Section 4

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 Discover Activity

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 13, 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.

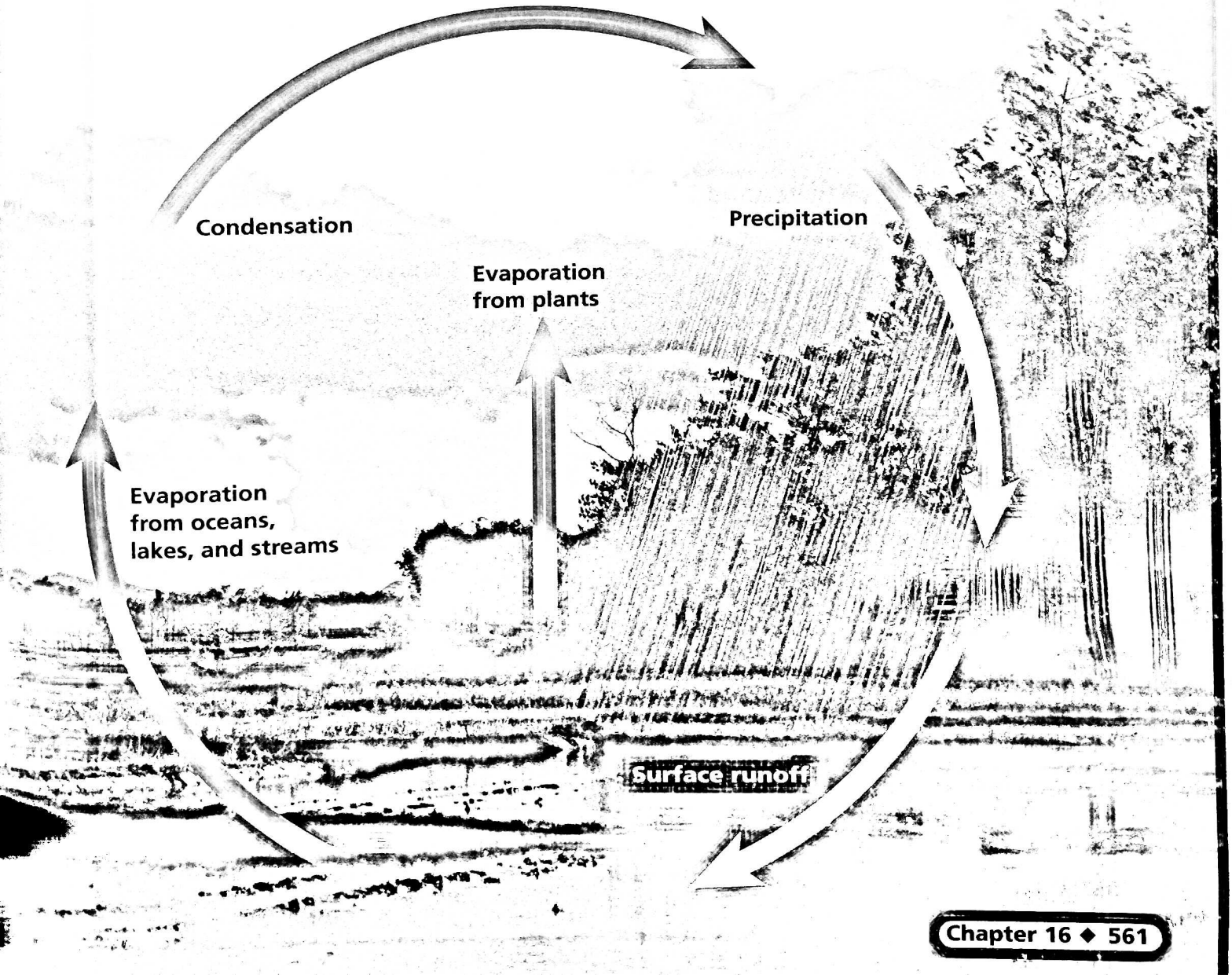
Relative Humidity Weather reports usually refer to the water vapor in the air as relative humidity. **Relative humidity** is the percentage of water vapor that is actually in the air compared to the maximum amount of water vapor the air can hold at a particular temperature. For example, at 10°C, 1 cubic 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 13
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



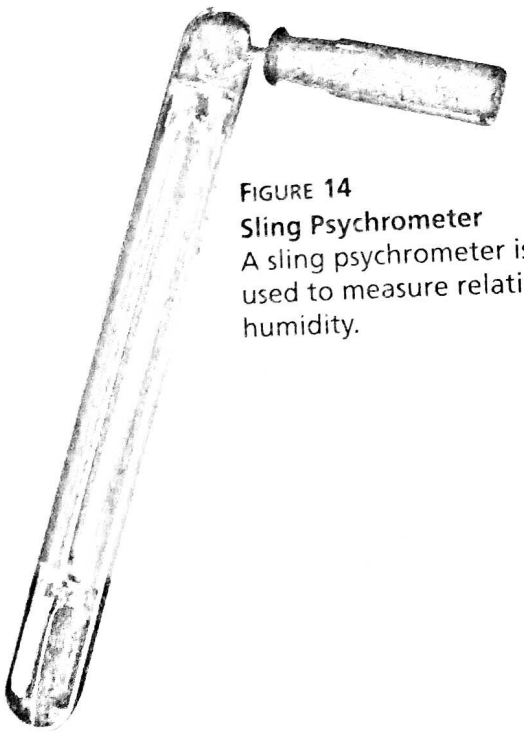


FIGURE 14
Sling Psychrometer
A sling psychrometer is used to measure relative humidity.

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 14. 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.

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

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.?
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.

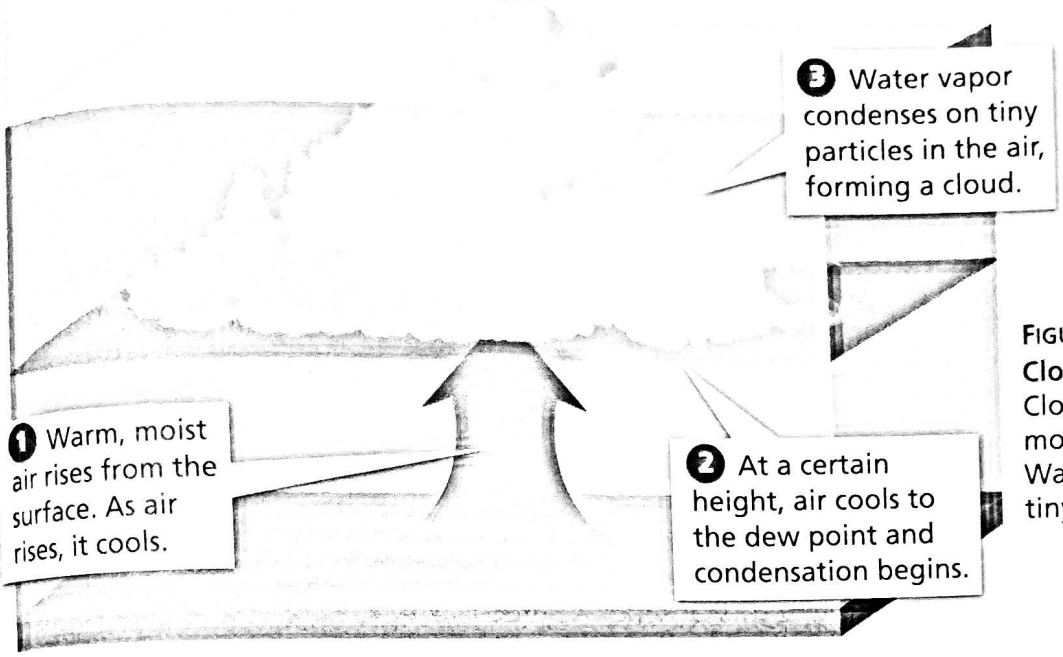


FIGURE 15
Cloud Formation
Clouds form when warm, moist air rises and cools. Water vapor condenses onto tiny particles in the air.

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?**

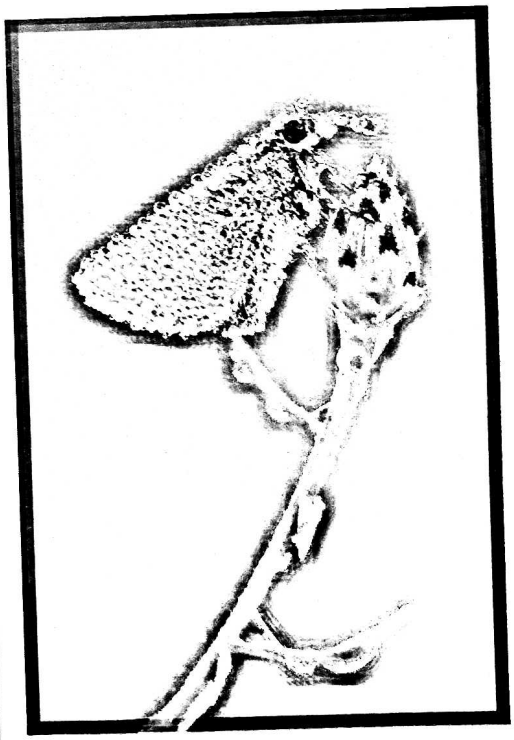


FIGURE 16
Condensation
Water vapor condensed on this insect to form dew. **Predicting** *What would happen if the surface were below freezing?*

Types of Clouds

Clouds come in many different shapes, as shown in Figure 17. **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

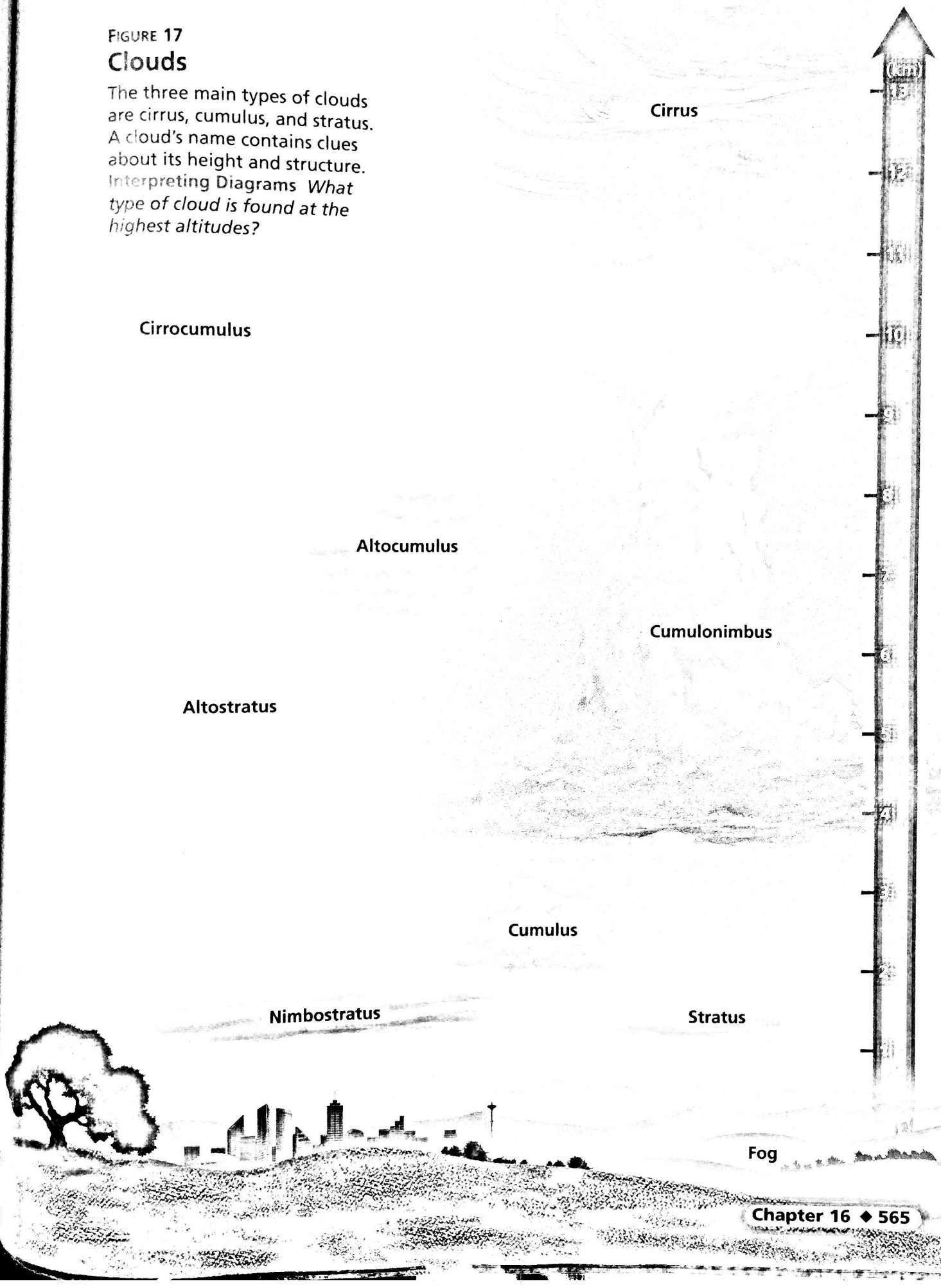
Stratus Clouds Clouds that form in flat layers are called **stratus** (STRAT us) clouds. Recall that *strato* means "spread out." Stratus clouds usually cover all or most of the sky and are a uniform dull, gray color. As stratus clouds thicken, they may produce drizzle, rain, or snow. They are then called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

Reading Checkpoint **What are stratus clouds?**

FIGURE 17

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?*



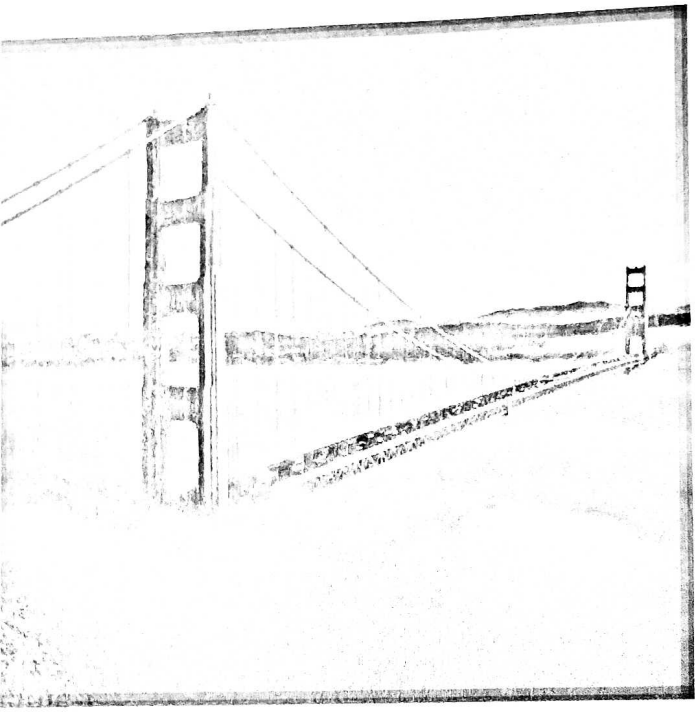


FIGURE 18
Fog Around the Golden Gate Bridge
The cold ocean water of San Francisco Bay is often covered by fog in the early morning.
Predicting *What will happen as the sun rises and warms the air?*

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 4 Assessment

Target Reading Skill

Asking Questions Use the answers to the questions you wrote about the headings to help answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** What is humidity?
   b. **Comparing and Contrasting** How are humidity and relative humidity different?
   c. **Calculating** Suppose a sample of air can at most hold 10 grams of water vapor. If the sample actually has 2 grams of water vapor, what is its relative humidity?
2. a. **Identifying** What process is involved in cloud formation?
   b. **Summarizing** What two conditions are needed for clouds to form?
   c. **Inferring** When are clouds formed by ice crystals instead of drops of liquid water?
3. a. **Listing** What are the three main types of clouds?
   b. **Describing** Briefly describe each of the three main types of clouds.
   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.