In this chapter, you get a quick review of Mother Nature’s dual-purpose system and plenty of opportunities to test your knowledge about the lungs and other parts of the respiratory system.

**Breathing In Oxygen, Breathing Out CO₂**

Respiration, or the exchange of gases between an organism and its environment, occurs in three distinct processes:

- **Breathing**: The technical term is pulmonary ventilation, or the movement of air into and out of the lungs. (Breathing is also called inspiration and expiration.)

- **Exchanging gases**: This takes place between the alveolar cells in the lungs, the blood, and the body’s cells in two ways:
  - **Pulmonary, or external, respiration**: The exchange in the lungs when blood gains oxygen and loses carbon dioxide, transforming it from venous blood into arterial blood
  - **Systemic, or internal, respiration**: The exchange within systemic capillaries when the blood releases some of its oxygen and collects carbon dioxide from the tissues

- **Cellular respiration**: Oxygen is used in the catabolism of substances like glucose for the production of energy (see Chapter 1).
Here are some key respiratory terms to keep in mind:

- **Adult breathing rate**: About 12 to 20 times per minute.
- **Anoxia**: Oxygen deficiency in which the cells either don’t have or can’t utilize sufficient oxygen to perform normal functions.
- **Asphyxia**: Lack of oxygen with an increase in carbon dioxide in the blood and tissues; accompanied by a feeling of suffocation leading to coma.
- **Expiration or exhalation**: The diaphragm returns to its domed shape as the muscle fibers relax, via elastic recoil of the lungs and tissues lining the thoracic cavity, the external intercostal muscles relax, and the internal intercostal muscles contract. This movement pulls the ribs back into place, decreasing the volume of the thoracic cavity and increasing pressure, forcing air out of the lungs.
- **Hypoxia**: Low oxygen content in the inspired air.
- **Inspiration or inhalation**: When the muscles of the diaphragm contract, its dome shape flattens; simultaneously, the contraction of the external intercostal muscles pulls the ribs upward and increases the volume of the thoracic cavity, decreasing the intra-alveolar pressure. The pressure difference between the atmosphere and the lungs diffuses air into the respiratory tract.
- **Lung capacity**: The vital capacity plus the residual air.
- **Mediastinum**: The region between the lungs extending from the sternum ventrally (at the front) to the thoracic vertebrae dorsally (at the back), and superiorly (top) from the entrance of the thoracic cavity to the diaphragm inferiorly (at the bottom).
- **Minimal air**: The volume of air in the lungs when they’re completely collapsed (150 cubic centimeters in an adult).
- **Phrenic nerve**: The nerve that innervates (stimulates) the diaphragm.
- **Residual air**: The volume of air remaining in the lungs after the most forceful expiration (1,200 cubic centimeters in an adult).
- **Respiratory centers**: Nerve centers for regulating breathing located in the medulla oblongata, or brain stem. The centers are influenced by the amount of carbon dioxide in the blood.
- **Tidal air**: The volume of air inspired and expired in the resting state (500 cubic centimeters in an adult).
- **Vital capacity**: The volume of air moved by the most forceful expiration after a maximum inspiration. It represents the total moveable air in the lungs (4,600 cubic centimeters in an adult).

Here’s what happens as you breathe in and out (see Figure 8-1): Red blood cells use a pigment called hemoglobin to carry oxygen and carbon dioxide throughout the body through the circulatory system (for more on that system, turn to Chapter 10). Hemoglobin bonds loosely with oxygen, or O\(_2\), to carry it throughout the body; the bonded hemoglobin is called oxyhemoglobin.

After hemoglobin releases its oxygen molecules, it picks up carbon dioxide, or CO\(_2\), to deliver to the lungs for exhalation. The freshly bonded hemoglobin becomes carbohemoglobin (carbhemoglobin or carbaminohemoglobin).
1. Which of the following gases are dissolved and held in chemical combination in the blood?
   a. Nitrogen and CO₂
   b. Chlorine and CO
   c. Oxygen and CO₂
   d. Nitrogen and O₂

2. The chemical of most significance in gaseous transport is
   a. Acetylcholine
   b. Hemoglobin
   c. Adrenaline
   d. Antihistamines

3.-6. Fill in the blanks to complete the following sentences:

   Upon inhalation, molecules of 3. ____________ diffuse into the lung’s tissues. From there, these molecules then diffuse into 4. ____________ cells, which contain a pigment called 5. ____________. Simultaneously, a second substance formed during cellular respiration, 6. ____________, is released to the lung tissues to be expelled during exhalation.

Q. The air that moves in and out of the lungs during normal, quiet breathing is called
   a. Tidal volume, or tidal air
   b. Inspiratory reserve
   c. Vital capacity
   d. Lung capacity

A. The correct answer is tidal volume, or tidal air. The question asks only about air moved during normal, quiet breathing, not the kind of forceful air movement involved in measuring lung capacity. Think of the normal ebb and flow of the ocean’s tide as opposed to the waves of a raging storm.

See whether you’re carrying away enough information about respiration by tackling the following practice questions:
7. The average breathing rate per minute of adults is
   a. 120 breaths
   b. 100 breaths
   c. 72 breaths
   d. 20 breaths

8–12. Match the respiration terms with their descriptions.
8. _____ Anoxia
   a. Low O$_2$ content in air breathed in
9. _____ Internal respiration
   b. O$_2$ lacking and excessive CO$_2$
10. _____ Asphyxia
    c. Gaseous exchange between capillaries and cells
11. _____ Hypoxia
    d. Without O$_2$ at the cell level
12. _____ Pulmonary, or external, respiration
    e. Gaseous exchange in lungs

Inhaling the Basics about the Respiratory Tract

We fill and empty our lungs by contracting and relaxing the respiratory muscles, which include the dome-shaped diaphragm and the intercostal muscles that surround the rib cage. As these muscles contract, air moves through a series of interconnected chambers in the following order (see Figure 8-2): Nose → Pharynx → Larynx → Trachea → Bronchi → Bronchioles → Alveolar ducts → Alveoli. We look at the details of each chamber in that order.

Knowing about the nose (and sinuses)

You may care a great deal about how your nose is shaped, but the shape actually makes little difference to your body. The nose is simply the most visible part of your respiratory tract. Beyond those oh-so-familiar nostrils — which are formally called nares — the septum divides the nasal cavity into two chambers called the nasal fossae. The internal openings at the posterior of the fossae are called the choanae. Inside the nostril is a slight dilation extending to the apex of the nose called the vestibule; it’s lined by skin covered with hairs, plus mucous glands and sebaceous glands that help trap dust and particles before they can enter the lungs.

Each nasal cavity is divided into an olfactory region and a respiratory region.

- The olfactory region lies in the upper part of the nasal cavity. Fine filaments distributed over its mucous membrane are actually special nerves devoted to the sense of smell. The bipolar olfactory cells’ axons thread through openings in the cribriform plate (from the Latin crillum for “sieve”) and then come together to form the olfactory nerve (cranial nerve I) that terminates in the olfactory centers of the brain’s cerebral cortex.

- The nasal cavity’s respiratory region is covered by a mucous membrane made up of pseudostratified, ciliated columnar epithelium (remember the ten types of epithelium in Chapter 4?) containing mucous and sebaceous glands. The secretions from these glands form a protective layer that warms, moistens, and helps
to filter air as it’s inhaled. Beneath the protective layer, areolar connective tissue containing lymphocytes (which form a thin lymphoid tissue) removes foreign materials. A layer of blood vessels next to the peristomeum (the membrane covering the surface of bones) forms a rich plexus (network) that tends to swell when irritated or inflamed, closing the osia (openings) of the nasal sinuses. Don’t you just hate it when that happens?

Ah, the sinuses. They can be such headaches. Lined with a ciliated columnar epithelium (refer to Chapter 4’s tissue discussion), sinuses are cavities in the bone that reduce the skull’s weight and act as resonators for the voice. Each of the sinuses is named for the bone containing it, as follows:

- **Frontal sinuses** are located in the front bone behind the eyebrows. (If you’ve ever flown in an airplane with a sinus infection, these are the suckers that hit you right behind the eyes.)
- **Maxillary sinuses** are located in the maxillae, or upper lip.
- **Ethmoid and sphenoid sinuses** are located in the ethmoid and sphenoid bones in the cranial cavity’s floor.

Beyond the sinuses and connected to them are nasal ducts that extend from the medial angle of the eyes to the nasal cavity. These ducts let serous fluid — a biology term referring to any fluid resembling serum — from the eyes’ lacrimal glands (tear ducts) flow into the nasal cavity.

The nasal cavity performs several important functions:

- It drains mucous secretions from the sinuses.
- It drains lacrimal secretions from the eyes.
- It prepares inhaled air for the lungs by warming, moistening, and filtering it. Dust and bacteria are caught in the mucous and passed outward from the nasal cavity by the motion of the cilia. Some of that gunk is taken up by lymphatic tissue in the nasal cavity and respiratory tubes for delivery to the lymph nodes, which destroy invading germs.

Beyond the nasal cavity is the nasopharynx, which connects — you guessed it — the nasal cavity to the pharynx.

With a bit of a refresher on the nasal and sinus passages, do you think you can hit the following practice questions on the nose?

13. Which of the following statements about the mucous membranes of the nasal cavity is not true?
   a. They contain an abundant blood supply.
   b. They moisten the air that flows over them.
   c. They’re composed of stratified squamous epithelium.
   d. They become inflamed, causing the membrane to swell and close the nasal sinuses.

14. A nasal sinus would not be found in the
   a. Frontal bone
   b. Ethmoid
   c. Maxilla
   d. Vomer
   e. Sphenoid
15.–30. Use the terms that follow to identify the structures of the respiratory tract shown in Figure 8-2.

Dealing with throaty matters

In laymen’s terms, it’s the throat. But you know better, right? The top of the throat consists of these key parts:
Pharynx: The pharynx is an oval, fibromuscular sac about 5 inches long and tapering to \(\frac{1}{2}\) inch in diameter at its anteroposterior end, which is a fancy biology term meaning “front to back.” In fact, the point where the pharynx connects to the esophagus is the narrowest part of the entire digestive tract. Eustachian tubes connected to the middle ears enter the pharynx on each side. On the back wall of the pharynx is a mass of lymphoid tissue called the pharyngeal tonsil, or adenoids.

Larynx: Connecting the pharynx with the trachea, this collection of nine cartilages is what makes a man’s prominent Adam’s apple. Also called the voice box, the larynx looks like a triangular box flattened dorsally and at the sides that becomes narrow and cylindrical toward the base (see Figure 8-3). Ligaments connect the cartilages controlled by several muscles; the inside of the larynx is lined with a mucous membrane that continues into the trachea.

Three of the larynx’s nine cartilages go solo — the thyroid, the cricoid, and the epiglottis — while three more come in pairs — the arytenoids, the corniculates, and the cuneiforms. The thyroid cartilage (thyroid in Greek means “shield-shaped) is largest and consists of two plates called laminae that are fused just beneath the skin to form a shield-shaped process, the Adam’s apple. Immediately above the Adam’s apple, the laminae are separated by a V-shaped notch called the superior thyroid notch. The ring-shaped cricoid cartilage is smaller but thicker and stronger, with shallow notches at the top of its broad back that connect, or articulate, with the base of the arytenoid cartilages. The arytenoid cartilages both are shaped like pyramids, with the vocal folds attached at the back and the controlling muscles that move the arytenoids attached at the sides, moving the vocal cords. On top of the arytenoids are the corniculate cartilages, small conical structures for attachment of muscles regulating tension on the vocal cords. Nestled in front of these and inside the aryepiglottic fold, the cuneiform cartilages stiffen the soft tissues in the vicinity. The epiglottis, sometimes called the lid on the voice box, is a leaf-shaped cartilage that projects upward behind the root of the tongue. Attached at its stem end, the epiglottis opens during respiration and reflexively closes during swallowing to keep food and liquids from getting into the respiratory tract.

Two types of folds play different roles inside the larynx. The true vocal folds, or cords, are V-shaped when relaxed. When talking, the folds stretch for high sounds or slacken for low sounds, causing the opening into the glottis — the opening in the larynx — to form an oval. Sounds are produced when air is forced over the folds, causing them to vibrate. Just above these folds are the ventricular vocal folds, also known as vestibular or false folds, that don’t produce sounds. Muscle fibers within these folds help close the glottis during swallowing.

Following are some practice questions dealing with the throat:

31. The vocal folds change position by the movement of the cartilage known as
   a. Cuneiforms
   b. Thyroid
   c. Arytenoids
   d. Cricoid
   e. Epiglottis
32.–36. Match the anatomical structure with its function.
   32. _____ Epiglottis  a. Voice box lid
   33. _____ Nasal fossae  b. Respiratory center
   34. _____ Medulla oblongata  c. Prevents collapse of trachea
   35. _____ C-shaped cartilaginous rings  d. Nasal cavity
   36. _____ Thyroid cartilage  e. Adam’s apple

37. The opening between the two vocal folds is called the
   a. Epiglottis
   b. Bronchi
   c. Alveoli
   d. Glottis
   e. Larynx

38. The loud voice of a person speaking is due to
   a. Vibrating vocal folds
   b. Vibrating chest muscles
   c. Increased air from lungs
   d. Vibrating pharynx
   e. Vibrating trachea

39.–52. Use the terms that follow to identify the structures of the larynx shown in Figure 8-3. Some terms may be used more than once.

Figure 8-3:
Front (a) and lateral (b) views of the larynx.

Illustration by Imageering Media Services Inc.
e. Arytenoid cartilage
f. Ventricular fold (false vocal cord)
g. Laryngeal prominence (Adam's apple)
h. Cuneiform cartilage
i. Arytenoid muscle
j. True vocal cord
k. Tracheal cartilages
l. Corniculate cartilage

Going deep inside the lungs

After the pharynx and larynx comes the trachea, more popularly known as the windpipe. Roughly 6 inches long in adults, it’s a tube connected to the larynx in front of the esophagus that’s made up of C-shaped rings of hyaline cartilage and fibrous connective tissue that strengthen it and keep it open. Like the larynx, the trachea’s lined with mucous membrane covered in cilia. Just above the heart, the trachea splits into two bronchi divided by a sharp ridge called the carina, with each leading to a lung. But they’re not identical: The right primary bronchus is shorter and wider than the left primary bronchus. Each primary bronchus divides into secondary bronchi with a branch going to each lobe of the lung; the right side gets three secondary bronchi while the left gets only two. Once inside a designated lobe, the bronchi divides again into tertiary bronchi. The right lung has ten such branches: three in the superior (or upper) lobe, two in the middle lobe, and five in the inferior (or lower) lobe. The left lung has only four tertiary bronchi: two in the upper lobe and two in the lower lobe.

Each tertiary bronchi subdivides one more time into smaller tubes called bronchioles (see Figure 8-4), which lack the supporting cartilage of the larger structures. Each bronchiole ends in an elongated sac called the atrium (also known as an alveolar duct or alveolar sac). Alveoli (or air cells) surround the atria, as do small capillaries that pick up oxygen for delivery elsewhere in the body and dump off carbon dioxide fetched from elsewhere. Overall, there are 23 branches in the respiratory system, with a combined surface area (counting the alveoli) the size of a tennis court!

Knowing that the bronchi aren’t evenly distributed, you may have guessed that the lungs aren’t identical either. You’re right. They’re both spongy and porous because of the air in the sacs, but the right lung is larger, wider, and shorter than the left lung and has three lobes. The left lung divides into only two lobes and is both narrower and longer to make room for the heart because two-thirds of that organ lies to the left of the body’s midline. Each lobe is made up of many lobules, each with a bronchiole ending in an atrium inside.

Covering each lung is a thin serous membrane called the visceral pleura that folds back on itself to form a second outer layer, the parietal pleura, with a pleural cavity between the two layers. These two layers secrete a watery fluid into the cavity to lubricate the surfaces that rub against each other as you breathe. When the pleural membrane becomes inflamed in a condition called pleurisy, a sticky discharge roughens the pleura, causing painful irritation. An accompanying bacterial infection means that pus accumulates in the pleural cavity in a condition known as empyema.
Blood comes to the lungs through two sources: the pulmonary arteries and the bronchial arteries. The pulmonary trunk comes from the right ventricle of the heart and then branches into the two pulmonary arteries carrying venous blood (the only arteries that contain blood loaded with carbon dioxide from various parts of the body) to the lungs. That blood goes through capillaries in the lungs where the carbon dioxide leaves the blood and enters the alveoli to be expelled during exhalation; oxygen leaves the alveoli through the capillaries to enter the bloodstream. After that, oxygenated arterial blood returns to the left atrium through the pulmonary veins (the only veins that contain oxygenated blood), completing the cycle. Bronchial arteries branch off the thoracic aorta of the heart, supplying the lung tissue with nutrients and oxygen.

Following are some practice questions dealing with the lungs:

53. Cartilage is not found in the
   a. Primary bronchi
   b. Secondary bronchi
   c. Bronchioles
   d. Trachea
   e. Larynx

54. Gaseous exchange occurs between the capillaries and the
   a. Trachea
   b. Alveolar sacs
   c. Primary bronchi
   d. Terminal bronchioles
   e. Secondary bronchi

55–59. Fill in the blanks to complete the following sentences:

   The trachea divides into two 55. ______________, which then divide into 56. ______________ with a branch going to each lobe of the lung. Upon entering the lobe, each divides into 57. ______________, subdividing into smaller tubes called 58. ______________. They terminate in an elongated sac called the atrium surrounded by 59. ______________ or air cells.

60. If a pin were to pierce the body from the outside in the thoracic region, the third structure it would reach would be the
   a. Pleural cavity
   b. Visceral pleura
   c. Parietal pleura
   d. Lung
61–69. Use the terms that follow to identify the structures of the bronchiole shown in Figure 8-4.

a. Smooth muscle
b. Pulmonary venule
c. Alveolar sac
d. Terminal bronchiole
e. Pulmonary capillary
f. Pulmonary arteriole
g. Alveolar duct
h. Lymphatic vessel
i. Alveoli

**Damaging Air**

A number of pulmonary diseases can plague human lungs. Inhaling metal and mineral dust can be particularly harmful because the particles cut into and embed themselves in delicate lung tissue, leaving nonfunctional and less pliable scar tissue. Specific lung conditions include

- **Silicosis**, commonly found among construction workers, is caused by deposits of sand particles in the lungs.
Anthracosis, or black lung, occurs among coal miners because of coal dust accumulating in the lungs.

Rhinitis, or the common cold, can be caused by several different kinds of viral infections. Undue exposure may activate the virus or cause the body to become more susceptible to the virus.

70. The disease referred to as anthracosis is caused by
   a. A bacterial infection
   b. Inhaling coal dust
   c. Inhaling sand particles
   d. Undue exposure
   e. Inflammation of the pleura membrane