SECTION 1

Water in the Air

What will the weather be this weekend? Depending on what you have planned, knowing the answer to this question could be important. A picnic in the rain can be a mess!

READING WARM-UP

Objectives

- Explain how water moves through the water cycle.
- Describe how relative humidity is affected by temperature and levels of water vapor.
- Describe the relationship between dew point and condensation.
- List three types of cloud forms.
- Identify four kinds of precipitation.

Terms to Learn

weather
humidity
relative humidity
condensation
cloud
precipitation

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

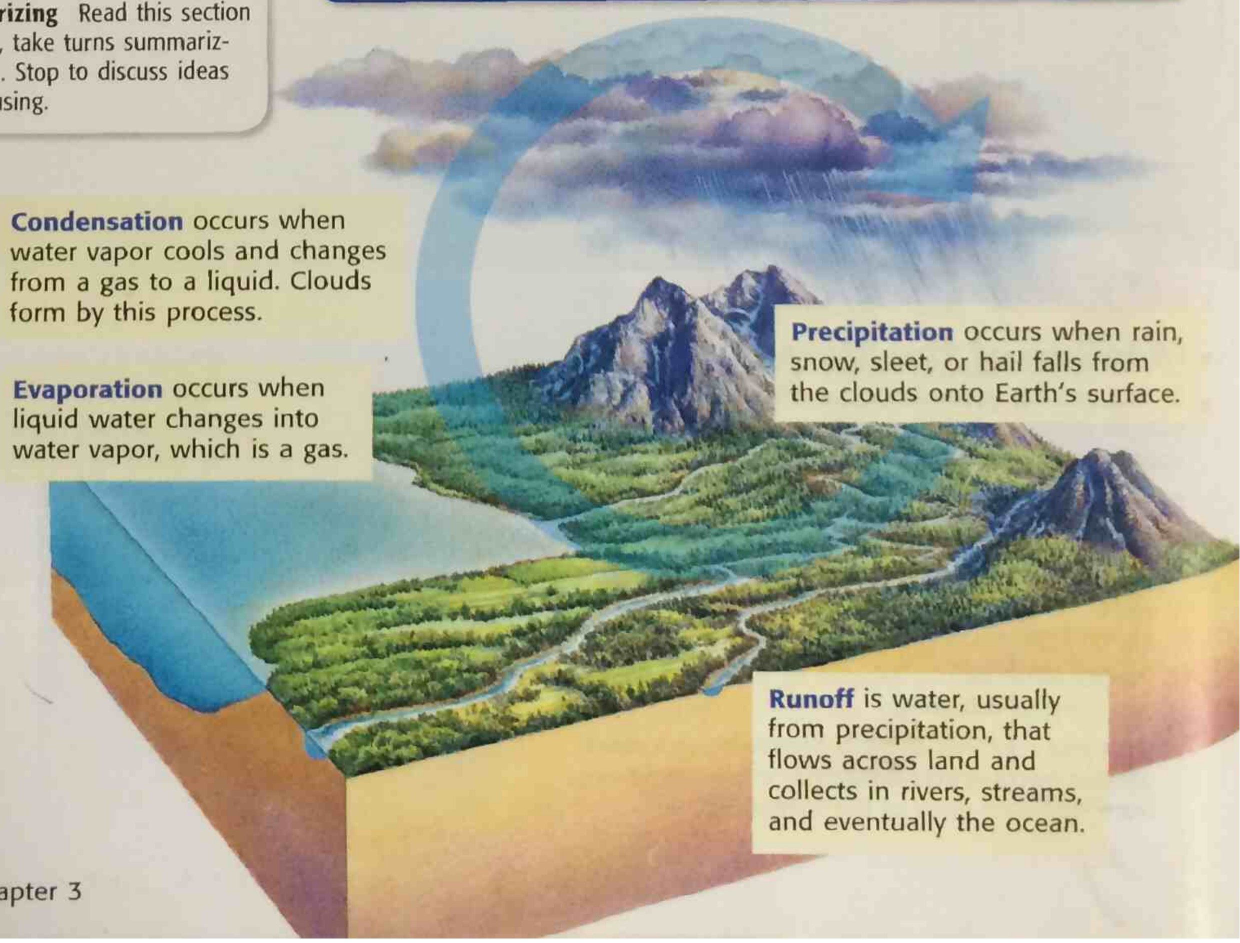
Have you ever wondered what weather is? **Weather** is the condition of the atmosphere at a certain time and place. The condition of the atmosphere is affected by the amount of water in the air. So, to understand weather, you need to understand how water cycles through Earth's atmosphere.

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 sources on Earth's surface—such as lakes, oceans, and plants—into the air, onto and over land, into the ground, and back to the surface. The movement of water through the water cycle is shown in **Figure 1.**

Reading Check What is the water cycle? (*See the Appendix for answers to Reading Checks.*)

Figure 1 The Water Cycle



Condensation occurs when water vapor cools and changes from a gas to a liquid. Clouds form by this process.

Evaporation occurs when liquid water changes into water vapor, which is a gas.

Precipitation occurs when rain, snow, sleet, or hail falls from the clouds onto Earth's surface.

Runoff is water, usually from precipitation, that flows across land and collects in rivers, streams, and eventually the ocean.

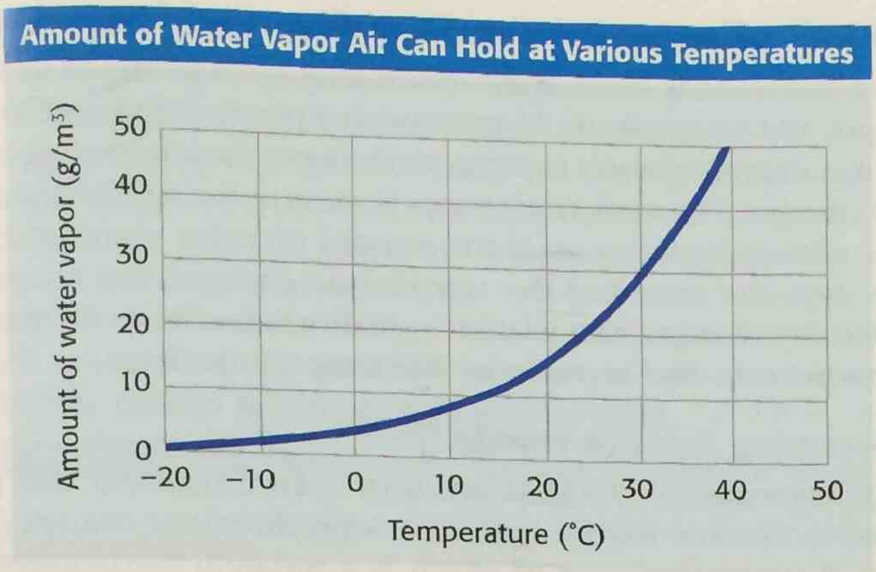


Figure 2 *This graph shows that as air gets warmer, the amount of water vapor that the air can hold increases.*

Humidity

As water evaporates from lakes, oceans, and plants, it becomes *water vapor,* or moisture in the air. Water vapor is invisible. The amount of water vapor in the air is called **humidity.** As water evaporates and becomes water vapor, the humidity of the air increases. The air's ability to hold water vapor changes as the temperature of the air changes. **Figure 2** shows that as the temperature of the air increases, the air's ability to hold water vapor also increases.

weather the short-term state of the atmosphere, including temperature, humidity, precipitation, wind, and visibility

humidity the amount of water vapor in the air

relative humidity the ratio of the amount of water vapor in the air to the maximum amount of water vapor the air can hold at a set temperature

Relative Humidity

One way to express humidity is through relative humidity. **Relative humidity** is the amount of water vapor in the air compared with the maximum amount of water vapor that the air can hold at a certain temperature. So, relative humidity is given as a percentage. When air holds all of the water that it can at a given temperature, it is said to be *saturated.* Saturated air has a relative humidity of 100%. But how do you find the relative humidity of air that is not saturated? If you know the maximum amount of water vapor that air can hold at a given temperature and the actual amount of water vapor in the air, 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 by using the following formula:

$$\frac{\textit{actual water vapor content } (g/m^3)}{\textit{saturation water vapor content } (g/m^3)} \times 100 = \textit{relative humidity } (\%)$$

$$\frac{18 \text{ g/m}^3}{24 \text{ g/m}^3} = 75\%$$

MATH PRACTICE

Relative Humidity

Assume that 1 m^3 of air at 25°C contains 11 g of water vapor. At this temperature, the air can hold 24 g/m^3 of water vapor. Calculate the relative humidity of the air.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HZ5WEAW.**

Factors Affecting Relative Humidity

Two factors that affect relative humidity are amount of water vapor and temperature. At constant temperature and pressure, as the amount of water vapor in air changes, the relative humidity changes. The more water vapor there is in the air, the higher the relative humidity is. If the amount of water vapor in the air stays the same but the temperature changes, the relative humidity changes. The relative humidity decreases as the temperature rises and increases as the temperature drops.

Measuring Relative Humidity

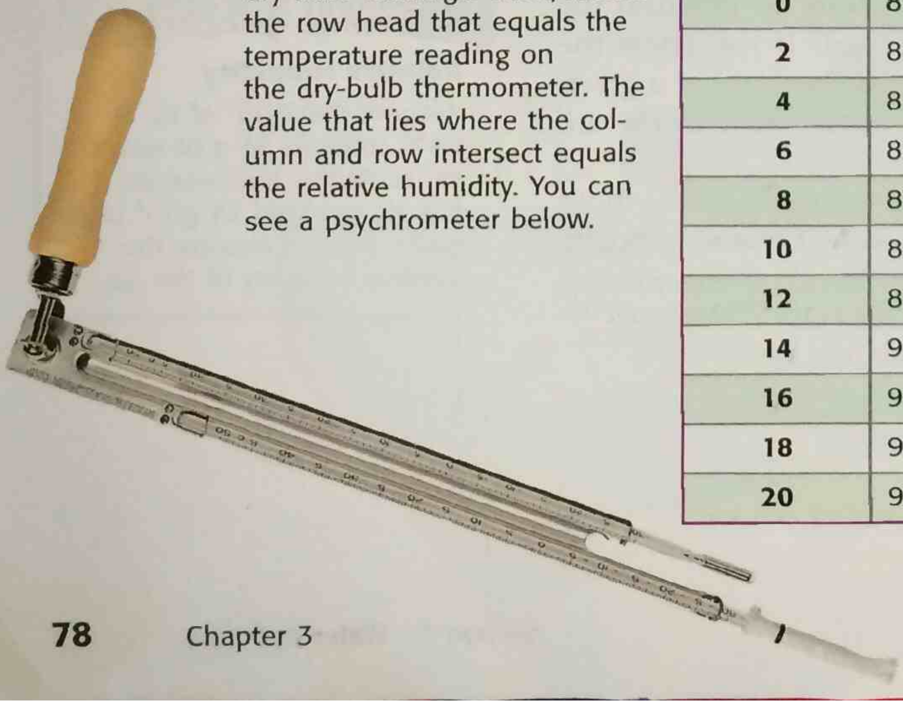
A *psychrometer* (sie KRAHM uht uhr) is an instrument that is used to measure relative humidity. A psychrometer consists of two thermometers, one of which is a wet-bulb thermometer. The bulb of a wet-bulb thermometer is covered with a damp cloth. The other thermometer is a dry-bulb thermometer.

The difference in temperature readings between the thermometers indicates the amount of water vapor in the air. The larger the difference between the two readings is, the less water vapor the air contains and thus the lower the humidity is. **Figure 3** shows how to use a table of differences between wet-bulb and dry-bulb readings to determine relative humidity.

Reading Check What tool is used to measure relative humidity?

Figure 3 **Determining Relative Humidity**

Find the relative humidity by locating the column head that is equal to the difference between the wet-bulb and dry-bulb readings. Then, locate the row head that equals the temperature reading on the dry-bulb thermometer. The value that lies where the column and row intersect equals the relative humidity. You can see a psychrometer below.



Relative Humidity (%)								
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

How a Wet-Bulb Thermometer Works

A wet-bulb thermometer works differently than a dry-bulb thermometer, which measures only air temperature. As air passes over the wet-bulb thermometer, the water in the cloth evaporates. As the water evaporates, the cloth cools. If the humidity is low, the water will evaporate more quickly and the temperature reading on the wet-bulb thermometer will drop. If the humidity is high, only a small amount of water will evaporate from the cloth of the wet-bulb thermometer and the change in temperature will be small.

Reading Check Explain how a wet-bulb thermometer works.

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

Condensation

You have probably seen water droplets form on the outside of a glass of ice water, as shown in **Figure 4.** Where did those water drops come from? The water came from the surrounding air, and droplets formed as a result 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, which means that the air must have a relative humidity of 100%. Condensation occurs when saturated air cools.

condensation the change of state from a gas to a liquid

Dew Point

Air can become saturated when water vapor is added to the air through evaporation. Air can also become saturated when it cools to its dew point. The *dew point* is the temperature at which a gas condenses into a liquid. At its dew point, air is saturated. The ice in the glass of water causes the air surrounding the glass to cool to its dew point.

Before water vapor can condense, though, it must have a surface to condense on. In the case of the glass of ice water, water vapor condenses on the outside of the glass.

Quick Lab

Out of Thin Air

1. Pour **room-temperature water** into a **plastic container,** such as a drinking cup, until the water level is near the top of the cup.
2. Observe the outside of the container, and record your observations.
3. Add **one or two ice cubes** to the container of water.
4. Watch the outside of the container for any changes.
5. What happened to the outside of the container?
6. What is the liquid on the container?
7. Where did the liquid come from? Explain your answer.

Figure 5 **Three Forms of Clouds**

Cumulus clouds look like piles of cotton balls.

Stratus clouds are not as tall as cumulus clouds, but they cover more area.

Cirrus clouds are made of ice crystals.

Clouds

Have you ever wondered what clouds are and how they form? 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. When the air is saturated, the water vapor changes to a liquid or a solid, depending on the air temperature. At temperatures above freezing, water vapor condenses on small particles in the air and forms tiny water droplets. At temperatures below freezing, water vapor changes to a solid to form ice crystals. Clouds are classified by form, as shown in **Figure 5,** and by altitude.

cloud a collection of small water droplets or ice crystals suspended in the air, which forms when the air is cooled and condensation occurs

Cumulus Clouds

Puffy, white clouds that tend to have flat bottoms are called *cumulus clouds* (KYOO myoo luhs KLOWDZ). Cumulus clouds form when warm air rises. These clouds generally indicate fair weather. However, when these clouds get larger, they produce thunderstorms. Thunderstorms come from a kind of cumulus cloud called a *cumulonimbus cloud* (KYOO myoo loh NIM buhs KLOWD). Clouds that have names that include *-nimbus* or *nimbo-* are likely to produce precipitation.

Stratus Clouds

Clouds called *stratus clouds* (STRAYT uhs KLOWDZ) are clouds that form in layers. Stratus clouds cover large areas of the sky and often block out the sun. These clouds can be caused by a gentle lifting of a large body of air into the atmosphere. *Nimbostratus clouds* (NIM boh STRAYT uhs KLOWDZ) are dark stratus clouds that usually produce light to heavy, continuous rain. *Fog* is a stratus cloud that has formed near the ground.

CONNECTION TO Language Arts

Cloud Clues Did you know that the name of a cloud actually describes the characteristics of the cloud? For example, the word *cumulus* comes from the Latin word meaning "heap." A cumulus cloud is a puffy, white cloud, which could be described as a "heap" of clouds. Use a dictionary or the Internet to find the word origins of the names of the other cloud types you learn about in this section.

Cirrus Clouds

As you can see in **Figure 5**, *cirrus clouds* (SIR uhs KLOWDZ) are thin, feathery, white clouds found at high altitudes. Cirrus clouds form when the wind is strong. If they get thicker, cirrus clouds indicate that a change in the weather is coming.

Clouds and Altitude

Clouds are also classified by the altitude at which they form. **Figure 6** shows two altitude groups used to describe clouds and the altitudes at which they form in the middle latitudes. The prefix *cirro-* is used to describe clouds that form at high altitudes. For example, a cumulus cloud that forms high in the atmosphere is called a *cirrocumulus cloud*. The prefix *alto-* describes clouds that form at middle altitudes. Clouds that form at low altitudes do not have a specific prefix to describe them.

Reading Check **At what altitude does an altostratus cloud form?**

Figure 6 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 drops and ice crystals. The prefix *alto-* is used to describe middle clouds.

Low Clouds Low clouds are made up of water drops. There is no specific prefix used to describe low clouds.

Figure 7 *Snowflakes are six-sided ice crystals that can be several millimeters to several centimeters in size.*

Precipitation

When water from the air returns to Earth's surface, it returns as precipitation. **Precipitation** is water, in solid or liquid form, that falls from the air to Earth. There are four major forms of precipitation—rain, snow, sleet, and hail.

Rain

The most common form of precipitation is *rain.* A cloud produces rain when the water drops in the cloud become large enough to fall. A water drop in a cloud begins as a droplet that is smaller than the period at the end of this sentence. Before such a water drop falls as rain, it must become about 100 times its original size.

Sleet and Snow

Sleet forms when rain falls through a layer of freezing air. The rain freezes in the air, which produces falling ice. *Snow* forms when temperatures are so cold that water vapor changes directly to a solid. Snow can fall as single ice crystals or can join to form snowflakes, as shown in **Figure 7.**

Hail

Balls or lumps of ice that fall from clouds are called *hail.* Hail forms in cumulonimbus clouds. When updrafts of air in the clouds carry raindrops high in the clouds, the raindrops freeze and hail forms. As hail falls, water drops coat it. Another updraft of air can send the hail up again. Here, the water drops collected on the hail freeze to form another layer of ice on the hail. This process can happen many times. Eventually, the hail becomes too heavy to be carried by the updrafts and so falls to Earth's surface, as shown in **Figure 8.**

precipitation any form of water that falls to the Earth's surface from the clouds

Figure 8 *The impact of large hailstones can damage property and crops. The inset photograph shows layers inside of a hailstone, which reveal how it formed.*