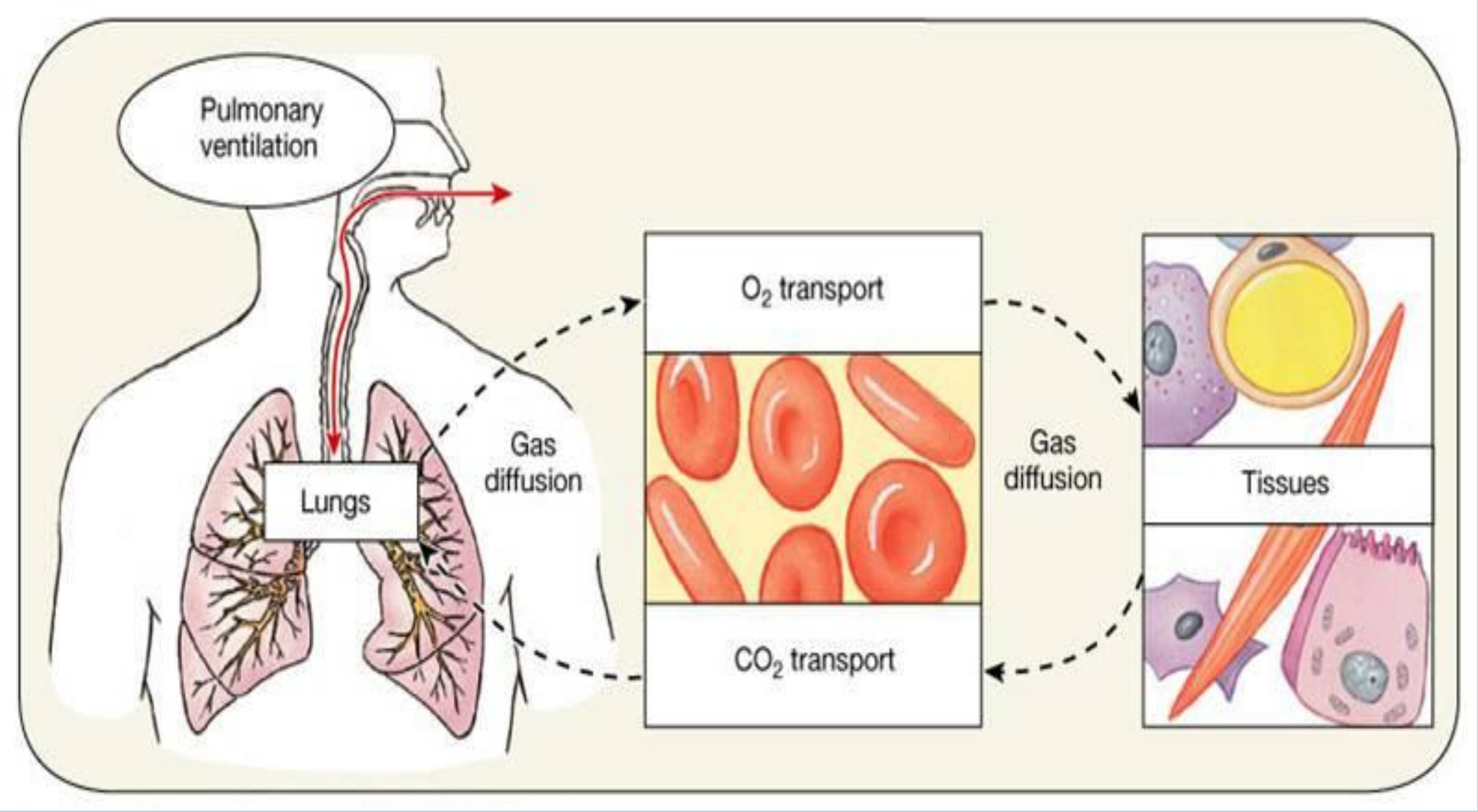
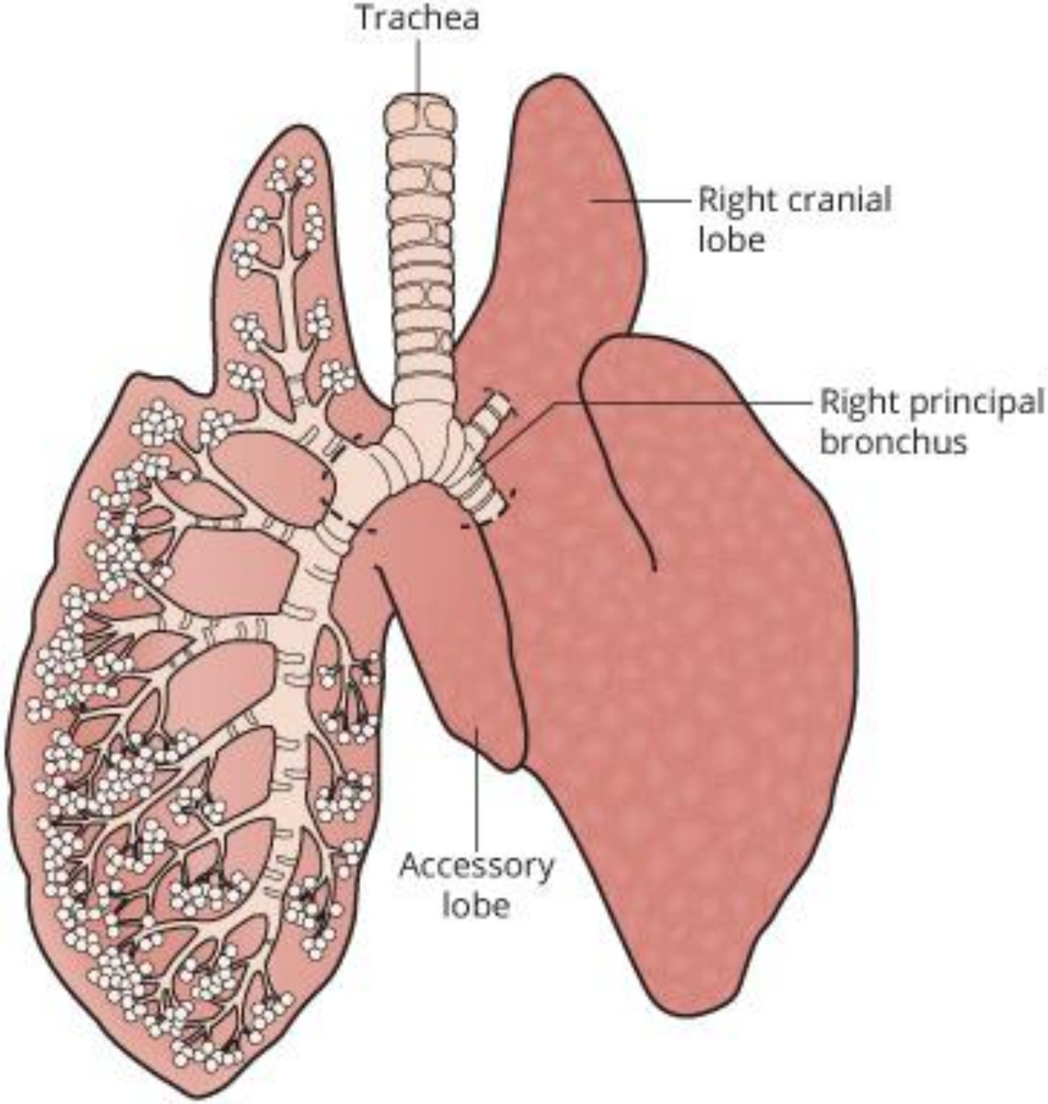
Physiology of Respiratory System

The importance of the respiratory system is indicated in its role in providing oxygen to cellular activity and neuron function. In fact, a lack of oxygen can actually kill the cells that are essential to brain activity.

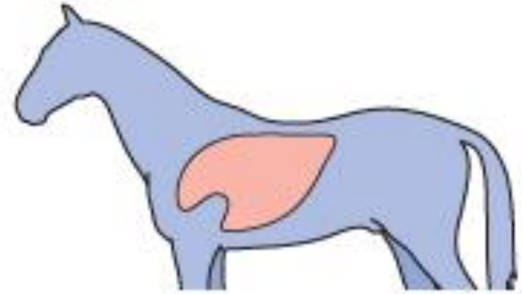
Respiration



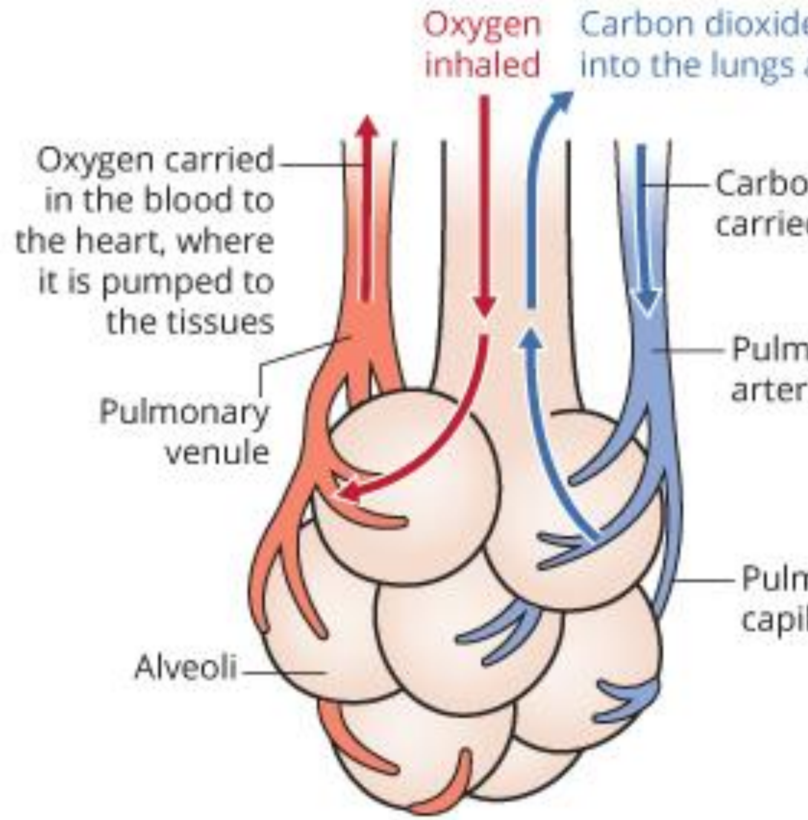
The Respiratory System



The trachea and lungs showing the brachial tree in the left lung



Position of the lungs

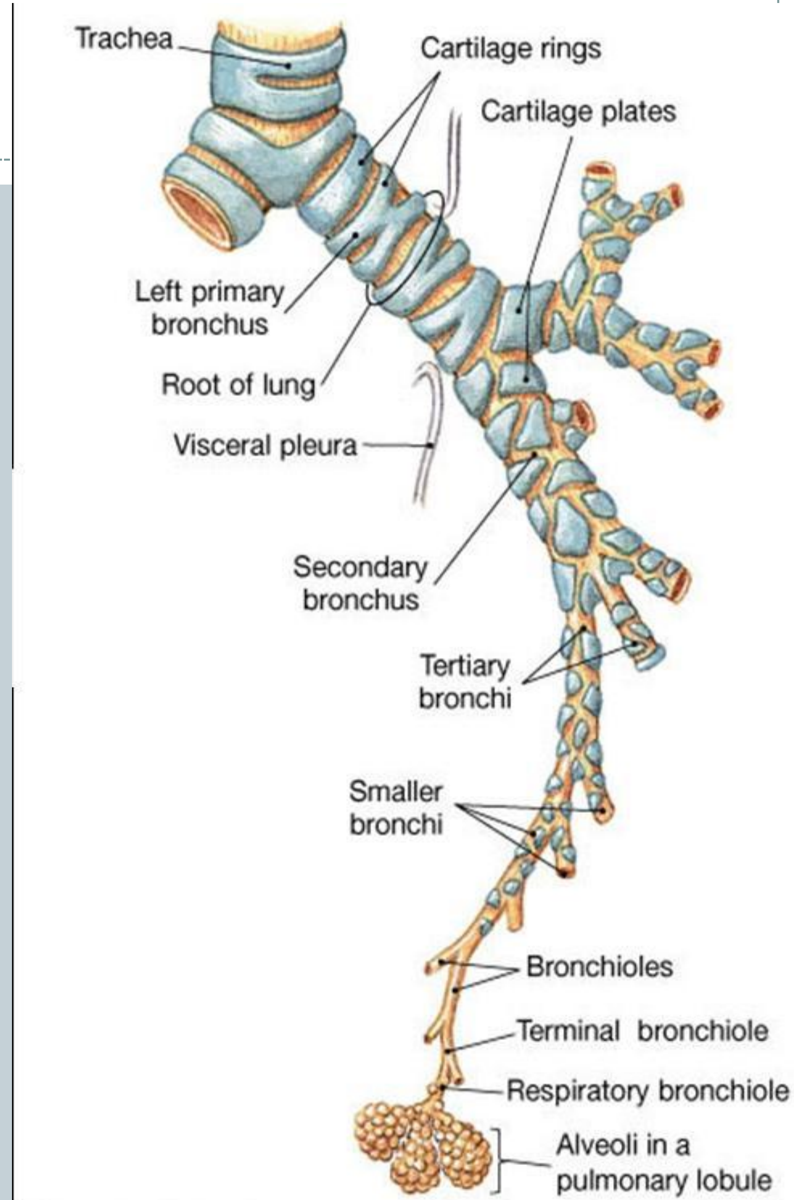


Gaseous exchange

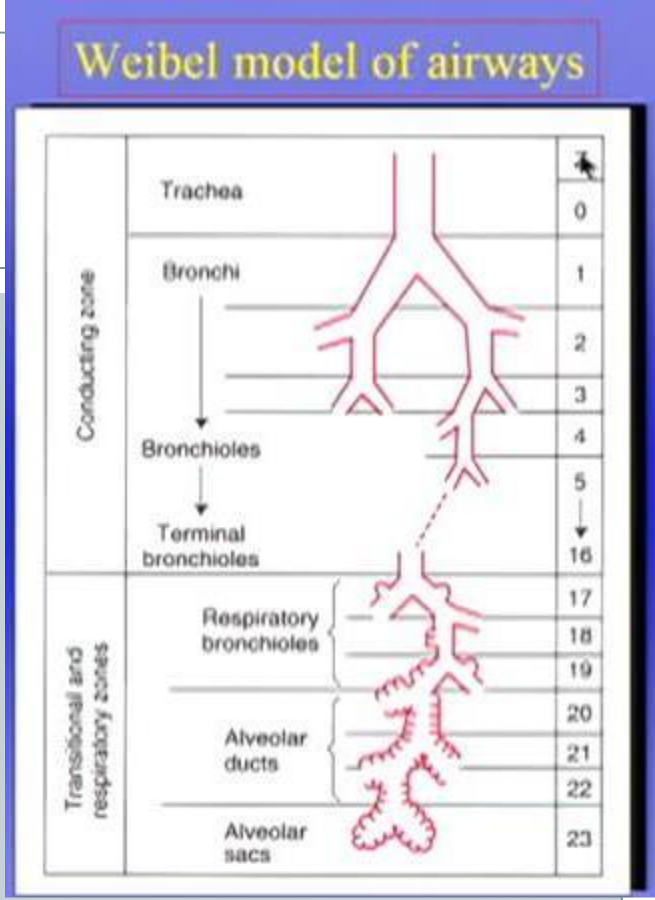
The Air Passages

nose ---> pharynx ---> larynx ---> trachea ---> primary bronchi ---> secondary bronchi ---> tertiary bronchi ---> bronchioles ---> terminal bronchioles ---> respiratory bronchioles ---> alveolar duct ---> alveoli

The trachea is the tube that ducts the air down the throat. Incomplete rings of cartilage in its walls help keep it open even when the neck is bent and head turned. The fact that acrobats and people that tie themselves in knots doing yoga still keep breathing during the most contorted manoeuvres shows how effective this arrangement is. The air passage now divides into the two **bronchi** that take the air to the right and left lungs before dividing into smaller and smaller **bronchioles** that spread throughout the lungs to carry air to the alveoli. Smooth muscles in the walls of the bronchi and bronchioles adjust the diameter of the air passages.



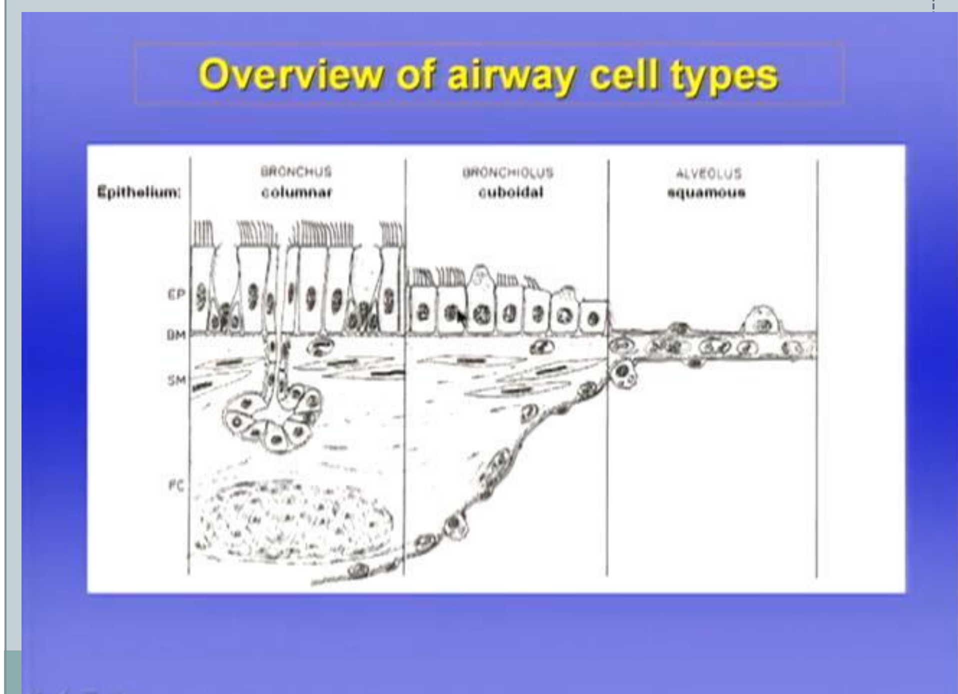
- **Respiratory Divisions**
- Conducting Zone
- Respiratory Zone
- **Conducting Zone**
- Made up of rigid passageways that serve to
  - warm,
  - moisten, and
  - filter the inhaled air:
- nose, nasal cavity, pharynx, larynx, trachea, primary bronchi, tertiary bronchi, bronchioles, terminal bronchioles.
- Air passages undergo 23 orders of branching in the lungs which significantly **increases cross sectional area** for
- **Respiratory Zone**
- Site of gas exchange
- Consists of respiratory bronchioles, alveolar ducts, alveolar sacs, and about 300 million alveoli
- Accounts for most of the lungs' volume
- Provide tremendous surface area for gas exchange



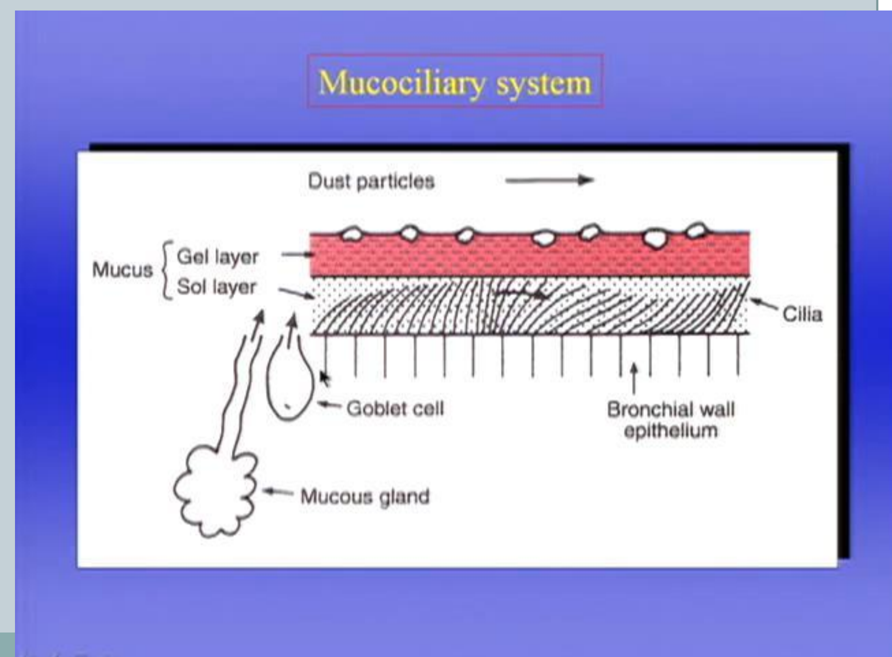
Airway's cellular types

Cells within airway

Pulmonary epithelial cells
Goblet cells
Clara cells
Fibroblast cells
Smooth muscle cells



Structure of the mucociliary system



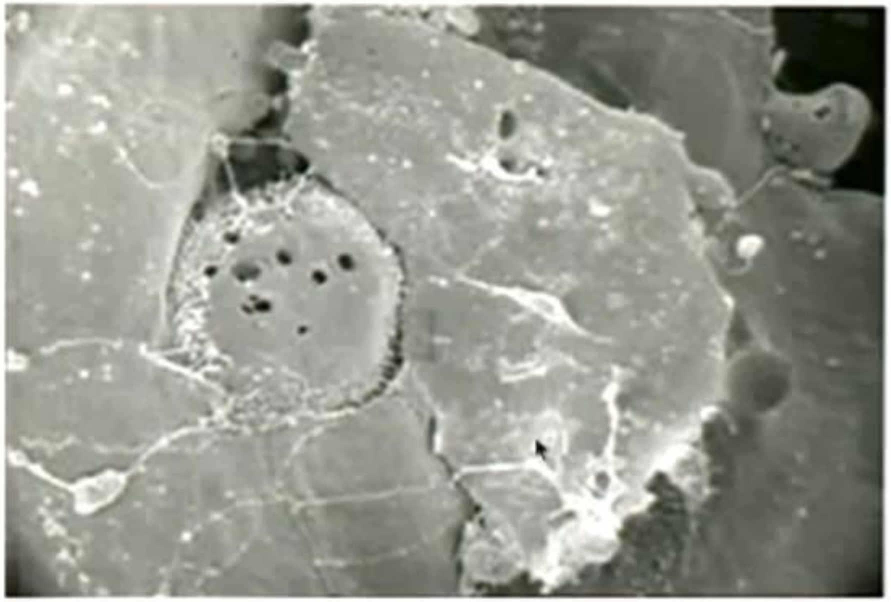
Dead space

- Definition - It is the volume of the respiratory tract that does not participate in gas exchange. It is approximately 300 ml in normal lungs.

  1-Anatomical dead space

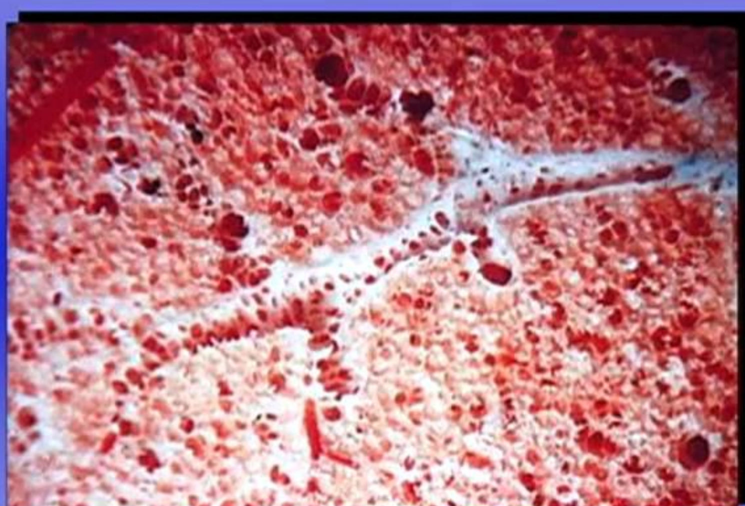
  2-Physiological dead space

Alveolar macrophage with types I and II epithelial cells

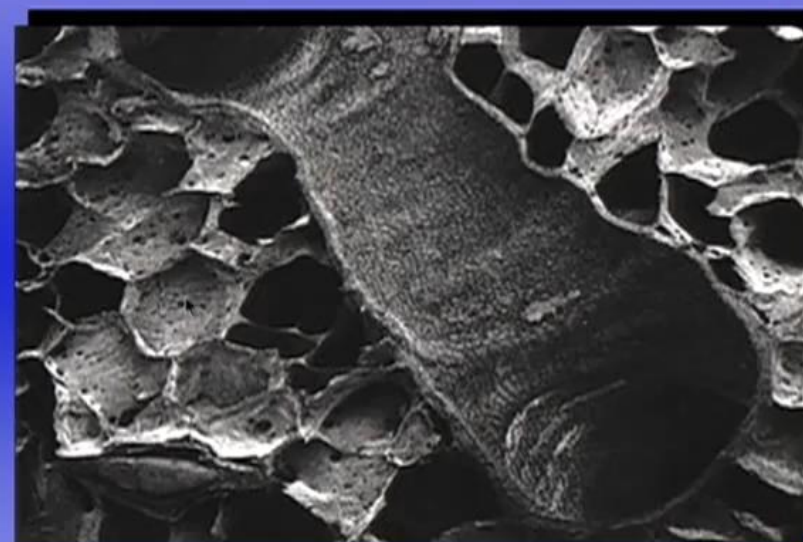


Type II alveolar epithelial cell

Alveolar ducts and alveoli

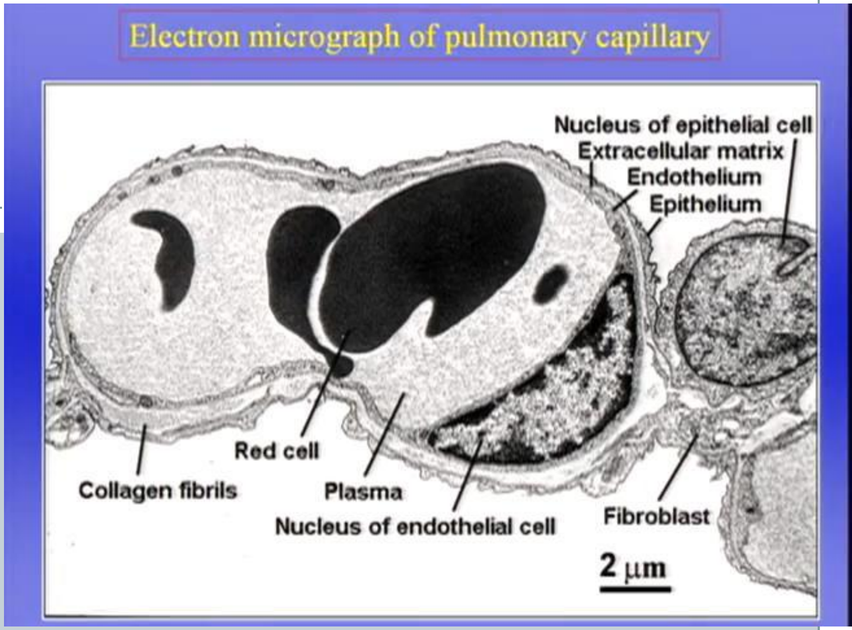


Scanning electron micrograph of small airway and alveoli



Gases Diffusion and Transportation

Blood Gas Barrier



1. A layer of fluid lining the alveolus and containing surfactant that reduces the surface tension of the alveolar fluid

2. The alveolar epithelium composed of thin epithelial cells

3. An epithelial basement membrane

4. A thin interstitial space between the alveolar epithelium and the capillary membrane

5. A capillary basement membrane that in many places fuses with the alveolar epithelial basement membrane

6. The capillary endothelial membrane

Alveoli structure

two types of epithelial cells.

Type I cells are flat cells with large cytoplasmic extensions and are the primary lining cells of the alveoli, covering approximately 95% of the alveolar epithelial surface area.

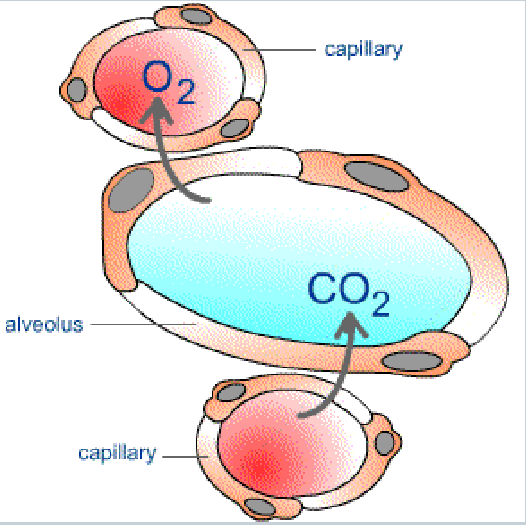
Type II cells (granular pneumocytes) are thicker and contain numerous lamellar inclusion bodies. A primary function of these cells is to secrete surfactant; however

The alveoli also contain other specialized cells, including pulmonary alveolar macrophages (PAMs, or AMs), lymphocytes, plasma cells, neuroendocrine cells, and mast cells. The mast cells contain heparin, various lipids, histamine, and various proteases that participate in allergic reactions

Gases diffusion and transportation:-

Diffusion of any gas is judged by the Fick's law of diffusion , in which transfer of any gas (v•)through a sheet of tissue is proportional to tissue surface area (A) and the difference in gas partial pressure (P1- P2) between the two sides of the tissue , and inversely to thickness of the tissue(T)

$$V\ gas = \frac{A \times D \times (P_1 - P_2)}{T}$$



V gas = rate of diffusion

A = tissue surface area

T = tissue thickness

D = diffusion coefficient of gas

P_1-P_2 = difference in partial pressure

Lung is big A(50-100 m^2) and Low T(microne)

D :- diffusion coaffeciant of any gas it depends on :-a. property of tissue

b. molecular of gas

c. solubility of gas

Partial Pressure Gradients for gases diffusion

- **Partial Pressure Gradients**
- The **partial pressure of oxygen (PO_2) of venous blood is 40 mm Hg**
- The **PO_2 in the alveoli is ~100 mm Hg**
- Steep gradient allows PO_2 gradients to rapidly reach equilibrium (0.25sec)
- Blood can move quickly through the pulmonary capillary and still be adequately oxygenated

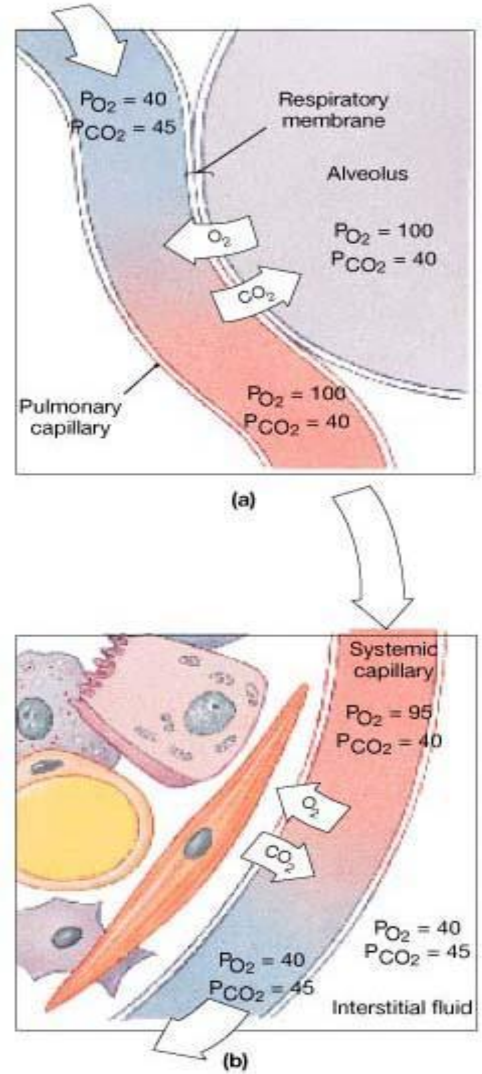
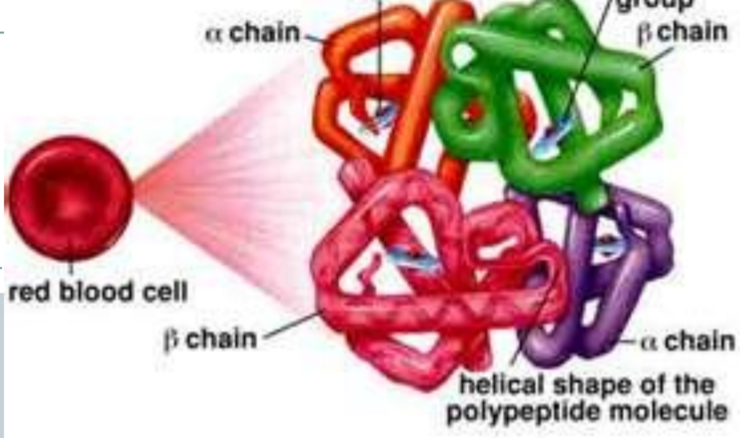


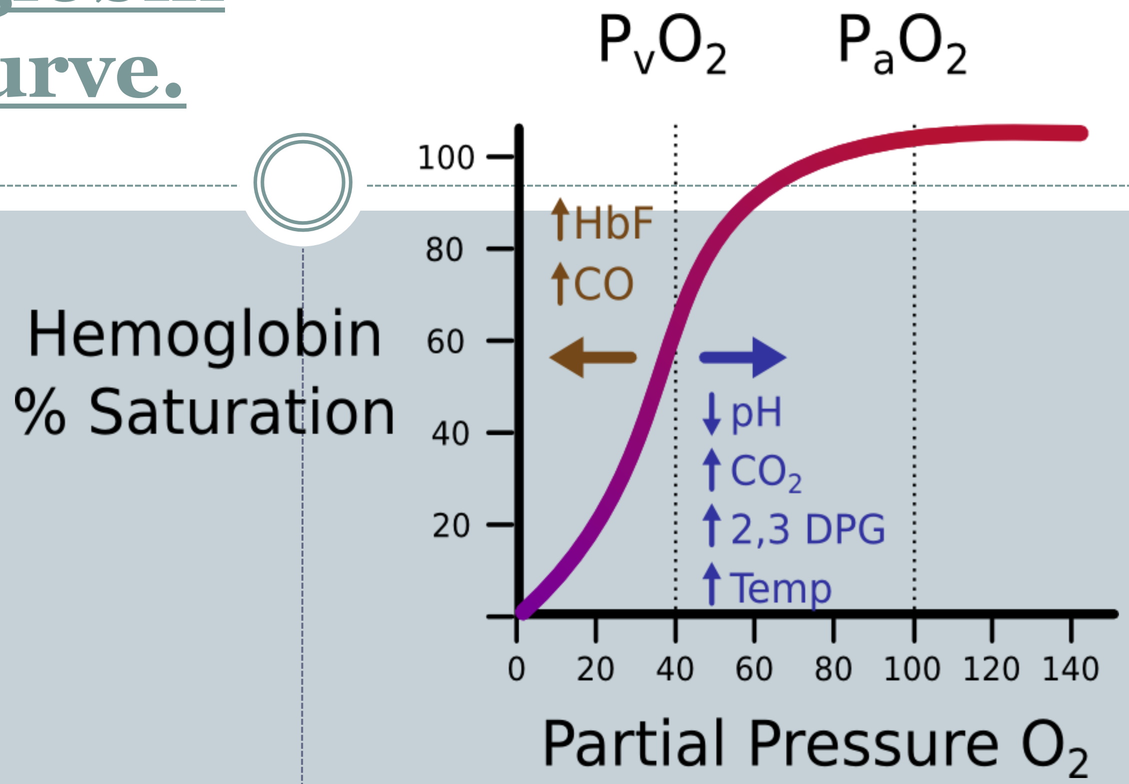
FIGURE 23-20 An Overview of Respiratory Processes and Partial Pressures in Respiration. (a) Partial pressures and diffusion at the respirator

Oxygen Transport



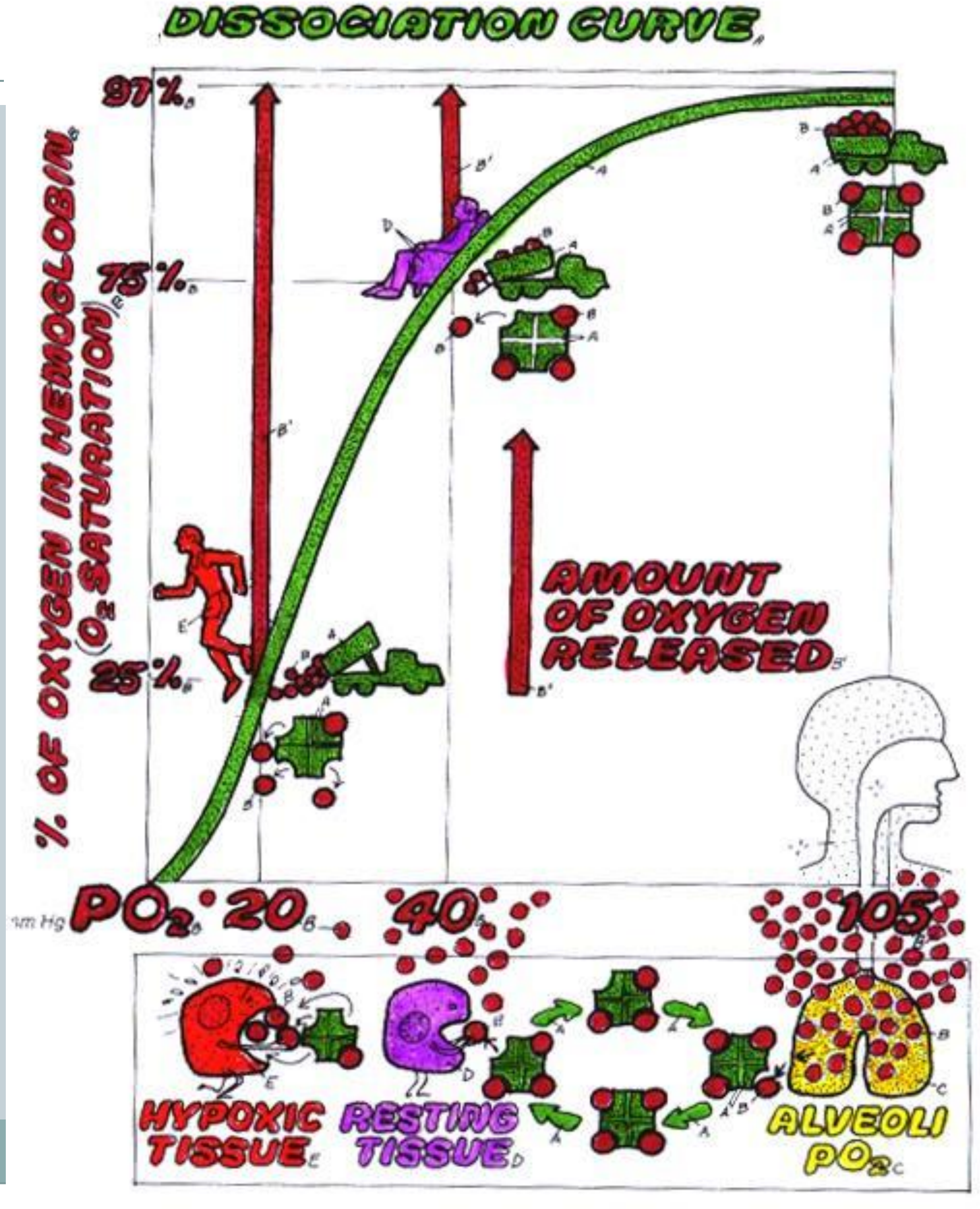
- 1-Dissolved oxygen
- For each mmHg there is 0. 003 ml O2 per 100 ml of blood so for adult man at PO2 100 mmHg contains 0.3 ml of oxygen per 100 mi blood , which is inadequate , and must be another method for the sopply of oxygen.
- 2-Reaction of Hemoglobin
- Hemoglobin is a protein made up of four subunits, each of which contains a heme moiety attached to a polypeptide chain. In normal adults, most of the hemoglobin molecules contain two-α and two chains. Heme is a porphyrin ring complex that includes one atom of ferrous iron. Each of the four iron atoms in hemoglobin can reversibly bind one O_2 molecule. The iron stays in the ferrous state, so that the reaction is oxygenation, not oxidation. It has been customary to write the reaction of hemoglobin with O_2 as Hb + O_2 ¨Æ HbO_2. Because it contains four deoxyhemoglobin (Hb) units, the hemoglobin molecule can also be represented as Hb_4, and it actually reacts with four molecules of O_2 to form Hb_4O_8.

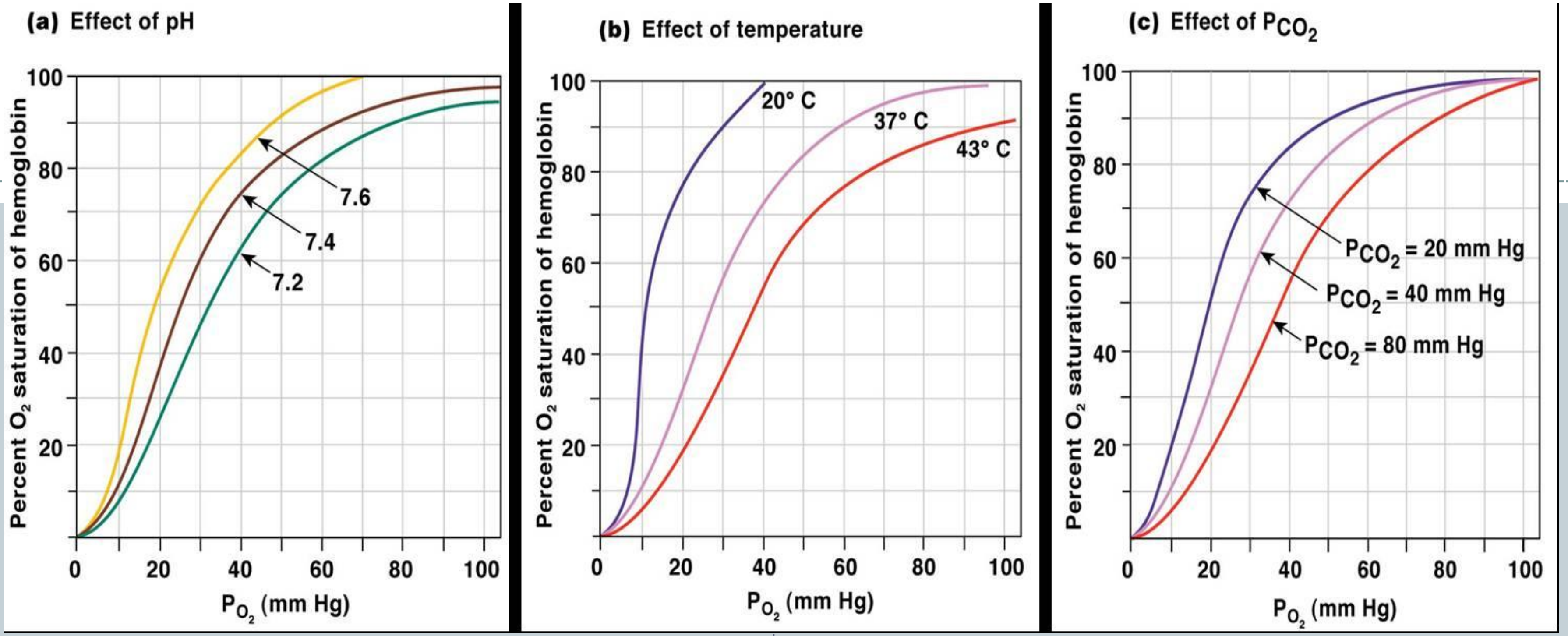
Oxygen–hemoglobin dissociation curve.



PO_2	Hb%
10	13.5
20	35
30	60
50	80

- **Factors Influencing Hb Saturation**
  Temperature
  H+ ion concentration
  PCO_2
  BPG


DISSOCIATION CURVE
% OF OXYGEN IN HEMOGLOBIN
(O_2 SATURATION)
97%
75%
25%
AMOUNT
OF OXYGEN
RELEASED
PO2
20
40
105
mm Hg
HYPOXIC
TISSUE
RESTING
TISSUE
ALVEOLI
PO2



Increases of these factors decrease hemoglobin's affinity for oxygen and enhance oxygen unloading from the blood, shifts the curve to the right. When the curve is shifted in this direction, a higher PO_2 is required for hemoglobin to bind a given amount of O_2

H+ and CO_2 modify the structure of Hb - Bohr effect

DPG produced by RBC metabolism when environmental O_2 levels are low

Carbon Dioxide Transport

- Carbon dioxide is transported in the blood in three forms
- Dissolved in plasma – 7 to 10%
- Chemically bound to hemoglobin – 20% is carried in RBCs as **carbaminohemoglobin**
- Bicarbonate ion in plasma – **70% is transported as bicarbonate (HCO_3^-)**
- Removing O_2 from Hb increases the ability of Hb to pick up CO_2 and CO_2 generated H^+ is called the **Haldane effect.**
- **At the tissues**, as more CO_2 enters the blood:More oxygen dissociates from Hb (Bohr effect). Unloading O_2 allows more CO_2 to combine with Hb (Haldane effect), and more bicarbonate ions are formed. This situation is reversed in pulmonary circulation
-

Hypoxemia and Hypoxia

Hypoxemia: *is an abnormally low PO2 in arterial blood caused by:-*

- *Hypoventilation*
- *Diffusion impairment*
- *Shunt*
- *ventilation – perfusion inequality*

Hypoxia *: is an abnormally law O2 delivery to tissue*

- **anemic hypoxia** that due to reduction of the oxygen-carrying capacity of the blood owing to decreased total hemoglobin or altered hemoglobin constituents.
- **histotoxic hypoxia** that due to impaired use of oxygen by tissues.
- **hypoxic hypoxia** that due to insufficient oxygen reaching the blood. Hypoxic hypoxia is a problem in normal individuals at high altitudes and is a complication of pneumonia and a variety of other diseases of the lung
- **stagnant hypoxia** that due to failure to transport sufficient oxygen because of inadequate blood flow.