SECTION 1

READING WARM-UP

Terms to Learn

weather
water cycle
humidity
relative humidity
condensation
dew point
cloud
precipitation

What You'll Do

- Explain how water moves through the water cycle.
- Define *relative humidity.*
- Explain what the dew point is and its relation to condensation.
- Describe the three major cloud forms.
- Describe the four major types of precipitation.

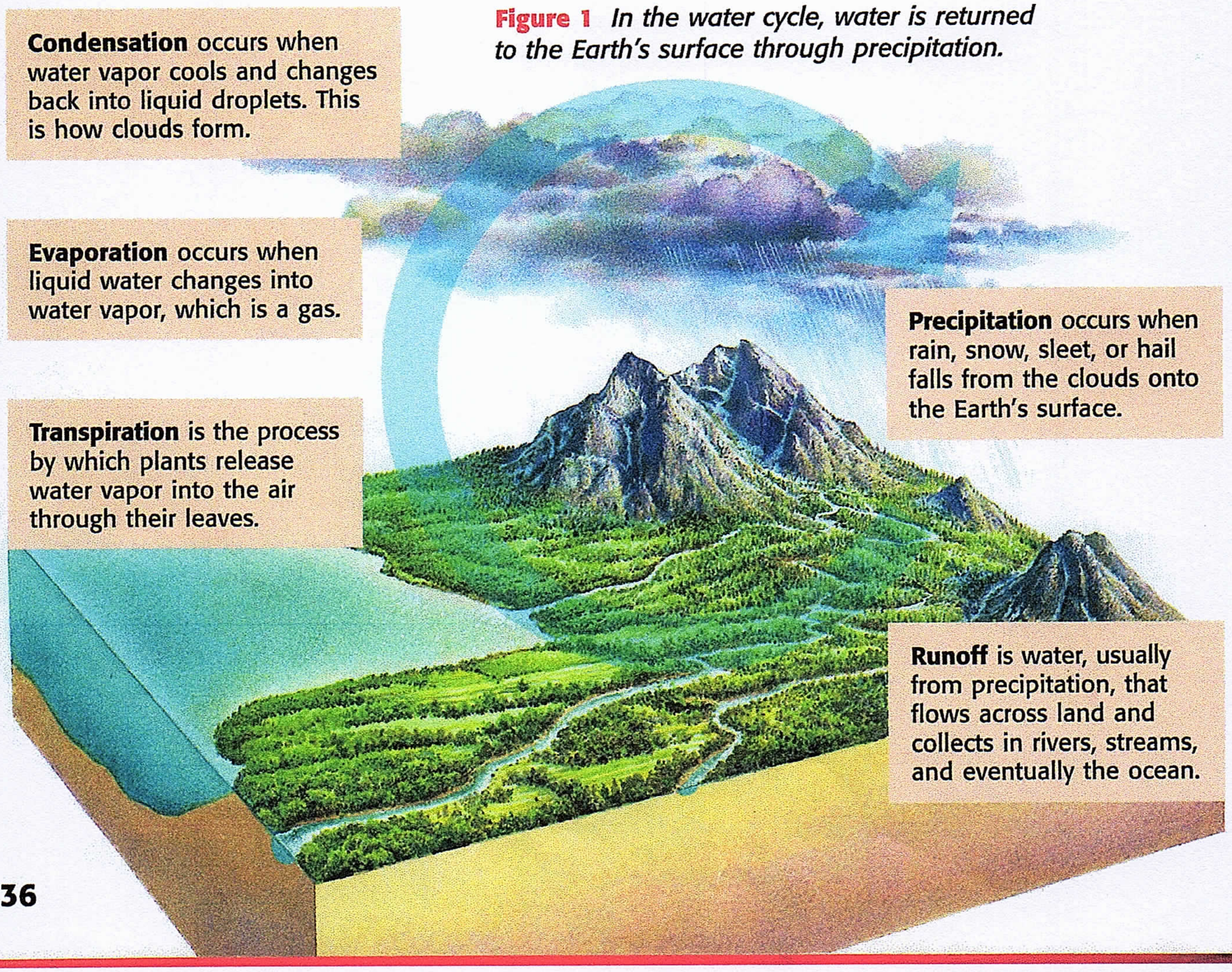
Water in the Air

There might not be a pot of gold at the end of a rainbow, but rainbows hold another secret that you might not be aware of. Rainbows are evidence that the air contains water. Water droplets break up sunlight into the different colors that you can see in a rainbow. Water can exist in the air as a solid, liquid, or gas. Ice, a solid, is found in clouds as snowflakes. Liquid water exists in clouds as water droplets. And water in gaseous form exists in the air as water vapor. Water in the air affects the weather. **Weather** is the condition of the atmosphere at a particular time and place. In this section you will learn how water affects the weather.

The Water Cycle

Water in liquid, solid, and gaseous states is constantly being recycled through the water cycle. The **water cycle** is the continuous movement of water from water sources, such as lakes and oceans, into the air, onto and over land, into the ground, and back to the water sources. Look at **Figure 1** below to see how water moves through the water cycle.

Figure 1 *In the water cycle, water is returned to the Earth's surface through precipitation.*



Humidity

Have you ever spent a long time styling your hair before school and had a bad hair day anyway? You walked outside and—wham—your straight hair became limp, or your curly hair became frizzy. Most bad hair days can be blamed on humidity. **Humidity** is the amount of water vapor or moisture in the air. And it is the moisture in the air that makes your hair go crazy, as shown in **Figure 2.**

As water evaporates, the humidity of the air increases. But air's ability to hold water vapor depends on air temperature. As temperature increases, the air's ability to hold water also increases. **Figure 3** shows the relationship between air temperature and air's ability to hold water.

Figure 2 *When there is more water in the air, your hair absorbs moisture and becomes longer.*

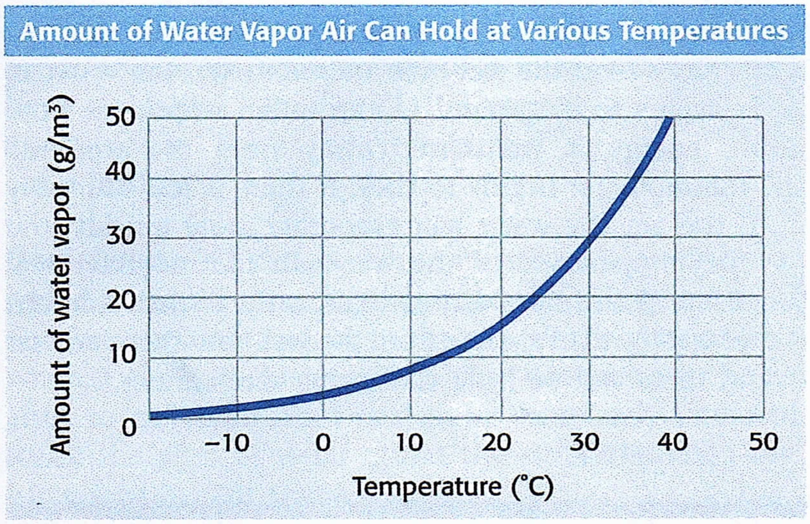


Figure 3 *This graph shows that warmer air can hold more water vapor than cooler air.*

Relative Humidity **Relative humidity** is the amount of moisture the air contains compared with the maximum amount it can hold at a particular temperature. Relative humidity is given as a percentage. When air holds all the water it can at a given temperature, the air is said to be *saturated.* Saturated air has a relative humidity of 100 percent. But how do you find the relative humidity of air that is not saturated? If you know the maximum amount of water vapor air can hold at a particular temperature and you know how much water vapor the air is actually holding, you can calculate the relative humidity.

Suppose that 1 m^3 of air at a certain temperature can hold 24 g of water vapor. However, you know that the air actually contains 18 g of water vapor. You can calculate the relative humidity using the following formula:

$$\frac{\text{(present) } 18\ g/m^3}{\text{(saturated) } 24\ g/m^3} \times 100 = \text{(relative humidity) } 75\%$$

MATH BREAK

Relating Relative Humidity

Assume that a sample of air 1 m^3 at 25°C, contains 11 g of water vapor. Calculate the relative humidity of the air using the value for saturated air shown in Figure 3.

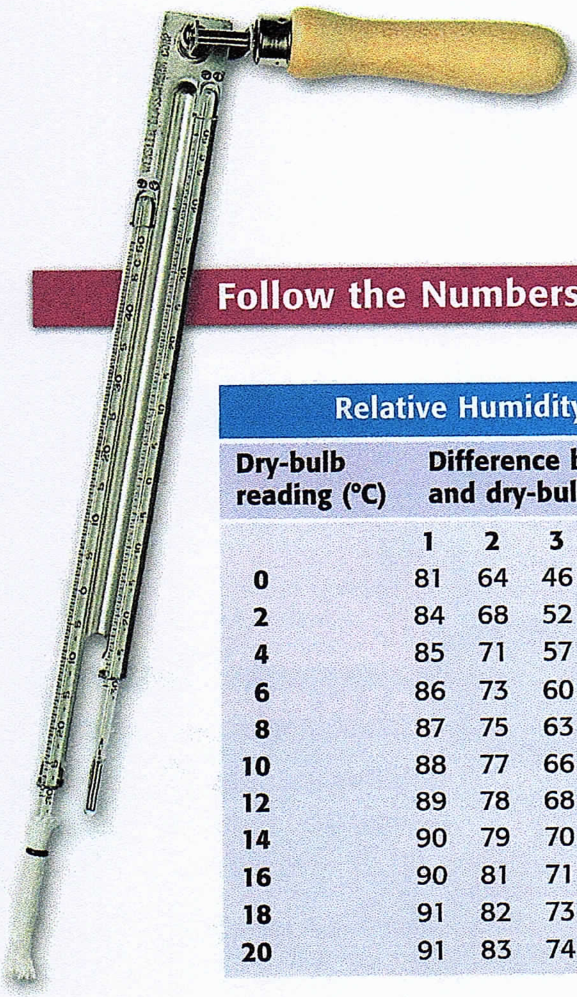
Self-Check

How does humidity relate to the water cycle? *(Turn to page 136 to check your answer.)*

Water Vapor Versus Temperature If the temperature stays the same, relative humidity changes as water vapor enters or leaves the air. The more water vapor that is in the air at a particular temperature, the higher the relative humidity is. Relative humidity is also affected by changes in temperature. If the amount of water vapor in the air stays the same, the relative humidity decreases as the temperature rises and increases as the temperature drops.

Measuring Relative Humidity A *psychrometer* (sie KRAHM uht uhr) is an instrument used to measure relative humidity. It consists of two thermometers. One thermometer is called a wet-bulb thermometer. The bulb of this thermometer is covered with a damp cloth. The other thermometer is a dry-bulb thermometer. The dry-bulb thermometer measures air temperature.

As air passes over the wet-bulb thermometer, the water in the cloth begins to evaporate. As the water evaporates from the cloth, energy is transferred away from the wet-bulb and the thermometer begins to cool. If there is less humidity in the air, the water will evaporate more quickly and the temperature of the wet-bulb thermometer will drop. If the humidity is high, only a small amount of water will evaporate from the wet-bulb thermometer and there will be little change in temperature.



Follow the Numbers

Relative Humidity (in percentage)

Dry-bulb reading (°C)	Difference between wet-bulb reading and dry-bulb reading (°C)							
	1	2	3	4	5	6	7	8
0	81	64	46	29	13			
2	84	68	52	37	22	7		
4	85	71	57	43	29	16		
6	86	73	60	48	35	24	11	
8	87	75	63	51	40	29	19	8
10	88	77	66	55	44	34	24	15
12	89	78	68	58	48	39	29	21
14	90	79	70	60	51	42	34	26
16	90	81	71	63	54	46	38	30
18	91	82	73	65	57	49	41	34
20	91	83	74	66	59	51	44	37

Relative humidity can be determined using a table such as this one. Locate the column that shows the difference between the wet-bulb and dry-bulb readings. Then locate the row that lists the temperature reading on the dry-bulb thermometer. The value where the column and row intersect is the relative humidity.

The difference in temperature readings between the wet-bulb and dry-bulb thermometers indicates the amount of water vapor in the air. A larger difference between the two readings indicates that there is less water vapor in the air and thus lower humidity.

The Process of Condensation

You have probably seen water droplets form on the outside of a glass of ice water, as shown in **Figure 4.** Did you ever wonder where those water droplets came from? The water came from the surrounding air, and droplets formed because of condensation. **Condensation** is the process by which a gas, such as water vapor, becomes a liquid. Before condensation can occur, the air must be saturated; it must have a relative humidity of 100 percent. Condensation occurs when saturated air cools further.

Figure 4 *Condensation occurred when the air next to the glass cooled to below its dew point.*

Dew Point Air can become saturated when water vapor is added to the air through evaporation or transpiration. Air can also become saturated, as in the case of the glass of ice water, when it cools to its dew point. The **dew point** is the temperature to which air must cool to be completely saturated. The ice in the glass of water causes the air surrounding the glass to cool to its dew point.

Before it can condense, water vapor must also have a surface to condense on. On the glass of ice water, water vapor condenses on the sides of the glass. Another example you may already be familiar with is water vapor condensing on grass, forming small water droplets called *dew.*

SECTION REVIEW

1. What is the difference between humidity and relative humidity?
2. What are two ways that air can become saturated with water vapor?
3. What does a relative humidity of 75 percent mean?
4. How does the water cycle contribute to condensation?
5. **Analyzing Relationships** What happens to relative humidity as the air temperature drops below the dew point?

QuickLab

Out of Thin Air

1. Take a **plastic container,** such as a jar or drinking glass, and fill it almost to the top with room-temperature **water.**
2. Observe the outside of the can or container. Record your observations.
3. Add one or two **ice cubes,** and watch the outside of the container for any changes.
4. What happened to the outside of the container?
5. What is the liquid?
6. Where did the liquid come from? Why?

TRY at HOME

Clouds

Some look like cotton balls, some look like locks of hair, and others look like blankets of gray blocking out the sun. But what *are* clouds and how do they form? And why are there so many different-looking clouds? A **cloud** is a collection of millions of tiny water droplets or ice crystals. Clouds form as warm air rises and cools. As the rising air cools, it becomes saturated. At saturation the water vapor changes to a liquid or a solid depending on the air temperature. At higher temperatures, water vapor condenses on small particles, such as dust, smoke, and salt, suspended in the air as tiny water droplets. At temperatures below freezing, water vapor changes directly to a solid, forming ice crystals.

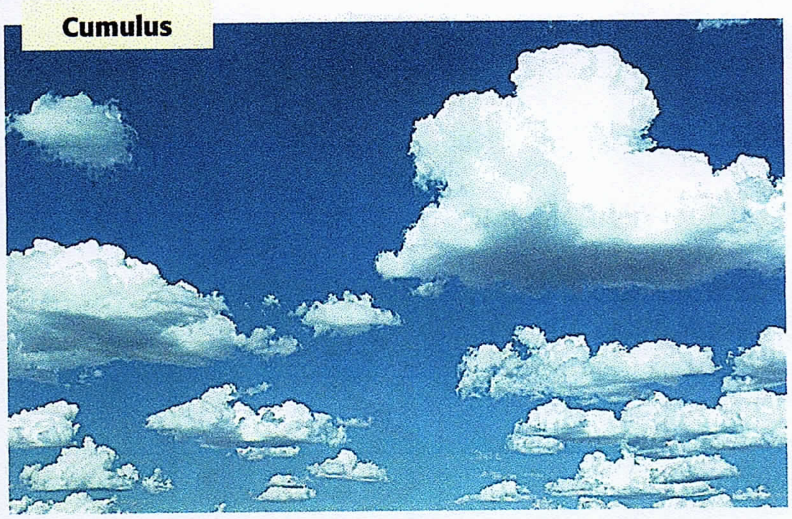


Figure 5 *Cumulus clouds look like piles of cotton balls.*

Cumulus Clouds Puffy, white clouds that tend to have flat bottoms, as shown in **Figure 5,** are called *cumulus clouds*. Cumulus clouds form when warm air rises. These clouds generally indicate fair weather. However, when these clouds get larger they produce thunderstorms. A cumulus cloud that produces thunderstorms is called a *cumulonimbus cloud*. When *-nimbus* or *nimbo-* is part of a cloud's name, it means that precipitation might fall from the cloud.

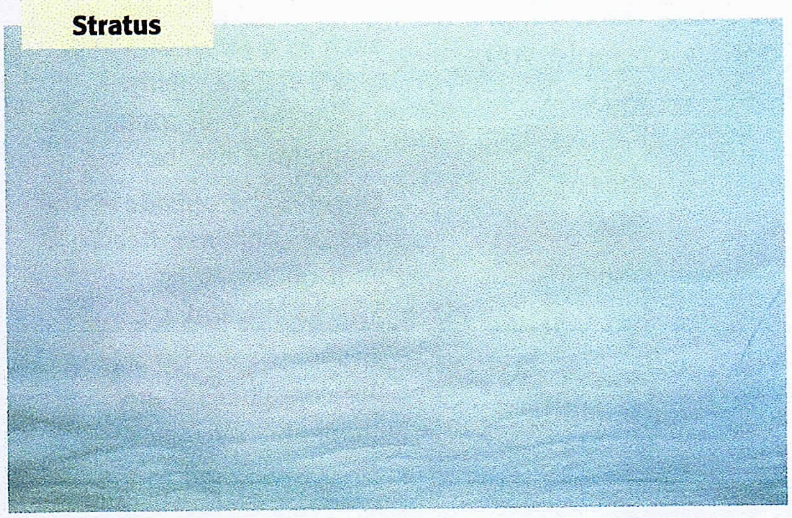


Figure 6 *Although stratus clouds are not as tall as cumulus clouds, they cover more area.*

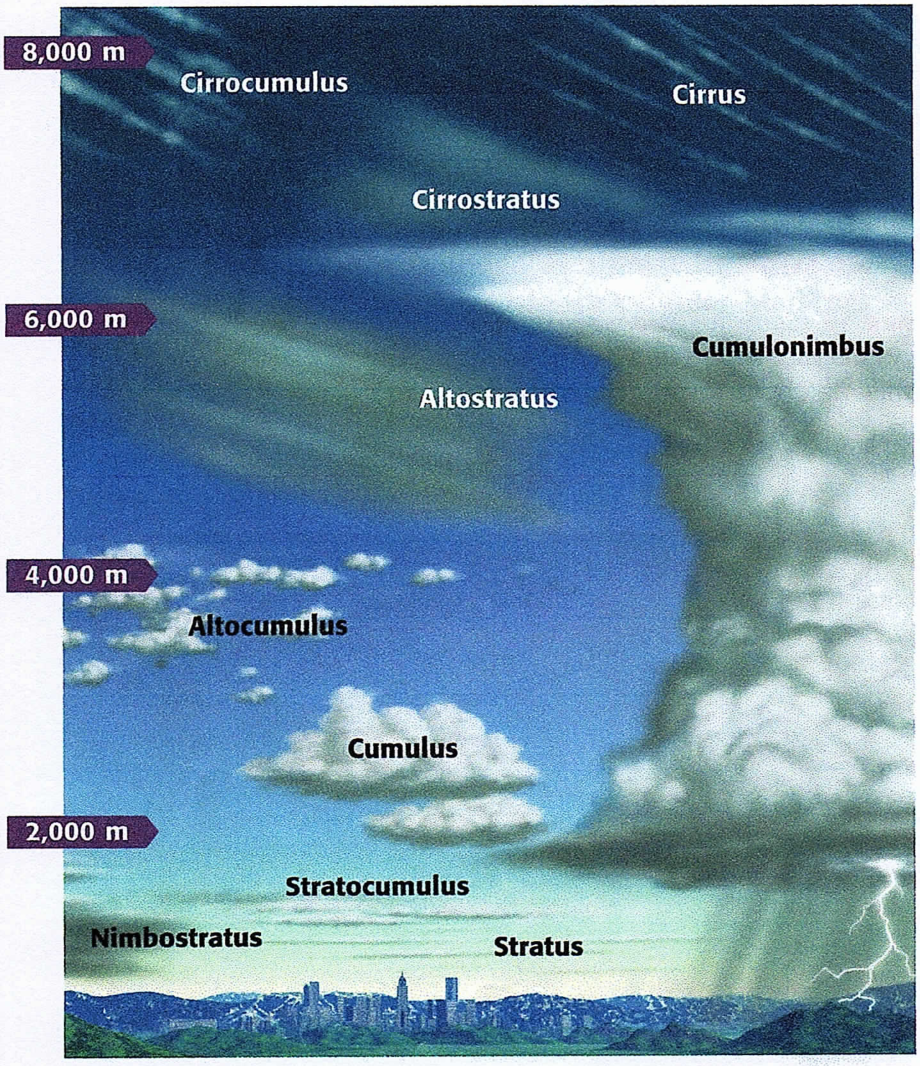
Stratus Clouds Clouds that form in layers, as shown in **Figure 6,** are called *stratus clouds*. Stratus clouds cover large areas of the sky, often blocking out the sun. These clouds are caused by a gentle lifting of a large body of air into the atmosphere. *Nimbostratus clouds* are dark stratus clouds that usually produce light to heavy, continuous rain. When water vapor condenses near the ground, it forms a stratus cloud called *fog*.

Cirrus Clouds As you can see in **Figure 7**, *cirrus* (SIR uhs) *clouds* are thin, feathery, white clouds found at high altitudes. Cirrus clouds form when the wind is strong. Cirrus clouds may indicate approaching bad weather if they thicken and lower in altitude.

Clouds are also classified by the altitude at which they form. The illustration in **Figure 8** shows the three altitude groups used to categorize clouds.

Figure 7 *Cirrus clouds are made of ice crystals.*

Figure 8 Cloud Types Based on Form and Altitude



High Clouds
Because of the cold temperatures at high altitude, high clouds are made up of ice crystals. The prefix *cirro-* is used to describe high clouds.

Middle Clouds
Middle clouds can be made up of both water droplets and ice crystals. The prefix *alto-* is used to describe middle clouds.

Low Clouds
Low clouds are made up of water droplets. The prefix *strato-* is commonly used to describe these types of clouds.

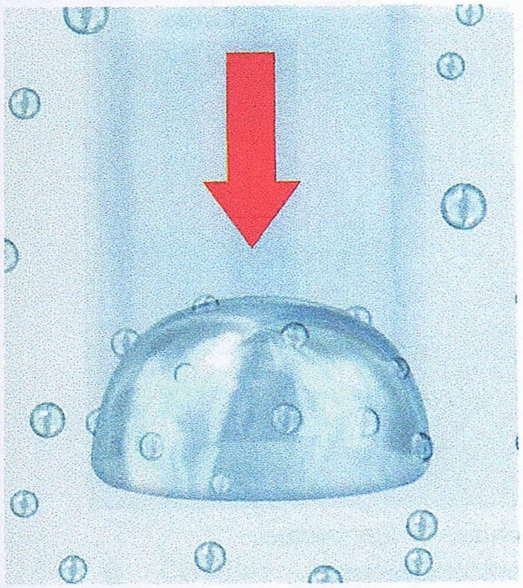


Figure 9 *Cloud droplets get larger by colliding and joining with other droplets. When the water droplets become too heavy, they fall as precipitation.*

Precipitation

Water vapor that condenses to form clouds can eventually fall to the ground as precipitation. **Precipitation** is water, in solid or liquid form, that falls from the air to the Earth. There are four major forms of precipitation—rain, snow, sleet, and hail.

Rain, the most common form of precipitation, is liquid water that falls from the clouds to Earth. A cloud produces rain when its water droplets become large enough to fall. A cloud droplet begins as a water droplet smaller than the period at the end of this sentence. Before a cloud droplet falls as precipitation, it must increase in size to about 100 times its normal diameter. **Figure 9** illustrates how a water droplet increases in size until it is finally large enough to fall as precipitation.

Snow and Sleet The most common form of solid precipitation is *snow.* Snow forms when temperatures are so cold that water vapor changes directly to a solid. Snow can fall as individual ice crystals or combine to form snowflakes, like the one shown in **Figure 10.**

Sleet, also called freezing rain, forms when rain falls through a layer of freezing air. The rain freezes, producing falling ice. Sometimes rain does not freeze until it hits a surface near the ground. When this happens, the rain changes into a layer of ice called *glaze,* as shown in **Figure 11.**

Figure 10 *Snowflakes are six-sided ice crystals that range in size from several millimeters to several centimeters.*

Figure 11 *Glaze ice forms as rain freezes on surfaces near the ground.*

Hail Solid precipitation that falls as balls or lumps of ice is called *hail.* Hail usually forms in cumulonimbus clouds. Updrafts of air in the clouds carry raindrops to high altitudes in the cloud, where they freeze. As the frozen raindrops fall, they collide and combine with water droplets. Another updraft of air can send the hail up again high into the cloud. Here the water drops collected by the hail freeze, forming another layer of frozen ice. If the upward movement of air is strong enough, the hail can accumulate many layers of ice. Eventually, the hail becomes too heavy and falls to the Earth's surface, as shown in **Figure 12.** Hail is usually associated with warm weather and most often occurs during the spring and summer months.

Figure 12 *The impact of large hailstones can damage property and crops.*

Measuring Precipitation A *rain gauge* is an instrument used to measure the amount of rainfall. A rain gauge typically consists of a funnel and a cylinder, as shown in **Figure 13.** Rain falls into the funnel and collects in the cylinder. Markings on the cylinder indicate how much rain has fallen.

Snow is measured by both depth and water content. The depth of snow is measured using a measuring stick. The snow's water content is determined by melting the snow and measuring the amount of water.

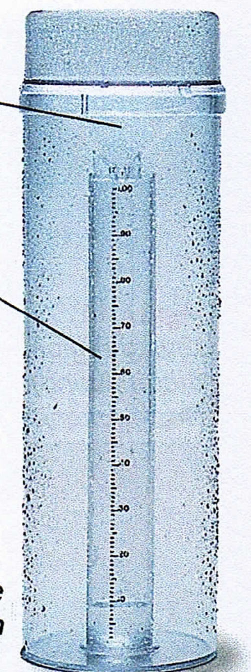


Figure 13 *Rain gauges measure only the precipitation that falls in a particular place.*

SECTION REVIEW

1. How do clouds form?
2. Why are some clouds formed from water droplets, while others are made up of ice crystals?
3. Describe how rain forms.
4. **Applying Concepts** How can rain and hail fall from the same cumulonimbus cloud?

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