HUMAN PHYSIOLOGY AND CLINICAL BIOCHEMISTRY

Topic: Respiration

Lecture 1

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PHYSIOLOGY OF RESPIRATION

Respiration includes 2 processes:

1) **External respiration** – is the uptake of O2 and excretion of CO2 in the lungs
2) **Internal respiration**

means the O2 and CO2 exchange between the cells and capillary blood. The quality of these respiration processes depends on:

a) **pulmonary ventilation** – it means the inflow and outflow of air between the atmosphere and the lung alveoli
b) **diffusion of gases** oxygen and CO2 between the alveoli and the blood
c) **perfusion** – of lungs with blood
d) **transport** of O2 and CO2 in the blood
e) **regulation of respiration**

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Upper airways - nose, nasopharynynx - borderline - larynx

Lower airways - trachea, bronchi, bronchioles.

Alveoli - Tiny air sacs at the end of the bronchioles (tiny branches of air tubes in the lungs).

Alveoli are lined by a fluid called surfactant. This fluid maintains the shape of the air sac and helps keep it open so that oxygen and CO2 can pass.

The alveoli are made up of two different types of cells. Each type has different functions:

Type I pneumocytes. These are the cells responsible for the exchange of oxygen and CO2.

Type II pneumocytes. These cells perform two important functions. They produce surfactant, the fluid inside the alveoli that helps keep the balloon shape from collapsing. They can also turn into type I cells in order to repair damage.

Alveoli also contain immune cells called alveolar macrophages.

Macrophages clean up any particles that are breathed in and make it to the alveoli. They also remove dead cells and bacteria.

300 milion - total surface area 70 m^2, lined pneumocytes

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Inspiration - an active process - contraction of the inspiratory muscles: - Diaphragm, External intercostal muscles, Auxiliary-accessory-inspiratory muscles: Scalene and sternocleidomasoid m.m.

Expiration - passive process - given by elasticity of the chest and lungs

Muscles That Cause Lung Expansion and Contraction

The lungs can be expanded and contracted in two ways: (1) by downward and upward movement of the diaphragm to lengthen or shorten the chest cavity, and (2) by elevation and depression of the ribs to increase and decrease the antero posterior diameter of the chest cavity.

During inspiration, contraction of the diaphragm pulls the lower surfaces of the lungs downward.

Then, during expiration, the diaphragm simply relaxes, and the elastic recoil of the lungs, chest wall, and abdominal structures compresses the lungs and expels the air.

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The most important muscles that raise the rib cage are the external intercostals, but others that help are the

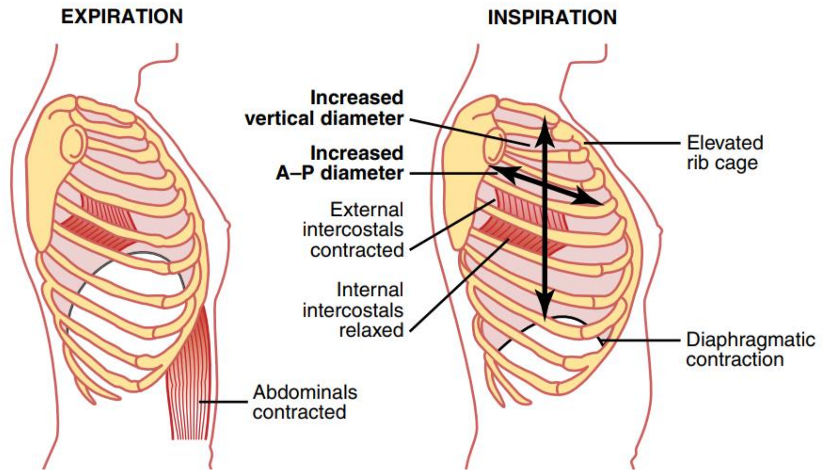
(1) sternocleidomastoid muscles, which lift upward on the sternum;

(2) anterior serrati, which lift many of the ribs; and

(3) scaleni, which lift the first two ribs.

The muscles that pull the rib cage downward during expiration are mainly the

(1) **abdominal recti,** which have the powerful effect of pulling downward on the lower ribs at the same time that they and other abdominal muscles also compress the abdominal contents upward against the diaphragm, and (2) internal intercostals.



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Pressures That Cause the Movement of Air In and Out of the Lungs

Lung is an elastic structure that collapses like a balloon and expels all its air through the trachea

There are no attachments between the lung and the walls of the chest cage, except its hilum from the mediastinum, the middle section of the chest cavity.

Lungs are held to the thoracic wall as if glued there, except that they are well lubricated and can slide freely as the chest expands and contracts

Pleural pressure

is the pressure of the fluid in the thin space between the lung pleura and the chest wall pleura.

The normal pleural pressure at the beginning of inspiration is about −5 centimeters of water, which is the amount of suction required to hold the lungs open to their resting level. Then, during normal inspiration, expansion of the chest cage pulls outward on the lungs with greater force and creates more negative pressure, to an average of about −7.5 centimeters of water.

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The increasing negativity of the pleural pressure from −5 to −7.5 during inspiration and in the upper panel an increase in lung volume of 0.5 liter.

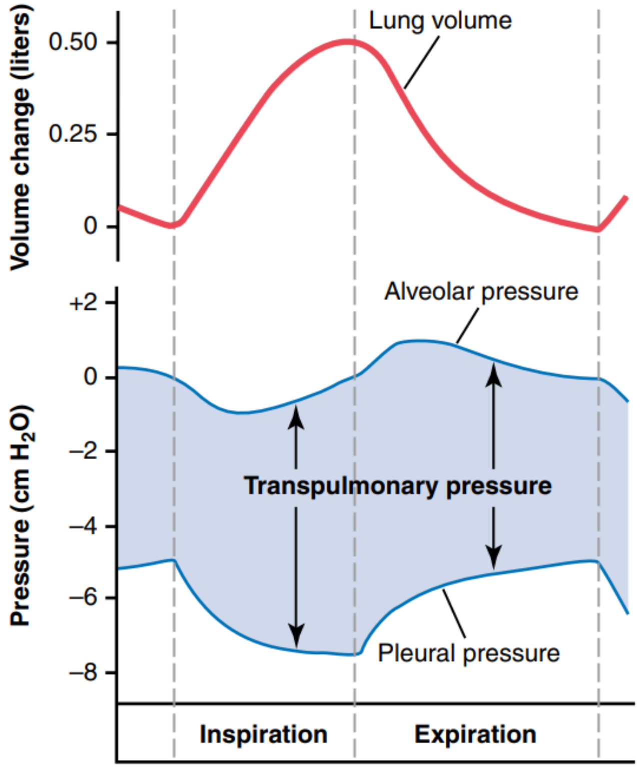
during expiration, the events are essentially reversed.

Alveolar Pressure Alveolar pressure is the pressure of the air inside the lung alveoli.

To cause inward flow of air into the alveoli during inspiration, the pressure in the alveoli must fall to a value slightly below atmospheric pressure (below 0).

The second curve (labeled "alveolar pressure") demonstrates that during normal inspiration, alveolar pressure decreases to about −1 centimeters of water.

This slight negative pressure is enough to pull 0.5 liter of air into the lungs in the 2 seconds required for normal quiet inspiration During expiration, opposite pressures occur: The alveolar pressure rises to about +1 centimeter of water, and this forces the 0.5 liter of inspired air out of the lungs during the 2 to 3 seconds of expiration.



Transpulmonary Pressure

difference between the alveolar pressure and the pleural pressure. This is called the transpulmonary pressure. It is the pressure difference between that in the alveoli and that on the outer surfaces of the lungs, and it is a measure of the elastic forces in the lungs that tend to collapse the lungs at each instant of respiration, called the recoil pressure

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Pulmonary Volumes

Pulmonary lung volumes that, when added together, equal the maximum volume to which the lungs can be expanded. The significance of each of these volumes is the following:

1. The tidal volume is the volume of air inspired or expired with each normal breath; it amounts to about 500 milliliters in the adult male.

2. The inspiratory reserve volume is the extra volume of air that can be inspired over and above the normal tidal volume when the person inspires with full force; it is usually equal to about 3000 milliliters.

3. The expiratory reserve volume is the maximum extra volume of air that can be expired by forceful expiration after the end of a normal tidal expiration; this normally amounts to about 1100 milliliters.

4. The residual volume is the volume of air remaining in the lungs after the most forceful expiration; this volume averages about 1200 milliliters.

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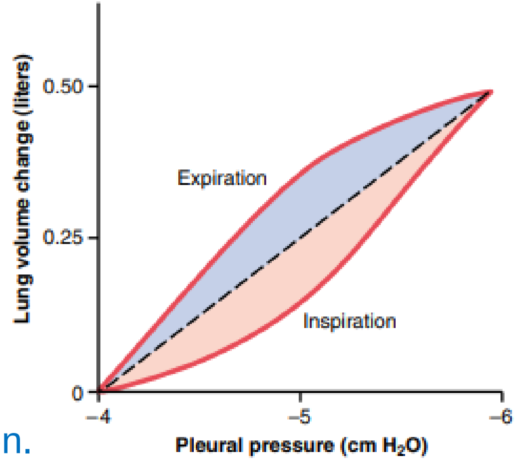
Compliance diagram in a healthy person.



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Pulmonary Capacities

In describing events in the pulmonary cycle, it is sometimes desirable to consider two or more of the volumes together. Such combinations are called pulmonary capacities.

1. The inspiratory capacity equals the tidal volume plus the inspiratory reserve volume. This is the amount of air (about 3500 milliliters) a person can breathe in, beginning at the normal expiratory level and distend ing the lungs to the maximum amount.

2. The functional residual capacity equals the expiratory reserve volume plus the residual volume. This is the amount of air that remains in the lungs at the end of normal expiration (about 2300 milliliters).

3. The vital capacity equals the inspiratory reserve volume plus the tidal volume plus the expiratory reserve volume. This is the maximum amount of air a person can expel from the lungs after first filling the lungs to their maximum extent and then expiring to the maximum extent (about 4600 milliliters).

4. The total lung capacity is the maximum volume to which the lungs can be expanded with the greatest possible effort (about 5800 milliliters); it is equal to the vital capacity plus the residual volume.

All pulmonary volumes and capacities are about 20 to 25 percent less in women than in men, and they are greater in large and athletic people than in small and asthenic people.

The residual volume (RV) can be determined by subtracting expiratory reserve volume (ERV), as measured by normal spirometry, from the FRC (functional residual capacity).

$$RV = FRC - ERV$$

Total lung capacity (TLC) can be determined by adding the inspiratory capacity (IC) to the FRC.

$$TLC = FRC + IC$$

The functional residual capacity (FRC), which is the volume of air that remains in the lungs at the end of each normal expiration, is important to lung function.

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- Alveolar ventilation per minute is the total volume of new air entering the alveoli and adjacent gas exchange areas each minute. It is equal to the respiratory rate times the amount of new air that enters these areas with each breath.
  - $V_A = F_{req} X (V_T - V_D)$
- Where V_A is the volume of alveolar ventilation per minute, F_{req} is the frequency of respiration per minute, V_T is the tidal volume, and V_D is the physiologic dead space volume.
- Thus, with a normal tidal volume of 500 milliliters, a normal dead space of 150 milliliters, and a respiratory rate of 12 breaths per minute, alveolar ventilation equals 12 × (500 − 150), or 4200ml/min.
- **Alveolar ventilation is one of the major factors determining the concentrations of oxygen and carbon dioxide in the alveoli.**

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Pulmonary Circulation,

The lung has two circulations:

(1) **A high-pressure, low-flow circulation** supplies systemic arterial blood to the trachea, the bronchial tree including the terminal bronchioles, the supporting tissues of the lung, and the outer coats (adventia) of the pulmonary arteries and veins. The bronchial arteries, which are branches of the thoracic aorta, supply most of this systemic arterial blood at a pressure that is only slightly lower than the aortic pressure.

(2) **A low-pressure, high-flow circulation** that supplies venous blood from all parts of the body to the alveolar capillaries where oxygen is added and carbon dioxide is removed.

The pulmonary artery, which receives blood from the right ventricle, and its arterial branches carry blood to the alveolar capillaries for gas exchange and the pulmonary veins then return the blood to the left atrium to be pumped by the left ventricle though the systemic circulation.

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Physiologic Anatomy of the Pulmonary Circulatory System

Pulmonary Vessels.

The pulmonary artery extends only 5 centimeters beyond the apex of the right ventricle and then divides into right and left main branches that supply blood to the two respective lungs. The pulmonary artery is thin, with a wall thickness one third that of the aorta. The pulmonary arterial branches are very short, and all the pulmonary arteries, even the smaller arteries and arterioles, have larger diameters than their counterpart systemic arteries.

The pulmonary veins, like the pulmonary arteries, are also short. They immediately empty their effluent blood into the left atrium.

Bronchial Vessels.

Blood also flows to the lungs through small bronchial arteries that originate from the systemic circulation, amounting to about 1 to 2 percent of the total cardiac output.

This bronchial arterial blood is oxygenated blood, in contrast to the partially deoxygenated blood in the pulmonary arteries.

It supplies the supporting tissues of the lungs, including the connective tissue, septa, and large and small bronchi.

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- After this bronchial and arterial blood has passed through the supporting tissues, it empties into the pulmonary veins and enters the left atrium, rather than passing back to the right atrium.

- **Lymphatics.**

Lymph vessels are present in all the supportive tissues of the lung, beginning in the connective tissue spaces that surround the terminal bronchioles, coursing to the hilum of the lung, and then mainly into the right thoracic lymph duct. Particulate matter entering the alveoli is partly removed by way of these channels, and plasma protein leaking from the lung capillaries is also removed from the lung tissues, thereby helping to prevent pulmonary edema.

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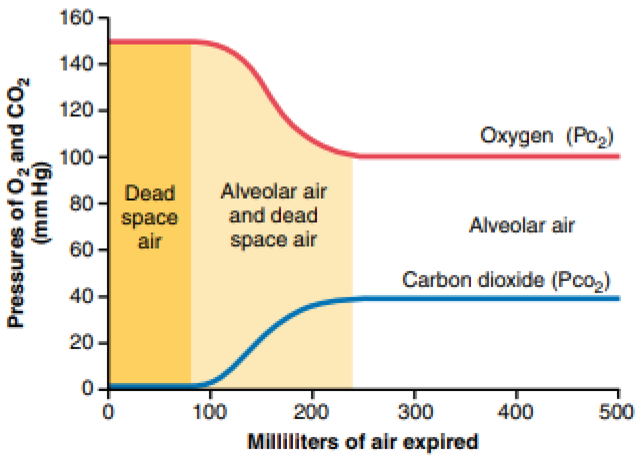
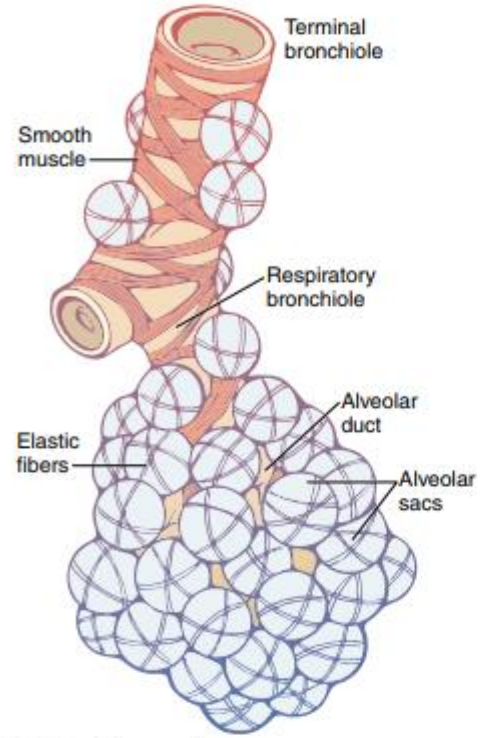
Physical Principles of Gas Exchange; Diffusion of Oxygen and Carbon Dioxide Through the Respiratory Membrane



Oxygen and carbon dioxide partial pressures in the various portions of normal expired air.



Respiratory unit.

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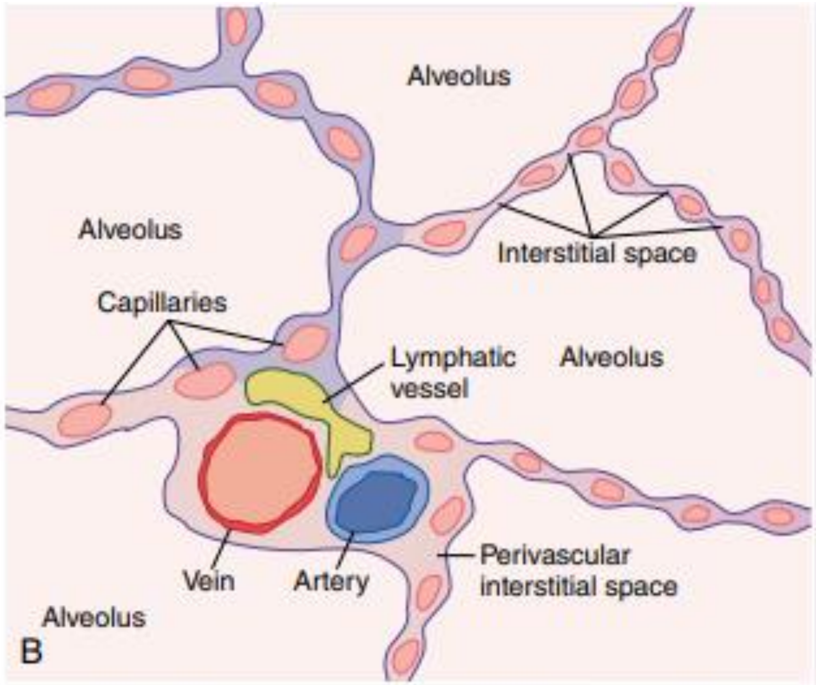
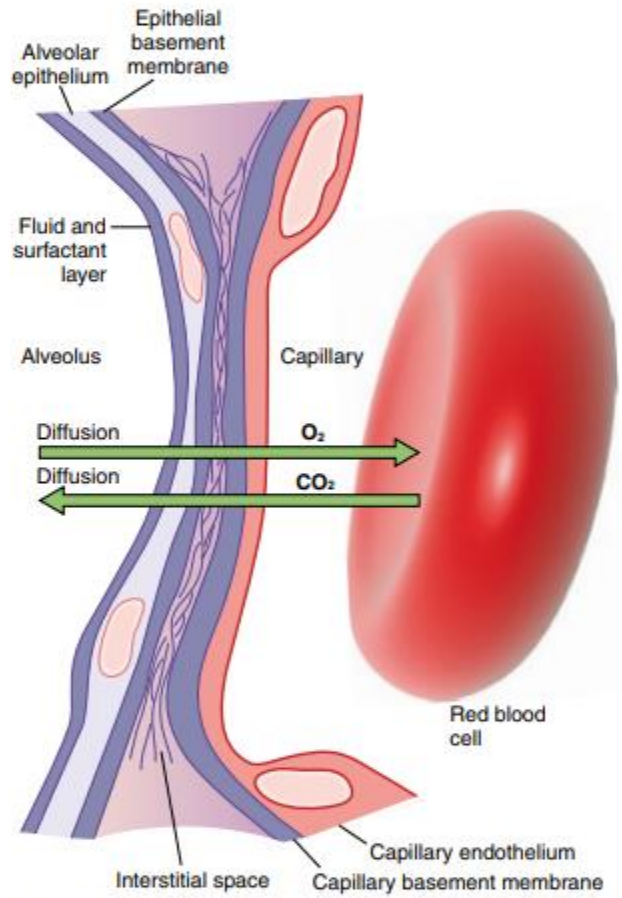


A, Surface view of capillaries in an alveolar wall. *B*, Cross-sectional view of alveolar walls and their vascular supply.



Ultrastructure of the alveolar respiratory membrane, shown in cross section.

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