### Section 37–3

#### 1 FOCUS

**Objectives**

- **37.3.1** Describe respiration.
- **37.3.2** Identify the function of the respiratory system.
- **37.3.3** Describe gas exchange and breathing.
- **37.3.4** Explain how smoking affects the respiratory system.

**Guide for Reading**

**Vocabulary Preview**

Call students’ attention to the Vocabulary terms. Ask: Which term refers to a respiratory disease? (Emphysema) Which term refers to a toxic chemical in tobacco smoke? (Nicotine) Point out that all the rest of the words are structures of the respiratory system.

**Reading Strategy**

Before students read the section, have them predict how respiration, gas exchange, and breathing are related. As they read, they should check to see if their predictions were correct.

#### 2 INSTRUCT

**What Is Respiration?**

**Address Misconceptions**

Students may have the misconception that breathing is the same as respiration. Remind students that respiration is the exchange of gases that takes place in the alveoli of the lungs. Breathing is the movement of air into and out of the lungs. Ask: How is breathing related to respiration? (Inhaling provides a fresh supply of oxygen to the lungs; exhaling removes excess carbon dioxide from the lungs.)

**Key Concepts**

- What is the function of the respiratory system?
- How does smoking affect the respiratory system?

**Vocabulary**

- pharynx
- trachea
- larynx
- bronchus
- alveolus
- diaphragm
- nicotine
- emphysema

**Reading Strategy: Monitoring Your Understanding**

Make a table with three columns labeled K, W, and L. Before you read, write what you know about respiration in column K and what you want to learn in column W. After you read, write what you have learned in column L.

**What Is Respiration?**

When paramedics rush to the aid of an injured person, they check to see if the person is breathing. If the person's chest is not rising and falling and they cannot feel or hear air being exhaled from the mouth or nose, it is likely that the person is not breathing. Paramedics will ignore broken bones or burns to focus on breathing because there is no time to lose! If breathing stops for more than a few minutes, a life may be lost.

Paramedics can do mouth-to-mouth rescue breathing to force air into the lungs. They can do chest compressions to keep the blood circulating. Cardiopulmonary resuscitation, or CPR, is rescue breathing combined with chest compressions.

**What Is Respiration?**

In biology, the word **respiration** is used in two slightly different ways. Cellular respiration, which takes place in mitochondria, is the release of energy from the breakdown of food molecules in the presence of oxygen. Without oxygen, cells lose much of their ability to produce ATP. Without ATP, cells cannot synthesize new molecules, pump ions, or carry nerve impulses.

The blood carries oxygen from the lungs to the body’s tissues, and carries carbon dioxide—a waste product of cellular respiration—in the opposite direction. At the level of the organism, respiration means the process of gas exchange—the release of carbon dioxide and the uptake of oxygen between the lungs and the environment.

**The Human Respiratory System**

The basic function performed by the human respiratory system is remarkably simple—to bring about the exchange of oxygen and carbon dioxide between the blood, the air, and tissues. With each breath, air enters the body through the air passageways and fills the lungs, where gas exchange takes place. The respiratory system consists of the nose, pharynx, larynx, trachea, bronchi, and lungs.

**Figure 37–13** shows the structures of the respiratory system.

Air moves through the nose to a tube at the back of the mouth called the pharynx, or throat. The **pharynx** serves as a passageway for both air and food. Air moves from the pharynx into the **trachea**, or windpipe. A flap of tissue called the epiglottis covers the entrance to the trachea when you swallow.

**Figure 37–12** In this cross section of the trachea, the cilia have been colored green. **Inferring** What is the role of cilia in the respiratory system?

#### SECTIONS RESOURCES

**Print:**

- Laboratory Manual A, Chapter 37 Lab
- Reading and Study Workbook A, Section 37–3
- Adapted Reading and Study Workbook B, Section 37–3

**Technology:**

- iText, Section 37–3
- Animated Biological Concepts DVD, 42 Human Respiration
- Transparencies Plus, Section 37–3

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The Human Respiratory System

Use Visuals

Figure 37–13 Make sure students understand how the drawing on the right relates to the drawing on the left. Have students use the drawings to trace the pathway of air through the respiratory system as they read about it in the text. They should identify each of the structures through which the air passes, starting with the nose and ending with the alveoli.

Use Community Resources

Invite a paramedic to demonstrate to the class rescue breathing (mouth-to-mouth) and chest compressions. Before the paramedic arrives, tell students that people sometimes stop breathing in cases of drowning, electric shock, or smoke inhalation and that rescue breathing helps keep them alive until they begin breathing again on their own. Also explain how choking occurs because of the role of the pharynx in both the digestive and respiratory systems. Suggest that students prepare questions in advance for the paramedic to address.

Cilia and Mucus

The respiratory passageways allow air to pass directly into some of the most delicate tissues in the body. To keep the lung tissue healthy, air entering the respiratory system must be warmed, moistened, and filtered. Large dust particles get trapped by the hairs lining the entrance to the nasal cavity. Some of the cells that line the respiratory system produce a thin layer of mucus. The mucus moistens the air and traps inhaled particles of dust or smoke. Cilia sweep the trapped particles and mucus away from the lungs toward the pharynx. The mucus and trapped particles are either swallowed or spit out. These protective measures help keep the lungs clean and open for the important work of gas exchange.

Circulatory and Respiratory Systems
37–3 (continued)

Gas Exchange

Build Science Skills

Inferring Explain how exhaled air is used in rescue breathing. Point out that exhaled air has already gone through the gas exchange process in the lungs. Ask: How can rescue breathing provide the person receiving the “second-hand” air with enough oxygen to survive? (Exhaled air contains about 75 percent of the oxygen of inhaled air—more than enough to keep a person alive.)

Demonstration

Make limewater in a clear glass container by adding calcium hydroxide to water until the solution is saturated. Tell students that when carbon dioxide reacts with limewater, it causes the limewater to turn cloudy. Have a student volunteer exhale through a straw into the limewater. (Caution the student not to suck any of the limewater through the straw.) While the student exhales, have other students observe what happens. (The limewater turns cloudy.) Ask: Why did the limewater turn cloudy? (The exhaled breath contained carbon dioxide.)

Breathing

Build Science Skills

Measuring Students can measure their lung capacity. (Advise any with respiratory illnesses, such as asthma or bronchitis, to avoid participating.) Give each student a large round balloon and, with students working in pairs, tell one student to inhale as large a breath as possible and then to exhale it as completely as possible into the balloon. Students should hold the balloons shut until their partner measures the circumference with a tape measure. Then, repeat the steps for the other partner. Students can calculate their lung capacity by finding the volume of the inflated balloon, using the formula \( V = \frac{4}{3}\pi r^3 \), where \( r \) is the radius of the inflated balloon. The radius can be found from the circumference, using the formula \( c = 2\pi r \).

Figure 37–14 Gas exchange occurs by diffusion across the membrane of an alveolus and a capillary. Drawing Conclusions: Where is oxygen more concentrated, in an alveolus or in a capillary?

The Larynx At the top of the trachea is the larynx. The larynx contains two highly elastic folds of tissue known as the vocal cords. When muscles pull the vocal cords together, the air moving between them causes the cords to vibrate and produce sounds. Your ability to speak, shout, and sing comes from these tissues.

The Bronchi From the larynx, air passes through the trachea into two large passageways in the chest cavity called bronchi (singular: bronchus). Each bronchus leads into one of the lungs. Within each lung, the large bronchus subdivides into smaller bronchi, which lead to even smaller passageways called bronchioles. Air moving along this path can be compared to a motorist who takes an exit off an eight-lane highway onto a four-lane highway, makes a turn onto a two-lane road, and ends up on a narrow country lane. The bronchi and bronchioles are surrounded by smooth muscle that helps to support them and enables the autonomic nervous system to regulate the size of the air passageways. The bronchioles continue to subdivide until they reach a series of dead ends—millions of tiny air sacs called alveoli (singular: alveolus). Alveoli are grouped in little clusters, like bunches of grapes. A delicate network of thin-walled capillaries surrounds each alveolus.

Gas Exchange

There are about 150 million alveoli in each healthy lung, providing an enormous surface area for gas exchange. Oxygen dissolves in the moisture on the inner surface of the alveoli and then diffuses across the thin-walled capillaries into the blood. Carbon dioxide in the bloodstream diffuses in the opposite direction, across the membrane of an alveolus and into the air within it. This process is illustrated in Figure 37–14.

The process of gas exchange in the lungs is very efficient. The air that you inhale usually contains 21 percent oxygen and 0.04 percent carbon dioxide. Exhaled air usually contains less than 15 percent oxygen and 4 percent carbon dioxide. The lungs remove about one fourth of the oxygen in the air that you inhale and increase the carbon dioxide content of that air by a factor of 100.

Because oxygen dissolves easily, you may wonder why hemoglobin, the oxygen-carrying protein in blood, is needed at all. The reason is efficiency. Hemoglobin binds with so much oxygen that it increases the oxygen-carrying capacity of the blood more than 60 times. Without hemoglobin to carry the oxygen that it uses, your body might need as much as 300 liters of blood to get the same result!
Breathing

Breathing is the movement of air into and out of the lungs. Surprisingly, there are no muscles connected to the lungs. The force that drives air into the lungs comes from ordinary air pressure. How does the body use this force to inflate the lungs? The lungs are sealed in two sacs, called the pleural membranes, inside the chest cavity. At the bottom of the cavity is a large, flat muscle known as the diaphragm.

As Figure 37–15 shows, when you breathe in, or inhale, the diaphragm contracts and the rib cage rises up. This expands the volume of the chest cavity. Because the chest cavity is tightly sealed, this creates a partial vacuum inside the cavity. Atmospheric pressure does the rest, filling the lungs as air rushes into the breathing passages.

Most of the time, exhaling is a passive event. When the rib cage lowers and the diaphragm muscle relaxes, the pressure in the chest cavity becomes greater than atmospheric pressure. Air rushes back out of the lungs. To blow out a candle, you need a greater force. Muscles surrounding the chest cavity provide that extra force, contracting vigorously just as the diaphragm relaxes.

If you have ever seen a respiratory care practitioner (also called RCP) working on a ventilator, you know what a life-saving job this is. RCPs are specially trained professionals who help patients who can’t breathe on their own. They work in hospitals, long-term care facilities, and even homes and hospices. Respiratory care practitioners also often work with patients who have chronic conditions that affect their breathing. They provide care to patients of all ages, from newborns to the oldest adults.

Respiratory care practitioners are in high demand. With a growing population of people with chronic lung conditions, there will always be a need for these skilled professionals.

Respiratory care practitioners provide care in a variety of settings, including hospitals, long-term care facilities, hospices, and homes. They also work in schools, rehabilitation facilities, and the military. Some RCPs even work for airlines, offering critical care to passengers during long flights.

Education and Training

To become a respiratory care practitioner, you need a two-year or four-year training program. Certification exams are required, and individual states have additional licensing requirements.

Skills

Respiratory care practitioners need excellent interpersonal and communication skills. They must be able to work well with a variety of people, including patients, families, and other healthcare providers. They also need good decision-making skills, the ability to work independently, and a strong sense of responsibility.

Highlights

Respiratory care practitioners are in high demand. With a growing population of people with chronic lung conditions, there will always be a need for these skilled professionals. They provide care in a variety of settings, including hospitals, long-term care facilities, hospices, and homes. They also work in schools, rehabilitation facilities, and the military. Some RCPs even work for airlines, offering critical care to passengers during long flights.

To get started, you can contact the National Board for Respiratory Care or the American Association for Respiratory Care, or you can contact the respiratory care department of a local hospital.

To be a respiratory care practitioner, you need a combination of education, training, and experience. You must also have excellent interpersonal and communication skills. If you are interested in this career, you can contact the National Board for Respiratory Care or the American Association for Respiratory Care, or you can contact the respiratory care department of a local hospital.

Answers to . . .

Figure 37–14 As an alveolus relaxes, the pressure in the chest cavity becomes greater than atmospheric pressure, so air rushes out of the lungs.

Figure 37–15 In an alveolus, the diaphragm relaxes, the pressure in the chest cavity becomes greater than atmospheric pressure, so air rushes out of the lungs.
How Breathing Is Controlled

Objective: Students will be able to formulate a hypothesis about how breathing is affected by carbon dioxide.

Skills Focus: Drawing Conclusions, Inferring, Observing

Materials: seltzer tablet, plastic cup or 250-mL beaker, water

Time: 10 minutes

Safety: Get parental permission before doing this lab. Students who have breathing problems should not perform this lab. Students should remain seated while doing this lab.

Strategies:
- For best results use straight-sided plastic cups or beakers.
- Room-temperature water will produce more carbon dioxide.

Expected Outcome: Students should observe that inhaling carbon dioxide makes them feel short of breath and in need of more air.

Analyze and Conclude:
1. Students may say they felt short of breath or as if they needed more air.
2. If students hypothesized that they would feel out of breath, their hypothesis was supported.
3. The stimulus of increased carbon dioxide indicates that gases are not being exchanged in the lungs and, therefore, that the body is not receiving enough oxygen. The increase in carbon dioxide stimulates breathing, which both removes carbon dioxide and brings in oxygen.

Build Science Skills

Inferring: Explain that extremely rapid or deep breathing, which is called hyperventilation, is caused by lower-than-normal levels of carbon dioxide in the blood. Point out that breathing into a paper bag for a few minutes can stop hyperventilation.

Ask: Why does breathing into a paper bag stop hyperventilation? (It leads to a normal level of carbon dioxide in the blood, and this slows down the rate of breathing.)

How does your body respond to increases in carbon dioxide?

Materials: seltzer tablet, plastic cup

Procedure:
1. Formulating Hypotheses: Carbon dioxide is a waste material synthesized during the cellular process of respiration. Write a hypothesis about how your breathing will be affected if the level of carbon dioxide increases.
2. Place approximately 100 mL of water in the cup and add a seltzer tablet. The bubbles in the water are carbon dioxide. Bring the cup up to your face and inhale deeply.

Analyze and Conclude:
1. Observing: Describe what happened when you inhaled the carbon dioxide.
2. Drawing Conclusions: Did your results support your hypothesis or not? Explain your answer.
3. Inferring: Why is it important for your body to respond to the stimulus of increased carbon dioxide?

BIOLOGY UPDATE

Asthma on the rise

Asthma is a potentially fatal respiratory illness characterized by repeated asthmatic attacks, during which muscles surrounding the air passages that lead to the lungs contract. Constriction of the air passages makes it difficult to get enough air. It can also cause death in severe attacks. An estimated 5 to 10 percent of high-school students suffer from asthma. That number is higher than ever before and is still on the rise. Some scientists think that the increase in asthma may be partly due to air pollution. Laws regulating smokestack emissions and the use of coal have led to a reduction in industrial air pollution. However, air pollution from motor-vehicle exhaust contains many substances that are harmful to the respiratory system, including carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides, lead, and hydrocarbons.
That the breathing center responds primarily to carbon dioxide can have dangerous consequences. Consider a plane flying at high altitude. Although the amount of oxygen in the air decreases as the altitude increases, the passengers do not need oxygen masks because the cabin is pressurized. Oxygen is available for use in an emergency, but the passengers often have to be told to begin breathing the oxygen. Although their bodies may be starving for oxygen, they have no more carbon dioxide in their blood than usual, so the breathing center does not sense a problem. The pilot in Figure 37–16 is not in a pressurized cabin and must use an oxygen mask at high altitudes.

**Tobacco and the Respiratory System**

The upper part of the respiratory system is generally able to filter out dust and foreign particles that could damage the lungs. Millions of people engage in an activity—smoking tobacco—that damages and eventually destroys this protective system.

**Substances in Tobacco**

Tobacco smoke contains many substances that affect the body. Three of the most dangerous substances are nicotine, carbon monoxide, and tar. **Nicotine** is a stimulant drug that increases the heart rate and blood pressure. Carbon monoxide is a poisonous gas that blocks the transport of oxygen by hemoglobin in the blood. It decreases the blood’s ability to supply oxygen to its tissues, depriving the heart and other organs of the oxygen they need to function. Tar contains a number of compounds that have been shown to cause cancer.

**Facts and Figures**

**Smoking, cancer, and death**

A person who smokes cigarettes is 10 to 15 times more likely to develop lung cancer than a non-smoker. The more cigarettes one smokes, the greater the chances of developing lung cancer and the more likely one is to die from lung cancer. If a person smokes two or more packs of cigarettes a day, he or she is 20 to 25 times more likely to die from lung cancer than a non-smoker. Three of every four deaths from lung cancer in women are caused by smoking. Cancer is not the only risk that smokers face. Smokers are also three times more likely to die from a heart attack than nonsmokers. Men in their thirties who smoke can expect to lose about eight years of life if they do not quit smoking.

**Make Connections**

Chemistry: Elaborate on how carbon monoxide in tobacco smoke blocks the transport of oxygen by the blood. Remind students that oxygen normally binds with the iron in hemoglobin molecules. Explain that when carbon monoxide is present in the blood, it binds with hemoglobin at the same site, but much more strongly, so the oxygen is not released to the cells where it is needed. Ask: Besides tobacco smoke, what are some other sources of carbon monoxide? (Possible answers include car exhausts and faulty fireplaces, gas furnaces, and other gas appliances.)

**Answers to . . .**

The breathing center monitors the amount of carbon dioxide in the blood. As the level rises, nerve impulses from the breathing center cause the diaphragm to contract.

Figure 37–16 The mountain climber would base the decision on the altitude of the mountain.
Smoking can cause respiratory diseases such as chronic bronchitis, emphysema, and lung cancer. In chronic bronchitis, the bronchi become swollen and clogged with mucus. Even smoking a moderate number of cigarettes on a regular basis can produce chronic bronchitis. Affected people often find simple activities, such as climbing stairs, difficult.

Long-term smoking can also cause a respiratory disease called emphysema (em-fuh-SEE-muh). This is the loss of elasticity in the tissues of the lungs. This condition makes breathing very difficult. People who have emphysema cannot get enough oxygen to the body tissues or rid the body of excess carbon dioxide.

Smoking is an important, but preventable, cause of lung cancer. Figure 37–17 shows the effects of smoking on the lungs. Lung cancer is particularly deadly because its cells can spread to other locations. By the time lung cancer is detected, it usually has spread to dozens of other places. About 160,000 people in the United States are diagnosed with lung cancer each year. Few will survive for five years after the diagnosis.

Doll’s doctors
It is common knowledge today that cigarette smoking is the major cause of lung cancer and a contributing factor to a number of other serious health problems. However, as recently as 1950, doctors were unaware of the health risks of tobacco use. All that changed in the 1950s with the innovative research of Sir Richard Doll. Doll used epidemiological methods to establish a link between cigarette smoking and many serious illnesses, including lung cancer and heart disease.

His approach was to follow a large sample of people over many years to establish correlations between suspected risk factors and the development of disease. Ironically, the sample Doll followed to establish the link between smoking and lung cancer was a group of British doctors. Doll later used the same method to study the effects of other risk factors on cancer development, including the effects of asbestos on the development of a certain type of lung cancer.
Smoking is also a major cause of heart disease. Smoking constricts, or narrows, the blood vessels. This causes blood pressure to rise and makes the heart work harder. The effects of smoking on the circulatory system can be seen in Figure 37–18. There is a drastic change in body temperature and in circulation immediately after smoking a cigarette. Smoking doubles the risk of death from heart disease for men between 45 and 65. Moreover, for men and women of all ages, the risk of death from heart disease is greater among smokers than among nonsmokers.

**Smoking and the Nonsmoker** In recent years, evidence has shown that tobacco smoke is damaging to anyone who inhales it, not just the smoker. For this reason, many states have restricted smoking in restaurants and other public places.

Passive smoking, or inhaling the smoke of others, is particularly damaging to young children because their lungs are still developing. Studies now indicate that the children of smokers are twice as likely as children of nonsmokers to develop respiratory problems, such as asthma.

**Dealing With Tobacco** Whatever the age of a smoker, and no matter how long that person has smoked, his or her health can be improved by quitting. Nicotine is a powerful drug with strong addictive qualities that make it very difficult to quit smoking. Thus, considering the cost, the medical dangers, and the powerful addiction, the best solution is not to begin smoking.

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**3 ASSESS**

**Evaluate Understanding**

Write the following words on the chalkboard: nose, larynx, pharynx, trachea, lung, bronchus, alveolus. Call on students at random to describe the function of each structure.

**Reteach**

Work with students to create a simple schematic diagram showing what occurs during the process of gas exchange in the alveoli.

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**Figure 37–18** These thermograms provide a color-coded map of temperature distribution over the body surface (blue = cold; pink = hot). The top thermogram shows the forearm and hand area prior to smoking a cigarette. The bottom thermogram shows the same area after smoking. **Interpreting Graphics** Do you think circulation is increased or decreased after smoking?