Lecture 6

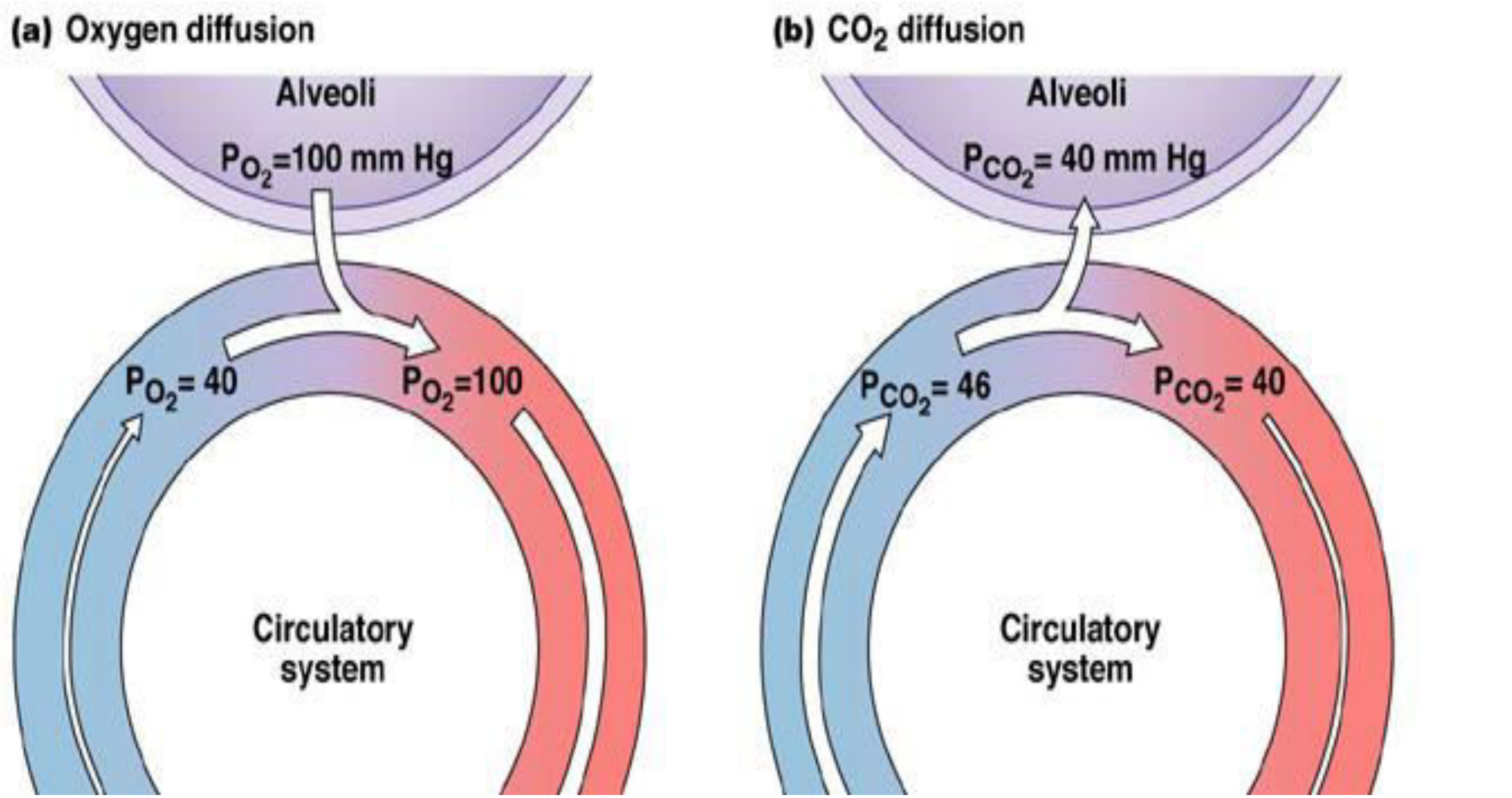
GAS EXCHANGE

Objectives

- Composition of air in different parts of respiratory system and difference in the composition of atmospheric air and alveolar air
- Factors affecting diffusion of gases through respiratory membrane
- Diffusion limited and perfusion limited gas exchange
- Definition of diffusion capacity, the difference between the diffusion capacity of O_2 and that of CO_2 in the lungs.
- Effect of V/Q on alveolar gas concentration

Gas exchange

- Is a continuous process
- Occurs through alveolo-capillary membrane by simple diffusion due to differences in partial pressure

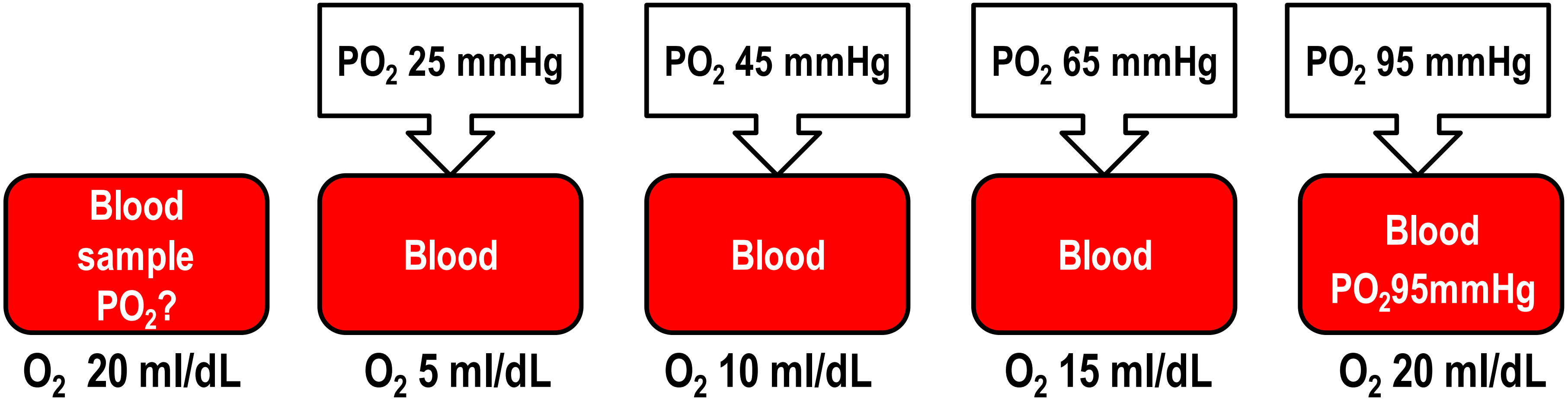


Properties of gases: (partial pressure)

- Air is a mixture of gases
  - Dalton's law of partial pressure: The pressure exerted by any one gas in a mixture of gases (its partial pressure) is equal to the total pressure times the fraction of the total amount of gas it represents.
  - Gas diffuse from area of high pressure to area of low pressure

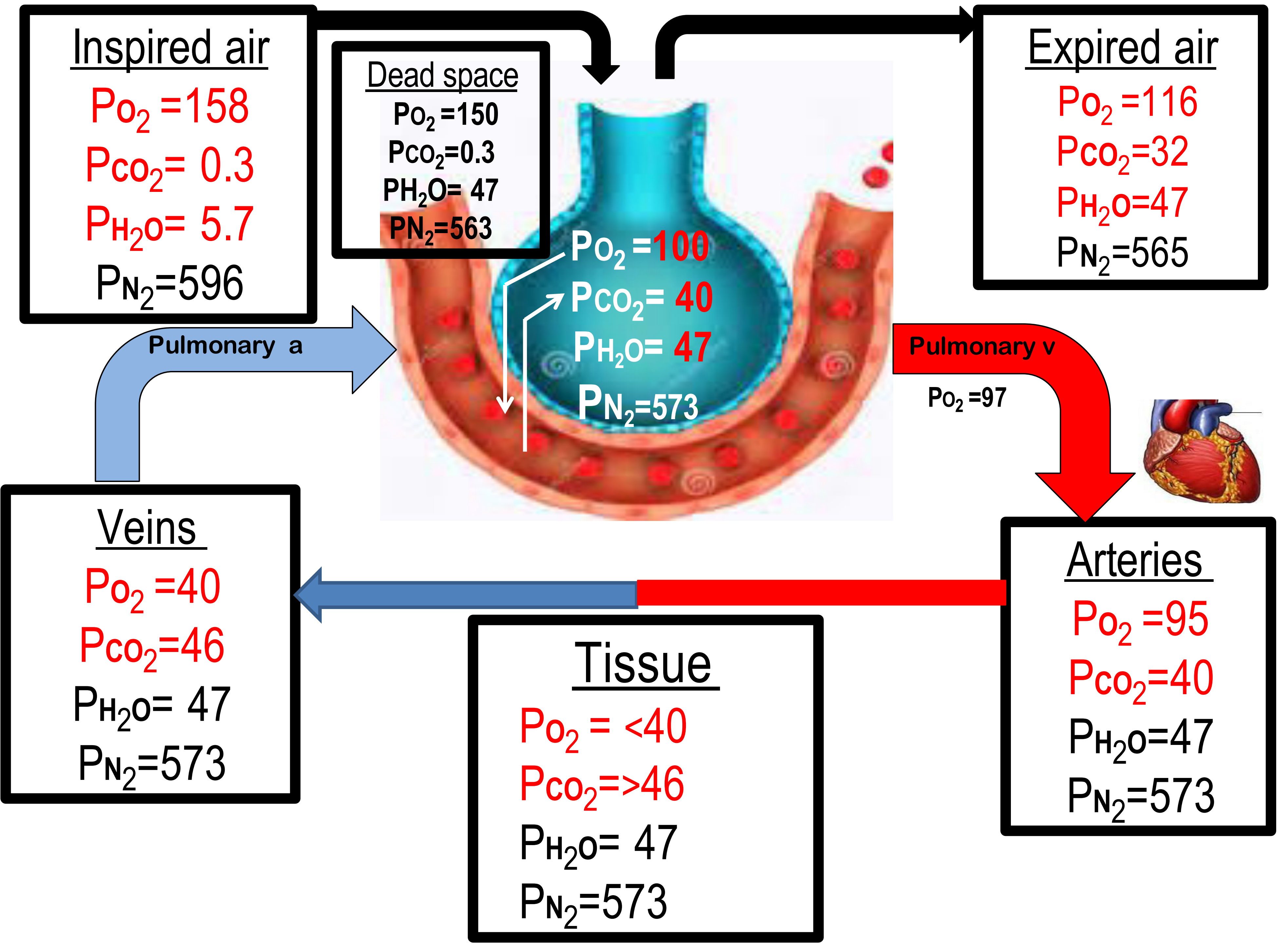
Gas	%	Partial pressure of gases in dry atmospheric air (mmHg)
N_2	79	PN_2 $0.79 \times 760 =$ **600**
O_2	21	PO_2 $0.21 \times 760 =$ **160**
CO_2	0.04	PCO_2 $0.0004 \times 760 =$ **0.3**
H_20		

- The partial pressure of gases in a liquid is the pressure that in the gaseous phase in equilibrium with the liquid, would produce the conccentrstion of gas molecules found in the liquid



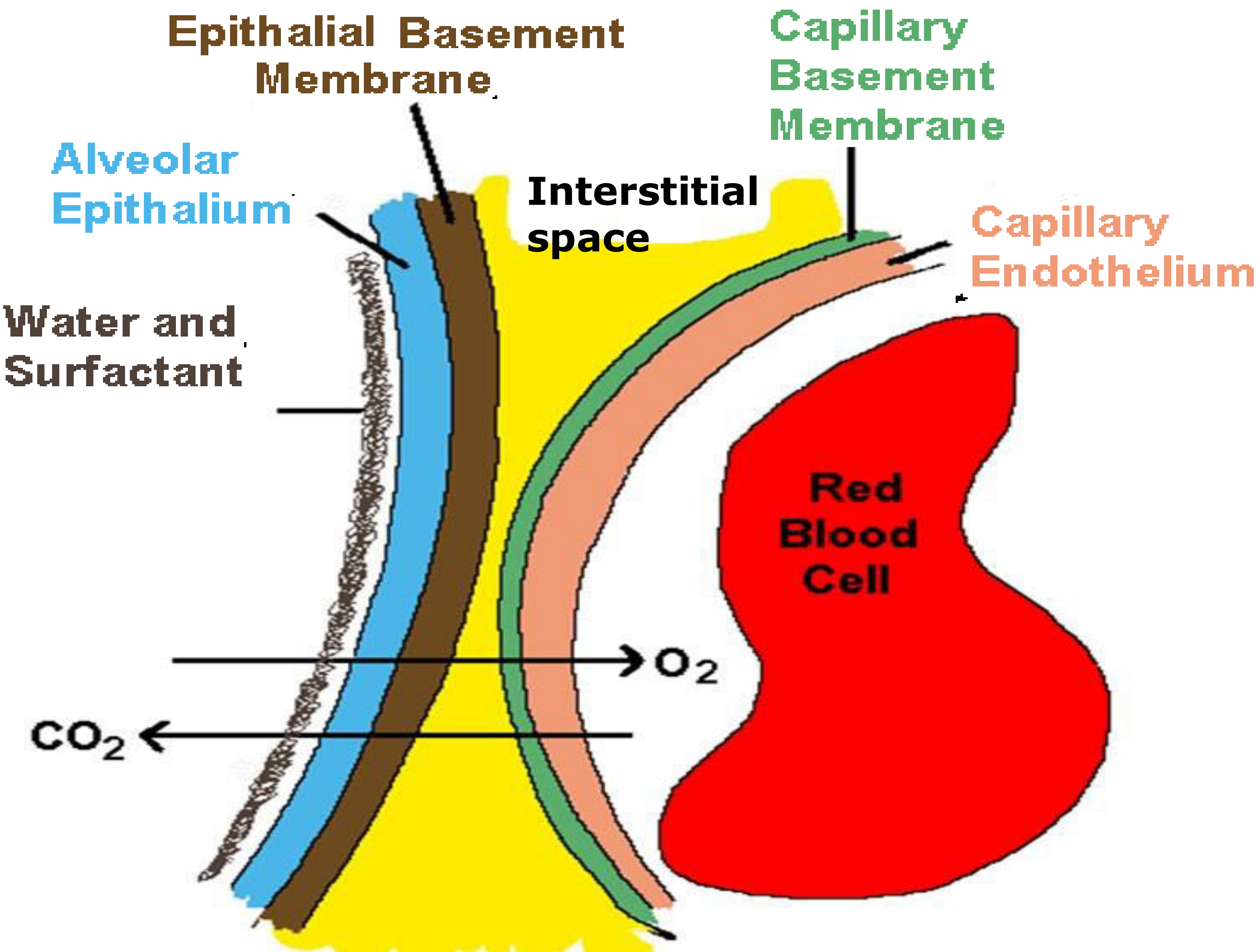
Composition of air in different parts of respiratory system

Pressure mm Hg	Dry atmosph. air	Inspired air	Dead space air	Alveolar air
PO_2	$0.21 \times 760 = 160$	$0.21 \times 754 = 158$	$0.21 \times 713 = 149.7$	100
PCO_2	$0.004 \times 760 = 0.3$	$0.004 \times 754 = 0.3$	$0.004 \times 713 = 0.3$	40
PH_2O		5.7	47	47
PN_2	$0.79 \times 760 = 600$	$0.79 \times 754 = 596$	$0.79 \times 713 = 563$	573
Total	760	760	760	760



Inspired air
P_{O_2} =158
P_{CO_2}= 0.3
P_{H_2O}= 5.7
P_{N_2}=596
Dead space
P_{O_2} =150
P_{CO_2}=0.3
PH_2O= 47
PN_2=563
P_{O_2} =100
P_{CO_2}= 40
P_{H_2O}= 47
P_{N_2}=573
Expired air
P_{O_2} =116
P_{CO_2}=32
P_{H_2O}=47
P_{N_2}=565
Pulmonary a
Pulmonary v
P_{O_2} =97
Veins
P_{O_2} =40
P_{CO_2}=46
P_{H_2O}= 47
P_{N_2}=573
Tissue
P_{O_2} = <40
P_{CO_2}=>46
P_{H_2O}= 47
P_{N_2}=573
Arteries
P_{O_2} =95
P_{CO_2}=40
P_{H_2O}=47
P_{N_2}=573

Diffusion of gases through Respiratory Membrane
Layers of the respiratory membrane



Factors that affect rate of gas diffusion through the respiratory membrane

1) Thickness of respiratory membrane

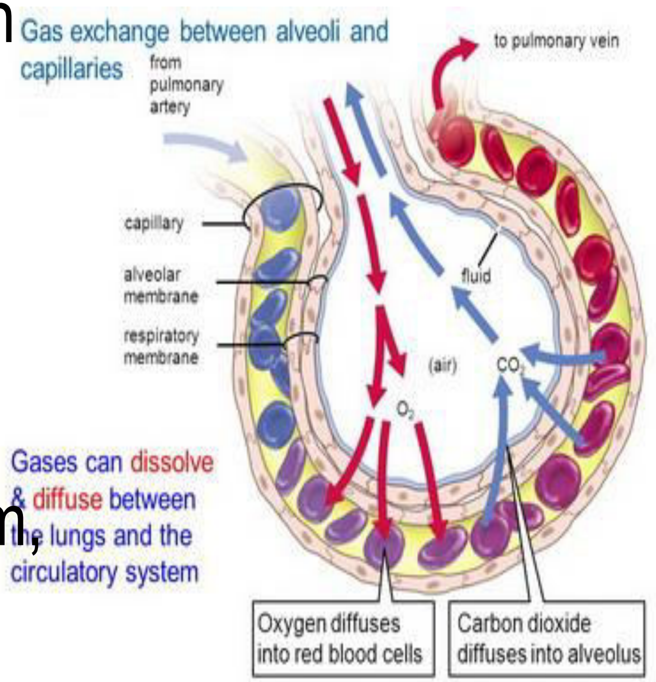
- 2 Factors increases the rate of diffusion through the respiratory membrane

1) Thin respiratory membrane (0.6 μm)

   ☞ ↑ Thickness → ↓ rate of diffusion (e.g. pulmonary edema & fibrosis)

2) Diameter of pulmonary capillary = 8 μm, diameter of RBC =7.2 μm

   ☞ RBC are squeezed through pulmonary capillary → in close contact with respiratory membrane



2) Surface area of respiratory membrane:

- Rate of diffusion is directly proportional to the surface area of respiratory membrane (70 m^2)

☞ ↓ Emphysema, chronic smokers and pneumectomy

3) Partial pressure difference of gases

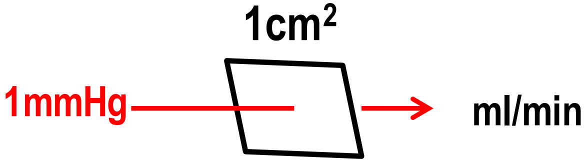
- ↑Partial pressure gradient →↑ rate of diffusion

☞ Gases diffuse from a region of higher partial pr to a region of lower partial pr across the membrane until the pr of the gases on the two sides become equal

	Alveolar air	**Pulmonary capillary blood**	**Partial pressure gradient**
PO_2 mmHg	100	40	60
PCO_2 mmHg	40	46	6

4) Diffusion coefficient

- Definition: Volume of gas in ml which diffuses through 1cm^2 of a membrane in one minute when there is a pressure difference of 1mm Hg across the membrane



$$\text{Diffusion coefficient } \alpha \frac{S}{\sqrt[2]{M.Wt}}$$

- ↑Diffusion coefficient⇨ ↑ rate of gas diffusion
- Diffusion coefficient of O_2=1, CO_2=20, N_2=0.5, CO=0.8, He=0.9 (The diffusion coefficient of CO_2 is 20 times more than that of O_2)

$$D \alpha \frac{\Delta P \times A \times S}{d \times \sqrt[2]{M.Wt}}$$

- D=Rate of diffusion of the gas, ΔP= Pressure gradient, A=Surface area, S=Solubility of the gas, d=Thickness of the respiratory membrane, MW= Molecular weight of the gas.

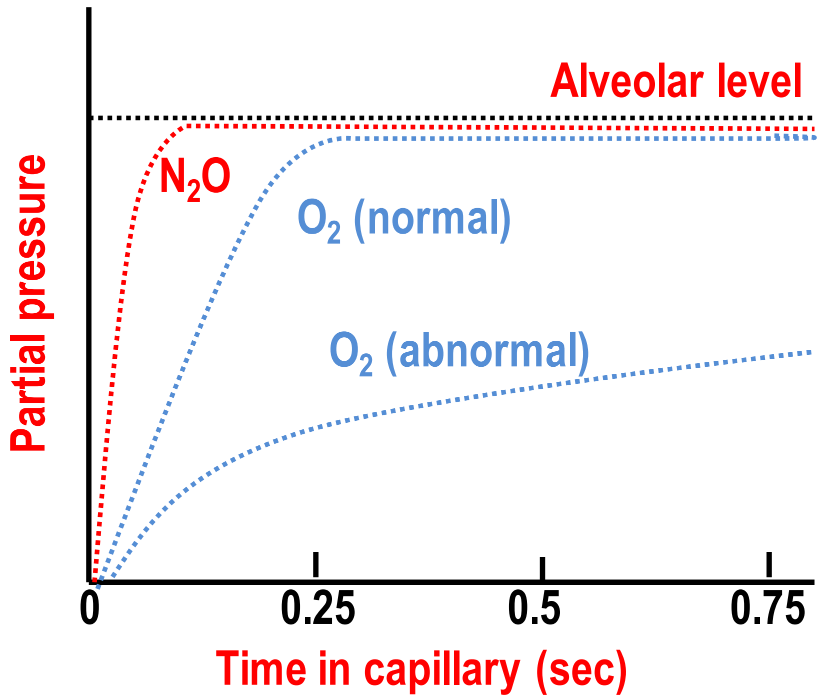
Perfusion- limited & diffusion limited gas exchange

- Depends on their reaction with substances in the blood
- Blood takes 0.75 sec to traverse the pul. capillaries at rest

Perfusion limited exchange

⊙ Aesthetic gas nitrous oxide (N_2O)

- Doesn't form bond with Hb
- ↑ N_2O in blood → rapid ↑ P_{N_2O} (equilibrium within 0.1 sec)
- Diffusion of N_2O can be increased only if perfusion increases

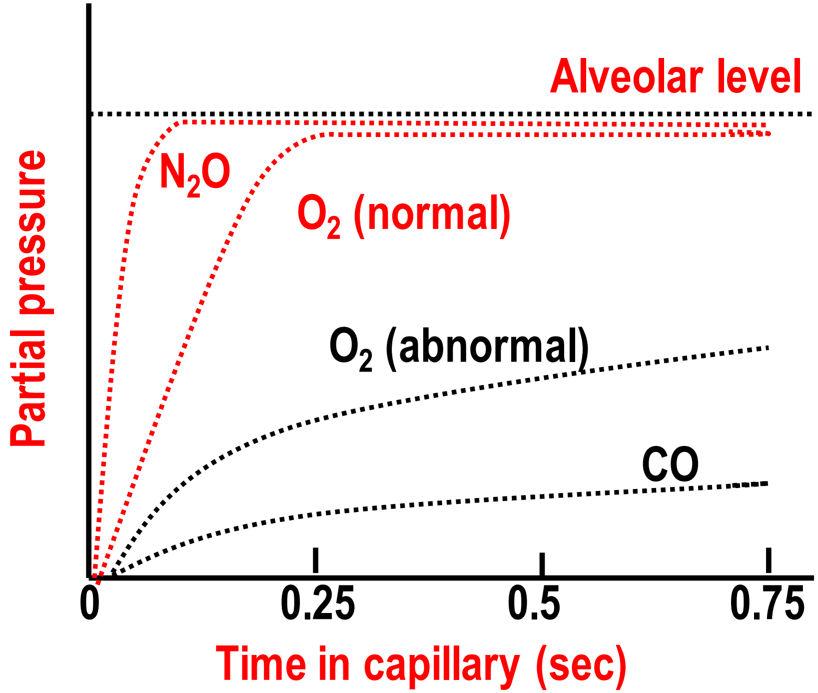


⊙ Oxygen (O_2)

- Reach equilibrium with within 0.3 sec (perfusion limited)
- In fibrosis (thickening of resp membrane) & emphysema (↓surface area of resp membrane) → ↓O_2 diffusion (diffusion limited)

Diffusion limited exchange

- Carbon monoxide (CO)
  - Strong bond to Hb → ↑ CO in blood → minimum ↑ P_{CO}
  - Equilibrium is not reached in 0.75 sec
  - Transfer of CO is limited by the rate of diffusion, not the amount of blood available



Perfusion limited gases	**Diffusion limited gases**
N_2O (anesthetic gas)	CO
CO_2	
O_2 (Normal condition)	O_2 (Emphysema, fibrosis, exercise)