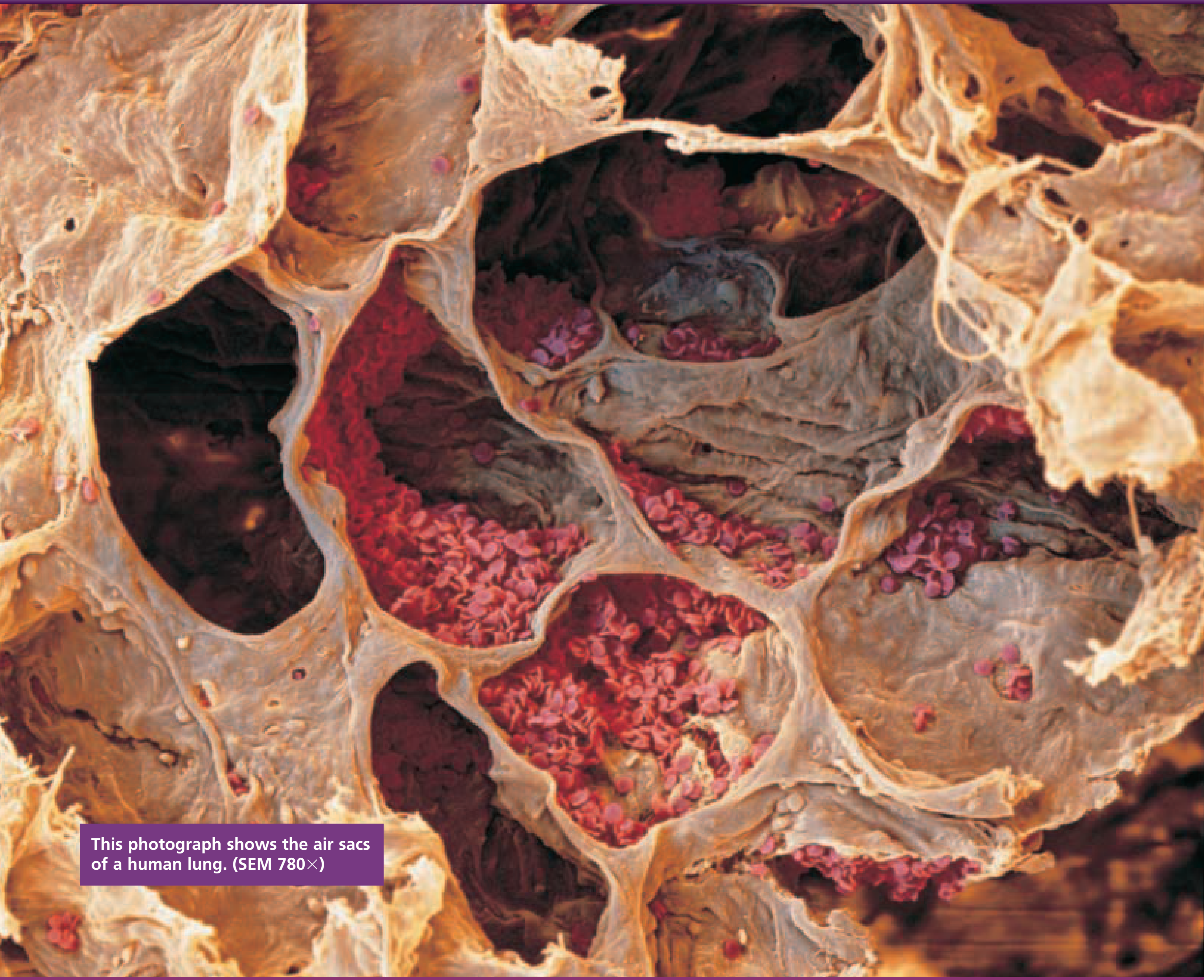
CHAPTER 46

# Circulatory and Respiratory Systems



This photograph shows the air sacs of a human lung. (SEM 780×)

SECTION 3

## OBJECTIVES

- **Differentiate** external respiration from internal respiration.
- **Trace** the path of air from the atmosphere to the bloodstream.
- **Describe** how gases are exchanged in the lungs and transported in the bloodstream.
- **Summarize** the skeletal and muscular changes that occur during breathing.
- **Describe** how the rate of breathing is controlled.

## VOCABULARY

**respiratory system**
**external respiration**
**internal respiration**
**lung**
**pharynx**
**epiglottis**
**trachea**
**larynx**
**bronchus**
**bronchiole**
**alveolus**
**inspiration**
**diaphragm**
**expiration**



# THE RESPIRATORY SYSTEM

*The blood transports oxygen from the lungs to cells and carries carbon dioxide from the cells to the lungs. It is the function of the **respiratory system** to exchange gases with the cardiovascular system.*

## RESPIRATION

The respiratory system involves both external respiration and internal respiration. **External respiration** is the exchange of gases between the atmosphere and the blood. **Internal respiration** is the exchange of gases between the blood and the cells of the body. Once oxygen is in the cells, the cells use it to break down glucose and make ATP by the process of aerobic respiration. Without oxygen, the body could not obtain enough energy from food to survive. Excess carbon dioxide produced as a waste product of aerobic respiration is toxic to cells and is removed from the cells by internal respiration.

## THE LUNGS

The **lungs** are the site of gas exchange between the atmosphere and the blood. Notice in Figure 46-16 that the right lung has three divisions, or lobes. It is slightly heavier than the two-lobed left lung. The lungs are located inside the *thoracic cavity*, bounded by the rib cage and the diaphragm. Lining the entire cavity and covering the lungs are *pleura*, membranes that secrete a slippery fluid that decreases friction from the movement of the lungs during breathing.

### The Path of Air

Refer to Figure 46-16 to trace the path air follows from the atmosphere to the capillaries in the lungs. External respiration begins at the mouth and at the nose. Air filters through the small hairs of the nose and passes into the nasal cavity, located above the roof of the mouth. In the nasal cavity, mucous membranes warm and moisten the air, which helps prevent damage to the delicate tissues that form the respiratory system. The walls of the nasal cavity are also lined with cilia. These cilia trap particles that are inhaled and are eventually swept into the throat, where they are swallowed.

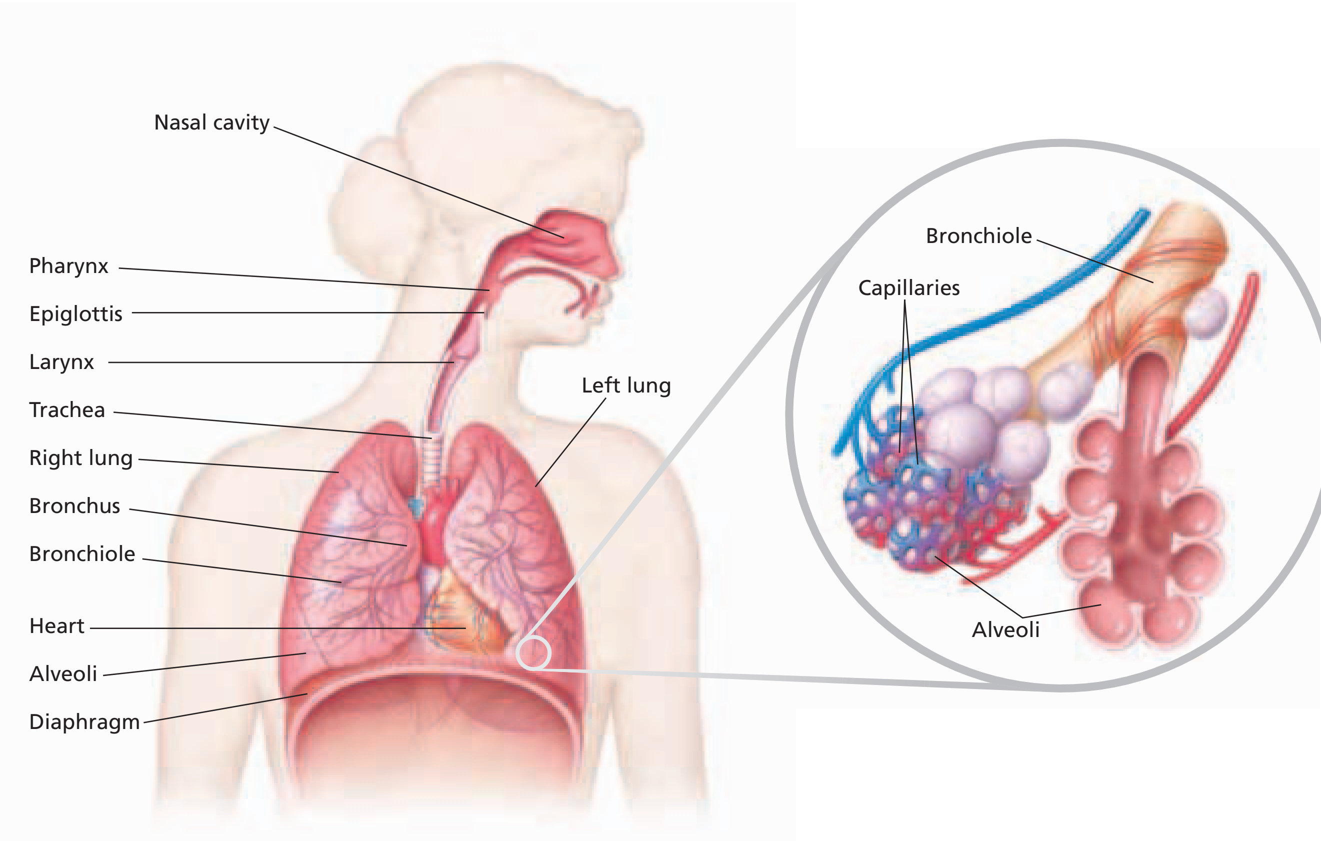



**FIGURE 46-16**

Trace the passage of air from the atmosphere to the lungs. Oxygen in the air finally reaches the alveoli, the functional units of the respiratory system. All exchange of gases between the respiratory system and the cardiovascular system occurs in the alveoli.

The moistened, filtered air then moves into the throat, or **pharynx** (FER-inks), a tube at the back of the nasal cavities and the mouth. The pharynx contains passageways for both food and air. When food is swallowed, a flap of cartilage, called the **epiglottis,** presses down and covers the opening to the air passage. When air is being taken in, the epiglottis is in an upright position, allowing air to pass into a cartilaginous tube called the windpipe, or **trachea** (TRAY-kee-uh). The trachea is about 10 to 12 cm long and has walls lined with ciliated cells that trap inhaled particles. The cilia sweep the particles and mucus away from the lungs toward the throat.

At the upper end of the trachea is the voicebox, or **larynx** (LER-inks). Sounds are produced when air is forced past two ligaments—the *vocal cords*—that stretch across the larynx. The pitch and volume of the sound produced varies with the amount of tension on the vocal cords and on the amount of air being forced past them.

The trachea then branches into two **bronchi** (BRAHN-kie) (singular, bronchus), each of which leads to a lung. The walls of the bronchi consist of smooth muscle and cartilage and are lined with cilia and mucus. Within the lungs, the bronchi branch into smaller and smaller tubes. The smallest of these tubes are known as **bronchioles,** which are also lined with cilia and mucus. Eventually the bronchioles end in clusters of tiny air sacs called **alveoli** (al-VEE-oh-LIE) (singular, alveolus). A network of capillaries surrounds each alveolus, as you can see in the detailed view shown in Figure 46-16. All exchange of gases in the lungs occurs in the alveoli. To facilitate this exchange, the surface area of the lungs is enormous. A healthy lung contains nearly 300 million alveoli and has a total surface area of about 70 $m^2$—about 40 times the surface area of the skin.

# GAS EXCHANGE AND TRANSPORT

In the lungs, gases are exchanged between the alveoli and the blood in the capillaries. Oxygen ($O_2$) to be transported throughout the body moves into the bloodstream, and carbon dioxide ($CO_2$) to be eliminated from the body moves into the alveoli.

## Gas Exchange in the Lungs

Figure 46-17 illustrates the direction in which oxygen and carbon dioxide move in the alveoli. When air moves into the lungs, the oxygen in the air crosses the thin alveolar membranes as well as the capillary walls and dissolves in the blood. Carbon dioxide moves in the opposite direction, crossing the capillary walls and thin alveolar membranes and entering the alveoli.

Air moving into the alveoli is rich in oxygen and contains little carbon dioxide. In contrast, blood in the capillaries surrounding the alveoli is low in oxygen and contains high levels of carbon dioxide. Substances diffuse from an area of higher concentration to an area of lower concentration. Consequently, oxygen diffuses from the alveoli into the blood, and carbon dioxide diffuses from the blood into the alveoli. The enormous surface area of the alveoli increases the rate of diffusion of these two gases.

## Transport of Oxygen

When oxygen diffuses into the blood, only a small amount remains dissolved in the plasma. Most of the oxygen—95 to 98 percent—moves into the red blood cells, where it combines with hemoglobin, an iron-containing protein. Each hemoglobin molecule contains four iron atoms. Each iron atom can bind to one oxygen molecule. Thus, one hemoglobin molecule can carry up to four molecules of oxygen. There are about 250 million hemoglobin molecules in each red blood cell. When oxygenated blood reaches body tissues, the oxygen concentration is higher in the blood than in the body tissues. Thus, oxygen is released from hemoglobin and diffuses out of the capillaries and into surrounding cells.

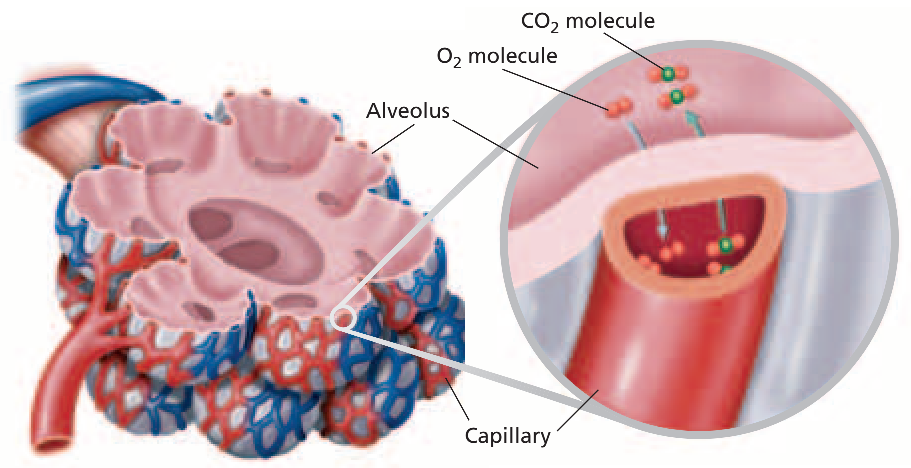



**FIGURE 46-17**

Because of concentration gradients, oxygen and carbon dioxide diffuse across the alveoli and capillary walls.

## Transport of Carbon Dioxide

Because the concentration of carbon dioxide ($CO_2$) is higher in the cells, it diffuses out of the cells and into the blood. Only about 7 percent of the carbon dioxide dissolves in the plasma. Approximately 23 percent binds to hemoglobin. The remaining 70 percent is carried in the blood as bicarbonate ions ($HCO_3^-$). As shown in the equation below, $CO_2$ reacts with water in the plasma to form carbonic acid ($H_2CO_3$). In turn, the carbonic acid disassociates into bicarbonate ions and hydrogen ions ($H^+$):

$$H_2O + CO_2 \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

Thus, most of the $CO_2$ travels in the blood as bicarbonate ions. When the blood reaches the lungs, the reactions are reversed:

$$HCO_3^- + H^+ \rightleftharpoons H_2CO_3 \rightleftharpoons H_2O + CO_2$$

Bicarbonate ions combine with hydrogen ions to form carbonic acid, which in turn forms carbon dioxide and water. The carbon dioxide diffuses out of the capillaries into the alveoli and is exhaled into the atmosphere.

# MECHANISM OF BREATHING

Breathing is the process of moving air into and out of the lungs. **Inspiration,** shown in Figure 46-18, is the process of taking air into the lungs. When you take a deep breath, your chest expands as muscles contract to move the ribs up and outward. At the same time, your **diaphragm,** a large skeletal muscle that separates the thoracic cavity from the abdominal cavity, flattens and pushes down on the abdomen. Muscles in the abdominal wall in turn relax. This action provides room for the flattened diaphragm.

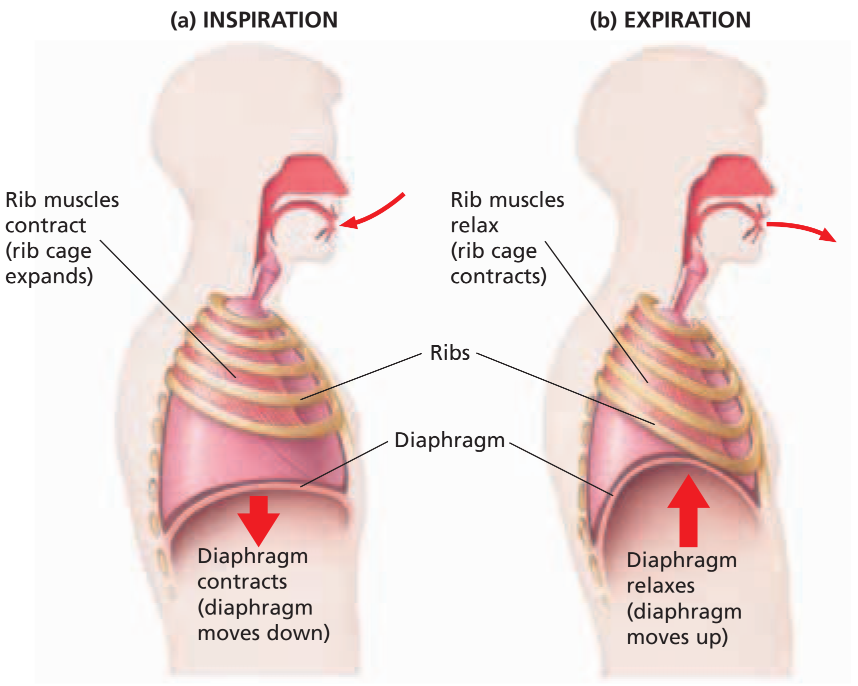



**FIGURE 46-18**

The diaphragm, a large skeletal muscle that separates the thoracic cavity from the abdominal cavity, and the muscles between the ribs control the movement of the thoracic cavity during breathing. If these muscles were paralyzed, then inspiration and expiration would not occur.

When the diaphragm flattens and the ribs are lifted up and out, the volume of the lungs increases. An increased volume reduces the air pressure within the lungs. At this point, the air pressure inside the lungs is lower than the air pressure outside the body. As a result, air from the atmosphere moves into the lungs.

During **expiration,** the process of releasing air from the lungs, the reverse movements take place, as shown in Figure 46-18. As the diaphragm and rib muscles relax, the elastic tissues of the lungs recoil, deflating the lungs. The volume of the lungs decreases. Because the volume is smaller, the air pressure inside the cavity becomes greater than the air pressure outside the body. This pressure difference forces air out of the lungs until the pressures are again equal.

**Word Roots and Origins**

***expiration***

from the Latin *expir*, which means "to breathe out"

## Regulation of Breathing

The rate at which oxygen is used depends on the activity of the cells. The greater their activity, the more oxygen they need and the faster the body needs to breathe. The slower their activity, the slower the body needs to breathe. Both rate and depth of breathing change in order to provide oxygen and eliminate carbon dioxide.

The rate of breathing is controlled by the brain and brain stem, which monitors the concentration of carbon dioxide in the blood. As activity increases, high levels of carbon dioxide in the blood stimulate nerve cells in the brain. The brain stem in turn stimulates the diaphragm to increase the breathing rate and depth. When the carbon dioxide concentration in the blood returns to lower levels, the sensors in the brain send a message to the respiratory muscles to return to a slower breathing rate. All this is controlled subconsciously by control centers in the brain. However, a person can temporarily override the respiratory control system at any time, holding his or her breath until losing consciousness. Then the brain stem takes control, and normal breathing resumes. This mechanism allows humans to swim underwater for short periods and to sleep without concern for breathing.

## SECTION 3 REVIEW

1. How does internal respiration differ from external respiration?
2. Outline the path of oxygen from the atmosphere to the bloodstream.
3. Explain the process of gas exchange in the lungs.
4. Differentiate between oxygen transport and carbon dioxide transport in the bloodstream.
5. Sequence the skeletal and muscular changes that take place when a person inhales.
6. What factors regulate the rate of breathing?

**CRITICAL THINKING**

7. **Relating Concepts** Predict the effect that increasing altitude would have on blood-oxygen saturation.
8. **Applying Information** Why does a single-celled organism not need a respiratory system?
9. **Predicting Results** Normally, arterial blood is about 98 percent saturated with oxygen. What are two conditions that could result in lower oxygen saturation?

# CHAPTER HIGHLIGHTS

## SECTION 1 The Circulatory System

- The human circulatory system is made up of the cardiovascular system and the lymphatic system.
- The heart is a muscular organ that pumps blood through an intricate network of blood vessels.
- Blood flows from the body into the heart, which then pumps blood to the lungs. After oxygenation, blood returns to the heart, which pumps blood to the rest of the body.
- Arteries carry blood away from the heart. Materials are exchanged at the capillaries. Veins contain valves and carry blood back to the heart.
- In pulmonary circulation, blood travels between the heart and lungs. In systemic circulation, blood travels between the heart and all other body tissues.
- The lymphatic system returns lymph, fluid that has collected in the tissues, to the bloodstream.

### Vocabulary

**cardiovascular system** (p. 933)
**lymphatic system** (p. 933)
**atrium** (p. 933)
**ventricle** (p. 933)
**valve** (p. 934)
**aorta** (p. 935)
**sinoatrial node** (p. 935)
**atrioventricular node** (p. 935)
**pulse** (p. 935)
**artery** (p. 936)
**blood pressure** (p. 936)
**hypertension** (p. 936)
**capillary** (p. 936)
**vein** (p. 937)
**pulmonary circulation** (p. 937)
**systemic circulation** (p. 937)
**atherosclerosis** (p. 938)
**lymph** (p. 939)

## SECTION 2 Blood

- Blood is composed of plasma (water, metabolites, wastes, salts, and proteins), red blood cells, white blood cells, and platelets.
- Red blood cells transport oxygen. White blood cells help defend the body against disease. Platelets are essential to the formation of a blood clot.
- Blood clotting occurs when platelets release a clotting protein, which causes a clotting reaction to occur. A fibrin net forms, trapping blood cells and platelets.
- Human blood can be grouped into four types—A, B, AB, and O—based on proteins on the surface of red blood cells. Another antigen called *Rh factor,* is sometimes present on red blood cells.

### Vocabulary

**plasma** (p. 940)
**red blood cell (erythrocyte)** (p. 940)
**hemoglobin** (p. 940)
**white blood cell (leukocyte)** (p. 941)
**phagocyte** (p. 941)
**antibody** (p. 941)
**platelet** (p. 942)
**fibrin** (p. 942)
**blood type** (p. 943)
**antigen** (p. 943)
**Rh factor** (p. 943)

## SECTION 3 The Respiratory System

- External respiration is the exchange of gases between the atmosphere and the blood. Internal respiration is the exchange of gases between the blood and the cells of the body.
- The lungs are the site of gas exchange between the atmosphere and the blood.
- Air enters through the mouth or nose, passes through the pharynx, larynx, trachea, bronchi and bronchioles and into alveoli. A network of capillaries surrounds each alveolus. All exchange of gases in the lungs occurs at the alveoli.
- Most oxygen is carried attached to hemoglobin. Some carbon dioxide is carried bound to hemoglobin. A small amount is dissolved in plasma. Most carbon dioxide is carried as bicarbonate ions.
- During inspiration, the diaphragm and rib muscles contract, the thoracic cavity expands, and air is pulled into the lungs. During expiration, the diaphragm and rib muscles relax, the thoracic cavity contracts, and air is forced out of the lungs.
- The rate of breathing is controlled by nerve centers in the brain that monitor the level of carbon dioxide in the blood.

### Vocabulary

**respiratory system** (p. 946)
**external respiration** (p. 946)
**internal respiration** (p. 946)
**lung** (p. 946)
**pharynx** (p. 947)
**epiglottis** (p. 947)
**trachea** (p. 947)
**larynx** (p. 947)
**bronchus** (p. 947)
**bronchiole** (p. 947)
**alveolus** (p. 947)
**inspiration** (p. 949)
**diaphragm** (p. 949)
**expiration** (p. 950)

# CHAPTER REVIEW

## USING VOCABULARY

1. Distinguish between *systolic pressure* and *diastolic pressure.*
2. Choose the term that does not belong in the following group: *erythrocyte, hemoglobin, leukocyte,* and *platelet.* Explain why it does not belong.
3. For each pair of terms, explain the relationship between the terms.
   a. *atrioventricular valve* and *semilunar valve*
   b. *artery* and *vein*
   c. *expiration* and *inspiration*
4. **Word Roots and Origins** The word *phagocyte* is derived from the Greek word *phagein,* which means "to eat." The suffix *cyte* means "cell." Using this information, explain why the term *phagocyte* is a good name for the biological process that the term describes.

## UNDERSTANDING KEY CONCEPTS

5. **Identify** the parts of the human heart, and describe the function of each part.
6. **Outline** the route that blood takes through the heart, lungs, and body.
7. **Relate** the structure of arteries, veins, and capillaries to the function of each.
8. **Compare** the pulmonary arteries and the aorta.
9. **Compare** the pulmonary veins and the inferior vena cava.
10. **Summarize** the roles of the lymphatic system.
11. **Discuss** the function of each of the components of blood.
12. **Identify** the structure that red blood cells lack that limits their life span.
13. **Describe** three differences between white blood cells and red blood cells.
14. **Sequence** the process of blood-clot formation that occurs after a vessel is injured.
15. **Explain** the A-B-O blood-typing system.
16. **Identify** the role of the Rh factor in determining blood compatibility for transfusion.
17. **Compare** external respiration with internal respiration.
18. **Sequence** the path oxygen travels from the environment into the blood.
19. **Compare** the transport and exchange of oxygen and carbon dioxide.
20. **Describe** the movement of the diaphragm and the rib muscles during inspiration and expiration.
21. **Name** the factor that stimulates the brain stem to increase the breathing rate.
22. **CONCEPT MAPPING** Use the following terms to create a concept map that shows the relationship between the cardiovascular, lymphatic, and respiratory systems: *artery, capillary, vein, lymphatic system, pulmonary circulation, systemic circulation, atrium, ventricle, aorta,* and *vena cava.*

## CRITICAL THINKING

23. **Inferring Relationships** A person with anemia can have too few red blood cells or low hemoglobin levels. The most common symptom is a lack of energy. Why would anemia cause this symptom?
24. **Applying Information** Explain how the lymphatic system moves lymph through the body without the aid of a pumping organ like that of the cardiovascular system.
25. **Analyzing Concepts** One function of the cardiovascular system is to help maintain a uniform body temperature. Explain how the constant circulation of blood throughout the body can accomplish this task.
26. **Interpreting Graphics** Copy the blood-type table below on a sheet of paper. Fill in the missing information for each type.

**TABLE 1** ***Blood Type***

| Blood type | Antigen on the red blood cell | Antibodies in plasma | Can receive blood from | Can donate blood to |
|---|---|---|---|---|
| A | | B | O, A | A, AB |
| B | B | | O, B | B, AB |
| AB | A, B | Neither A nor B | O, A, B, AB | |
| O | Neither A nor B | A, B | | O, A, B, AB |

27. **Calculating Data** Calculate the number of times a person's heart will beat if the person lives 75 years. Assume that the average heart beats 70 times per minute.
28. **Recognizing Relationships** Assuming that the heart of an overweight person beats an additional 10 times per minute, explain why being overweight can put additional strain on the heart.

# Standardized Test Preparation

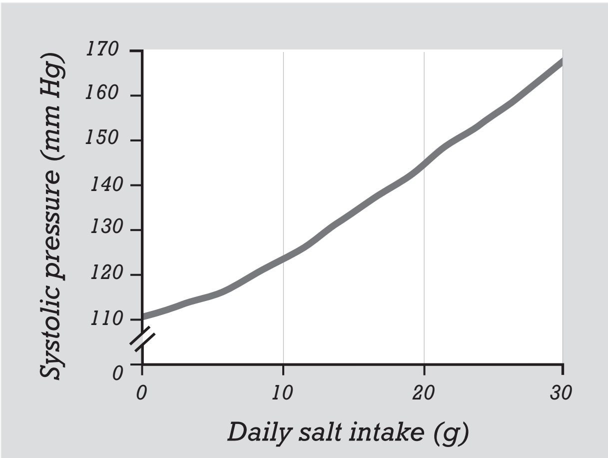
**DIRECTIONS:** Choose the letter of the answer choice that best answers the question.

1. In what direction does blood move during ventricular systole?
   **A.** from the atria to the veins
   **B.** from the ventricles to the atria
   **C.** from the atria to the ventricles
   **D.** from the ventricles to the arteries

2. What is the function of the lymphatic system?
   **F.** It opens two-way vessels.
   **G.** It helps the body fight infections.
   **H.** It interacts with the respiratory system.
   **J.** It transports intercellular fluid away from the heart.

3. Fibrin is a protein that does which of the following?
   **A.** transports oxygen
   **B.** helps form a blood clot
   **C.** destroys invading microorganisms
   **D.** stimulates the production of antibodies

**INTERPRETING GRAPHICS:** The graph below shows how systolic pressure is affected by salt intake. Use the graph to answer the question that follows.

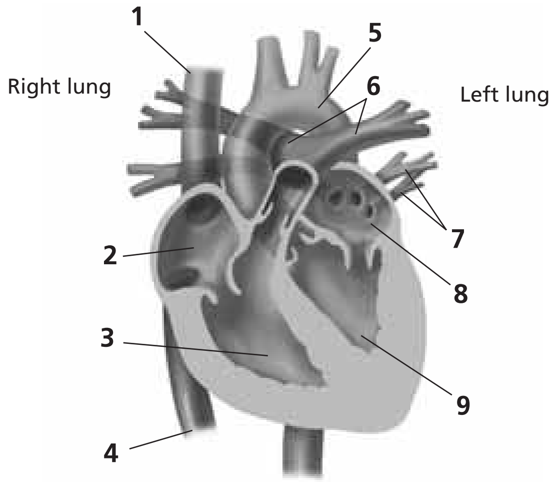



4. What is the relationship between salt intake and blood pressure?
   **F.** As salt intake increases, blood pressure increases.
   **G.** As salt intake increases, blood pressure decreases.
   **H.** Salt intake of 20 g per day results in stable blood pressure.
   **J.** Salt intake of 30 g per day results in stable blood pressure.

**DIRECTIONS:** Complete the following analogy.

5. superior vena cava : deoxygenated blood :: pulmonary veins :
   **A.** type A blood
   **B.** type B blood
   **C.** oxygenated blood
   **D.** deoxygenated blood

**INTERPRETING GRAPHICS:** The model below shows a cross section of the heart. Use the model to answer the question that follows.




6. Which numbers point to vessels that bring blood into the heart?
   **F.** 1, 4, and 7
   **G.** 1, 5, and 6
   **H.** 4, 5, and 6
   **J.** 5 and 6 only

## SHORT RESPONSE

Even a small increase or decrease in blood volume has an effect on blood pressure. When an accident victim suffers significant blood loss, the person is transfused with plasma rather than whole blood.

Why is plasma effective in meeting the immediate threat to life?

## EXTENDED RESPONSE

Polio is a disease that paralyzes muscles by affecting the nerves that make the muscles move.

*Part A* List muscles involved in breathing.

*Part B* Explain how polio might affect breathing.

**Test TIP** Slow, deep breathing helps a person relax. If you suffer from test anxiety, focus on your breathing in order to calm down.

# Measuring Lung Volumes and $CO_2$ Production

## OBJECTIVES

- Use indirect measurement to determine lung capacity.
- Determine the effect of exercise on breathing rate and $CO_2$ production.

## PROCESS SKILLS

- measuring
- hypothesizing
- collecting data
- analyzing data
- experimenting

## MATERIALS

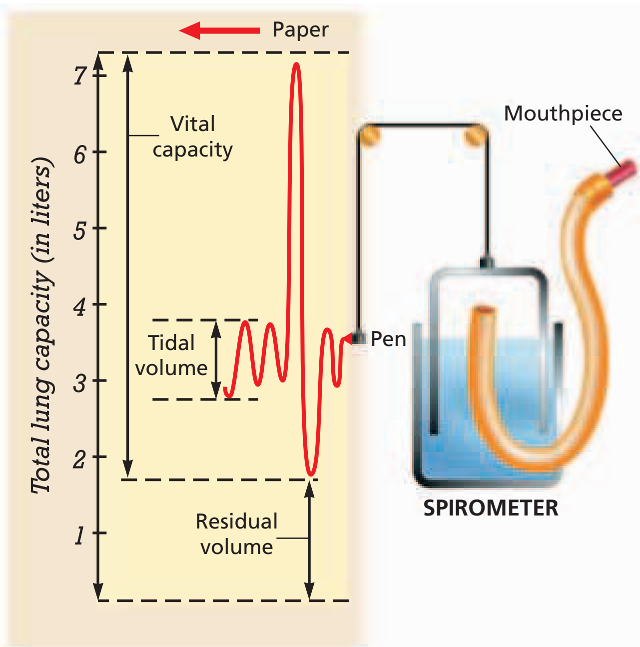
- safety goggles
- lab apron
- disposable gloves
- 1 L bromothymol indicator solution
- drinking straws
- 100 mL Erlenmeyer flasks, 2 per group
- 100 mL graduated cylinders
- marker
- plastic wrap
- spirometer
- stopwatch or clock with second hand

## Background

1. A spirometer is an instrument used to measure the volume of air a person can breathe.
2. Compare the diagram of a spirometer on the right with the spirometer you will be using to complete this investigation. The marking pen creates a line that can be compared with the scale on the left side to measure liters of air.
3. Tidal volume is the volume of air inhaled or exhaled during a normal breath.
4. Lung capacity is the total volume of air that the lungs can hold. Total lung capacity is 5 to 6 L. What factors might increase or reduce lung capacity?
5. Expiratory reserve volume is the amount of air that can be forcefully exhaled after a normal exhalation.
6. Vital capacity is the maximum amount of air that can be inhaled or exhaled.
7. Carbon dioxide is soluble in water. You can determine the relative amount of $CO_2$ in your breath by using an indicator to react with the $CO_2$. Higher $CO_2$ levels will react with the indicator solution faster.

## PART A Tidal Volume, Expiratory Volume, and Vital Capacity

1. Make a data table in your notebook like the one shown on the next page (Part A Lung Volumes).
2. Place a clean mouthpiece in the end of the spirometer. **CAUTION Many diseases are spread by body fluids, such as saliva. Do NOT share a mouthpiece with anyone.** Inhale a normal breath. Hold your nose, then exhale a normal breath into the spirometer. Record your data in the table.
3. Measure your expiratory reserve volume by first breathing a normal breath and exhaling normally. Then put the spirometer tube to your mouth as you forcefully exhale whatever air is left in your lungs. Be sure to force out as much air as possible. Record your data in the table.



## PART A *Lung Volumes*

| | Average for young adult males | Average for young adult females | Average for athletes | Your readings |
|---|---|---|---|---|
| **Tidal volume** | 500 mL | | | |
| **Expiratory reserve volume** | 100 mL | | | |
| **Vital capacity** | 4,600 mL | | | |

**4.** The table includes values for young adult males. The average volumes for young adult females are 20–25 percent lower than those of males. Calculate the average volumes for young adult females. Athletes can have volumes that are 30–40 percent greater than the average for their gender. Calculate the average volumes for athletes.

**5.** Dispose of your mouthpiece in the designated waste container.

## PART B Breathing Rate and $CO_2$ Production

**6.** Discuss with your partners the use of bromothymol blue as an indicator of $CO_2$. Develop a hypothesis that describes a relationship between air volume exhaled during rest or exercise and the volume of $CO_2$ exhaled.

**7.** Make a data table in your notebook like the one on this page, titled "Part B $CO_2$ Production".

**8.** Label two flasks as 1 and 2.

**9.** CAUTION **Wear safety goggles at all times during this procedure. If you get the indicator solution on your skin or clothing, wash it off at the sink while calling to your teacher. If you get the indicator solution in your eyes, immediately flush it out at the eyewash station while calling to your teacher.**

**10.** Add 100 mL of indicator solution to each flask. Cover the mouth of each flask with plastic wrap.

**11.** Remove the plastic wrap from flask 1. Begin the stopwatch. Blow gently through one straw into flask 1 until the solution turns a yellowish color, exhaling slowly so that the solution does not bubble up. CAUTION **Be careful not to inhale the solution or get it in your mouth.** Stop the stopwatch.

**12.** Record in your data table the time in seconds that it took to see a color change in flask 1.

**13.** Exercise by jogging in place or doing jumping jacks for 2 min. Begin the stopwatch immediately. Blow gently through a new straw into flask 2 until the solution becomes the same yellowish color as the solution in flask 1. Stop the stopwatch.

**14.** In your data table, record the amount of time in seconds that it took to get the same yellow color in flask 2 as you got in flask 1.

**15.** Calculate the difference in the amount of time it took to see a color change in the two flasks. What can you infer about the amount of $CO_2$ you exhaled before and after exercise?

**16.** Clean up your materials. Pour the solutions down the sink, and rinse the sink thoroughly with water. Wash your hands before leaving the lab.

## Analysis and Conclusions

**1.** How did your tidal volume compare with that of your classmates?

**2.** What are the independent and dependent variables in Part B? How did you vary the independent variable and measure changes in the dependent variable?

**3.** Why were the flasks covered with plastic wrap?

**4.** Do your data support your hypothesis from Part B? Explain your answers.

**5.** How do you know whether you produced more carbon dioxide before or after you exercised?

**6.** What were some of the possible sources of error in your experiment?

### PART B $CO_2$ *Production*

| | |
|---|---|
| **Time for color change in flask 1** | |
| **Time for color change in flask 2** | |
| **Difference in time between flask 1 and flask 2** | |

## Further Inquiry

Design an experiment to determine whether exercise affects heart rate in the same way it affects breathing rate and tidal volume.