RESPIRATORY BLOCK

كلية الطب البشري
السنة الأولى

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رقم المذكرة
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عدد الصفحات
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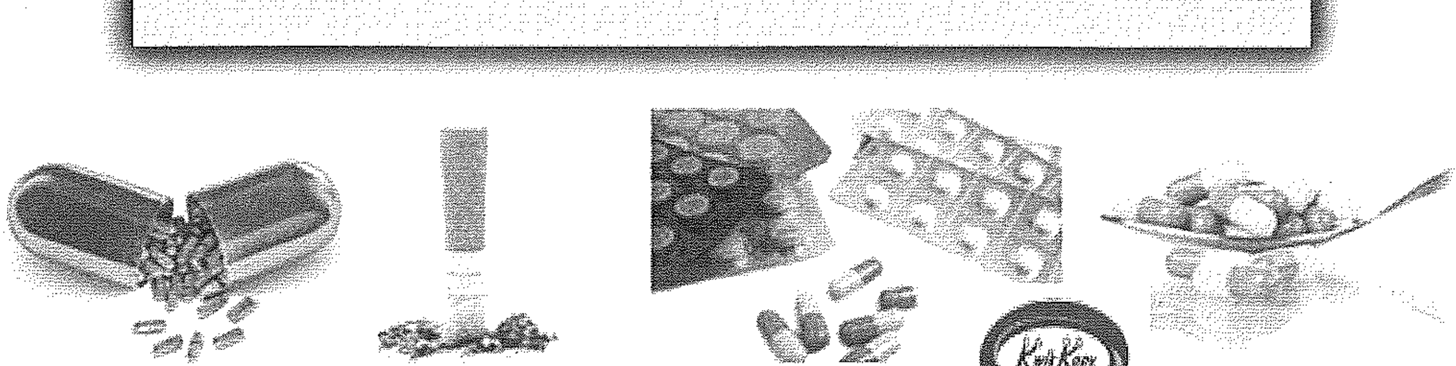
Gas exchange and Transfer
Physiology
Dr.sultan



GAS EXCHANGE AND TRANSFER

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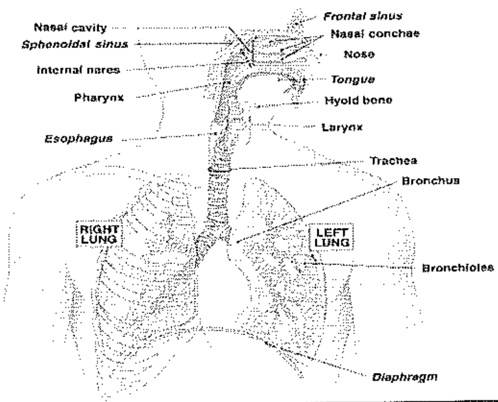
PHYSIOLOGICAL ANATOMY OF RESPIRATORY SYSTEM



- Upper tract
  - Nose, pharynx and associated structures
- Lower tract
  - Larynx, trachea, bronchi, lungs

TRACHEOBRONCHIAL TREE

Conducting zone

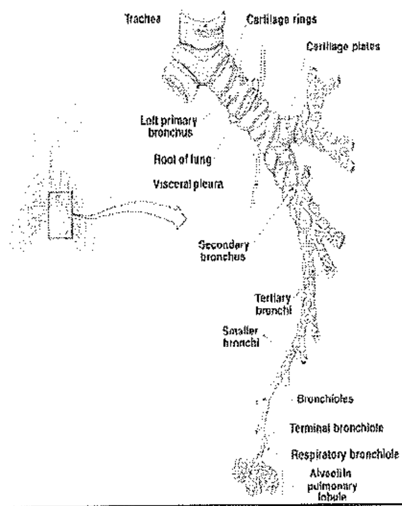
- Trachea to terminal bronchioles which is ciliated for removal of debris
- Passageway for air movement
- Cartilage holds tube system open and smooth muscle controls tube diameter

- Respiratory zone: Respiratory bronchioles to alveoli, site for gas exchange

ANATOMICAL AND PHYSIOLOGICAL DEAD SPACE

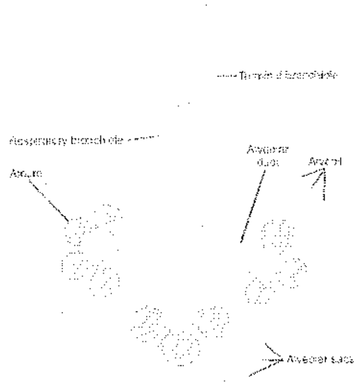
Dead space ventilation is that part of minute ventilation that does not take part in gas exchange. Dead space ventilation includes (1) air that enters only conducting airways [anatomic dead space]

(2) Air that reaches alveoli but does not exchange carbon dioxide or oxygen with the capillary blood. The combined volume of these two areas is often referred to as *physiologic dead space.*

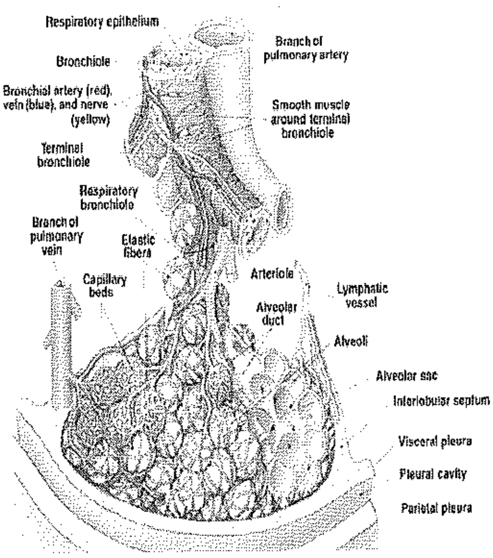


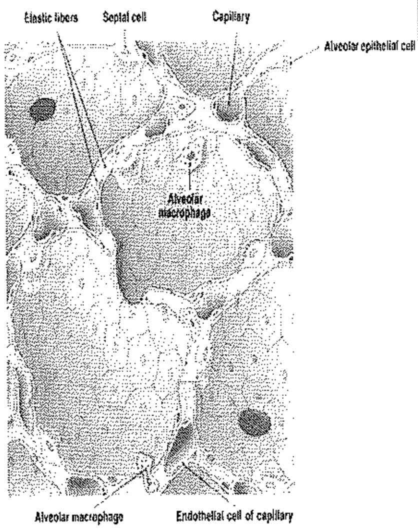
RESPIRATORY ZONE

Respiratory unit also called respiratory lobule, composed of a respiratory bronchiole, alveolar ducts, atria, and alveoli. There are about 300 million alveoli in the two lungs, and each alveolus has an average diameter of about 0.2 millimeter.

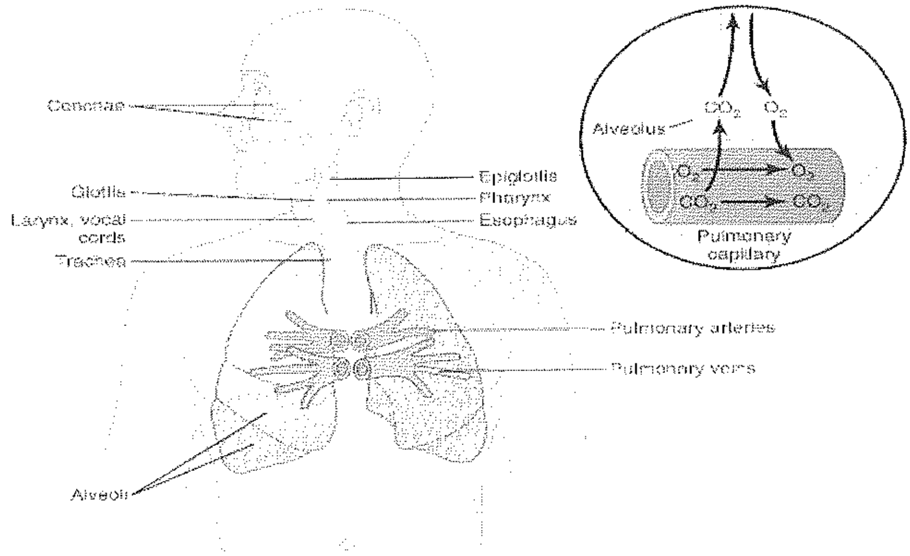


BRONCHIOLES AND ALVEOLI





BRONCHIOLES AND ALVEOLI



DIFFUSING CAPACITY OF THE LUNG [DL]

The diffusing capacity is defined as the amount of gas transferred from alveoli to capillary blood per minute for mmHg pressure difference e.g. ml/min/mmHg.

DLO_2 = diffusion capacity of lung for oxygen

DLCO= diffusion capacity of lung for carbon monoxide

TLCO= transfer factor for carbon monoxide

PHYSICAL PRINCIPLES OF GAS EXCHANGE

- Partial pressure
  - The pressure exerted by each type of gas in a mixture
  - Dalton's law
  - Water vapor pressure
- Diffusion of gases through liquids
  - Concentration of a gas in a liquid is determined by its partial pressure and its solubility coefficient
  - Henry's law

PHYSICAL PRINCIPLES OF GAS EXCHANGE

Diffusion is a process that occurs when there is a difference in the concentration of a substance between two areas

The substance, for example oxygen, will diffuse from an area of high concentration to an area of low concentration

No energy is required from the body for this process

GAS LAWS

Avogadro's law and number: Equal volumes of gas at the same pressure contain the same number of molecules.

Concentration of gas - Gas pressure

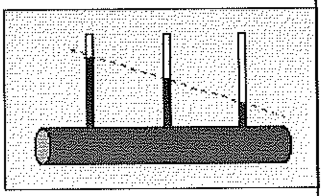
Boyle's law of gas V ~ P

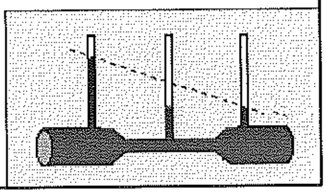
Pressure varies inversely with volume

Volume varies inversely with pressure

GAS LAWS

Laws of Gas Flow:
Laminar flow – Turbulence
Poiseuille's law states that flow rate is inversely related to both the tube length and to the viscosity of the gas
Bernouli's law relates the loss in pressure to the resistance of a system. Total pressure is divided between flow(forward pressure) and lateral pressure





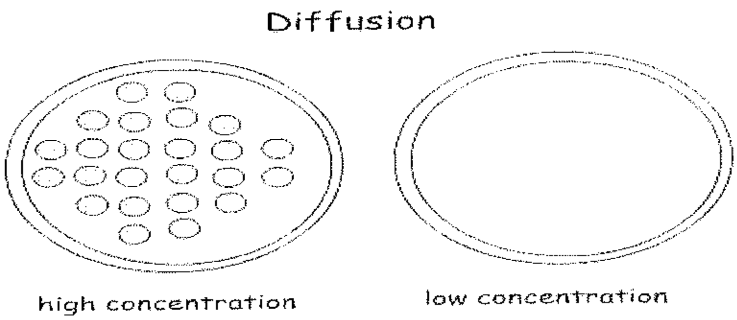
GAS LAWS

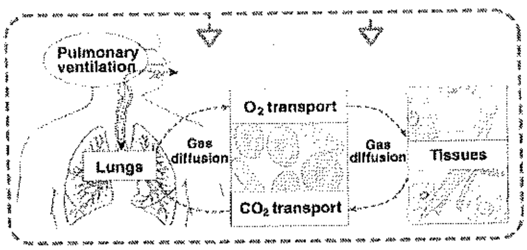
Graham's Law: Diffusion of gases varies with molecular weight higher molecular weight the slower the diffusion
Henry's Law - law of the coke bottle
The amount of gas dissolved in a liquid varies directly with the total quantity of gas and the pressure of the gas.
Charles's Law : Effects of temperature on a gas, pressure varies with temperature
Dalton's Law of Partial Pressure: Partial Pressure of a gas is proportional to the proportion of that gas in a mixture of gases

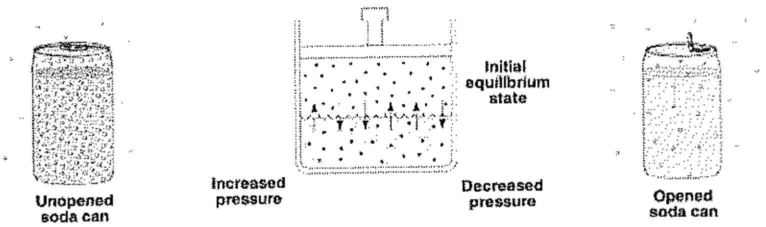
CHANGES IN PARTIAL PRESSURES

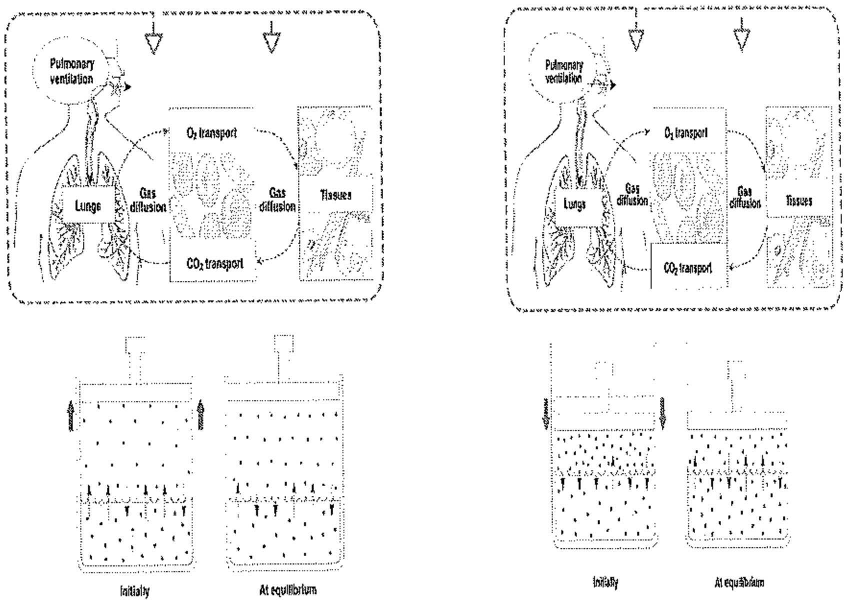
After the alveoli are ventilated with fresh air, the next step in the respiratory process is to:
diffusion of oxygen from the alveoli into the pulmonary blood and diffusion of carbon dioxide in the opposite direction, out of the blood.
The process of diffusion is simply the random motion of molecules intertwining their way in all directions through the respiratory membrane and adjacent fluids.

PHYSICAL PRINCIPLES OF GAS EXCHANGE



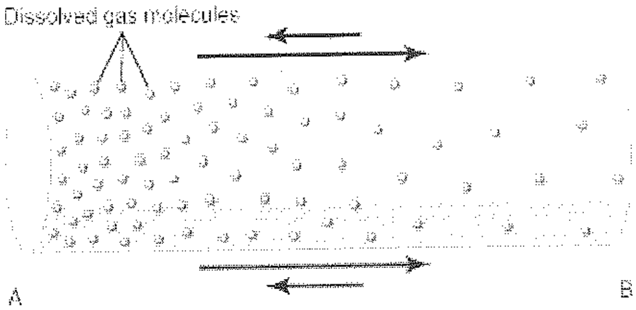






Diffusion of oxygen from one end of a chamber (A) to the other (B). The difference between the lengths of the arrows represents *net diffusion*

Partial pressure= Concentration of the dissolved gas / solubility coefficient



PHYSICAL PRINCIPLES OF GAS EXCHANGE

- Diffusion of gases through the respiratory membrane
  - Depends on membrane's thickness, the diffusion coefficient of gas, surface areas of membrane, partial pressure of gases in alveoli and blood
- Relationship between ventilation and pulmonary capillary flow
  - Increased ventilation or increased pulmonary capillary blood flow increases gas exchange
  - Physiologic shunt is deoxygenated blood returning from lungs

OXYGEN AND CARBON DIOXIDE DIFFUSION GRADIENTS

- Oxygen
  - Moves from alveoli into blood. Blood is almost completely saturated with oxygen when it leaves the capillary
  - PO_2 in blood decreases because of mixing with deoxygenated blood
  - Oxygen moves from tissue capillaries into the tissues
- Carbon dioxide
  - Moves from tissues into tissue capillaries
  - Moves from pulmonary capillaries into the alveoli

PARTIAL PRESSURES OF RESPIRATORY GASES AS THEY ENTER AND LEAVE THE LUNGS [AT SEA LEVEL]

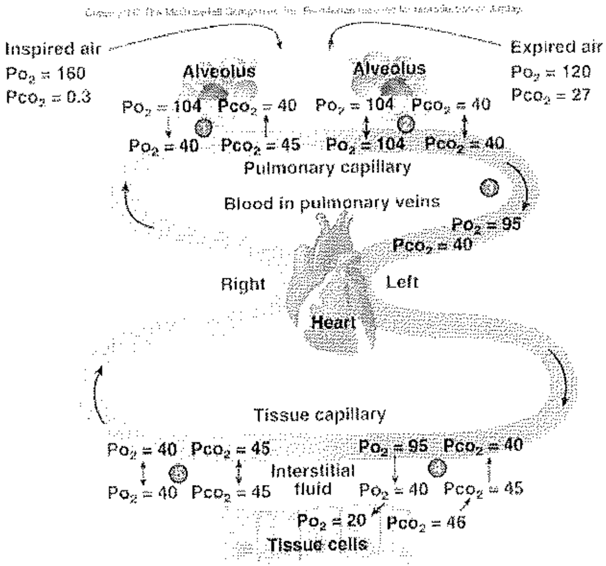
	Atmospheric Air (mm Hg)	Humidified Air (mm Hg)	Alveolar Air (mm Hg)	Expired Air (mm Hg)
N_2	597.0 (78.62%)	563.4 (74.09%)	569.0 (74.9%)	566.0 (74.5%)
O_2	159.0 (20.84%)	149.3 (19.67%)	104.0 (13.6%)	120.0 (15.7%)
CO_2	0.3 (0.04%)	0.3 (0.04%)	40.0 (5.3%)	27.0 (3.6%)
H_2O	3.7 (0.50%)	47.0 (6.20%)	47.0 (6.2%)	47.0 (6.2%)
TOTAL	760.0 (100.0%)	760.0 (100.0%)	760.0 (100.0%)	760.0 (100.0%)

O_2 AND CO_2 IN EXPIRED AIR

The PCO_2 in the expired air is lower than in the alveolar air because of the mixing of the dead space air during expiration. Anatomical dead space has lowest partial pressure for CO_2 .

The partial pressure of water vapor at a normal body temperature of 37°C is 47 mm Hg, which is therefore the partial pressure of water vapor in the alveolar air. Because the total pressure in the alveoli cannot rise to more than the atmospheric pressure (760 mm Hg), this water vapor simply *dilutes all the other gases in the inspired air.*

Changes in Partial Pressures



LAYERS OF THE RESPIRATORY MEMBRANE

Fluid and surfactant layer
Alveolar epithelial layer
Epithelial basement membrane layer
Interstitial space
Capillary basement membrane layer
Capillary endothelial layer

RESPIRATORY MEMBRANE

Overall thickness of the respiratory membrane in is as little as 0.2 micrometer, and it averages about 0.6 micrometer.

Total surface area of the respiratory membrane is about 70 square meters in the normal adult human male.

This is equivalent to the floor area of a 25–by-30–foot room.

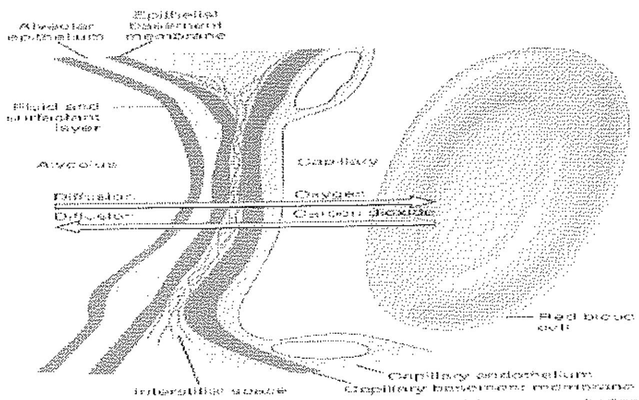
The total quantity of blood in the capillaries of the lungs at any given instant is 60 to 140 milliliters.

DIFFUSION CAPACITY OF O2 AND CO2 AT RESPIRATORY MEMBRANE

The diffusing capacity for oxygen under resting conditions averages 21 ml/min/mm Hg. The mean oxygen pressure difference across the respiratory membrane during normal, quiet breathing is about 11 mm Hg. Multiplication of this pressure by the diffusing capacity (11 *21) gives a total of about 230 milliliters of oxygen diffusing through the respiratory membrane each minute.

The diffusion coefficient of carbon dioxide is slightly more than 20 times that of oxygen, diffusing capacity for carbon dioxide under resting conditions is about 400 to 450 ml/min/ mm Hg and during exercise of about 1200 to 1300 ml/ min/mm Hg.

LAYERS OF THE RESPIRATORY MEMBRANE



DIFFUSION OF OXYGEN FROM ALVEOLUS INTO PULMONARY BLOOD

Partial pressure of oxygen in the alveolus is 104 mm Hg, whereas the PO2 of the venous blood entering the capillary is an average 40 mm Hg since a large amount of O2 has been removed from blood as it passes through the peripheral tissues, the initial pressure difference that causes oxygen to diffuse into the pulmonary capillary is 104-40 = 64 mm Hg.

Diffusion of O2 from capillaries into interstitial fluid

Partial pressure of O2 in the arterial end of the capillaries is 95 mm Hg while in interstitial fluid it is 40 mm Hg. Therefore O2 diffuses from arterial end of capillary into the interstitial fluid

DIFFUSION OF O2 FROM INTERSTITIAL FLUID INTO CELLS

Diffusion of O2 from interstitial fluid into cells:

The partial pressure of O2 in interstitial fluid is 40 mm Hg, while that in the cells is 23 mm Hg therefore O2 diffuses from interstitial fluid into the cells

DIFFUSION OF CO2

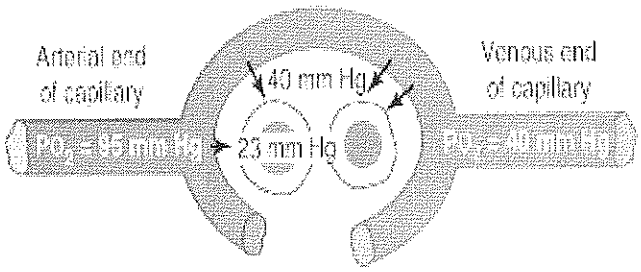
The diffusion of CO2 occurs in the opposite direction, of oxygen. It diffuses from the cells to the interstitial fluid and to alveoli

i. Diffusion of CO2 from cells to interstitial fluid: Partial pressure of CO2 within the cell is 46 mm Hg while its pressure in the interstitial fluid is 45 mm Hg. Thus it diffuses from the cells to the interstitial fluid

ii. Diffusion of CO2 from interstitial fluid into capillaries:
Partial pressure of CO2 in interstitial fluid is 45 mm Hg while in the arterial end of the capillaries, is 40 mm Hg. Therefore, CO2 diffuses from interstitial fluid into the capillaries.

Diffusion of CO2 from pulmonary blood into alveoli
Partial pressure of CO2 in pulmonary blood is 45 mm Hg while in the alveolus, it is 40 mm Hg. So CO2 diffuses from pulmonary blood into the alveoli.

DIFFUSION OF OXYGEN FROM A TISSUE CAPILLARY TO THE CELLS (PO2 IN INTERSTITIAL FLUID = 40 mmHg, AND IN TISSUE CELLS = 23 mmHg



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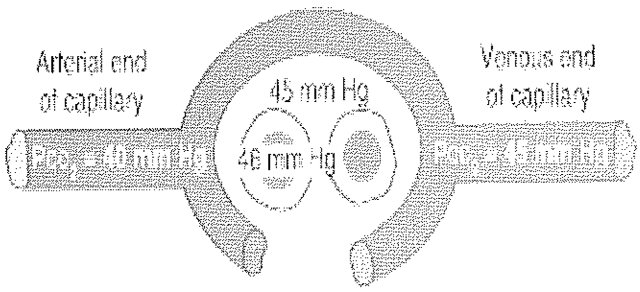
UPTAKE OF CARBON DIOXIDE BY THE BLOOD IN THE TISSUE CAPILLARIES: (PCO2 IN TISSUE CELLS = 46 mmHg AND IN INTERSTITIAL FLUID=45 mmHg



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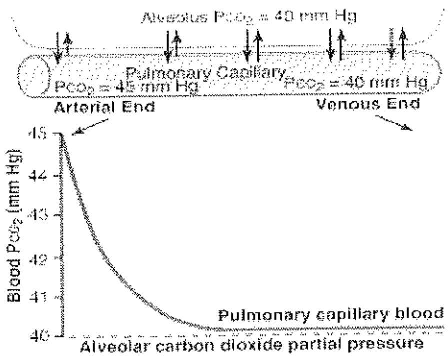
Diffusion of carbon dioxide from the pulmonary blood into the alveolus



FACTORS EFFECTING DIFFUSION

- Surface Area of the respiratory membrane
- Thickness of the alveolar membrane
- Partial Pressure Gradient
- Diffusion Coefficient:

FACTORS EFFECTING DIFFUSION

1. **The thickness of the alveolar-capillary membrane:** The rate diffusion through the membrane is inversely proportional to the thickness of the membrane, and any factor that increases thickness will interfere with normal respiratory exchange of gases.

2. **The surface area for diffusion:** When the surface area is reduced to one-third of normal, exchange of gases through the membrane is impeded to a significant degree, even under resting conditions.

FACTORS EFFECTING DIFFUSION

3. **The pressure difference between alveolar and capillary gas:** Pressure difference across the membrane will ultimately affect the gaseous diffusion.

4. **The diffusion coefficient for the membrane:** The diffusion coefficient depends on the solubility of the gas in the membrane and on the molecular weight of the gas.