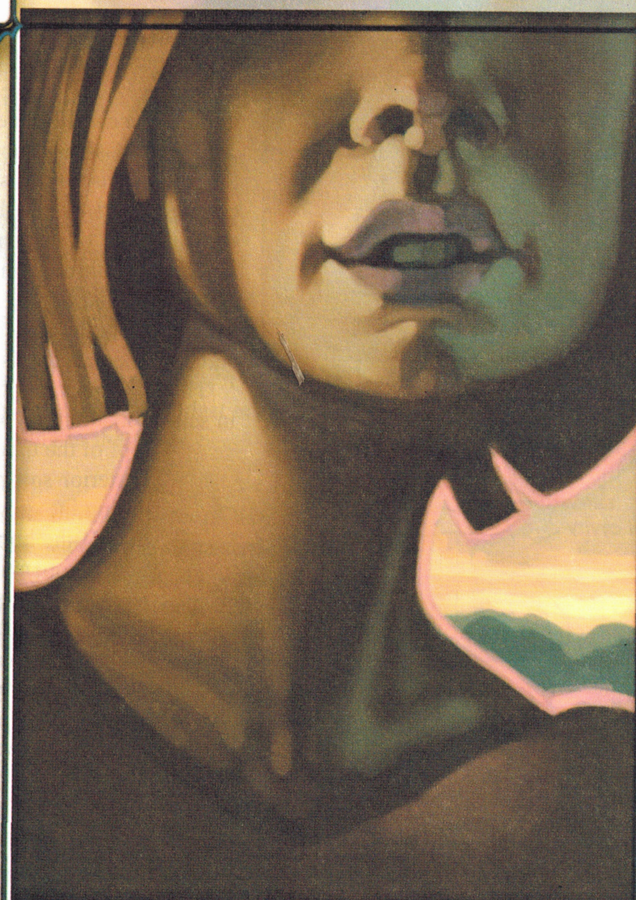
21

Incoming Substances



Facets

21A—The Respiratory System

The quality of air and food that enter the body affects physical condition. To make wise decisions regarding diet and other habits, a person should understand what his body needs and how it uses incoming substances.

21A-1 Anatomy of the Respiratory System

The respiratory system consists of organs that transport oxygen and carbon dioxide to and from the blood: the nose, pharynx, trachea, bronchial tubes, and lungs. Basically the respiratory system brings air from the atmosphere into the lungs. Oxygen in the lungs, however, does most body cells little good. The oxygen in the lungs goes into the blood, which then transfers it to the body cells. Carbon dioxide is removed from the cells by the blood and is returned to the lungs.

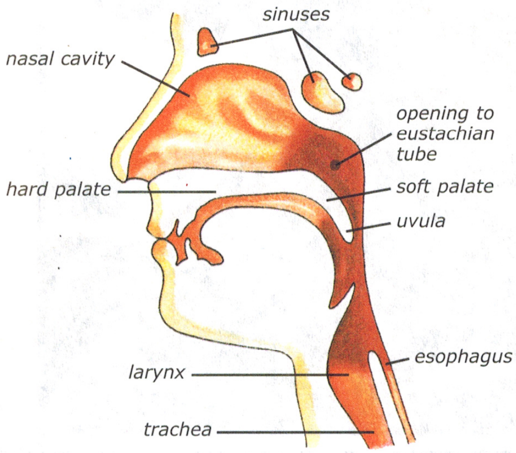
21A-1 Objectives

- Describe the functions of the respiratory system's structures
- Explain how gases are exchanged in the lungs

The Nose

The term *nose* refers not only to a part of the face (external nose) but also to the **nasal cavity**. The nasal cavity is posterior to the external nose and is separated sagittally into right and left sides by the *nasal septum*. A ciliated mucous

21A.1
SEM of the ciliated mucous membrane of the nose



21A.2
The pharynx is the dark shaded area.

membrane lines the nasal cavities and filters bacteria, smoke, and dust particles from the air. If anything irritates the nasal membranes, it often stimulates a sneeze. A sneeze is a deep breathing-in followed by a blast of air up through the nasal cavities. It serves to expel the irritating substance.

The nasal sinuses open either into the nasal cavity or into the pharynx. Since the sinuses are also lined with ciliated mucous membranes, the mucus continually drains into the nasal cavity and pharynx. If these membranes become infected or swollen, the sinuses become painful and congested.

Air drawn through the nasal cavities is not only filtered but also warmed and humidified before it reaches the remainder of the respiratory system. This prevents the delicate linings of these structures from becoming cold and dry when air that is not particularly warm and moist is breathed in.

The upper portion of the nasal cavity has nerve endings that are involved in sensing odors. The **palate** (PAL it) serves as the "floor" of the nose and roof of the mouth. It has two parts: the anterior hard palate and the posterior soft palate. The bones of the hard palate grow together during the growth of the embryo and form a suture along the midline. If the bones do not grow together properly, the baby is born with an opening between the mouth and nasal cavity, called a cleft palate. This disorder may also include a divided upper lip, a condition called cleft lip.

The soft palate is primarily muscle tissue that ends in a structure called the uvula (YOO vyuh luh). When swallowing, the uvula moves posteriorly and superiorly to prevent food from entering the posterior aspect of the nasal cavities.

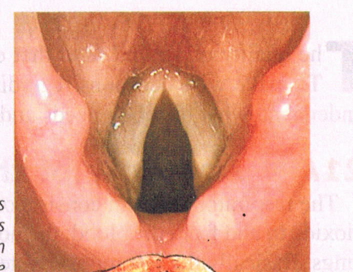
The Pharynx and Larynx

The **pharynx**, commonly called the throat, is a muscular tube about 13 cm (5 in.) long, lined with a ciliated mucous membrane. It extends from the posterior aspect of the nasal cavity to the esophagus. Because of its anatomical position, the pharynx is a part of both the respiratory and the digestive systems.

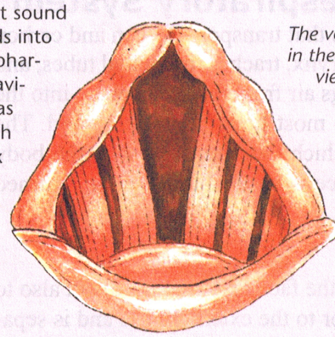
The Voice

Human vocal sounds originate from the vibration of the vocal cords as air from the lungs moves over them. Decreasing the muscular tension on vocal cords produces lower-pitched sounds, and higher-pitched sounds are produced when the cords are pulled tighter. Because the vocal cords in females are usually thinner and shorter than those in males, they vibrate more rapidly, giving women a higher range of pitch than men.

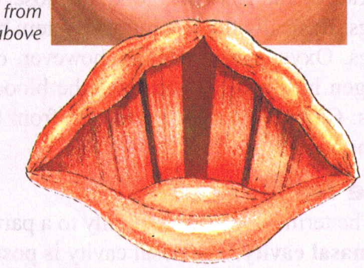
Other structures convert sound produced by the vocal folds into recognizable speech. The pharynx, mouth cavity, nasal cavities, and nasal sinuses act as resonating chambers (much the same as the sound box of a violin). The narrowing and dilating of the pharynx walls, along with tongue placement, help form vowel sounds. The tongue, lips, teeth, and palate form consonant sounds.



The vocal cords in the larynx as viewed from above



Open (normal breathing)



Partially closed (producing sound)

The pharynx has seven openings:

- Two openings from the posterior aspect of the nasal cavities for air flow
- Two passageways to the middle ear called eustachian tubes for equalizing air pressure
- The opening at the posterior aspect of the mouth cavity for passage of food and air
- The entrance to the esophagus—the passageway to the stomach
- The entrance to the larynx—the passageway to the trachea for air

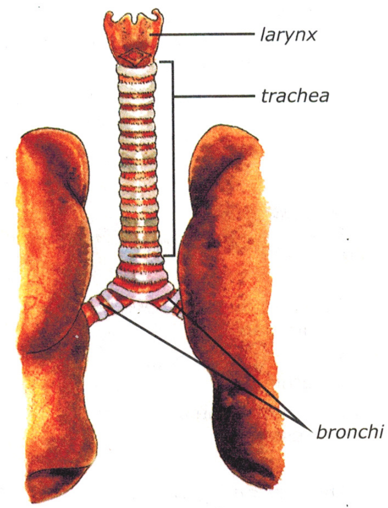
The **larynx**, or voice box, is a short passageway that leads from the pharynx to the trachea. The walls of the larynx consist of several cartilaginous structures held together by muscles and ligaments. The larynx contains a pair of mucous membrane folds known as the **vocal cords**, or vocal folds. The space between the folds is the **glottis**. The closing of the glottis is the last action that the body takes to prevent substances from going to the lungs.

The Trachea and Bronchi

The **trachea** is a cylindrical tube extending from the inferior aspect of the larynx approximately 12 cm (4.8 in.). It is about 2.5 cm wide and is supported by several C-shaped cartilaginous rings. The open ends of these incomplete rings are adjacent to the esophagus. Muscular and membranous tissues between the cartilage rings provide flexibility, allowing the neck to flex in all directions without injuring the trachea.

A ciliated mucous membrane lines the trachea and traps foreign matter such as dust and pollen. Cilia move foreign substances up to the pharynx, where they are swallowed and destroyed by the stomach acid.

The trachea ends behind the heart, where it divides into two primary **bronchi*** (BRAHNG KYE). The bronchi (*sing.* bronchus) resemble the trachea in structure but have a smaller diameter. Additionally, the bronchi have complete cartilaginous rings. An obstruction or irritation in the bronchi or in the trachea stimulates the cough reflex. Coughing involves taking a deep breath and then forcing air from the lungs against the closed glottis. When the glottis opens suddenly, a blast of air is forced through the larynx, pharynx, and mouth, usually carrying with it the substance that stimulated the cough reflex.



21A.3
The trachea

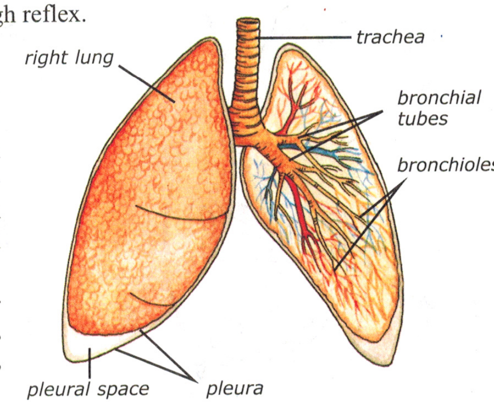
The Lungs

Each **lung** is divided internally into nine segments, and each segment receives a separate branch of the bronchus. The bronchi subdivide into smaller **bronchial** (BRAHNG kee ul) **tubes**, which in turn branch to form bronchioles. The bronchioles do not have cartilaginous tissue in their walls or cilia in their lining. There are more than 250 000 bronchioles in the lungs. All bronchioles end in **alveoli*** (al VEE uh LYE), which are microscopic bubblelike sacs.

Most of the lung tissue, then, is composed of the alveoli—approximately 300 million. If it were possible to open and flatten all alveoli, bronchioles, and other tubular passageways of the respiratory system, they would cover about 65 m^2 (78 yd^2).

An extensive network of small blood vessels called capillaries surrounds each alveolus. The walls of the alveoli and the walls of the capillaries are each made of a single layer of epithelial cells. This close physical relationship of alveoli and blood capillaries provides for rapid exchange of carbon dioxide and oxygen.

The **pleura*** (PL*OO*R uh) is a delicate membrane that lines the thoracic cavity and covers the lungs. The pleural space is between



21A.4
Structures of the lungs

bronchi: (Gk. BRONKOS, windpipe)
alveoli: (L. ALVEOLUS, small cavity)
pleura: (Gk. PLEURA, rib)

these two layers and contains pleural fluid. The pleural fluid provides lubrication to reduce the friction between the lungs and walls of the thorax. If either air or fluid, such as blood, enters the pleural space, it prevents the lung from inflating. The air or fluid must be removed as soon as possible.

Key Terms 21A-1

nasal cavity	larynx	trachea	bronchial tube
palate	vocal cords	bronchi	alveoli
pharynx	glottis	lung	pleura

Review Questions 21A-1

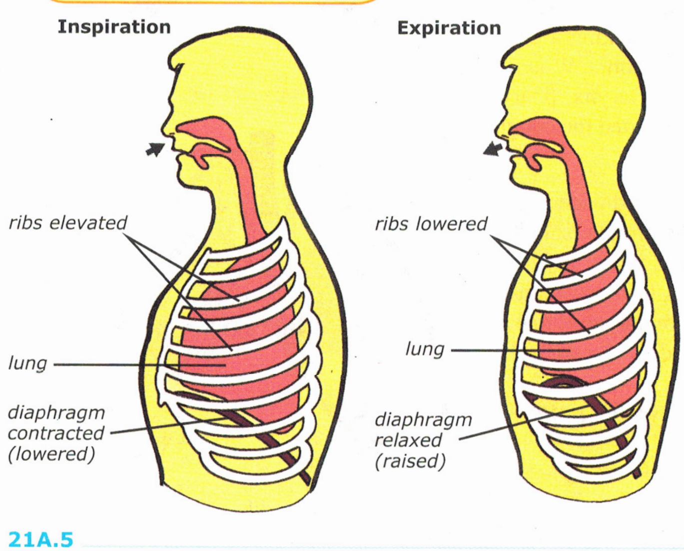
1. Name, in order, the structures by or through which a molecule of air passes as it enters the nose and passes to the capillaries.
2. What are the functions of the mucous membranes lining the respiratory system?
3. List the openings of the pharynx and tell where they lead.
4. Describe the pleura, the pleural space, and the pleural fluid.

21A-2 Objectives

- Contrast the three phases of respiration
- Explain the mechanics of breathing
- Summarize the gas exchange process

21A-2 Respiration

Respiration is usually divided into three phases—external, internal, and cellular. **External respiration** involves the passage of oxygen in the air from the alveoli into the blood. **Internal respiration** refers to the passage of oxygen from the blood into the body cells. Cellular respiration refers to the use of oxygen in converting foods to water, carbon dioxide, and energy (see Chap. 4, Sec. A).



21A.5
The mechanics of breathing

Mechanics of Breathing

Breathing involves the movement of outside air into the alveoli and then out again. Filling the lungs is **inspiration**,* and forcing air out of the lungs is **expiration**.* During inspiration the dome-shaped diaphragm muscle contracts, moves inferiorly, and becomes flatter, while the ribs move superiorly and laterally. These movements increase the chest volume, reducing the pressure in the lungs so that air rushes into them.

When the diaphragm relaxes and the ribs are depressed following inspiration, the tissues of the lungs rebound to force air out. The abdominal organs that were slightly compressed during inspiration spring back and push the diaphragm upward. These body changes constitute expiration. When a person needs to control expiration, as in singing, the abdominal muscles squeeze the abdominal organs upward against the diaphragm to force out the air.

inspiration: in- (in) + -spira- (to breathe)

expiration: ex- (out) + -(s)pira- (to breathe)

Air Volumes Exchanged in Breathing

The amount of air that enters and leaves the lungs during a normal inspiration and expiration during sleep is about 0.5 L. This volume of air is known as the **tidal volume**.

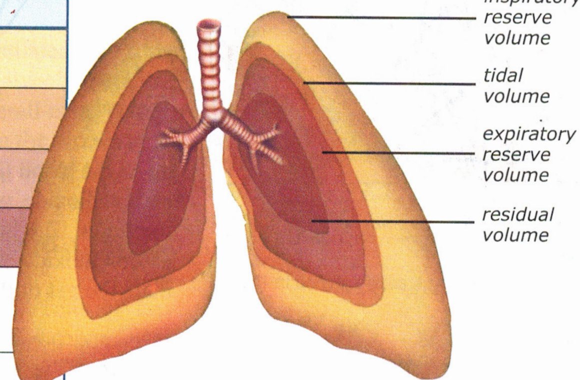
If a person breathes in as much as he can, he has accomplished forced inspiration. The air that enters the lungs in addition to the tidal volume is called the **inspiratory reserve volume** or complemental air. Normal adults have about 3 L of inspiratory reserve volume.

Forced expiration is forcing out as much breath as one can, about 1 L of air in addition to the tidal volume. This quantity of air is known as the **expiratory reserve volume** or supplemental air. The air that remains in the lungs after forced expiration is the **residual volume** (about 1 L).

The combined total of tidal volume, inspiratory reserve volume, and expiratory reserve volume is the **vital capacity**. This is the amount of air a person can exchange between his lungs and the environment. The sum of all lung volumes (vital capacity and residual volume) is called the **total lung capacity** and is about 5.5 L.

***Table 21A-1* Lung Volumes**

Name	Description	Approximate volume
Tidal volume (TV)	Amount of air that normally enters and leaves lungs at rest	500 mL
Inspiratory reserve volume (IRV)	Normal tidal volume plus air volume forcefully inspired	3000 mL
Expiratory reserve volume (ERV)	Normal tidal volume plus air volume forcefully expired	1000 mL
Residual volume (RV)	Air remaining in lungs after forced expiration	1000 mL
Vital capacity (VC)	Total volume that can be exchanged with environment: VC = TV + IRV + ERV	4500 mL
Total lung capacity (TLC)	Total volume lungs can hold: TLC = VC + RV	5500 mL



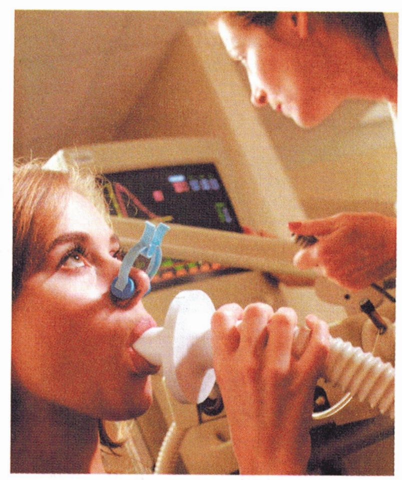
21A.6
Lung volumes

Lung volumes and capacities are primarily dependent on the size and physique of the individual and vary considerably. Body position and posture also cause variation in air volumes. For example, the air volumes are greater when a person is standing than when he is sitting or lying down. This explains why it is easier to sing when standing. Diseases that restrict the breathing mechanism or occupy space inside the lungs will also affect lung volumes.

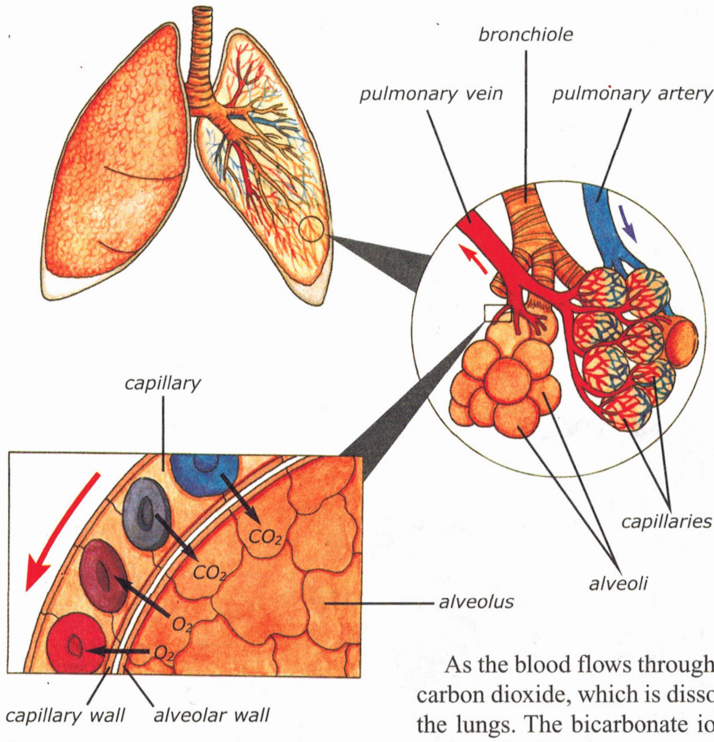
Transport and Exchange of Oxygen and Carbon Dioxide

The gases in the blood do not travel as tiny bubbles but are either dissolved or chemically combined with other blood substances. Almost all the oxygen (98%) in the blood is combined with **hemoglobin**, the red oxygen-carrying pigment of the red blood cells.

Hemoglobin is a complex two-part molecule made of *heme* and *globin*. The heme portion of the molecule contains four atoms of iron, each of which can combine with one oxygen molecule. As oxygen moves from the alveoli into the blood, it combines rapidly with hemoglobin to form *oxyhemoglobin*. Oxyhemoglobin is a brilliant red whereas hemoglobin without oxygen is a dull purplish red. The chemical bonds that form between oxygen and hemoglobin are rather unstable; therefore, the oxygen can be released quickly to the body cells for use in cellular respiration.



21A.7
A spirometer is used to accurately measure lung capacity.



21A.8
Oxygen exchange at the alveoli in the lungs

Oxygen diffuses through the alveolar walls into the blood because there is a higher concentration of oxygen in the air inside the alveoli than there is in deoxygenated blood. In the capillaries of the body, oxygen leaves the oxyhemoglobin because there is a greater concentration of oxygen in the blood cells. The blood absorbs the carbon dioxide produced by cellular respiration because, when flowing through the capillaries of the tissues, it has less carbon dioxide in it than do the tissues.

Carbon dioxide is transported to the lungs in three different ways. Most of the carbon dioxide (up to 70%) is transported in the form of bicarbonate ions (HCO_3^-) in the fluid of the blood. About 7% of the carbon dioxide is also dissolved in the fluid portion (plasma) of the blood. Only about 15%–20% of the carbon dioxide of the blood is combined with the hemoglobin. Hemoglobin can carry both oxygen and carbon dioxide at the same time since they do not compete for the same bonding sites.

As the blood flows through the capillaries that cover the alveoli, most of the carbon dioxide, which is dissolved or attached to the hemoglobin, diffuses into the lungs. The bicarbonate ions, through a complicated process, also release carbon dioxide; however, most of them remain in the bloodstream to help regulate the pH of the blood.

Unit 5: The Respiratory System

1. Name, in order, the structures through which air passes as it travels from the nose to the capillaries.
2. What are the functions of the mucous membranes in the respiratory system?
3. Draw a sketch of a section of the respiratory system (like the one on page 656) and label its parts.
4. What is the pleura?
5. What happens in the body to bring air into the lung?
6. How much air enters and leaves the lungs during a normal breath? What is the name of this volume?
7. What is hemoglobin and why do you need it in your blood cells?