Section 1
Water in the Air

Key Concept The sun's energy drives the water cycle and causes differences in humidity that may lead to precipitation.

What You Will Learn
- The amount of water vapor in the air is known as humidity.
- Differences in pressure, temperature, and humidity cause clouds and precipitation.

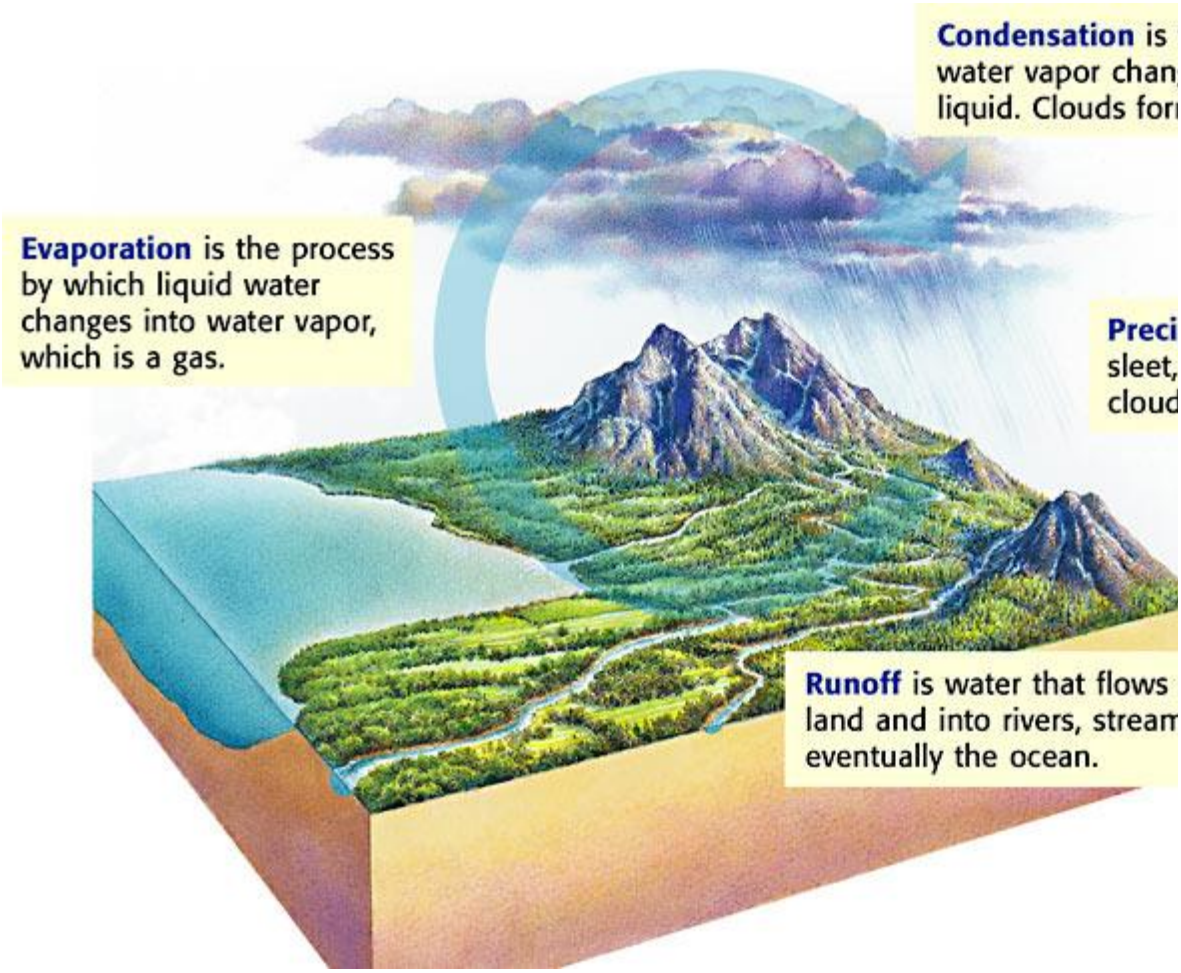
Why It Matters
Understanding how water moves through the water cycle is the basis for understanding weather.

What will the weather be tomorrow? Depending on what you have planned, knowing the answer to this question could be important. A day at the beach in the rain would be no fun!

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. To understand weather, you need to understand how water moves through the atmosphere.

The Water Cycle
The sun's energy heats Earth's surface and causes water to change states. For example, as the water in the ocean is heated, it may change to water vapor. If the water vapor cools, it may condense to form water droplets that make up clouds. This movement of water between the atmosphere, the land, and the oceans is called the *water cycle.* The water cycle is shown in **Figure 1.**

Figure 1 The Water Cycle



Standards Check What is the main source of energy for the water cycle?

Humidity

Water vapor makes up between 1% and 4% of the total composition of Earth's atmosphere by volume. However, this small amount of water vapor greatly affects weather and climate. The amount of water vapor in the air is known as **humidity**.

Humidity depends on the rates of evaporation and condensation. In general, the rate of evaporation increases as air temperature increases. The rate of condensation is determined by vapor pressure. *Vapor pressure* is that part of total atmospheric pressure that is caused by water vapor, as shown in **Figure 2.** As vapor pressure increases, the rate of condensation increases. When the rate of evaporation equals the rate of condensation, the air is saturated with water molecules. The temperature at which this balance happens is called the **dew point.** At temperatures below the dew point, liquid water droplets form on a surface or on tiny particles in the air.

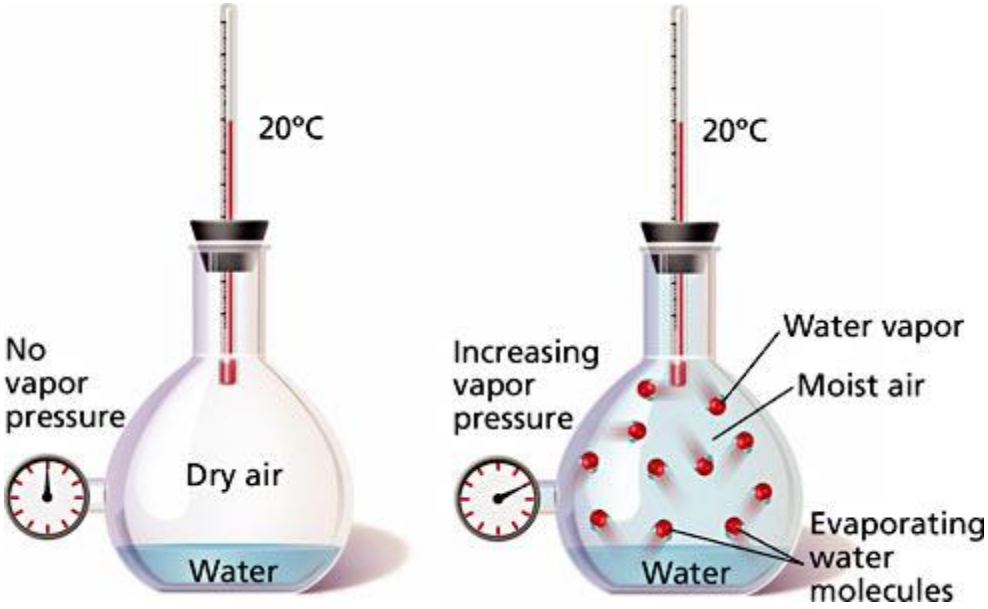


Figure 2 When water comes into contact with dry air, some of the water molecules evaporate into the dry air. The addition of the water molecules to the air causes the air pressure to increase. This increase in pressure is due to vapor pressure.

Relative Humidity

A common way for scientists to express the amount of water vapor in the air is by using relative humidity. **Relative humidity** is the ratio of the amount of water vapor in the air to the amount of water vapor needed to reach saturation at a given temperature. In other words, relative humidity is a measure of how close the air is to the dew point. At a certain temperature, air is saturated when it has 24 g of water

vapor per 1 m^3 of air. But, the air actually has 18 g of water vapor. You can calculate the relative humidity by using the following formula:

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

$$\frac{18\ g/m^3}{24\ g/m^3} \times 100 = 75\%$$

Measuring Relative Humidity

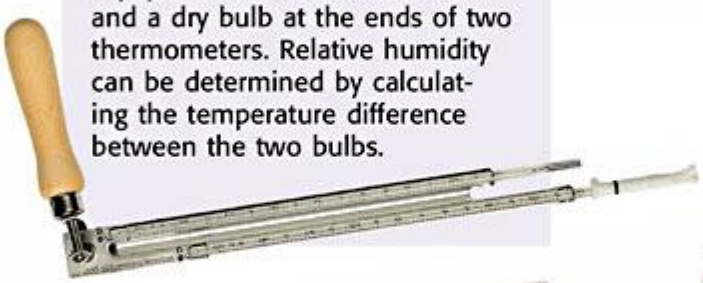
Over time, the way scientists measure humidity has changed. **Figure 3** shows some of the instruments scientists have used to measure humidity. Meteorologists today commonly measure humidity by using a humidity sensor that has a thin-film polymer. The thin-film polymer in the sensor absorbs water vapor as the relative humidity in the air rises, and thin-film polymer releases water vapor as the relative humidity drops. As the amount of water in the film changes, the electrical properties of the film change. The amount of stored electric charge is measured and quickly converted into a relative-humidity reading. Other instruments that have been used to measure humidity are hair hygrometers, dew cells, and psychrometers.

Figure 3 Instruments for Measuring Relative Humidity

This hair hygrometer from the 1800s measures humidity by means of a human hair, which contracts and expands as humidity changes.

Dew cells are of hygrometer measure dew

A psychrometer has a wet bulb and a dry bulb at the ends of two thermometers. Relative humidity can be determined by calculating the temperature difference between the two bulbs.



Instruments that use thin-film polymers can determine relative humidity by measuring the polymer film's ability to store electricity.

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 droplets come from? They came from the surrounding air. The droplets formed as a result of condensation. **Condensation** is the process by which a gas, such as water vapor, becomes a liquid. For liquid water droplets to form, the air must be saturated, or have a relative humidity of 100%. Air can become saturated when water vapor enters the air through evaporation. Air can also become saturated when it cools to below its dew point.

Figure 4 Water droplets formed when the air around the glass cooled to below the dew point.

Dew Point and Condensation

The dew point is the temperature at which the rate of condensation equals the rate of evaporation. When ice cubes are added to the glass of water, the temperature of the water drops. The cold water absorbs heat from the glass by conduction, and the glass cools, too. By conduction, the glass absorbs heat from the

air. As a result, the temperature of the air next to the glass drops to below the dew point. As the condensation rate exceeds the evaporation rate, water droplets form on the glass.

Reaching the Dew Point

When the air is nearly saturated, only a small temperature drop is needed for air to reach its dew point. During the night, grass, leaves, and other things near the ground lose heat. Air may cool to below the dew point when the air touches these cold surfaces. The water droplets that form are called *dew*.

Standards Check How does a drop in temperature cause condensation?

Clouds and Precipitation

A cloud is a collection of millions of tiny water droplets or ice crystals. Clouds form as air rises and cools. When the air cools to below the dew point, water droplets or ice crystals form. At temperatures above 0°C, water vapor condenses on small particles in the air and forms tiny water droplets. At temperatures below 0°C, water vapor changes to a solid to form ice crystals.

Types of Clouds

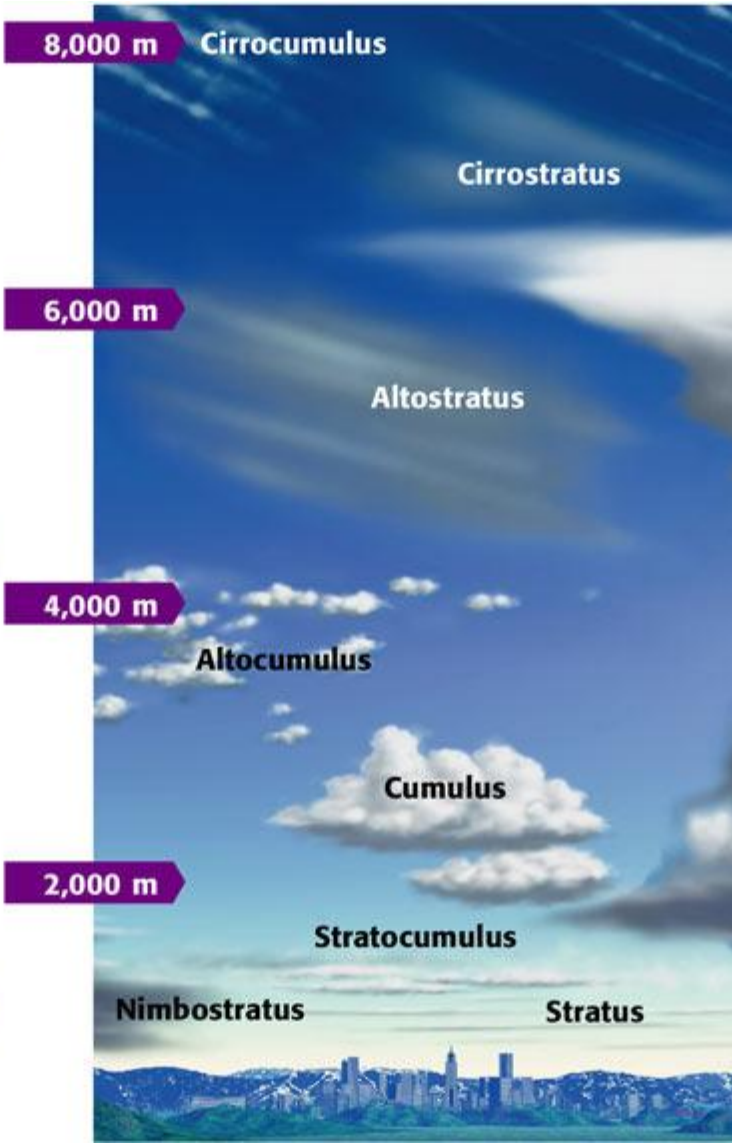
Clouds are classified by their shape and their altitude, as shown in **Figure 5.** The three cloud forms are stratus clouds, cumulus clouds, and cirrus clouds. There are also three altitude groups: low clouds (0 m to 2,000 m), middle clouds (2,000 m to 6,000 m), and high clouds (above 6,000 m).

Figure 5 Cloud Types Based on Shape 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. There is no specific prefix to describe low clouds.



Standards Check How does air movement cause clouds to form?

Precipitation

Most cloud droplets have a diameter of about 20 micrometers, which is smaller than the period at the end of this sentence. Droplets of this size fall very slowly through the air. When a droplet reaches a certain size, it falls as precipitation.

Precipitation is water, in any form, that falls to Earth's surface from the clouds. There are four major forms of precipitation—rain, snow, sleet, and hail. Rain is the most common form of precipitation. Hail, lumps of ice that fall from clouds, is less common. **Figure 6** shows a cross section of a hailstone.

Figure 6 The layers in a hailstone show that the hailstone was repeatedly coated in water and then frozen.

Standards Check What is precipitation, and what causes it?

Section Summary

- The sun's energy causes water to change states and to move through the water cycle.
- The amount of water vapor in the air is called *humidity.*
- When the temperature of the air cools to the dew point, the air is saturated and liquid water droplets form.
- Clouds form as air rises and cools, which causes water droplets to form on small particles in the air.
- Precipitation is water, in any form, that falls to Earth's surface from the clouds.

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