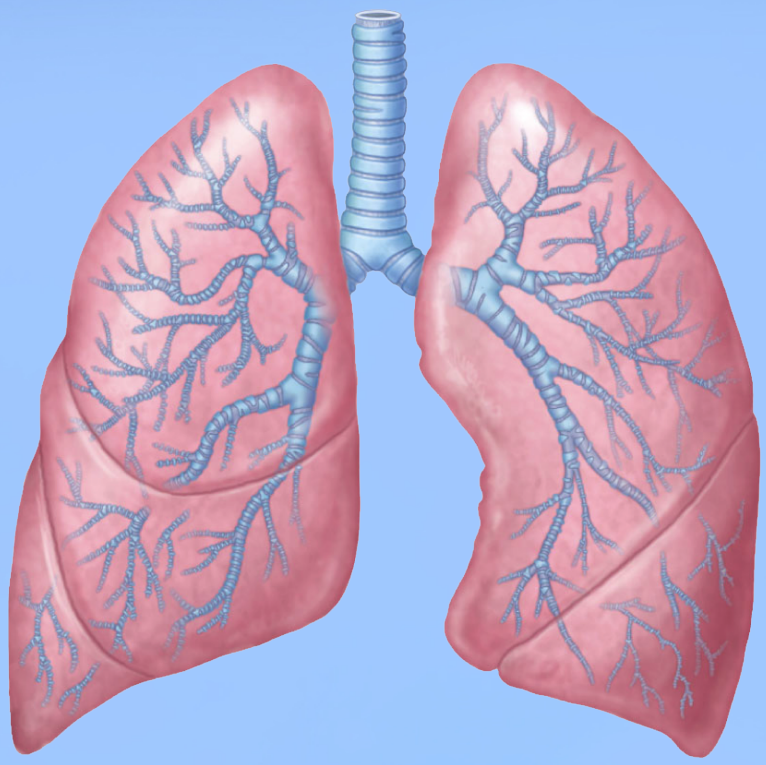
5 Gas Transfer (Diffusion of O_2 and co_2)

Physiology Team 433



Respiratory Block

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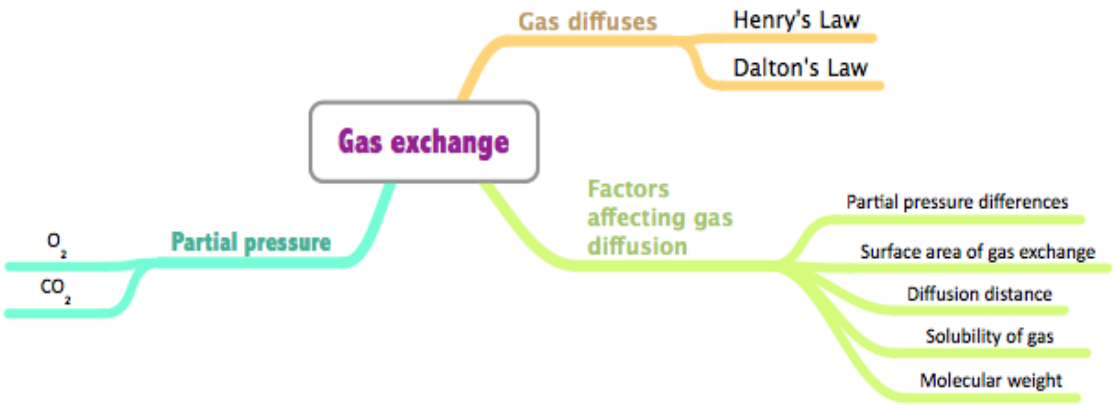
Objectives:

1-Define partial pressure of a gas, how is influenced by altitude.
2- Understand that the pressure exerted by each gas in a mixture of gases is independent of the pressure exerted by the other gases (Dalton's Law
3- Understand that gases in a liquid diffuse from higher partial pressure to lower partial pressure (Henry's Law)
4- Describe the factors that determine the concentration of a gas in a liquid
5- Describe the components of the alveolar-capillary membrane (i.e., what does a molecule of gas pass through).
6- know the various factors determing gas transfer: surface area, thickness, partial pressure difference and diffusion coefficient of gas.
7- State the partial pressures of oxygen and carbon dioxide in the atmosphere, alveolar gas, at the end of the pulmonary capillary, in systemic capillaries, and at the beginning of a pulmonary capillary.

Mind Map:



GAS EXCHANGE THROUGH THE RESPIRATORY MEMBRANE:

Remember that

- The rate of diffusion of each of these gases is directly proportional to the partial pressure of the gas.
- Pressure is caused by the constant impact of kinetically moving molecules against a surface
- Diffusion depends on the difference in the pressure, The pressure of each gas alone is called partial pressure (P)
- After ventilation the next step is the a process called [diffusion of oxygen and carbon dioxide]

DIFFUSION AND FACTORS AFFECTING GAS DIFFUSION:

Diffusion is a process leading to equalization of oxygen and carbon dioxide concentrations between two compartments **(alveolus and pulmonary blood capillary)**

FACTORS AFFECTING GAS DIFFUSION		
Formula	$D \alpha \frac{\Delta P \times A \times S}{d \times \sqrt{MW}}$	
Factors	**1) P: Partial pressure differences** **2) A: Surface area for gas exchange** **3) D: Diffusion distance** 4) **MW: Molecular weight and (S) solubility of gas**	
Diffusion coefficient of the gas	$\frac{S}{\sqrt{MW}}$	**This part of equation is related to the gas**. ✓ Oxygen = 1.0 ✓ Carbon dioxide =20.0 ✓ Nitrogen =0.53. ❖ The remaining values (P,A,d)related to the membrane.
	The importance of it:	The relative rates at which different gases at the same pressure level will diffuse are proportional to their diffusion coefficient
Note that:	✓ O_2 has lower molecular weight than CO_2, But CO_2 is 24 times more soluble than O_2 ✓ Net result: CO_2 diffusion approx. 20 times faster than O_2 diffusion.	

COMPOSITION OF RESPIRATORY AIR:

	Inhaled air	Exhaled air
Nitrogen	79%	79%
Oxygen	20%	16%
Carbon Dioxide	TRACE	4%

Dalton's Law → Pressure exerted by each gas in a mixture of gases is independent of the pressure exerted by the other gases.

Henry's Law → Gases in a liquid diffuse from higher partial pressure to lower partial pressure.

PARTIAL PRESSURE OF O_2 AND CO_2

O_2	
O_2 concentration in the atmosphere	21%
PO_2 in atmosphere: (Total × concentration of o_2)	$(760 \times \frac{21}{100}) =$ 160 mmHg. (1)
PO_2 in alveoli	104 mmHg. (3)

CO_2	
Co_2 concentration in the atmosphere	0.04%
PCO_2 in atmosphere: (Total × concentration of CO_2)	$(760 \text{ mmHg} \times \frac{0.04}{100}) =$ 0.3mmHg. (2)
PCO_2 in alveoli	40 mmHg. (4)

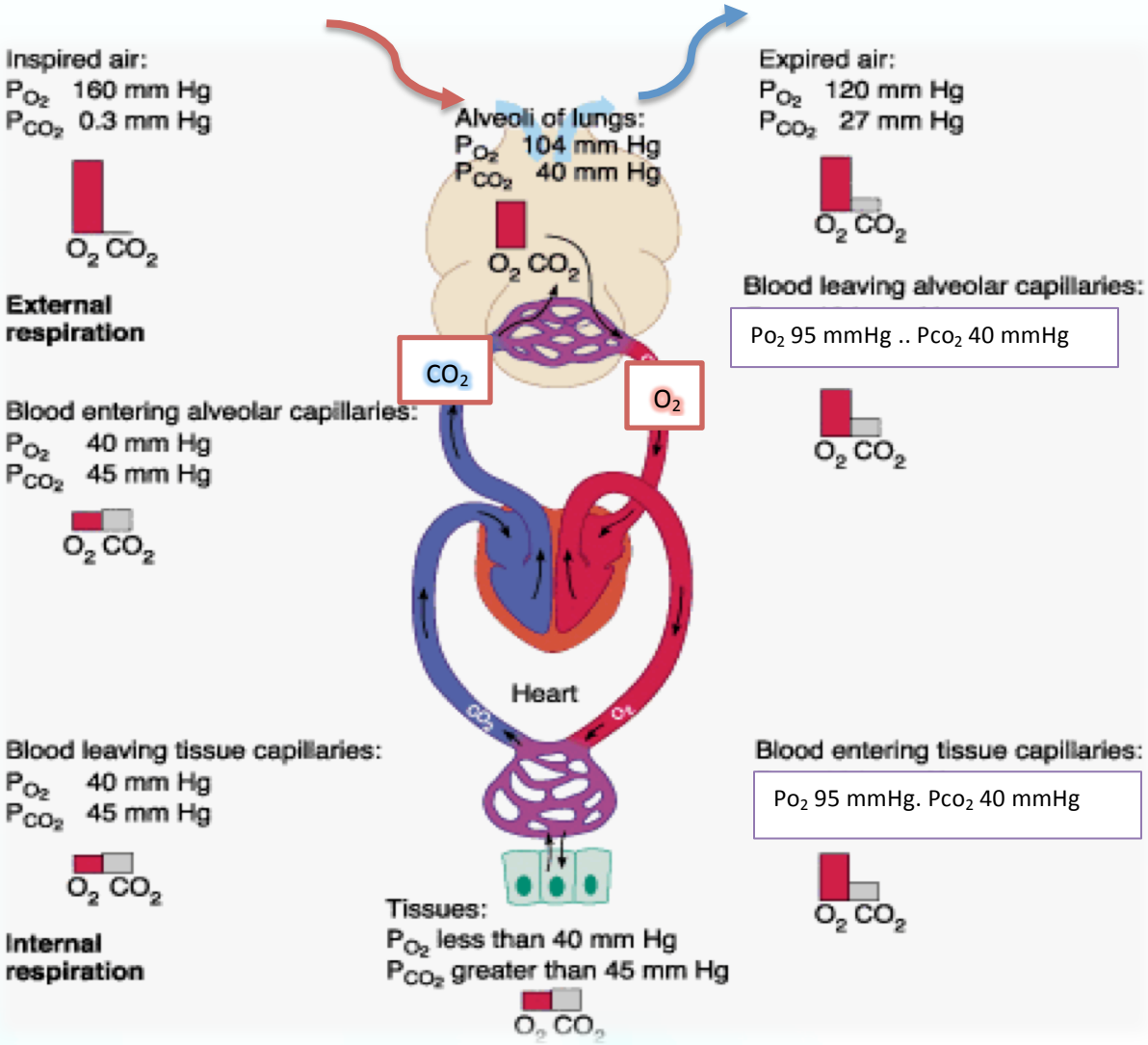
Note

(1) This mixes with "old" air already present in alveolus
(3) It is lower because it's mixed with water and co_2 in the alveoli and that decrease the PO_2

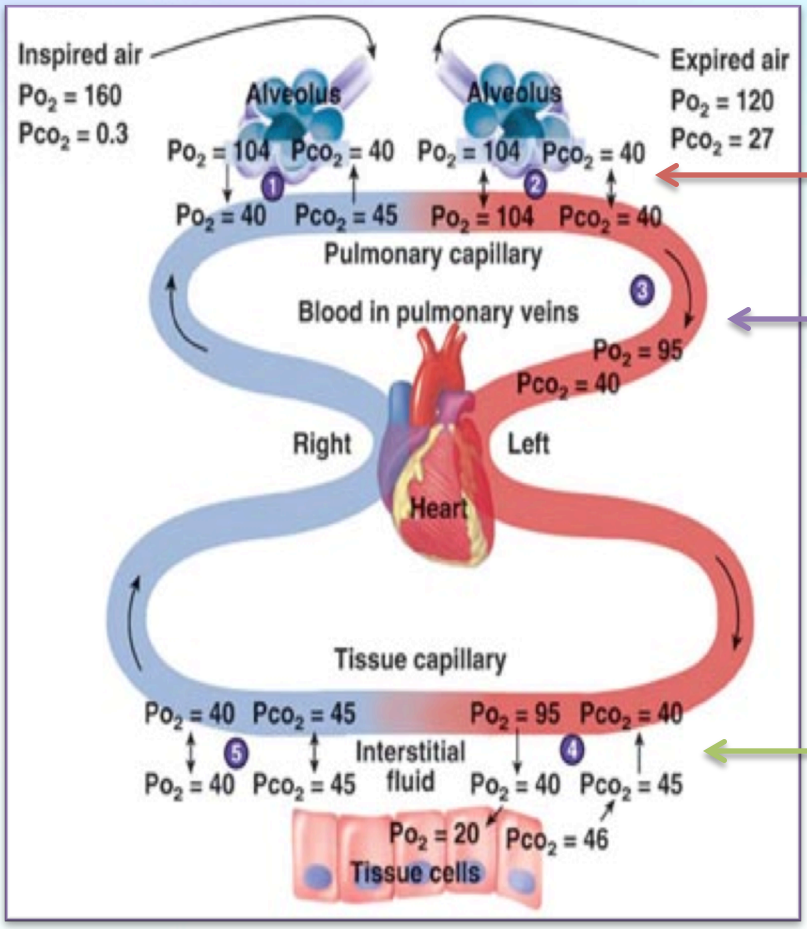
(2) This mixes with high CO2 levels from residual volume in the alveoli.
(4) It is higher because it is mixed with the co_2 from the residual volume in alveoli

PARTIAL PRESSURE OF GASES IN INSPIRED AIR AND ALVEOLAR AIR

	Inspired air	Alveolar air
H_2O	Variable	47 mmHg
CO_2	**0.3 mmHg**	**40 mmHg**
O_2	**160 mmHg**	**104 mmHg**
N_2	**601 mmHg**	**568 mmHg**
Total pressure	**760 mmHg**	**760 mmHg**



GAS EXCHANGE



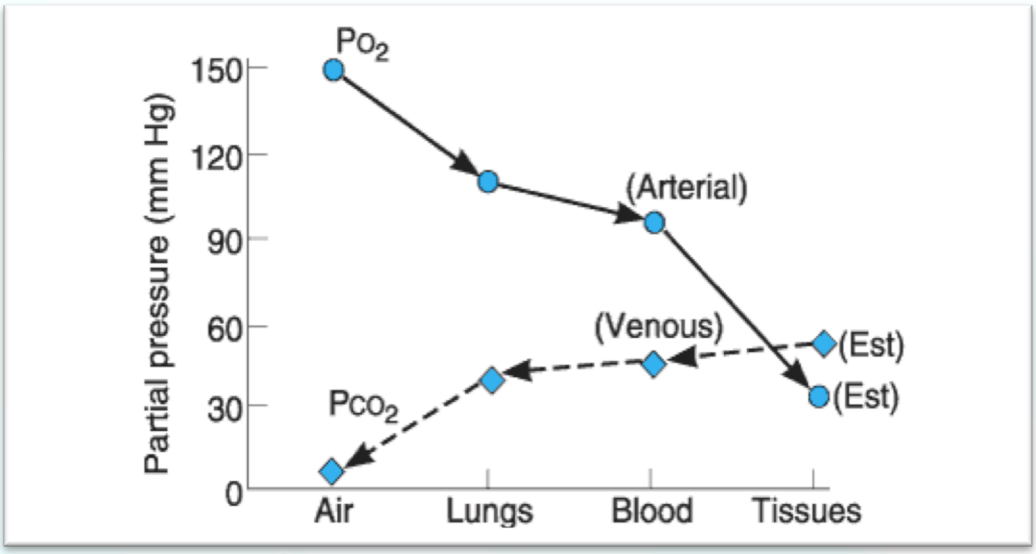
The exchange happens when the pressure diffuses in the Alveoli more than in capillaries.
(hight pressure to lowe pressure)

In the arterial blood (vein capillary) there is the pure oxygenated blood and deoxygenated blood which came from bronchi, So that cause decrease the PO_2. **THAT CALLED PHYSIOLOGICAL SHUNT**

Which is : Mixed of arterial and venous blood in pulmonary circulation and that lead to decrease the PO_2.

The exchanging between the capillaries and tissue stop when there is a balance or
PO_2 in capillaries become 40
PCO_2 in capillaries become 46

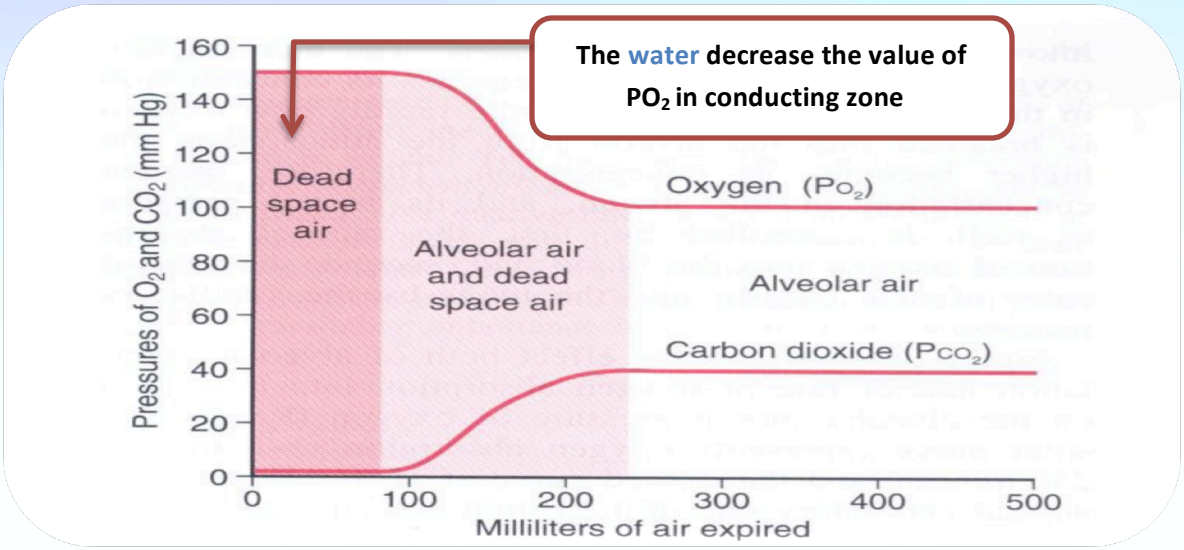
PO_2 AND PCO_2 IN AIR, LUNG AND TISSUE



	PO_2	PCO_2
High in	Atmosphere	Tissue
Low in	Tissue	Atmosphere

PO_2 and **PCO_2** values **in air, lungs, blood, and tissue**. Both O_2 and CO_2 diffuse "downhill" along gradients of decreasing partial pressure.

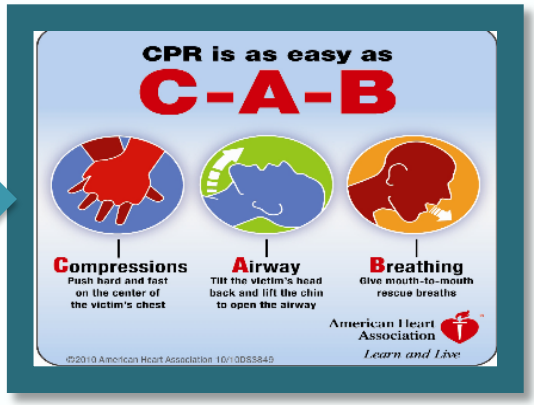
PO_2 AND PCO_2 IN VARIOUS POTIONS OF NORMAL EXPIRED AND INSPIRED AIR



The PO_2 in expired air more than PO_2 in alveoli

Because **PO_2** in **alveoli** (104 mmHg) will mixed with the PO_2 in **dead space** (149 mmHg) and that lead to **increase** the **PO_2**

For that we use the expired air in the first aid



O_2 AND CO_2 CONCENTRATION IN THE ALVEOLI

250 ml of oxygen enter the pulmonary capillaries/min

- At resting condition
- At ventilatory rate of 4.2 L/min

1000 ml of oxygen is absorbed by the pulmonary capillaries per minute

- During exercise

The rate of alveolar ventilation **must increase** 4 times to maintain the alveolar PO_2 at the normal value of 104 mmHg

(كلما زاد الاستهلاك يزيد الإمداد)

200 ml/min, at normal rate of alveolar ventilation of 4.2 L/min.

- Normal rate of CO2 excretion

Changing in the alveolar ventilation to maintain the alveolar PO_2 and PCO_2 at the normal values.

Q1: The diffusion of the gas depends on th difference in:

A- pressure
B- solubility
C- speed

Q2:Co_2 diffusion is faster 20 time more than o_2 because:

A- CO_2 has a lower molecular weight.
B- CO_2 more soluble than O_2.
C- None of the above.

Q3: With increasing of the surface area in gas exchange the diffusion Will :

A- Increase
B- Decrease
C- No change

Q4: Which of these gases we don't use during inhaled and exhaled:

A- CO_2
B- O_2
C- N_2

Q5: The exchange happens when the pressure diffuses in the Alveoli:

A- Less than in capillaries
B- More than in capillaries.
C- Same as in capillaries

Q6: PO_2 in the atmosphere:

A- 160 mmHg
B- 104 mmgh
C- 40 mmgh

Q7: Po2 in the arterial blood of the pulmonary capillaries:

A- 40 mmgh
B- 95 mmgh
C- 104 mmgh

Q8: 4\At resting condition:

A- 200 ml of oxygen enter the pulmonary capillaries/min.
B- 1000 ml of oxygen enter the pulmonary capillaries/min.
C- 250 ml of oxygen enter the pulmonary capillaries/min.

Answers: 1- A 2- B 3- A 4- C 5-B 6- A 7-B 8-C

Summary

- Gas exchange throw the respiratory membrane
- The rate of diffusion of each of these gases is directly proportional to the pressure caused by this gas alone which is called the partial pressure of the gas
- The exchange happen when the pressure diffuse in Alveoli more than in capillaries.

- The factor affect gas diffusion $D \alpha \frac{\Delta P \times A \times S}{d \times \sqrt{MW}}$
- CO_2 diffusion approx. 20 times faster than O_2 diffusion

	N_2	O2	CO_2
Composition of expired air	**79%**	**16%**	**4%**
Composition of inhaled air	**79%**	**20%**	**TRACE**

- **partial pressure of o_2 and co_2**

PO2 in atmosphere 160 mmHg PO2 in alveoli 104 mmHg

PCO_2 in atmosphere 0.3mmHg PCO_2 in alveoli 40 mmHg

	PO_2	PCO_2
High in	atmosphere	tissue
Low in	Tissue	atmosphere

- **Physiological shunt**: Mixed of arterial and venous blood in pulmonary circulation and that lead to decrease the PO_2
- The PO_2 in expired air more than PO_2 in alveoli
- O_2 and PO_2 concentration in the alveoli
- During the exercise, the rate of alveolar ventilation **must increase** maintain the alveolar PO_2 at the normal value of 104 mmHg

http://www.youtube.com/watch?v=nRpwdwm06Ic