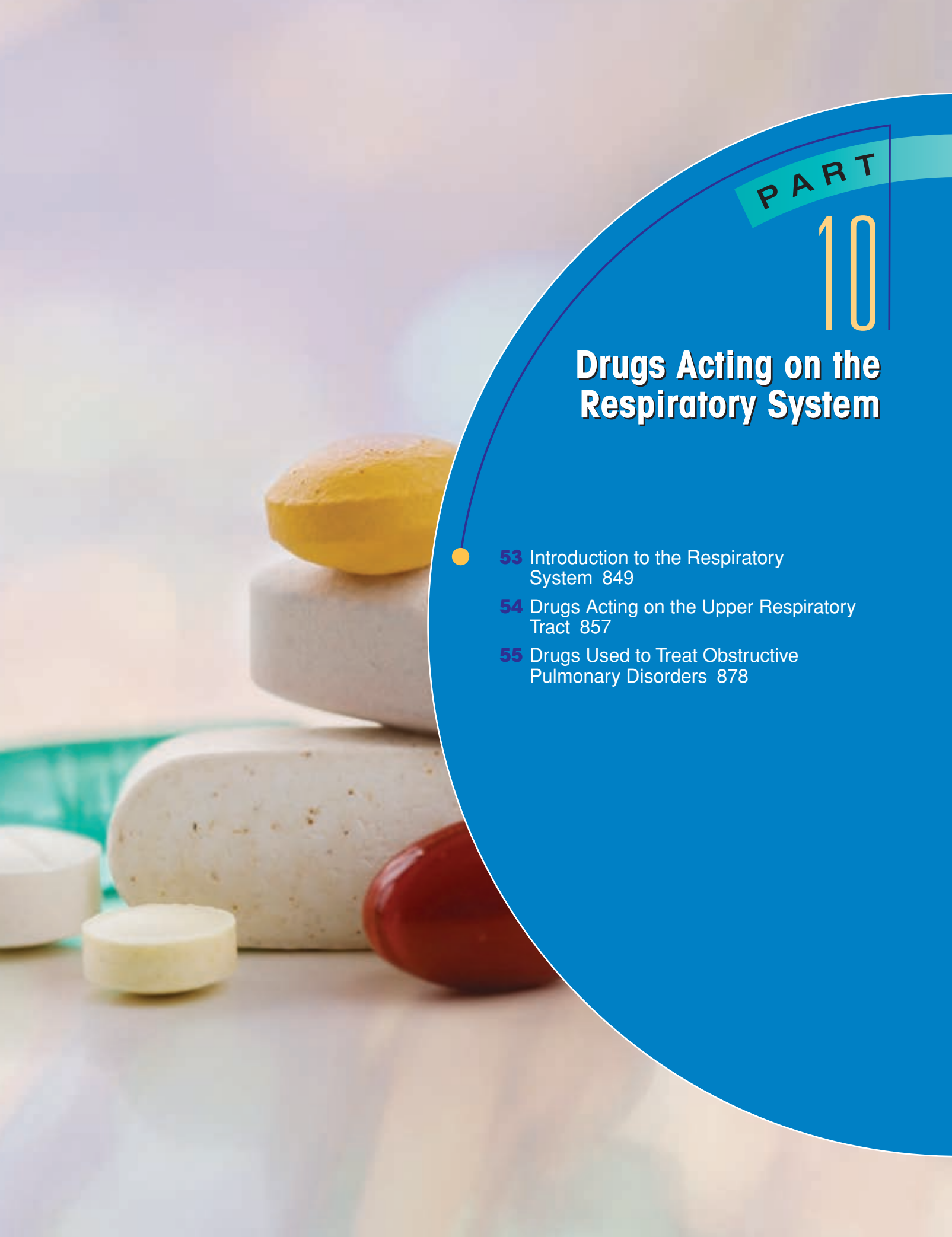


PART 10

Drugs Acting on the Respiratory System

Introduction to the Respiratory System

53

Learning Objectives

Upon completion of this chapter, you will be able to:

1. Describe the major structures of the respiratory system, including the role of each in respiration.
2. Describe the process of respiration, with clinical examples of problems that can arise with alterations in the respiratory membrane.
3. Differentiate between the common conditions that affect the upper respiratory system.
4. Identify three conditions involving the lower respiratory tract, including the clinical presentations of these conditions.
5. Discuss the process involved in obstructive respiratory diseases, correlating this to the signs and symptoms of these diseases.

Glossary of Key Terms

alveoli: the respiratory sac, the smallest unit of the lungs, where gas exchange occurs
asthma: disorder characterized by recurrent episodes of bronchospasm (i.e., bronchial muscle spasm leading to narrowed or obstructed airways)
atelectasis: collapse of once-expanded alveoli
bronchial tree: the conducting airways leading into the alveoli; they branch smaller and smaller, appearing much like a tree
chronic obstructive pulmonary disease (COPD): chronic condition that occurs over time; often the result of chronic bronchitis or repeated and severe asthma attacks; leads to destruction of the respiratory defense mechanisms and physical structure
cilia: microscopic, hair-like projections of the epithelial cell membrane lining the upper respiratory tract, which are constantly moving and directing the mucus and any trapped substance toward the throat
common cold: viral infection of the upper respiratory tract that initiates the release of histamine and prostaglandins and causes an inflammatory response
cough: reflex response to irritation in the respiratory membrane, results in expelling of forced air through the mouth
cystic fibrosis: a hereditary disease that results in the accumulation of copious amounts of very thick secretions in the lungs, which will eventually lead to obstruction of the airways and destruction of the lung tissue
larynx: the vocal chords and the epiglottis, which close during swallowing to protect the lower respiratory tract from any foreign particles
lower respiratory tract: the bronchi and the alveoli that make up the lungs; the area where gas exchange takes place
pneumonia: inflammation of the lungs that can be caused by bacterial or viral invasion of the tissue or by aspiration of foreign substances
pneumothorax: air in the pleural space exerting high pressure against the alveoli
respiration: the act of breathing to allow the exchange of gases, a basic process for living things
respiratory distress syndrome (RDS): disorder found in premature neonates whose lungs have not had time to mature and who are lacking sufficient surfactant to maintain open airways to allow for respiration
respiratory membrane: area through which gas exchange must be made; made up of the capillary endothelium, the capillary basement membrane, the interstitial space, the alveolar basement membrane, the alveolar endothelium, and the surfactant layer
seasonal rhinitis: inflammation of the nasal cavity, commonly called hay fever; caused by reaction to a specific antigen
sinuses: air-filled passages through the skull that open into the nasal passage
sinusitis: inflammation of the epithelial lining of the sinus cavities
sneeze: reflex response to irritation to receptors in the nares, results in expelling of forced air through the nose
surfactant: lipoprotein that reduces surface tension in the alveoli, allowing them to stay open to allow gas exchange
trachea: the main conducting airway leading into the lungs
upper respiratory tract: the nose, mouth, pharynx, larynx, and trachea—the conducting airways where no gas exchange occurs
ventilation: the movement of gases in and out of the lungs

The respiratory system is essential for survival. It brings oxygen into the body, allows for the exchange of gases, and leads to the expulsion of carbon dioxide and other waste products. The normal functioning of the respiratory system depends on an intricate balance of the nervous, cardiovascular, and musculoskeletal systems. Numerous conditions can affect the respiratory tract and interfere with the body's ability to ensure adequate oxygenation and gas exchange.

STRUCTURE AND FUNCTION OF THE RESPIRATORY SYSTEM

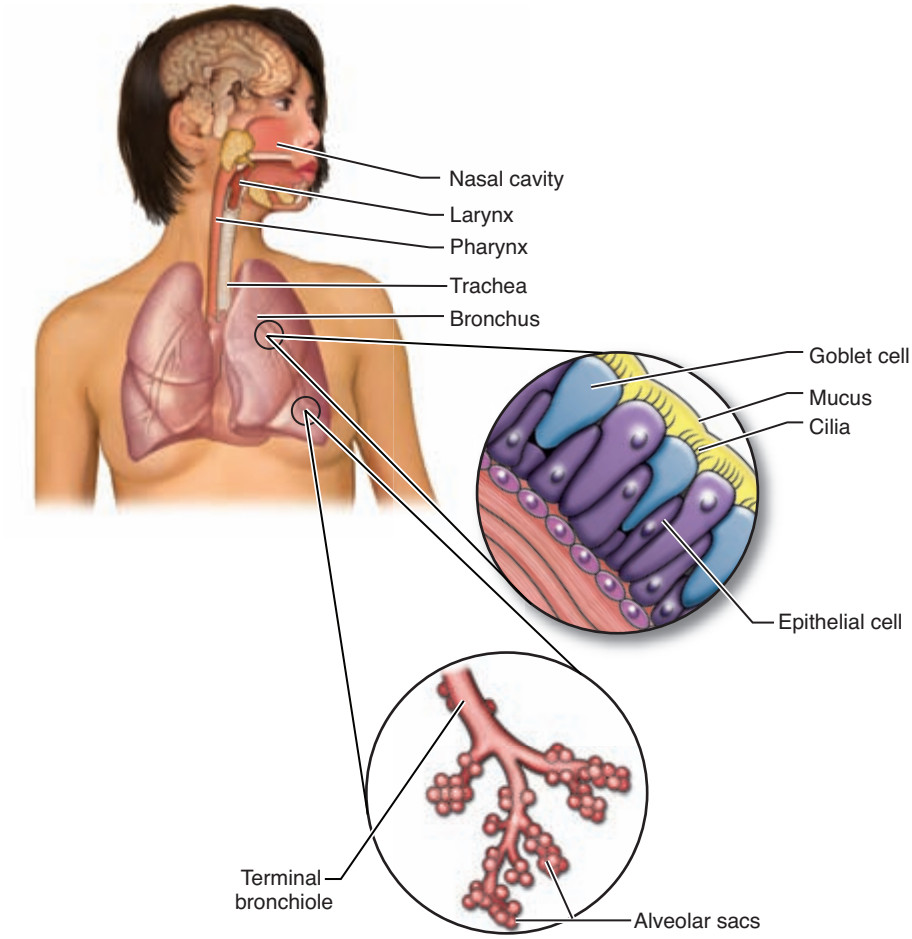
The respiratory system consists of two major components: the **upper respiratory tract** and the **lower respiratory tract.** The upper portion, or conducting airways, is composed of the nose, mouth, pharynx, larynx, and trachea. The lower portion is made up of the **bronchial tree** (Figure 53.1). The smallest bronchi and the **alveoli** (respiratory sacs), which make up the lungs, where gas exchange takes place, are called the respiratory airways.

The Upper Respiratory Tract

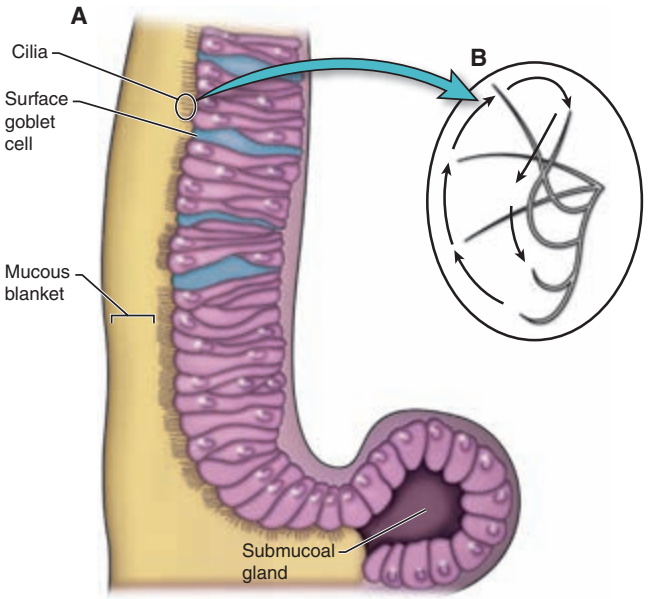
The upper respiratory tract is primarily involved in the movement of air in and out of the body, called **ventilation.** Air usually moves into the body through the nose and into the nasal cavity. The nasal hairs catch and filter foreign substances that may be present in the inhaled air. The air is warmed and humidified as it passes by blood vessels close to the surface of the epithelial lining in the nasal cavity. The epithelial lining contains goblet cells that produce mucus. This mucus traps dust, microorganisms, pollen, and any other foreign substances. The epithelial cells of the lining also contain **cilia**—microscopic, hair-like projections of the cell membrane—which are constantly moving and directing the mucus and any trapped substances down toward the throat (Figure 53.2). The action of the goblet cells and cilia is commonly called the mucociliary escalator.

Pairs of **sinuses** (air-filled passages through the skull open into the nasal cavity. Because the epithelial lining of the nasal passage is continuous with the lining of the sinuses, the mucus produced in the sinuses drains into the nasal cavity. From there, the mucus drains into the throat and is swallowed into the gastrointestinal tract, where stomach acid destroys foreign materials.

Air moves from the nasal cavity into the pharynx and **larynx.** The larynx contains the vocal chords and the epiglottis, which closes during swallowing to protect the lower respiratory tract from any foreign particles. From the larynx, air proceeds to the **trachea,** the main conducting airway into



● FIGURE 53.1 The respiratory tract.



● FIGURE 53.2 **A.** The mucociliary escalator. **B.** Conceptual scheme of ciliary movement, which allows forward motion to move the viscous gel layer and backward motion to occur entirely within the less viscous layer of the mucous blanket.

the lungs. The trachea bifurcates, or divides, into two main bronchi, which further divide into smaller and smaller branches. All of these tubes contain mucus-producing goblet cells and cilia to entrap any particles that may have escaped the upper protective mechanisms. The cilia in these tubes move the mucus up the trachea and into the throat, where again it is swallowed.

The walls of the trachea and conducting bronchi are highly sensitive to irritation. When receptors in the walls are stimulated, a central nervous system reflex is initiated and a **cough** results. The cough causes air to be pushed through the bronchial tree under tremendous pressure, cleaning out any foreign irritant. This reflex, along with the similar **sneeze** reflex (which is initiated by receptors in the nasal cavity), forces foreign materials directly out of the system, opening it for more efficient flow of gas.

Throughout the airways, many macrophage scavengers freely move about the epithelium and destroy invaders. Mast cells are present in abundance and release histamine, serotonin, adenosine triphosphate (ATP), and other chemicals to ensure a rapid and intense inflammatory reaction to any cell injury. The end result of these various defense mechanisms is that the lower respiratory tract is virtually sterile—an important protection against respiratory infection that could interfere with essential gas exchange.

The Lower Respiratory Tract

The lower respiratory tract (i.e., the respiratory airways) is composed of the bronchial tree, the smallest bronchioles, and the alveoli (see Figure 53.1). The bronchial tubes are composed of three layers: cartilage, muscle, and epithelial cells. The cartilage keeps the tube open, but it becomes progressively less abundant as the bronchi divide and get smaller. The muscles keep the bronchi open; the muscles in the bronchi become smaller and less abundant, with only a few muscle fibers remaining in the terminal bronchi and alveoli. The epithelial cells are very similar in structure and function to the epithelial cells in the nasal passage. The alveoli at the end of the bronchioles form the respiratory membrane. These structures are the functional units of the lungs where gas exchange occurs.

The lungs are two spongy organs that fill the chest cavity. They are separated by the mediastinum, which contains the heart, esophagus, thymus gland, and various blood vessels and nerves. The lungs are made up of the bronchial tree, the alveoli, the blood supply to the lungs, and the blood coming from the right ventricle to the alveoli for gas exchange and elastic tissue, which is important in allowing the expansion and recoil of the lungs to allow ventilation. The left lung is composed of two lobes or sections, and the right lung is composed of three lobes. The lung tissue receives its blood supply from the bronchial artery, which branches directly off the aorta. The alveoli receive unoxygenated blood from the right ventricle via the pulmonary artery. The delivery of this blood to the alveoli is referred to as pulmonary perfusion.

Gas Exchange

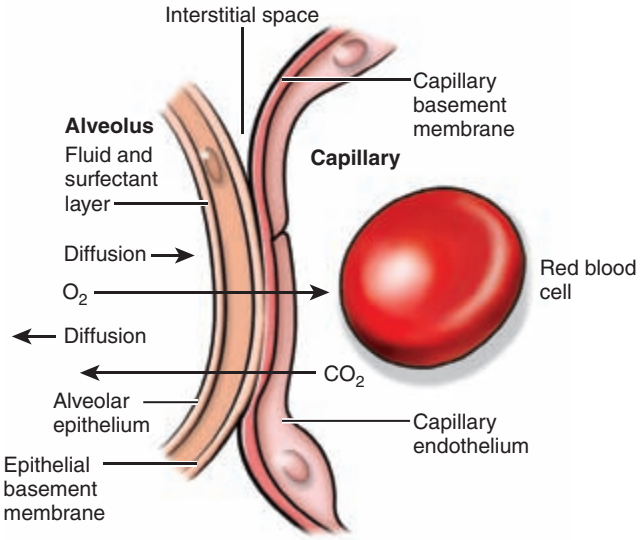
Gas exchange occurs in the alveoli. In this process, carbon dioxide is lost from the blood and oxygen is transferred to the blood. The exchange of gases at the alveolar level is called **respiration.** The alveolar sac holds the gas, allowing needed oxygen to diffuse across the **respiratory membrane** into the capillary while carbon dioxide, which is more abundant in the capillary blood, diffuses across the membrane and enters the alveolar sac to be expired.

The respiratory membrane is made up of the capillary endothelium, the capillary basement membrane, the interstitial space, the alveolar basement membrane, the alveolar epithelium, and the surfactant layer (Figure 53.3). The sac is able to stay open because the surface tension of the cells is decreased by the lipoprotein **surfactant.** Absence of surfactant leads to alveolar collapse. Surfactant is produced by the type II cells in the alveoli. These cells have other metabolic functions, including the conversion of angiotensin I to angiotensin II, the degradation of serotonin, and possibly the metabolism of various hormones.

The oxygenated blood is returned to the left atrium via the pulmonary veins; from there it is pumped throughout the body to deliver oxygen to the cells and to pick up waste products.

Respiration

Respiration, or the act of breathing to allow gas exchange, is controlled by the central nervous system. The inspiratory muscles—diaphragm, external intercostals, and abdominal



● FIGURE 53.3 The respiratory membrane.

muscles—are stimulated to contract by the respiratory center in the medulla. The medulla receives input from chemoreceptors (neuroreceptors sensitive to carbon dioxide and acid levels) to increase the rate and/or depth of respiration to maintain homeostasis in the body.

The vagus nerve, a predominantly parasympathetic nerve, plays a key role in stimulating diaphragm contraction and inspiration. Vagal stimulation also leads to a bronchoconstriction or tightening. The sympathetic system also innervates the respiratory system. Stimulation of the sympathetic system leads to increased rate and depth of respiration and dilation of the bronchi to allow freer flow of air through the system.

KEY POINTS

- The respiratory system has two parts: the upper respiratory tract, which includes the nose, pharynx, larynx, and trachea, and the lower respiratory tract, which includes the bronchial tree and alveoli. Gas exchanges occur in the alveoli.
- Nasal hairs, mucus-producing goblet cells, cilia, the superficial blood supply of the upper respiratory tract, and the cough and sneeze reflexes all work to keep foreign substances from entering the lower respiratory tract.
- Gas exchange occurs across the respiratory membrane in the alveolar sac. The alveoli produce surfactant, which reduces surface tension, among other functions.
- The medulla controls respiration, which depends on a functioning muscular system and a balance between the sympathetic and parasympathetic systems.

RESPIRATORY PATHOPHYSIOLOGY

Several conditions or disorders of the upper and lower respiratory tracts can interfere with the functioning of the respiratory system. These problems can range from generalized discomfort to life-threatening changes in gas exchange. Having a basic understanding of the processes at work will facilitate the understanding of the drugs that are used to treat these disorders.

Upper Respiratory Tract Conditions

The most common conditions that affect the upper respiratory tract involve the inflammatory response and its efects on the mucosal layer of the conducting airways.

The Common Cold

A number of viruses cause the **common cold.** These viruses invade the tissues of the upper respiratory tract, initiating the release of histamine and prostaglandins and causing an inflammatory response. As a result of the inflammator response, the mucous membranes become engorged with blood, the tissues swell, and the goblet cells increase the production of mucus. These effects cause the person with a common cold to complain of sinus pain, nasal congestion, runny nose, sneezing, watery eyes, scratchy throat, and headache. In susceptible people, this swelling can block the outlet of the eustachian tube, which drains the inner ear and equalizes pressure across the tympanic membrane. If this outlet becomes blocked, feelings of ear stuffiness and pain can occu , and the individual is more likely to develop an ear infection (otitis media).

Seasonal Rhinitis

A similar condition that afflicts many people is allergic or **seasonal rhinitis** (an inflammation of the nasal cavity), commonly called hay fever. This condition occurs when the upper airways respond to a specific antigen (e.g. pollen, mold, dust) with a vigorous inflammatory response resulting again in nasal congestion, sneezing, stuffiness and watery eyes.

Sinusitis

Other areas of the upper respiratory tract can become irritated or infected, with a resultant inflammation of that particula area. **Sinusitis** occurs when the epithelial lining of the sinus cavities becomes inflamed. The resultant swelling often causes severe pain due to pressure against the bone, which cannot stretch, leading to blockage of the sinus passage.The danger of a sinus infection is that, if it is left untreated, microorganisms can travel up the sinus passages and into brain tissue.

Pharyngitis and Laryngitis

Pharyngitis and laryngitis are infections of the pharynx and larynx, respectively. These infections are frequently caused by common bacteria or viruses. Pharyngitis and laryngitis are frequently seen with influenza which is caused by a variety of different viruses and produces uncomfortable respiratory symptoms or other inflammations along with fever, muscle aches and pains, and malaise.

Lower Respiratory Tract Conditions

A number of disorders affect the lower respiratory tract, including atelectasis, pneumonia (bacterial, viral, or aspiration), bronchitis or inflammation of the bronchi (acute and chronic), bronchiectasis, and the obstructive disorders—asthma, chronic obstructive pulmonary disease (COPD), cystic fibrosis, and respiratory distress syndrome (RDS). Tuberculosis, discussed in Chapter 9, is a bacterial infection. Once known as consumption, this disease has been responsible for many respiratory deaths throughout the centuries. All of these disorders involve, to some degree, an alteration in the ability to move gases in and out of the lungs.

Atelectasis

Atelectasis, the collapse of once-expanded alveoli, can occur as a result of outside pressure against the alveoli—for example, from a pulmonary tumor, a **pneumothorax** (air in the pleural space exerting high pressure against the alveoli), or a pleural effusion. Atelectasis most commonly occurs as a result of airway blockage, which prevents air from entering the alveoli, keeping the lung expanded. This occurs when a mucous plug, edema of the bronchioles, or a collection of pus or secretions occludes the airway and prevents the movement of air. Patients may experience atelectasis after surgery, when the effects of anesthesia, pain, and decreased coughing reflexes can lead to a decreased tidal volume and accumulation of secretions in the lower airways. Patients may present with crackles, dyspnea, fever, cough, hypoxia, and changes in chest wall movement. Treatment may involve clearing the airways, delivering oxygen, and assisting ventilation. In the case of a pneumothorax, treatment also involves the insertion of a chest tube to restore the negative pressure to the space between the pleura.

Pneumonia

Pneumonia is an inflammation of the lungs caused either by bacterial or viral invasion of the tissue or by aspiration of foreign substances into the lower respiratory tract. The rapid inflammatory response to any foreign presence in the lower respiratory tract leads to localized swelling, engorgement, and exudation of protective sera. The respiratory membrane is affected, resulting in decreased gas exchange. Patients complain of difficulty breathing and fatigue, and they present with fever, noisy breath sounds, and poor oxygenation.

Bronchitis

Acute bronchitis occurs when bacteria, viruses, or foreign materials infect the inner layer of the bronchi. There is an immediate inflammatory reaction at the site of the infection resulting in swelling, increased blood flow in that area, and changes in capillary permeability, leading to leakage of proteins into the area. The person with bronchitis may have a narrowed airway during the inflammation; this condition can be very serious in a person with obstructed or narrowed airflow. Chronic bronchitis is an inflammation of the bronchi that does not clear.

Bronchiectasis

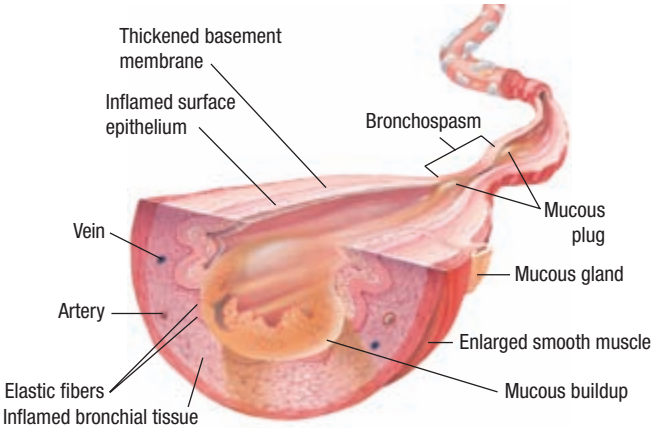
Bronchiectasis is a chronic disease that involves the bronchi and bronchioles. It is characterized by dilation of the bronchial tree and chronic infection and inflammation of the bronchial passages. With chronic inflammation the bronchial epithelial cells are replaced by a fibrous scar tissue. The loss of the protective mucus and ciliary movement of the epithelial cell membranes, combined with the dilation of the bronchial tree, leads to chronic infections in the now-unprotected lower areas of the lung tissue. Patients with bronchiectasis often have an underlying medical condition that makes them more susceptible to infections (e.g., immune suppression, acquired immune deficiency syndrome, chronic inflammatory conditions). Patients present with the signs and symptoms of acute infection, including fever, malaise, myalgia, arthralgia, and a purulent, productive cough.

Obstructive Pulmonary Diseases

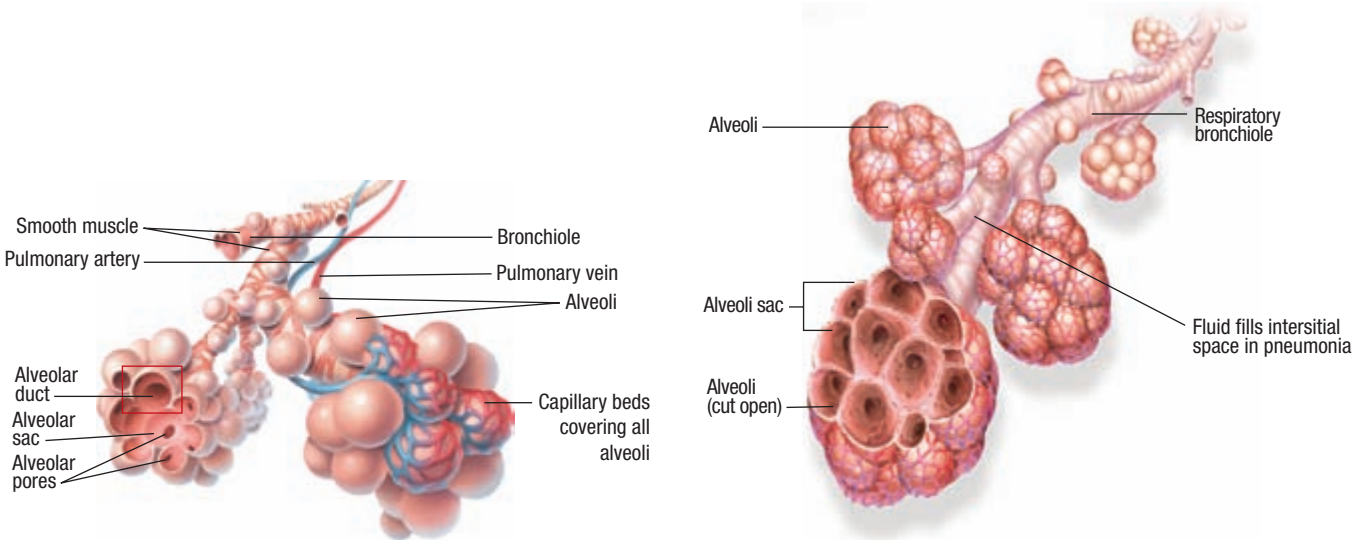
As noted previously, the obstructive pulmonary diseases include asthma, cystic fibrosis COPD, and RDS.

Asthma

Asthma is characterized by reversible bronchospasm, inflammation, and hyperactive airways (Figure 53.4). The hyperactivity is triggered by allergens or nonallergic inhaled irritants or by factors such as exercise and emotions. The trigger causes an immediate release of histamine, which results in bronchospasm in about 10 minutes. The later response (3 to 5 hours) is cytokine-mediated inflammation mucus production, and edema contributing to obstruction. Appropriate treatment depends on understanding the early and late responses. The extreme case of asthma is called status asthmaticus; this is a life-threatening bronchospasm that does not respond to usual treatment and occludes airflow into the lungs.



● FIGURE 53.4 Asthma. The bronchiole is obstructed on expiration, particularly by muscle spasm, edema of the mucosa, and thick secretions.



● FIGURE 53.5 Distended and destroyed alveoli versus normal alveoli.

Chronic Obstructive Pulmonary Disease (COPD)

Chronic obstructive pulmonary disease (COPD) is a permanent, chronic obstruction of airways, often related to cigarette smoking. It is caused by two related disorders—emphysema and chronic bronchitis—both of which result in airfl w obstruction on e xpiration, as well as o verinflation of the lungs an poor gas e xchange. Emphysema is characterized by loss of the elastic tissue of the lungs, destruction of alv eolar walls, and a resultant alv eolar hyperinflation with a tenden y to collapse with e xpiration. Chronic bronchitis is a permanent inflammation of the air ays with mucus secretion, edema, and poor inflammatory defenses. Characteristics of both dis orders often are present in a person with COPD (Figure 53.5).

Cystic Fibrosis

Cystic fib osis (CF) is a hereditary disease in volving the exocrine glands of the respiratory, gastrointestinal, and reproductive tracts. CF results in the accumulation of copious amounts of very thick secretions in the lungs. Eventually, the secretions obstruct the airways, leading to destruction of the lung tissue. Treatment is aimed at keeping the secretions flui and mo ving and maintaining airw ay patenc y as much as possible.

Respiratory Distress Syndrome

Respiratory distress syndrome (RDS) causes obstruction at the alveolar level. It is frequently seen in premature infants who are delivered before their lungs have fully developed and while surfactant levels are still very low. Surfactant is necessary for lo wering the surf ace tension in the alv eoli so that they can stay open to allo w the fl w of gases. If surf actant levels are lo w, the alveoli do not e xpand and cannot recei ve air, leading to decreased gas e xchange, low oxygen le vels, and generalized distress throughout the body as cells do not receive the oxygen that the y need to survi ve. Treatment is aimed at instilling surfactant to prevent atelectasis and to allow the lungs to expand.

Acute respiratory distress syndrome (ARDS) is characterized by progressi ve loss of lung compliance and increasing hypoxia. This syndrome typically results from a severe insult to the body , such as cardio vascular collapse, major b urns, severe trauma, or rapid depressurization. Treatment of ARDS involves reversal of the underlying cause of the problem combined with ventilatory support.

KEY POINTS

- Inflammation of the lower respiratory tract can result in serious disorders that interfere with gas exchange, including bronchitis and pneumonia.
- Obstructive disorders interfere with the ability to deliver gases to the alveoli because of obstructions in the conducting airways and eventually in the respiratory airways. These disorders include asthma, chronic obstructive pulmonary disease (COPD), cystic fibrosis, and respiratory distress syndrome (RDS).

CHAPTER SUMMARY

- The respiratory system is composed of the upper respiratory tract, which includes the nose, pharynx, larynx, and trachea, and the lower respiratory tract, which includes the bronchial tree and the alveoli.
- The respiratory system is essential for survival; it brings oxygen into the body, allows for the exchange of gases, and expels carbon dioxide and other waste products.
- The upper airways have many features to protect the fragile alveoli: hairs filter the air; goblet cells produce mucus to tra

foreign material; cilia move the trapped material toward the throat for swallowing; the blood supply close to the surface warms the air and adds humidity to improve gas movement and gas exchange; and the cough and sneeze refl xes clear the airways.
- The alveolar sac is where gas exchange occurs across the respiratory membrane. The alveoli produce surfactant to decrease surface tension within the sac and facilitate diffusion.
- Respiration is controlled through the medulla in the central nervous system and depends on a balance between the sympathetic and parasympathetic systems and a functioning muscular system.
- Inflammation of the upper respiratory tract is seen in ma y disorders, including the common cold, seasonal rhinitis, sinusitis, pharyngitis, and laryngitis.
- Inflammation of the l wer respiratory tract can result in serious disorders that interfere with gas exchange, including bronchitis and pneumonia.
- Obstructive disorders interfere with the ability to deliver gases to the alveoli because of obstructions in the conducting airways and eventually in the respiratory airways. These disorders include asthma, chronic obstructive pulmonary disease (COPD), cystic fibrosis and respiratory distress syndrome (RDS).

WEB LINKS

For a virtual tour of the respiratory tract, refer to the following Internet source:

http://www.InnerBody.com

CHECK YOUR UNDERSTANDING

Answers to the questions in this chapter can be found in Answers to Check Your Understanding Questions on the CD-Rom in the front of the book.

Multiple Choice

Select the best answer to the following.

1. The nurse emphasizes the need to take sinusitis very seriously because
   a. it can cause a loss of sleep and exhaustion.
   b. it can lead to a painful otitis media.
   c. if it is left untreated, microorganisms can travel to brain tissue.
   d. drainage from infected sinus membranes often leads to pneumonia.

2. Diffusion of CO_2 from the tissues into the capillary blood
   a. occurs if the tissue concentration of CO_2 is greater than that in the blood.
   b. decreases as blood acidity increases.
   c. increases in the absence of carbonic anhydrase.
   d. is accompanied by a decrease in plasma bicarbonate.

3. The type II cells of the walls of the alveoli function to
   a. replace mucus in the alveoli.
   b. produce serotonin.
   c. secrete surfactant.
   d. protect lungs from bacterial invasion.

4. A patient who coughs is experiencing a reflex caused by
   a. inflammation irritating the sinuses in the skull.
   b. irritants affecting receptor sites in the nasal cavity.
   c. pressure against the eustachian tube.
   d. irritation to receptors in the trachea and conducting airways

5. Which of the following is most critical for respiration to occur?
   a. Low levels of oxygen
   b. Low levels of CO_2
   c. Functioning inspiratory muscles
   d. An actively functioning autonomic system

6. After teaching a community group about the common cold, the instructor determines that the teaching was successful when the group states which of the following as the cause?
   a. Bacteria that grow best in the cold
   b. Allergens in the environment
   c. Irritation of the delicate mucous membrane
   d. A number of different viruses

7. A patient with COPD would be expected to have
   a. an acute viral infection of the respiratory tract.
   b. loss of protective respiratory mechanisms due to prolonged irritation or damage.
   c. localized swelling and inflammation within the lungs.
   d. inflammation or swelling of the sinus membranes over a prolonged period.

Multiple Response

Select all that apply.

1. Which of the following would a nurse expect to assess if a patient has inflammation of the upper respiratory tract?
   a. A runny nose
   b. Laryngitis

c. Sneezing
d. Hypoxia
e. Rales
f. Wheezing

2. For gas exchange to occur in the lungs, oxygen must pass through which of the following?
a. The conducting airways
b. The alveolar epithelium
c. The pleural fluid
d. The interstitial alveolar wall
e. The capillary basement membrane
f. The interstitial space

3. The nose performs which of the following functions in the respiratory system?
a. Serves as a passageway for air movement
b. Warms and humidifies the air
c. Cleanses the air using hair fibers
d. Stimulates surfactant release from the alveoli
e. Initiates the cough reflex
f. Initiates the sneeze reflex

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