Section 1

Water in the Atmosphere

Reading Focus

Key Concepts

- What is humidity and how is it measured?
- How do clouds form?
- What are the three main types of clouds?

Key Terms

- water cycle • evaporation
- humidity • relative humidity
- psychrometer • condensation
- dew point • cirrus
- cumulus • stratus

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask *what* or *how* questions for each heading. As you read, write answers to your questions.

The Water Cycle

Question	Answer
How does the water cycle work?	During the water cycle . . .

Lab zone Standards Warm-Up

How Does Fog Form?

1. Fill a narrow-necked plastic bottle with hot tap water. Pour out most of the water, leaving about 3 cm at the bottom. **CAUTION:** *Avoid spilling hot water. Do not use water that is so hot that you cannot safely hold the bottle.*
2. Place an ice cube on the mouth of the bottle. What happens?
3. Repeat Steps 1 and 2 using cold water instead of hot water. What happens?

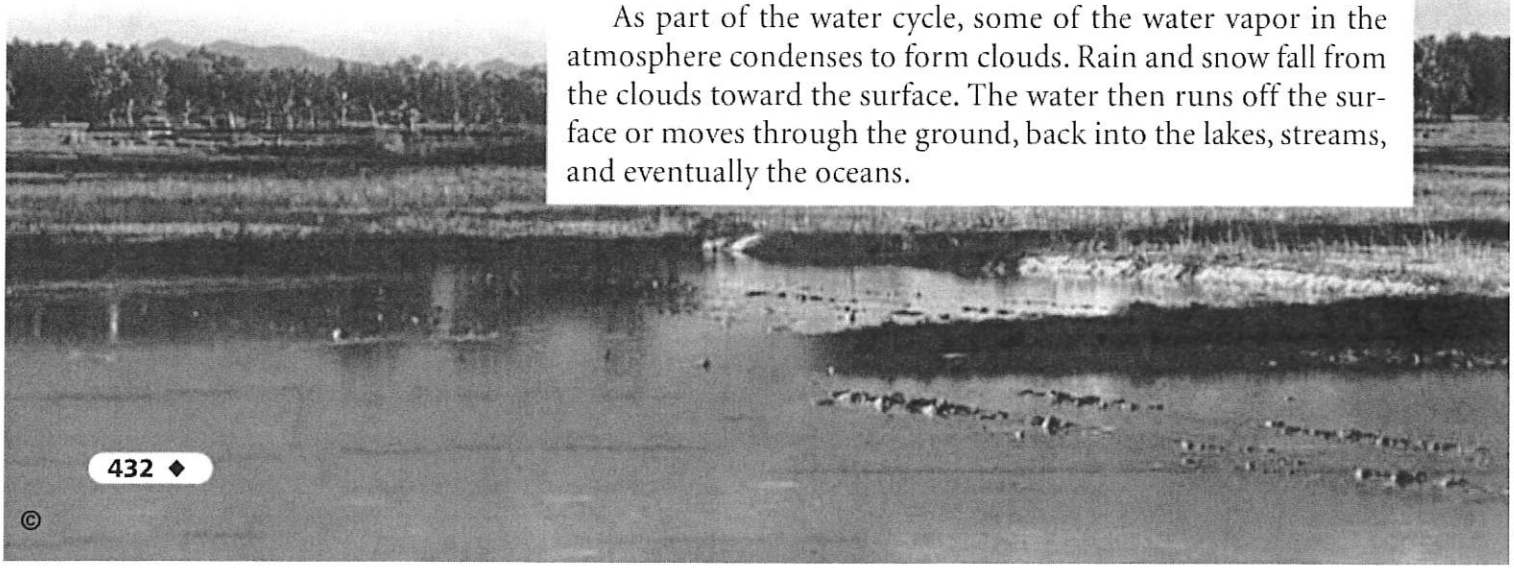
Think It Over

Developing Hypotheses How can you explain your observations? Why is there a difference between what happens with the hot water and what happens with the cold water?

During a rainstorm, the air feels moist. On a clear, cloudless day, the air may feel dry. As the sun heats the land and oceans, the amount of water in the atmosphere changes. Water is always moving between the atmosphere and Earth's surface.

The movement of water between the atmosphere and Earth's surface is called the **water cycle.** As you can see in Figure 1, water vapor enters the air by evaporation from the oceans and other bodies of water. **Evaporation** is the process by which water molecules in liquid water escape into the air as water vapor. Water vapor is also added to the air by living things. Water enters the roots of plants, rises to the leaves, and is released as water vapor.

As part of the water cycle, some of the water vapor in the atmosphere condenses to form clouds. Rain and snow fall from the clouds toward the surface. The water then runs off the surface or moves through the ground, back into the lakes, streams, and eventually the oceans.



Humidity

How is the quantity of water vapor in the atmosphere measured? **Humidity** is a measure of the amount of water vapor in the air. Air's ability to hold water vapor depends on its temperature. Warm air can hold more water vapor than cool air.

Relative Humidity Weather reports usually refer to the water vapor in the air as relative humidity. **Relative humidity** is the percentage of water vapor that is actually in the air compared to the maximum amount of water vapor the air can hold at a particular temperature. For example, at 10°C, 1 cubic meter of air can hold at most 8 grams of water vapor. If there actually were 8 grams of water vapor in the air, then the relative humidity of the air would be 100 percent. Air with a relative humidity of 100 percent is said to be saturated. If the air had 4 grams of water vapor, the relative humidity would be half, or 50 percent.

FIGURE 1
Water Cycle
In the water cycle, water moves from oceans, lakes, rivers, and plants into the atmosphere and then falls back to Earth.

Go Online
active art

For: Water Cycle Activity
Visit: PHSchool.com
Web Code: cfp-4024

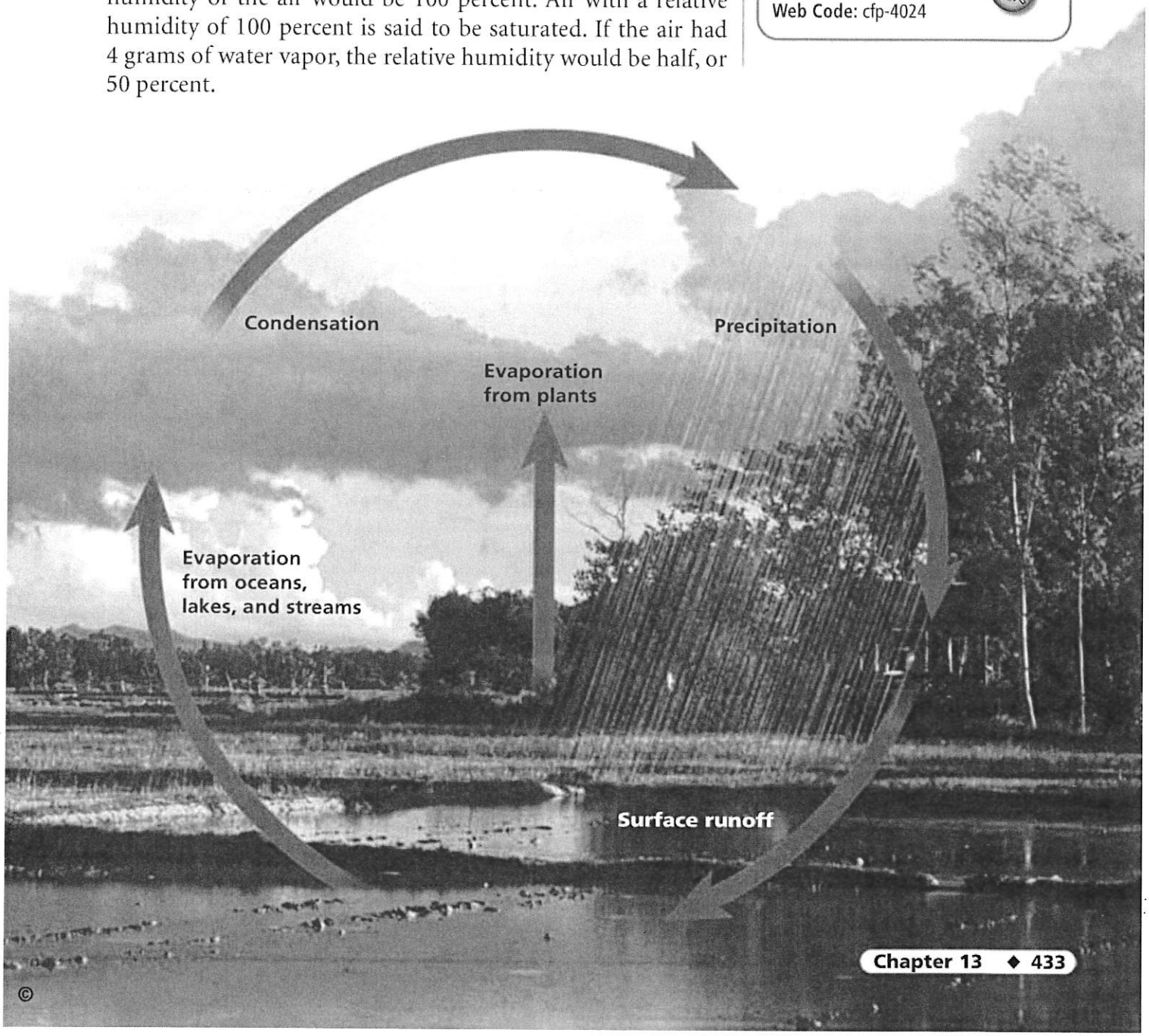


FIGURE 2
Sling Psychrometer
A sling psychrometer is used to measure relative humidity.

Measuring Relative Humidity **Relative humidity can be measured with an instrument called a psychrometer.** A psychrometer (sy KRAHM uh tur) has two thermometers, a wet-bulb thermometer and a dry-bulb thermometer, as shown in Figure 2. The bulb of the wet-bulb thermometer has a cloth covering that is moistened with water. When the psychrometer is "slung," or spun by its handle, air blows over both thermometers. Because the wet-bulb thermometer is cooled by evaporation, its reading drops below that of the dry-bulb thermometer.

If the relative humidity is high, the water on the wet bulb evaporates slowly, and the wet-bulb temperature does not change much. If the relative humidity is low, the water on the wet bulb evaporates rapidly, and the wet-bulb temperature drops. The relative humidity can be found by comparing the temperatures of the wet-bulb and dry-bulb thermometers.

Reading Checkpoint **What instrument measures relative humidity?**

Math Analyzing Data

Determining Relative Humidity

Relative humidity is affected by temperature. Use the data table to answer the questions below. First, find the dry-bulb temperature in the left column of the table. Then find the difference between the wet- and dry-bulb temperatures across the top of the table. The number in the table where these two readings intersect indicates the relative humidity in percent.

1. Interpreting Data At noon, the readings on a sling psychrometer are 18°C for the dry-bulb thermometer and 14°C for the wet-bulb thermometer. What is the relative humidity?
2. Interpreting Data At 5 P.M., the psychrometer is used again. The reading on the dry-bulb thermometer is 12°C, and the reading on the wet-bulb thermometer is 11°C. Determine the new relative humidity.
3. Interpreting Data How did the temperature change between noon and 5 P.M.?

Relative Humidity

Dry-Bulb Reading (°C)	Difference Between Wet- and Dry-Bulb Readings (°C)				
	1	2	3	4	5
10	88	76	65	54	43
12	88	78	67	57	48
14	89	79	69	60	50
16	90	80	71	62	54
18	91	81	72	64	56
20	91	82	74	66	58
22	92	83	75	68	60

4. Interpreting Data How did relative humidity change during the course of the day?
5. Drawing Conclusions How was the relative humidity affected by air temperature? Explain your answer.

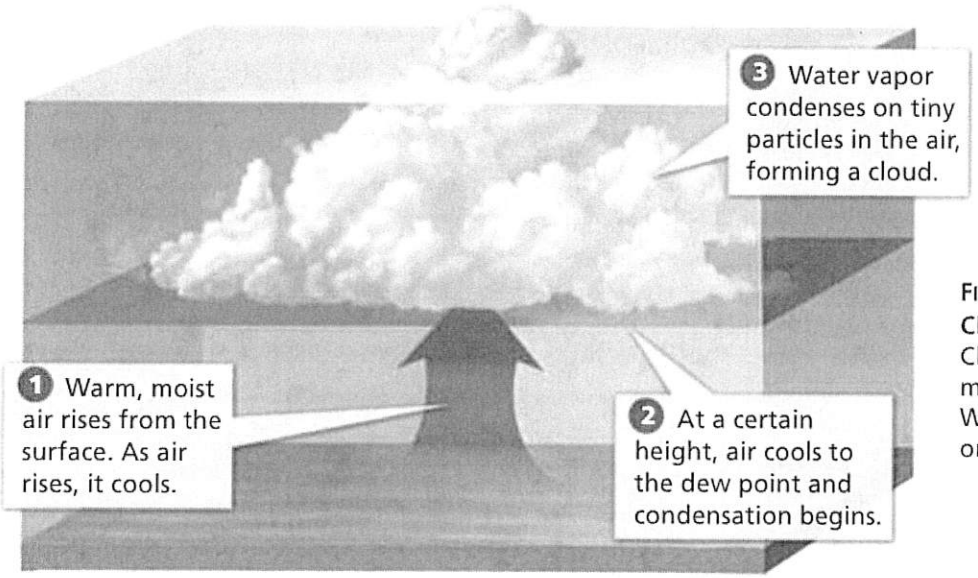


FIGURE 3
Cloud Formation
Clouds form when warm, moist air rises and cools. Water vapor condenses onto tiny particles in the air.

How Clouds Form

When you look at a cloud, you are seeing millions of tiny water droplets or ice crystals. **Clouds form when water vapor in the air condenses to form liquid water or ice crystals.** Molecules of water vapor in the air become liquid water in the process of condensation. How does water in the atmosphere condense? Two conditions are required for condensation: cooling of the air and the presence of particles in the air.

The Role of Cooling As you have learned, cold air holds less water vapor than warm air. As air cools, the amount of water vapor it can hold decreases. The water vapor condenses into tiny droplets of water or ice crystals.

The temperature at which condensation begins is called the dew point. If the dew point is above freezing, the water vapor forms water droplets. If the dew point is below freezing, the water vapor may change directly into ice crystals.

The Role of Particles But something else besides a change in temperature is needed for cloud formation. For water vapor to condense, tiny particles must be present so the water has a surface on which to condense. In cloud formation, most of these particles are salt crystals, dust from soil, and smoke. Water vapor also condenses onto solid surfaces, such as blades of grass or window panes. Liquid water that condenses from the air onto a cooler surface is called dew. Ice that has been deposited on a surface that is below freezing is called frost.

Reading Checkpoint **What two factors are required for condensation to occur?**

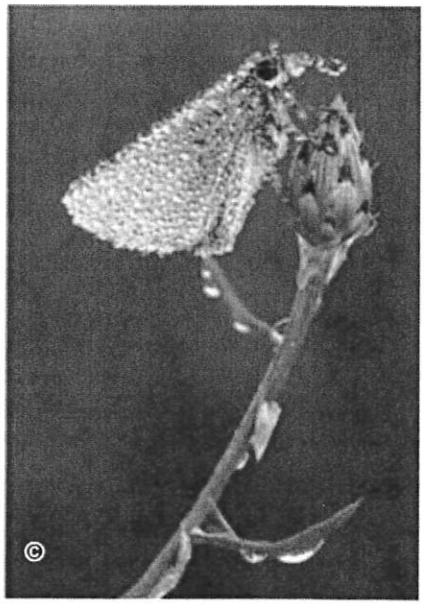
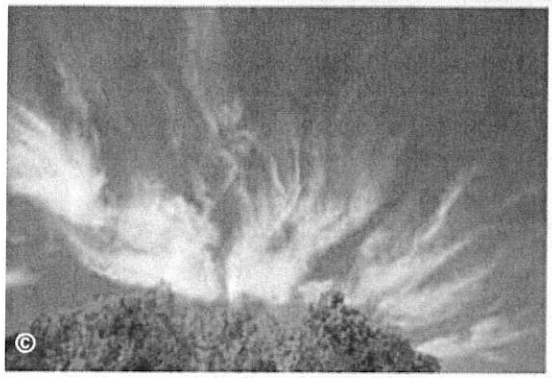


FIGURE 4
Condensation
Water vapor condensed on this insect to form dew. Predicting *What would happen if the surface were below freezing?*

Types of Clouds

Clouds come in many different shapes, as shown in Figure 5. **Scientists classify clouds into three main types based on their shape: cirrus, cumulus, and stratus. Clouds are further classified by their altitude.** Each type of cloud is associated with a different type of weather.

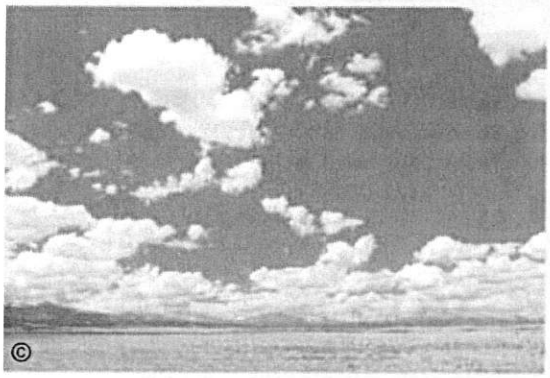
Cirrus Clouds



Cirrus Clouds Wispy, feathery clouds are known as **cirrus** (SEER us) clouds. *Cirrus* comes from a word meaning a curl of hair. Cirrus clouds form only at high levels, above about 6 kilometers, where temperatures are very low. As a result, cirrus clouds are made of ice crystals.

Cirrus clouds that have feathery "hooked" ends are sometimes called mare's tails. Cirrocumulus clouds, which look like rows of cotton balls, often indicate that a storm is on its way. The rows of cirrocumulus clouds look like the scales of a fish. For this reason, the term "mackerel sky" is used to describe a sky full of cirrocumulus clouds.

Cumulus Clouds



Cumulus Clouds Clouds that look like fluffy, rounded piles of cotton are called **cumulus** (KYOO myuh lus) clouds. The word *cumulus* means "heap" or "mass" in Latin. Cumulus clouds form less than 2 kilometers above the ground, but they may grow in size and height until they extend upward as much as 18 kilometers. Cumulus clouds that are not very tall usually indicate fair weather. These clouds, which are common on sunny days, are called "fair weather cumulus." Towering clouds with flat tops, called cumulonimbus clouds, often produce thunderstorms. The suffix *-nimbus* means "rain."

Stratus Clouds

Stratus Clouds Clouds that form in flat layers are called **stratus** (STRAT us) clouds. Recall that *strato* means "spread out." Stratus clouds usually cover all or most of the sky and are a uniform dull, gray color. As stratus clouds thicken, they may produce drizzle, rain, or snow. They are then called nimbostratus clouds.

Reading Checkpoint **What are stratus clouds?**

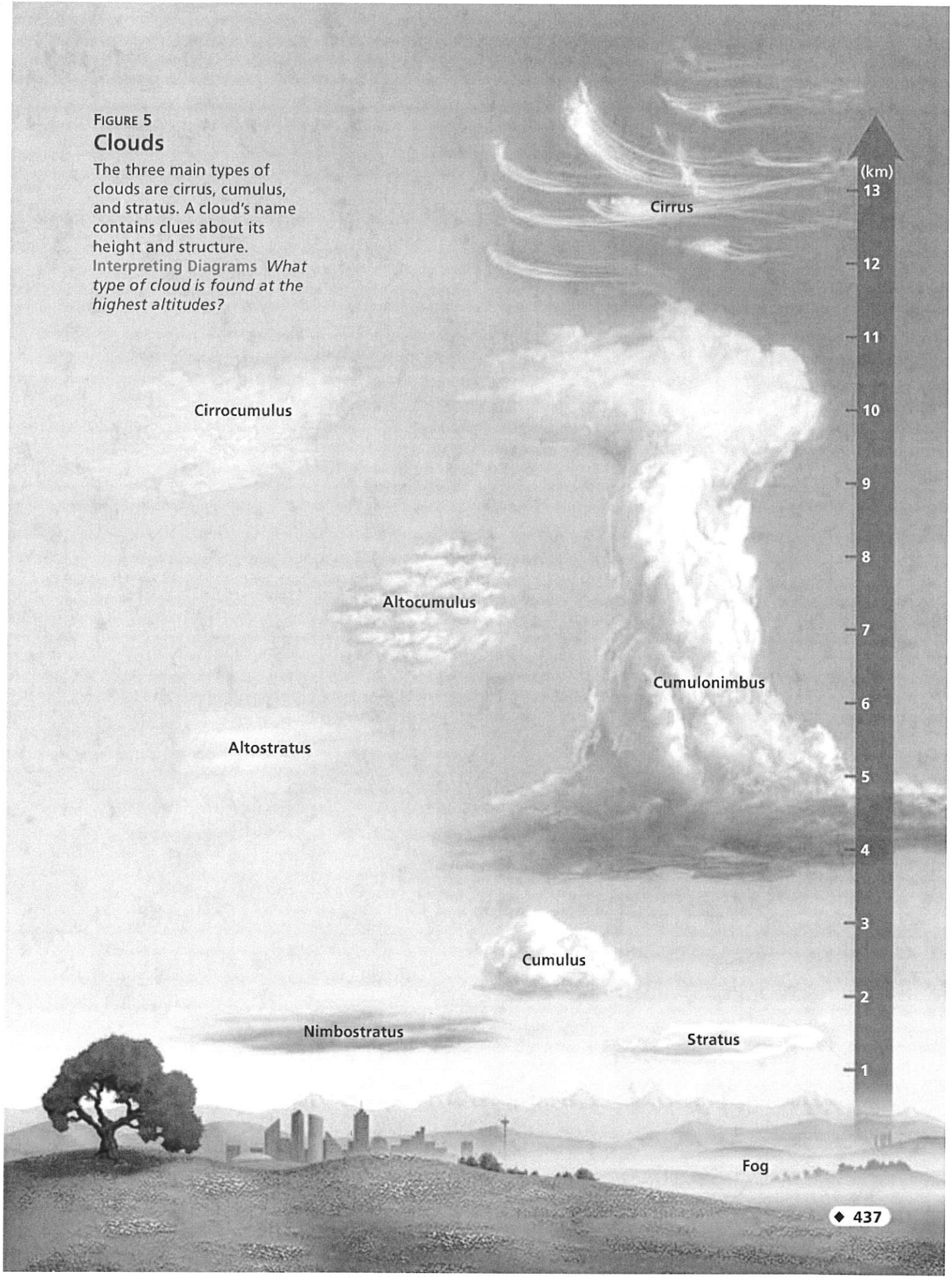


FIGURE 5

Clouds

The three main types of clouds are cirrus, cumulus, and stratus. A cloud's name contains clues about its height and structure.

Interpreting Diagrams *What type of cloud is found at the highest altitudes?*

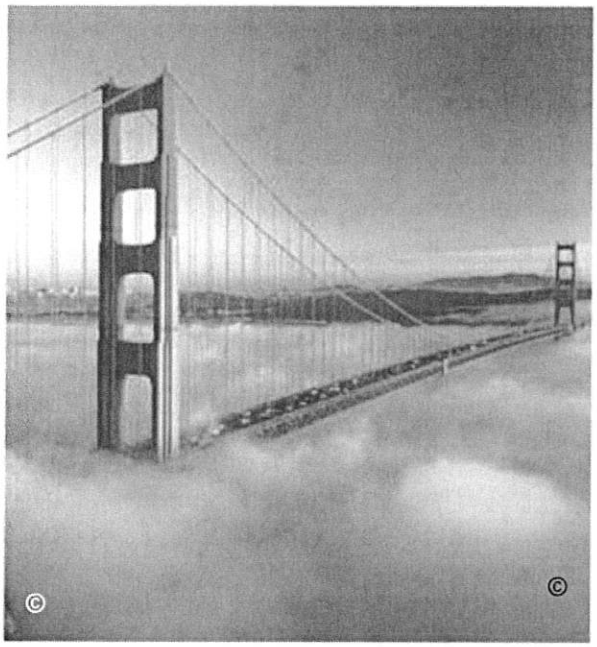


FIGURE 6
Fog Around the Golden Gate Bridge
The cold ocean water of San Francisco Bay is often covered by fog in the early morning.
Predicting *What will happen as the sun rises and warms the air?*

Altocumulus and Altostratus Part of a cloud's name may be based on its height. The names of clouds that form between 2 and 6 kilometers above Earth's surface have the prefix *alto-*, which means "high." The two main types of these clouds are altocumulus and altostratus. These are "middle-level" clouds that are higher than regular cumulus and stratus clouds, but lower than cirrus and other "high" clouds.

Fog Clouds that form at or near the ground are called fog. Fog often forms when the ground cools at night after a warm, humid day. The ground cools the air just above the ground to the air's dew point. The next day the heat of the morning sun "burns" the fog off as its water droplets evaporate. Fog is more common in areas near bodies of water or low-lying marshy areas. In mountainous areas, fog can form as warm, moist air moves up the mountain slopes and cools.

Reading Checkpoint **What is fog?**

Section 1 Assessment

Vocabulary Skill Identify Multiple Meanings
Review the two meanings of the word *relative*. Then use the scientific meaning in a sentence.

Reviewing Key Concepts

HINT 1. a. Reviewing What is humidity?

HINT b. Comparing and Contrasting How are humidity and relative humidity different?

HINT c. Calculating Suppose a sample of air can hold at most 10 grams of water vapor. If the sample actually has 2 grams of water vapor, what is its relative humidity?

HINT 2. a. Identifying What process is involved in cloud formation?

HINT b. Summarizing What two conditions are needed for clouds to form?

HINT c. Inferring When are clouds formed by ice crystals instead of drops of liquid water?

HINT 3. a. Listing What are the three main types of clouds?

HINT b. Describing Briefly describe each of the three main types of clouds.

HINT c. Classifying Classify each of the following cloud types as low-level, medium-level, or high-level: altocumulus, altostratus, cirrostratus, cirrus, cumulus, fog, nimbostratus, and stratus.

Lab zone At-Home Activity

Water in the Air Fill a large glass half full with cold water. Show your family members what happens as you add ice cubes to the water. Explain to your family that the water that appears on the outside of the glass comes from water vapor in the atmosphere. Also explain why the water on the outside of the glass only appears after you add ice to the water in the glass.

Section 2

Precipitation

Reading Preview

Key Concepts

- What are the common types of precipitation?

Key Terms

- precipitation

Target Reading Skill

Using Prior Knowledge Before you read, write what you know about precipitation in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. Precipitation can be rain or snow. 2.

What You Learned
1. 2.

Lab zone Standards Warm-Up

How Can You Make Hail?

1. Put on your goggles.
2. Put 15 g of salt into a beaker. Add 50 mL of water. Stir the solution until most of the salt is dissolved
3. Put 15 ml of cold water in a clean test tube.
4. Place the test tube in the beaker.
5. Fill the beaker almost to the top with crushed ice. Stir the ice mixture every minute for six minutes.
6. Remove the test tube from the beaker and drop an ice chip into the test tube. What happens?

Think It Over

Inferring Based on your observation, what conditions are necessary for hail to form?

In Arica, Chile, the average rainfall is less than 1 millimeter per year. But in Hawaii, the average rainfall on Mount Waialeale is about 12 meters per year. As you can see, rainfall varies greatly around the world.

Water evaporates from every water surface on Earth and from living things. This water eventually returns to the surface as precipitation. **Precipitation** (pree sip uh TAY shun) is any form of water that falls from clouds and reaches Earth's surface.

Not all clouds produce precipitation. For precipitation to occur, cloud droplets or ice crystals must grow heavy enough to fall through the air. One way that cloud droplets grow is by colliding and combining with other droplets. As the droplets grow larger, they move faster and collect more small droplets. Finally, the droplets become heavy enough to fall out of the cloud as raindrops.

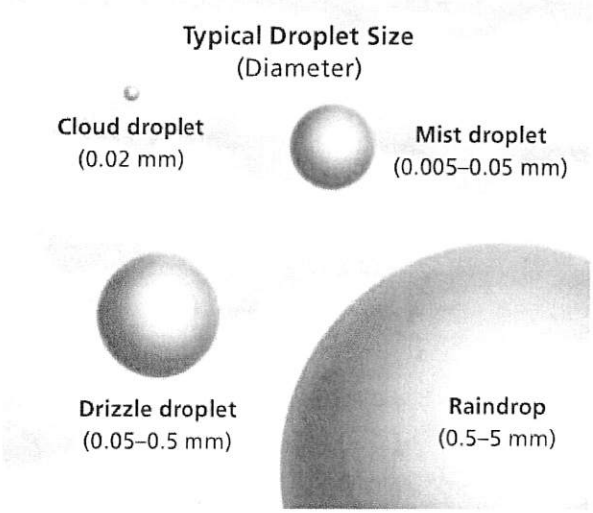


FIGURE 7
Water Droplets
Droplets come in many sizes. Believe it or not, a raindrop has about one million times as much water in it as a cloud droplet.

Types of Precipitation

In warm parts of the world, precipitation is almost always in the form of rain. In colder regions, precipitation may fall as snow or ice. **Common types of precipitation include rain, hail, snow, sleet, and freezing rain.**

Rain The most common kind of precipitation is rain. Drops of water are called rain if they are at least 0.5 millimeter in diameter. Precipitation made up of smaller drops of water is called drizzle. Precipitation of even smaller drops is called mist. Drizzle and mist usually fall from stratus clouds.

Hail Round pellets of ice larger than 5 millimeters in diameter are called hailstones. Hail forms only inside cumulonimbus clouds during thunderstorms. A hailstone starts as an ice pellet inside a cold region of a cloud. Strong updrafts carry the hailstone up through the cold region many times. Each time the hailstone goes through the cold region, a new layer of ice forms around it. Eventually the hailstone becomes heavy enough to fall to the ground. If you cut a hailstone in half, you often see shells of ice, like the layers of an onion, as shown in Figure 8. Because hailstones can grow quite large before finally falling to the ground, hail can cause tremendous damage to crops, buildings, and vehicles.

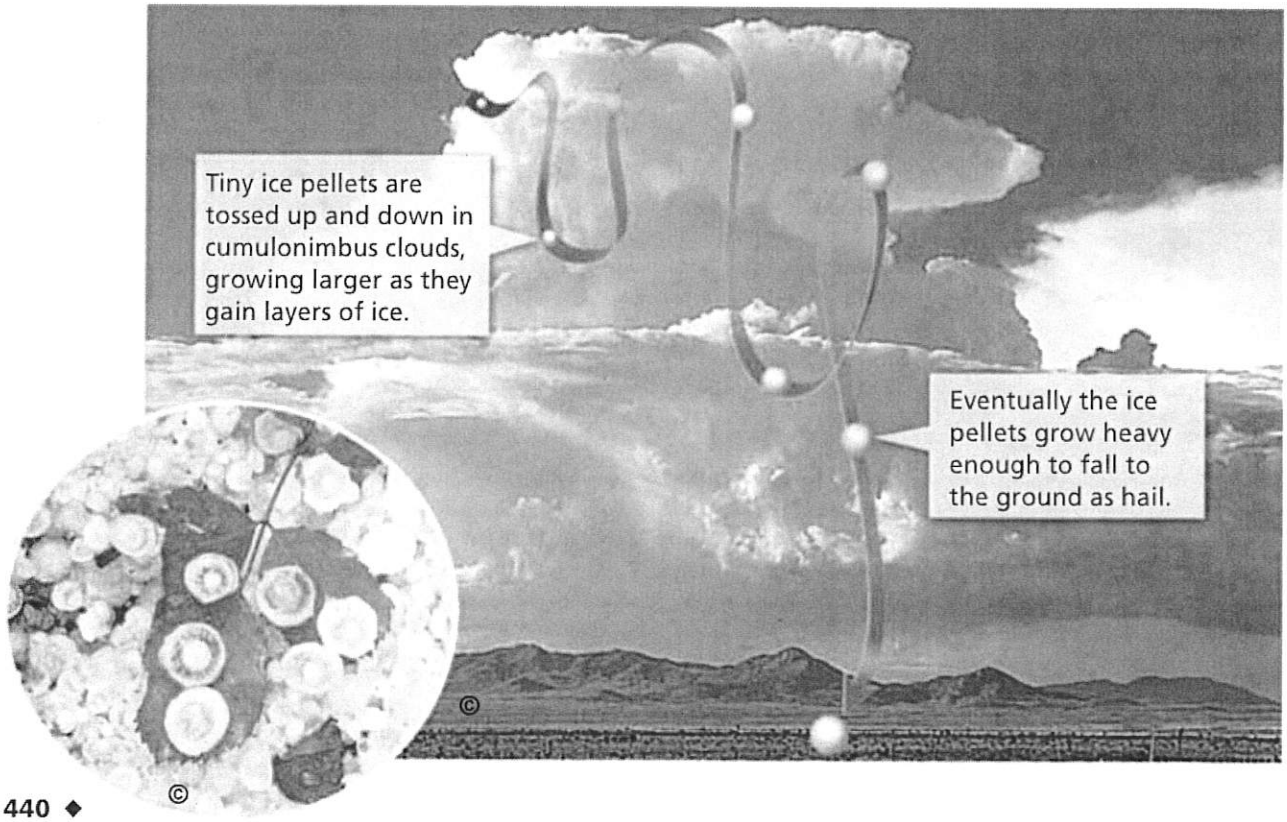


FIGURE 8
How Hail Forms
Hailstones start as small pellets of ice in cumulonimbus clouds. They grow larger as they are repeatedly tossed up and down, until they become so heavy that they fall to the ground.
Interpreting Diagrams *Why do hailstones grow larger as they are tossed up and down in a cloud?*

Snow Often water vapor in a cloud is converted directly into ice crystals called snowflakes. Snowflakes have an endless number of different shapes and patterns, all with six sides or branches. Powdery snow is produced when snow falls through cold, dry air. When snow falls through humid air that is close to freezing, the snowflakes tend to join together into larger clumps in which the individual crystals are hard to see.

Sleet Sometimes raindrops fall through a layer of air that is below 0°C, the freezing point of water. As they fall, the raindrops freeze into solid particles of ice. Ice particles smaller than 5 millimeters in diameter are called sleet.

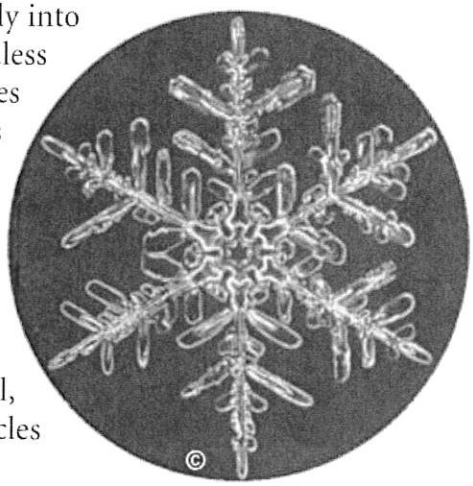


FIGURE 9
Snowflake
Snowflakes are tiny ice crystals. They all have six sides or branches.

Freezing Rain Sometimes raindrops falling through cold air near the ground do not freeze in the air. Instead, they freeze when they touch a cold surface. This kind of precipitation is called freezing rain.

In an ice storm, a smooth, thick layer of ice builds up on every surface. This can produce beautiful effects as it coats trees and bushes. However, the weight of the ice may break tree branches and cause them to fall onto power lines, causing power failures. Freezing rain and sleet can make sidewalks and roads slippery and dangerous.

Reading Checkpoint What is sleet?

Section 2 Assessment

Target Reading Skill Compare and Contrast Make a compare/contrast table for types of precipitation. How do rain, sleet, and hail form?

Reviewing Key Concepts

HINT
1. a. Listing Name the five common types of precipitation.

HINT
b. Comparing and Contrasting Compare and contrast freezing rain and sleet.

HINT
c. Classifying A thunderstorm produces precipitation in the form of ice particles that are about 6 millimeters in diameter. What type of precipitation would this be?

HINT
d. Relating Cause and Effect How do hailstones become so large in cumulonimbus clouds?

HINT
e. Relating Cause and Effect What conditions are necessary for freezing rain to occur?

Writing in Science

Firsthand Account Think about the most exciting experience you have had with precipitation. Write a paragraph about that event. Make sure you describe the precipitation itself as well as the effect it had on you.

Section 3

Air Masses and Fronts

Reading Preview

Key Concepts

- What are the major types of air masses in North America, and how do they move?
- What are the main types of fronts?
- What type of weather is associated with cyclones and anticyclones?

Key Terms

- air mass • tropical • polar
- maritime • continental
- front • occluded • cyclone
- anticyclone

Target Reading Skill

Comparing and Contrasting As you read, compare and contrast the four types of fronts by completing a table like the one below.

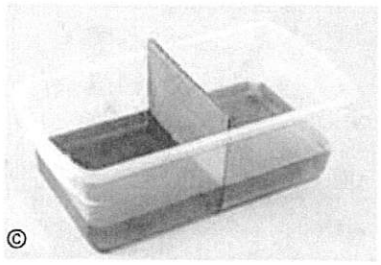
Types of Fronts

Front	How Forms	Type of Weather
Cold front	A cold air mass overtakes a warm air mass.	
Warm front		
Occluded front		

Lab zone Standards Warm-Up

How Do Fluids of Different Densities Behave?

1. Put on your apron. Place a cardboard divider across the middle of a plastic shoe box.
2. Add a few drops of red food coloring to a liter of warm water. Pour the red liquid, which represents low-density warm air, into the shoe box on one side of the divider.



3. Add about 100 mL of table salt and a few drops of blue food coloring to a liter of cold water. Pour the blue liquid, which represents high-density cold air, into the shoe box on the other side of the divider.
4. What do you think will happen if you remove the divider?
5. Now quickly remove the divider. Watch carefully from the side. What happens?

Think It Over

Developing Hypotheses Based on this activity, write a hypothesis stating what would happen if a mass of cold air ran into a mass of warm air.

Listen to the evening news in the winter and you may hear a weather forecast like this: "A huge mass of Arctic air is moving our way, bringing freezing temperatures." Today's weather can be influenced by air from thousands of kilometers away—perhaps from Canada or the Pacific Ocean. A huge body of air that has similar temperature, humidity, and air pressure at any given height is called an **air mass.** A single air mass may spread over millions of square kilometers and be up to 10 kilometers deep.

FIGURE 10
Major Snowstorm
In winter, humid air masses bring heavy snowstorms to areas like New York City.

Types of Air Masses

Scientists classify air masses according to two characteristics: temperature and humidity. **Four major types of air masses influence the weather in North America: maritime tropical, continental tropical, maritime polar, and continental polar.**

The characteristics of an air mass depend on the temperatures and moisture content of the region over which the air mass forms. Remember that temperature affects air pressure. Cold, dense air has a higher pressure, while warm, less dense air has a lower pressure. **Tropical,** or warm, air masses form in the tropics and have low air pressure. **Polar,** or cold, air masses form north of 50° north latitude and south of 50° south latitude. Polar air masses have high air pressure.

Whether an air mass is humid or dry depends on whether it forms over water or land. **Maritime** air masses form over oceans. Water evaporates from the oceans, so the air can become very humid. **Continental** air masses form over land. Continental air masses have less exposure to large amounts of moisture from bodies of water. Therefore, continental air masses are drier than maritime air masses.

Classifying Air Masses

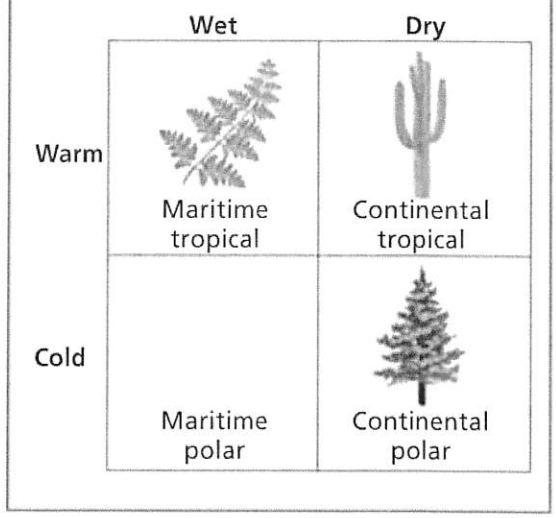
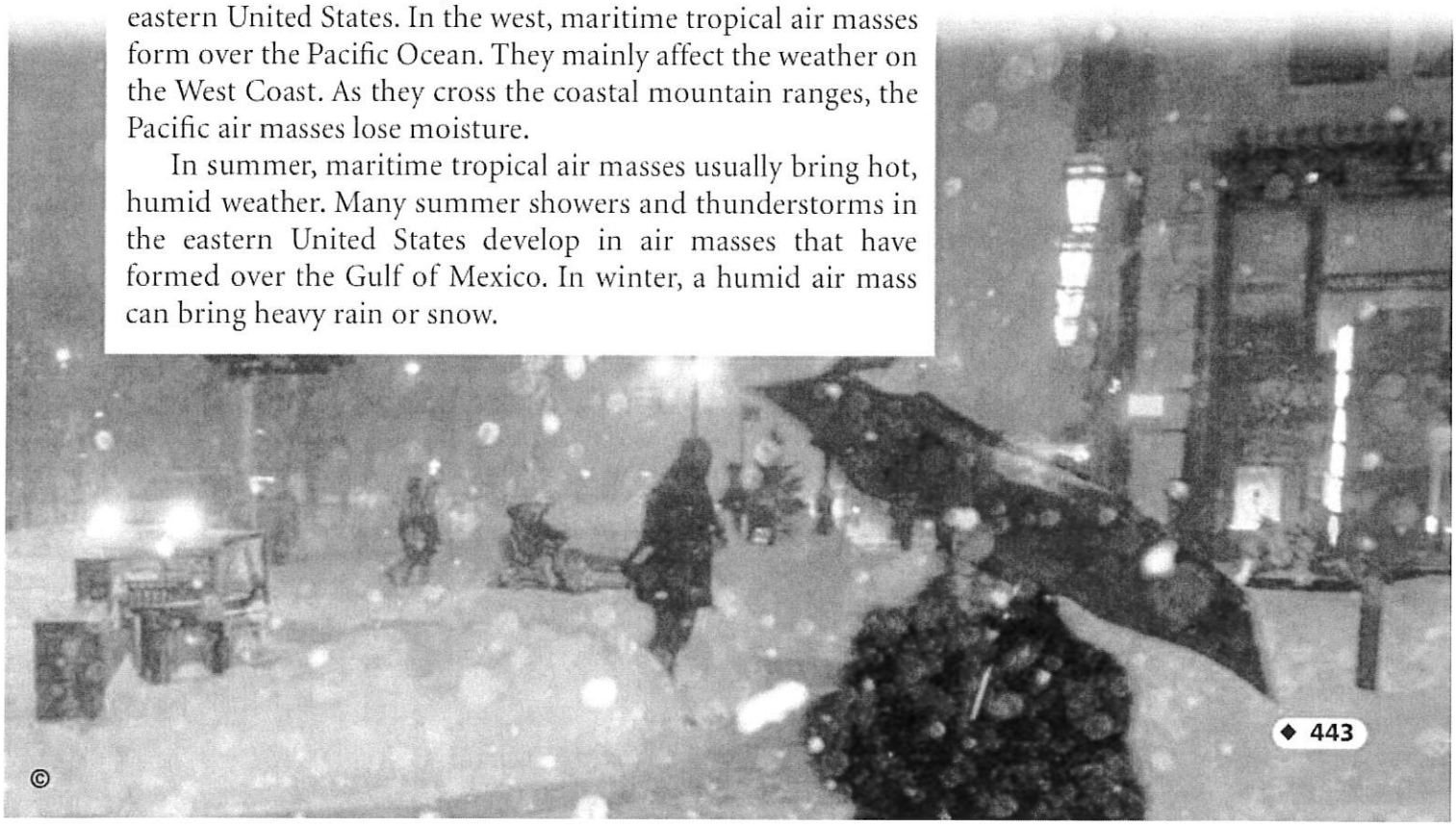


FIGURE 11
Air masses can be classified according to their temperature and humidity. Identifying *What type of air mass consists of warm, moist air?*

Maritime Tropical Warm, humid air masses form over tropical oceans. Maritime tropical air masses that form over the Gulf of Mexico and the Atlantic Ocean move first into the southeastern United States. These air masses then move north and northeast, where they influence weather in the central and eastern United States. In the west, maritime tropical air masses form over the Pacific Ocean. They mainly affect the weather on the West Coast. As they cross the coastal mountain ranges, the Pacific air masses lose moisture.

In summer, maritime tropical air masses usually bring hot, humid weather. Many summer showers and thunderstorms in the eastern United States develop in air masses that have formed over the Gulf of Mexico. In winter, a humid air mass can bring heavy rain or snow.



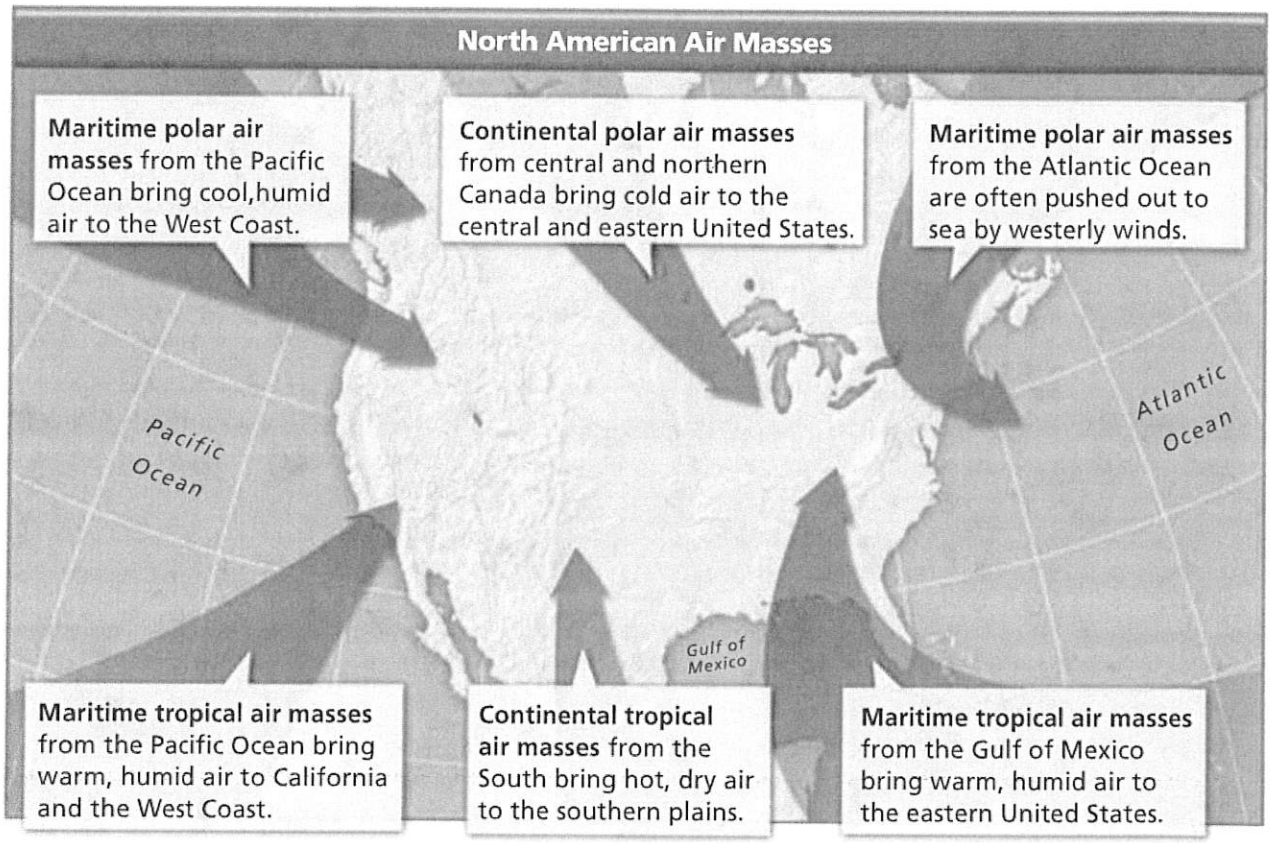


FIGURE 12
Air masses can be warm or cold, and humid or dry. As an air mass moves into an area, the weather changes.

Maritime Polar Cool, humid air masses form over the icy cold North Pacific and North Atlantic oceans. Maritime polar air masses affect the West Coast more than the East Coast. Even in summer, these masses of cool, humid air often bring fog, rain, and cool temperatures to the West Coast.

Continental Tropical Hot, dry air masses form mostly in summer over dry areas of the Southwest and northern Mexico. Continental tropical air masses cover a smaller area than other air masses. They occasionally move northeast, bringing hot, dry weather to the southern Great Plains.

Continental Polar Large continental polar air masses form over central and northern Canada and Alaska, as shown in Figure 12. Air masses that form near the Arctic Circle can bring bitterly cold weather with very low humidity. In winter, continental polar air masses bring clear, cold, dry air to much of North America. In summer, the air mass is milder. Storms may occur when continental polar air masses move south and collide with maritime tropical air masses moving north.

Reading Checkpoint **Where do continental polar air masses come from?**

How Air Masses Move

When an air mass moves into an area and interacts with other air masses, it causes the weather to change. **In the continental United States, air masses are commonly moved by the prevailing westerlies and jet streams.**

Prevailing Westerlies The prevailing westerlies, the major wind belts over the continental United States, generally push air masses from west to east. For example, maritime polar air masses from the Pacific Ocean are blown onto the West Coast, bringing low clouds and showers.

Jet Streams Embedded within the prevailing westerlies are jet streams. Recall that jet streams are bands of high-speed winds about 10 kilometers above Earth's surface. As jet streams blow from west to east, air masses are carried along their tracks.

Fronts As huge masses of air move across the land and the oceans, they collide with each other. But the air masses do not easily mix. Think about a bottle of oil and water. The less dense oil floats on top of the denser water. Something similar happens when two air masses with different temperatures and humidities collide. The air masses do not easily mix. The boundary where the air masses meet becomes a **front.** Storms and changeable weather often develop along fronts, as shown in Figure 13.

Lab zone Skills Activity

Calculating

When planes fly from west to east, they fly with the jet stream, and therefore can fly faster. When traveling from east to west, planes fly against the jet stream, and travel slower. To calculate the rate at which the planes fly, divide the distance traveled by the time it takes.

$$\text{Rate} = \frac{\text{Distance}}{\text{Time}}$$

If a plane flies from Denver, Colorado, to New York City, a distance of about 2,618 kilometers, it takes about 3 hours and 30 minutes. The return flight takes about 4 hours. Calculate the rates of air travel, in km/h, in each direction. How much extra speed does the jet stream add to the west-to-east flight?

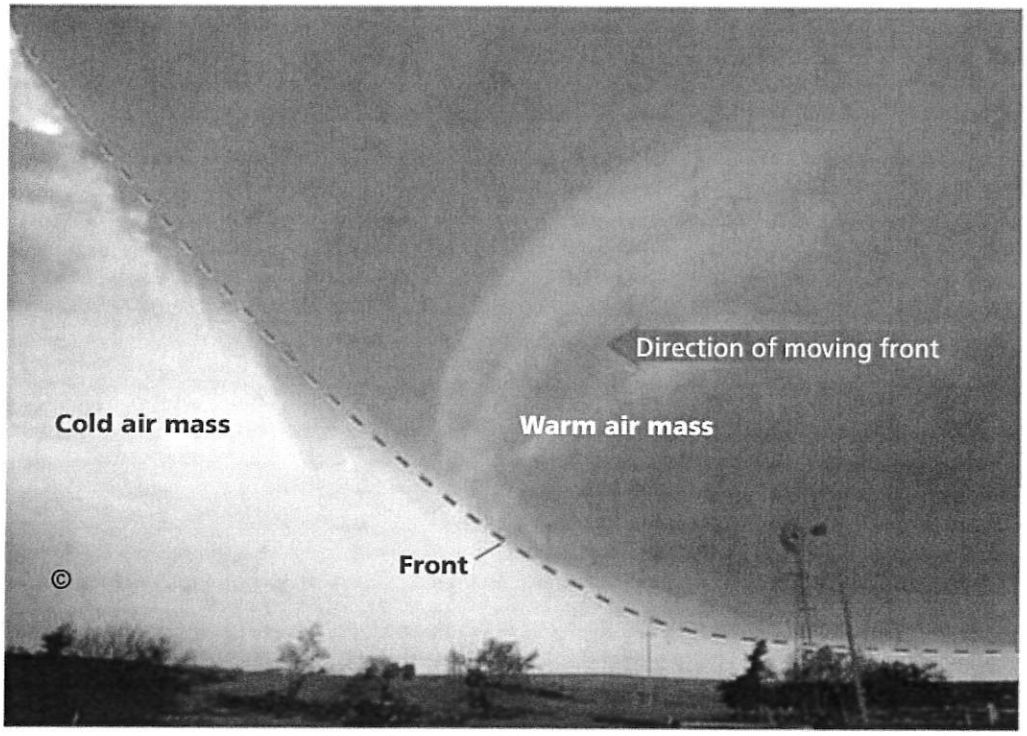
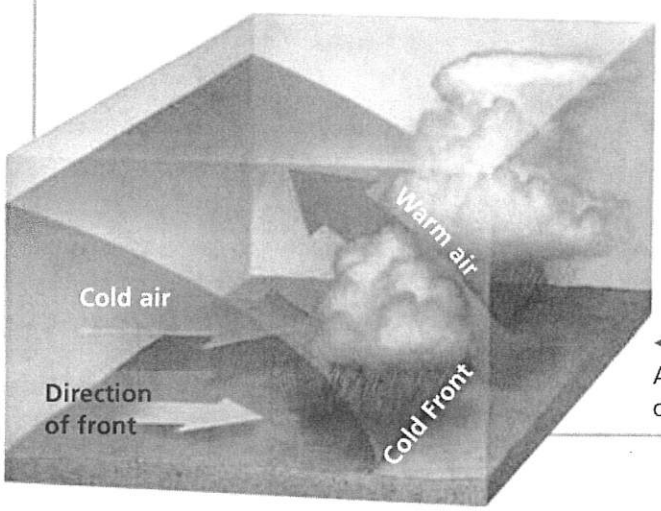


FIGURE 13
How a Front Forms
The boundary where unlike air masses meet is called a front. A front may be 15 to 600 kilometers wide and extend high into the troposphere.

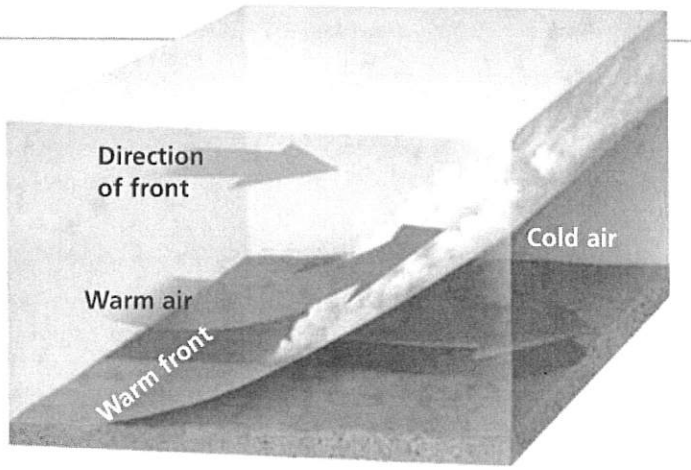
FIGURE 14

Types of Fronts

There are four types of fronts: cold fronts, warm fronts, stationary fronts, and occluded fronts. Interpreting Diagrams *What kind of weather occurs at a warm front?*



◀ **Cold Front**
A fast-moving cold air mass overtakes a warm air mass.



▲ **Warm Front**
A warm air mass overtakes a slow-moving cold air mass.

Types of Fronts

Colliding air masses can form four types of fronts: cold fronts, warm fronts, stationary fronts, and occluded fronts. The kind of front that develops depends on the characteristics of the air masses and how they are moving.

Cold Fronts As you have learned, cold air is dense and tends to sink. Warm air is less dense and tends to rise. When a rapidly moving cold air mass runs into a slowly moving warm air mass, the denser cold air slides under the lighter warm air. The warm air is pushed upward along the leading edge of the colder air, as shown in Figure 14. A cold front forms.

As the warm air rises, it expands and cools. Remember that warm air can hold more water vapor than cool air. The rising air soon reaches the dew point, the temperature at which the water vapor in the air condenses into droplets of liquid water or forms tiny ice crystals. Clouds form. If there is a lot of water vapor in the warm air, heavy rain or snow may fall. If the warm air mass contains only a little water vapor, then the cold front may be accompanied by only cloudy skies.

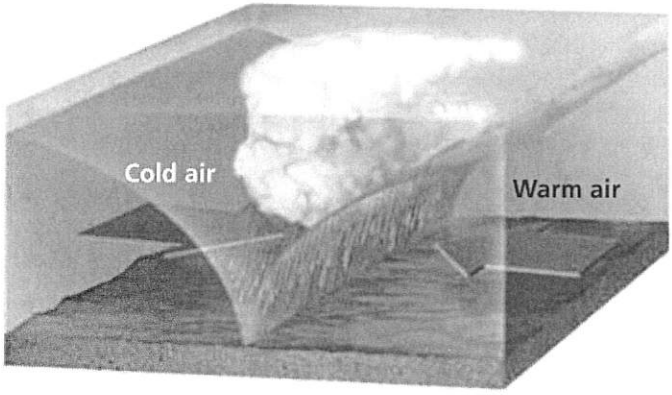
Since cold fronts tend to move quickly, they can cause abrupt weather changes, including thunderstorms. After a cold front passes through an area, colder, drier air moves in, often bringing clear skies, a shift in wind, and lower temperatures.

Reading Checkpoint **What type of weather do cold fronts bring?**

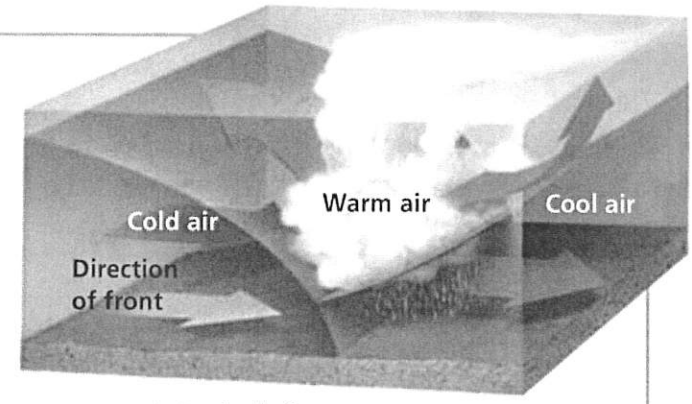
Lab zone **Skills Activity**

Classifying

At home, watch the weather forecast on television. Make a note of each time the weather reporter mentions a front. Classify the fronts mentioned or shown as cold, warm, stationary, or occluded. What type of weather is predicted to occur when the front arrives? Note the specific weather conditions, such as temperature and air pressure, associated with the front. Is each type of front always associated with the same type of weather?



▼ **Stationary Front**
Cold and warm air masses meet, but neither can move the other.



▲ **Occluded Front**
A warm air mass is caught between two cooler air masses.

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active art
For: Weather Fronts activity
Visit: PHSchool.com
Web Code: cfp-4031

Warm Fronts Clouds and precipitation also accompany warm fronts. At a warm front, a fast-moving warm air mass overtakes a slowly moving cold air mass. Because cold air is denser than warm air, the warm air moves over the cold air. If the warm air is humid, light rain or snow falls along the front. If the warm air is dry, scattered clouds form. Because warm fronts move slowly, the weather may be rainy or cloudy for several days. After a warm front passes through an area, the weather is likely to be warm and humid.

Stationary Fronts Sometimes cold and warm air masses meet, but neither one can move the other. The two air masses face each other in a "standoff." In this case, the front is called a stationary front. Where the warm and cool air meet, water vapor in the warm air condenses into rain, snow, fog, or clouds. If a stationary front remains stalled over an area, it may bring many days of clouds and precipitation.

Occluded Fronts The most complex weather situation occurs at an occluded front, where a warm air mass is caught between two cooler air masses. The denser cool air masses move underneath the less dense warm air mass and push the warm air upward. The two cooler air masses meet in the middle and may mix. The temperature near the ground becomes cooler. The warm air mass is cut off, or **occluded**, from the ground. As the warm air cools and its water vapor condenses, the weather may turn cloudy and rain or snow may fall.

Cyclones and Anticyclones

As air masses collide to form fronts, the boundary between the fronts sometimes becomes distorted. This distortion can be caused by surface features, such as mountains, or strong winds, such as the jet stream. When this happens, bends can develop along the front. The air begins to swirl. The swirling air can cause a low-pressure center to form.

Cyclones If you look at a weather map, you will see areas marked with an *L*. The L stands for "low," and indicates an area of relatively low air pressure. A swirling center of low air pressure is called a **cyclone**, from a Greek word meaning "wheel."

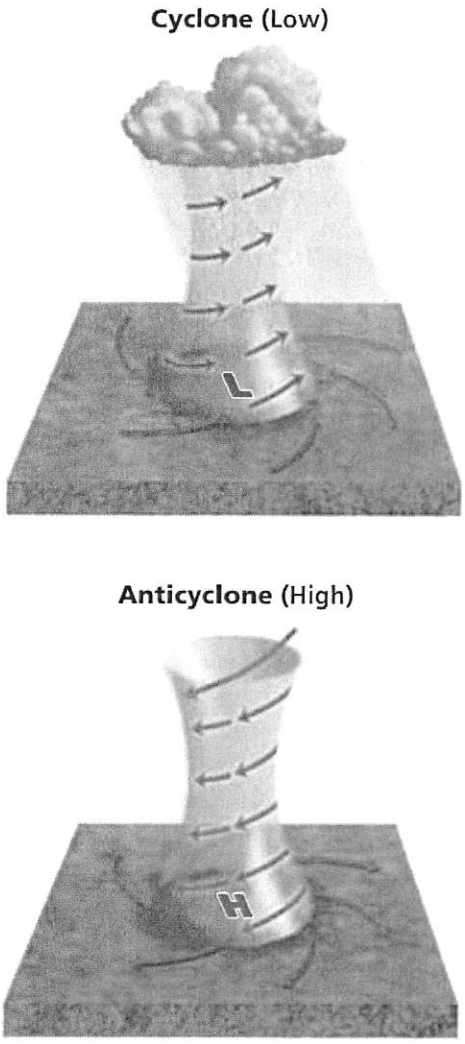
As warm air at the center of a cyclone rises, the air pressure decreases. Cooler air blows toward this low-pressure area from nearby areas where the air pressure is higher. As shown in Figure 15, winds spiral inward toward the center of the system. Winds in a cyclone spin counterclockwise in the Northern Hemisphere when viewed from above. In the Southern Hemisphere, cyclone winds spin in a clockwise direction.

Cyclones play a large part in the weather of the United States. As air rises in a cyclone, the air cools, forming clouds and precipitation. **Cyclones and decreasing air pressure are associated with clouds, wind, and precipitation.**

Anticyclones As its name suggests, an anticyclone is the opposite of a cyclone. **Anticyclones** are high-pressure centers of dry air. Anticyclones are usually called "highs"—*H* on a weather map. Winds spiral outward from the center of an anticyclone, moving toward areas of lower pressure. Because of the Coriolis effect, winds in an anticyclone spin clockwise in the Northern Hemisphere. Because air moves out from the center of the anticyclone, cool air moves downward from higher in the troposphere. As the cool air falls, it warms up, so its relative humidity drops. **The descending air in an anticyclone generally causes dry, clear weather.**

Reading Checkpoint What is an anticyclone?

FIGURE 15
Structure of Cyclones and Anticyclones
Winds spiral inward toward the low-pressure center of a cyclone. Winds spiral outward from the high-pressure center of an anticyclone.
Interpreting Diagrams *Do cyclone winds spin clockwise or counterclockwise in the Northern Hemisphere?*



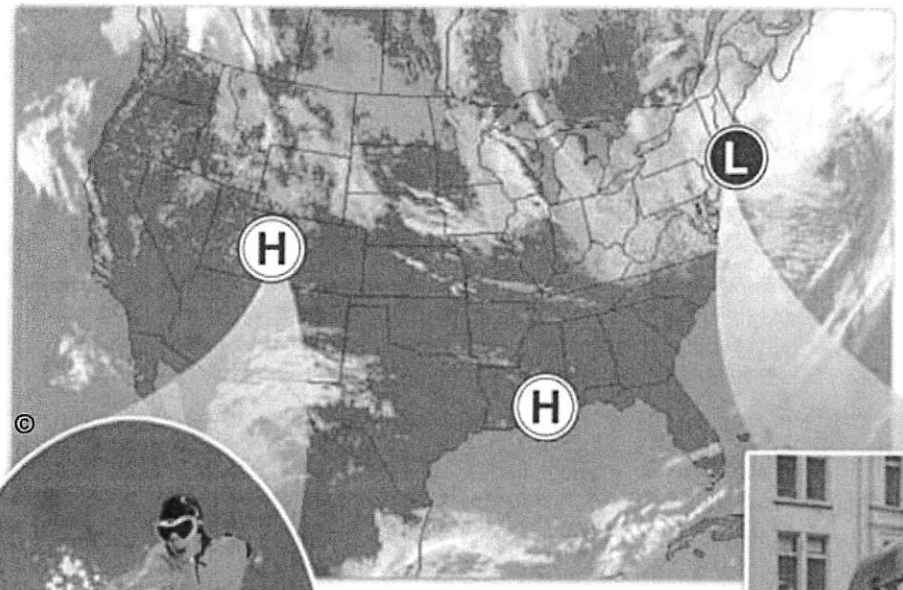


FIGURE 16
Highs and Lows
The satellite image shows a low-pressure area (cyclone) over the Northeast and high-pressure areas (anticyclones) over the South and West.

High-pressure areas usually have clear skies.

Low-pressure areas often bring precipitation.

Section 3 Assessment

Vocabulary Skill Identify Multiple Meanings
Use the scientific meaning of *front* in a sentence. Then use the everyday meaning in a sentence.

Reviewing Key Concepts

HINT
HINT
1. a. Reviewing What two characteristics are used to classify air masses?
   b. Classifying Classify the four major types of air masses according to whether they are dry or humid.
HINT
   c. Applying Concepts What type of air mass would form over the northern Atlantic Ocean?
HINT
2. a. Defining What is a front?
HINT
   b. Describing Name the four types of fronts and describe the type of weather each brings.
HINT
   c. Classifying What type of front would most likely be responsible for several days of rain and clouds?

HINT
HINT
3. a. Identifying What is a cyclone?
   b. Relating Cause and Effect How does air move in an anticyclone? How does this movement affect the weather?
HINT
   c. Comparing and Contrasting Compare cyclones and anticyclones. What type of weather is associated with each?

Writing in Science

News Report Suppose you are a television weather reporter covering a severe thunderstorm. Write a brief report to explain to viewers the conditions that caused the thunderstorm.

Section 4

Storms

Reading Preview

Key Concepts

- What are the main kinds of storms, and how do they form?
- What measures can you take to ensure safety in a storm?

Key Terms

- storm • thunderstorm
- lightning • tornado
- hurricane • storm surge

Target Reading Skill

Sequencing As you read, make a flowchart like the one below that shows how a hurricane forms. Write each step of the process in the flowchart in a separate box in the order in which it occurs.

Hurricane Formation

Begins as a low-pressure area over warm water, or a tropical disturbance.

↓

Warm, humid air rises and begins to spiral.

↓

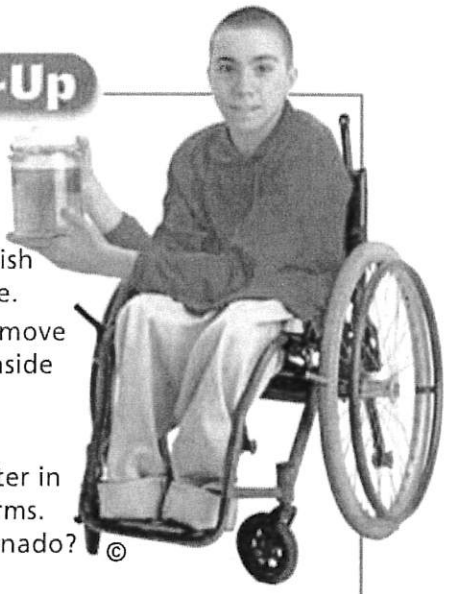
Lab zone Standards Warm-Up

Can You Make a Tornado?

1. Fill a large jar three-quarters full with water. Add a drop of liquid dish detergent and a penny or a marble.
2. Put the lid on the jar tightly. Now move the jar in a circle until the water inside begins to spin.

Think It Over

Observing What happens to the water in the jar? Describe the pattern that forms. How is it like a tornado? Unlike a tornado?



As a storm rages, lightning flashes and thunder rumbles. After the sky clears, dripping trees and numerous puddles are the only evidence of the passing storm. Right? Not always. Scientists search for other evidence—"fossil lightning"! When lightning strikes sand or sandy soil, the sand grains are fused together to form a fulgurite. The shape of the fulgurite reflects the path of the lightning bolt that formed it, as shown in Figure 17. These structures clearly show the tremendous power of storms.

A **storm** is a violent disturbance in the atmosphere. Storms involve sudden changes in air pressure, which in turn cause rapid air movements. Conditions that bring one kind of storm often cause other kinds of storms in the same area. For example, the conditions that cause thunderstorms can also cause tornadoes. There are several types of severe storms.

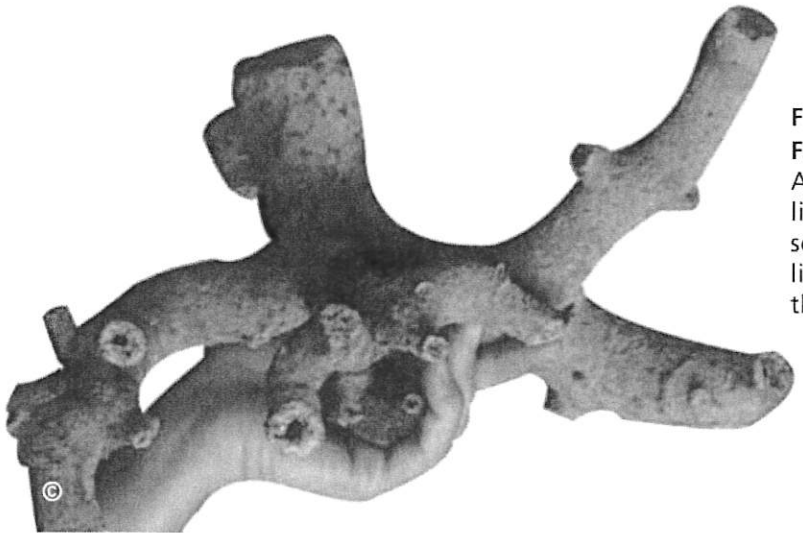


FIGURE 17
Fulgurites
A fulgurite forms when lightning strikes sand or sandy soil. The temperature of the lightning is so high that it melts the sand and forms a tube.

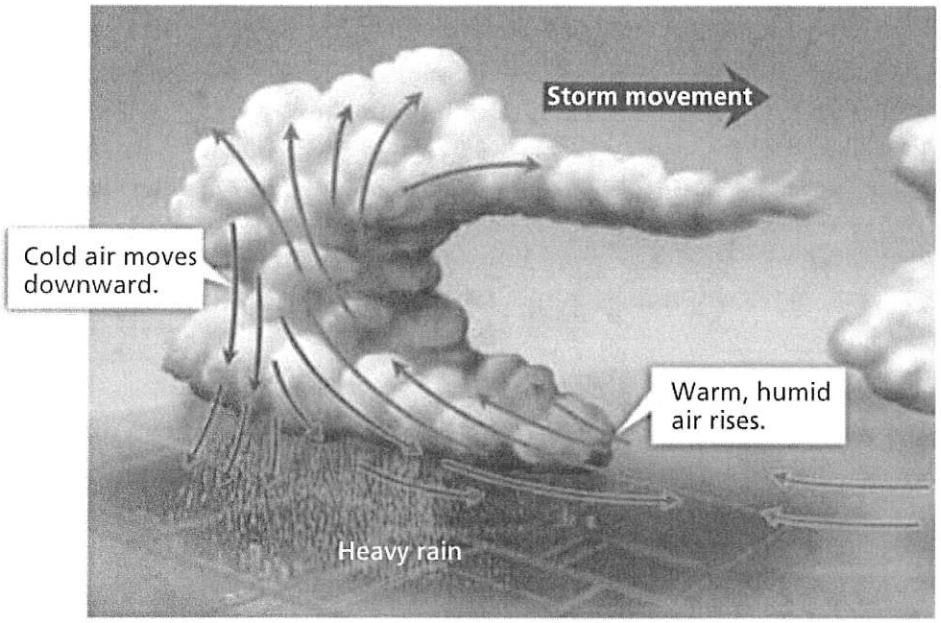


FIGURE 18
Thunderstorm Formation
A thunderstorm forms when warm, humid air rises rapidly within a cumulonimbus cloud.
Applying Concepts *Why do cumulonimbus clouds often form along cold fronts?*

Thunderstorms

Do you find thunderstorms frightening? Exciting? As you watch the brilliant flashes of lightning and listen to long rolls of thunder, you may wonder what caused them.

How Thunderstorms Form A thunderstorm is a small storm often accompanied by heavy precipitation and frequent thunder and lightning. **Thunderstorms form in large cumulonimbus clouds, also known as thunderheads.** Most cumulonimbus clouds form on hot, humid afternoons. They also form when warm air is forced upward along a cold front. In both cases, the warm, humid air rises rapidly. The air cools, forming dense thunderheads. Heavy rain falls, sometimes along with hail. Within the thunderhead are strong upward and downward winds—updrafts and downdrafts—as shown in Figure 18. Many thunderstorms form in the spring and summer in southern states or on the Western Plains.

Lightning and Thunder During a thunderstorm, areas of positive and negative electric charges build up in the storm clouds. Lightning is a sudden spark, or electric discharge, as these charges jump between parts of a cloud, between nearby clouds, or between a cloud and the ground. Lightning is similar to the shocks you sometimes feel when you touch a metal object on a very dry day, but on a much larger scale.

What causes thunder? A lightning bolt can heat the air near it to as much as 30,000°C, much hotter than the sun's surface. The rapidly heated air expands suddenly and explosively. Thunder is the sound of the explosion. Because light travels much faster than sound, you see lightning before you hear thunder.

Lab zone **Try This Activity**

Lightning Distances

Because light travels faster than sound, you see a lightning flash before you hear the clap of thunder. Here's how to calculate your distance from a thunderstorm. **CAUTION:** *Only do this activity inside a building.*

1. Count the number of seconds between the moment when you see the lightning and when you hear the thunder.
2. Divide the number of seconds you counted by three to get the approximate distance in kilometers. Example:

$$\frac{15\text{ s}}{3\text{ s/km}} = 5\text{ km}$$

Calculating Wait for another lightning flash and calculate the distance again. How can you tell whether a thunderstorm is moving toward you or away from you?

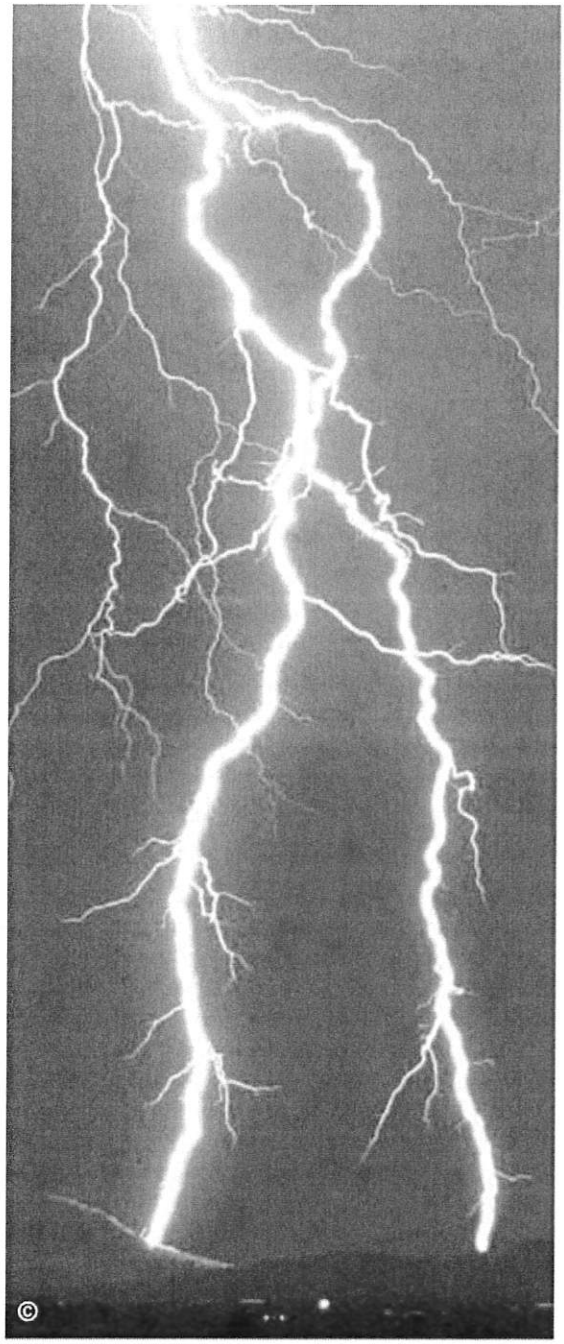


FIGURE 19
Lightning Striking Earth
Lightning occurs when electric charges jump within clouds, between clouds, or between clouds and the ground. Lightning can cause fires or serious injuries.

Thunderstorm Damage Thunderstorms can cause severe damage. The heavy rains associated with thunderstorms can flood low-lying areas. Lightning can also cause damage. When lightning strikes the ground, the hot, expanding air can shatter tree trunks or start forest fires. When lightning strikes people or animals, it acts like a powerful electric shock. Lightning can cause unconsciousness, serious burns, or even heart failure.

Floods A major danger during severe thunderstorms is flooding. Floods occur when so much water pours into a stream or river that its banks overflow, covering the surrounding land. In urban areas, floods can occur when the ground is already saturated by heavy rains. The water can't soak into the water-logged ground or the many areas covered with buildings, roads, and parking lots.

Floods can bury or wash away human and wildlife habitats. However, floods may also have benefits. For example, river floods can provide rich new soil for agriculture.

Thunderstorm Safety The safest place to be during a thunderstorm is indoors. If you are inside a house, avoid touching telephones, electrical appliances, or plumbing fixtures, all of which can conduct electricity. It is usually safe to stay in a car with a hard top during a thunderstorm. The electricity will move along the metal skin of the car and jump to the ground. **During thunderstorms, avoid places where lightning may strike. Also avoid objects that can conduct electricity, such as metal objects and bodies of water.**

How can you stay safe if you are caught outside during a thunderstorm? Don't seek shelter under a tree, because lightning may strike the tree and you. Instead, find a low area away from trees, fences, and poles. If you are swimming or in a boat, get to shore and find shelter away from the water.

Reading Checkpoint **How can lightning be dangerous?**

Tornadoes

A tornado is one of the most frightening and destructive types of storms. A **tornado** is a rapidly whirling, funnel-shaped cloud that reaches down from a storm cloud to touch Earth's surface. If a tornado occurs over a lake or ocean, the storm is known as a waterspout. Tornadoes are usually brief, but can be deadly. They may touch the ground for 15 minutes or less and be only a few hundred meters across. But wind speeds in the most intense tornadoes may approach 500 kilometers per hour.

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Web Code: cfd-4032

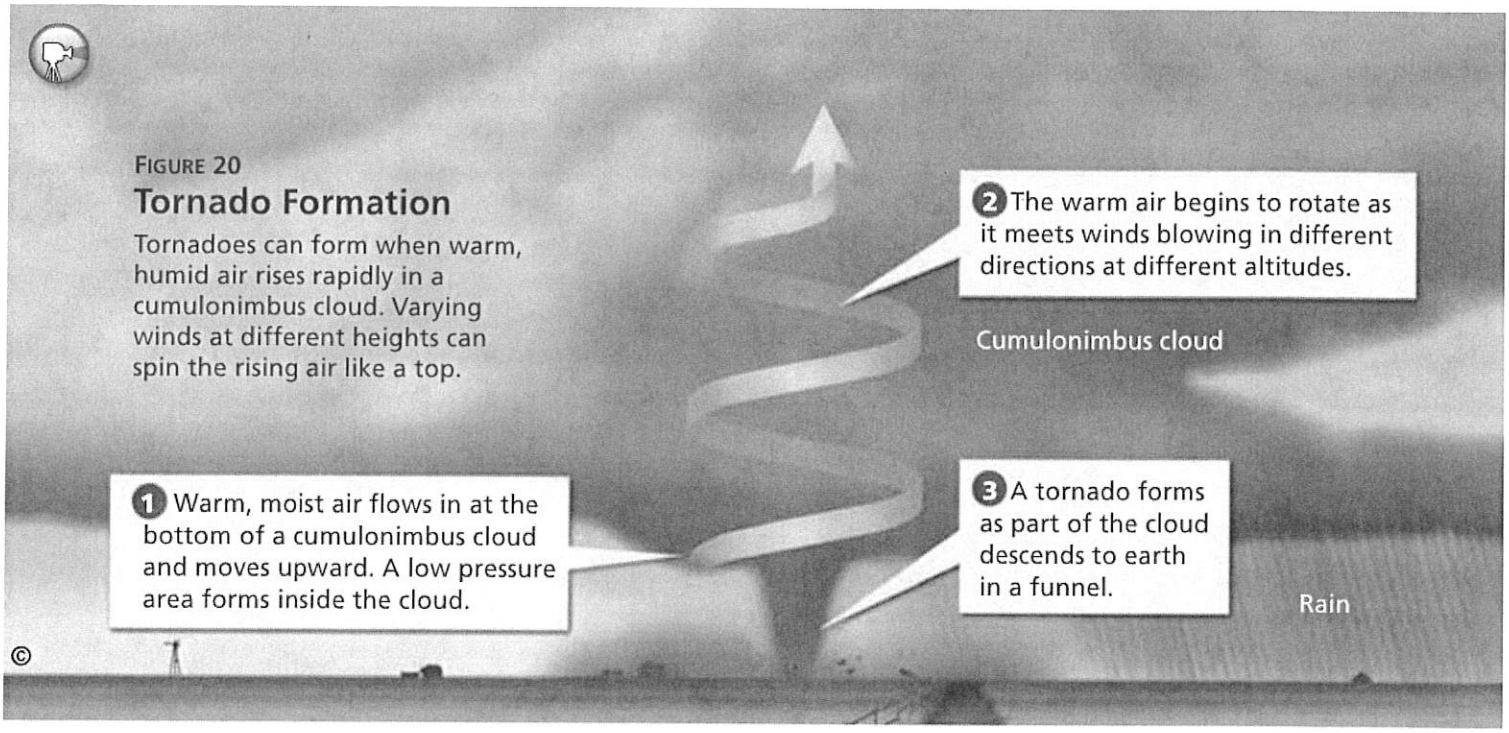


FIGURE 20
Tornado Formation
Tornadoes can form when warm, humid air rises rapidly in a cumulonimbus cloud. Varying winds at different heights can spin the rising air like a top.

How Tornadoes Form Tornadoes can form in any situation that produces severe weather. **Tornadoes most commonly develop in thick cumulonimbus clouds—the same clouds that bring thunderstorms.** Tornadoes are most likely to occur when thunderstorms are likely—in spring and early summer, often late in the afternoon when the ground is warm. The Great Plains often have the kind of weather pattern that is likely to create tornadoes: A warm, humid air mass moves north from the Gulf of Mexico into the lower Great Plains. A cold, dry air mass moves south from Canada. When the air masses meet, the cold air moves under the warm air, forcing it to rise. A squall line, or narrow band of thunderstorms, is likely to form, with storms traveling from southwest to northeast. A single squall line can produce ten or more tornadoes.

Tornado Alley About 800 tornadoes occur in the United States every year. Weather patterns on the Great Plains result in a "tornado alley," as shown in Figure 21. However, tornadoes can and do occur in nearly every part of the United States.

Tornado Safety **The safest place to be during a tornado is in a storm shelter or the basement of a well-built building.** Stay away from windows and doors to avoid flying debris. Lie on the floor under a sturdy piece of furniture, such as a large table. If you are outdoors, lie flat in a ditch.

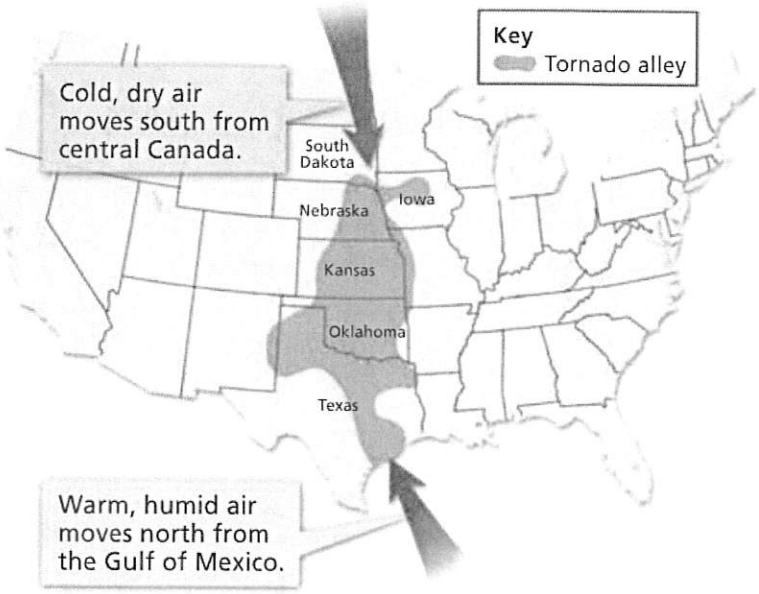


FIGURE 21
Tornado Alley
Tornadoes in the U.S. are most likely to occur in a region known as Tornado Alley. Interpreting Maps *Name five states that Tornado Alley crosses.*

Snowstorms

In the winter in the northern United States and at high elevations, a large amount of precipitation falls as snow. **All year round, most precipitation begins in clouds as snow. If the air is colder than 0°C all the way to the ground, the precipitation falls as snow.**

Heavy snowfalls can block roads, trapping people in their homes and making it hard for emergency vehicles to move. Extreme cold can damage crops and cause water pipes to freeze and burst.

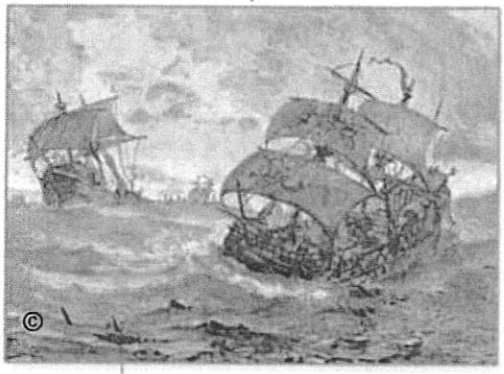
Science and History

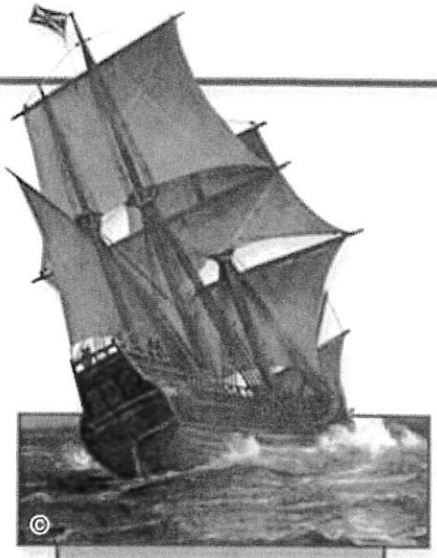
Weather That Changed History

Unanticipated storms have caused incredible damage, killed large numbers of people, and even changed the course of history.

1281 Japan
In an attempt to conquer Japan, Kublai Khan, the Mongol emperor of China, sent a fleet of ships carrying a huge army. A hurricane from the Pacific brought high winds and towering waves that sank the ships. The Japanese named the storm *kamikaze*, meaning "divine wind."

1588 England
King Philip II of Spain sent the Spanish Armada, a fleet of 130 ships, to invade England. Strong winds in the English Channel trapped the Armada near shore. Some Spanish ships escaped, but storms wrecked most of them.





1620 Massachusetts
English Pilgrims set sail for the Americas in the *Mayflower*. They had planned to land near the mouth of the Hudson River, but turned back north because of rough seas and storms. When the Pilgrims landed farther north, they decided to stay and so established Plymouth Colony.

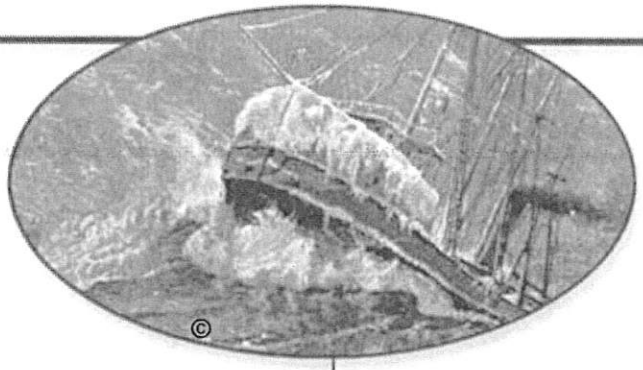
1200 1600 1700

Imagine being caught in a snowstorm when the wind suddenly picks up. High winds can blow falling snow sideways or pick up snow from the ground and suspend it in the air. This situation can be extremely dangerous because the blowing snow limits your vision and makes it easy to get lost. Also, strong winds cool a person's body rapidly. Heavy snowfalls can block roads, trapping people in their homes and making it hard for emergency vehicles to move. **If you are caught in a snowstorm, try to find shelter from the wind.** Cover exposed parts of your body and try to stay dry. If you are in a car, the driver should keep the engine running only if the exhaust pipe is clear of snow.

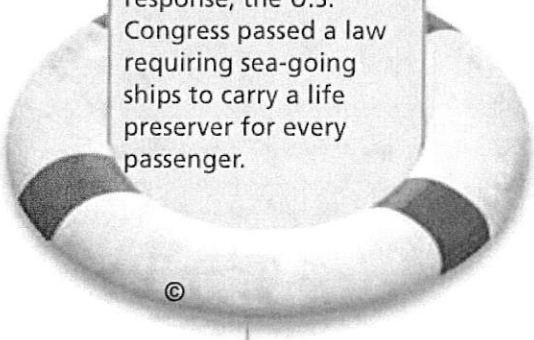
Reading Checkpoint **How can snowstorms be dangerous?**

Writing in Science

Research and Write
Many of these events happened before forecasters had the equipment to predict weather scientifically. Research one of the events in the timeline. Write an expository essay describing the event and how history might have been different if the people involved had had accurate weather predictions.



1837 North Carolina
The steamship *Home* sank during a hurricane off Ocracoke, North Carolina. In one of the worst storm-caused disasters at sea, 90 people died. In response, the U.S. Congress passed a law requiring sea-going ships to carry a life preserver for every passenger.



1870 Great Lakes
Learning that more than 1,900 boats had sunk in storms on the Great Lakes in 1869, Congress set up a national weather service, the Army Signal Corps. In 1891 the job of issuing weather warnings and forecasts went to a new agency, the U.S. Weather Bureau.

1900 and 1915 Texas
When a hurricane struck the port city of Galveston in 1900, it killed at least 8,000 people and destroyed much of the city. As a result, a seawall 5 meters high and 16 kilometers long was built. When another hurricane struck in 1915, the seawall greatly reduced the amount of damage.

1800 1900 2000

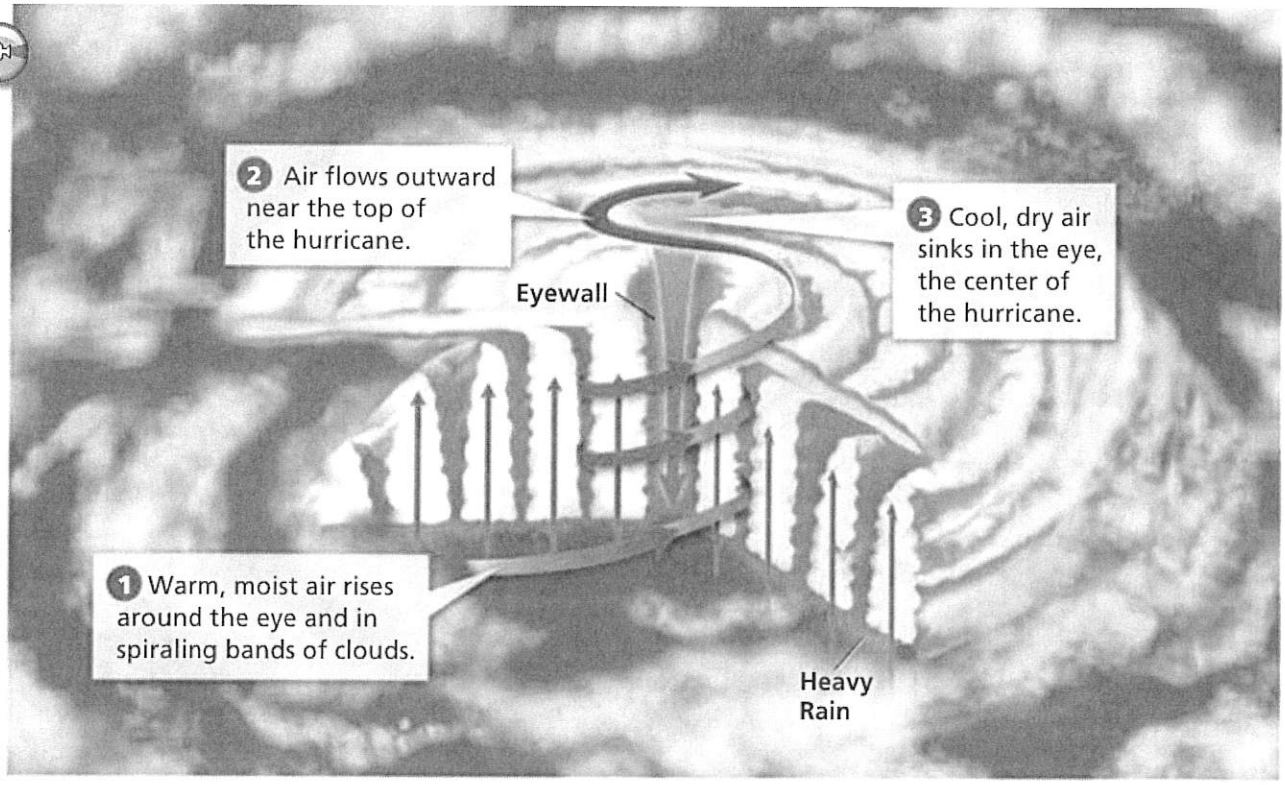


FIGURE 22
Structure of a Hurricane
In a hurricane, air moves rapidly around a low-pressure area called the eye.

Hurricanes

A **hurricane** is a tropical cyclone that has winds of 119 kilometers per hour or higher. A typical hurricane is about 600 kilometers across. Hurricanes form in the Atlantic, Pacific, and Indian oceans. In the western Pacific Ocean, hurricanes are called typhoons.

How Hurricanes Form A typical hurricane that strikes the United States forms in the Atlantic Ocean north of the equator in August, September, or October. **A hurricane begins over warm ocean water as a low-pressure area, or tropical disturbance.** If the tropical disturbance grows in size and strength, it becomes a tropical storm, which may then become a hurricane.

A hurricane draws its energy from the warm, humid air at the ocean's surface. As this air rises and forms clouds, more air is drawn into the system. Inside the storm are bands of very high winds and heavy rains. Winds spiral inward toward the area of lowest pressure at the center. The lower the air pressure at the center of a storm, the faster the winds blow toward the center. Hurricane winds may be as strong as 320 kilometers per hour.

Look at Figure 22. Hurricane winds are strongest in a narrow band around the center of the storm. At the center is a ring of clouds, called the eyewall, that enclose a quiet "eye." The wind gets stronger as the eye approaches. When the eye arrives, the weather changes suddenly. The air grows calm and the sky may clear. After the eye passes, the storm resumes, but the wind blows from the opposite direction.

How Hurricanes Move Hurricanes last longer than other storms, usually a week or more. During that period, they can travel quite far. Hurricanes that form in the Atlantic Ocean are steered by trade winds toward the Caribbean islands and the southeastern United States. After a hurricane passes over land, it no longer has warm, moist air to draw energy from. It gradually loses strength, although heavy rainfall may continue for several days.

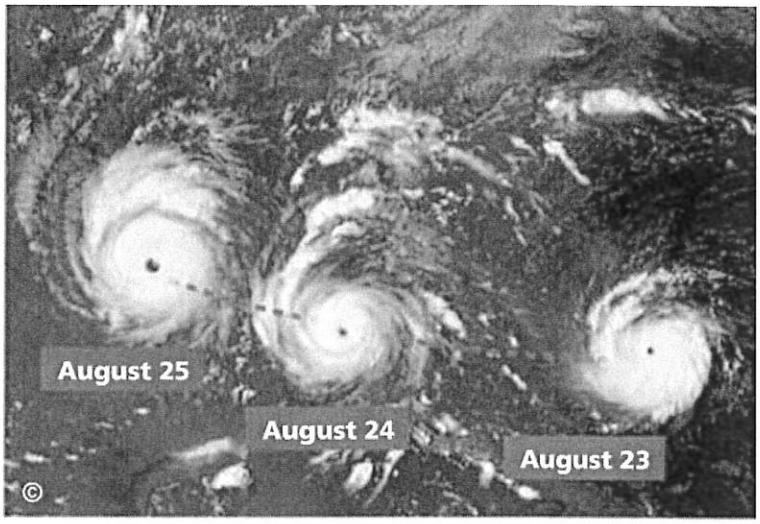


FIGURE 23
Hurricane Andrew
The path of Hurricane Andrew over three consecutive days can be seen in this photo montage.

Hurricane Damage When hurricanes come ashore, they bring high waves and severe flooding as well as wind damage. The low pressure and high winds of a hurricane over the ocean raise the level of the water up to 6 meters above normal sea level. The result is a **storm surge**, a "dome" of water that sweeps across the coast where the hurricane lands. Storm surges can cause great damage, washing away beaches, destroying buildings along the coast, and eroding coastlines.

Hurricane Safety Until the 1950s, a fast-moving hurricane could strike with little warning. People now receive information well in advance of an approaching hurricane. A "hurricane warning" means that hurricane conditions are expected within 24 hours. **If you hear a hurricane warning and are told to evacuate, leave the area immediately.**

Section 4 Assessment

Vocabulary Skill Identify Multiple Meanings
Explain how a tornado is different from a cyclone. Use the scientific meaning of *cyclone* from Section 3.

Reviewing Key Concepts

HINT HINT HINT HINT HINT HINT

1. a. Defining What is a thunderstorm?
   b. Describing What safety precautions should you follow during a thunderstorm?
2. a. Identifying What weather conditions are most likely to produce tornadoes?
   b. Developing Hypotheses Why do tornadoes occur most often in Tornado Alley?
3. a. Explaining Under what conditions does precipitation reach the ground as snow?
   b. Describing What should you do if you are caught in a snowstorm?
4. a. Defining What is a hurricane?
   b. Explaining How do hurricanes form?
   c. Relating Cause and Effect Why do hurricanes weaken as they pass over land?

HINT HINT HINT

Lab zone At-Home Activity

Storm Eyewitness Interview a family member or other adult about a dramatic storm that he or she has experienced. Before the interview, make a list of questions you would like to ask. For example, when and where did the storm occur? Write up your interview in a question-and-answer format, beginning with a short introduction.

Lab zone **Skills Lab**

Tracking a Hurricane

Problem

How can you predict when and where a hurricane will come ashore?

Skills Focus

interpreting data, predicting, drawing conclusions

Materials

- ruler
- red, blue, green, and brown pencils
- tracing paper

Procedure

1. Look at the plotted path of the hurricane on the map. Each dot represents the location of the eye of the hurricane at six-hour intervals. The last dot shows where the hurricane was located at noon on August 30.
2. Predict the path you think the hurricane will take. Place tracing paper over the map below. Using a red pencil, place an *X* on your tracing paper where you think the hurricane will first reach land. Next to your *X*, write the date and time you think the hurricane will come ashore.
3. Hurricane warnings are issued for an area that is likely to experience a hurricane within 24 hours. On your tracing paper, shade in red the area for which you would issue a hurricane warning.
4. Using the following data table, plot the next five positions for the storm using a blue pencil. Use your ruler to connect the dots to show the hurricane's path.

Data Table

Date and Time	Latitude	Longitude
August 30, 6:00 P.M.	28.3° N	86.8° W
August 31, midnight	28.4° N	86.0° W
August 31, 6:00 A.M.	28.6° N	85.3° W
August 31, noon	28.8° N	84.4° W
August 31, 6:00 P.M.	28.8° N	84.0° W

5. Based on the new data, decide if you need to change your prediction of where and when the hurricane will come ashore. Mark your new predictions in blue pencil on your tracing paper.
6. During September 1, you obtain four more positions. (Plot these points only after you have completed Step 5.) Based on these new data, use the green pencil to indicate when and where you now think the hurricane will come ashore.

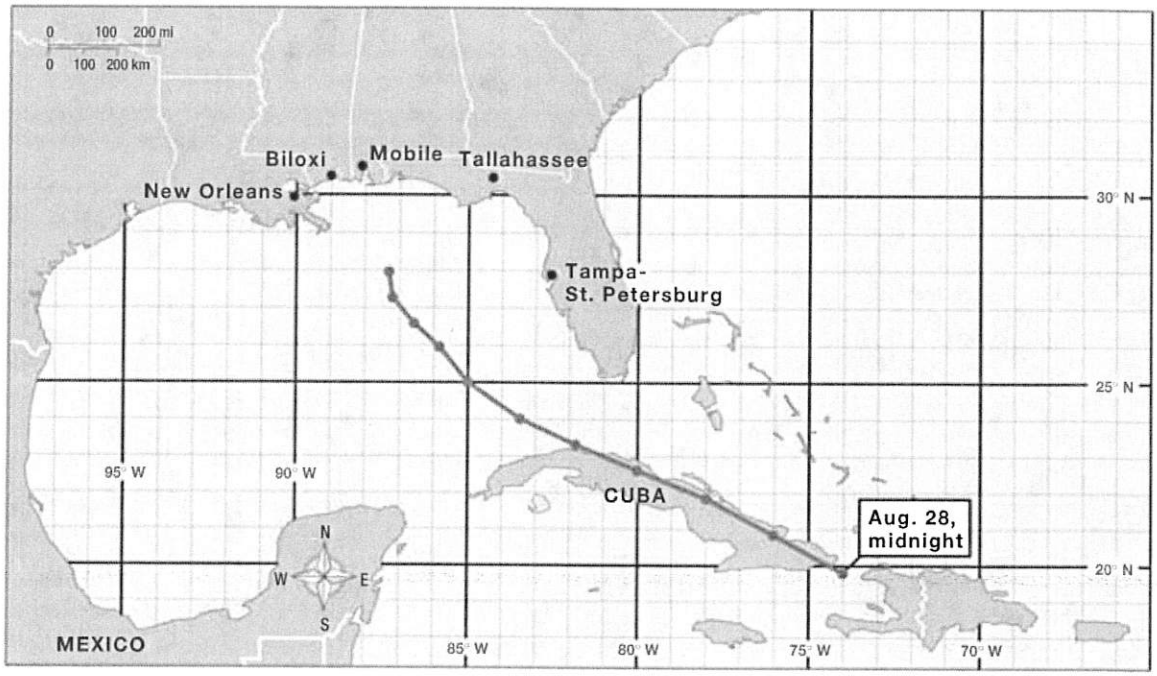
Data Table

Date and Time	Latitude	Longitude
September 1, midnight	28.8° N	83.8° W
September 1, 6:00 A.M.	28.6° N	83.9° W
September 1, noon	28.6° N	84.2° W
September 1, 6:00 P.M.	28.9° N	84.8° W

7. The next day, September 2, you plot four more positions using a brown pencil. (Plot these points only after you have completed Step 6.)

Data Table

Date and Time	Latitude	Longitude
September 2, midnight	29.4° N	85.9° W
September 2, 6:00 A.M.	29.7° N	87.3° W
September 2, noon	30.2° N	88.8° W
September 2, 6:00 P.M.	31.0° N	90.4° W



Analyze and Conclude

1. Interpreting Data Describe in detail the complete path of the hurricane you tracked. Include where it came ashore and identify any cities that were in the vicinity.
2. Predicting How did your predictions in Steps 2, 5, and 6 compare to what actually happened?
3. Interpreting Data What was unusual about your hurricane's path?
4. Inferring How do you think hurricanes with a path like this one affect the issuing of hurricane warnings?
5. Drawing Conclusions Why do you have to be so careful when issuing warnings? What problems might be caused if you issued an unnecessary hurricane warning? What might happen if a hurricane warning were issued too late?
6. Communicating In this activity, you only had data for the hurricane's position. If you were tracking a hurricane and issuing warnings, what other types of information would help you make decisions about the hurricane's path? Write a paragraph describing the additional information you would need.

More to Explore

With your teacher's help, search the Internet for more hurricane tracking data. Map the data and try to predict where the hurricane will come ashore.

Section 5 • Tech & Design •

Predicting the Weather

Reading Preview

Key Concepts

- How do weather forecasters predict the weather?
- What can be learned from the information on weather maps?

Key Terms

- meteorologist
- isobar
- isotherm

Target Reading Skill

Previewing Visuals Before you read, look at Figure 26, a weather map. Then write three questions about the map in a graphic organizer like the one below. As you read, answer your questions.

Weather Map

Q. What type of front is located west of Oklahoma City?
A.
Q.

Lab zone Standards Warm-Up

What's the Weather?

1. Look at the weather report in your local newspaper. Note what weather conditions are predicted for your area today, including temperature, precipitation, and wind speed.
2. Look out the window or think about what it was like the last time you were outside. Write down the actual weather conditions where you are.

Think It Over

Observing Does the weather report match what you observe? What is the same? What is different?

Every culture's folklore includes weather sayings. Many of these sayings are based on long-term observations. Sailors, pilots, farmers, and others who work outdoors are usually careful observers of clouds, winds, and other signs of changes in the weather. Two examples are shown below.

Why do these two weather sayings agree that a red morning sky means bad weather? Recall that in the United States, storms usually move from west to east. Clouds in the west may indicate an advancing low-pressure area, bringing stormy weather. If there are high clouds in the west in the morning, the rising sun in the east turns these clouds red. The reverse is true at sunset. As the sun sets in the west, it turns clouds in the east red. Clouds in the east may indicate that a storm is moving away to the east. A red sky is one kind of observation that helps people to predict the weather.

FIGURE 24
Red Sky
The red sky shown in this sunrise may indicate an approaching storm.

Evening red and morning gray
Will send the traveler on his way;
Evening gray and morning red
Will bring down rain upon his head.

Red sky in the morning,
sailors take warning;
Red sky at night,
sailor's delight.

FIGURE 25
Meteorologist at Work
Professional meteorologists use computers to help track and forecast the weather. Inferring *Why might a meteorologist need to refer to more than one computer screen?*

Weather Forecasting

The first step in forecasting is to collect data, either from simple, direct observations or through the use of instruments. For example, if a barometer shows that the air pressure is falling, you can expect a change in the weather. Falling air pressure usually indicates an approaching low-pressure area, possibly bringing rain or snow.

Go Online
PLANET DIARY
For: More on weather maps
Visit: PHSchool.com
Web Code: cfd-4033

Making Simple Observations You can read weather signs in the clouds, too. Cumulus clouds often form on warm afternoons when warm air rises. If you see these clouds growing larger and taller, you can expect them to become cumulonimbus clouds, which may produce a thunderstorm. If you can see thin cirrus clouds high in the sky, a warm front may be approaching.

Even careful weather observers often turn to professional meteorologists for weather information. **Meteorologists** (mee tee uh RAHL uh jists) are scientists who study the causes of weather and try to predict it.

Interpreting Complex Data Meteorologists are able to interpret information from a variety of sources, including local weather observers, instruments carried by balloons, satellites, and weather stations around the world. **Meteorologists use maps, charts, and computers to analyze weather data and to prepare weather forecasts.** They often use radar to track areas of rain or snow and to locate severe storms such as tornadoes. Forecasters can also follow the path of a storm system.

Where do weather reporters get their information? Most weather information comes from the National Weather Service. The National Weather Service uses balloons, satellites, radar, and surface instruments to gather weather data.

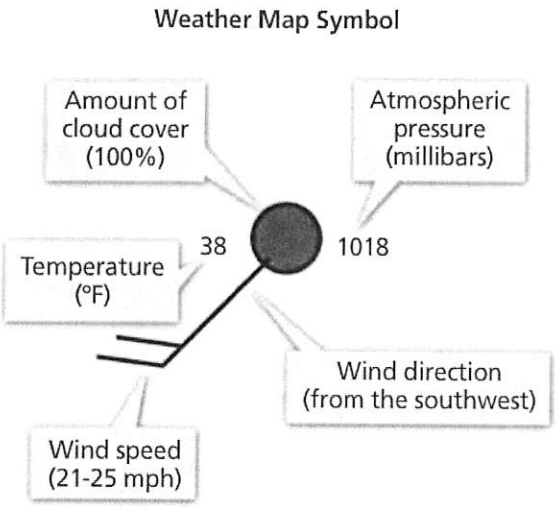
Reading Checkpoint What is a meteorologist?

FIGURE 26

Reading a Weather Map

The figure below shows what various weather symbols mean. At right, the weather map shows data collected from many weather stations.

Wind Speed (mph)	Symbol
1 – 2	
3 – 8	
9 – 14	
15 – 20	
21 – 25	
26 – 31	
32 – 37	
38 – 43	
44 – 49	
50 – 54	
55 – 60	
61 – 66	
67 – 71	
72 – 77	

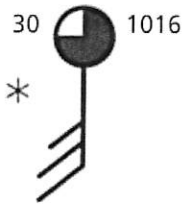


Cloud Cover (%)	Symbol
0	
10	
20–30	
40	
50	
60	
70–80	
90	
100	

Lab zone Skills Activity

Interpreting Data

Use Figure 26 to help you answer questions about this weather station data.



1. What is the temperature at this station?
2. What is the wind speed?
3. Which way is the wind blowing?
4. What is the air pressure?
5. What percent of the sky is covered by clouds?
6. What type of precipitation, if any, is falling?

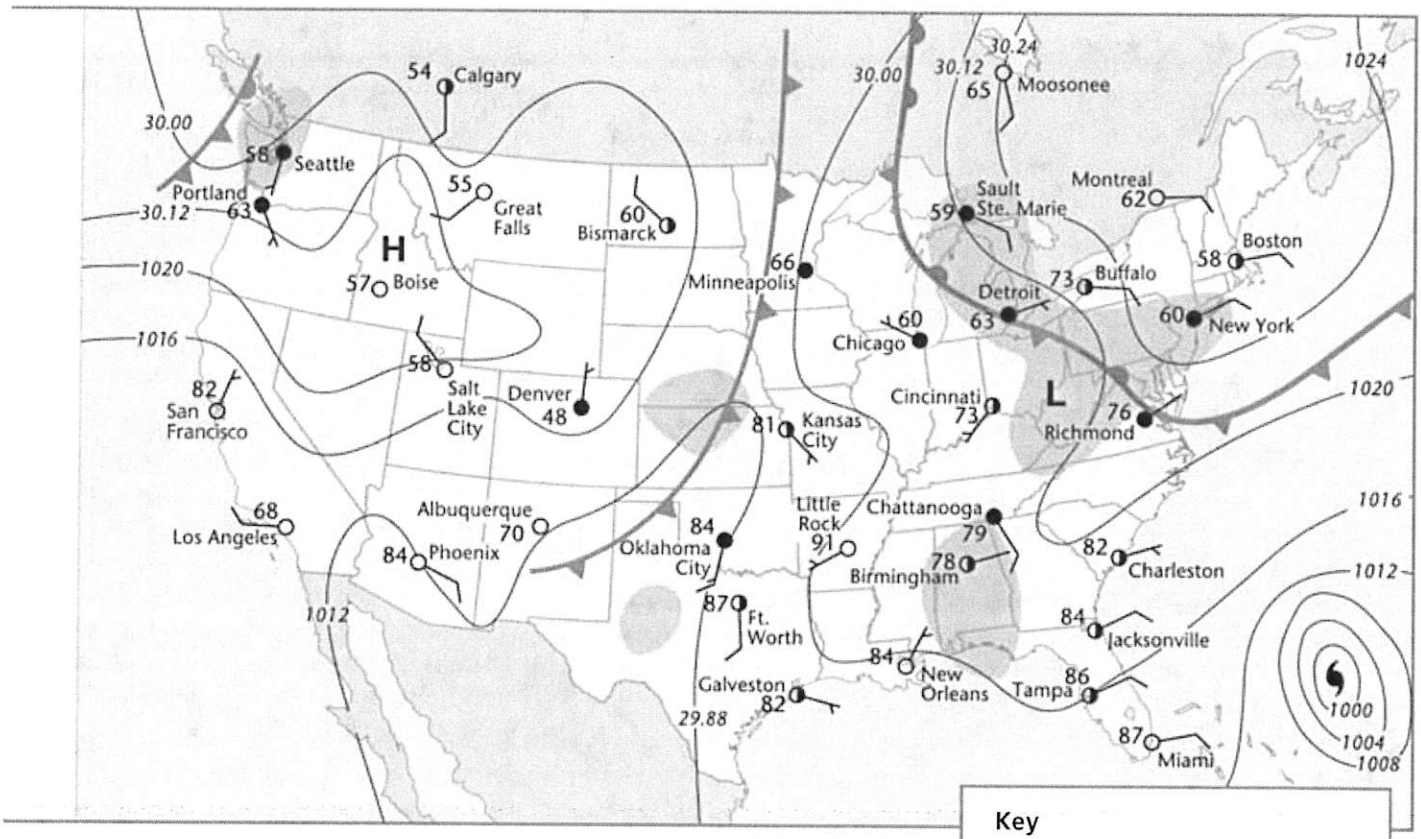
Reading Weather Maps

A weather map is a "snapshot" of conditions at a particular time over a large area. There are many types of weather maps. Weather forecasters often present maps generated by computers from surface data, radar, or satellite information.

Weather Service Maps Data from many local weather stations all over the country are assembled into weather maps at the National Weather Service. The data collected by a typical station is summarized in Figure 26 above. The simplified weather map on the next page includes most of the weather station data shown in the key.

On some weather maps, you see curved lines. These lines connect places where certain conditions—temperature or air pressure—are the same. **Isobars** are lines joining places on the map that have the same air pressure. (*Iso* means "equal" and *bar* means "pressure.") The numbers on the isobars are the pressure readings. Air pressure readings may be given in inches of mercury or in millibars or both. The isobars in Figure 26 are shown in both millbars and inches of mercury.

Isotherms are lines joining places that have the same temperature. The isotherm may be labeled with the temperature in degrees Fahrenheit, degrees Celsius, or both.



Key

- Drizzle
- Fog
- Hail
- Haze
- Hurricane
- −1020− Isobar
- Rain
- Shower
- Sleet
- Smoke
- Snow
- Thunderstorm
- Precipitation area
- Cold front
- Warm front
- Stationary front
- Occluded front

Newspaper Weather Maps Maps in newspapers are simplified versions of maps produced by the National Weather Service. Figure 27 on the next page shows a typical newspaper weather map. From what you have learned in this chapter, you can probably interpret most of the symbols on this map. **Standard symbols on weather maps show fronts, areas of high and low pressure, types of precipitation, and temperatures.** Note that the high and low temperatures are given in degrees Fahrenheit instead of Celsius.

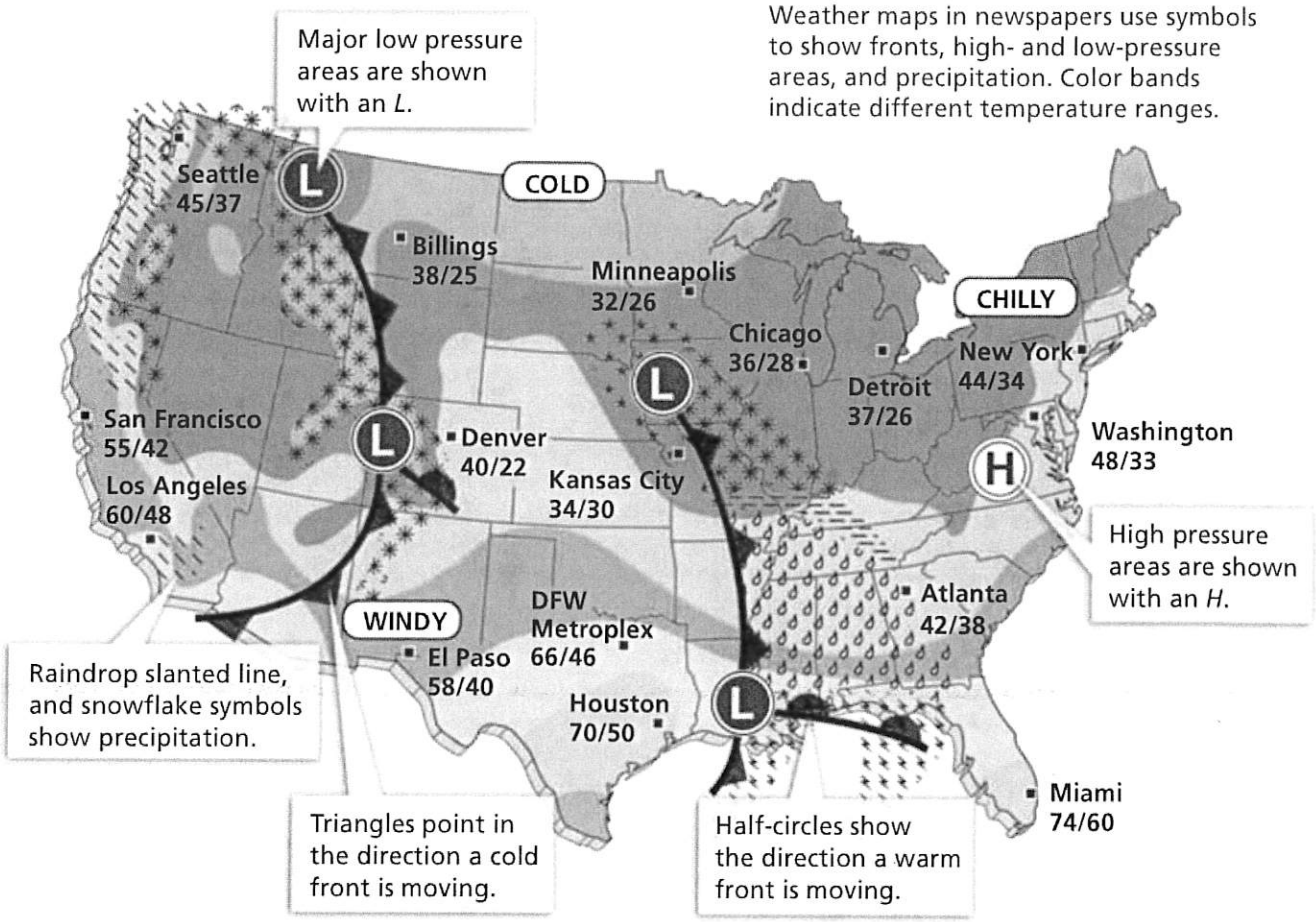
Limits of Weather Forecasts As computers have grown more powerful, and new satellites and radar technologies have been developed, scientists have been able to make better forecasts. But even with extremely fast computers, it is unlikely that forecasters will ever be able to predict the weather a month in advance with great accuracy. This has to do with the so-called "butterfly effect." The atmosphere works in such a way that a small change in the weather today can mean a larger change in the weather a week later! The name refers to a scientist's suggestion that even the flapping of a butterfly's wings causes a tiny disturbance in the atmosphere. This tiny event might cause a larger disturbance that could grow into a large storm.

Reading Checkpoint What is the "butterfly effect"?

FIGURE 27

Newspaper Weather Map

Weather maps in newspapers use symbols to show fronts, high- and low-pressure areas, and precipitation. Color bands indicate different temperature ranges.



Section 5 Assessment

Target Reading Skill Compare and Contrast Make a compare/contrast table for the types of lines found on weather maps. Compare isobars and isotherms. Include units of measure and descriptions.

Reviewing Key Concepts

HINT 1. a. Describing What is a meteorologist?

HINT b. Explaining What tools do meteorologists rely on to forecast the weather?

HINT 2. a. Identifying What is the symbol for a cold front on a weather map?

HINT b. Explaining How is wind direction indicated on a weather map?

HINT c. Interpreting Diagrams According to Figure 27, what is the weather like in Chicago? How might this change in a few hours?

d. Interpreting Diagrams Where on Figure 26 is a hurricane located? How does the air pressure near its center compare to the air pressure in Tampa Bay, Florida? HINT

Writing in Science

Weather Report Find a current weather map from a newspaper. Use the map to write a brief weather report for your region. Include a description of the various weather symbols used on the map.

Lab zone Skills Lab

Reading a Weather Map

Problem

How does a weather map communicate data?

Skills Focus

interpreting maps, observing, drawing conclusions

Procedure

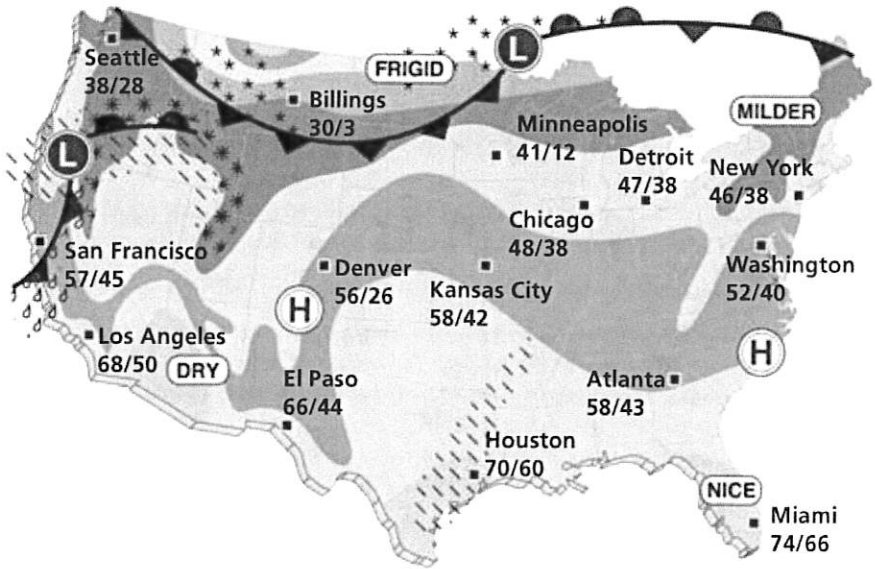
1. Examine the symbols on the weather map below. For more information about the symbols used on the map, refer to Figure 26 and Figure 27 earlier in this section.
2. Observe the different colors on the weather map below.
3. Find the symbols for snow and rain.
4. Locate the warm fronts and cold fronts.
5. Locate the symbols for high and low pressure.

Analyze and Conclude

1. Interpreting Maps What color represents the highest temperatures? What color represents the lowest temperatures?
2. Interpreting Maps Which city has the highest temperature? Which city has the lowest temperature?
3. Interpreting Maps Where on the map is it raining? Where on the map is it snowing?
4. Interpreting Maps How many different kinds of fronts are shown on the map?
5. Observing How many areas of low pressure are shown on the map? How many areas of high pressure are shown on the map?
6. Drawing Conclusions What season does this map represent? How do you know?
7. Communicating The triangles and semicircles on the front lines show which way the front is moving. What type of front is moving toward Minneapolis? What kind of weather do you think it will bring?

More to Explore

Compare this weather map to one shown on a television news report. Which symbols on these maps are similar? Which symbols are different?



Chapter 13 Study Guide

The BIG Idea

Weather and climate Differences in air pressure, air temperature, winds, and humidity produce changes in weather.

1 Water in the Atmosphere

Key Concepts

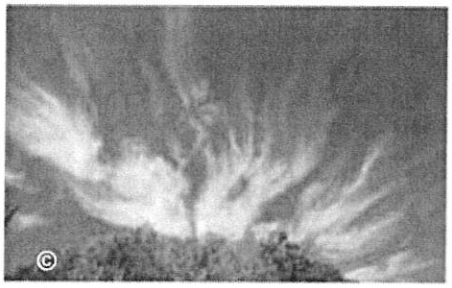
Relative humidity can be measured with an instrument called a psychrometer.

Clouds form when water vapor in the air condenses to form liquid water or ice crystals.

Scientists classify clouds into three main types based on their shape: cirrus, cumulus, and stratus. Clouds are also classified by altitude.

Key Terms

- water cycle
- evaporation
- humidity
- relative humidity
- psychrometer
- condensation
- dew point
- cirrus
- cumulus
- stratus



2 Precipitation

Key Concept

Common types of precipitation include rain, hail, snow, sleet, and freezing rain.

Key Term

- precipitation

3 Air Masses and Fronts

Key Concepts

Maritime tropical, continental tropical, maritime polar, and continental polar air masses influence the weather in North America.

In the continental United States, air masses are commonly moved by the prevailing westerlies and jet streams.

Colliding air masses can form four types of fronts: cold fronts, warm fronts, stationary fronts, and occluded fronts.

Cyclones and decreasing air pressure are associated with clouds, wind, and precipitation.

The descending air in an anticyclone generally causes dry, clear weather.

Key Terms

- air mass
- tropical
- polar
- maritime
- continental
- front
- occluded
- cyclone
- anticyclone

4 Storms

Key Concepts

Thunderstorms form in large cumulonimbus clouds, also known as thunderheads.

During thunderstorms, avoid places where lightning may strike.

Tornadoes most commonly develop in thick cumulonimbus clouds.

The safest place during a tornado is a storm shelter or the basement of a well-built building.

All year round, most precipitation begins in clouds as snow.

If you are caught in a snowstorm, try to find shelter from the wind.

A hurricane begins over warm ocean water as a low-pressure area, or tropical disturbance.

If you hear a hurricane warning and are told to evacuate, leave the area immediately.

Key Terms

- storm
- thunderstorm
- lightning
- tornado
- hurricane
- storm surge

5 Predicting the Weather

Key Concepts

Meteorologists use maps, charts, and computers to prepare weather forecasts.

Symbols on weather maps show fronts, pressure, precipitation, and temperatures.

Key Terms

- meteorologist
- isobar
- isotherm

Review and Assessment

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Organizing Information

Comparing and Contrasting Copy the table, which compares and contrasts thunderstorms, tornadoes, and hurricanes, onto a separate sheet of paper. Then complete it and add a title. (For more on Comparing and Contrasting, see the Skills Handbook.)

Type of Storm	Where Forms	Typical Time of Year	Safety Rules
Thunderstorm	Within large cumulonimbus clouds	a. ?	b. ?
Tornado	c. ?	Spring, early summer	d. ?
Hurricane	e. ?	f. ?	Evacuate or move inside a well-built building

Reviewing Key Terms

Choose the letter of the best answer.

HINT
1. A type of cloud that forms in flat layers and often covers much of the sky is
   a. cirrus. b. cumulus.
   c. fog. d. stratus.

HINT
2. Rain, sleet, and hail are all forms of
   a. evaporation.
   b. condensation.
   c. precipitation.
   d. convection.

HINT
3. Cool, clear weather usually follows a(n)
   a. warm front.
   b. cold front.
   c. stationary front.
   d. occluded front.

HINT
4. Very large tropical cyclones with high winds are called
   a. hurricanes.
   b. tornadoes.
   c. air masses.
   d. anticyclones.

HINT
5. Lines joining places that have the same temperature are
   a. isobars.
   b. isotherms.
   c. fronts.
   d. occluded.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

HINT
6. Winds that blow steadily from specific directions for long distances are called sea breezes.

HINT
7. Cirrus clouds are made mostly of ice crystals.

HINT
8. Summers in the Southwest are hot and dry because of maritime tropical air masses.

HINT
9. A cyclone is a high-pressure center of dry air.

HINT
10. On a weather map, isotherms join places on the map with the same air pressure.

Writing in Science

Descriptive Paragraph Imagine that you are a hurricane hunter—a scientist who flies into a hurricane to collect data. Describe what it would feel like as you flew through the hurricane's eyewall into its eye.

Discovery Channel School

Weather
Video Preview
Video Field Trip
▶ Video Assessment

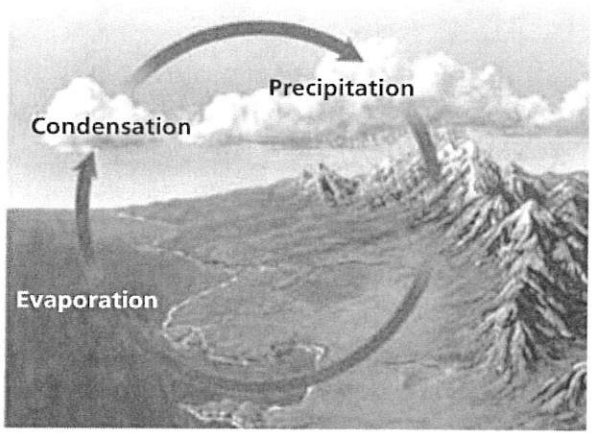
Review and Assessment

Checking Concepts

11. Why do clouds usually form high in the air instead of near Earth's surface?
12. Describe sleet, hail, and snow in terms of how each one forms.
13. Describe how wind patterns affect the movement of air masses in North America.
14. How does a cold front form?
15. Describe two situations in which floods can occur.
16. What happens to a hurricane when it moves onto land? Why?

Thinking Critically

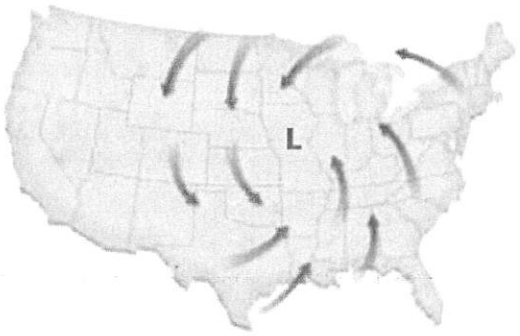
17. **Problem Solving** A psychrometer gives the same reading on both thermometers. What is the relative humidity?
18. **Relating Cause and Effect** How do differences in air density influence the movement of air along cold and warm fronts?
19. **Interpreting Diagrams** Describe the journey of a small particle of water through the water cycle, using the terms in the diagram below.



20. **Comparing and Contrasting** Compare thunderstorms and tornadoes. How are they similar? How are they different?
21. **Predicting** If air pressure is decreasing, what kind of weather is likely to occur?
22. **Applying Concepts** Would you expect hurricanes to form over the oceans off the northeast or northwest coasts of the United States? Explain.
23. **Applying Concepts** Why can't meteorologists accurately forecast the weather a month in advance?

Applying Skills

Use the map to answer Questions 24–27.



24. **Interpreting Maps** Does the map show a cyclone or an anticyclone? How can you tell?
25. **Interpreting Data** What do the arrows show about the movement of the winds in this pressure center? What else indicates wind direction?
26. **Making Models** Using this diagram as an example, draw a similar diagram to illustrate a high-pressure area. Remember to indicate wind direction in your diagram.
27. **Posing Questions** If you saw a pressure center like the one shown above on a weather map, what could you predict about the weather? What questions would you need to ask in order to make a better prediction?

Lab zone Chapter Project

Performance Assessment Present your weather maps and weather forecasts to the class. Discuss how accurate your weather predictions were. Explain any inaccuracies in your forecasts.

GA Preparing for the CRCT

Test-Taking Tip

Interpreting Graphs

A bar graph is used to compare quantities of different things. Each bar represents a quantity or amount of something. When answering a question with a bar graph, keep the following tips in mind. Read the title of the graph; the title should help you identify what information is shown on the graph. Then carefully examine the labels for the axes to determine what variables are plotted.

Sample Question

Use the graph at the right to determine how many tornadoes occurred in January.

A 30
B 25
C 5
D 15

Answer

First, find J for January on the *x*-axis. Then check the length of the bar and determine on the *y*-axis how many tornadoes occurred. The answer is **C**—five tornadoes occurred in January.

Choose the letter of the best answer.

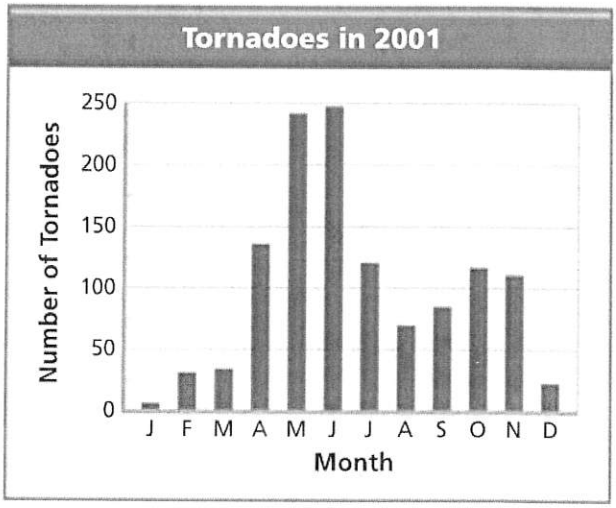
1. How are air masses classified?
   - **A** by temperature and pressure
   - **B** by pressure and humidity
   - **C** by temperature and density
   - **D** by temperature and humidity

   S6E4.a

2. A rapidly moving cold air mass meets a slowly moving warm air mass and forms a front. What will most likely occur at this front?
   - **A** The two air masses will mix together.
   - **B** The warm air will slide under the cold air. The cold air will rise and get warmer.
   - **C** Cold air will slide under the warm air. Warm air will rise and cool. Clouds will form.
   - **D** The less dense warm air will sink and cool. Clouds will form.

   S6E4.a

Use the graph below and your knowledge of science to answer Questions 3–4.



3. According to the graph, which two months in 2001 had the most tornadoes?
   - **A** April and May
   - **B** May and July
   - **C** May and June
   - **D** June and July

   S6E4.b

4. Which statement best summarizes the trend shown in the graph?
   - **A** Tornadoes always occur most frequently in May and June.
   - **B** Tornadoes occur when the weather is warmest.
   - **C** In 2001, tornadoes were most frequent in April, May, and June.
   - **D** Tornadoes are generally most frequent in the winter.

   S6E4.b

Constructed Response

5. Compare and contrast cyclones and anticyclones in terms of air pressure, temperature, wind direction, and humidity. What type of weather does each bring?

   S6E4.b