

# 11-5 What is air pressure?

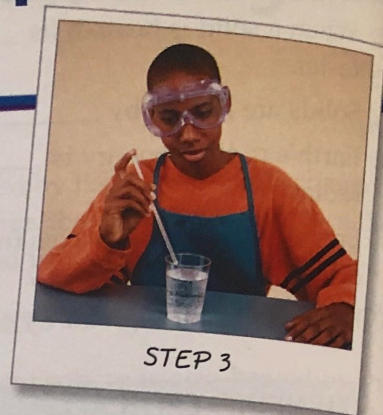
## INVESTIGATE



### Observing Air Pressure HANDS-ON ACTIVITY

1. Place a drinking straw in a cup of water.
2. Put your finger over the top end of the straw.
3. Take the straw out of the water. Observe the water inside the straw.
4. Hold the straw over the cup and remove your finger. Observe what happens.

**THINK ABOUT IT:** What happened when you removed the straw from the water with your finger on top of it? What holds the water in the straw? Why does the water fall out when you take your finger away? How is this activity related to air pressure?



### Objective

Explain air pressure and describe what affects it.

### Key Terms

**newton:** metric unit of force

**pressure:** amount of force per unit of area

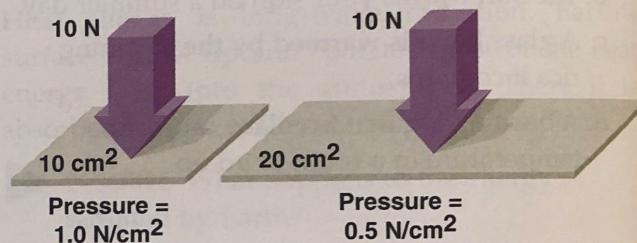
**Weight and Pressure** Weight is a force. If you hold a book in the palm of your hand, you feel the weight of the book pressing down. This force is measured in units called **newtons (N)**. A 1-kg mass has a force of about 10 N.

The amount of force per unit of area is called **pressure**. When you hold the book in the palm of your hand, the book's weight is spread over your hand. Suppose the book's force is 10 N, and your hand has an area of 100 square cm, or 100 cm<sup>2</sup>. The force on each square centimeter is then 10 N divided by 100 cm<sup>2</sup>, or 0.1 N/cm<sup>2</sup>. The pressure of the book on your hand is 0.1 N/cm<sup>2</sup>.

$$\frac{\text{Force}}{\text{Area}} = \text{Pressure}$$

$$\frac{10 \text{ N}}{100 \text{ cm}^2} = 0.1 \text{ N/cm}^2$$

A force exerted over a small area causes more pressure than the same force applied over a large area. See Figure 11-12 for an example of this.

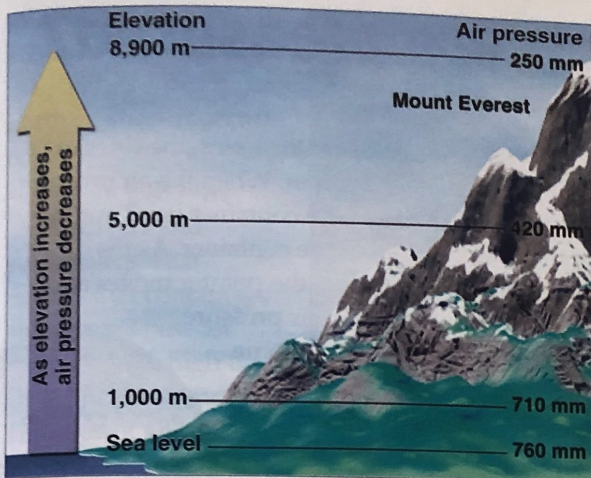


▲ **Figure 11-12** The same force exerted over a smaller area causes more pressure.

Air has weight. One liter of air weighs about 0.01 N at sea level. This is about the weight of a paper clip. The surface of Earth is at the bottom of the atmosphere. Air molecules are in constant motion and are pulled towards Earth's center by gravity. The force of all these moving molecules causes air pressure. Most of the air in the atmosphere is concentrated near Earth's surface. So air pressure is greatest near Earth's surface and decreases as altitude increases.

**1 EXPLAIN:** Why does air exert pressure on Earth's surface?

**Elevation** Air pressure changes with elevation, or height above sea level. The atmosphere is hundreds of kilometers thick. The weight of all this air causes more pressure near the ground. This pushes the air molecules closer together. Near the top of the atmosphere, the air molecules remain farther apart. There is very little weight of air pressing down. Therefore, the air pressure is lower. The higher the elevation, the lower the air pressure.

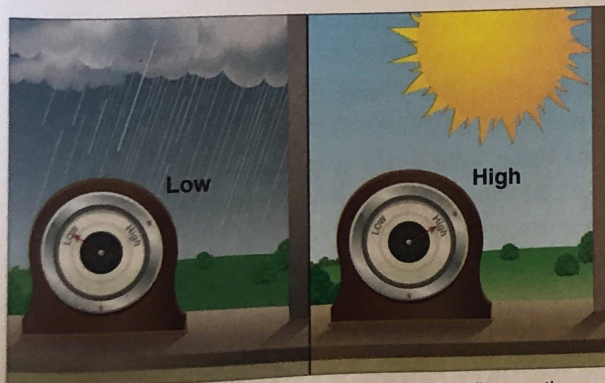


▲ **Figure 11-13** Elevation affects air pressure, which is measured in millimeters of mercury.

Air pressure decreases as distance above the surface increases. The air pressure on top of a mountain is less than the air pressure at sea level. Air pressure at sea level is about  $10 \text{ N/cm}^2$ .

2 **DESCRIBE:** How does elevation affect air pressure?

**Water Vapor** The more water vapor in the air, the lower the air pressure. Water evaporates from lakes, rivers, and oceans. Living things give off water vapor. All of this water vapor goes into the air. The lighter molecules of water vapor replace some of the other gas molecules in air. Air with a lot of water vapor weighs less than dry air with less water vapor. Thus, moist air exerts less pressure. Air pressure goes down as the amount of water vapor in the air goes up.



▲ **Figure 11-14** The weather conditions outside influence the air pressure.

3 **DESCRIBE:** How does water vapor affect air pressure?

**Temperature** Under ordinary conditions, the higher the temperature, the lower the air pressure. Heat makes air molecules move faster. As the molecules move faster, they spread apart. This makes the air less dense.

So warm air is less dense than cool air. In summer, when temperatures are higher, the air pressure is usually lower.

4 **RELATE:** How is temperature related to air pressure?

### ✓ CHECKING CONCEPTS

1. Pressure is the amount of \_\_\_\_\_ on a unit of area.
2. Air pressure at sea level is \_\_\_\_\_ than air pressure on top of a mountain.
3. Air pressure \_\_\_\_\_ as elevation increases.
4. Warm air weighs \_\_\_\_\_ than cool air.



### THINKING CRITICALLY

5. **CALCULATE:** A 5-N force pushes down on an area that is  $10 \text{ cm}^2$ . How much pressure does the force have?
6. **HYPOTHESIZE:** Why do ears “pop” in an airplane?

### Web InfoSearch

**The Magdeburg Hemispheres** In 1654, Otto von Guericke, the mayor of a small German town called Magdeburg, did an experiment. He made a hollow metal sphere with two halves, or hemispheres, fitted tightly together. Air was pumped out of the sphere through a valve. This lowered the air pressure inside. The higher outside air pressure held the sphere together.

**SEARCH:** Use the Internet to find out more about this experiment. Why couldn't horses pull the two hemispheres apart? Start your search at [www.conceptsandchallenges.com](http://www.conceptsandchallenges.com). Some key search words are **air pressure**, **Von Guericke**, and **Magdeburg**.

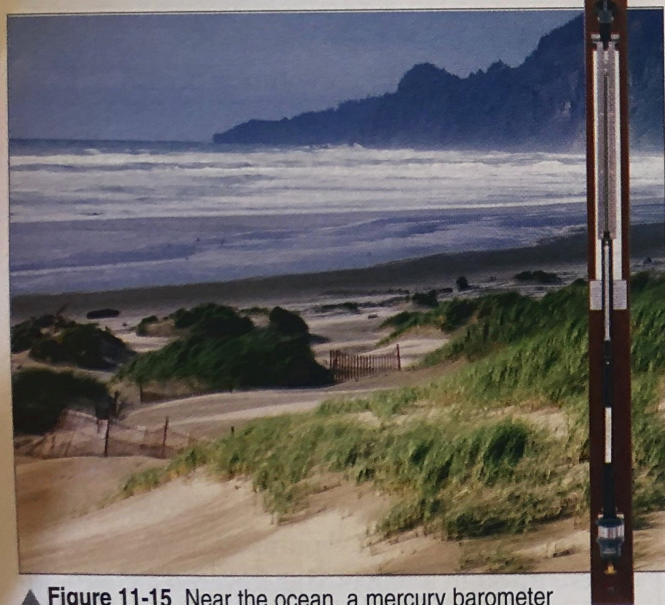
## Objective

Explain how a barometer measures air pressure.

## Key Term

**barometer** (buh-RAHM-uht-uhr): instrument used to measure air pressure

**Mercury Barometer** Air pressure is measured with an instrument called a **barometer**. A mercury barometer is a glass tube filled with mercury. It is open at one end. The space at the closed end of the tube forms a vacuum. The open end of the tube sits in a container of mercury. Air pressure pushes down on the surface of the mercury in the container. The mercury is pushed up the vacuum. At sea level, air pressure can raise a column of mercury to a height of 760 mm. As the air pressure changes, the level of mercury in the tube rises or falls.

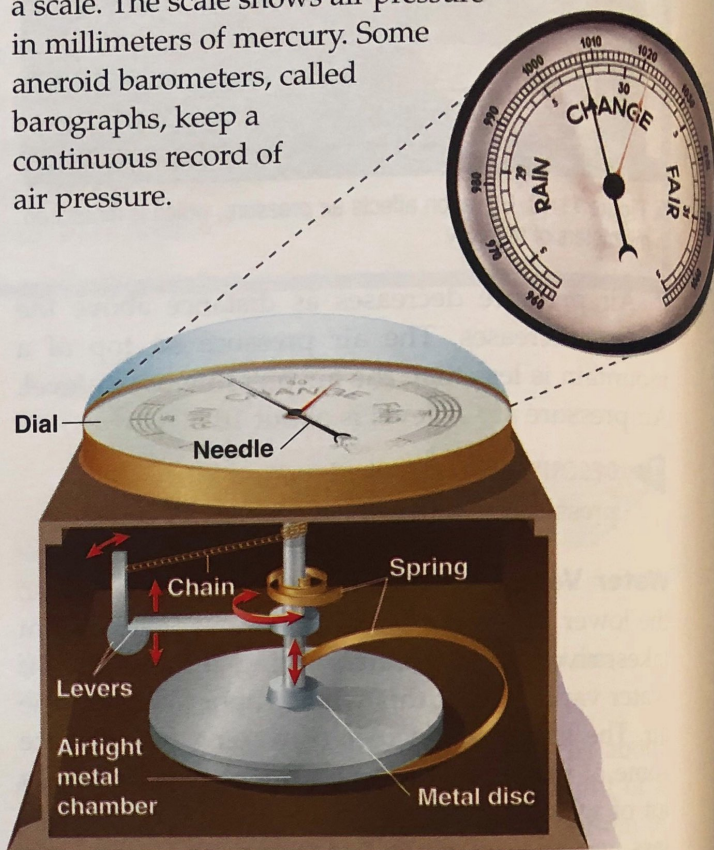


▲ **Figure 11-15** Near the ocean, a mercury barometer (on right) shows a reading of 760 mm.

1 **DEFINE:** What does a barometer do?

**Aneroid Barometer** Another kind of barometer is called an aneroid barometer. The word *aneroid* means “without liquid.” An aneroid barometer is made of an airtight metal container. The sides of the container are very thin. They can bend in or out.

When the air pressure increases, the sides of the metal container bend in. When the air pressure decreases, the sides of the container bend out. A pointer is connected to the container. As the container changes shape, the pointer moves along a scale. The scale shows air pressure in millimeters of mercury. Some aneroid barometers, called barographs, keep a continuous record of air pressure.



▲ **Figure 11-16** Aneroid barometer

2 **DESCRIBE:** How does an aneroid barometer work?

**Measuring Air Pressure** Standard air pressure at sea level measures 760 mm of mercury. This is sometimes called one atmosphere. Air pressure is also measured in millibars (mb). Standard air pressure is equal to 1,013.20 mb.

3 **ANALYZE:** How many millimeters of mercury equal 1,013.20 mb?

**Measuring Altitude** An altimeter is a device used to measure altitude. Pilots, scientists, surveyors, and mountain climbers all use altimeters.

At sea level, air pressure will raise a column of mercury 760 mm. As you go higher, air pressure decreases. The mercury column drops.

Mount Everest is about 8,900 m high. It is the highest point on Earth. The mercury column here is only about 250 mm high.

Skydivers and parachuters wear devices that contain altimeters. These let them see how high they are as they descend. This type of altimeter is actually an aneroid barometer.



▲ **Figure 11-17** Parachuters wear devices that contain altimeters.

4 **INFER:** Why do parachuters wear altimeters?

### ✓ CHECKING CONCEPTS

1. Air pressure is measured with a \_\_\_\_\_.
2. Two kinds of barometers are mercury barometers and \_\_\_\_\_ barometers.
3. The mercury column in a mercury barometer rises or falls with changes in \_\_\_\_\_.
4. Air pressure is measured in \_\_\_\_\_.



## How Do They Know That?

### MEASURING AIR PRESSURE

Evangelista Torricelli (eh-vahn-je-LEES-tah tawr-uh-CHEL-ee) (1608–1647) was an Italian scientist. During his lifetime, he made important improvements both in the microscope and in the telescope. His greatest accomplishment, however, was inventing the mercury barometer in 1643.

Torricelli filled a long glass tube with mercury. He placed his finger over one open end. (⚠ **CAUTION:** Mercury is poisonous to the touch. Do not attempt to repeat this experiment.) Then, he turned the tube upside down and placed it straight up in a container filled with mercury. When the mouth was under the surface of the mercury, Torricelli took his finger off the opening. The mercury in the tube dropped. It stopped at about 750 mm. At the top of the tube was a vacuum. Torricelli hypothesized that it was air pressure keeping the mercury in place.

**Thinking Critically** What was the air pressure in the city where Torricelli did his exp



### THINKING CRITICALLY

5. **CALCULATE:** Mercury is 13.6 times more dense than water. If a container of water can hold 20 g of water, how much more massive would an equal volume of mercury be?
6. **CALCULATE:** The density of mercury is 13.6 g/cm<sup>3</sup>. If air pressure at sea level supports a 760-mm column of mercury, how high a column of water can air pressure support at sea level?

### BUILDING MATH SKILLS

**Graphing** At sea level, normal air pressure is 760 mm of mercury. It drops about 10 mm for every 123 m rise in elevation. First, calculate normal air pressure for the following places, which are above sea level: Denver, CO (1,600 m); Kansas City, MO (230 m); Mount Whitney, CA (4,400 m); Mount St. Helens, WA (2,950 m); Mount Washington, NH (1,916 m); the Empire State Building in New York City (380 m). Then, calculate air pressure in Death Valley, CA (85 m below sea level). Make a bar graph showing the air pressure for each location.



▲ **Figure 11-18** Torricelli and his barometer