Alayen University

Anesthesia Department

Lecture 7

Respiratory System

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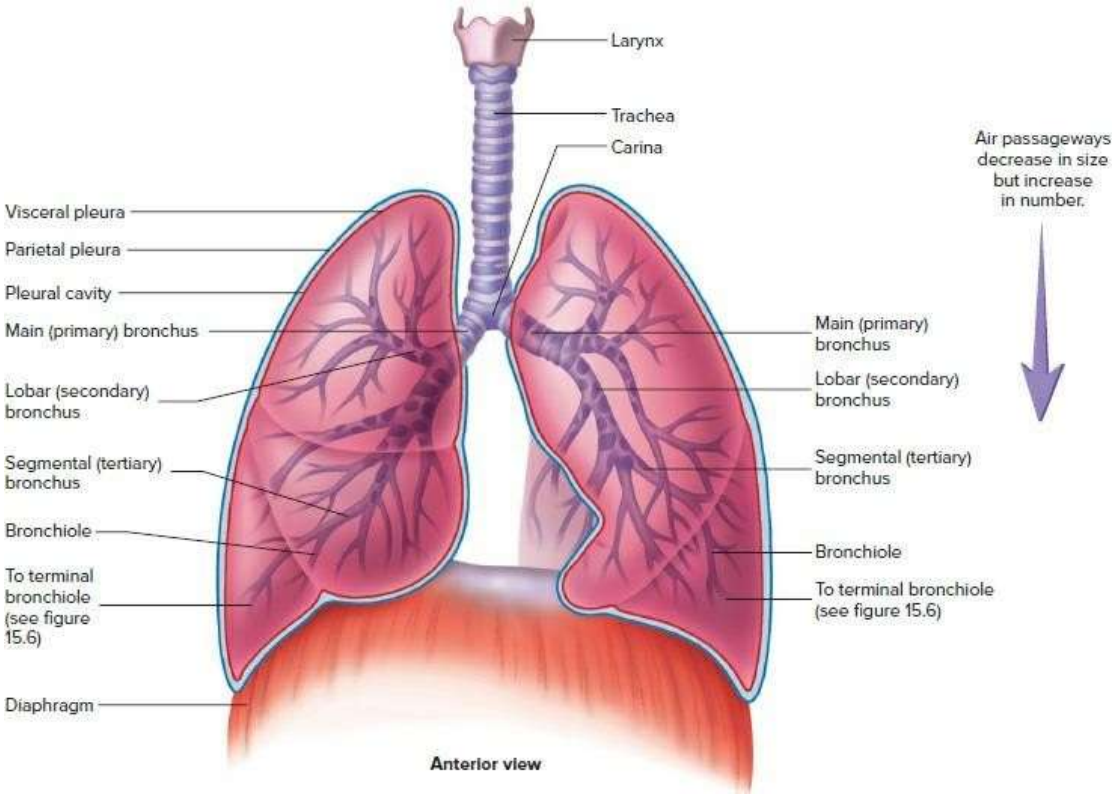
The Lower Respiratory Tract

Trachea

The **trachea** is commonly known as the windpipe. It allows air to flow into the lungs. The trachea is reinforced with 15–20 C-shaped pieces of cartilage called **tracheal rings.** The tracheal rings support the trachea and prevent it from collapsing. The cartilages support the anterior and lateral sides of the trachea to protect it while maintaining an open passageway for air. The trachea has an inside diameter of 12 mm and a length of 10–12 cm, descending from the larynx to the level of the fifth thoracic vertebra. The tracheal rings are incomplete circles with the thickest portion of cartilage at the anterior wall of the trachea. The posterior wall of the trachea is devoid of cartilage and contains an elastic ligamentous membrane and bundles of smooth muscle. The smooth muscle can narrow the diameter of the trachea by contracting, which aids in coughing. Narrowing the trachea's diameter causes air to move more forcefully through the trachea, helping to expel mucus and foreign objects during coughing. The esophagus lies immediately posterior to the cartilage- free posterior wall of the trachea.

Figure 15.5 Anatomy of the Trachea and Lungs
The trachea and lungs and the branching of the bronchi are shown. Each lung is surrounded by a pleural cavity, formed by the visceral and parietal pleurae.



Bronchi

The trachea divides to form two smaller tubes called **main bronchi,** or primary bronchi, each of which extends to a lung. At the location where the trachea divides into the two main bronchi is a ridge of cartilage called the **carina**. The carina is an important landmark for reading x-rays. In addition, the mucous membrane of the carina is very sensitive to mechanical stimulation. If foreign matter is inspired to the level of the carina, it stimulates a powerful cough reflex.

Tracheobronchial Tree

The **tracheobronchial tree** consists of the trachea and the network of air tubes in the lungs. The trachea divides to form a left and right main bronchus, each of which divides to form

smaller and smaller bronchi. The smaller bronchi continue getting smaller until they terminate in microscopic tubes and sacs. The right main bronchus is larger in diameter and more directly in line with the trachea than the left main bronchus. Because the right main bronchus is more in line with the trachea, an inspired object is more likely to become lodged in it than in the left main bronchus.

Alveoli

small, air-filled chambers where the air and the blood come into close contact with each other. From the terminal bronchioles to the alveoli, there are multiple levels of branching. In order from largest to smallest these branches are:

1. Respiratory bronchioles.
2. Alveolar ducts.
3. Alveolar sacs.

The tissue surrounding the alveoli contains elastic fibers, which allow the alveoli to expand during inspiration and recoil during expiration.

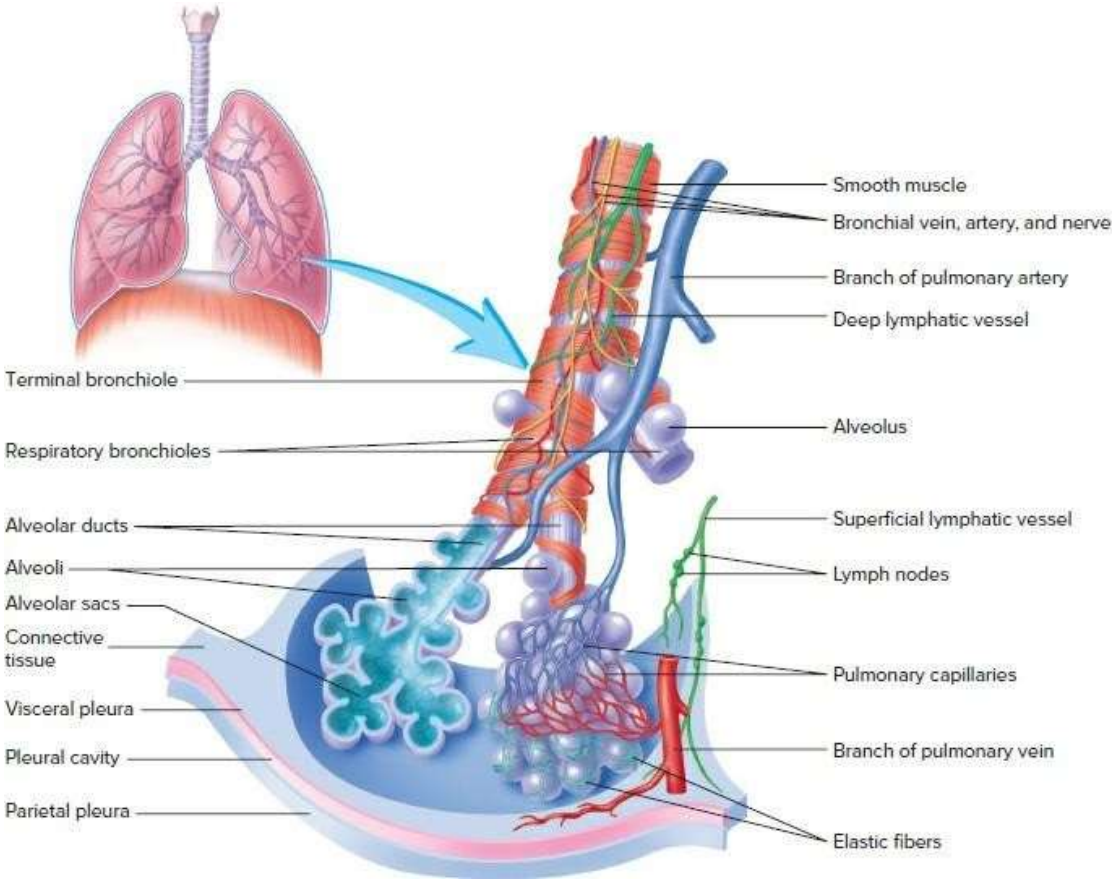


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Figure 15.6 Bronchioles and Alveoli
A terminal bronchiole branches to form respiratory bronchioles, which give rise to alveolar ducts. Alveoli connect to the alveolar ducts and respiratory bronchioles. The alveolar ducts end as two or three alveolar sacs.

Alveolar Structure

Approximately 300 million alveoli are in the two lungs. The average diameter of an alveolus is approximately 250 μm, and its wall is extremely thin. Two types of cells form the alveolar wall:

(1) squamous epithelial cells and (2) surfactant-secreting cells. The thin squamous epithelial cells form 90% of the alveolar surface. Most of the gas exchange between alveolar air and the blood takes place through these cells. Surfactant-secreting cells are round or cube-shaped secretory cells that

produce surfactant, which makes it easier for the alveoli to expand during inspiration.

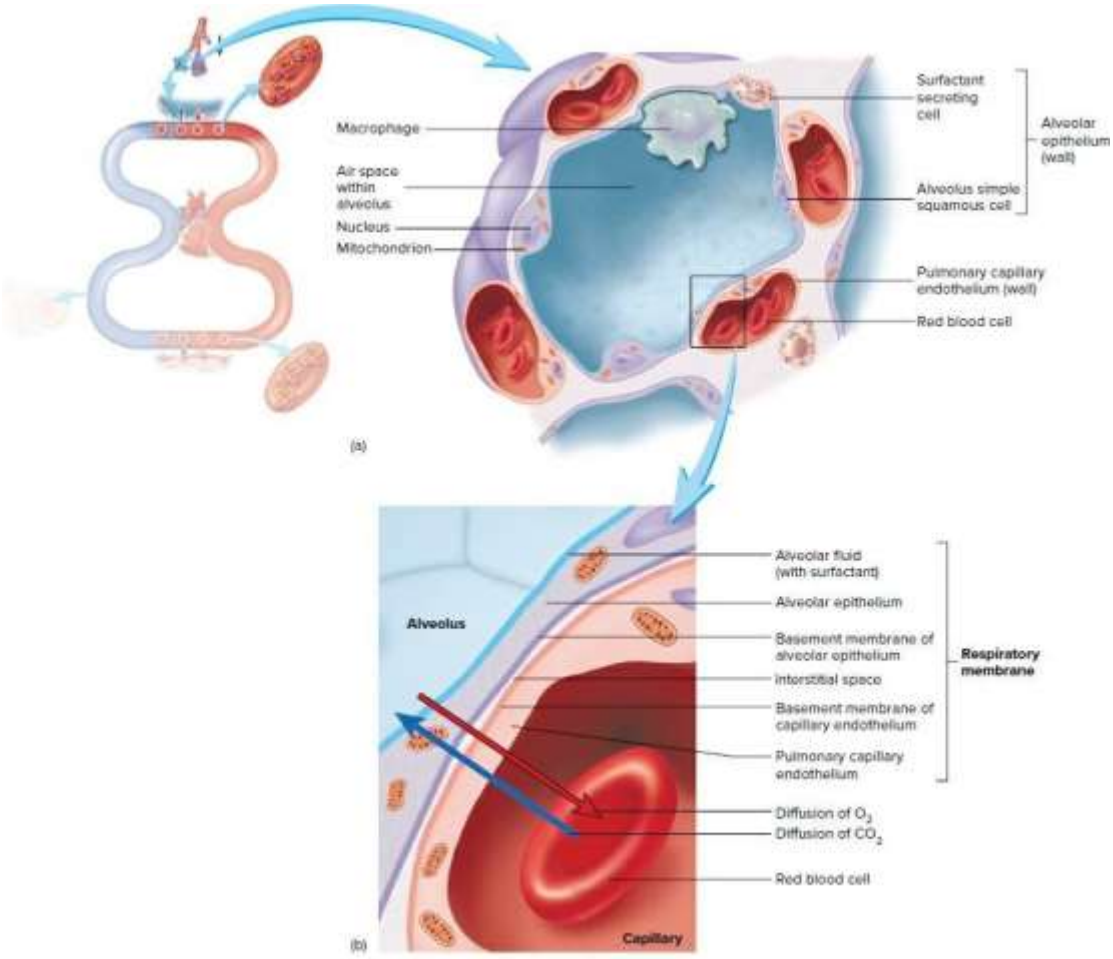

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Figure 15.7 Alveolus and the Respiratory Membrane
(a) Section of an alveolus, showing the air-filled interior and thin walls composed of simple squamous epithelium. The alveolus is surrounded by elastic connective tissue and blood capillaries. (b) O_2 and CO_2 diffuse across the six thin layers of the respiratory membrane.

Thoracic Wall and Muscles of Respiration

The thoracic wall consists of the (1) thoracic vertebrae, (2) ribs, (3) costal cartilages, (4) sternum, and (5) associated muscles. The **thoracic cavity** is the space enclosed by the thoracic wall and the **diaphragm**. The diaphragm is a sheet of skeletal muscle separating the thoracic cavity from the abdominal cavity. The diaphragm and other skeletal muscles

associated with the thoracic wall change thoracic volume during ventilation.

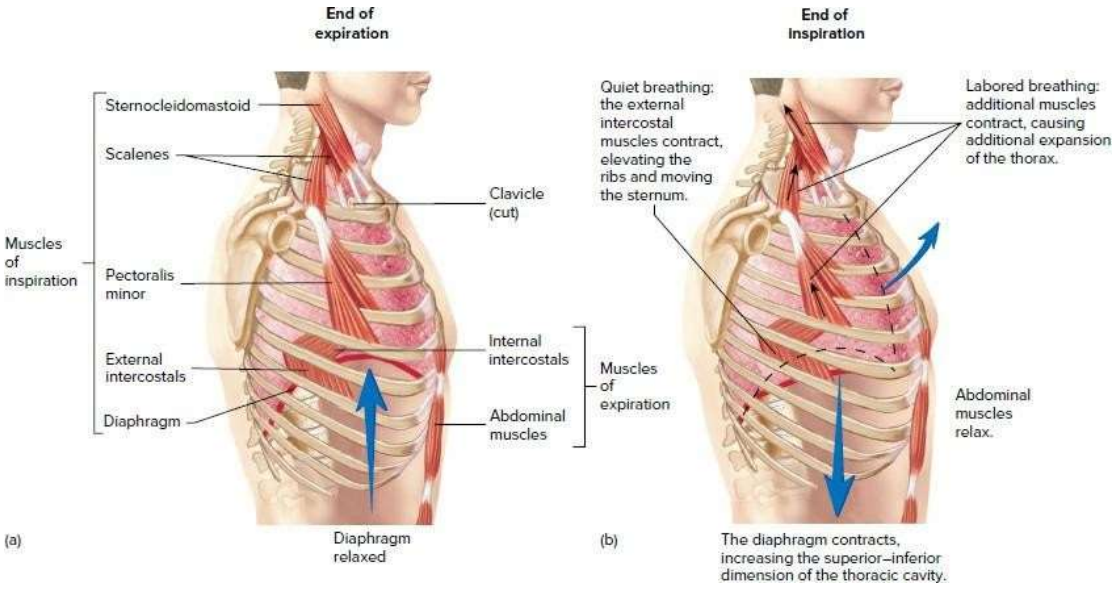


Figure 15.8 APR **Effect of the Muscles of Respiration on Thoracic Volume**
(a) Muscles of respiration at the end of expiration. (b) Muscles of respiration at the end of inspiration.

Lungs

The **lungs** are the primary organs of respiration. Based on their volume, they are among the largest organs of the body. Each lung is conical in shape and extends from the diaphragm to a point approximately 2.5 cm superior to the clavicle. The portion of the lungs in contact with the diaphragm is the **base.** The portion of the lungs that extends above the clavicle is called the **apex.** The right lung is larger than the left and weighs an average of 620 g, whereas the left lung weighs an average of 560 g.

The **hilum** is an indentation on the medial surface of the lung. The hilum is where structures, such as the main bronchus, blood vessels, nerves, and lymphatic vessels, enter or exit the lung. All the structures passing through the hilum are referred to as the **root of the lung.**

The right lung has three large sections called **lobes,** while the left lung has two lobes. The left lung also has a medial indentation called the **cardiac notch**.

This structural arrangement provides room for the heart to lie between the lungs.

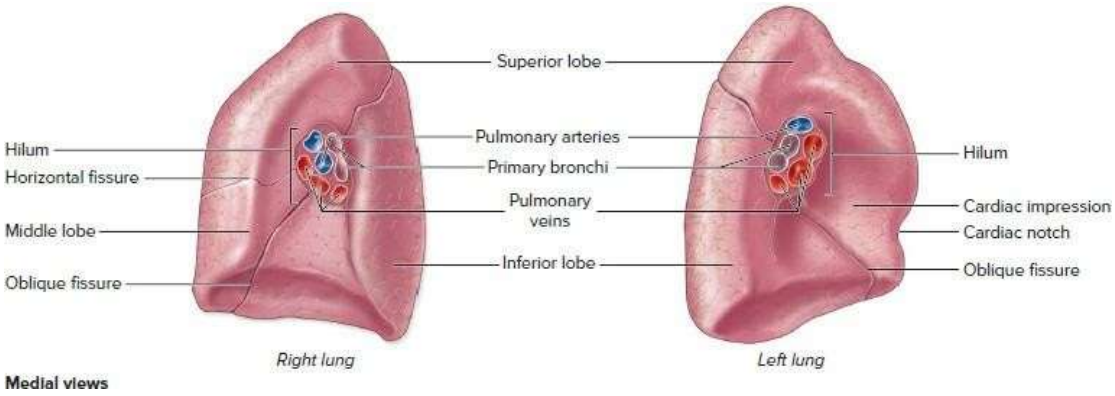


Figure 15.9 Lungs, Lung Lobes, and Bronchi
The right lung is divided into three lobes by the horizontal and oblique fissures. The left lung is divided into two lobes by the oblique fissure. A main bronchus supplies each lung, a lobar bronchus supplies each lung lobe, and segmental bronchi supply the bronchopulmonary segments (not visible).

Measurement of Lung Function

Pulmonary Volumes and Capacities

Spirometry is the process of measuring volumes of air that move into and out of the respiratory system, and a **spirometer** is the device used to measure these pulmonary volumes. There are four different pulmonary volumes measured in spirometry. The average values of the pulmonary volumes for a young adult male are:

1. Tidal volume. The **tidal volume** is the normal volume of air inspired and expired with each breath. At rest, quiet breathing results in a tidal volume of approximately 500 ml.
2. Expiratory reserve volume. The **expiratory reserve volume** is the amount of air that can be forcefully

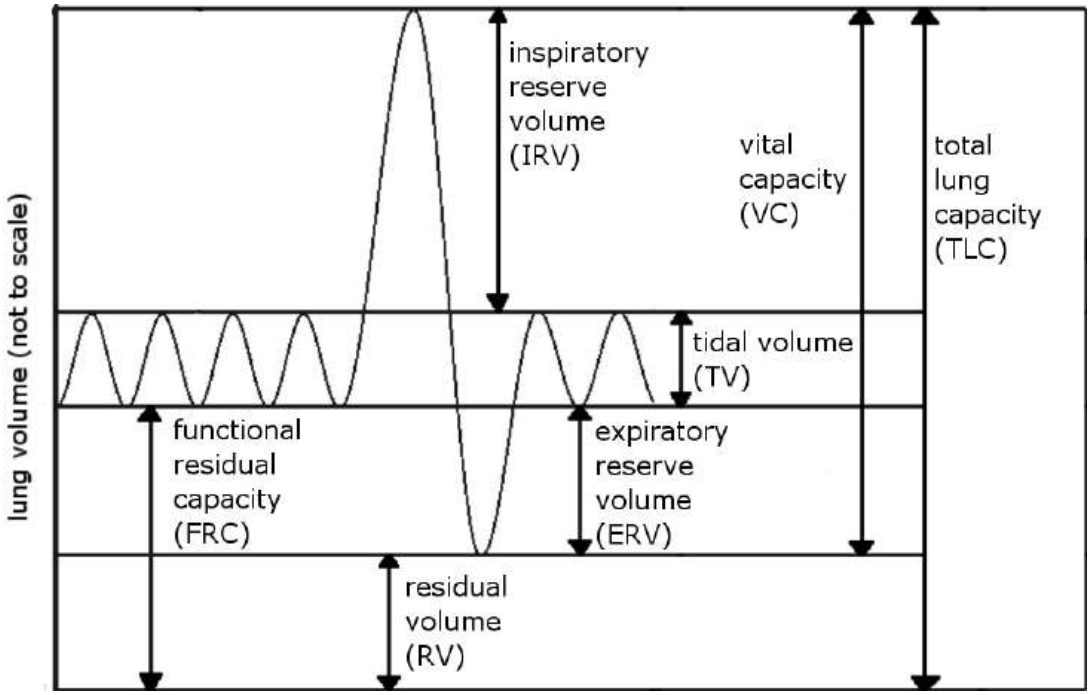
expired after a normal expiration (approximately 1100 mL at rest).

3. Residual volume. The **residual volume** is the volume of air remaining in the lungs after the forceful expiration (approximately 1200 mL).

4. Inspiratory reserve volume. The **inspiratory reserve volume** is the amount of air that can be inspired forcefully after a normal inspiration (approximately 3000 mL at rest).

Pulmonary capacities are the sum of two or more pulmonary volumes. Examples of pulmonary capacities are the following:

1. **Inspiratory capacity** is the tidal volume plus the inspiratory reserve volume (approximately 3500 mL at rest).
2. **Vital capacity** is the sum of the inspiratory reserve volume, the tidal volume, and the expiratory reserve volume (approximately 4600 mL).
3. **Functional residual capacity** is the expiratory reserve volume plus the residual volume. It is the amount of air remaining in the lungs at the end of a normal expiration (approximately 2500 mL at rest).
4. **Total lung capacity** is the sum of the inspiratory and expiratory reserve volumes plus the tidal volume and the residual volume (approximately 6000 mL).


lung volume (not to scale)
inspiratory reserve volume (IRV)
vital capacity (VC)
total lung capacity (TLC)
tidal volume (TV)
functional residual capacity (FRC)
expiratory reserve volume (ERV)
residual volume (RV)