



Climate

chapter preview

sections

- 1 What is climate?
- 2 Climate Types
- 3 Climatic Changes

Lab The Greenhouse Effect

Lab Microclimates



Virtual Lab How can locations be identified by their climate and topography?

Why do seasons change?

Why do some places have four distinct seasons, while others have only a wet and dry season? In this chapter, you will learn what climate is and how climates are classified. You will also learn what causes climate changes and how humans and animals adapt to different climates.

Science Journal Write a paragraph explaining what you already know about the causes of seasons.

Start-Up Activities



Tracking World Climates

You wouldn't go to Alaska to swim or to Jamaica to snow ski. You know the climates in these places aren't suited for these sports. In this lab, you'll explore the climates in different parts of the world.

1. Obtain a world atlas, globe, or large classroom map. Select several cities from different parts of the world.
2. Record the longitude and latitude of your cities. Note if they are near mountains or an ocean.
3. Research the average temperature of your cities. In what months are they hottest? Coldest? What is the average yearly rainfall? What kinds of plants and animals live in the region? Record your findings.
4. Compare your findings with those of the rest of your class. Can you see any relationship between latitude and climate? Do cities near an ocean or a mountain range have different climatic characteristics?
5. **Think Critically** Keep track of the daily weather conditions in your cities. Are these representative of the kind of climates your cities are supposed to have? Suggest reasons why day-to-day weather conditions may vary.

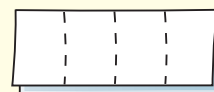
FOLDABLES™ Study Organizer

Classifying Climates Make the following Foldable to help you compare climatic types.

- STEP 1** Fold two pieces of paper lengthwise into thirds.



- STEP 2** Fold the papers widthwise into fourths.



- STEP 3** Unfold, lay the papers lengthwise, and draw lines along the folds as shown.



- STEP 4** Label your tables as shown.

| Climate Classification | | |
|------------------------|--|--|
| Tropical | | |
| Mild | | |
| Dry | | |

| Climate Classification | | |
|------------------------|--|--|
| Continental | | |
| Polar | | |
| High elevation | | |

Make a Table As you read the chapter, define each type of climate and write notes on its weather characteristics.



Preview this chapter's content and activities at green.msscience.com



What is climate?

as you read

What You'll Learn

- **Describe** what determines climate.
- **Explain** how latitude, oceans, and other factors affect the climate of a region.

Why It's Important

Climate affects the way you live.



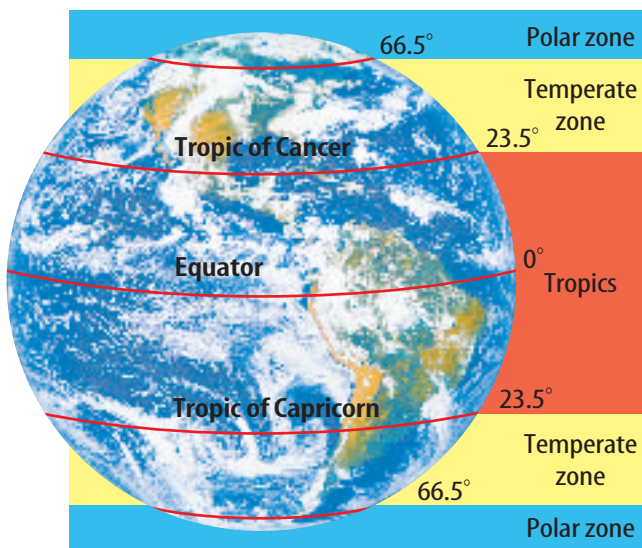
Review Vocabulary

latitudes: distance in degrees north or south of the equator

New Vocabulary

- climate
- polar zone
- tropics
- temperate zone

Figure 1 The tropics are warmer than the temperate zones and the polar zones because the tropics receive the most direct solar energy.



Climate

If you wandered through a tropical rain forest, you would see beautiful plants flowering in shades of pink and purple beneath a canopy of towering trees. A variety of exotic birds and other animals would dart among the tree branches and across the forest floor. The sounds of singing birds and croaking frogs would surround you. All of these organisms thrive in hot temperatures and abundant rainfall. Rain forests have a hot, wet climate. **Climate** is the pattern of weather that occurs in an area over many years. It determines the types of plants or animals that can survive, and it influences how people live.

Climate is determined by averaging the weather of a region over a long period of time, such as 30 years. Scientists average temperature, precipitation, air pressure, humidity, and number of days of sunshine to determine an area's climate. Some factors that affect the climate of a region include latitude, landforms, location of lakes and oceans, and ocean currents.

Latitude and Climate

As you can see in **Figure 1**, regions close to the equator receive the most solar radiation. Latitude, a measure of distance north or south of the equator, affects climate. **Figure 2** compares cities at different latitudes. The **tropics**—the region between latitudes 23.5°N and 23.5°S—receive the most solar radiation because the Sun shines almost directly over these areas. The tropics have temperatures that are always hot, except at high elevations. The **polar zones** extend from 66.5°N and 66.5°S latitude to the poles. Solar radiation hits these zones at a low angle, spreading energy over a large area. During winter, polar regions receive little or no solar radiation. Polar regions are never warm.



Reading Check

How does latitude affect climate?

Between the tropics and the polar zones are the **temperate zones**. Temperatures here are moderate. Most of the United States is in a temperate zone.

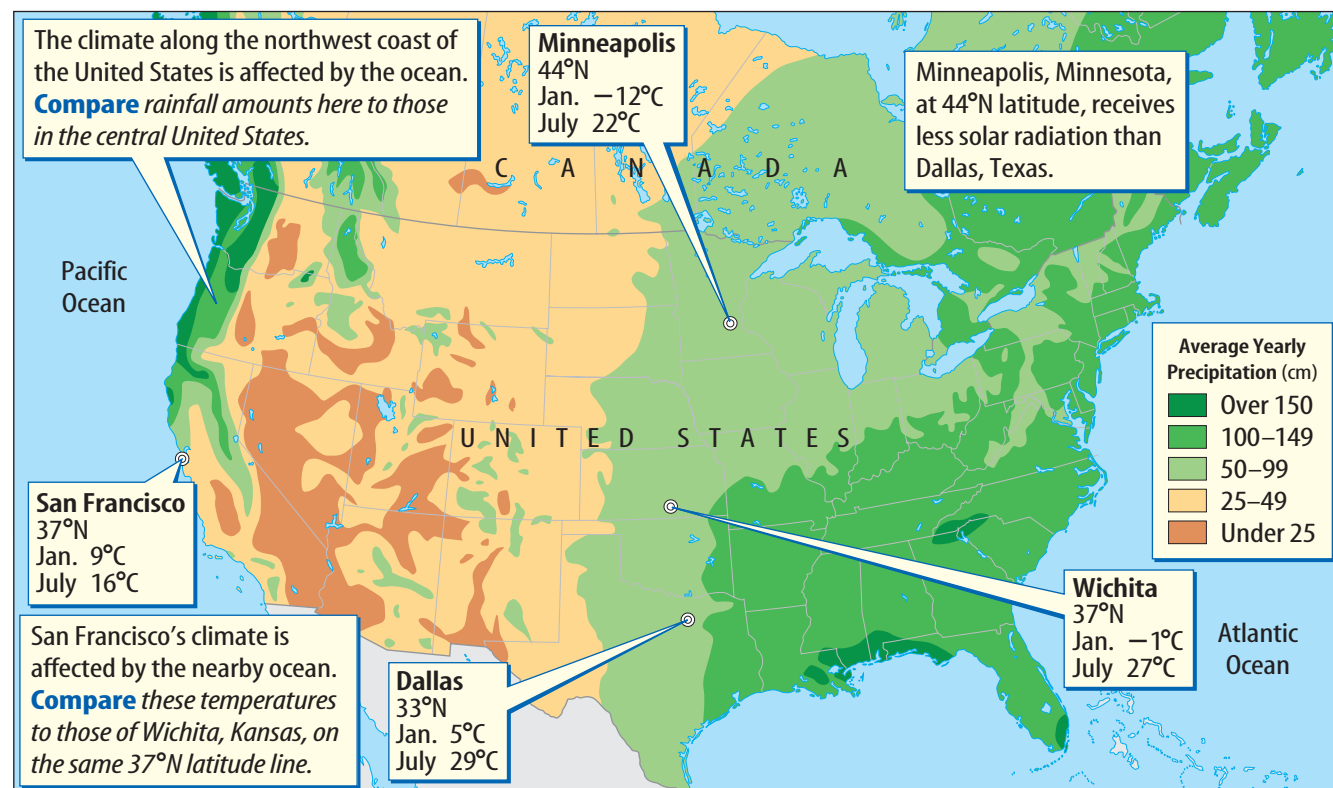


Other Factors

In addition to the general climate divisions of polar, temperate, and tropical, natural features such as large bodies of water, ocean currents, and mountains affect climate within each zone. Large cities also change weather patterns and influence the local climate.

Large Bodies of Water If you live or have vacationed near an ocean, you may have noticed that water heats up and cools down more slowly than land does. This is because it takes a lot more heat to increase the temperature of water than it takes to increase the temperature of land. In addition, water must give up more heat than land does for it to cool. Large bodies of water can affect the climate of coastal areas by absorbing or giving off heat. This causes many coastal regions to be warmer in the winter and cooler in the summer than inland areas at similar latitude. Look at **Figure 2** again. You can see the effect of an ocean on climate by comparing the average temperatures in a coastal city and an inland city, both located at 37°N latitude.

Figure 2 This map shows average daily low temperatures in four cities during January and July. It also shows average yearly precipitation.



Mini LAB

Observing Solar Radiation

Procedure

1. Darken the room.
2. Hold a **flashlight** about 30 cm from a **globe**. Shine the light directly on the equator. With your finger, trace around the light.
3. Now, tilt the flashlight to shine on 30°N latitude. The size of the lighted area should increase. Repeat at 60°N latitude.

Analysis

1. How did the size and shape of the light beam change as you directed the light toward higher latitudes?
2. How does Earth's tilt affect the solar radiation received by different latitudes?



Mountain Air When air rises over a mountain, the air expands and its temperature decreases, causing water vapor to condense and form rain. Temperature changes caused by air expanding or contracting also occur in some machines. Why does the air coming out of a bicycle pump feel cold?

Ocean Currents Ocean currents affect coastal climates. Warm currents begin near the equator and flow toward higher latitudes, warming the land regions they pass. When the currents cool off and flow back toward the equator, they cool the air and climates of nearby land.



Reading Check *How do ocean currents affect climate?*

Winds blowing from the sea are often moister than those blowing from land. Therefore, some coastal areas have wetter climates than places farther inland. Look at the northwest coast of the United States shown in **Figure 2**. The large amounts of precipitation in Washington, Oregon, and northern California can be explained by this moist ocean air.

Mountains At the same latitude, the climate is colder in the mountains than at sea level. When radiation from the Sun is absorbed by Earth's surface, it heats the land. Heat from Earth then warms the atmosphere. Because Earth's atmosphere gets thinner at higher altitudes, the air in the mountains has fewer molecules to absorb heat.

Applying Science

How do cities influence temperature?

The temperature in a city can be several degrees warmer than the temperature of nearby rural areas. This difference in temperature is called the heat island effect. Cities contain asphalt and concrete which heat up rapidly as they absorb energy from the Sun. Rural areas covered with vegetation stay cooler because plants and soil contain water. Water heats up more slowly and carries away heat as it evaporates. Is the heat island effect the same in summer and winter?

Identifying the Problem

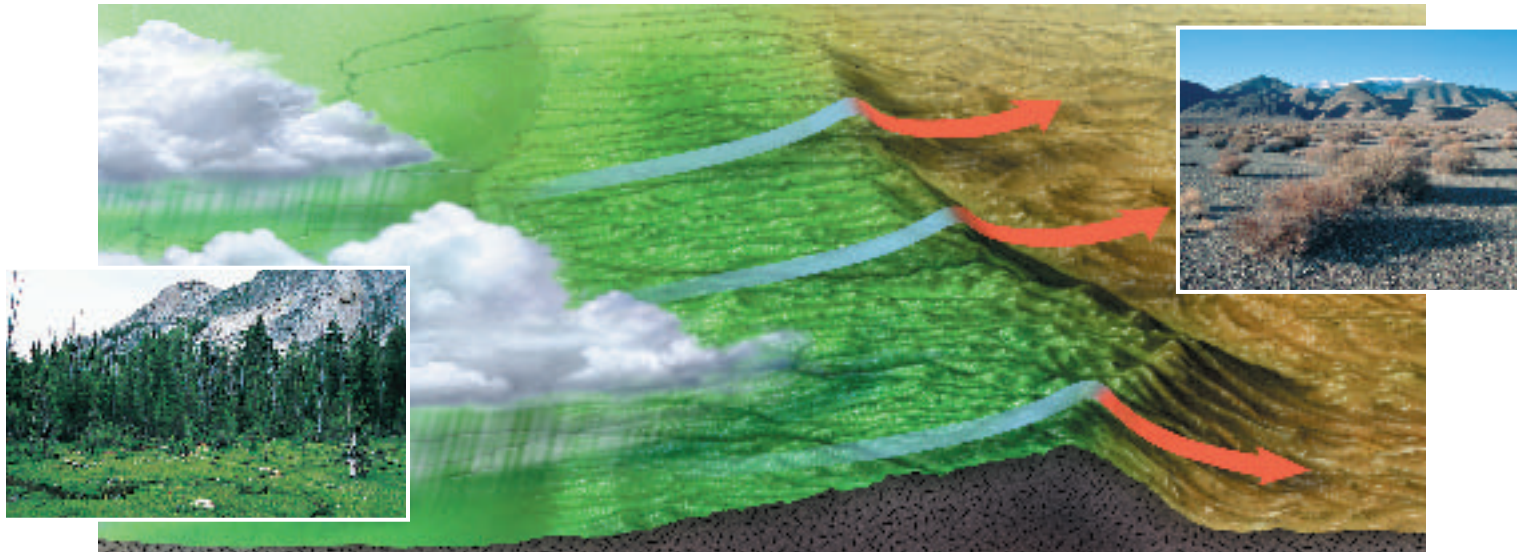
The table lists the average summer and winter high temperatures in and around a city in 1996 and 1997. By examining the data, can you tell if the heat island effect is the same in summer and winter?

Average Seasonal Temperatures

| Season | Temperature (°C) | |
|-------------|------------------|-------|
| | City | Rural |
| Winter 1996 | −3.0 | −4.4 |
| Summer 1996 | 23.5 | 20.9 |
| Winter 1997 | −0.1 | −1.8 |
| Summer 1997 | 23.6 | 21.2 |

Solving the Problem

1. Calculate the average difference between city and rural temperatures in summer and in winter. In which season is the heat island effect the largest?
2. For this area there are about 15 hours of daylight in summer and 9 hours in winter. Use this fact to explain your results from the previous question.



Rain Shadows Mountains also affect regional climates, as shown in **Figure 3**. On the windward side of a mountain range, air rises, cools, and drops its moisture. On the leeward side of a mountain range air descends, heats up, and dries the land. Deserts are common on the leeward sides of mountains.

Cities Large cities affect local climates. Streets, parking lots, and buildings heat up, in turn heating the air. Air pollution traps this heat, creating what is known as the heat-island effect. Temperatures in a city can be 5°C higher than in surrounding rural areas.

Figure 3 Large mountain ranges can affect climate by forcing air to rise over the windward side, cooling and bringing precipitation. The air descends with little or no moisture, creating desertlike conditions on the leeward side.

section 1 review

Summary

Latitude and Climate

- Climate is the pattern of weather that occurs in an area over many years.
- The tropics receive the most solar radiation because the Sun shines most directly there.
- The polar zones receive the least solar energy due to the low-angled rays.
- Temperate zones, located between the tropics and the polar zones, have moderate temperatures.

Other Factors

- Natural features such as large bodies of water, ocean currents, and mountains can affect local and regional climates.
- Large cities can change weather patterns and influence local climates.

Self Check

1. **Explain** how two cities located at the same latitude can have different climates.
2. **Describe** how mountains affect climate.
3. **Define** the heat island effect.
4. **Compare and contrast** tropical and polar climates.
5. **Think Critically** Explain why plants found at different elevations on a mountain might differ. How can latitude affect the elevation at which some plants are found?

Applying Math

6. **Solve One-Step Equations** The coolest average summer temperature in the United States is 2°C at Barrow, Alaska, and the warmest is 37°C at Death Valley, California. Calculate the range of average summer temperatures in the United States.



Climate Types

as you read

What You'll Learn

- **Describe** a climate classification system.
- **Explain** how organisms adapt to particular climates.

Why It's Important

Many organisms can survive only in climates to which they are adapted.



Review Vocabulary

regions: places united by specific characteristics

New Vocabulary

- adaptation
- hibernation

Figure 4 The type of vegetation in a region depends on the climate. **Describe** what these plants tell you about the climate shown here.

Classifying Climates

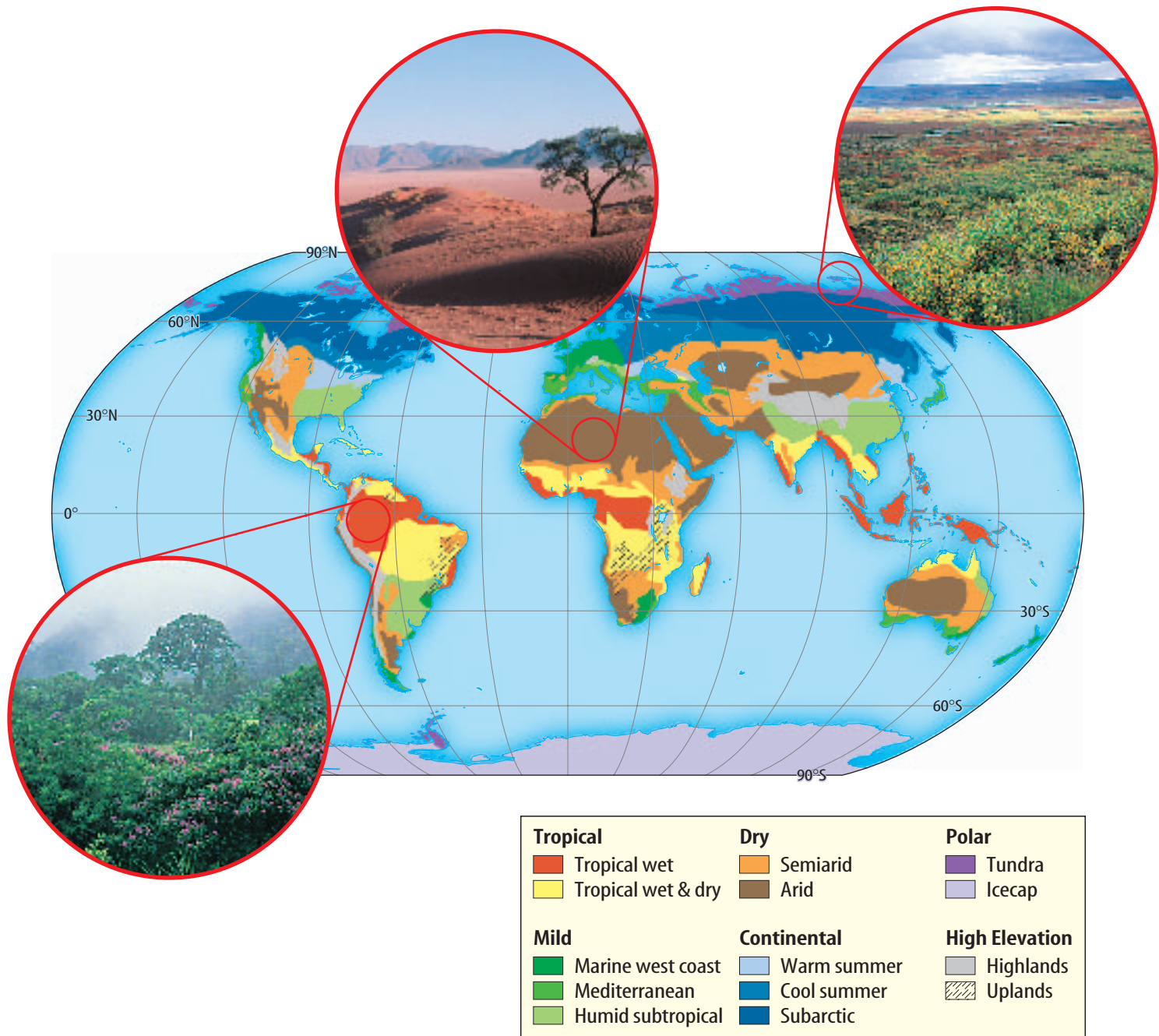
What is the climate like where you live? Would you call it generally warm? Usually wet and cold? Or different depending on the time of year? How would you classify the climate in your region? Life is full of familiar classification systems—from musical categories to food groups. Classifications help to organize your thoughts and to make your life more efficient. That's why Earth's climates also are classified and are organized into the various types that exist. Climatologists—people who study climates—usually use a system developed in 1918 by Wladimir Köppen to classify climates. Köppen observed that the types of plants found in a region depended on the climate of the area. **Figure 4** shows one type of region Köppen might have observed. He classified world climates by using the annual and monthly averages of temperature and precipitation of different regions. He then related the types and distribution of native vegetation to the various climates.

The climate classification system shown in **Figure 5** separates climates into six groups—tropical, mild, dry, continental, polar, and high elevation. These groups are further separated into types. For example, the dry climate classification is separated into semiarid and arid.

Adaptations

Climates vary around the world, and as Köppen observed, the type of climate that exists in an area determines the vegetation found there. Fir trees aren't found in deserts, nor are cacti found in rain forests. In fact, all organisms are best suited for certain climates. Organisms are adapted to their environment. An **adaptation** is any structure or behavior that helps an organism survive in its environment. Structural adaptations are inherited. They develop in a population over a long period of time. Once adapted to a particular climate, organisms may not be able to survive in other climates.





Structural Adaptations Some organisms have body structures that help them survive in certain climates. The fur of mammals is really hair that insulates them from cold temperatures. A cactus has a thick, fleshy stem. This structural adaptation helps a cactus hold water. The waxy stem covering prevents water inside the cactus from evaporating. Instead of broad leaves, these plants have spiny leaves, called needles, that further reduce water loss.



Reading Check How do cacti conserve water?

Figure 5 This map shows a climate classification system similar to the one developed by Köppen. **Describe** the patterns you can see in the locations of certain climate types.



Behavioral Adaptations Some organisms display behavioral adaptations that help them survive in a particular climate. For example, rodents and certain other mammals undergo a period of greatly reduced activity in winter called **hibernation**. During hibernation, body temperature drops and body processes are reduced to a minimum. Some of the factors thought to trigger hibernation include cooler temperatures, shorter days, and lack of adequate food. The length of time that an animal hibernates varies depending on the particular species of animal and the environmental conditions.



Reading Check

What is hibernation?

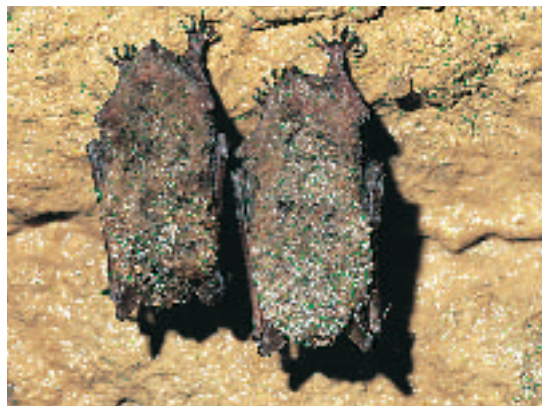
Other animals have adapted differently. During cold weather, bees cluster together in a tight ball to conserve heat. On hot, sunny days, desert snakes hide under rocks. At night when it's cooler, they slither out in search of food. Instead of drinking water as turtles and lizards do in wet climates, desert turtles and lizards obtain the moisture they need from their food. Some behavioral and structural adaptations are shown in **Figure 6**.

(l) S. R. Maglione/Photo Researchers, (c) Jack Grove/Tom Slack & Assoc., (b) Fritz Poking/Visuals Unlimited

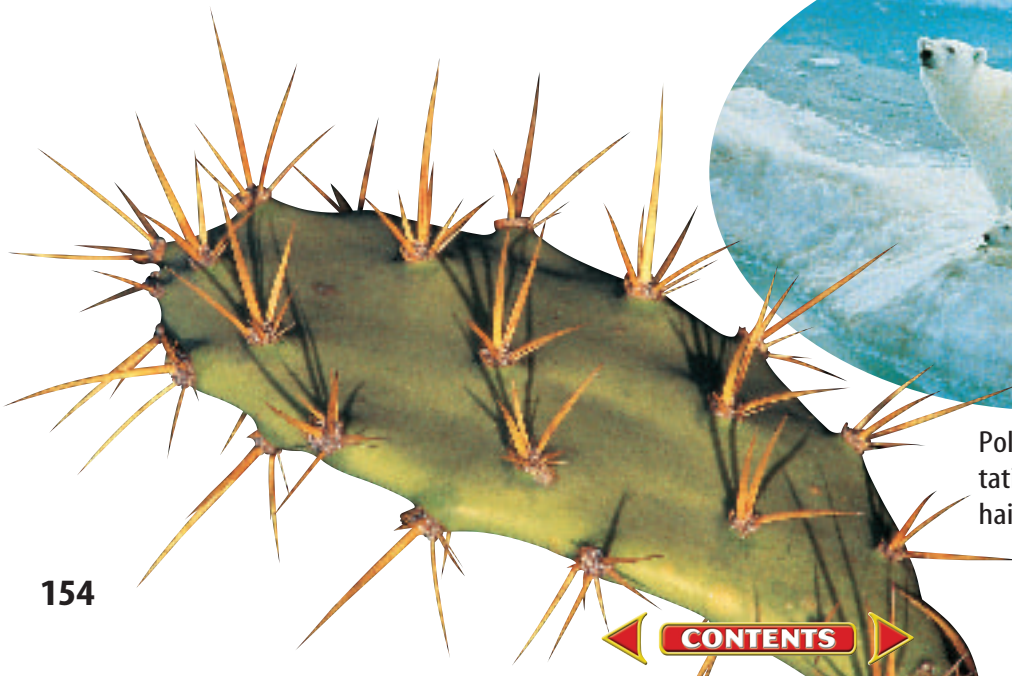
Figure 6 Organisms have structural and behavioral adaptations that help them survive in particular climates.

The needles and the waxy skin of a cactus are structural adaptations to a desert climate.

Infer how these adaptations help cacti conserve water.



These hibernating bats have adapted their behavior to survive winter.



Polar bears have structural adaptations to keep them warm. The hairs of their fur trap air and heat.



Figure 7 Lungfish survive periods of intense heat and drought by going into an inactive state called estivation. During the dry season when water evaporates, lungfish dig into the mud and curl up in a small chamber they make at the lake's bottom. During the wet season, lungfish reemerge to live in small lakes and pools.

Estivation Lungfish, shown in **Figure 7**, survive periods of intense heat by entering an inactive state called estivation (es tuh VAY shun). As the weather gets hot and water evaporates, the fish burrows into mud and covers itself in a leathery mixture of mud and mucus. It lives this way until the warm, dry months pass.

Like other organisms, you have adaptations that help you adjust to climate. In hot weather, your sweat glands release water onto your skin. The water evaporates, taking some heat with it. As a result, you become cooler. In cold weather, you may shiver to help your body stay warm. When you shiver, the rapid muscle movements produce some heat. What other adaptations to climate do people have?

section 2 review

Summary

Classifying Climates

- Climatologists classify climates into six main groups: tropical, mild, dry, continental, polar, and high elevation.

Adaptations

- Adaptations are any structures or behaviors that help an organism to survive.
- Structural adaptations such as fur, hair, and spiny needles help an organism to survive in certain climates.
- Behavioral adaptations include hibernation, a period of greatly reduced activity in winter; estivation, an inactive state during intense heat; clustering together in the cold; and obtaining water from food when water is not found elsewhere.

Self Check

1. **List** Use **Figure 5** and a world map to identify the climate type for each of the following locations: Cuba, North Korea, Egypt, and Uruguay.
2. **Compare and contrast** hibernation and estivation.
3. **Think Critically** What adaptations help dogs keep cool during hot weather?

Applying Skills

4. **Form Hypotheses** Some scientists have suggested that Earth's climate is getting warmer. What effects might this have on vegetation and animal life in various parts of the United States?
5. **Communicate** Research the types of vegetation found in the six climate regions shown in **Figure 5**. Write a paragraph in your Science Journal describing why vegetation can be used to help define climate boundaries.



Climatic Changes

as you read

What You'll Learn

- **Explain** what causes seasons.
- **Describe** how El Niño affects climate.
- **Explore** possible causes of climatic change.

Why It's Important

Changing climates could affect sea level and life on Earth.



Review Vocabulary

solar radiation: energy from the Sun transferred by waves or rays

New Vocabulary

- season
- El Niño
- greenhouse effect
- global warming
- deforestation

Earth's Seasons

In temperate zones, you can play softball under the summer Sun and in the winter go sledding with friends. Weather changes with the season. **Seasons** are short periods of climatic change caused by changes in the amount of solar radiation an area receives. **Figure 8** shows Earth revolving around the Sun. Because Earth is tilted, different areas of Earth receive changing amounts of solar radiation throughout the year.

Seasonal Changes Because of fairly constant solar radiation near the equator, the tropics do not have much seasonal temperature change. However, they do experience dry and rainy seasons. The middle latitudes, or temperate zones, have warm summers and cool winters. Spring and fall are usually mild.



Reading Check

What are seasons like in the tropics?

Figure 8 As Earth revolves around the Sun, different areas of Earth are tilted toward the Sun, which causes different seasons.

Identify During which northern hemisphere season is Earth closer to the Sun?

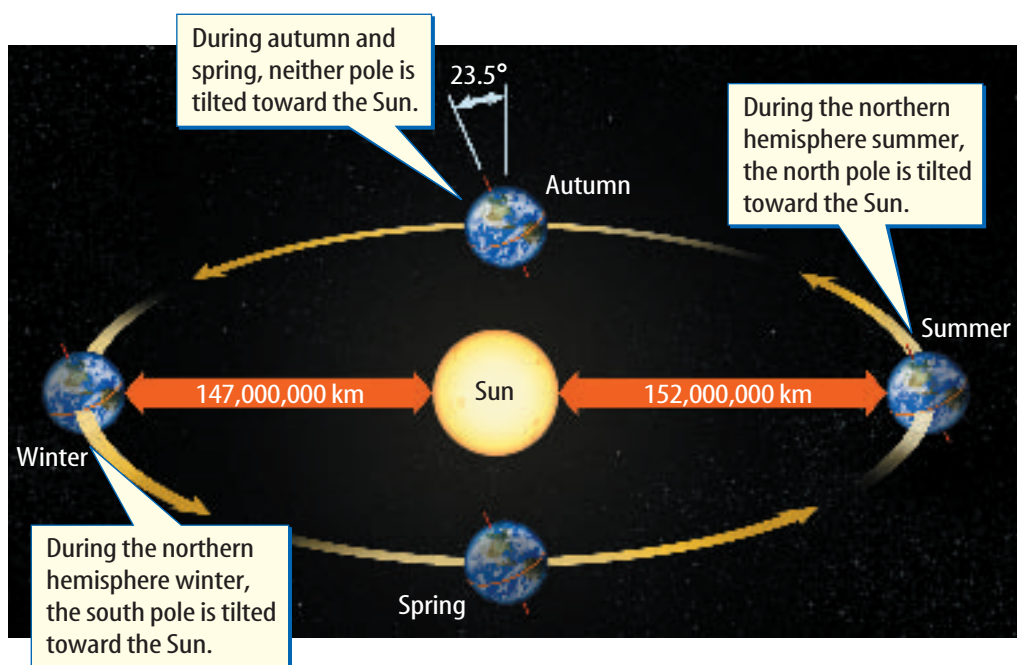




Figure 9 A strong El Niño, like the one that occurred in 1998, can affect weather patterns around the world.

A severe drought struck Indonesia, contributing to forest fires.



California was plagued by large storms that produced pounding surf and shoreline erosion.

High Latitudes During the year, the high latitudes near the poles have great differences in temperature and number of daylight hours. As shown in **Figure 8**, during summer in the northern hemisphere, the north pole is tilted toward the Sun. During summer at the north pole, the Sun doesn't set for nearly six months. During that same time, the Sun never rises at the south pole. At the equator days are about the same length all year long.

El Niño and La Niña

El Niño (el NEEN yoh) is a climatic event that involves the tropical Pacific Ocean and the atmosphere. During normal years, strong trade winds that blow east to west along the equator push warm surface water toward the western Pacific Ocean. Cold, deep water then is forced up from below along the coast of South America. During El Niño years, these winds weaken and sometimes reverse. The change in the winds allows warm, tropical water in the upper layers of the Pacific to flow back eastward to South America. Cold, deep water is no longer forced up from below. Ocean temperatures increase by 1°C to 7°C off the coast of Peru.

El Niño can affect weather patterns. It can alter the position and strength of one of the jet streams. This changes the atmospheric pressure off California and wind and precipitation patterns around the world. This can cause drought in Australia and Africa. This also affects monsoon rains in Indonesia and causes storms in California, as shown in **Figure 9**.

The opposite of El Niño is La Niña, shown in **Figure 10**. During La Niña, the winds blowing across the Pacific are stronger than normal, causing warm water to accumulate in the western Pacific. The water in the eastern Pacific near Peru is cooler than normal. La Niña may cause droughts in the southern United States and excess rainfall in the northwestern United States.



Modeling El Niño

Procedure

1. During El Niño, trade winds blowing across the Pacific Ocean from east to west slacken or even reverse. Surface waters move back toward the coast of Peru.
2. Add **warm water** to a **9-in × 13-in baking pan** until it is two-thirds full. Place the pan on a smooth countertop.
3. Blow as hard as you can across the surface of the water along the length of the pan. Next, blow with less force. Then, blow in the opposite direction.

Analysis

1. What happened to the water as you blew across its surface? What was different when you blew with less force and when you blew from the opposite direction?
2. Explain how this is similar to what happens during an El Niño event.

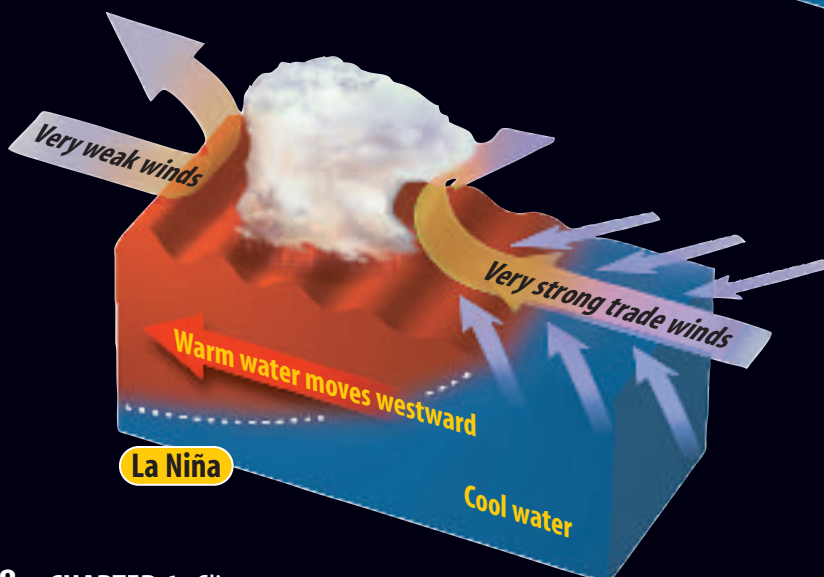
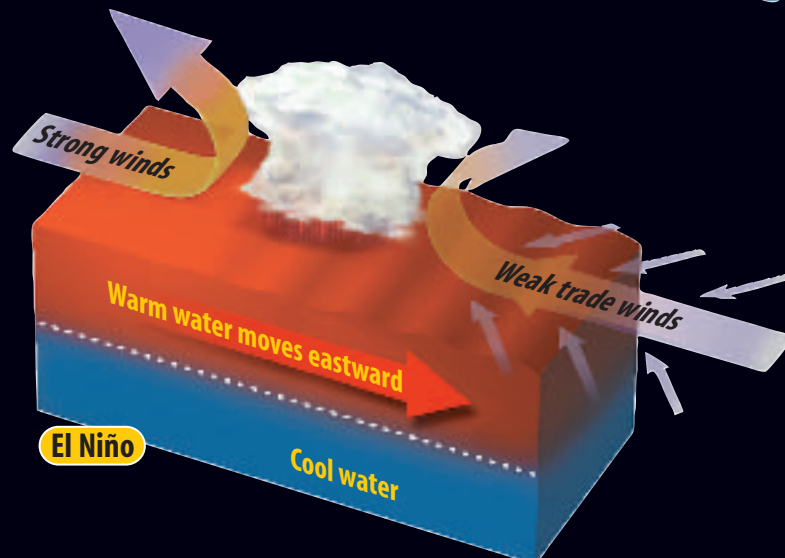
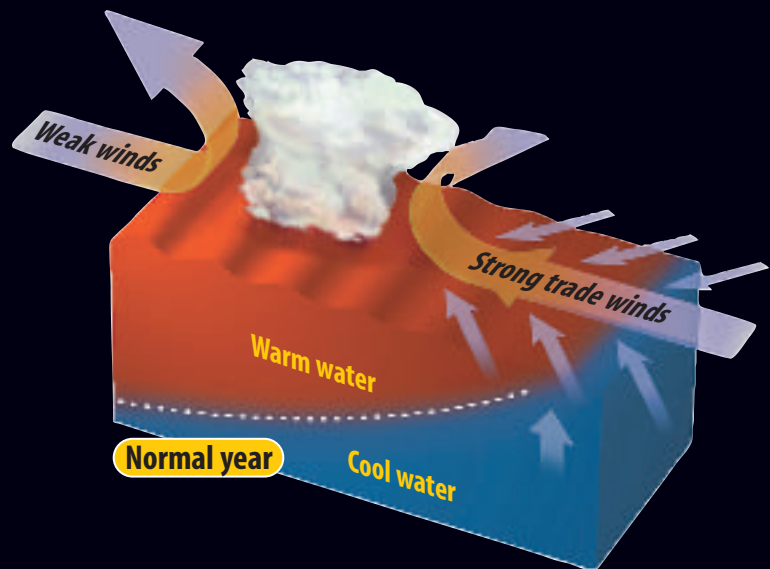




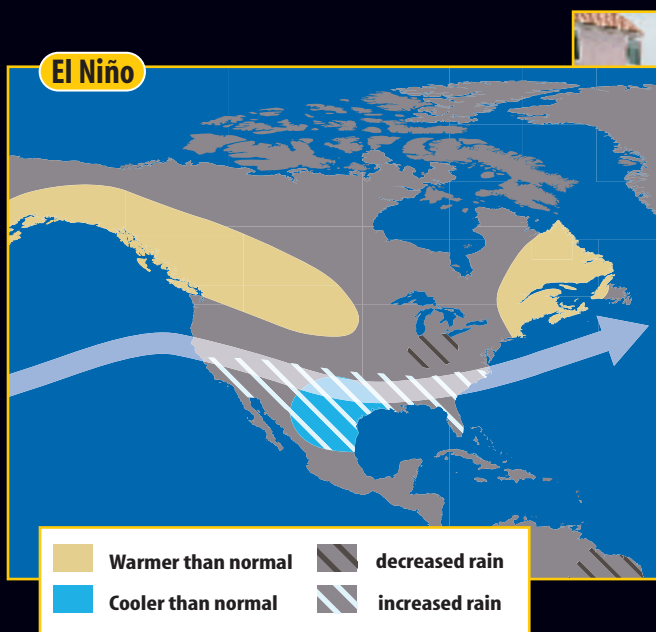
Figure 10

Weather in the United States can be affected by changes that occur thousands of kilometers away. Out in the middle of the Pacific Ocean, periodic warming and cooling of a huge mass of sea-water—phenomena known as El Niño and La Niña, respectively—can impact weather across North America. During normal years (right), when neither El Niño nor La Niña is in effect, strong winds tend to keep warm surface waters contained in the western Pacific while cooler water wells up to the surface in the eastern Pacific.

EL NIÑO During El Niño years, winds blowing west weaken and may even reverse. When this happens, warm waters in the western Pacific move eastward, preventing cold water from upwelling. These changes can alter global weather patterns and trigger heavier-than-normal precipitation across much of the United States.



LA NIÑA During La Niña years, stronger-than-normal winds push warm Pacific waters farther west, toward Asia. Cold, deep-sea waters then well up strongly in the eastern Pacific, bringing cooler and often drier weather to many parts of the United States.



Sun-warmed surface water spans the Pacific Ocean during El Niño years. Clouds form above the warm ocean, carrying moisture aloft. The jet stream, shown by the white arrow above, helps bring some of this warm, moist air to the United States.



▲ **LANDSLIDE** Heavy rains in California resulting from El Niño can lead to landslides. This upended house in Laguna Niguel, California, took a ride downhill during the El Niño storms of 1998.



During a typical La Niña year, warm ocean waters, clouds, and moisture are pushed away from North America. A weaker jet stream often brings cooler weather to the northern parts of the continent and hot, dry weather to southern areas.



▲ **PARCHED LAND** The Southeast may experience drought conditions, like those that struck the cornfields of Montgomery County, Maryland, during the La Niña summer of 1988.



Climatic Change

If you were exploring in Antarctica near Earth's south pole and found a 3-million-year-old fossil of a warm-weather plant or animal, what would it tell you? You might conclude that the climate of that region changed because Antarctica is much too cold for similar plants and animals to survive today. Some warm-weather fossils found in polar regions indicate that at times in Earth's past, worldwide climate was much warmer than at present. At other times Earth's climate has been much colder than it is today.

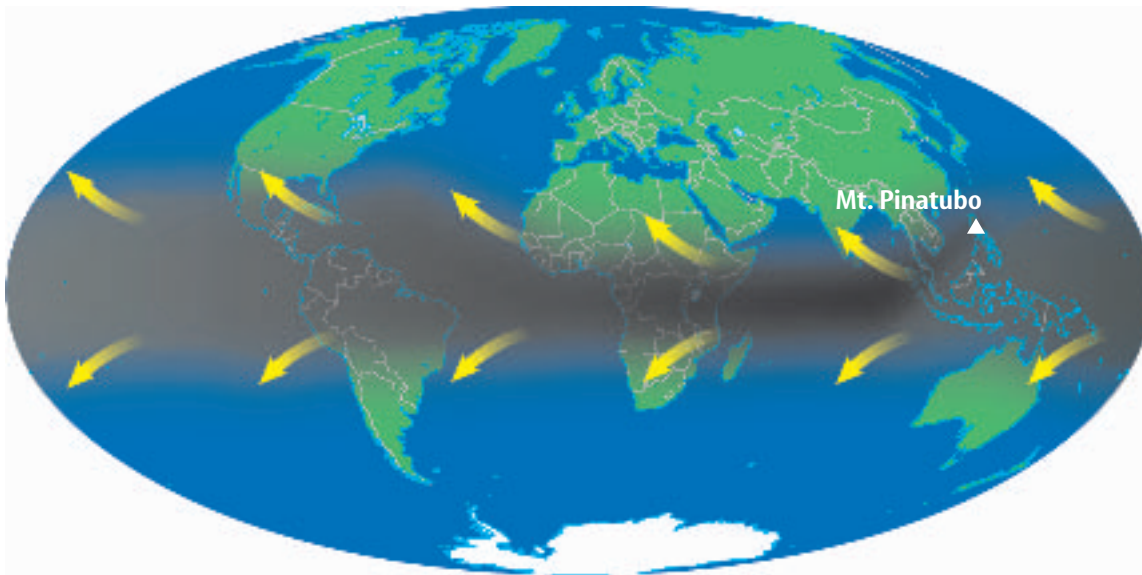
Sediments in many parts of the world show that at several different times in the past 2 million years, glaciers covered large parts of Earth's surface. These times are called ice ages. During the past 2 million years, ice ages have alternated with warm periods called interglacial intervals. Ice ages seem to last 60,000 to 100,000 years. Most interglacial periods are shorter, lasting 10,000 to 15,000 years. We are now in an interglacial interval that began about 11,500 years ago. Additional evidence suggests that climate can change even more quickly. Ice cores record climate in a way similar to tree rings. Cores drilled in Greenland show that during the last ice age, colder times lasting 1,000 to 2,000 years changed quickly to warmer spells that lasted about as long. **Figure 11** shows a scientist working with ice cores.

Figure 11 Some ice cores consist of layers of ice that record detailed climate information for individual years. These ice cores can cover more than 300,000 years. **Describe** how this is helpful.



What causes climatic change?

Climatic change has many varied causes. These causes of climatic change can operate over short periods of time or very long periods of time. Catastrophic events, including meteorite collisions and large volcanic eruptions, can affect climate over short periods of time, such as a year or several years. These events add solid particles and liquid droplets to the upper atmosphere, which can change climate. Another factor that can alter Earth's climate is short- or long-term changes in solar output, which is the amount of energy given off by the Sun. Changes in Earth's movements in space affect climate over many thousands of years, and movement of Earth's crustal plates can change climate over millions of years. All of these things can work separately or together to alter Earth's climate.



Atmospheric Solids and Liquids Small solid and liquid particles always are present in Earth's atmosphere. These particles can enter the atmosphere naturally or be added to the atmosphere by humans as pollution. Some ways that particles enter the atmosphere naturally include volcanic eruptions, soot from fires, and wind erosion of soil particles. Humans add particles to the atmosphere through automobile exhaust and smokestack emissions. These small particles can affect climate.

Catastrophic events such as meteorite collisions and volcanic eruptions put enormous volumes of dust, ash, and other particles into the atmosphere. These particles block so much solar radiation that they can cool the planet. **Figure 12** shows how a major volcanic eruption affected Earth's atmosphere.

In cities, particles put into the atmosphere as pollution can change the local climate. These particles can increase the amount of cloud cover downwind from the city. Some studies have even suggested that rainfall amounts can be reduced in these areas. This may happen because many small cloud droplets form rather than larger droplets that could produce rain.

Energy from the Sun Solar radiation provides Earth's energy. If the output of radiation from the Sun varies, Earth's climate could change. Some changes in the amount of energy given off by the Sun seem to be related to the presence of sunspots. Sunspots are dark spots on the surface of the Sun. **WARNING:** *Never look directly at the Sun.* Evidence supporting the link between sunspots and climate includes an extremely cold period in Europe between 1645 and 1715. During this time, very few sunspots appeared on the Sun.

Figure 12 Mount Pinatubo in the Philippines erupted in 1991. During the eruption, particles were spread high into the atmosphere and circled the globe. Over time, particles spread around the world, blocking some of the Sun's energy from reaching Earth. The gray areas show how particles from the eruption moved around the world.



Air Quality Control/Monitor

Atmospheric particles from pollution can affect human health as well as climate. These small particles, often called particulates, can enter the lungs and cause tissue damage. The Department of Environmental Protection employs people to monitor air pollution and its causes. Research what types of laws air quality control monitors must enforce.

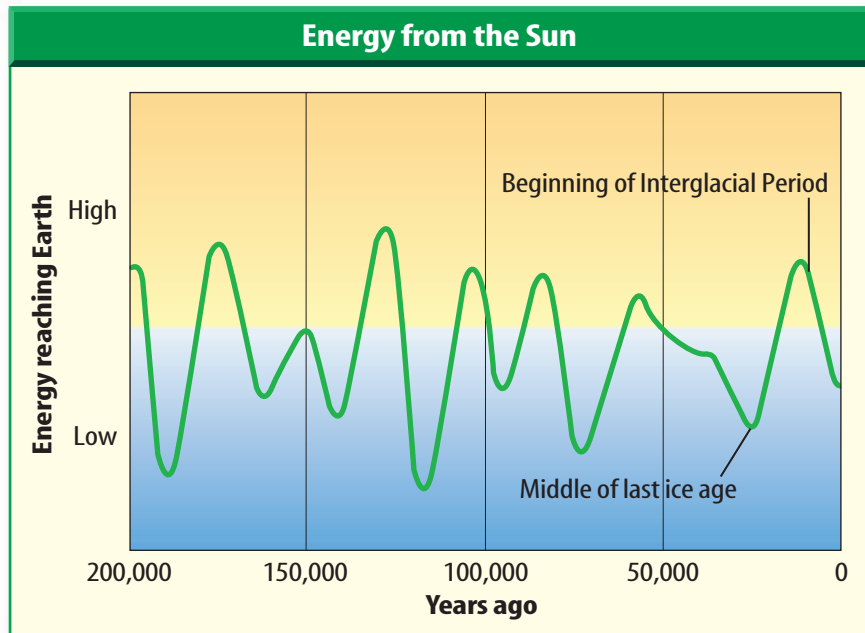


Figure 13 The curving line shows how the amount of the Sun's energy that strikes the northern hemisphere changed over the last 200,000 years.

Describe the amount of energy that reached the northern hemisphere during the last ice age.

Two additional Earth movements also cause climatic change. Earth's axis wobbles in space just like the axis of a top wobbles when it begins to spin more slowly. This can affect the amount of solar energy received by different parts of Earth. Also, the shape of Earth's orbit changes. Sometimes it is more circular than at present and sometimes it is more flattened. The shape of Earth's orbit changes over a 100,000-year cycle.

Amount of Solar Energy These movements of Earth cause the amount of solar energy reaching different parts of Earth to vary over time, as shown in **Figure 13**. These changes might have caused glaciers to grow and shrink over the last few million years. However, they do not explain why glaciers have occurred so rarely over long spans of geologic time.

Crustal Plate Movement Another explanation for major climatic change over tens or hundreds of millions of years concerns the movement of Earth's crustal plates. The movement of continents and oceans affects the transfer of heat on Earth, which in turn affects wind and precipitation patterns. Through time, these altered patterns can change climate. One example of this is when movement of Earth's plates created the Himalaya about 40 million years ago. The growth of these mountains changed climate over much of Earth.

As you've learned, many theories attempt to answer questions about why Earth's climate has changed through the ages. Probably all of these things play some role in changing climates. More study needs to be done before all the factors that affect climate will be understood.

Earth Movements Another explanation for some climatic changes involves Earth's movements in space. Earth's axis currently is tilted 23.5° from perpendicular to the plane of its orbit around the Sun. In the past, this tilt has increased to 24.5° and has decreased to 21.5° . When this tilt is at its maximum, the change between summer and winter is probably greater. Earth's tilt changes about every 41,000 years. Some scientists hypothesize that the change in tilt affects climate.



Climatic Changes Today

Beginning in 1992, representatives from many countries have met to discuss the greenhouse effect and global climate change. These subjects also have appeared frequently in the headlines of newspapers and magazines. Some people are concerned that the greenhouse effect could be responsible for some present-day warming of Earth's atmosphere and oceans.

The **greenhouse effect** is a natural heating process that occurs when certain gases in Earth's atmosphere trap heat. Radiation from the Sun strikes Earth's surface and causes it to warm. Some of this heat then is radiated back toward space. Some gases in the atmosphere, known as greenhouse gases, absorb a portion of this heat and then radiate heat back toward Earth, as shown in **Figure 14**. This keeps Earth warmer than it would be otherwise.

There are many natural greenhouse gases in Earth's atmosphere. Water vapor, carbon dioxide, and methane are some of the most important ones. Without these greenhouse gases, life would not be possible on Earth. Like Mars, Earth would be too cold. However, if the greenhouse effect is too strong, Earth could get too warm. High levels of carbon dioxide in its atmosphere indicate that this has happened on the planet Venus.



Topic: Greenhouse Effect

Visit green.msscience.com for Web links to information about the greenhouse effect.

Activity Research changes in the greenhouse effect over the last 200 years. Infer what might be causing the changes.

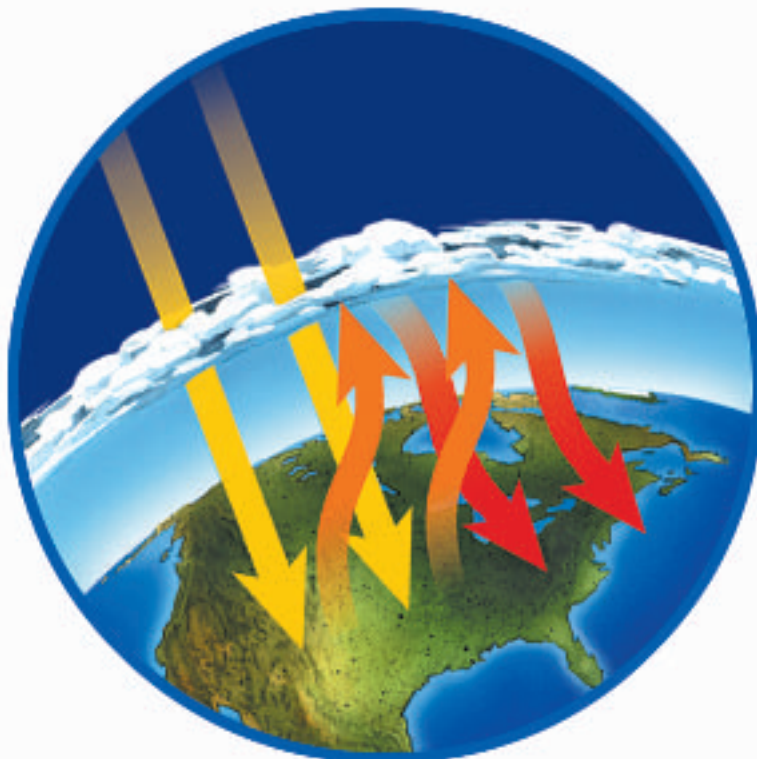


Figure 14 The Sun's radiation travels through Earth's atmosphere and heats the surface. Gases in our atmosphere trap the heat. **Compare and contrast** this to the way a greenhouse works.



Global Warming

Over the past 100 years, the average global surface temperature on Earth has increased by about 0.6°C . This increase in temperature is known as **global warming**. Over the same time period, atmospheric carbon dioxide has increased by about 20 percent. As a result, researchers hypothesize that the increase in global temperatures may be related to the increase in atmospheric carbon dioxide. Other hypotheses include the possibility that global warming might be caused by changes in the energy emitted by the Sun.

If Earth's average temperature continues to rise, many glaciers could melt. When glaciers melt, the extra water causes sea levels to rise. Low-lying coastal areas could experience increased flooding. Already some ice caps and small glaciers are beginning to melt and recede, as shown in **Figure 15**. Sea level is rising in some places. Some scientific studies show that these events are related to Earth's increased temperature.

You learned in the previous section that organisms are adapted to their environments. When environments change, can organisms cope? In some tropical waters around the world, corals are dying. Many people think these deaths are caused by warmer water to which the corals are not adapted.

Some climate models show that in the future, Earth's temperatures will increase faster than they have in the last 100 years. However, these predictions might change because of uncertainties in the climate models and in estimating future increases in atmospheric carbon dioxide.

Figure 15 This glacier in Greenland might have receded from its previous position because of global warming. The pile of sediment in front shows how far the glacier once reached.





Figure 16 When forests are cleared or burned, carbon dioxide levels increase in the atmosphere.

Human Activities

Human activities affect the air in Earth's atmosphere. Burning fossil fuels and removing vegetation increase the amount of carbon dioxide in the atmosphere. Because carbon dioxide is a greenhouse gas, it might contribute to global warming. Each year, the amount of carbon dioxide in the atmosphere continues to increase.

Burning Fossil Fuels When natural gas, oil, and coal are burned for energy, the carbon in these fossil fuels combines with atmospheric oxygen to form carbon dioxide. This increases the amount of carbon dioxide in Earth's atmosphere. Studies indicate that humans have increased carbon dioxide levels in the atmosphere by about 25 percent over the last 150 years.

Deforestation Destroying and cutting down trees, called **deforestation**, also affects the amount of carbon dioxide in the atmosphere. Forests, such as the one shown in **Figure 16**, are cleared for mining, roads, buildings, and grazing cattle. Large tracts of forest have been cleared in every country on Earth. Tropical forests have been decreasing at a rate of about one percent each year for the past two decades.

As trees grow, they take in carbon dioxide from the atmosphere. Trees use this carbon dioxide to produce wood and leaves. When trees are cut down, the carbon dioxide they could have removed from the atmosphere remains in the atmosphere. Cut-down trees often are burned for fuel or to clear the land. Burning trees produces even more carbon dioxide.



Reading Check

What can humans do to slow carbon dioxide increases in the atmosphere?



Topic: Deforestation

Visit green.msscience.com for Web links to information about deforestation.

Activity Collect data on the world's decline in forests. Infer what the world's forests will be like in 100 years.

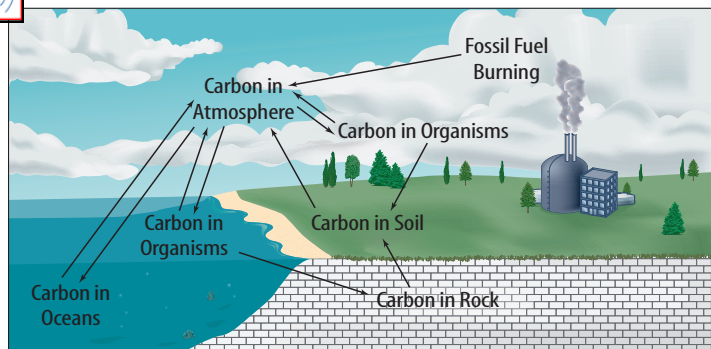


Figure 17 Carbon constantly is cycled among the atmosphere, oceans, solid earth, and biosphere.

photosynthetic organisms. Carbon dioxide is released as food is broken down to release energy. When organisms die and decay, some carbon is stored as humus in soil and some carbon is released as carbon dioxide. This carbon cycle is illustrated in **Figure 17**.

Some carbon dioxide in the atmosphere dissolves in the oceans, and is used by algae and other photosynthetic, aquatic organisms. Just as on land, aquatic organisms give off carbon dioxide. However, Earth's oceans currently absorb more carbon dioxide from the atmosphere than they give off.

When Earth's climate changes, the amount of carbon dioxide that cycles among atmosphere, ocean, and land also can change. Some people hypothesize that if Earth's climate continues to warm, more carbon dioxide may be absorbed by oceans and land. Scientists continue to collect data to study any changes in the global carbon cycle.

The Carbon Cycle

Carbon, primarily as carbon dioxide, is constantly recycled in nature among the atmosphere, Earth's oceans, and organisms that inhabit the land. Organisms that undergo photosynthesis on land and in the water take in carbon dioxide and produce and store carbon-based food. This food is consumed by non-

section 3 review

Summary

Earth's Seasons

- Seasons are short periods of climatic changes due to Earth's tilt on its axis while revolving around the Sun, causing differing amounts of solar energy to reach areas of Earth.

El Niño and La Niña

- El Niño begins in the tropical Pacific Ocean when trade winds weaken or reverse directions, disrupting the normal temperature and precipitation patterns around the globe.

Climatic Changes Today

- The greenhouse effect is a natural heating process that occurs when certain gases in Earth's atmosphere trap heat.
- Burning fossil fuels increases the amount of carbon dioxide in the air.
- Deforestation increases the amount of carbon dioxide in the atmosphere.

Self Check

- Explain** how Earth's tilted axis is responsible for seasons.
- Compare and contrast** El Niño and La Niña. What climate changes do they demonstrate?
- List** factors that can cause Earth's climate to change.
- Explain** how people are adding carbon dioxide to the atmosphere.
- Think Critically** If Earth's climate continues to warm, how might your community be affected?

Applying Skills

- Use Models** Using a globe, model the three movements of Earth in space that can cause climatic change.
- Use a word processor** to make a table that lists the different processes that might cause Earth's climate to change. Include in your table a description of the process and how it causes climate to change.

The Greenhouse Effect

Do you remember climbing into the car on a warm, sunny day? Why was it so hot inside the car when it wasn't that hot outside? It was hotter in the car because the car functioned like a greenhouse. You experienced the greenhouse effect.

Real-World Question

How can you demonstrate the greenhouse effect?

Goals

- **Model** the greenhouse effect.
- **Measure and graph** temperature changes.

Materials

identical large, empty glass jars (2)
lid for one jar
nonmercury thermometers (3)

Safety Precautions



WARNING: Be careful when you handle glass thermometers. If a thermometer breaks, do not touch it. Have your teacher dispose of the glass safely.

Procedure

1. Lay a thermometer inside each jar.
2. Place the jars next to each other by a sunny window. Lay the third thermometer between the jars.
3. **Record** the temperatures of the three thermometers. They should be the same.
4. Place the lid on one jar.
5. **Record** the temperatures of all three thermometers at the end of 5, 10, and 15 min.
6. Make a line graph that shows the temperatures of the three thermometers for the 15 min of the experiment.

Conclude and Apply

1. **Explain** why you placed a thermometer between the two jars.
2. **List** the constants in this experiment. What was the variable?
3. **Identify** which thermometer showed the greatest temperature change during your experiment.
4. **Analyze** what occurred in this experiment. How was the lid in this experiment like the greenhouse gases in the atmosphere?
5. **Infer** from this experiment why you should never leave a pet inside a closed car in warm weather.

Communicating Your Data

Give a brief speech describing your conclusions to your class.



MICROCLIMATES

Goals

- **Observe** temperature, wind speed, relative humidity, and precipitation in areas outside your school.
- **Identify** local microclimates.

Materials

thermometers
psychrometer
paper strip or wind sock
large cans (4 or 5)
* beakers or rain gauges
(4 or 5)

unlined paper

*Alternate materials

Safety Precautions



WARNING: If a thermometer breaks, do not touch it. Have your teacher dispose of the glass safely.

Real-World Question

A microclimate is a localized climate that differs from the main climate of a region. Buildings in a city, for instance, can affect the climate of the surrounding area. Large buildings, such as the Bank of America Plaza in Dallas, Texas, can create microclimates by blocking the Sun or changing wind patterns. Does your school create microclimates?

Procedure

1. Select four or five sites around your school building. Also, select a control site well away from the school.
2. Attach a thermometer to an object near each of the locations you selected. Set up a rain gauge, beaker, or can to collect precipitation.
3. Visit each site at two predetermined times, one in the morning and one in the afternoon, each day for a week. Record the temperature and measure any precipitation that might have fallen. Use a wind sock or paper strip to determine wind direction.

Relative Humidity

| Dry Bulb Temperature (°C) | Dry Bulb Temperature Minus Wet Bulb Temperature (°C) | | | | | | | | | |
|---------------------------|--|----|----|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 14 | 90 | 79 | 70 | 60 | 51 | 42 | 34 | 26 | 18 | 10 |
| 15 | 90 | 80 | 71 | 61 | 53 | 44 | 36 | 27 | 20 | 13 |
| 16 | 90 | 81 | 71 | 63 | 54 | 46 | 38 | 30 | 23 | 15 |
| 17 | 90 | 81 | 72 | 64 | 55 | 47 | 40 | 32 | 25 | 18 |
| 18 | 91 | 82 | 73 | 65 | 57 | 49 | 41 | 34 | 27 | 20 |
| 19 | 91 | 82 | 74 | 65 | 58 | 50 | 43 | 36 | 29 | 22 |
| 20 | 91 | 83 | 74 | 66 | 59 | 51 | 44 | 37 | 31 | 24 |
| 21 | 91 | 83 | 75 | 67 | 60 | 53 | 46 | 39 | 32 | 26 |
| 22 | 92 | 83 | 76 | 68 | 61 | 54 | 47 | 40 | 34 | 28 |
| 23 | 92 | 84 | 76 | 69 | 62 | 55 | 48 | 42 | 36 | 30 |
| 24 | 92 | 84 | 77 | 69 | 62 | 56 | 49 | 43 | 37 | 31 |
| 25 | 92 | 84 | 77 | 70 | 63 | 57 | 50 | 44 | 39 | 33 |

Using Scientific Methods

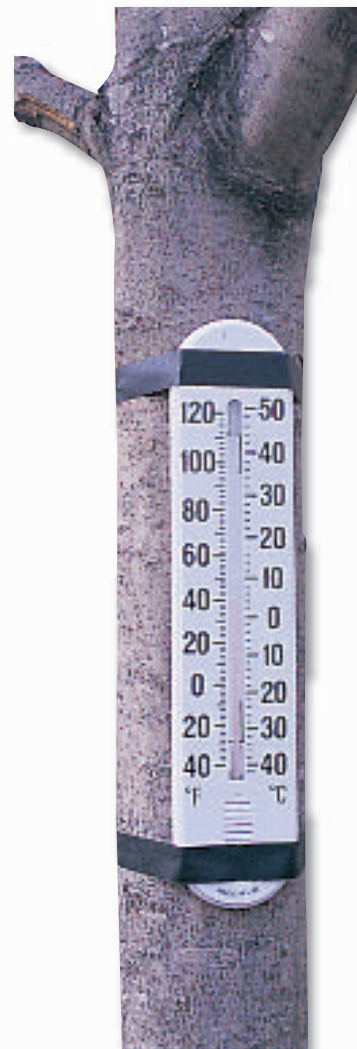
4. To find relative humidity, you'll need to use a psychrometer. A psychrometer is an instrument with two thermometers—one wet and one dry. As moisture from the wet thermometer evaporates, it takes heat energy from its environment, and the environment immediately around the wet thermometer cools. The thermometer records a lower temperature. Relative humidity can be found by finding the difference between the wet thermometer and the dry thermometer and by using the chart on the previous page. Record all of your weather data.

Analyze Your Data

1. Make separate line graphs for temperature, relative humidity, and precipitation for your morning and afternoon data. Make a table showing wind direction data.
2. **Compare and contrast** weather data for each of your sites. What microclimates did you identify around your school building? How did these climates differ from the control site? How did they differ from each other?

Conclude and Apply

1. **Explain** Why did you take weather data at a control site away from the school building? How did the control help you analyze and interpret your data?
2. **Infer** what conditions could have caused the microclimates that you identified. Are your microclimates similar to those that might exist in a large city? Explain.



Communicating Your Data

Use your graphs to make a large poster explaining your conclusions. Display your poster in the school building. **For more help, refer to the Science Skill Handbook.**

The Year there was No Summer

You've seen pictures of erupting volcanoes. One kind of volcano sends smoke, rock, and ash high into the air above the crater. Another kind of volcano erupts with fiery, red-hot rivers of lava snaking down its sides. Erupting volcanoes are nature's forces at their mightiest, causing destruction and death. But not everyone realizes how far-reaching the destruction can be. Large volcanic eruptions can affect people thousands of kilometers away. In fact, major volcanic eruptions can have effects that reach around the globe.

An erupting volcano can temporarily change Earth's climate. The ash a volcano ejects into the atmosphere can create day after day without sunshine. Other particles move high into the atmosphere and are carried all the way around Earth, sometimes causing global temperatures to drop for several months.

The Summer That Never Came

An example of a volcanic eruption with wide-ranging effects occurred in 1783 in Iceland, an island nation in the North Atlantic Ocean. Winds carried a black cloud of ash from an erupting volcano in Iceland westward across northern Canada, Alaska, and across the Pacific Ocean to Japan. The summer turned bitterly cold in these places. Water froze, and heavy snowstorms pelted the land. Sulfurous gases from the erupting volcano combined with water to form particles of acid that reflected solar energy back into space. This "blanket" in the atmosphere kept the Sun's rays from heating up part of Earth.

The most tragic result of this eruption was the death of many Kauwerak people, who lived in western Alaska. Only a handful of Kauwerak survived the summer that never came. They had no opportunity to catch needed foods to keep them alive through the following winter.

Locate Using an atlas, locate Indonesia and Iceland. Using reference materials, find five facts about each place. Make a map of each nation and illustrate the map with your five facts.

Science  **online**

For more information, visit
green.msscience.com/time

Reviewing Main Ideas

Section 1 What is climate?

1. An area's climate is the average weather over a long period of time, such as 30 years.
2. The three main climate zones are tropical, polar, and temperate.
3. Features such as oceans, mountains, and even large cities affect climate.

Section 2 Climate Types

1. Climates can be classified by various characteristics, such as temperature, precipitation, and vegetation. World climates commonly are separated into six major groups.
2. Organisms have structural and behavioral adaptations that help them survive in particular climates. Many organisms can survive only in the climate they are adapted to.

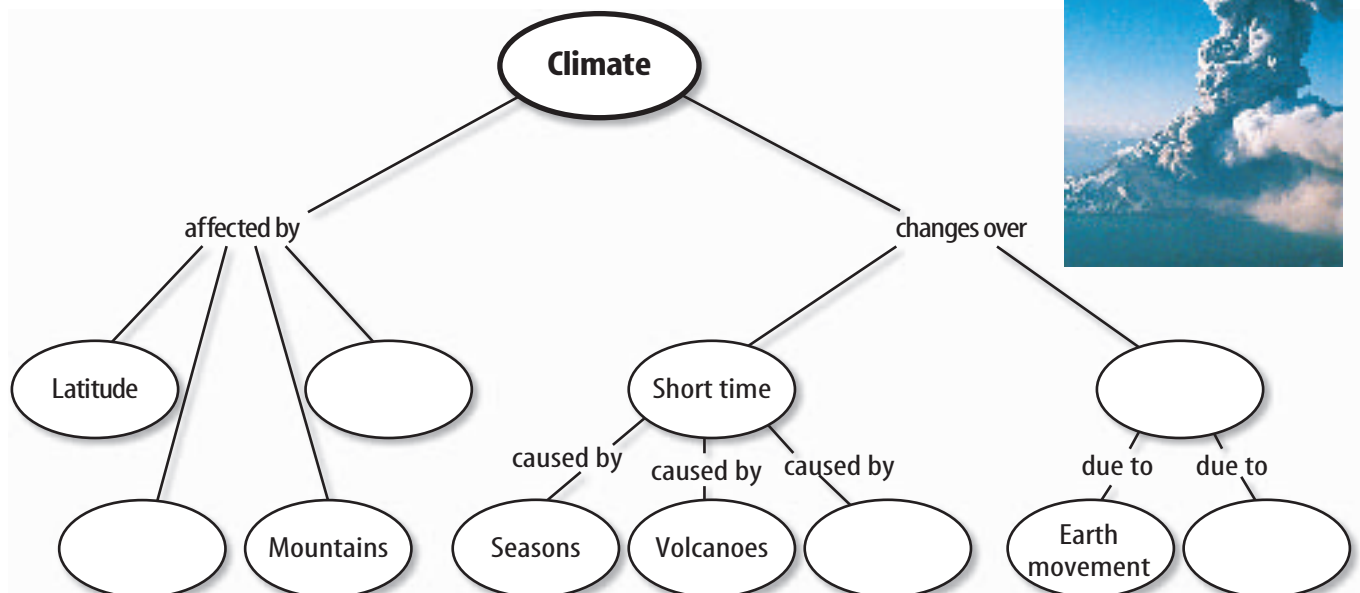
3. Adaptations develop in a population over a long period of time.

Section 3 Climatic Changes

1. Seasons are caused by the tilt of Earth's axis as Earth revolves around the Sun.
2. El Niño disrupts normal temperature and precipitation patterns around the world.
3. Geological records show that over the past few million years, Earth's climate has alternated between ice ages and warmer periods.
4. The greenhouse effect occurs when certain gases trap heat in Earth's atmosphere.
5. Carbon dioxide enters the atmosphere when fossil fuels such as oil and coal are burned.

Visualizing Main Ideas

Copy and complete the following concept map on climate.



Using Vocabulary

| | |
|--------------------------|-----------------------|
| adaptation p. 152 | hibernation p. 154 |
| climate p. 148 | polar zone p. 148 |
| deforestation p. 165 | season p. 156 |
| El Niño p. 157 | temperate zone p. 148 |
| global warming p. 164 | tropics p. 148 |
| greenhouse effect p. 163 | |

Fill in the blanks with the correct vocabulary word or words.

1. Earth's north pole is in the _____.
2. _____ causes the Pacific Ocean to become warmer off the coast of Peru.
3. During _____, an animal's body temperature drops.
4. _____ is the pattern of weather that occurs over many years.
5. _____ means global temperatures are rising.

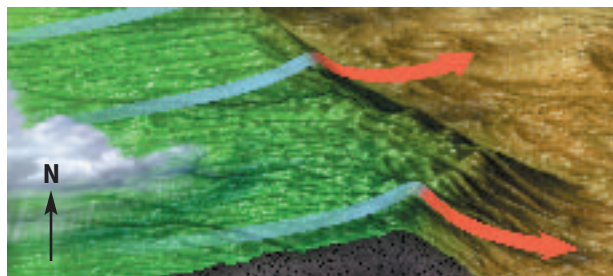
Checking Concepts

Choose the word or phrase that best answers the question.

6. Which of the following is a greenhouse gas in Earth's atmosphere?
A) helium C) hydrogen
B) carbon dioxide D) oxygen
7. During which of the following is the eastern Pacific warmer than normal?
A) El Niño C) summer
B) La Niña D) spring
8. Which latitude receives the most direct rays of the Sun year-round?
A) 60°N C) 30°S
B) 90°N D) 0°

9. What happens as you climb a mountain?
A) temperature decreases
B) temperature increases
C) air pressure increases
D) air pressure remains constant
10. Which of the following is true of El Niño?
A) It cools the Pacific Ocean near Peru.
B) It causes flooding in Australia.
C) It cools the waters off Alaska.
D) It may occur when the trade winds slacken or reverse.
11. What do changes in Earth's orbit affect?
A) Earth's shape C) Earth's rotation
B) Earth's climate D) Earth's tilt
12. The Köppen climate classification system includes categories based on precipitation and what other factor?
A) temperature C) winds
B) air pressure D) latitude
13. Which of the following is an example of structural adaptation?
A) hibernation C) fur
B) migration D) estivation
14. Which of these can people do in order to help reduce global warming?
A) burn coal C) conserve energy
B) remove trees D) produce methane

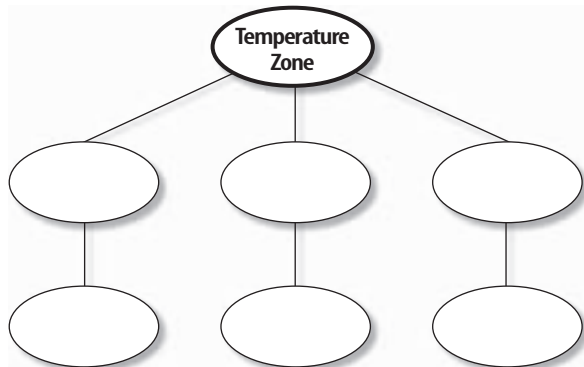
Use the illustration below to answer question 15.



15. What would you most likely find on the leeward side of this mountain range?
A) lakes C) deserts
B) rain forests D) glaciers

Thinking Critically

16. **Draw a Conclusion** How could climate change cause the types of organisms in an area to change?
17. **Infer** What might you infer if you find fossils of tropical plants in a desert?
18. **Describe** On a summer day, why would a Florida beach be cooler than an orange grove that is 2 km inland?
19. **Infer** what would happen to global climates if the Sun emitted more energy.
20. **Explain** why it will be cooler if you climb to a higher elevation in a desert.
21. **Communicate** Explain how atmospheric pressure over the Pacific Ocean might affect how the trade winds blow.
22. **Predict** Make a chain-of-events chart to explain the effect of a major volcanic eruption on climate.
23. **Form Hypotheses** A mountain glacier in South America has been getting smaller over several decades. What hypotheses should a scientist consider to explain why this is occurring?
24. **Concept Map** Copy and complete the concept map using the following: *tropics*, 0° – 23.5° latitude, *polar*, *temperate*, 23.5° – 66.5° latitude, and 66.5° latitude to poles.



25. **Explain** how global warming might lead to the extinction of some organisms.
26. **Describe** how dust and ash from large volcanoes can change the atmosphere.
27. **Explain** how heat energy carried by ocean currents influences climate.
28. **Describe** how sediments, fossils, and ice cores record Earth's geologic history.
29. **Describe** how volcanic eruptions or meteorite collisions have changed past climates.

Performance Activities

30. **Science Display** Make a display illustrating different factors that can affect climate. Be sure to include detailed diagrams and descriptions for each factor in your display. Present your display to the class.

Applying Math

Use the table below to answer questions 31 and 32.

Precipitation in Phoenix, Arizona

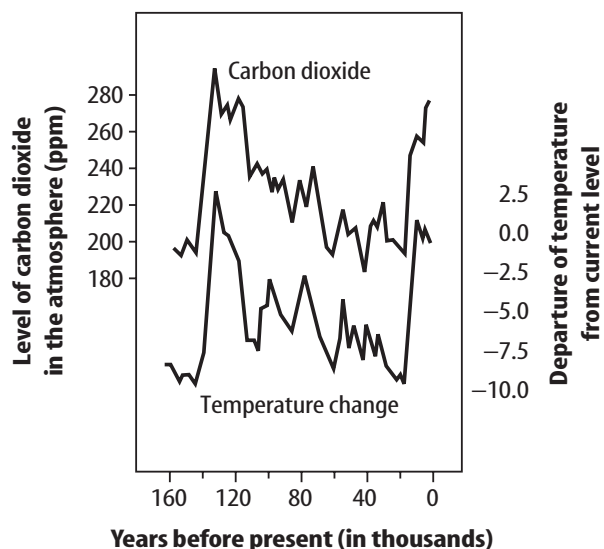
| Season | Precipitation (cm) |
|--------|--------------------|
| Winter | 5.7 |
| Spring | 1.2 |
| Summer | 6.7 |
| Autumn | 5.9 |
| Total | 19.5 |

31. **Precipitation Amounts** The following table gives average precipitation amounts for Phoenix, Arizona. Make a bar graph of these data. Which climate type do you think Phoenix represents?
32. **Local Precipitation** Use the table above to help estimate seasonal precipitation for your city or one that you choose. Create a bar graph for that data.

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the graph below to answer questions 1 and 2.



- Which of these statements is true according to the graph?
 - Earth's mean temperature has never been hotter than it is today.
 - The level of CO_2 has never been higher than today.
 - The mean global temperature 60,000 years ago was less than today.
 - The level of CO_2 in the atmosphere 80,000 years ago was 280 parts per million.
- Which of the following statements best describes this graph?
 - As CO_2 levels have increased, so has global temperature.
 - As CO_2 levels have increased, global temperature has decreased.
 - As global temperature has increased, CO_2 levels have decreased.
 - No relationship exists between CO_2 and global temperatures.

Use the table below to answer question 3.

| Apparent Temperature Index | | | | | |
|----------------------------|----|----|----|-----|-----|
| Relative Humidity (%) | | | | | |
| Air Temperature (°F) | | 80 | 85 | 90 | 95 |
| | 85 | 97 | 99 | 102 | 105 |
| | 80 | 86 | 87 | 88 | 89 |
| | 75 | 78 | 78 | 79 | 79 |
| | 70 | 71 | 71 | 71 | 71 |

- The National Weather Service created the Apparent Temperature Index to show the temperature the human body feels when heat and humidity are combined. If the relative humidity is 85% and the temperature is 75°F, what is the apparent temperature?
 - 78°F
 - 79°F
 - 88°F
 - 89°F
- What is the most likely reason that the air temperature is warmest at the tropical latitudes?
 - These latitudes receive the most solar radiation because there are no clouds.
 - These latitudes receive the most solar radiation because the sun's angle is high.
 - These latitudes receive the least solar radiation because the sun's angle is low.
 - These latitudes receive the least solar radiation because of heavy cloud cover.

Test-Taking Tip

Qualifiers Look for quantifiers in a question. Such questions are not looking for absolute answers. Qualifiers would be words such as *most likely*, *most common*, or *least common*.

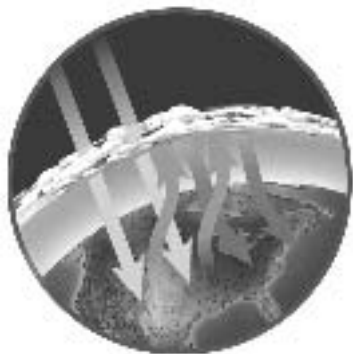
Question 4 Look for the most likely scientific explanation.

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

5. Explain how a large body of water can affect the climate of a nearby area.
6. Describe the relationship between ocean currents and precipitation in a coastal region.
7. The city of Redmond, Oregon is near the Cascade Mountain Range. The average annual rainfall for the Redmond, OR area is about 8 inches. Infer whether Redmond, OR is located on the windward side or leeward side of the mountain range. Explain your answer.

Use the figure below to answer question 8.

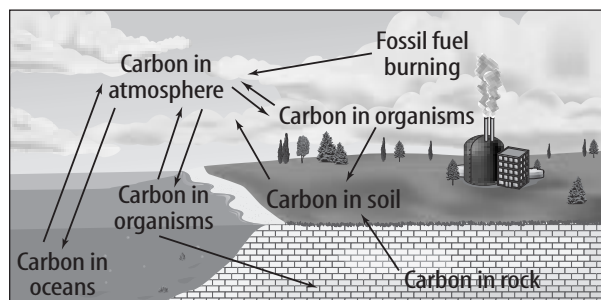


8. What is the greenhouse effect?
9. List three greenhouse gases.
10. How does the greenhouse effect positively affect life on Earth? How could it negatively affect life on Earth?
11. Explain why the temperature of a city can be up to 5°C warmer than the surrounding rural areas.
12. What are the different ways in which solid and liquid particles enter the Earth's atmosphere?

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the figure below to answer questions 13–15.



13. Describe the carbon cycle. Explain how carbon is transferred from organisms to soil.
14. How does the burning of fossil fuels affect the amount of carbon dioxide entering the carbon cycle?
15. How does deforestation affect the amount of carbon dioxide entering the carbon cycle?
16. In 1991 Mt. Pinatubo erupted, releasing volcanic particulates into the atmosphere. Temperatures around the world fell by as much as 0.7°C below average during 1992. How was this global temperature change related to the volcanic eruption?
17. What is global warming? What hypotheses help explain global warming? Explain the relationship between global warming and the level of seawater.
18. A scientist analyzes the pollen of ancient plants found preserved in lake sediments. The pollen is determined to be from a plant that needs moisture and year-round warm temperatures to grow. Make an inference about the type of climate that area experienced during the time the plant lived.