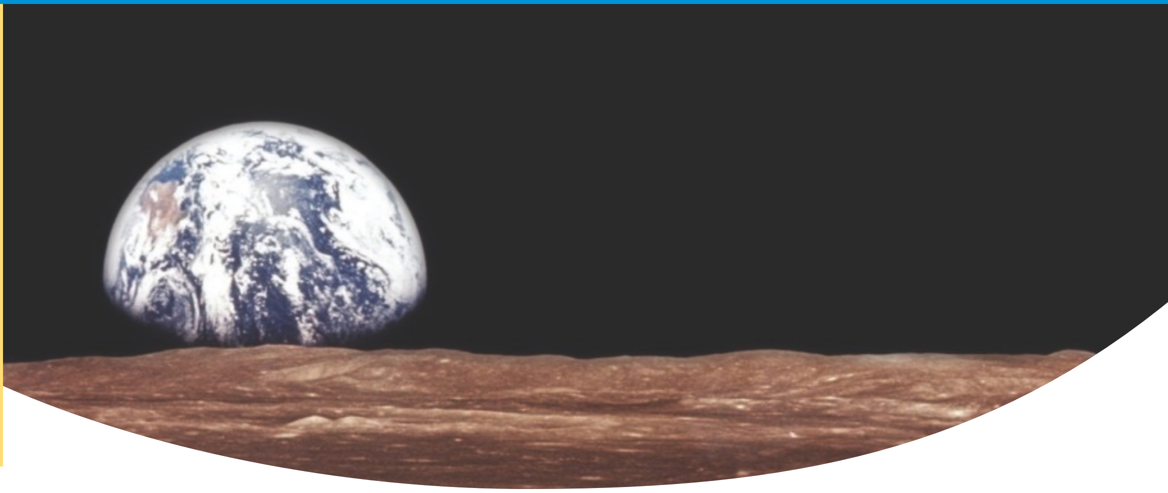
Mass media were quick to label the entire $150 million project a complete failure. But was it? In science, few experiments are total failures, because even flawed designs usually produce useful data. Biosphere 2 showed that its living and physical systems used more oxygen than they produced, and produced more carbon dioxide than they could absorb. In fact, Biosphere 2's "ocean" produced the first evidence that increased atmospheric carbon dioxide concentrations can cause ocean acidification. Today, the facility is run by the University of Arizona as one of the only places where certain types of large-scale experiments can be conducted.

What can we learn from Biosphere 2 about how Earth's much larger systems work? What are the natural subsystems that operate on a global scale? How can studying small parts of the biosphere help us understand the planet-sized picture?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

LESSON 3.1

Introduction to Global Systems



KEY QUESTIONS

- *Why is ecology important?*
- *What methods are used in ecological studies?*
- *What are biotic and abiotic factors?*
- *How can we model global systems?*

VOCABULARY

biosphere
ecology
species
population
community
ecosystem
biotic factor
abiotic factor
atmosphere
hydrosphere
geosphere

READING TOOL

As you read, use the lesson headings and subheadings to help you organize this lesson into the table in your **Biology Foundations Workbook.**

VIDEO

Watch this video to learn about various sampling techniques.

In the early days of space travel, astronauts made lots of scientific discoveries about the moon and space. That was expected. But they also made some unexpected emotional discoveries when they saw our planet suspended in lifeless space. "We came all this way," Astronaut William Anders wrote, "to study the moon, and the most important thing is that we discovered the Earth." Scott Carpenter added, "It's small. It's isolated, and there is no resupply." Wally Schirra summed it up: "I left Earth three times and found no other place to go. Please take care of Spaceship Earth." How might we care for Spaceship Earth? A good start would be to understand the global systems that shape our planet.

Ecology: Studying Our Living Planet

Astronauts were impressed with Earth's beauty, and with their understanding that our planet is covered with a thin skin of life that biologists call the biosphere. The biosphere includes all life on Earth, from bacteria underground, to trees in rain forests, fishes in the oceans, mold spores floating in the air … and humans. Because all forms of life are tightly connected with their surroundings, the **biosphere** includes all parts of Earth in which life exists.

The Science of Ecology All forms of life interact with each other and with their environments. ***Ecology is the scientific study of interactions among organisms, populations, and communities and their interactions with their environment.*** The root of the word *ecology* is the Greek word *oikos*, meaning "house." **Ecology** is the study of nature's "houses," organisms that live in those houses, and interactions based on energy and nutrients. *Oikos* is also the root of the word *economics*. Economics studies human "houses" and interactions based on money or trade, energy, and nutrients.

Why Study Ecology? Although economics studies human economy, and ecology studies the economy of nature, those two fields developed independently. For much of history, that wasn't a global problem. Human populations were small and scattered. Our environmental impacts were local. In many cases, human economies could function more or less independently from nature's economy … or so people thought.

Recently we've learned (sometimes the hard way) that economics and ecology are actually tightly linked. As human populations have grown, and as the power of our technology have increased, our impact on local and global environments has also grown. The world is changing around us. As you will learn later in this unit, much of that change is caused by human activity. In the midst of this change in both local and global environments, some economists are discovering what biologists have known for years: Human economies depend on healthy ecological systems for essential needs such as drinkable water and fertile soil.

We need to understand ecology so that we can design human economies that are sustainable—which means that they can function without constantly degrading the environment. We also need to learn to design our economies in ways that offer resilience, which means that they can adapt and continue to function as global ecology changes around us.

Levels of Ecological Organization Ecologists study organisms and their environments on several levels. These levels of organization are shown in **Figure 3-1**. Some ecologists study individual organisms. Others study communities, ecosystems, or the entire biosphere. Ecological studies on a global scale are vital to charting a sustainable course for humanity.

READING CHECK **Summarize** What is the difference between a population and a community?

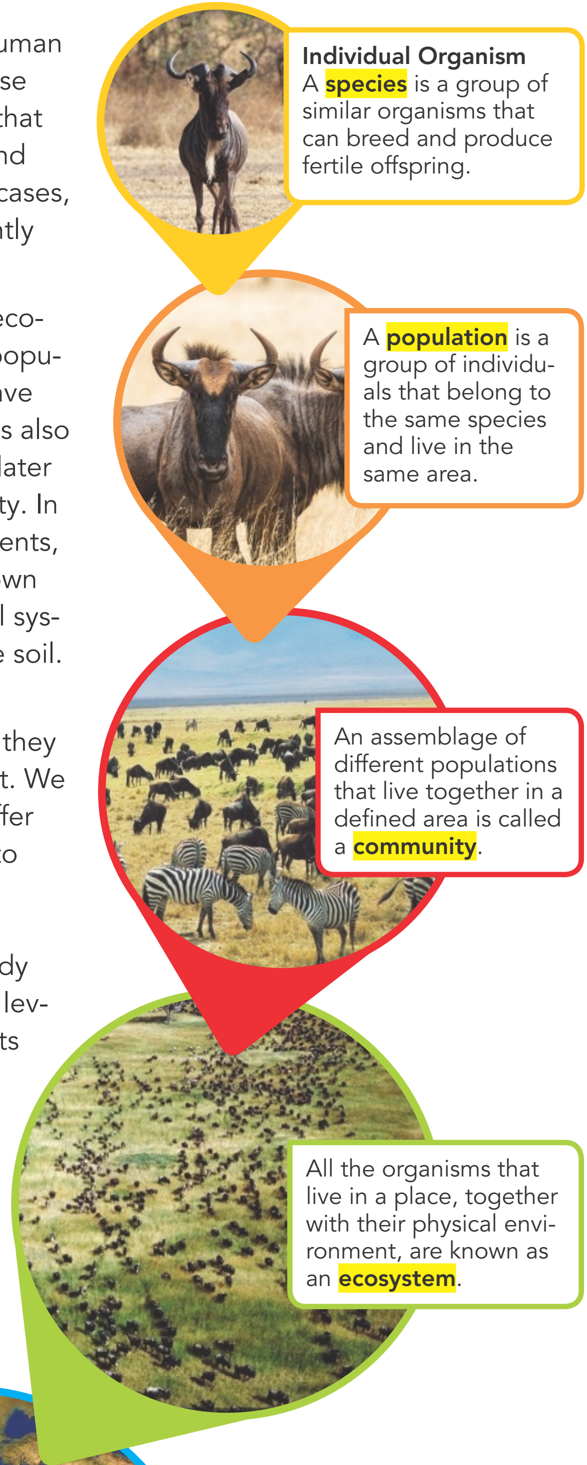
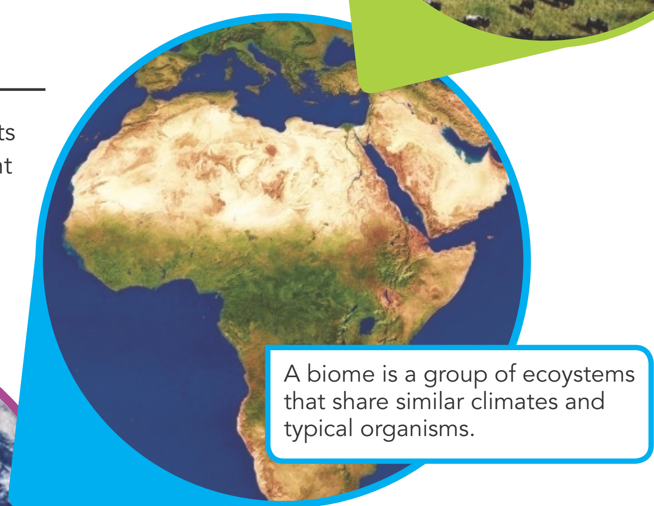


Figure 3-1

Levels of Organization

The kinds of questions that ecologists may ask about the living environment can vary, depending on the level at which the ecologist works.



CASE STUDY

Figure 3-2

Studying Environmental Conditions

Scientists gather ecological data in many ways. In this particular experiment, scientists are studying the effects of elevated levels of carbon dioxide on plant growth. Data collected in experiments such as this, can be used to model, make inferences, or apply to larger-scale experiments.

Gathering Ecological Data

Given the wide range of systems and levels of organization that ecologists study, it isn't surprising that their studies may use a wide range of approaches and tools. ***Ecologists generally rely on three main approaches, all of which are part of scientific methodology: observation, experimentation, and modeling. Many studies involve all three approaches, with ecologists using tools ranging from DNA analysis to data gathered from satellites.***

Observation Observation is often the first step in asking ecological questions. Some observations are simple, such as: Which species live here? How many individuals of each species are there in a community? Other observations are more complex: What happens if a particular species is removed from a community? How will organisms respond to climate changes? If these questions are asked properly, they can lead to the development of testable scientific hypotheses.

Experimentation Experiments are designed to test hypotheses by gathering data that support or reject those hypotheses. Some ecological experiments, such as the one shown in **Figure 3-2**, carefully monitor conditions in selected parts of natural environments. This can be difficult to do, because some variables, such as weather, cannot be controlled.

Alternatively, ecologists may design artificial environments, like Biosphere 2. Experiments in artificial environments show how plants, bacteria, animals, or artificial communities react to changes such as temperature, lighting, or carbon dioxide concentration.

Modeling Many ecological processes, such as climate change, occur over long periods of time or occur over areas as large as our entire planet. Ecologists often make models to help them understand these phenomena. Many ecological models consist of mathematical formulas based on data that have been collected through observation and experimentation. Useful models make predictions that lead to the development of additional hypotheses. Those hypotheses, in turn, may lead to the design of new experiments to test them. Additional data may also lead to changes in models that improve their ability to make useful predictions.

READING CHECK **Apply Concepts** When have you used the skills of observation, experimentation, or modeling? Describe an example of how you have used this skill.

Biotic and Abiotic Factors

When we talk about an organisms's environment, we are referring to all the conditions, or factors, around the organism that affect it in any way. Traditionally, these factors have been divided into biotic factors and abiotic factors.

Biotic Factors Living things affect one another, and are therefore parts of each others' environment. ***A biotic factor is any living part of the environment with which an organism might interact.*** **Biotic factors** important to the heron, for example, might include the fish it eats, predators that eat herons, and other species that compete with them for food or space.

Abiotic Factors Physical factors also affect organisms. ***An abiotic factor is any nonliving part of the environment, such as sunlight, heat, precipitation, humidity, wind or water currents, and soil type.*** For example, a heron could be affected by **abiotic factors** such as water availability and quality, temperature, and humidity.

Biotic and Abiotic Factors Together The difference between biotic and abiotic factors may seem clear. But many so-called abiotic factors are strongly influenced by organisms, which means that they aren't entirely abiotic. Bullfrogs, for example, often hang out in soft "muck" along the shores of ponds. You might think that muck is a strictly abiotic factor, because it contains nonliving particles of sand and mud. But typical pond muck also contains decomposing plant material from trees and other plants around the pond. Muck is also home to bacteria and fungi that decompose the remains of other organisms while using them as "food." That's a lot of "biotic" mixed in with "abiotic"!

READING TOOL

Use **Figure 3-3** to create a Venn diagram listing the biotic and abiotic factors in the pond ecosystem shown.

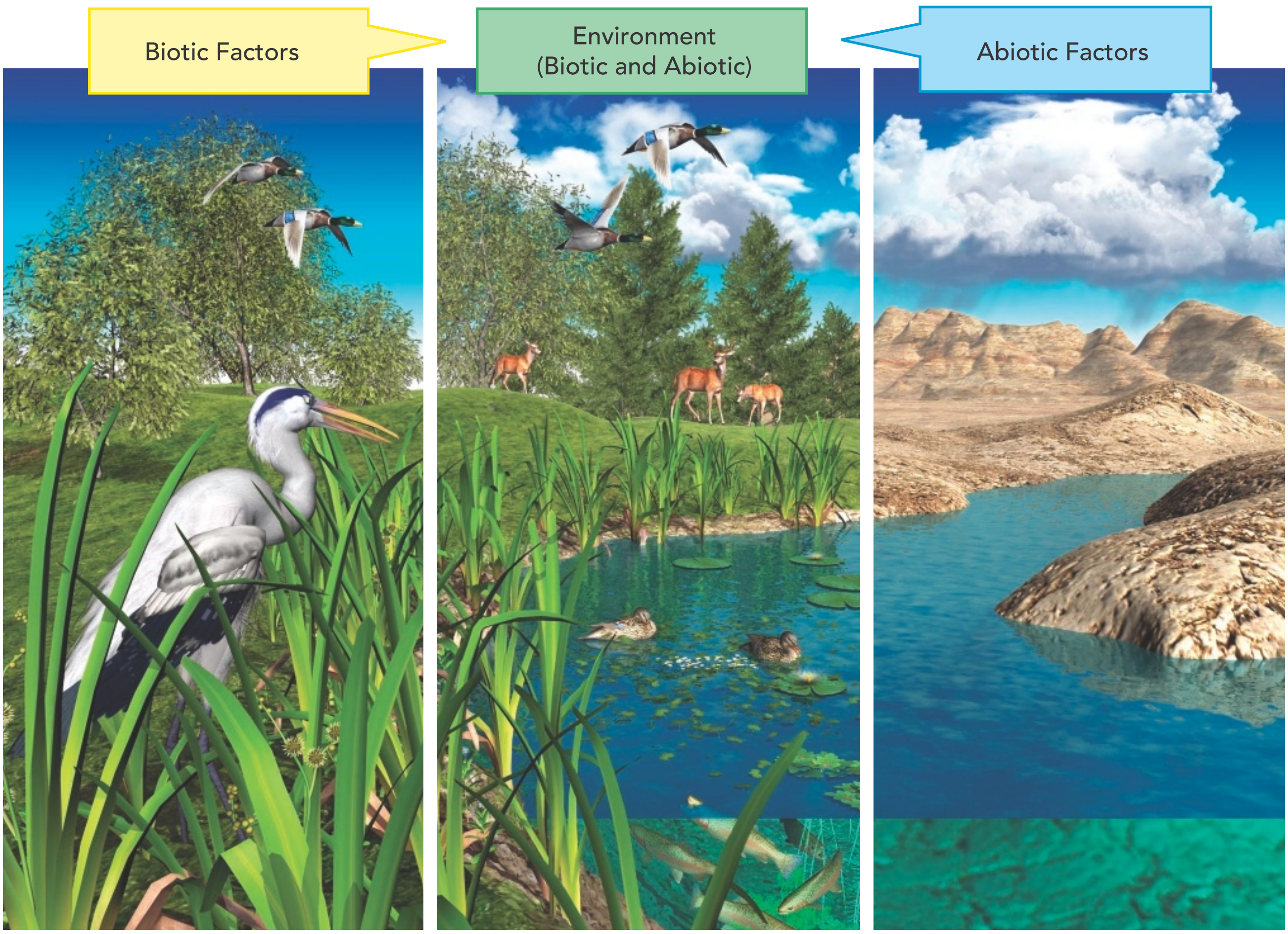
INTERACTIVITY

Measure how various abiotic factors affect organisms in a pond.

Figure 3-3

Biotic and Abiotic Factors

Like all ecosystems, this pond is affected by a combination of biotic and abiotic factors. Some environmental factors are a mix of biotic and abiotic components. Biotic and abiotic factors are dynamic, meaning that they constantly affect each other.



"Abiotic" conditions around a pond's mucky shore are also shaped by organisms. Trees and shrubs around the pond provide shade from strong sun, affecting the amount of sunlight and the range of temperatures the muck experiences. Those plants can also provide protection from dry winds, affecting the humidity of air above the muck. Plant roots determine how much soil washes into the pond during heavy rains. If pine trees grow nearby, decomposing needles make the soil acidic. Decomposing oak leaves, on the other hand, make soil more alkaline.

READING CHECK **Explain** Give two examples of how abiotic factors are influenced by biotic factors.

INTERACTIVITY

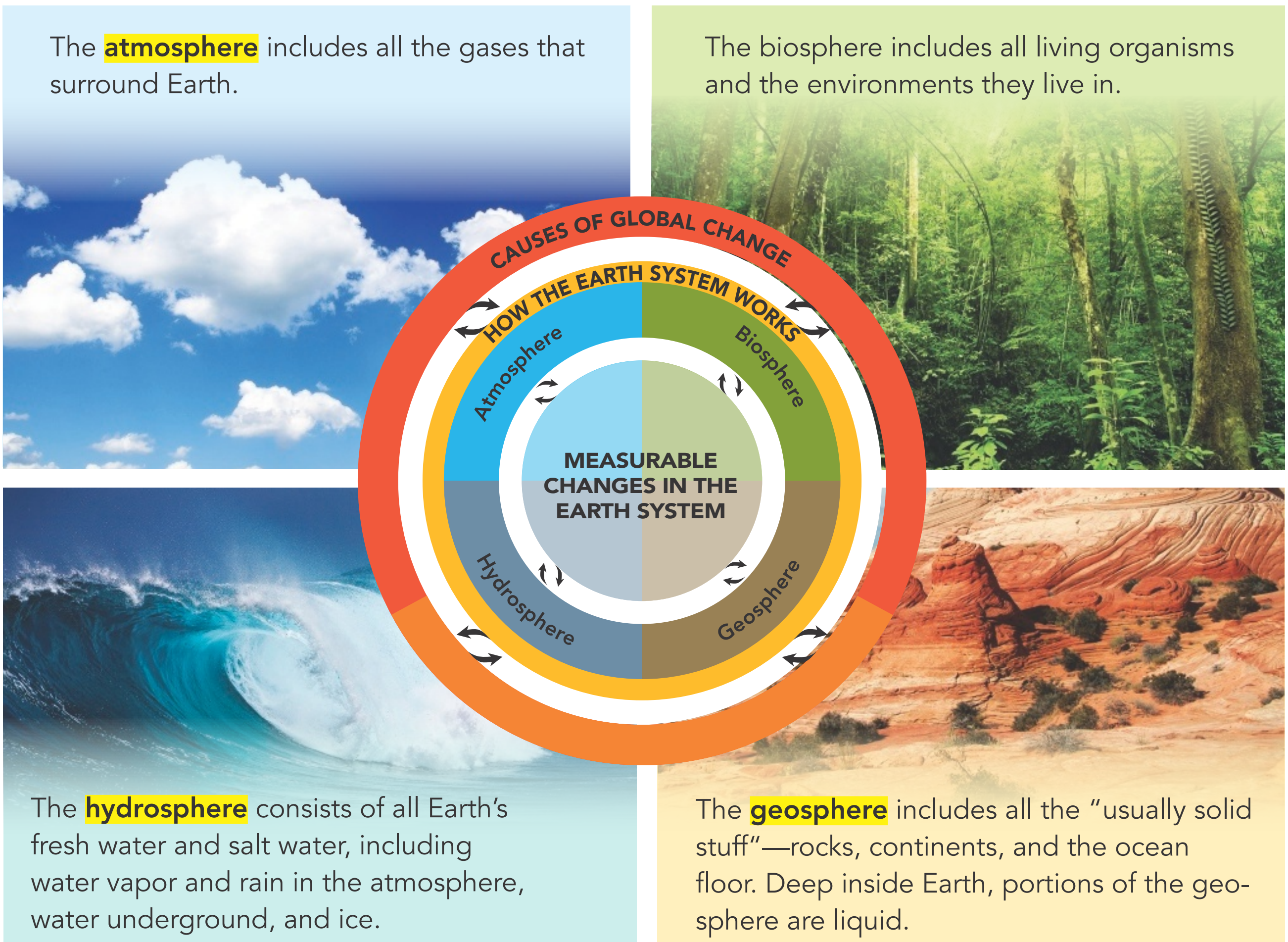
Figure 3-4

Model of Earth Systems

Earth's four global systems are constantly interacting. **Infer** What are some ways that the biosphere interacts with the other three systems?

Modeling Global Systems

A dynamic mix of biotic and abiotic factors shapes all ecosystems—from ponds to global systems. So understanding global ecology is tough! Yet that understanding is vital to humanity's future. How can we handle this challenge? ***One way to understand global systems is to develop a model that shows those systems, the processes that operate within in each system, and ways those systems and processes interact.*** One model, shown in **Figure 3-4** begins by identifying four major global spheres—the biosphere, the atmosphere, the hydrosphere, and the geosphere.



The **atmosphere** includes all the gases that surround Earth.

The biosphere includes all living organisms and the environments they live in.

The **hydrosphere** consists of all Earth's fresh water and salt water, including water vapor and rain in the atmosphere, water underground, and ice.

The **geosphere** includes all the "usually solid stuff"—rocks, continents, and the ocean floor. Deep inside Earth, portions of the geo-sphere are liquid.

Global Systems and Change Our model has three main parts, each of which represents a category of ecological concepts and processes. You will see this model referred to throughout this unit.

The model's outer ring, labeled "Causes of Global Change," represents a combination of human activities and nonhuman events and processes that can drive changes in Earth's global systems. In this chapter, we will discuss several nonhuman causes of global change. Human causes of global change will be discussed in Chapter 7.

The model's middle ring, labeled "How the Earth System Works," represents events, processes, and cycles within the biosphere, atmosphere, geosphere, and hydrosphere. This part of the model includes some phenomena we discuss in this chapter, including the global climate system. It also includes cycles of matter, energy flow, and interactions among organisms that we will discuss in later chapters.

The model's inner circle, "Measurable Changes in the Earth System," contains the kinds of changes in global systems that scientists can measure. These include changes in climate, sea level, air and water quality, and so on. We emphasize "measurable changes" to emphasize that these represent data, not hypotheses.

This model, like most models, can't describe everything as accurately as we might like. For example, the hydrosphere includes water that is physically located in the atmosphere and the geosphere. The biosphere as we defined it earlier includes parts of the atmosphere, hydrosphere, and geosphere. Still, as we develop this model, you will see that it provides a useful framework for organizing information, demonstrating cause and effect, arguing from evidence, and examining connections among ecological events and processes. The model includes changes in global systems that scientists can measure, and the effects those changes have on ecological systems, including human society.

BUILD VOCABULARY

Multiple Meanings In geometry, a *sphere* is the shape of a round ball. In terms such as *biosphere* and *atmosphere*, it is a region or area.

INTERACTIVITY

Explore a tundra to learn about the levels of organization, Earth systems, and abiotic and biotic factors that make up this biome.

In Your Neighborhood Lab Open-Ended Inquiry

Abiotic Factors and Plant Selection

Problem What plants will grow well in a garden near you?

For plants to grow, they need the right combination of biotic and abiotic factors. In this lab, you will collect data about abiotic factors in your region. Then, you will plan a garden by selecting the plants that can grow successfully in your area.

You can find this lab online in your digital course.

Visual Analogy

Figure 3-5

The Earth Systems Model as a Jigsaw Puzzle

The earth systems model is similar to a jigsaw puzzle. Each piece of the puzzle represents a different process within the biosphere. As you work through this unit, you will see references to the model and the icons that represent the processes.

Building and Using The Model Where do we go from here in building the model, and how will it be useful? To answer those questions, let's start by saying that you will be learning about a lot of events, processes, and interactions in this unit. If that was all you learned, you would be left with a long list of facts to memorize, without a clear way to understand how those individual pieces of information relate to the way the world works. You would have no way to relate those facts to one another.

In a sense, you would have what you could think of as lots of separate pieces of a very complicated jigsaw puzzle …without a clear idea of how those pieces fit together to form a picture of global systems. It would also be difficult for you to relate individual events and processes to important crosscutting concepts in biology.

That's where the Understanding Global Change model comes in. The model serves as a kind of "information organizer." Whenever we discuss important ecological events and processes, each of them will be assigned a visual icon, like those shown in **Figure 3-5**. Some icons represent processes in Earth's systems. Other icons represent causes of global change. Still other icons represent measurable effects of change. As we learn about these events and processes, we will add their icons to the model in much the same way that you would assemble a puzzle.

As we build the model across the unit, it will help you create concept maps that show how, for example, different aspects of weather and climate influence organisms, and how various causes of global change can affect climate. As you build the model, you can use it to explore connections among causes and effects in global change.

LESSON 3.1 Review

KEY QUESTIONS

1. What is the definition of *ecology*?
2. Describe the three basic methods of ecological research.
3. How are biotic and abiotic factors related? What is the difference between them?
4. Describe an approach for understanding global systems and the changes they undergo.

CRITICAL THINKING

5. **CASE STUDY** Which approach to ecological investigations is illustrated by Biosphere 2? Defend your classification.
6. **Systems and System Models** In creating a model of our living planet, scientists need to consider four major Earth systems. Briefly describe these four systems, and then explain why it is difficult to study these systems individually.

Climate, Weather, and Life

LESSON 3.2

KEY QUESTIONS

- *What is the difference between weather and climate?*
- *How are Earth's climate and average temperature determined?*
- *What causes ocean currents?*
- *What factors shape regional climate?*
- *What does climate change involve?*

HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

VOCABULARY
climate
weather
greenhouse effect

READING TOOL

As you read, identify the cause and effect relationships that the text describes. Fill in the table in your **Biology Foundations Workbook.**

People always talk about the weather. Storms like Hurricane Katrina or superstorm Sandy can cause widespread damage and loss of life. A summer may be uncomfortably hot, or a winter bitterly cold. Weather and climate are two terms we use to describe variations and averages in environmental factors that affect our lives.

Climate and Weather

Weather and climate are important parts of local and national conversations these days, so it is worth looking at them closely. ***Climate is defined by patterns and averages of temperature, precipitation, clouds, and wind over many years.*** **Climate** also includes the frequency of extreme weather events such as heat waves, droughts, and floods, as shown in **Figure 3-6**. ***Weather consists of short-term changes in temperature, precipitation, clouds, and wind from day to day, or minute to minute.*** **Weather** can change rapidly, and can be tough to predict. It may be sunny in the morning but rainy in the afternoon. Climate is usually more predictable, so you wouldn't be surprised if you heard that it is hot today in Miami, Florida, but cool in Seattle, Washington.

Either short-term weather changes (such as droughts) or long-term climate changes (such as the frequency of droughts) can make the difference between success and failure of crops. Weather and climate also shape natural populations, communities, and ecosystems.

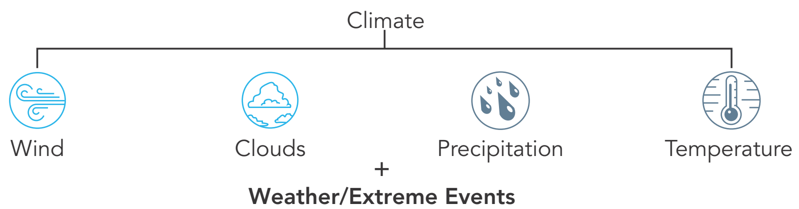


Figure 3-6
Climate

Climate includes long-term averages of wind, clouds, precipitation, temperature, and extreme weather events such as droughts, floods, and heat waves.

INTERACTIVITY

Learn how the greenhouse effect relates to the concept of solar energy.

ANIMATION

hhmi | BioInteractive

The Global Climate System

Climate and weather are produced by a global climate system composed of winds and ocean currents. ***The global climate system is powered and shaped by the total amount of solar energy retained in the biosphere as heat, and by the unequal distribution of that heat between the equator and the poles.***

Solar Energy and the Greenhouse Effect

The main force that shapes climate is solar energy that arrives as sunlight striking Earth's surface. Some of that energy is reflected into space, and some is absorbed and converted into heat. Some heat, in turn, is re-radiated into space, and some is trapped within the atmosphere. ***Earth's average temperature is determined by the balance between the amount of heat that stays in the atmosphere and the amount of heat that is lost to space.***

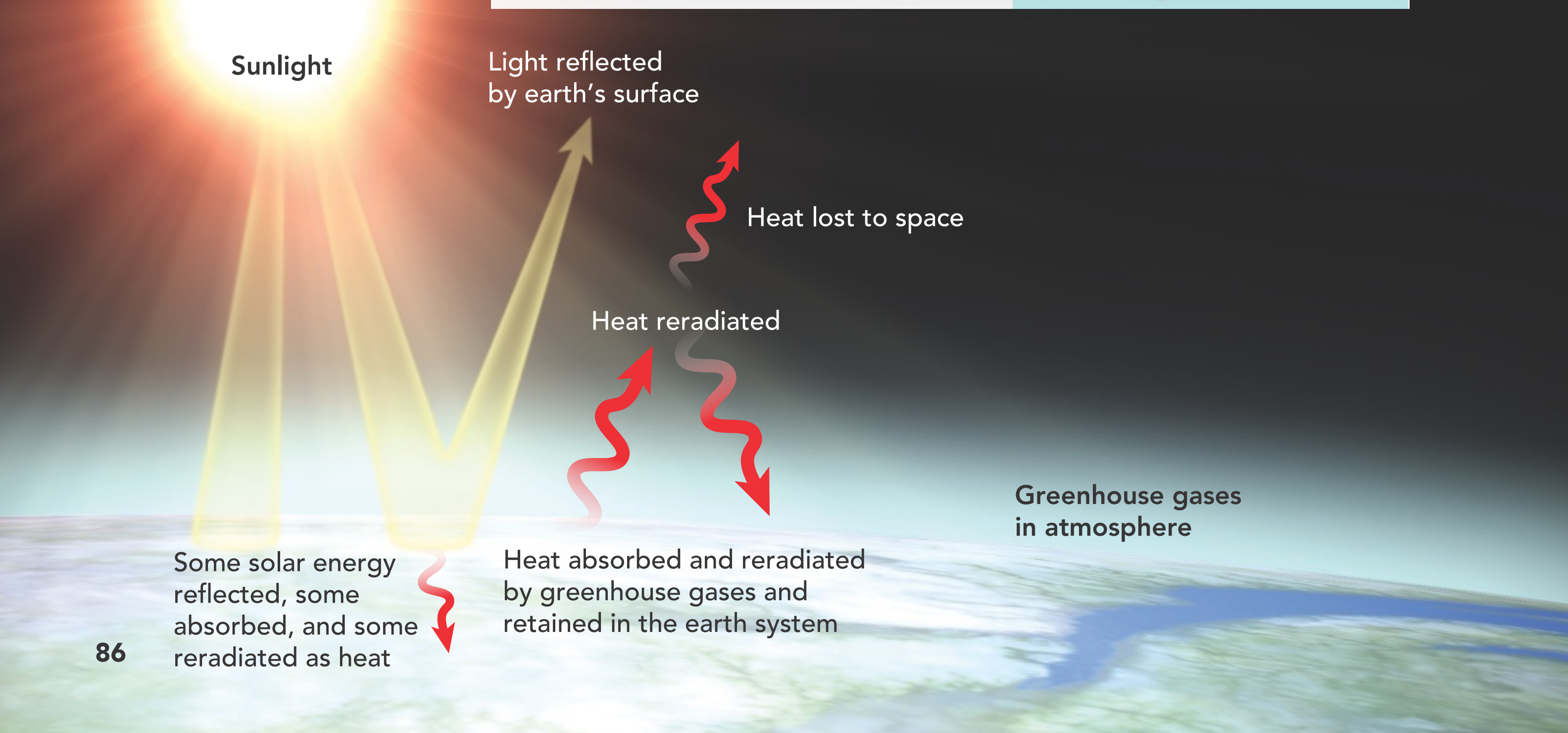
This balance is largely controlled by the concentrations of three gases in the atmosphere—carbon dioxide, methane, and water vapor. These gases, called greenhouse gases, act like glass in a greenhouse. The gases allow visible light to enter but trap heat, as shown in **Figure 3-7**. This phenomenon is called the **greenhouse effect**. Without the greenhouse effect, Earth would be about 30 degrees Celsius cooler than it is today. Note that these three gases enter and leave the atmosphere as part of global cycles of matter. Their concentration in the atmosphere can therefore be affected by changes in those cycles driven by both nonhuman causes and by human activities. If changes in these cycles increase the greenhouse gas concentrations, the atmosphere retains more heat, and Earth warms. If changes decrease greenhouse gas concentrations, more heat escapes, and Earth cools.

Visual Analogy

Figure 3-7

The Greenhouse Effect

Greenhouse gases in the atmosphere allow solar radiation to enter the biosphere but slow down the loss of reradiated heat to space.



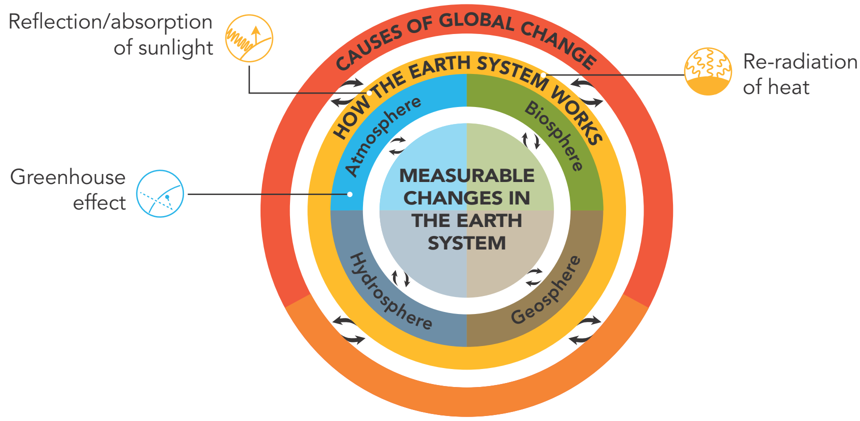


Figure 3-8

Global Change And The Greenhouse Effect

The amount of sunlight that is reflected or absorbed, the amount of heat that is re-radiated in the Earth system, and the intensity of the greenhouse effect influences Earth's energy balance.

Latitude and Solar Energy Because Earth is curved and tilted on its axis, solar radiation strikes the surface at angles that vary from place to place and at different times of the year. Earth's curvature causes the same amount of solar energy to spread out over a larger area near the poles than near the equator, as **Figure 3-9** shows. Near the equator, the sun is directly overhead at noon, and day length varies little over the year. North and south of the equator, the sun drops lower in the sky during winter as tilted Earth revolves in orbit, and days become shorter. For both these reasons, more solar energy per unit area, and therefore more heat, arrives each year near the equator than near the poles.

The difference in heat received at the poles compared to the equator creates three main climate zones: tropical, temperate, and polar. The tropical zone is located between 23.5° north and 23.5° south latitudes near the equator. Here temperatures near sea level are warm or hot all year. Two temperate zones are located between 23.5° and 66.5° north and south latitudes. Here, summers may be quite hot, and winters can be very cold. The polar zones lie beyond the temperate zones, between 66.5° and 90° north and south latitudes. Here, winters are bitterly cold, and summers barely get warm.

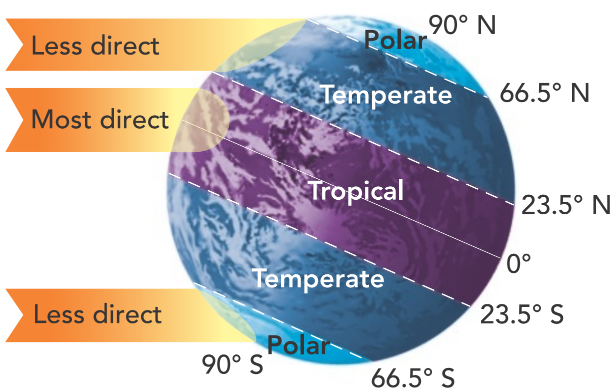


Figure 3-9

Climate Zones

Earth's climate zones are produced by unequal distribution of the solar energy across Earths' surface. The tilt of Earth's axis causes this distribution to change over the course of a year, resulting in seasons.

HS-ESS2-4

Quick Lab **Guided Inquiry**

Why Do Different Earth Surfaces Have Different Temperatures?

1. Review the procedure. Prepare a data table to record the temperature measurements.
2. Half fill each of three cups: one cup with gravel, a second cup with soil, and a third cup with water.
3. Place a thermometer inside each cup. Record the temperatures.
4. Place each cup under the heat lamp. Wait 30 minutes and then record the temperatures again.

ANALYZE AND CONCLUDE

1. **Use Models** How do the materials you used in the model represent Earth's surface?
2. **Draw Conclusions** Use the data in your data table as evidence to draw a conclusion about the way Earth's surface is heated by sunlight.
3. **Form a Hypothesis** What if you turned off the heat lamp, and then measured the temperatures of the three cups over time? Form a hypothesis, and then test it with your teacher's approval.

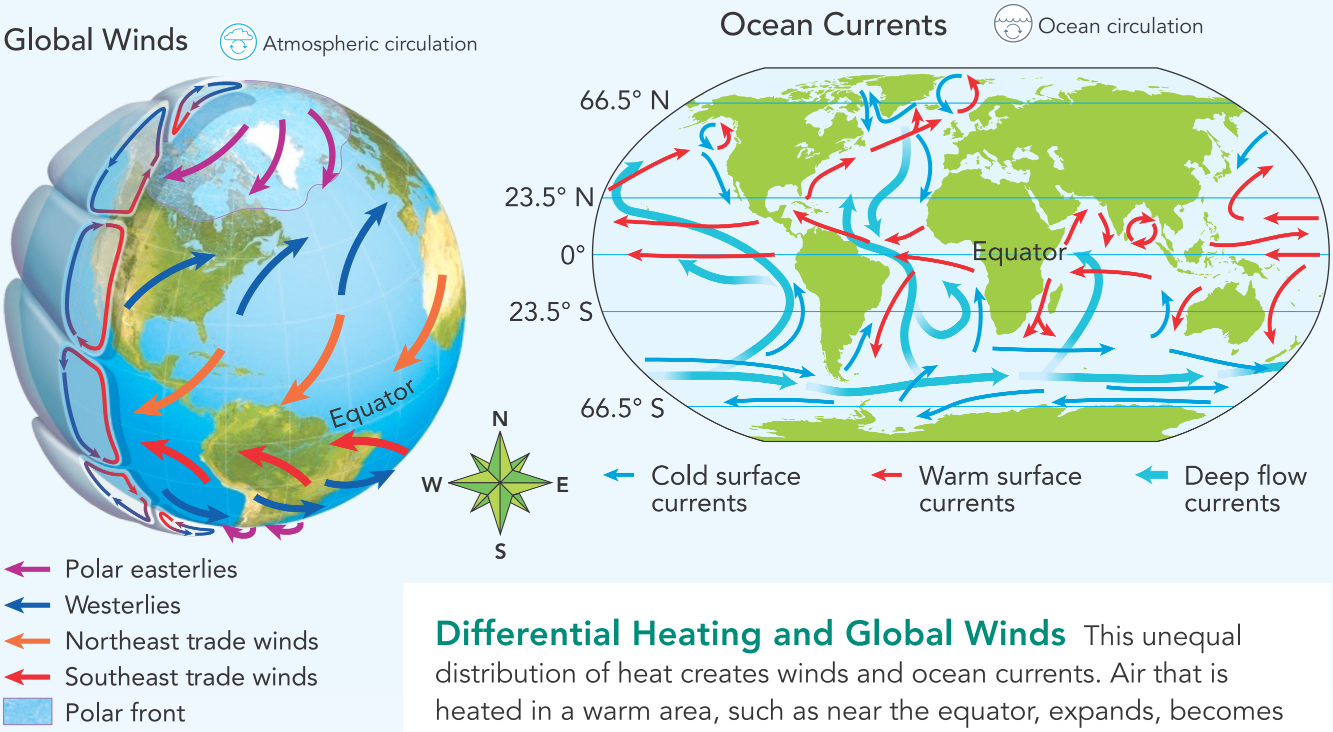


Figure 3-10

Global Winds and Ocean Currents

Earth's winds (left) and ocean currents (right) interact to help produce climate patterns. The paths of winds and currents are the result of heating and cooling, Earth's rotation, and geographic features.

Differential Heating and Global Winds This unequal distribution of heat creates winds and ocean currents. Air that is heated in a warm area, such as near the equator, expands, becomes less dense, and rises. As the air rises, it spreads north and south, losing heat along the way. As that air cools, it becomes more dense and sinks. Meanwhile, cold air over the poles also sinks. This pattern of rising and sinking air creates circulating cells of air that rise, travel north or south, sink towards Earth's surface, warm, and then rise again. As that air travels from places where it sinks to places where it rises, it creates winds, as shown in **Figure 3-10**. Earth's rotation causes winds to blow from west to east over both land and sea in the temperate zones, and from east to west over the tropics and the poles.

READING CHECK Synthesize Information How does wind form?

Ocean Currents

An oceanographer might say that ocean currents would flow around the world in much the way global winds do … but continents get in their way! ***Ocean currents are driven and shaped by patterns of warming and cooling, by winds, and by the locations of continents.***

Winds and Surface Currents Prevailing winds blowing over the ocean create surface currents that profoundly affect weather and climate in coastal areas. The warm Gulf Stream, for example, travels north along the east coast of North America, carrying heat from the Caribbean and Gulf of Mexico. Air passing over the Gulf Stream picks up moisture and heat, moderating winter temperatures in coastal areas. Along the West coast, the cool California Current carries cold water southwards, cooling the Pacific Northwest and the California coast. These interactions between atmosphere and hydrosphere shape weather and climate in coastal areas around the world. These interactions also influence water temperature and salinity that affect marine organisms and communities.

Deep Ocean Currents Cold ocean water near the poles sinks and flows along the ocean floor. This bottom water rises to the surface in some places, through a process called upwelling. Upwelling usually occurs where prevailing winds push surface water away from a continent. Cold water from the bottom rises to take the place of that surface water. One of the best-known upwellings in the Western Hemisphere occurs in the eastern Pacific Ocean off the coast of Peru. Increases and decreases in the strength of this upwelling are part of a phenomenon called El Niño. El Niño affects weather patterns from the southwestern United States all the way across the Pacific to Australia and Indonesia.

READING TOOL

Identify the effects of winds, ocean currents, and mountains on climate. Take notes in your notebook.

VIDEO

Learn about El Niño and its effects on weather and climate.

Regional Climate

Washington State and Montana are located at similar latitudes, and are affected by the same prevailing winds that blow from west to east. Yet Montana has a very different climate than coastal Washington. Why? Because of mountains. ***Regional climates are shaped by latitude, by the transport of heat and moisture by winds and ocean currents, and by geographic features such as mountain ranges, large bodies of water, and ocean currents.***

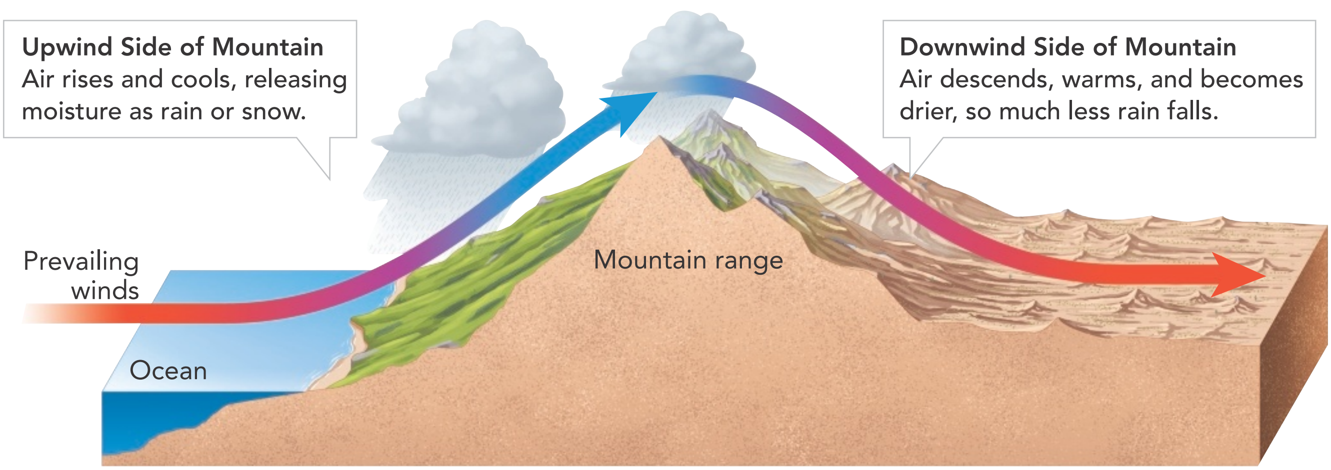
The states of Oregon and Washington border the northern Pacific Ocean, where cold surface currents cool and humidify the prevailing winds that blow over them from west to east. That moist air hits the Cascade Mountains, is pushed upwards, and cools, causing moisture to condense and form clouds. Those clouds drop rain or snow, mainly on the western side of the mountains that faces the winds, as seen in **Figure 3-11**. For that reason, coastal climate in these states is cool and wet, and it supports a temperate rain forest. East of the Cascades, that same air sinks to lower altitudes, warms, and dries out. As a result, eastern Washington and Montana are drier and much warmer in summer, and can get much colder in winter.

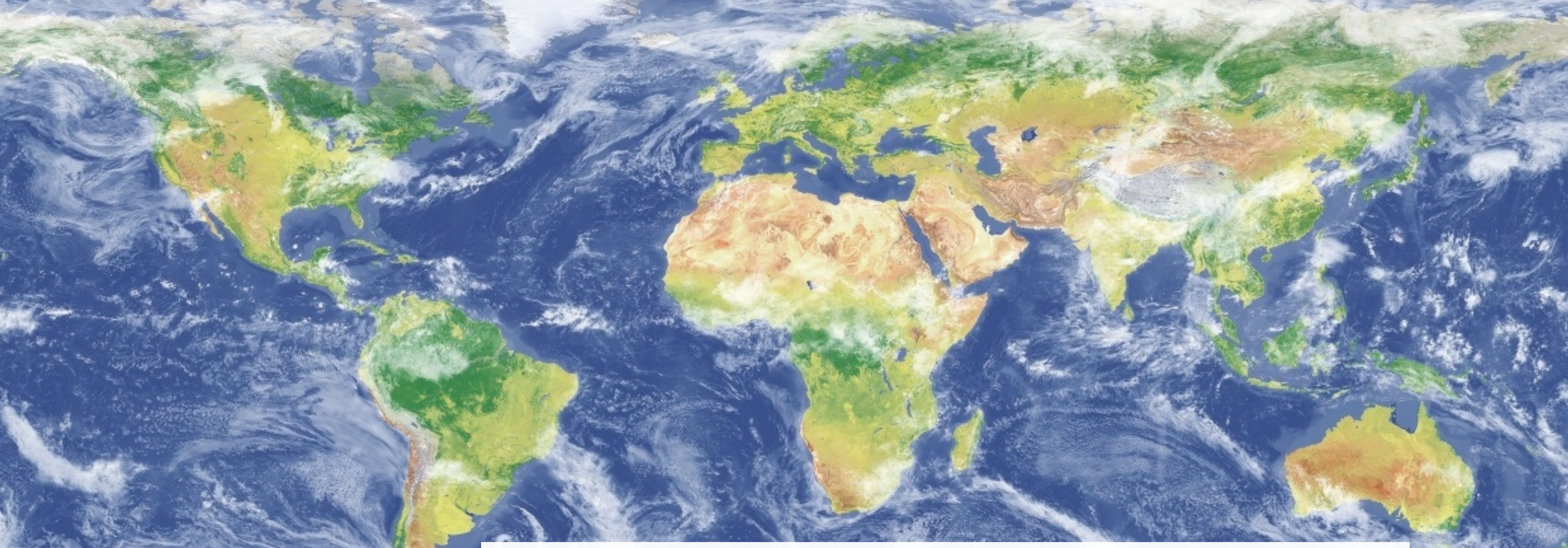
READING CHECK **Cause and Effect** What causes more rain to fall on one side of a mountain than the other side?

Figure 3-11

The Effect of Coastal Mountains

As moist ocean air rises over the upwind side of coastal mountains, it condenses, cools, and drops precipitation. With depleted moisture, the sinking air warms and becomes drier.





Changes in Climate

Earth's climate has remained pretty stable during recorded human history. The patterns of clouds, deserts, and vegetative areas as shown in **Figure 3-12** could be taken from any typical day over the last several thousand years. But global climate has changed dramatically over the far longer history of life. Earth's average temperature has increased and decreased over periods ranging from tens of thousands to millions of years. Those changes in temperature affected both the structure and the function of the global climate system. Recall that climate involves a lot more than just temperature. It also includes winds, precipitation, clouds, and extreme weather events. Climate change, therefore, involves more than global warming or cooling. ***Climate change involves changes in temperature, clouds, winds, patterns and amounts of precipitation, and the frequency and severity of extreme weather events.*** **Figure 3-13** shows climate change in the "Measurable changes" portion of our global change model.

Figure 3-12

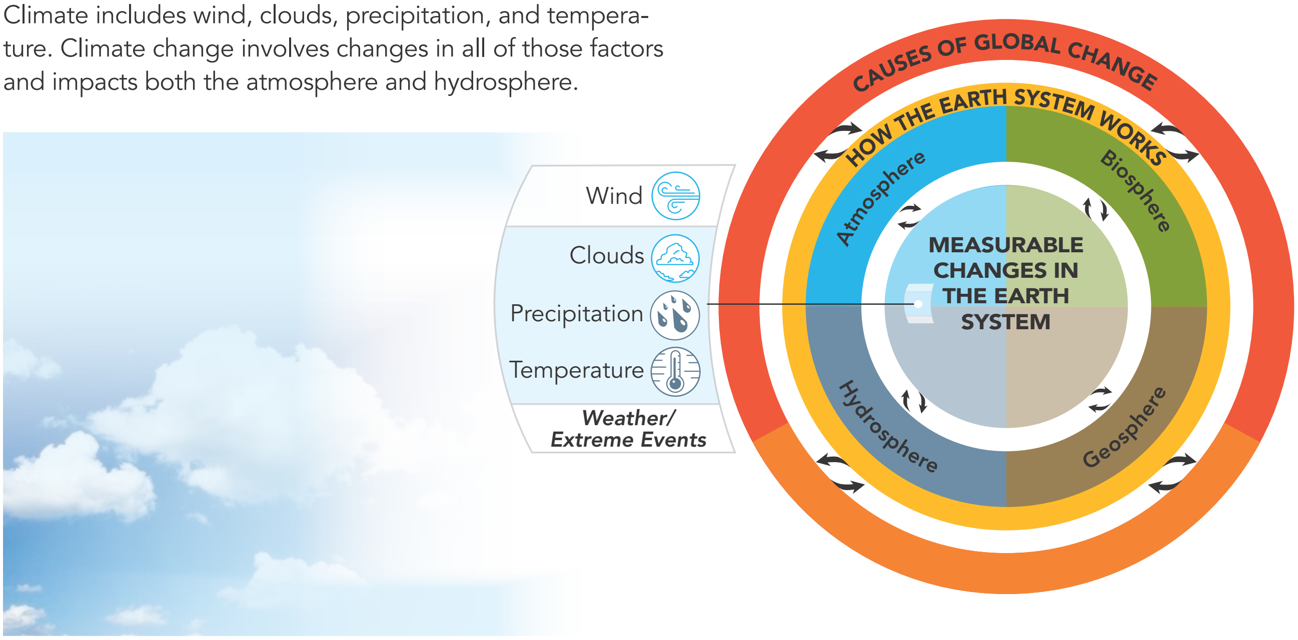
Global Climate

In this computer-generated map of Earth, the white regions show a typical example of cloud cover. **Predict** How could changes to the global winds and ocean currents affect climate on land?

Figure 3-13

Climate Change

Climate includes wind, clouds, precipitation, and temperature. Climate change involves changes in all of those factors and impacts both the atmosphere and hydrosphere.



Nonhuman Causes of Climate Change

Several factors have caused long-term changes in regional and global climate. As shown in **Figure 3-14**, these factors include: changes in solar energy, variations in Earth's orbit, meteorite impacts, changes in the distributions of continents and oceans, mountain building, volcanic activity, and meteorite impact.

The sun's output of solar energy varies over time. Changes in Earth's orbit and the tilt of its axis vary, in cycles of about 100,000 years. Once in a while, a giant meteorite hits Earth—like the one that led to the extinction of dinosaurs around 65 million years ago. The positions of Earth's continents change over millions of years, in ways that affect patterns of both winds and ocean currents. Episodes of mountain building can cause dramatic changes in regional climate, by affecting temperatures and patterns of precipitation. Major changes in the amount of volcanic activity worldwide can cause changes in the concentrations of greenhouse gases in the atmosphere.

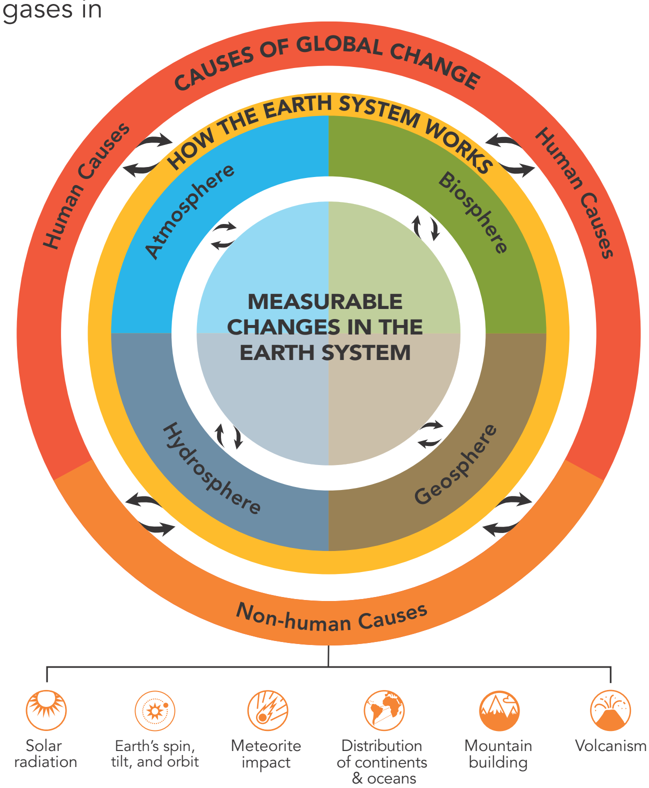
Results of Past Changes in Global Climate

These factors have caused both warm and cold periods over long periods of time. The most recent cold cycle caused the last major glacial period, which ended about 10,000 years ago. The global climate system creates regional climates that govern which plants, animals, and other organisms can survive in different places. Some changes in global climate have occurred slowly enough that most life on Earth could adapt and survive. But five times in Earth's history, climate change happened too fast for many organisms to survive, and vast numbers of species of all kinds died off. Those episodes are known as mass extinctions. In the Evolution unit, we will discuss mass extinctions driven by these nonhuman causes of global change. And in the last chapter of this unit, we will discuss whether human causes of global change are driving another mass extinction right now.

Figure 3-14

Nonhuman Causes of Climate Change

Geological and astronomical systems, processes, and events have caused major changes to global systems over the history of life on Earth. However, most of these nonhuman causes of global change act over extremely long time scales, ranging from thousands to millions of years.



HS-LS2-2, HS-ESS2-4

LESSON 3.2 Review

KEY QUESTIONS

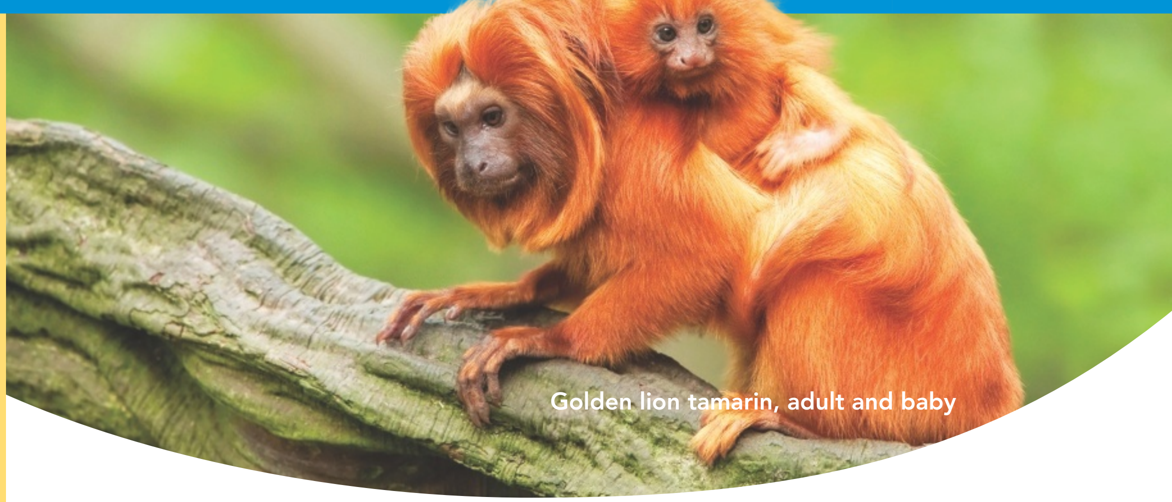
1. Explain how *weather* and *climate* differ.
2. How does solar energy and the greenhouse effect impact Earth's global climate system?
3. Describe the factors that affect ocean currents.
4. What are the factors that result in different climates in different parts of the world?
5. Describe the different causes of climate change.

CRITICAL THINKING

6. **Apply Scientific Reasoning** How might the speed of climate change affect the ability of life on Earth to adapt and survive?
7. **CASE STUDY** For Biosphere 2 to meet its goal, why was it necessary for it to replicate a variety of climates?

LESSON 3.3

Biomes and Aquatic Ecosystems



Golden lion tamarin, adult and baby

KEY QUESTIONS

- *What abiotic and biotic factors characterize a biome?*
- *What factors shape aquatic ecosystems?*
- *What are the major categories of freshwater ecosystems?*
- *Why are estuaries so important?*

HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

VOCABULARY

biome
canopy
understory
humus
taiga
permafrost
photic zone
aphotic zone
plankton
wetland
estuary

READING TOOL

As you read, note the similarities and differences between the different land biomes and aquatic ecosystems. Take notes in your **Biology Foundations Workbook.**

VIDEO

Watch this video to learn about the tundra biome and its inhabitants.

The factors that create regional climates establish conditions that govern which plants, animals, and other organisms can survive in particular geographic areas. These areas are described in this lesson.

Life on Land: Natural Biomes

Ecologists typically classify the homes of organisms into roughly ten different regional climate communities called **biomes**. ***Biomes are described in terms of abiotic factors such as climate and soil type, and biotic factors such as plant and animal life.*** Each biome is associated with seasonal patterns of temperature and precipitation that can be summarized in a graph called a climate diagram, like the one in **Figure 3-15**. The distribution of major biomes is shown in **Figure 3-16**. Note that even within a defined biome, there is often considerable variation among plant and animal communities. These variations can be caused by differences in exposure, elevation, or local soil conditions. Local conditions also can change over time.

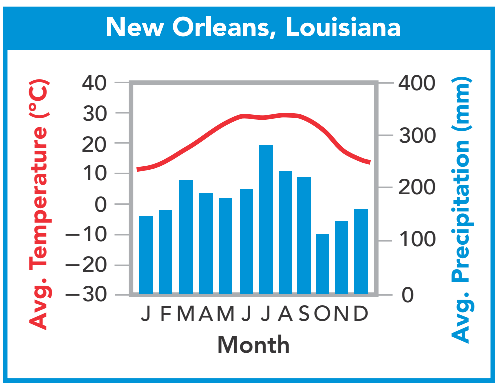


Figure 3-15

Climate Diagram

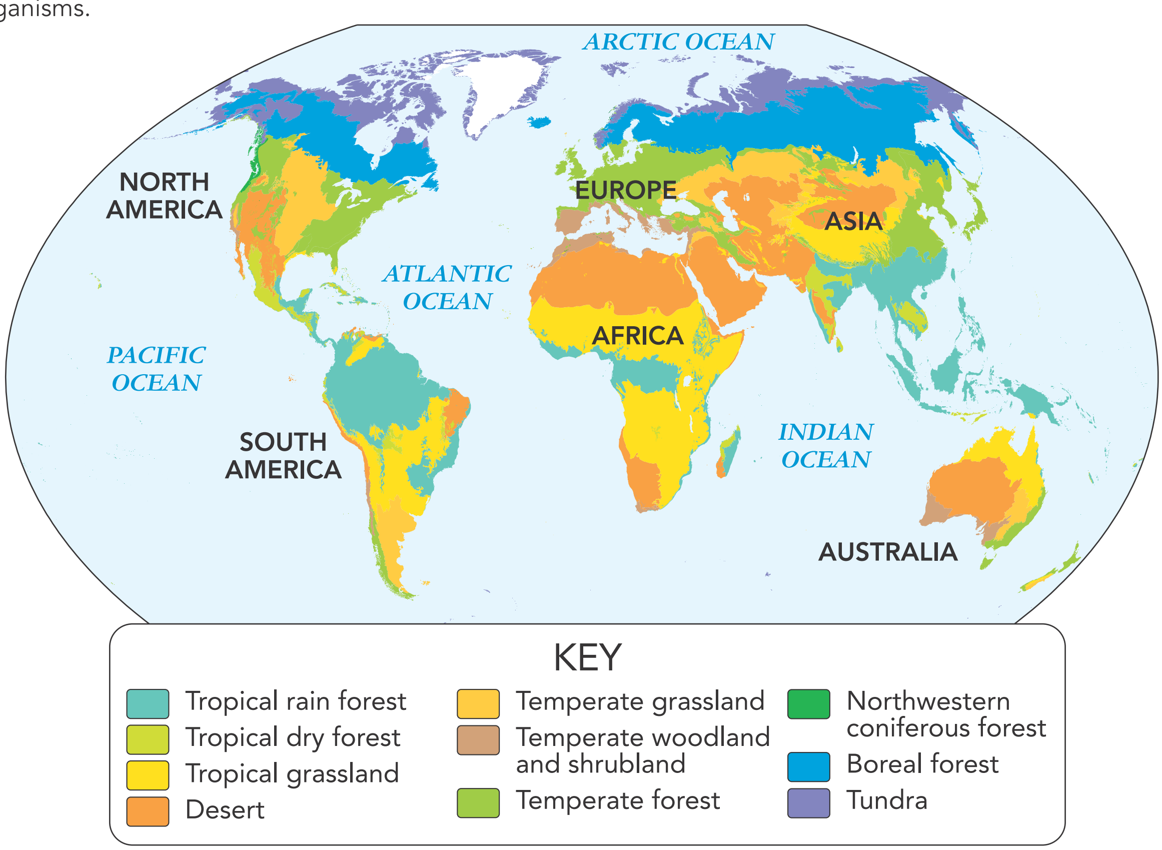
A climate diagram shows the average temperature and precipitation of a given location during each month of the year. In this graph, and those to follow, temperature is plotted as a red line, and precipitation is shown as vertical blue bars.

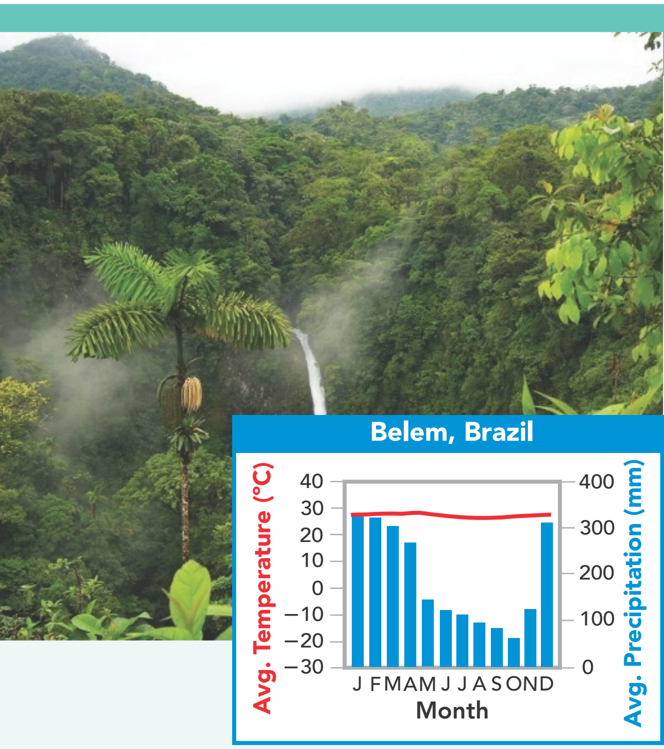
Visual Summary

Figure 3-16

Biomes

This map shows the locations of the world's major biomes. Each biome has a characteristic climate and community of organisms.





TROPICAL RAIN FOREST

Tropical rain forests have more species than all of the other biomes combined. Tropical rain forests typically get at least 2 meters of rain annually. Tall trees form a dense, leafy covering called a **canopy** from 50 to 80 meters above the forest floor. In the shade below, shorter trees and vines form a layer called the **understory**. Organic matter on the forest floor is recycled and reused so quickly that the soil in most tropical rain forests is not very rich in nutrients.

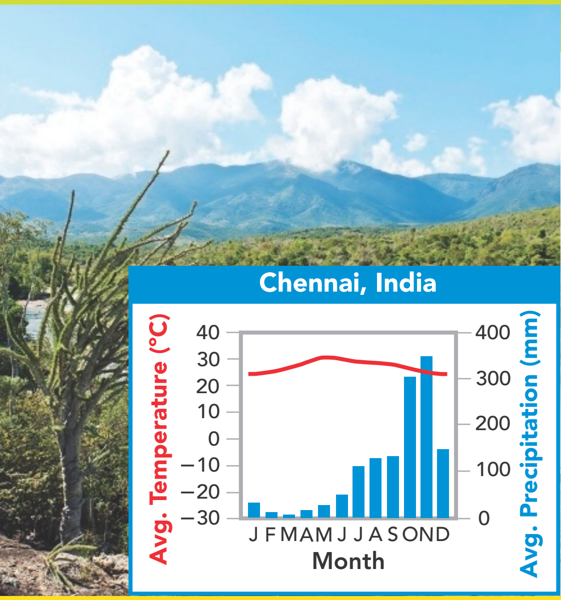
Abiotic factors: warm and wet year-round; thin, nutrient-poor soils subject to erosion

Biotic factors

Plant life: Understory plants compete for sunlight, so many have large leaves to capture light. Tall trees growing in shallow soil often have buttress roots, which act like props for support. Epiphytic plants grow on the branches of tall plants, taking advantage of available sunlight.

Animal life: Animals are active all year. Many use camouflage to hide from predators; some can change color to match their surroundings. Animals in the canopy have adaptations for climbing, jumping, and flight.

TROPICAL DRY FOREST



Tropical dry forests grow where rainy seasons alternate with dry seasons. In most places, a period of rain is followed by a prolonged period of drought.

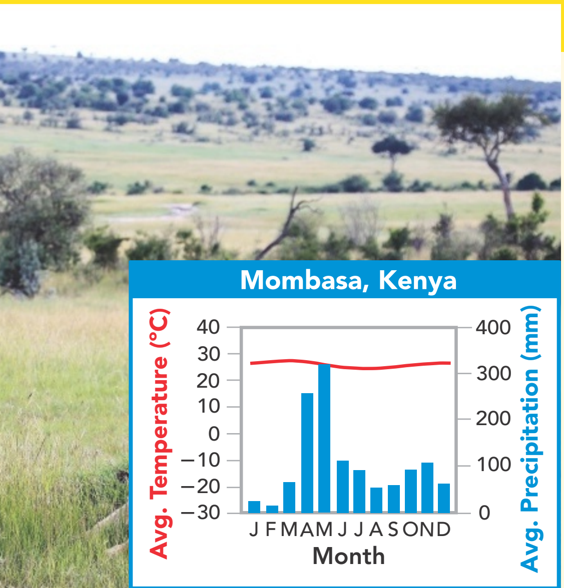
Abiotic factors: warm year-round; alternating wet and dry seasons; rich soils subject to erosion

Biotic factors

Plant life: Many plants here lose their leaves during the dry season. Some leaves have an extra thick waxy layer to reduce water loss. Others store water in their tissues.

Animal life: Many animals reduce their need for water by entering long periods of inactivity similar to hibernation, but typically taking place during a dry season. Other animals, including many birds and primates, move to areas where water is available during the dry season.

TROPICAL GRASSLAND/SAVANNA/SHRUBLAND



This biome receives more seasonal rainfall than deserts but less than tropical dry forests. Grassy areas are spotted with isolated trees and small groves of trees and shrubs.

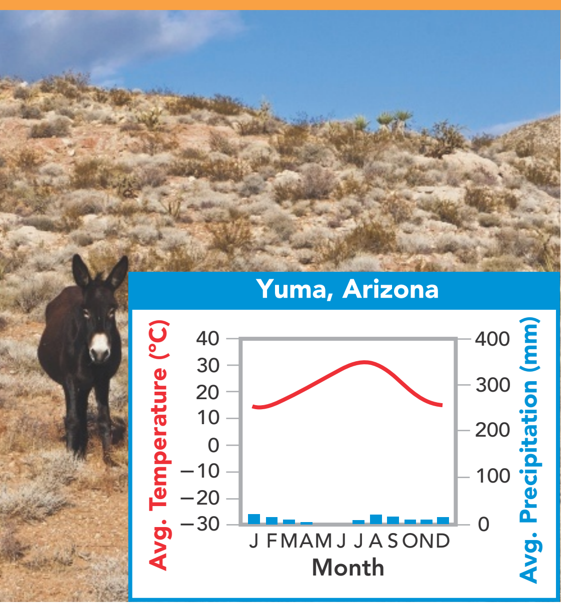
Abiotic factors: warm; seasonal rainfall; compact soils; frequent fires set by lightning

Biotic factors

Plant life: Plant adaptations are similar to those in the tropical dry forest, including waxy leaf coverings and seasonal leaf loss. Some grasses have a high silica content that makes them less appetizing to grazing herbivores. Also, grasses have adaptations that enable them to continue to grow after being grazed.

Animal life: Many animals migrate in search of water during the dry season, while some smaller animals burrow and remain dormant.

DESERT



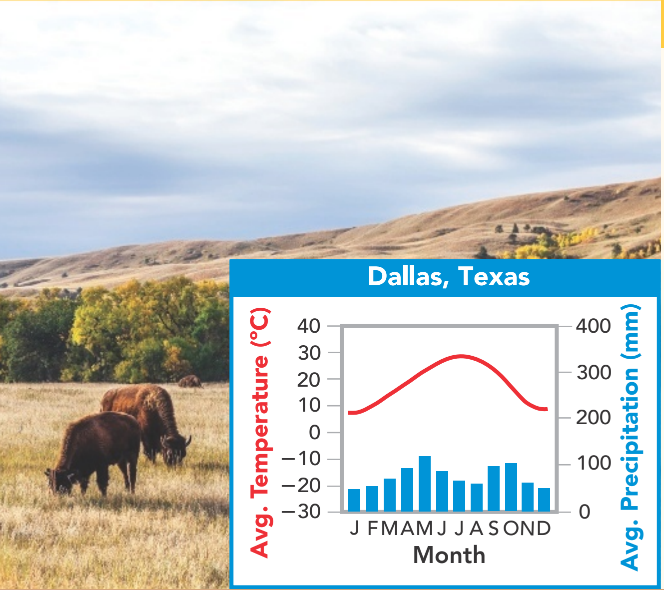
Deserts receive less than 25 centimeters of precipitation annually, but vary greatly depending on elevation and latitude. Many deserts undergo extreme daily temperature changes between hot and cold.

Abiotic factors: low precipitation; variable temperatures; soils rich in minerals but poor in organic material

Biotic factors

Plant life: Many plants, including cacti, store water in their tissues, and minimize leaf surface area to cut down on water loss. Cactus spines are actually modified leaves.

Animal life: Many desert animals get the water they need from their food. To avoid the heat of the day, many are active only at night. Blood vessels near the skin help animals lose body heat.



TEMPERATE GRASSLAND

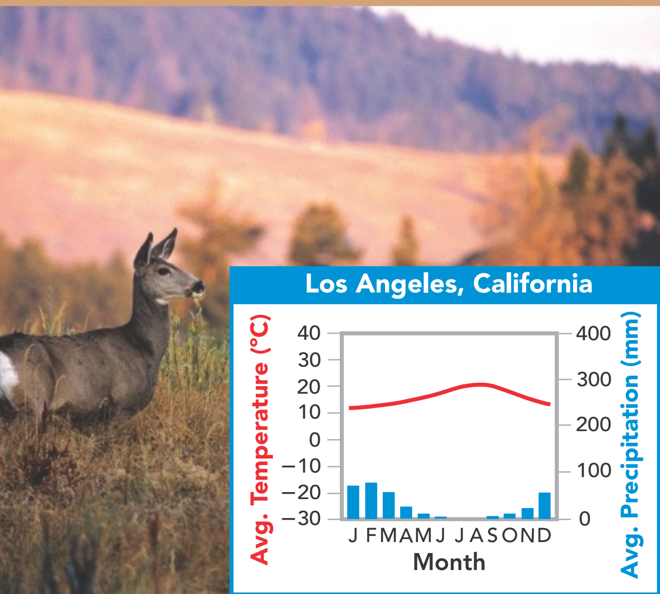
Plains and prairies with fertile soils once covered much of the Midwestern and central United States, land that is now used for farms. Periodic fires and heavy grazing by herbivores maintained the plant communities dominated by grasses.

Abiotic factors: warm to hot summers; cold winters; moderately seasonal precipitation; fertile soils; occasional fires

Biotic factors

Plant life: Grassland plants, especially grasses, are resistant to grazing and fire. Dispersal of seeds by wind is common. The root structure of native grassland plants helps establish and retain deep, rich, fertile topsoil.

Animal life: These open, exposed environments make predation a constant threat for smaller animals. Camouflage and burrowing are common protective adaptations.



TEMPERATE WOODLAND AND SHRUBLAND

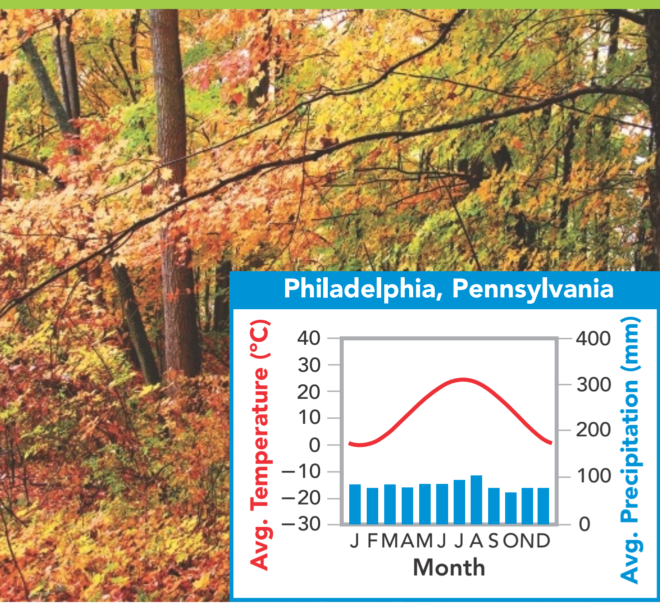
Here, large areas of grasses and wildflowers such as poppies are interspersed with oak and other trees. Communities that are more shrubland than forest are known as chaparral. Dense, low plants that contain flammable oils make fire a constant threat.

Abiotic factors: warm, dry summers; cool, moist winters; thin, nutrient-poor soils; periodic fires

Biotic factors

Plant life: Woody chaparral plants have tough waxy leaves that resist water loss. Fire resistance is important, although the seeds of some plants need fire to germinate.

Animal life: Animals tend to eat varied diets of grasses, leaves, shrubs, and other vegetation. In exposed shrubland, camouflage is common.



TEMPERATE FOREST

Temperate forests have cold winters and warm summers. Coniferous trees produce seed-bearing cones. In autumn, deciduous trees shed their leaves. Fertile soils are often rich in **humus**, a material formed from decaying leaves and other organic matter.

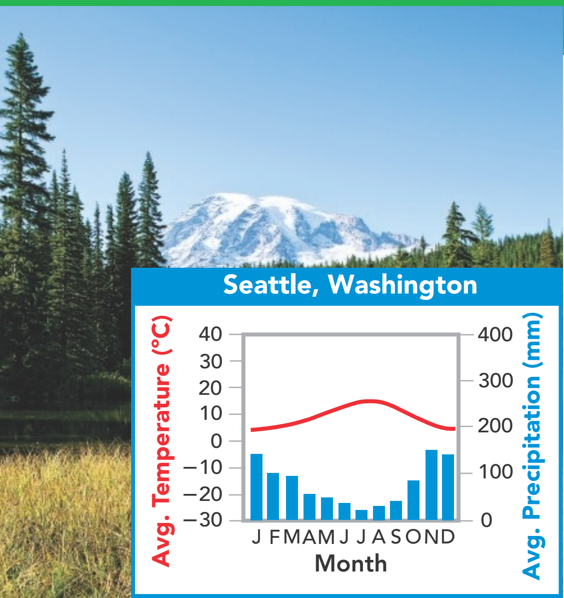
Abiotic factors: cold to moderate winters; warm summers; year-round precipitation; fertile soils

Biotic factors

Plant life: Deciduous trees drop their leaves and go into a state of dormancy in winter. Conifers have needlelike leaves that minimize water loss in dry winter air.

Animal life: Animals may cope with changing weather by hibernating or migrating to warmer climates. Other animals may be camouflaged to escape predation in the winter when bare trees leave them more exposed.

NORTHWESTERN CONIFEROUS FOREST



Mild, moist air and abundant rainfall nurture many tall conifers, from giant redwoods to spruce, fir, and hemlock, along with flowering trees and shrubs. Moss often covers tree trunks and the forest floor. This biome is sometimes called a "temperate rain forest."

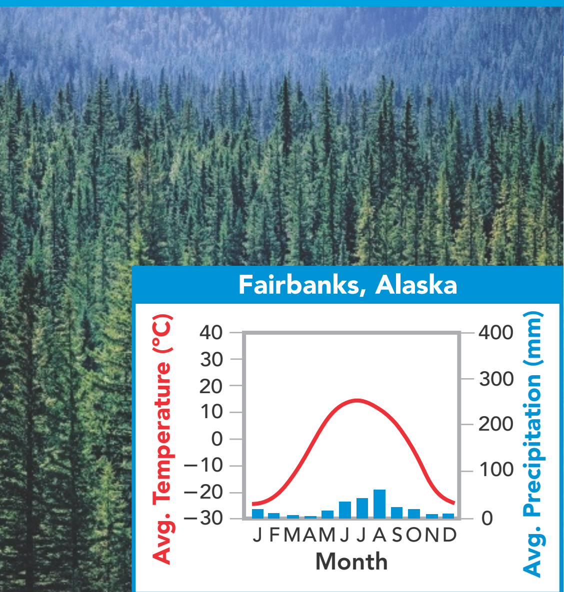
Abiotic factors: mild temperatures; abundant precipitation in fall, winter, and spring; cool, dry summers; rocky, acidic soils

Biotic factors

Plant life: Seasonal temperature variation means that there is less diversity here than in tropical rain forests. However, ample water and nutrients support lush, dense plant growth.

Animal life: Camouflage helps insects and ground-dwelling mammals avoid predation. Many animals are browsers—they eat a varied diet—an advantage in an environment where vegetation changes seasonally.

BOREAL FOREST/TAIGA



The word *boreal* comes from the Greek word for "north." Dense forests of coniferous evergreens along the northern edge of the temperate zone are called boreal forests, or **taiga** (TY guh). Winters are bitterly cold, but summers are mild and long enough to allow the ground to thaw.

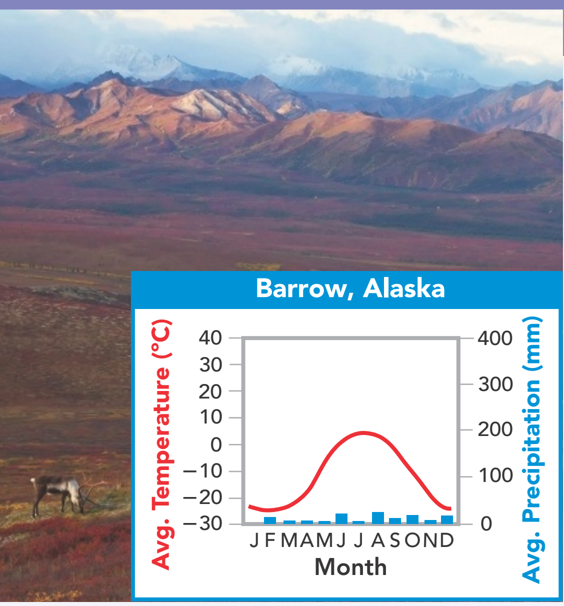
Abiotic factors: long, cold winters; short, mild summers; moderate precipitation; high humidity; acidic, nutrient-poor soils

Biotic factors

Plant life: Conifers' shape and wax-covered needlelike leaves shed snow, and prevent excess water loss.

Animal life: Staying warm is the major challenge. Most have small extremities and extra insulation in the form of fat or downy feathers. Some migrate to warmer areas in winter.

TUNDRA



The tundra is characterized by **permafrost**, a layer of permanently frozen subsoil. During the short, cool summer, the ground thaws to a depth of a few centimeters and becomes soggy. This cycle of thawing and freezing rips and crushes plant roots, which is one reason that tundra plants are small and stunted. Cold temperatures, high winds, a short growing season, and humus-poor soils also limit plant height.

Abiotic factors: strong winds; low precipitation; short and soggy summers; long, cold, dark winters; thin soils

Biotic factors

Plant life: Ground-hugging mosses and other low-growing plants avoid damage from frequent strong winds. Seed dispersal by wind is common.

Animal life: Many animals migrate to avoid winters. Year-round residents display adaptations, among them natural antifreeze, small extremities that limit heat loss, and a varied diet.

Polar Regions Polar regions border the tundra and are cold year-round. Plants are few, though some algae grow on snow and ice. Where rocks and ground are exposed seasonally, mosses and lichens may grow. Marine mammals, insects, and mites are the typical animals. In the north, where polar bears live, the Arctic Ocean is covered with sea ice, although more and more ice is melting each summer. In the south, the continent of Antarctica, inhabited by many species of penguins, is covered by ice nearly 5 kilometers thick in places.

Biomes Today There's just one problem with the traditional concept of biomes: There aren't many natural communities left. In our modern world, humans have altered nearly 75 percent of all land outside the steepest mountain slopes, the coldest polar regions, and the driest deserts. If you go outside your school or home, the overwhelming odds are that there won't be one shred of an original, untouched biome anywhere near you.

The concept of biomes, however, remains useful for describing large regions in which natural biological systems contain certain organisms and function in certain ways. Those regions differ from one another in terms of climate and other environmental factors in ways that are useful to understand, even if the original ecosystem is no longer there. And, as you will learn later in this unit, areas that have been modified by humans are still influenced by the same factors that shaped the ecosystems before our species came along.

INTERACTIVITY

Study three organisms to determine what biomes they are best suited for.

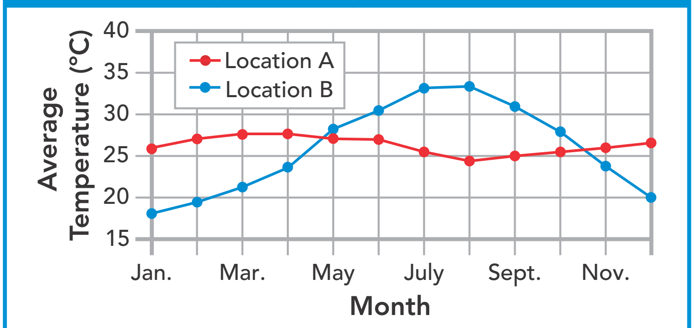
HS-LS2-2

Analyzing Data

Which Biome?

An ecologist collected climate data from two locations. The graph shows the monthly average temperatures in the two locations. In Location A, the total yearly precipitation is 273 cm. In Location B, the total yearly precipitation is 11 cm.

Average Monthly Temperatures



1. **Analyze Graphs** What specific question is this graph addressing?
2. **Analyze Graphs** Use the graph as evidence to draw a conclusion about the temperature over the course of the year in Location A and Location B.
3. **Apply Scientific Reasoning** In which biome would you expect to find each location, given the precipitation and temperature data? Use scientific reasoning to explain your answer.
4. **Construct Graphs** Look up the average monthly temperature last year for your community. Construct a graph and plot the data. Then, research the monthly rainfall for your city, and plot those data on your graph. Based on your results, which biome do you live in? Did the data predict the biome correctly?

Marine Ecosystems

Similar to organisms living on land, underwater organisms are affected by external environmental factors. ***Aquatic ecosystems are described primarily by salinity, depth, temperature, flow rate, and concentrations of dissolved nutrients.*** There are three main groups of aquatic ecosystems: marine ecosystems, freshwater ecosystems, and estuaries.

Just as biomes typically occupy certain latitudes and longitudes, marine ecosystems typically occupy specific areas within the ocean. Ecologists usually divide the ocean into zones based on depth and distance from shore, as shown in **Figure 3-17**.

Water depth influences aquatic life because sunlight doesn't penetrate far in water. The sunlit region near the surface in which photosynthesis can occur is known as the **photic zone**. The photic zone may be as deep as 200 meters in tropical seas, but just a few meters deep or less in rivers and swamps. Below the photic zone is the dark **aphotic zone**, where photosynthesis cannot occur.

Food chains in many aquatic ecosystems are based on **plankton**, a term that includes floating algae—called phytoplankton—and small, free-swimming animals called zooplankton. Phytoplankton need enough light for photosynthesis, so they can grow only in the photic zone. Zooplankton, many of which feed on phytoplankton, may swim up and down, in and out of the photic zone.

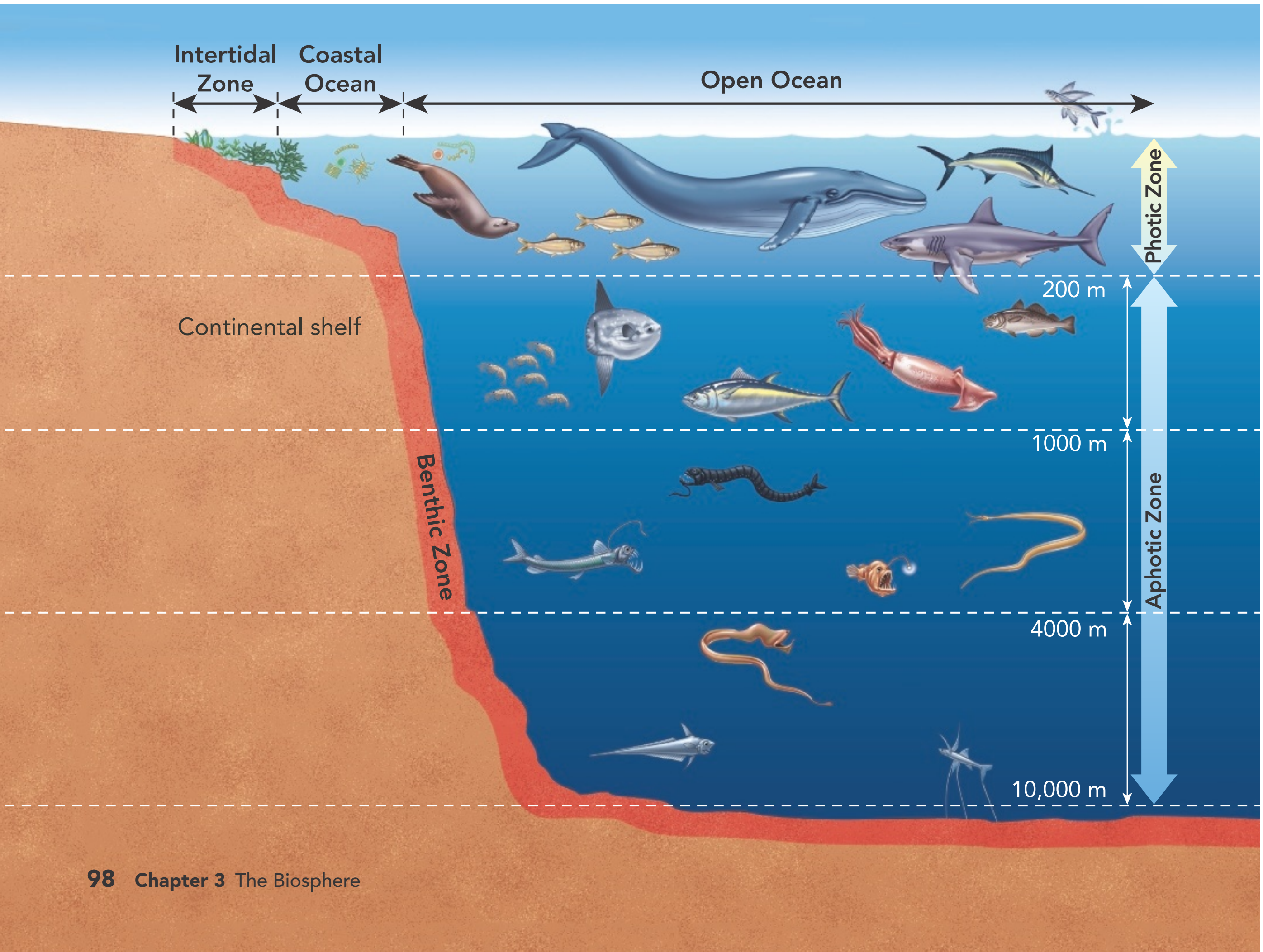
BUILD VOCABULARY

Prefixes The prefix *photo-* refers to light. A photic zone is well-lit, and photosynthesis uses the energy of light.

Figure 3-17

Ocean Zones

The ocean can be divided vertically into zones based on light penetration and depth, and horizontally into zones based on distance from shore.



Intertidal Zone Organisms in the intertidal zone are submerged in seawater at high tide and exposed to air and sunlight at low tide. These organisms experience regular and extreme changes in temperature, and are often battered by waves and currents. There are many different types of intertidal communities. A typical rocky intertidal community exists in temperate regions where exposed rocks line the shore. There, barnacles and seaweed permanently attach themselves to the rocks.

Coastal Ocean The coastal ocean extends from the low-tide mark to the outer edge of the continental shelf—the relatively shallow border that surrounds the continents. Water here is brightly lit, and is often supplied with nutrients by freshwater runoff from land. As a result, coastal oceans tend to be highly productive. Kelp forests and coral reefs are two important coastal communities. A coral reef is shown in **Figure 3-18**.

Figure 3-18
Coastal Ocean: Coral Reef

Tropical coral reefs are among the most diverse and productive communities on Earth.

Open Ocean The open ocean begins at the edge of the continental shelf and extends outward. More than 90 percent of the world's ocean area is open ocean. Depth ranges from about 500 meters along continental slopes to more than 10,000 meters in deep ocean trenches. The open ocean can be divided into two main zones according to light penetration: the photic zone and the aphotic zone.

Open Ocean Photic Zone The open ocean typically has low nutrient levels and supports only the smallest species of phytoplankton. Still, the sunlit top 100 meters of the open ocean cover much of Earth's surface. So, most photosynthesis occurs here—and not in rain forests or other terrestrial environments.

Open Ocean Aphotic Zone The permanently dark aphotic zone includes the deepest parts of the ocean, where no photosynthesis can occur. Deep ocean organisms are exposed to high pressure, frigid temperatures, and total darkness. The deep ocean floor was once thought to be nearly devoid of life but is now known to have islands of high productivity. Deep-sea vents, where superheated water boils out of cracks on the ocean floor, support entire ecosystems based on chemical energy.

READING CHECK **Compare** How does the coastal ocean zone compare with the open ocean zone?

INTERACTIVITY

Learn about how factors such as chemistry, light, salinity, and temperature are influenced at different depths.

Freshwater Ecosystems

Only 3 percent of Earth's surface water is fresh water, but that small percentage provides terrestrial organisms with drinking water, food, and transportation. Often, a chain of streams, lakes, and rivers begins in the interior of a continent and flows through several biomes to the sea. ***Freshwater ecosystems can be divided into three main categories: rivers and streams, lakes and ponds, and freshwater wetlands.***

RIVERS AND STREAMS

Rivers, streams, creeks, and brooks often originate from underground water sources in mountains or hills. Near a source, water has plenty of dissolved oxygen but little plant life. Downstream, sediments build up and plants establish themselves. Still farther downstream, water may meander slowly through flat areas. Animals in many rivers and streams depend on terrestrial plants and animals that live along their banks. Often, a chain of streams and rivers begins in the interior of a continent and flows through several biomes to the sea.

LAKES AND PONDS

Much of the life in lakes and ponds depends on a combination of plankton and attached algae and plants. Water typically flows in and out of lakes and ponds, often through rivers or streams. Water also circulates between the surface and the bottom during at least some seasons. This circulation distributes heat, oxygen, and nutrients. During a cold winter, thick ice might cover the lake for many months. Fish and other animals still live in the liquid water beneath.

INTERACTIVITY

FRESHWATER WETLANDS

A **wetland** is an ecosystem in which water either covers the soil or is present at or near the surface for at least part of the year. Water may flow through freshwater wetlands or stay in place. Wetlands are often nutrient-rich and highly productive, and they serve as breeding grounds for many organisms. Freshwater wetlands have important environmental functions: they purify water by filtering pollutants and help to prevent flooding by absorbing large amounts of water and releasing it slowly. Three main types of freshwater wetlands are freshwater bogs, freshwater marshes, and freshwater swamps.

Estuaries

An **estuary** (ES tyoo er ee) is a wetland formed where a river meets the sea. Fresh water and salt water often mix here, rising and falling with ocean tides. ***Estuaries serve as spawning and nursery grounds for many ecologically and commercially important fish and shellfish.*** The species include bluefish, striped bass, shrimp, and crabs.

Salt marshes are temperate estuaries characterized by salt-tolerant grasses above the low-tide line and seagrasses below water. One of the largest salt marshes in the United States surrounds the Chesapeake Bay in Maryland.

Mangrove swamps are tropical estuaries characterized by several species of salt-tolerant trees, collectively called mangroves. The largest mangrove area in America is part of Florida's Everglades National Park, shown in **Figure 3-19**.

Figure 3-19

Mangrove Swamps

Mangroves have several adaptations for growing in salty water. Roots that grow down from branches, called prop roots, help stabilize the plant in the damp soil.

HS-LS2-2

LESSON 3.3 Review

KEY QUESTIONS

1. What abiotic and biotic factors describe a biome? Give examples for a specific biome.
2. What factors define aquatic ecosystems?
3. Why are wetlands important?
4. Where are estuaries found?

CRITICAL THINKING

5. **Connect to Society** Many years ago, a wetland area was filled in to build a baseball field and playground. Now the town proposes to restore the area to become a shallow pond surrounded by a marsh. What do you think are the strongest arguments for and against this plan? What information would help people decide whether or not to support the plan?
6. **Critique** Shrublands are often referred to as *scrub* or *scrubland*. Why do you think the authors decided to use the term *shrubland* instead? Do you agree or disagree with their choice?

CASE STUDY WRAP-UP

Can we make a working model of our living planet?

Biosphere 2, a habitat designed to model a life-sustaining space colony, didn't make the grade. But its "failure" taught us a lot.

HS-LS2-2, HS-ESS2-4, HS-ETS1-2, HS-ETS1-3

Make Your Case

Engineers and ecologists thought they'd designed a system that could sustain eight people sealed off from the outside world. But unexpected things happened. Some problems involved chemical reactions with parts of the project's structure. Others arose when organisms that were stocked in the system—and some that got in on their own—interacted in unexpected ways. Research the detailed history of Biosphere 2, along with more recent efforts to design self-sustaining systems.

Developing and Using Models

1. **Evaluate Models** Biosphere 2 was intended to be a small-scale model of Biosphere 1. From your research, discuss the limitations of this model.
2. **Evaluate and Revise** If you were an engineer designing a new artificial biosphere, what approach would you use? How could your design attempt to avoid the problems faced by Biosphere 2? Can you find any papers published by current projects using this facility to support your explanation with evidence?

Technology on the Case

Eyes Above the Sky

Biosphereans could easily measure changes in their habitat's mini-ecosystems using simple tools. They could see which species were doing well, and which were dying. They could easily record population changes in weedy plants and insect pests. But many natural systems are far too large to be studied using standard methods. New technology offers a solution to this problem.

For years, scientists have been using satellites and airplanes to carry devices sensitive to short-wave ultraviolet (UV) and long-wave infrared (IR) light. These tools can distinguish forests, grasslands, and farms. Now, an amazing improvement is being developed at the Carnegie Institute for Science. Spectranomics, as it is called, can identify individual tree species in a forest, and even record their height.

How does it work? New technology precisely measures light reflected by plants across a very broad spectrum. The data make it possible to pinpoint individual trees and shrubs. Meanwhile, researchers on the ground take samples of plant leaves, record which wavelengths those leaves absorb and reflect, and identify the species to which each type of leaf belongs. When data gathered by the airborne instruments are analyzed together with the information that connects plant leaf characteristics with species names, they identify plant species!

Careers on the Case

Work Toward a Solution

Organizing data for useful analysis is the job of a data scientist.

Data Scientist

Data scientists are experts at selecting the most useful way to display complex data. Then they design and construct their displays, often with the aid of computers. Some data scientists work to display data on climate or populations. Others work for engineers, financial institutions, and other businesses.

VIDEO

Watch this video to learn about other careers in biology.

hhmi | BioInteractive

STUDY GUIDE

Lesson Review

Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

3.1 Introduction to Global Systems

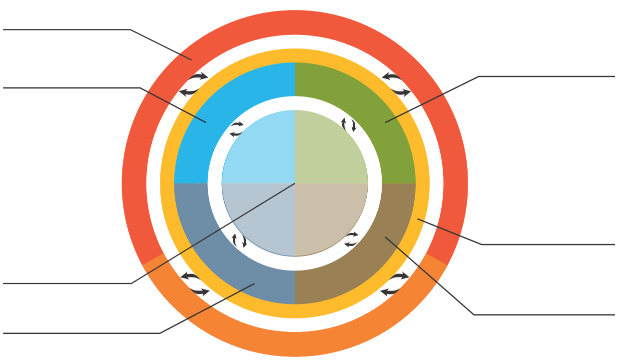
Ecology is the scientific study of interactions among organisms, populations, and communities and their interactions with their environment.

Ecologists generally rely on three main approaches, all of which are part of scientific methodology: observation, experimentation, and modeling. Ecologists may use tools ranging from DNA analysis to data gathered from satellites.

A biotic factor is any living part of the environment with which an organism might interact, including animals, plants, mushrooms, and bacteria. An abiotic factor is any nonliving part of the environment, such as sunlight, heat, precipitation, humidity, wind or water currents, and soil type.

The model of global systems has three major components: causes of global change, Earth's global system processes (how the Earth system works), and the measurable changes in the Earth system that scientists can monitor. Processes in the atmosphere, hydrosphere, geosphere, and biosphere interact to shape global ecosystems and climate.

- biosphere
- ecology
- species
- population
- community
- ecosystem
- biotic factor
- abiotic factor
- atmosphere
- hydrosphere
- geosphere



Use Models Identify the three main parts of the model, and the four spheres that are used to organize concepts in two of these parts.

3.2 Climate, Weather, and Life

Climate is defined by patterns and averages of temperature, precipitation, clouds, and wind over many years. Weather consists of short-term changes in temperature, precipitation, clouds, and wind from day to day, or minute to minute.

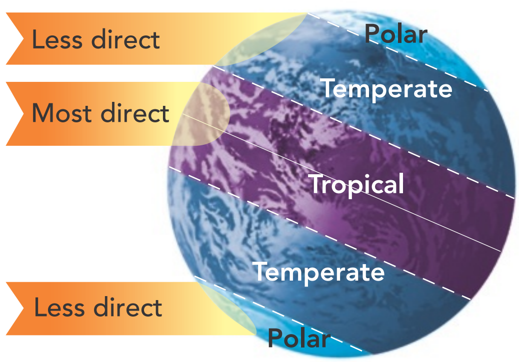
The global climate system is powered and shaped by the total amount of solar energy retained in the biosphere as heat, and by the unequal distribution of that heat between the equator and the poles. Earth's average temperature is determined by the balance between the amount of heat that stays in the atmosphere and the amount of heat that is lost to space.

Ocean currents are driven and shaped by patterns of warming and cooling, by winds, and by the locations of continents.

Regional climates are shaped by latitude, the transport of heat and moisture by winds and ocean currents, and by geographic features such as mountain ranges, large bodies of water, and ocean currents.

Climate change involves changes in temperature, clouds, winds, patterns and amounts of precipitation, and the frequency and severity of extreme weather events.

- climate
- weather
- greenhouse effect



Observe Which climate zone gets the least amount of direct sunlight? The most direct sunlight?

3.3 Biomes and Aquatic Ecosystems

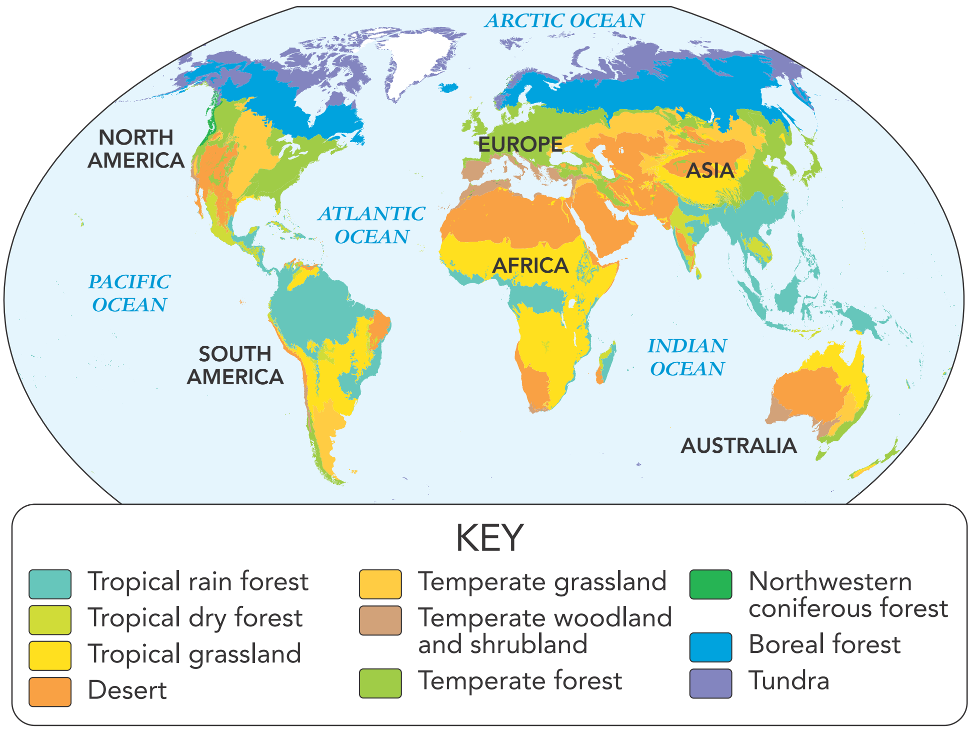
Biomes are described in terms of abiotic factors such as climate and soil type, and biotic factors such as plant and animal life.

Aquatic ecosystems are described primarily by salinity, depth, temperature, flow rate, and concentrations of dissolved nutrients.

Freshwater ecosystems can be divided into three main categories: rivers and streams, lakes and ponds, and freshwater wetlands.

Estuaries serve as spawning and nursery grounds for many ecologically and commercially important fish and shellfish.

- biome
- canopy
- understory
- humus
- taiga
- permafrost
- photic zone
- aphotic zone
- plankton
- wetland
- estuary



Compare Find the locations of boreal forests, temperate forests, and tropical rain forests. How do the locations compare?

Organize Information

Complete the table. For each cause, identify an effect and describe an example.

Cause	→	Effect	Example
Greenhouse gases	→	warms the atmosphere.	1.
Wind currents	→	2.	3.
Ocean currents	→	4.	El Niño

PERFORMANCE-BASED ASSESSMENT

Meet the Anthromes

Construct an Argument

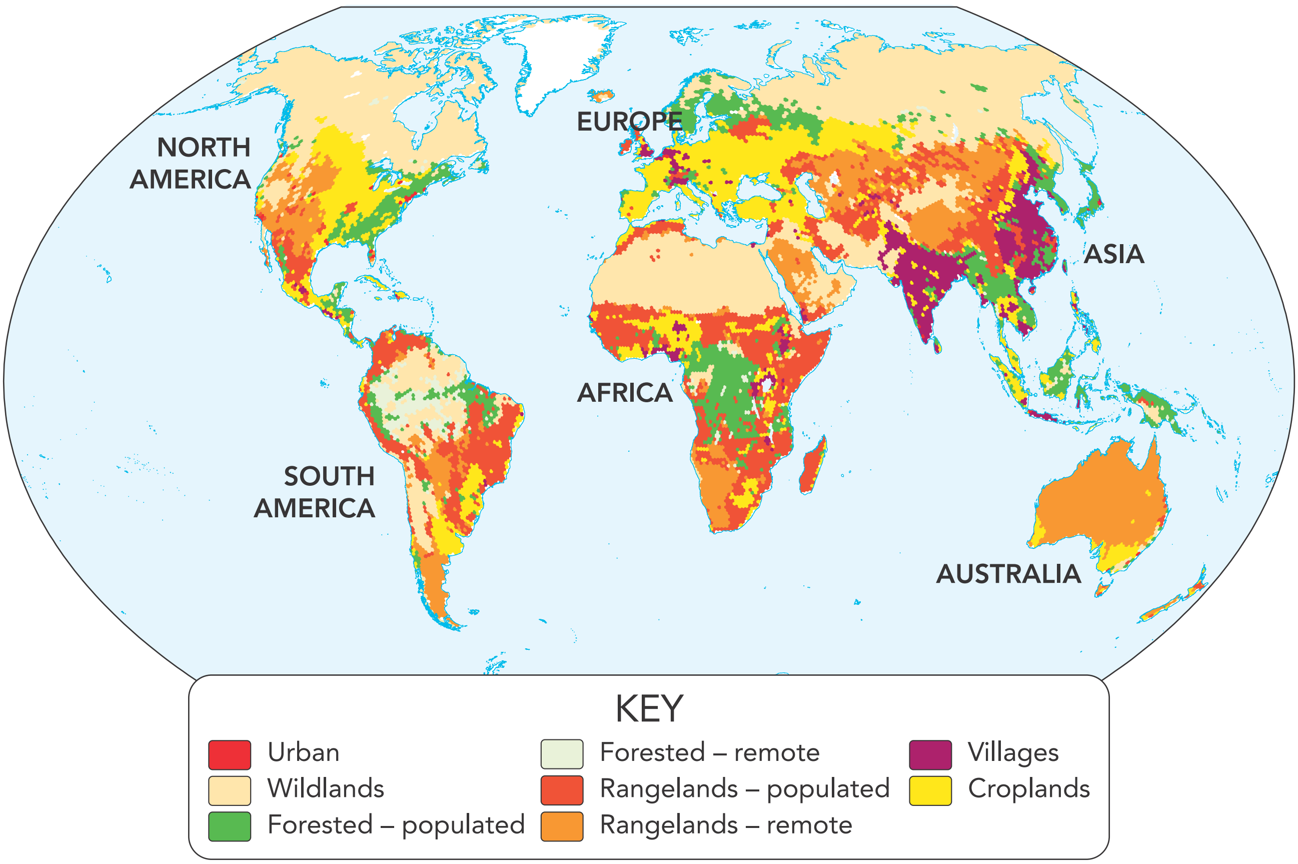
HS-ESS3-6, CCSS.ELA-LITERACY.WHST.9-10.8, CCSS.ELA-LITERACY.WHST.9-10.9

Mosses and lichens grow on the tundra, lions hunt zebras on grasslands, and tall pine trees cover the taiga. However, do these classifications of biomes apply to the place where you live? Probably not. Scientists use the term *anthropogenic biome*, or *anthrome*, to describe biomes that humans have altered. Examples include dense urban areas. Here, buildings and pavement may cover nearly all of the land, with only small areas put aside for parks or stands of trees. Other anthromes consist of land used for farm crops and livestock. In these anthromes, human-selected plants and animals have replaced native species.

The map shows the major anthromes of the world. Compare it to the map of the natural biomes shown in **Figure 3-16**.

1. **Classify** Describe the properties of the place where you live. Then, use the information in the map to classify the anthrome you live in.
2. **Synthesize Information** How does the distribution of anthromes across the world compare to the distribution of biomes?
3. **Use Evidence to Construct an Argument** How do you think the world's natural biomes and anthromes will change in the future? Conduct research to help you construct your argument. Look for data and opinions from different sources, such as these.
   - nonprofit organizations devoted to conservation and wildlife
   - government agencies
   - economists and business groups
4. **Communicate** Write a short essay to present your argument about the future of Earth's natural biomes and anthromes. Support your argument with evidence from this chapter and from your research. Address the following criteria in your essay:
   - Predict which natural biomes or anthromes will expand, which will shrink, and which will stay the same size.
   - Include data, scientific reasoning, or expert opinions to support your predictions.
   - Cite your sources and evaluate their credibility. If you find reliable sources that provide conflicting information or opinions, discuss your evaluation of them.

In suburbs, pavement and houses have replaced the natural biome.



Anthromes
This map shows the locations of major anthropogenic biomes of the world.

CHAPTER 3

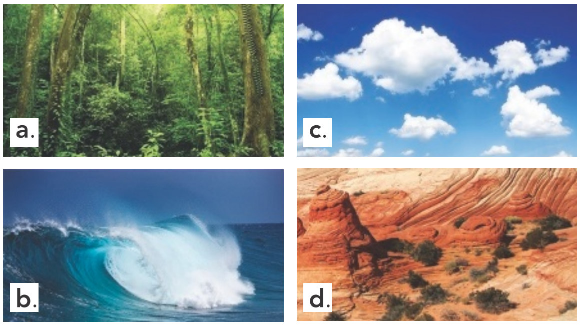
ASSESSMENT

KEY QUESTIONS AND TERMS

3.1 Introduction to Global Systems

1. The study of the complex system of interactions that sustain life on the planet is
   a. zoology. c. chemistry.
   b. ecology. d. economics.

2. Which photo represents the geosphere?



3. Nonliving factors of an environment are
   a. biotic. c. abiotic.
   b. bacteria. d. plankton.

4. The global system that contains most of the life on Earth is the
   a. atmosphere. c. hydrosphere.
   b. geosphere. d. biosphere.

5. Compare the terms *population*, *community*, and *ecosystem*.

6. What are the three general approaches that are used to study ecology?

7. What are the properties of a useful model of global systems?

8. Describe one of the interactions between the four major Earth systems.

3.2 Climate, Weather, and Life

HS-LS2-2, HS-ESS2-4

9. The climate zone closest to the equator is
   a. polar. c. tropical.
   b. temperate. d. torrid.

10. Average temperatures, precipitation, and wind patterns in an area define its
    a. geosphere. c. weather.
    b. climate. d. atmosphere.

11. The concentrations of gases in the atmosphere that trap heat produce
    a. radiation.
    b. solar energy.
    c. the greenhouse effect.
    d. the hydrosphere.

12. How is climate different from weather?

13. What accounts for the unequal distribution of heat between the equator and the poles?

14. What causes wind?

15. What factors affect the path of an ocean current?

16. How do mountain ranges affect climate?

17. What are some of the long-term, natural causes of climate change?

3.3 Biomes and Aquatic Ecosystems

HS-LS2-2

18. The biome that supports more species than all other biomes is the
    a. savannah.
    b. temperate grassland.
    c. boreal forest.
    d. tropical rain forest.

19. Taiga is a synonym for the
    a. boreal forest.
    b. temperate woodland.
    c. tropical dry forest.
    d. desert.

20. Which variable do scientists use to divide the open ocean into two zones?
    a. salinity
    b. latitude
    c. depth
    d. oxygen

21. Which biome is characterized by permafrost?

22. What factors describe aquatic ecosystems?

23. What is the ocean zone in which photosynthesis cannot occur?

24. Describe the difference between a wetland and an estuary.

25. Where does the most photosynthesis on Earth occur?

CRITICAL THINKING

HS-LS2-2, HS-ESS2-4

26. **Compare and Contrast** How are aquatic ecosystems similar to ecosystems on land? How are they different?

27. **Plan Your Investigation** Ecologists have discovered that the seeds of many plants that grow in forests cannot germinate unless they have been exposed to fire. Design an experiment to test whether a particular plant has seeds with this requirement. Include your hypothesis statement, a description of both the control and experimental groups, and an outline of your procedure.

28. **Use Models** Give an example of a model biologists use to better understand ecological phenomena. How does the model help?

29. **Construct an Argument** One friend says biotic factors are more important than abiotic factors to ecology. Another friend says abiotic factors are more important than biotic factors. What do you think? Defend your position using examples from a specific biome of your choice.

30. **Construct an Explanation** A plant grower has a greenhouse where she grows plants in the winter. The greenhouse is exposed to direct sunlight and often gets too hot for the plants. She paints the inside of the glass with a chalky white paint, and the temperature drops to comfortable levels. Explain why this solution works.

31. **Integrate Information** Although the amount of precipitation is low, most parts of the tundra are very wet during the summer. How would you explain this apparent contradiction?

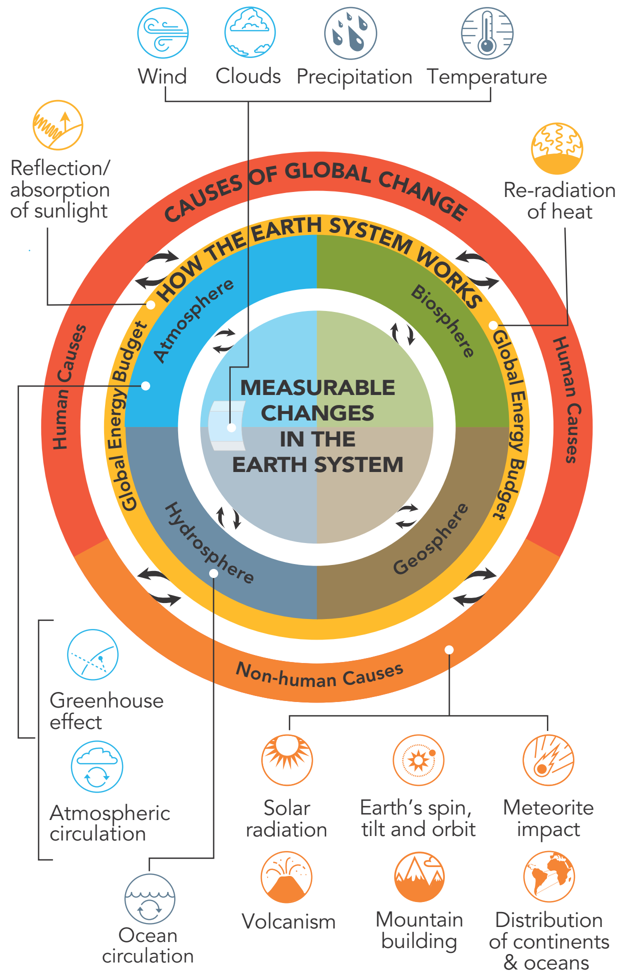
32. **Identify Patterns** Consider these two biomes: (1) the temperate grassland and (2) the temperate woodland and shrubland. Coyotes live in both biomes. Describe two adaptations that might enable coyotes to tolerate conditions in both biomes.

33. **Construct an Explanation** How does the greenhouse effect help to explain Earth's climate?

34. **Form a Hypothesis** The deep ocean lies within the aphotic zone and is very cold. Suggest some of the unique characteristics that enable animals to live in the deep ocean.

35. **Communicate Information** A developer has proposed filling in a salt marsh to create a coastal resort. What positive and negative effects do you think this proposal would have on wildlife and local residents? Would you support the proposal?

Use the Understanding Global Change model to answer questions 36 and 37.



36. **Use Models** How are processes in the How the Earth System Works category related to Measurable Changes in the Earth System? Describe at least one relationship between two topics shown in the model.

37. **Evaluate Models** What does the model communicate about how processes and phenomena shape global systems? What have you learned about these topics that is not explained in the model?

CROSSCUTTING CONCEPTS

38. **Structure and Function** Deciduous trees in tropical dry forests lose water through their leaves every day. During summers with adequate rain, the leaves remain on the trees. During the cold dry season, the trees drop their leaves. In an especially dry summer, how might the adaptation of dropping leaves enable a tree to tolerate the drought?

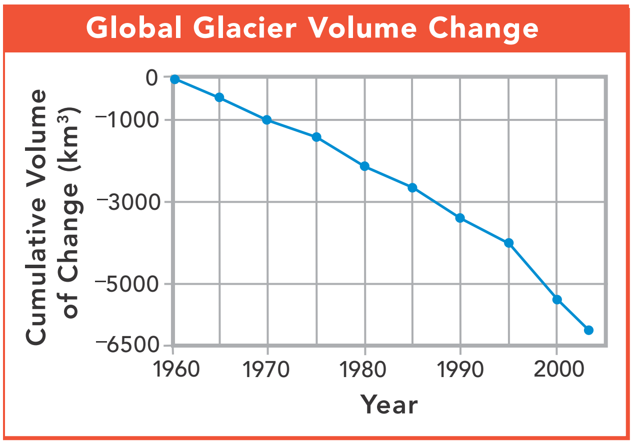
39. **Systems and System Models** Review the models in **Figure 3-1** and **Figure 3-4**. How are these two models similar or different? Are all of the components of the model in **Figure 3-1** represented in **Figure 3-4**? Explain why or why not.

MATH CONNECTIONS

Analyze and Interpret Data

CCSS.MATH.CONTENT.HSN.Q.A.2,
CCSS.MATH.CONTENT.HSS.IC.B.6

The graph below summarizes the changes in the total volume of ice in all the world's glaciers since 1960. (Volume is calculated from measurements of glacier surface area and depth.) Note that the volume changes on the *y*-axis are negative, meaning an overall loss of volume. Use the graph to answer questions 40–42.



40. **Analyze Graphs** In which ten-year span was the greatest volume of glacial ice lost? What was the total loss of volume over that timespan?

41. **Calculate** Suppose a particular glacier covers 100 km^2, and it loses 30 cm of depth in a decade. Approximately what volume (km^3) is lost? Show your work.

42. **Conduct Research** Investigate the most reasonable explanation for the loss of global glacier mass since 1960. Summarize your findings in a short paragraph.

LANGUAGE ARTS CONNECTIONS

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.2

43. **Write Explanatory Texts** Choose one of the major biomes, and write an overview of its characteristics. Explain how abiotic factors and common plants and wildlife are interrelated. Support your explanation with specific examples.

Read About Science

CCSS.ELA-LITERACY.RST.9-10.2

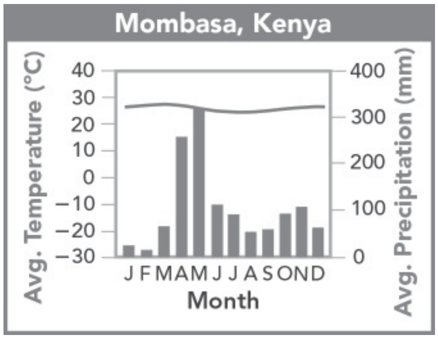
44. **Central Ideas** Review Lesson 3.2 to summarize generally how heat (or lack of heat) affects the vertical movements of large masses of air and large volumes of water. Then summarize the effects of other factors that influence wind and ocean currents and regional climate patterns.

END-OF-COURSE TEST PRACTICE

1. Kara uses a model that shows slight changes to Earth's motion through space over many thousands of years. This model helps her explain long-term climate change due to what variable?
   A. volcanic activity
   B. meteor or asteroid strikes
   C. ocean circulation
   D. carbon dioxide levels in the atmosphere
   E. input of solar energy
2. Lionel uses a model that includes the atmosphere and sunlight to predict Earth's temperatures. In this model, why does increasing the levels of carbon dioxide in the atmosphere cause temperatures to increase?
   A. Sunlight passes through carbon dioxide.
   B. Sunlight is absorbed by carbon dioxide.
   C. Heat is trapped by carbon dioxide.
   D. Carbon dioxide generates heat.
   E. Carbon dioxide reacts with water to release heat.
3. Scientists have concluded that human activities are affecting the atmosphere and causing rapid climate change on a global scale. Which statement provides the strongest evidence that these changes to global climate are NOT the result of natural causes, such as variations in Earth's orbit?
   A. Until recently, Earth's climate had remained relatively constant.
   B. Variations in Earth's orbit cannot be measured precisely.
   C. Variations in Earth's orbit would affect climate only minimally.
   D. Earth's climate depends mostly on the output of the sun.
   E. Variations in Earth's orbit occur gradually over 100,000 years.

Questions 4 and 5

This climate diagram shows the average temperature (line graph) and precipitation (bar graph) during each month of the year.



4. Plants that thrive in this type of climate are most likely adapted to which of these conditions?
   A. seasonal variations in temperature
   B. seasonal variations in precipitation
   C. year-long cold temperatures
   D. dense, competitive growth
   E. rich, fertile soil
5. Which plant feature would MOST LIKELY be common in this type of climate?
   A. leaves with waxy coverings
   B. tall, woody trunks
   C. broad, flat leaves
   D. watery fruits
   E. roots that dangle in the air

ASSESSMENT

For additional assessment practice, go online to access your digital course.

If You Have Trouble With...					
Question	1	2	3	4	5
See Lesson	3.2	3.2	3.3	3.3	3.3
Performance Expectation	HS-ESS2-4	HS-ESS2-4	HS-ESS3-6	HS-LS2-2	HS-LS2-2