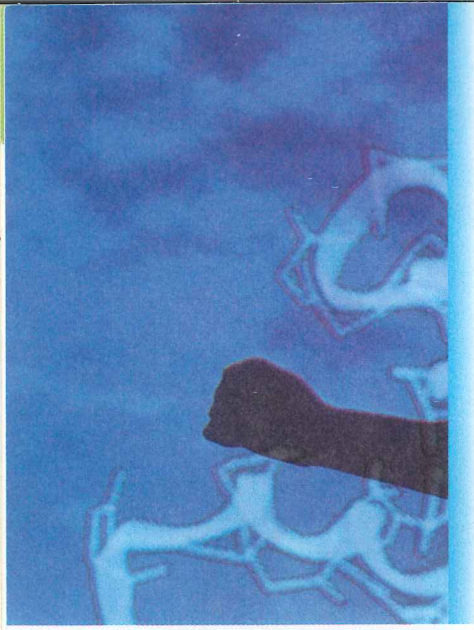

(Objective Checklist, continued)

- Define *apnea, dyspnea, hyperventilation, hypoventilation,* and *chronic obstructive pulmonary disease (COPD).*

RESPIRATORY DISORDERS **(pp. 422–424)**

- Describe the symptoms and probable causes of COPD and lung cancer.

DEVELOPMENTAL ASPECTS OF THE RESPIRATORY SYSTEM **(pp. 424 and 426)**

- Describe normal changes that occur in respiratory system functioning from infancy to old age.

The trillions of cells in the body require an abundant and continuous supply of oxygen to carry out their vital functions. We cannot "do without oxygen" for even a little while, as we can without food or water. Furthermore, as cells use oxygen, they give off carbon dioxide, a waste product the body must get rid of.

The *cardiovascular* and *respiratory systems* share responsibility for supplying the body with oxygen and disposing of carbon dioxide. The respiratory system organs oversee the gas exchanges that occur between the blood and the external environment. The transportation of respiratory gases between the lungs and the tissue cells is accomplished by the cardiovascular system organs, using blood as the transporting fluid. If either system fails, body cells begin to die from oxygen starvation and accumulation of carbon dioxide.

Functional Anatomy of the Respiratory System

The organs of the **respiratory system** include the nose, pharynx, larynx, trachea, bronchi and their smaller branches, and the lungs, which contain the *alveoli* (al-ve′o-li), or terminal air sacs. Since gas exchanges with the blood happen only in the alveoli, the other respiratory system structures are really just *conducting passageways* that allow air to reach the lungs. However, these passageways have another, very important job. They purify, humidify, and warm incoming air. Thus, the air finally reaching the lungs has many fewer irritants (such as dust or bacteria) than when it entered the system, and it is warm and damp. As the respiratory system organs are described in detail next, locate each on Figure 13.1.

The Nose

The **nose,** whether "pug" or "ski-jump" in shape, is the only externally visible part of the respiratory system. During breathing, air enters the nose by passing through the **external nares,** or **nostrils.** The interior of the nose consists of the **nasal cavity,** divided by a midline **nasal septum.** The *olfactory receptors* for the sense of smell are located in the mucosa in the slitlike superior part of the nasal cavity, just beneath the ethmoid bone. The rest of the mucosa lining the nasal cavity, called the *respiratory mucosa,* rests on a rich network of thin-walled veins that warms the air as it flows past. (Because of the superficial location of these blood vessels, nosebleeds are common and often profuse.) In addition, the sticky mucus produced by the mucosa's glands moistens the air and traps incoming bacteria and other foreign debris. The ciliated cells of the nasal mucosa create a gentle current that moves contaminated mucus posteriorly toward the throat (pharynx), where it is swallowed and digested by stomach juices. We are usually unaware of this important ciliary action, but when the external temperature is extremely cold, these cilia become sluggish, allowing mucus to accumulate in the nasal cavity and to dribble outward through the nostrils. This helps explain why you might have a "runny" nose on a crisp, wintry day.

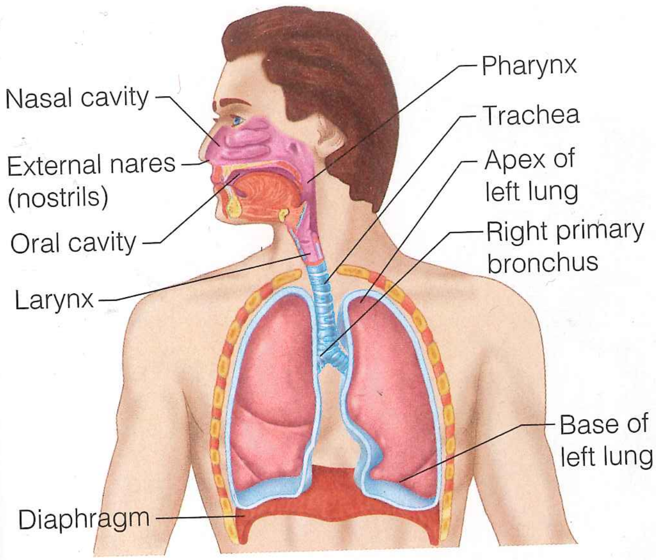

Figure 13.1 The major respiratory organs shown in relation to surrounding structures.

As shown in Figures 13.1 and 13.2, the lateral walls of the nasal cavity are uneven owing to three mucosa-covered projections or lobes, called **conchae** (kong′ke), which greatly increase the surface area of the mucosa exposed to the air. The conchae also increase the air turbulence in the nasal cavity. As the air swirls through the twists and turns, inhaled particles are deflected onto the mucus-coated surfaces, where they are trapped and prevented from reaching the lungs.

The nasal cavity is separated from the oral cavity below by a partition, the **palate** (pal′et). Anteriorly, where the palate is supported by bone, is the **hard palate;** the unsupported posterior part is the **soft palate.**

HOMEOSTATIC IMBALANCE The genetic defect *cleft palate* (failure of the bones forming the palate to fuse medially) results in breathing difficulty as well as problems with oral cavity functions such as chewing and speaking. ▲

The nasal cavity is surrounded by a ring of **paranasal sinuses** located in the frontal, sphenoid, ethmoid, and maxillary bones. (See Figure 5.10, p. 128.) The sinuses lighten the skull, and they act as resonance chambers for speech. They also produce mucus, which drains into the nasal cavities. The suctioning effect created by nose blowing helps to drain the sinuses. The nasolacrimal ducts, which drain tears from the eyes, also empty into the nasal cavities.

HOMEOSTATIC IMBALANCE Cold viruses and various allergens can cause *rhinitis* (ri-ni′tis), inflammation of the nasal mucosa. The excessive mucus produced results in nasal congestion and postnasal drip. Because the nasal mucosa is continuous throughout the respiratory tract and extends tentacle-like into the nasolacrimal (tear) ducts and paranasal sinuses, nasal cavity infections often spread to those regions as well. **Sinusitis,** or sinus inflammation, is difficult to treat and can cause marked changes in voice quality. When the passageways connecting the sinuses to the nasal cavity are blocked with mucus or infectious matter, the air in the sinus cavities is absorbed. The result is a partial vacuum and a *sinus headache* localized over the inflamed area. ▲

Pharynx

The **pharynx** (far′inks) is a muscular passageway about 13 cm (5 inches) long that vaguely resembles a short length of red garden hose. Commonly called the *throat,* the pharynx serves as a common passageway for food and air (Figures 13.1 and 13.2). It is continuous with the nasal cavity anteriorly via the **internal nares.**

Air enters the superior portion, the **nasopharynx** (na″zo-far′inks), from the nasal cavity and then descends through the **oropharynx** (o″ro-far′inks) and **laryngopharynx** (lah-ring″go-far′inks) to enter the larynx below. Food enters the mouth and then travels along with air through the oropharynx and laryngopharynx. But instead of entering the larynx, it is directed into the *esophagus* (ĕ-sof′ah-gus) posteriorly.

The auditory tubes, which drain the middle ear, open into the nasopharynx. Since the mucosae of these two regions are continuous, ear infections such as *otitis media* (o-ti′tis me′de-ah) may follow a sore throat or other types of pharyngeal infections.

Clusters of lymphatic tissue called *tonsils* are also found in the pharynx. The **pharyngeal** (far-rin′je-al) **tonsil,** often called *adenoid,* is located high in the nasopharynx. The **palatine tonsils** are

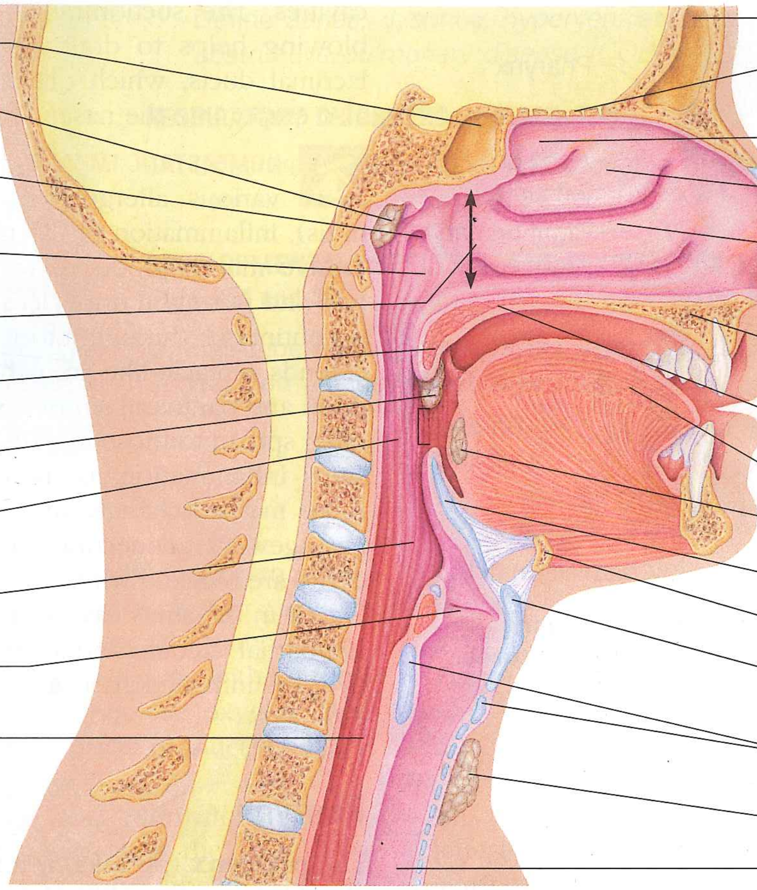

Figure 13.2 Basic anatomy of the upper respiratory tract, sagittal section.

in the oropharynx at the end of the soft palate; the **lingual tonsils** are at the base of the tongue. The role of the tonsils in body protection is described in Chapter 12 (p. 372).

HOMEOSTATIC IMBALANCE If the pharyngeal tonsil becomes inflamed and swollen (as during a bacterial infection), it obstructs the nasopharynx and forces the person to breathe through the mouth. In mouth breathing, air is not properly moistened, warmed, or filtered before reaching the lungs. Many children seem to have almost continuous *tonsillitis.* Years ago the belief was that the tonsils were more trouble than they were worth in such cases, and they were routinely removed. Presently, because of the widespread use of antibiotics, this is no longer necessary (or true). ▲

Larynx

The **larynx** (lar′inks), or *voice box,* routes air and food into the proper channels and plays a role in speech. Located inferior to the pharynx (see Figures 13.1 and 13.2), it is formed by eight rigid hyaline cartilages and a spoon-shaped flap of elastic cartilage, the epiglottis (ep″ĭ-glot′tis). The largest of the hyaline cartilages is the shield-shaped **thyroid cartilage,** which protrudes anteriorly and is commonly called the *Adam's apple.* Sometimes referred to as the "guardian of the airways," the **epiglottis** protects the superior opening of the larynx. When we are not swallowing, the epiglottis does not restrict the passage of air into the lower respiratory passages. When we swallow food or fluids, the situation changes dramatically; the larynx is pulled upward and the epiglottis tips, forming a lid over

Figure 13.3 Cilia in the trachea. The cilia are the yellow, grasslike projections surrounded by the mucus-secreting goblet cells, which exhibit short microvilli (orange). (Scanning electron micrograph, 221,000×.)

the opening of the larynx. This routes food into the esophagus, or food tube, posteriorly. If anything other than air enters the larynx, a *cough reflex* is triggered to expel the substance and prevent it from continuing into the lungs. Because this protective reflex does *not* work when we are unconscious, it is never a good idea to try to give fluids to an unconscious person when attempting to revive him or her.

- Palpate your larynx by placing your hand midway on the anterior surface of your neck. Swallow. Can you feel the larynx rising as you swallow?

Part of the mucous membrane of the larynx forms a pair of folds, called the **vocal folds,** or **true vocal cords,** which vibrate with expelled air. This ability of the vocal folds to vibrate allows us to speak. The slitlike passageway between the vocal folds is the **glottis.**

Trachea

Air entering the **trachea** (tra′ke-ah), or windpipe, from the larynx travels down its length (10–12 cm, or about 4 inches) to the level of the fifth thoracic vertebra, which is approximately midchest (Figure 13.1). The trachea is lined with a ciliated mucosa (Figure 13.3). The cilia beat continuously and in a direction opposite to that of the incoming air. They propel mucus, loaded with dust particles and other debris, away from the lungs to the throat, where it can be swallowed or spat out.

HOMEOSTATIC IMBALANCE Smoking inhibits ciliary activity and ultimately destroys the cilia. Without these cilia, coughing is the only means of preventing mucus from accumulating in the lungs. Smokers with respiratory congestion should avoid medications that inhibit the cough reflex. ▲

The trachea is fairly rigid because its walls are reinforced with C-shaped rings of hyaline cartilage. These rings serve a double purpose. The open parts of the rings abut the esophagus and allow it to expand anteriorly when we swallow a large piece of food. The solid portions support the trachea walls and keep it *patent,* or open, in spite of the pressure changes that occur during breathing.

HOMEOSTATIC IMBALANCE Because the trachea is the only way air can enter the lungs, tracheal obstruction is life-threatening. Many people have suffocated after choking on a piece of food that suddenly closed off the trachea (or the glottis of the larynx). The **Heimlich maneuver,** a procedure in which the air in a person's own lungs is used to "pop out," or expel, an obstructing piece of food, has saved many other people from becoming victims of such "café coronaries." The Heimlich maneuver is simple to learn and easy to do. However, it is best learned by demonstration because cracked ribs are a distinct possibility when it is done incorrectly. In some cases of obstructed breathing, an emergency *tracheostomy* (tra′ke-ost′o-me; surgical opening of the trachea) is done to provide an alternate route for air to reach the lungs. Individuals with tracheostomy tubes in place form huge amounts of mucus the first few days because of irritation to the trachea. Thus, they must be suctioned frequently during this time to prevent the mucus from pooling in their lungs. ▲

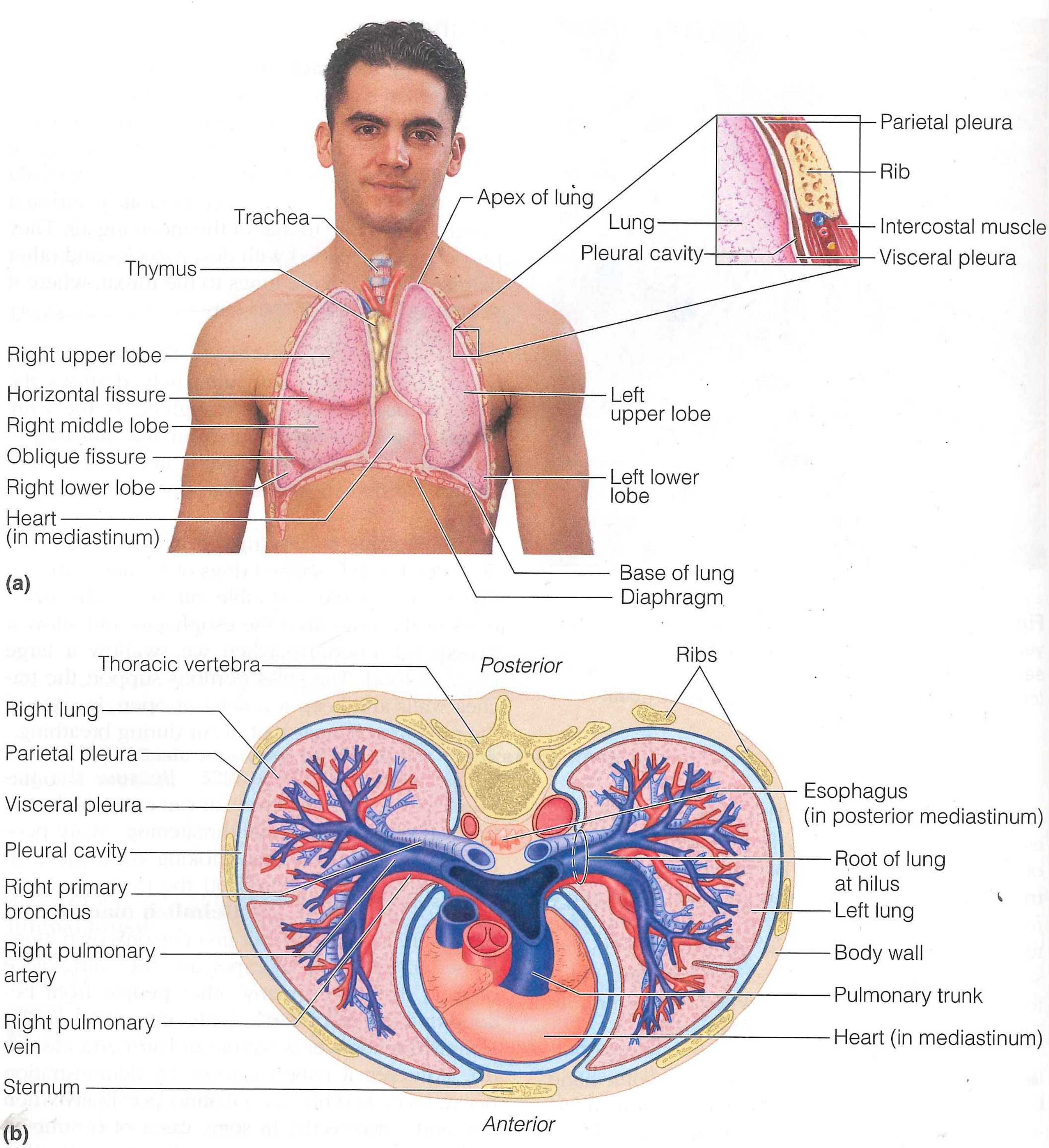

Figure 13.4 Anatomical relationships of organs in the thoracic cavity. (a) Anterior view of the thoracic cavity organs, showing the position of the lungs, which flank the heart laterally. **(b)** Transverse section through the thorax, showing the relationship of the lungs, the pleural membranes, the major organs present in the mediastinum, and the thorax.

Primary Bronchi

The right and left **primary bronchi** (brong'ki) are formed by the division of the trachea. Each primary bronchus runs obliquely before it plunges into the medial depression (*hilus*) of the lung on its own side (see Figures 13.1 and 13.4). The right primary bronchus is wider, shorter, and straighter than the left. Consequently, it is the more common site for an inhaled foreign object to become lodged. By the time incoming air reaches the bronchi, it is warm, cleansed of most impurities, and well humidified. The smaller subdivisions of the primary bronchi within the lungs are direct routes to the air sacs.

Lungs

The paired **lungs** are fairly large organs. They occupy the entire thoracic cavity except for the most central area, the **mediastinum** (me″de-as-ti'num), which houses the heart, the great blood vessels, bronchi, esophagus, and other organs (Figure 13.4). The narrow superior portion of each lung, the **apex,** is located just deep to the clavicle. The broad lung area resting on the diaphragm is the **base.** Each lung is divided into lobes by fissures; the left lung has two lobes, and the right lung has three.

The surface of each lung is covered with a visceral serosa called the **pulmonary,** or **visceral, pleura** (ploor'ah), and the walls of the thoracic cavity are lined by the **parietal pleura.** The pleural membranes produce *pleural fluid,* a slippery serous secretion which allows the lungs to glide easily over the thorax wall during breathing movements and causes the two pleural layers to cling together. The pleurae can slide easily from side to side across one another, but they strongly resist being pulled apart. Consequently, the lungs are held tightly to the thorax wall, and the *pleural space* is more of a potential space than an actual one. As described shortly, this condition of tightly adhering pleural membranes is absolutely essential for normal breathing. Figure 13.4 shows the position of the pleura on the lungs and the thorax wall.

HOMEOSTATIC IMBALANCE *Pleurisy* (ploo'rĭ-se), inflammation of the pleura, can be caused by decreased secretion of pleural fluid. The pleural surfaces become dry and rough, which results in friction and stabbing pain with each breath. Conversely, the pleurae may produce excessive amounts of fluid, which exerts pressure on the lungs. This type of pleurisy hinders breathing movements, but it is much less painful than the dry rubbing type. ▲

After the primary bronchi enter the lungs, they subdivide into smaller and smaller branches (secondary and tertiary bronchi, and so on), finally ending in the smallest of the conducting passageways, the **bronchioles** (brong'ke-ōlz). Because of this branching and rebranching of the respiratory passageways within the lungs, the network formed is often referred to as the *bronchial* or *respiratory tree.* All but the smallest branches have reinforcing cartilage in their walls.

The *terminal bronchioles* lead into *respiratory zone structures,* even smaller conduits that eventually terminate in **alveoli** (al-ve'o-li; *alveol* = small cavity), or air sacs (Figure 13.5). The **respiratory zone,** which includes the *respiratory bronchioles, alveolar ducts,* alveolar sacs, and alveoli, is the only site of gas exchange. All other respiratory passages are **conducting zone structures** that serve as conduits to and from the respiratory zone. There are millions of the clustered alveoli, which resemble bunches of grapes, and they make up the bulk of the lungs. Consequently, the lungs are mostly air spaces. The balance of the lung tissue, its *stroma,* is elastic connective tissue. Thus, in spite of their relatively large size, the lungs weigh only about 2½ pounds, and they are soft and spongy.

The Respiratory Membrane

The walls of the alveoli are composed largely of a single, thin layer of squamous epithelial cells. The thinness of their walls is hard to imagine, but a sheet of tissue paper is much thicker. *Alveolar pores* connect neighboring air sacs and provide alternate routes for air to reach alveoli whose feeder bronchioles have been clogged by mucus or otherwise blocked. The external surfaces of the alveoli are covered with a "cobweb" of pulmonary capillaries. Together, the alveolar and capillary walls and their fused basement membranes construct the **respiratory membrane (air-blood**

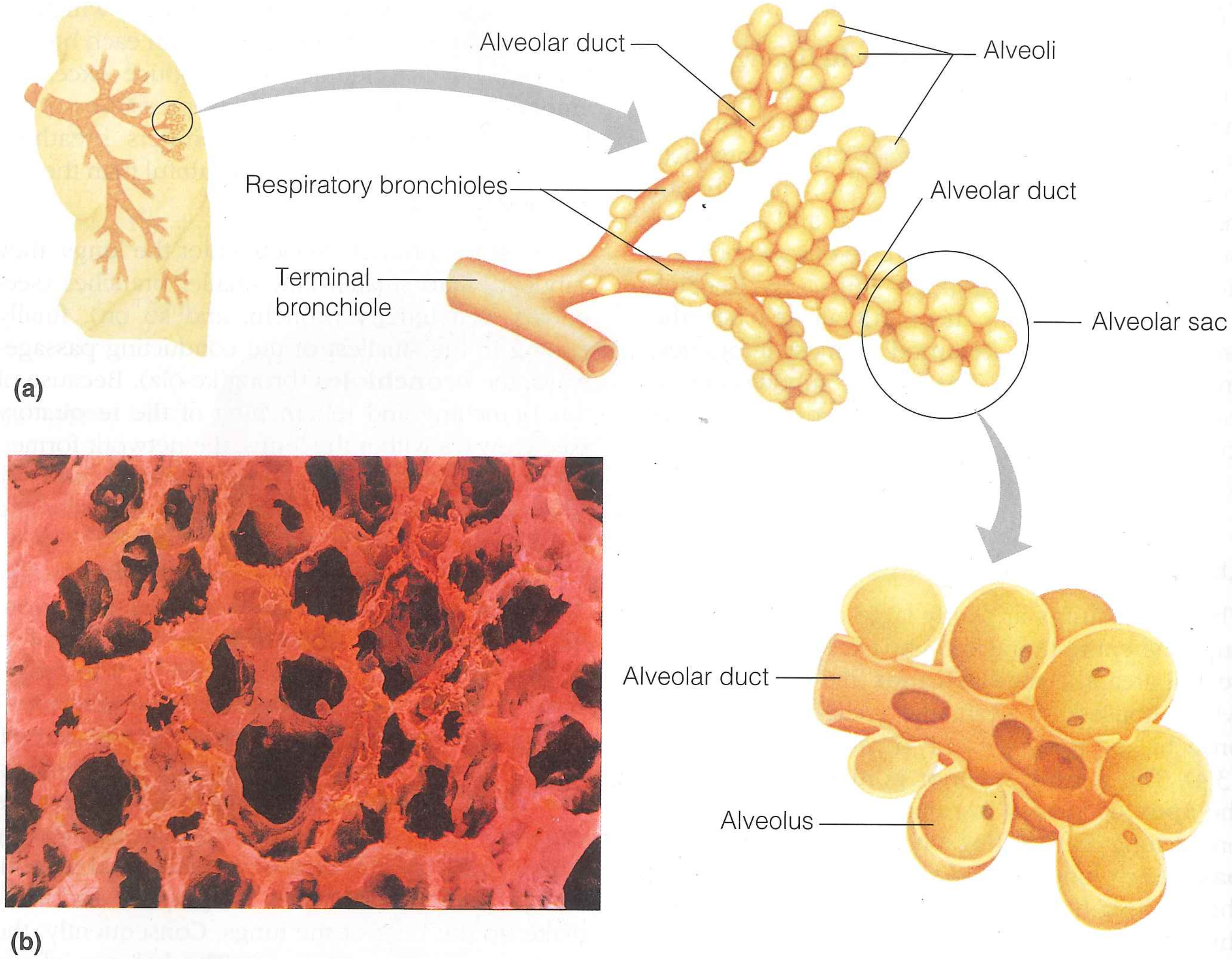

Figure 13.5 Respiratory zone structures. (a) Diagrammatic view of respiratory bronchioles, alveolar ducts, and alveoli. **(b)** Scanning electron micrograph (SEM) of human lung tissue, showing the final divisions of the respiratory tree (475×).

barrier), which has gas (air) flowing past on one side and blood flowing past on the other (Figure 13.6). The gas exchanges occur by simple diffusion through the respiratory membrane—oxygen passing from the alveolar air into the capillary blood and carbon dioxide leaving the blood to enter the gas-filled alveolus. It has been estimated that the total gas exchange surface provided by the alveolar walls of a healthy man is 50 to 70 square meters, or approximately 40 times greater than the surface area of his skin.

The final line of defense for the respiratory system is in the alveoli. Macrophages, sometimes called "dust cells," wander in and out of the alveoli picking up bacteria, carbon particles, and other debris. Also scattered amid the epithelial cells that form most of the alveolar walls are chunky cuboidal cells, which look very different. The cuboidal cells produce a lipid (fat) molecule called *surfactant,* which coats the gas-exposed alveolar surfaces and is very important in lung function (as described on p. 424).