Physiology of the Respiratory system

Overview

Respiration, as the term is generally used, includes two processes:
External respiration, the absorption of O2 and removal of CO2 from the body as a whole.
Internal respiration: the utilization of O2 and production of CO2 by cells and the gaseous exchanges between the cells and their fluid medium.

The Respiratory System

The respiratory system is made up of a gas-exchanging organ the lungs and a "pump" that ventilates the lungs .

The functions of the respiratory system are:

1. Gas exchange
2. Acid – base balance
3. Pulmonary defense and metabolism
4. Handling of bioactive materials (angiotensin….)
5. Phonation (sound generated by vocal folds vibration).

The pump consists of:

1-the chest wall & the respiratory muscles, which increase and decrease the size of the thoracic cavity

2-the areas in the brain that control the muscles and the tracts

3- Nerves that connect the brain to the muscles.

At rest, a normal human breathes 12 to 15 times a minute.

About 500 mL of air per breath, or 6 to 8 L/min, is inspired and expired.

This air mixes with the gas in the alveoli, and, by simple diffusion, O2 enters the blood in the pulmonary capillaries while CO2 enters the alveoli for excretion through the lung with Traces of other gases, such as methane from the intestines are also found in expired air.

Alcohol and acetone are expired when present in appreciable quantities in the body. Indeed over 250 different volatile substances have been identified in human breath.

Air Passages

After passing through the nasal passages and pharynx, where it is warmed and takes up water vapor, the inspired air passes down the trachea and through the bronchioles, respiratory bronchioles, and alveolar ducts to the alveoli, where gas exchange occurs (Figure 35–1).

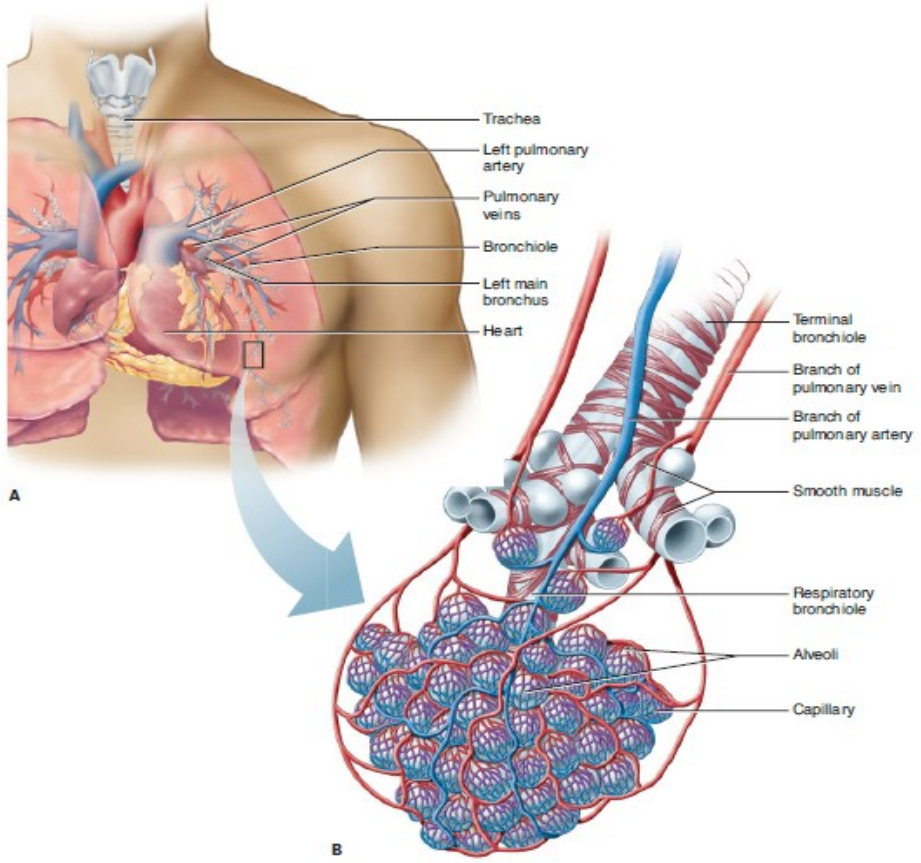

FIGURE 35–1 **Structure of the respiratory system. A)** The respiratory system is diagrammed with a transparent lung to emphasize the flow of air into and out of the system. **B)** Enlargement of boxed area from (A) shows transition from conducting airway to the respiratory airway, with emphasis on the anatomy of the alveoli. Red and blue represent oxygenated and deoxygenated blood, respectively. (*Continued*)

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The trachea : or windpipe which is located in the neck in front of the esophagus (a muscular tube that carries food to the stomach). The trachea is a tube supported by rings of cartilage (fig. 16.5).

Air enters the trachea from **the pharynx,** which is the cavity behind the palate that receives the contents of both the oral and nasal passages.

In order for air to enter or leave the trachea and lungs, however, it must pass through a valvelike opening called **the glottis** between the vocal folds.

The ventricular and vocal folds are part of the larynx, or voice box

The projection at the front of the throat, commonly called **the "Adam's apple,"** is formed by the largest cartilage of the larynx

Between the trachea and the alveolar sacs, the airways divide into **bronchi & bronchioles, and terminal bronchioles, alveolar ducts, and alveoli.**

.These multiple divisions greatly increase the total cross-sectional area of the airways

The alveoli are surrounded by pulmonary capillaries (Figure35-1)

In most areas, air and blood are separated only by the alveolar epithelium and the capillary endothelium,

Humans have 300 million alveoli, and the total area of the alveolar walls in contact with capillaries in both lungs is about 70 m^2.

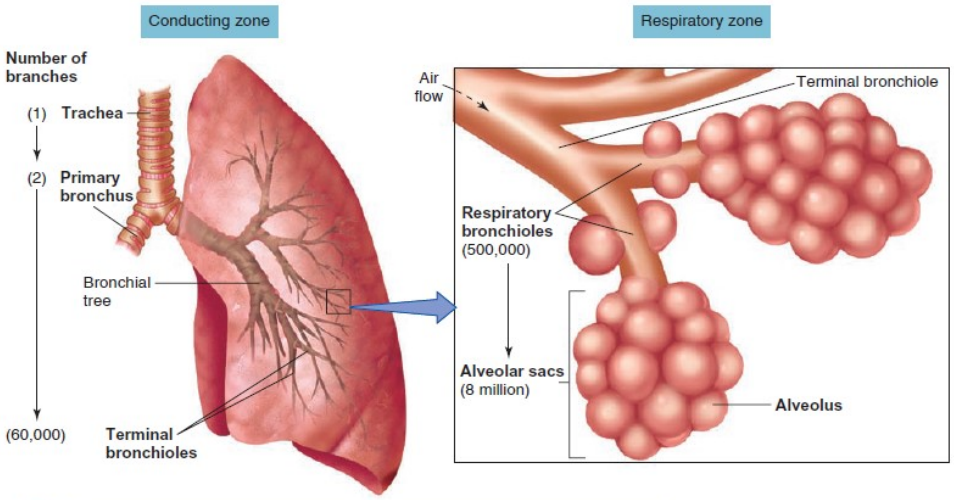

Figure 16.4 **The conducting and respiratory zones of the respiratory system.** The conducting zone consists of airways that conduct the air to the respiratory zone, which is the region where gas exchange occurs. The numbers of each member of the airways and the total number of alveolar sacs are shown in parentheses.

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Autonomic innervation of respiratory :

- **Sympathetic discharge through adrenal gland (no direct sympathetic innervation causes pulmonary vasoconstriction, bronchodilation ,and decrease glandular secretions**
- **Parasympathetic discharge cause vasodilation ,bronchoconstriction ,and increase glandular secretions**

The alveoli epithelial cells:

are lined by two types of epithelial cells:

Type I cells :are the major site of gas exchange

Type II cells .are the primary source of pulmonary surfactant

; however, they are also important in alveolar repair as well as other cellular physiology. **The Mucous layer, commonly referred to as the mucous blanket , covers the epithelial lining of the trachiobronchial tree.**

The mucus is produced by :

1- the goblet cells
2- the submucosal or bronchial glands.

The alveoli also contain other specialized cells, including:

(pulmonary alveolar macrophages ,lymphocytes, plasma cells , neuroendocrine cells mast cells.)

The mast cells contain heparin, various lipids, histamine, and various proteases that participate in allergic reactions

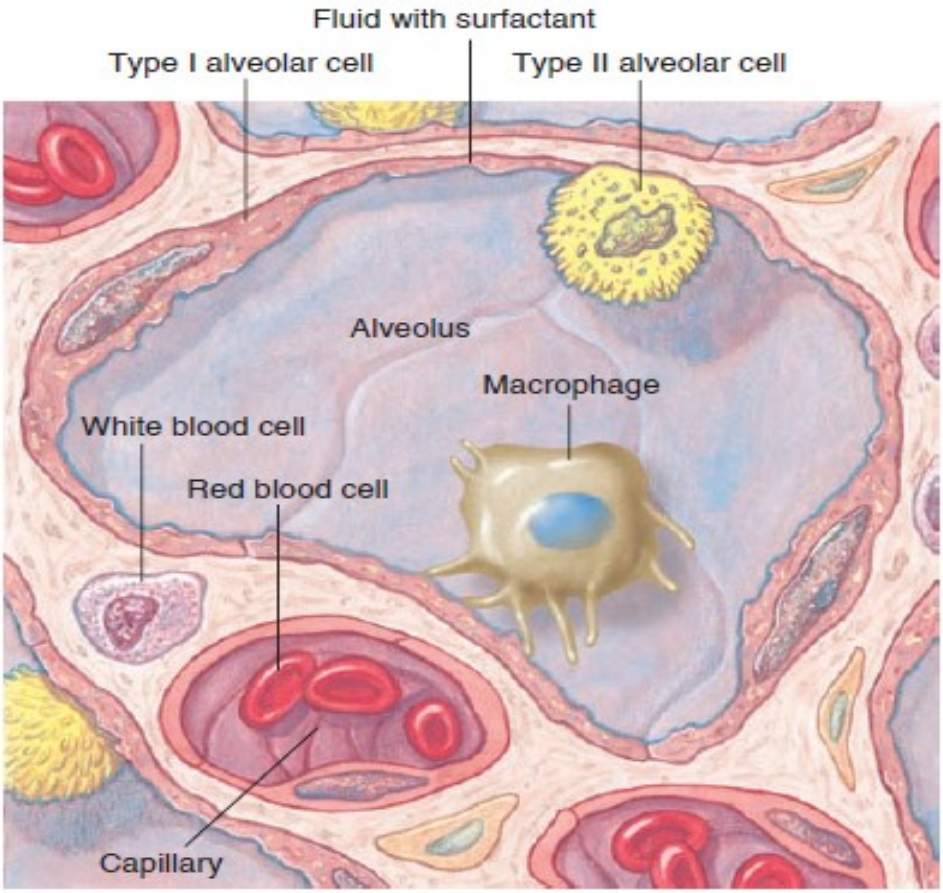

Figure 16.1 **The relationship between lung alveoli and pulmonary capillaries.** Notice that alveolar walls are quite narrow and lined with type I and type II alveolar cells. Pulmonary macrophages can phagocytose particles that enter the lungs.

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The Bronchi & Their Innervation

The trachea and bronchi have cartilage in their walls but relatively little smooth muscle. They are lined by a ciliated epithelium that contains mucous and serous glands. Cilia are present as far as the respiratory bronchioles. The walls of the bronchi and bronchioles are innervated by the autonomic nervous system.

Anatomy Of Blood Flow In The Lung

Both the pulmonary circulation and the bronchial circulation contribute to blood flow in the lung.

In the pulmonary circulation, almost all the blood in the body passes via the pulmonary artery to the pulmonary capillary bed, where it is oxygenated and returned to the left atrium via the pulmonary veins (Figure 35–4).

They form capillaries, which drain into bronchial veins or anastomose with pulmonary capillaries or veins) Figure 35–5).

The bronchial circulation nourishes the trachea down to the terminal bronchioles and also supplies the pleura and hilar lymph nodes.

It should be noted that lymphatic channels are more abundant in the lungs than in any other organ.

Mechanics of Respiration

Inspiration & Expiration

The lungs and the chest wall are elastic structures. Normally no more than a thin layer of fluid is present between the lungs and the **chest wall (intrapleural space) provide The lungs slide easily on the chest wall**

The pressure in the "space" between the lungs and chest **wall (intrapleural pressure)**

Ventilation cycle

Pulmonary ventilation consists of two phases: *inspiration* and *expiration.* Inspiration (inhalation) and expiration (exhalation) are accomplished by alternately increasing and decreasing the volumes of the thorax and lungs (fig. 16.12).

Inspiration is an active process while

Expiration during quiet breathing **is passive** since no muscles contract

1-The contraction of the inspiratory muscles increases **intrathoracic volume**

2-**The intrapleural pressure** at the base of the lungs, which is **normally about –2.5 mm Hg** decreases to about –6 mm Hg.

3-**The lungs** are pulled into a more expanded position.

4-**The pressure in the airway** becomes slightly negative, and air flows into the lungs. 5- **At the end of inspiration**, **expiration starts** when the lung recoil begins to pull the chest back to the expiratory position, where the recoil pressures of the lungs and chest wall balance. The pressure in the airway becomes slightly positive, and air flows out of the lungs.

Expiration during quiet breathing is passive in the sense that no muscles that decrease intrathoracic volume contract.

Physical Properties of the Lungs

A-Compliance: In order for inspiration to occur, the lungs must be able to expand when stretched; they must have high **compliance.**
The lungs are very distensible (stretchable)—they are, in fact, about a hundred times more distensible than a toy balloon.

B-Elasticity : The tendency to get smaller is also aided by *surface tension* forces within the alveoli.
The term elasticity refers to the tendency of a structure to return to its initial size after being distended. Because of their high content of elastin proteins, the lungs are very elastic and resist distension.

C-Surface Tension

The forces that act to resist distension include elastic resistance and the surface tension that is exerted by fluid in the alveoli. "

The thin film of fluid normally present in the alveolus has a surface tension, produced because water molecules at the surface are attracted more to other water molecules han to air.

Alveolar fluid contains a substance that reduces surface tension.

This substance is called surfactant , secreted into the **alveoli by type II alveolar cells** and consists of phospholipids, Surfactant becomes interspersed between water molecules at the water–air interface; this reduces the hydrogen bonds between water molecules at the surface and thereby reduces the surface tension.

FUNCTION OF SURFACTANT

Surfactant **prevents alveoli from collapsing during expiration**& the alveoli remain open and a residual volume of air remains in the lungs. Since the alveoli do not collapse, less surface tension.

Note/ Surfactant begins to be produced in late fetal life. For this reason, premature babies are sometimes born with lungs that lack sufficient surfactant and their alveoli are collapsed as a result. This condition is called **respiratory distress syndrome** RDS).

A full-term pregnancy lasts 37 to 42 weeks. RDS occurs in about 60% of babies born at less than 28 weeks .The risk of RDS can be assessed by analysis of amniotic fluid (surrounding the fetus), and mothers can be given exogenous **corticosteroids** to accelerate the maturation of their fetus's lungs.

Lung Volumes

- **Tidal volume** : is the amount of air that moves into the lungs with each inspiration or the amount that moves out with each expiration.
- The air left in the lungs after a maximal expiratory effort is **the residual volume**

Normal values for these lung volumes, and names applied to combinations of them, are shown in Figure 35–7.

- The space in the conducting zone of the airways occupied by gas that **does not exchange** with blood in the pulmonary vessels is the **respiratory dead space**.

1. **The forced vital capacity (FVC)** the largest amount of air that can be expired after a maximal inspiratory effort, is frequently measured clinically as **an index of pulmonary function**. It gives useful information about the strength of the respiratory muscles and other aspects of pulmonary function.

2-FEV1 The fraction of the vital capacity expired during the first second of a forced expiration is referred to as

The FEV1 to FVC ratio (FEV1 / FVC) is a useful tool in the **diagnosis of airway disease** .

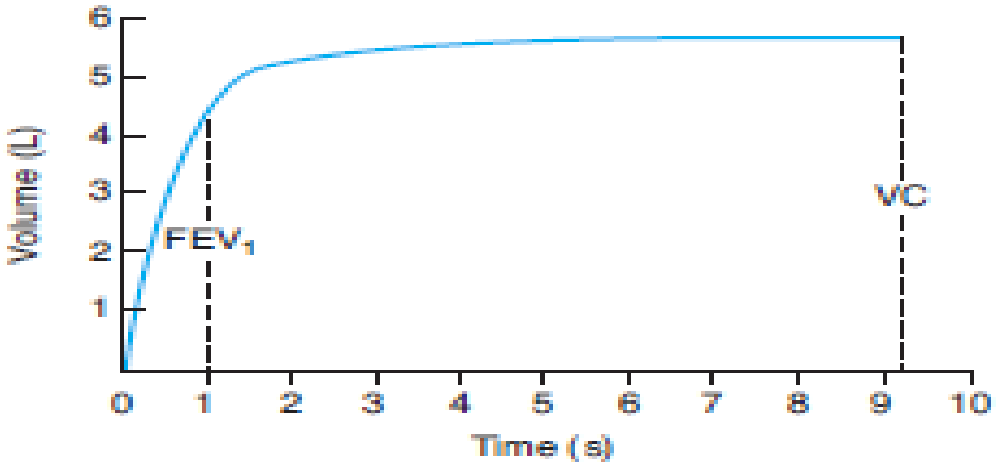

FIGURE 35–8 Volume of gas expired by a normal adult man during a forced expiration, demonstrating the FEV_1 and the total vital capacity (VC). (Reproduced, with permission, from Crapo RO: Pulmonary-function testing. N Engl J Med 1994;331:25. Copyright © 1994, Massachusetts Medical Society.)

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Pulmonary Function Tests

Pulmonary function may be assessed clinically by means of a technique known as spirometry. In this procedure, a subject breathes in a closed system in which air is trapped within a light plastic bell floating in water.

The bell moves up when the subject exhales and down when the subject inhales. The movements of the bell cause corresponding movements of a pen, which traces a record of the breathing called a spirogram)fig. 16.15). More sophisticated computerized devices are now more commonly employ

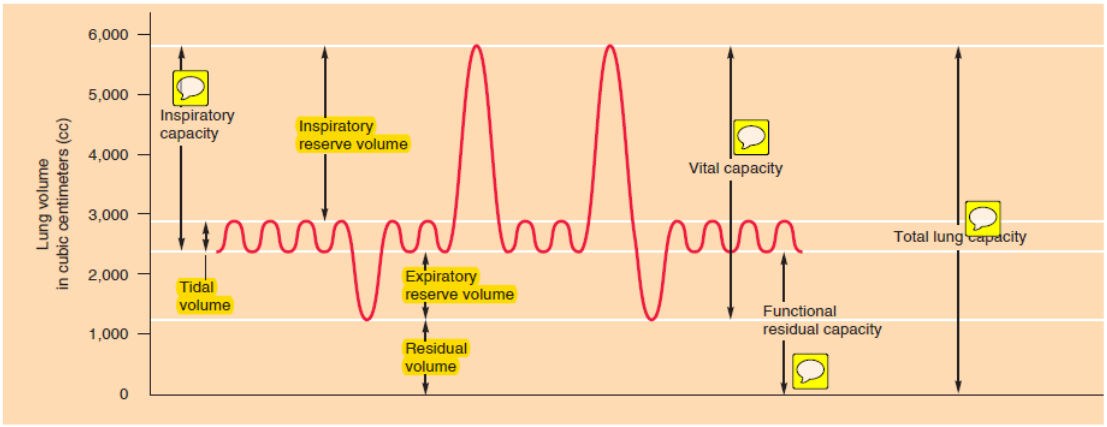

Figure 16.15 **A spirogram showing lung volumes and capacities.** A lung capacity is the sum of two or more lung volumes.

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