Physiology Team 432

6th Lecture

Oxygen and Carbon dioxide Transport

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Oxygen and Carbon dioxide Transport

Objectives:

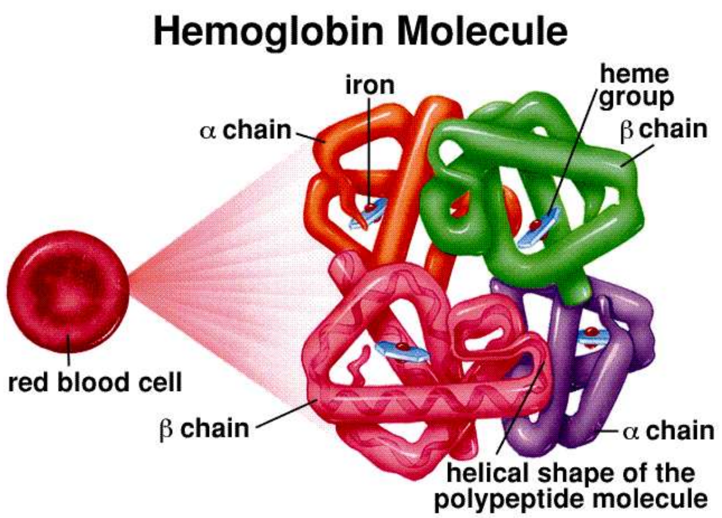
1. Understand the forms of oxygen transport in the blood, the importance of each.
2. Differentiate between O2 capacity, O2 content, and O2 saturation.
3. Describe (oxygen-hemoglobin dissociation curve).
4. Define the P50 and its significance.
5. How DPG, temperature, H+ ions and PCO2 affect affinity of O2 for Hemoglobin and the physiological importance of these effects.
6. Describe the three forms of carbon dioxide that are transported in the blood, and the chloride shift.

Forms of O_2 Transport

- Dissolved in plasma **“soluble”** **3%**
- Bound to Hemoglobin **“Oxyhemoglobin”** **97%**

* When PO_2 = 100 mmHg

* For each 100ml of blood



❖ **Hemoglobin has 4 groups of Heme , each one can carry one Oxygen molecule.**

If Hb carried 4 molecules of Oxygen then it is fully saturated

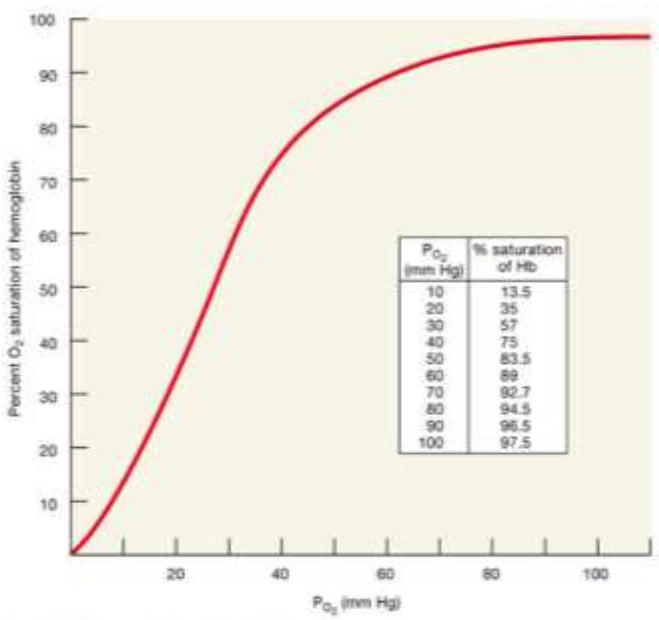
❖ **PO_2 affects:**

1-the Hb–Oxygen binding :

- If PO_2 increases Hb bind O_2
- If PO_2 decreases Hb release O_2

2-the saturation level in a relation called :
” Oxyhemoglobin Saturation Curve” :

- Higher PO_2 results in greater Hb saturation
- S-shaped curve or sigmoid.



❖ **O_2 binding capacity:** maximum amount of O_2 bound to hemoglobin (ml O_2/100ml blood) measured at 100% saturation.

❖ **Saturation:** % of heme groups bound to O_2 "how many Hb is saturated"

$$Saturation\ of\ HB = 100 \times \frac{O2\ Content}{\text{Oxygen Binding Capacity}}$$

❖ **O_2 content :**

- It is the amount of Oxygen in blood (ml O_2/100 ml Blood)
- Differs from person to another, depending on the amount of Hb each person has and Hb saturation.
- To measure it :

  In **arterial blood** we need to know how many gram of Hb is in 100ml of blood (normal=13-18g).

  When the saturation is 100%:

  15g Hb * 1.34 = 20 ml O_2

  "1.34 is a constant of the amount of oxygen that 1g Hb can carry"

  But if Hb is not fully saturated, e.g. if it is 97%:

  (15g Hb*97/100) * 1.34 = 19.4 ml O_2

  In **venous blood** we must take out the amount of oxygen released from hemoglobin to the tissues which is:

  - at rest 25% or 5ml O_2 per each 100ml blood. "Constant"

  So the O_2 content =

  19.4 - 5 = 14.4 ml O_2/100ml blood

  - During strenuous exercise , the oxygen uptake to the tissue increase three folds so 15ml O_2 is given/100ml blood.

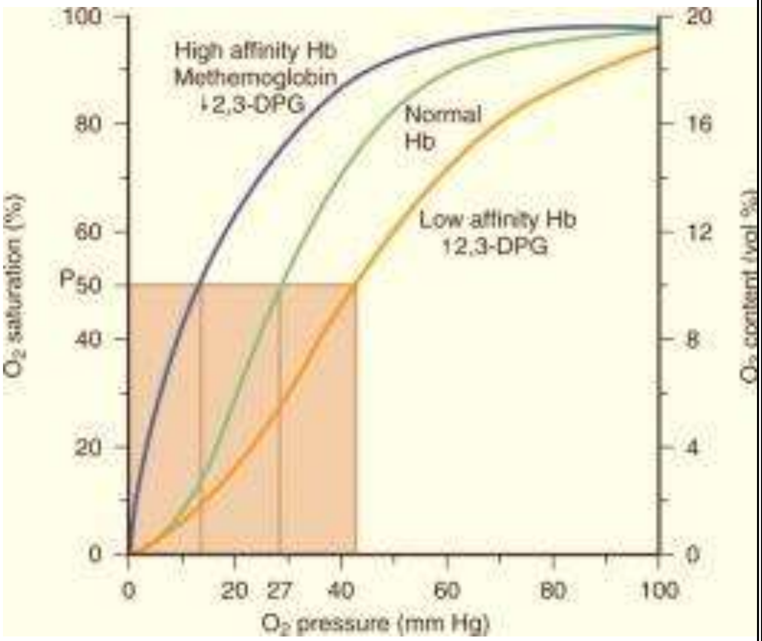
  Which makes the O_2 content =

  19.4 - 15 = 4.4ml O_2/100ml blood.

- At rest , tissues consume 250ml O_2/ min and produce 200ml CO_2 "5000ml blood".

❖ Oxyhemoglobin Dissociation Curve

A curve which shows the relation between PO_2 and $Hb\text{-}O_2$ and O_2 content



- The position of it can be determined by <u>Measuring the P50</u>

  P50 : is **<u>arterial</u>** PO_2 at which 50% of the Hb is saturated with O_2,

  Normally P50 = 26.5 or 27.

Left shifted curve :	Right shifted curve :
↓P50 ↑affinity of Hb to O2	↑P50 ↓affinity of Hb to O2
- easy binding "loading" - hard releasing "unloading" - in fetal Hb	- hard binding "loading" - easy releasing "unloading" - during exercise
↓ (H+, temperature, PCO2, 2-3DPG) ↑pH	↑ (H+, temperature, PCO2, 2-3DPG) ↓pH

- **2,3DPG:**
  - It is synthesized in RBCs from the glycolytic pathway.
  - Binds tightly to reduce Hb.
  - Increases in the RBCs in anemia and hypoxemia to maintain tissue oxygenation cause its increased facilitates the oxygen rlease.

❖ Utilization coefficient:

The percentage of the blood that gives up its oxygen as it passes through the tissues capillaries.

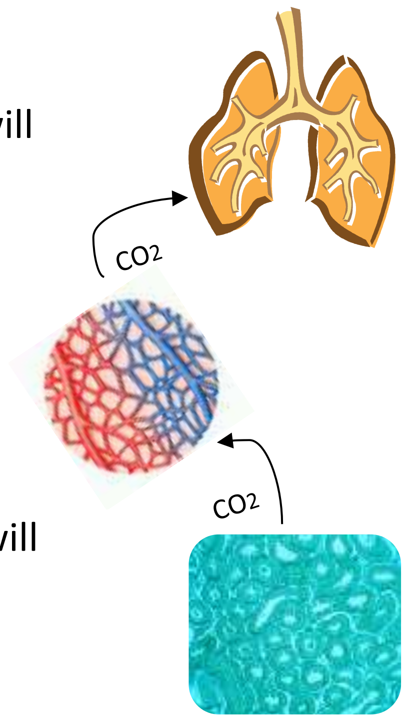
$$= \frac{O_2 \text{ delivered to the tissue}}{O_2 \text{ content of arterial blood}}$$

- Normally at rest = 5ml/20ml = 25%
- During exercise = 15ml/20ml = 75%-85%

❖ **Bohr Effect:** the effect of carbon dioxide and hydrogen ions on the curve.

At lung:

- The movement of CO_2 from blood to alveoli will decrease blood CO` & H+
  and increase O_2 affinity to Hb , that will shift the curve to left "allow more O_2 transport to tissues"



At tissues :

- The movement of CO_2 from tissues to blood will increase blood CO_2 & H+
  and decrease O_2 affinity to Hb , that will shift the curve to right.

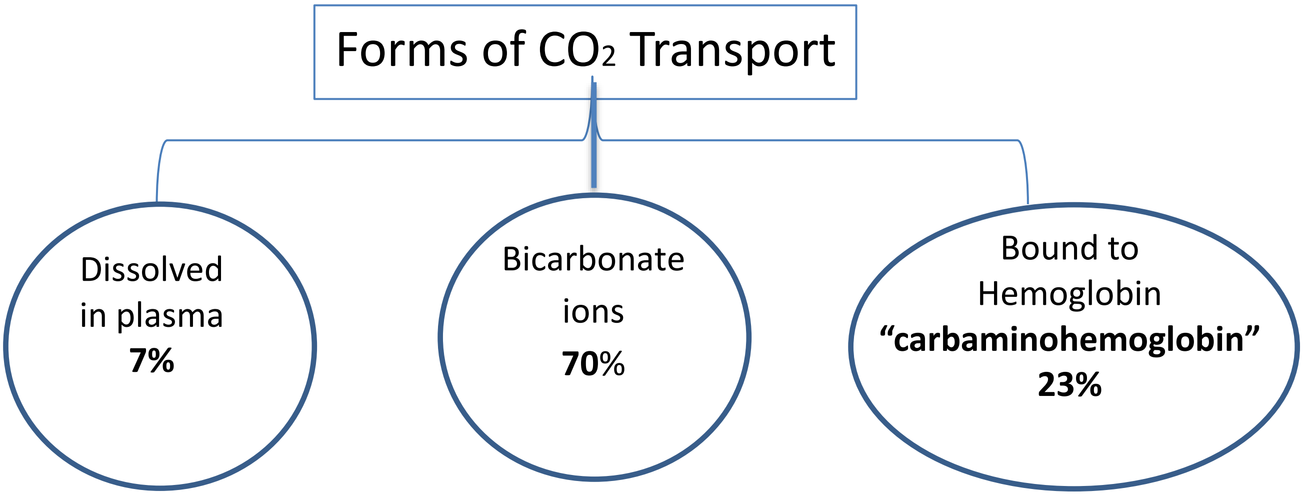
❖ **Dissolved O_2:** unbound O_2 in blood (ml O_2/100ml blood)

- It is mainly responsible for creating Partial Pressure of O_2 (PO_2)
- **At arterial blood/100 ml :** PO_2 = 95mmHg → 0.29ml O_2 is dissolved. 0.17ml of it transported to tissues

- **At venous blood/100ml :** PO2 =40mmHg → 0.12ml O2 <u>remain</u> dissolved.

❖ **Displacement of O2 by Carbon monoxide:**

The affinity of Hb to Co is very high, Co can binds with Hb about 250 times as O2, Which causes left shift of the O2-Hb curve.



- Each 100ml of blood carries 4ml CO2 from the tissue and gives 5ml O2 per min.

- **Formation of Bicarbonate :**

A- In the systemic capillaries:

1- Carbon dioxide produced in the tissue cells diffuses into the blood plasma. The largest fraction of carbon dioxide diffuses into the red blood cells.

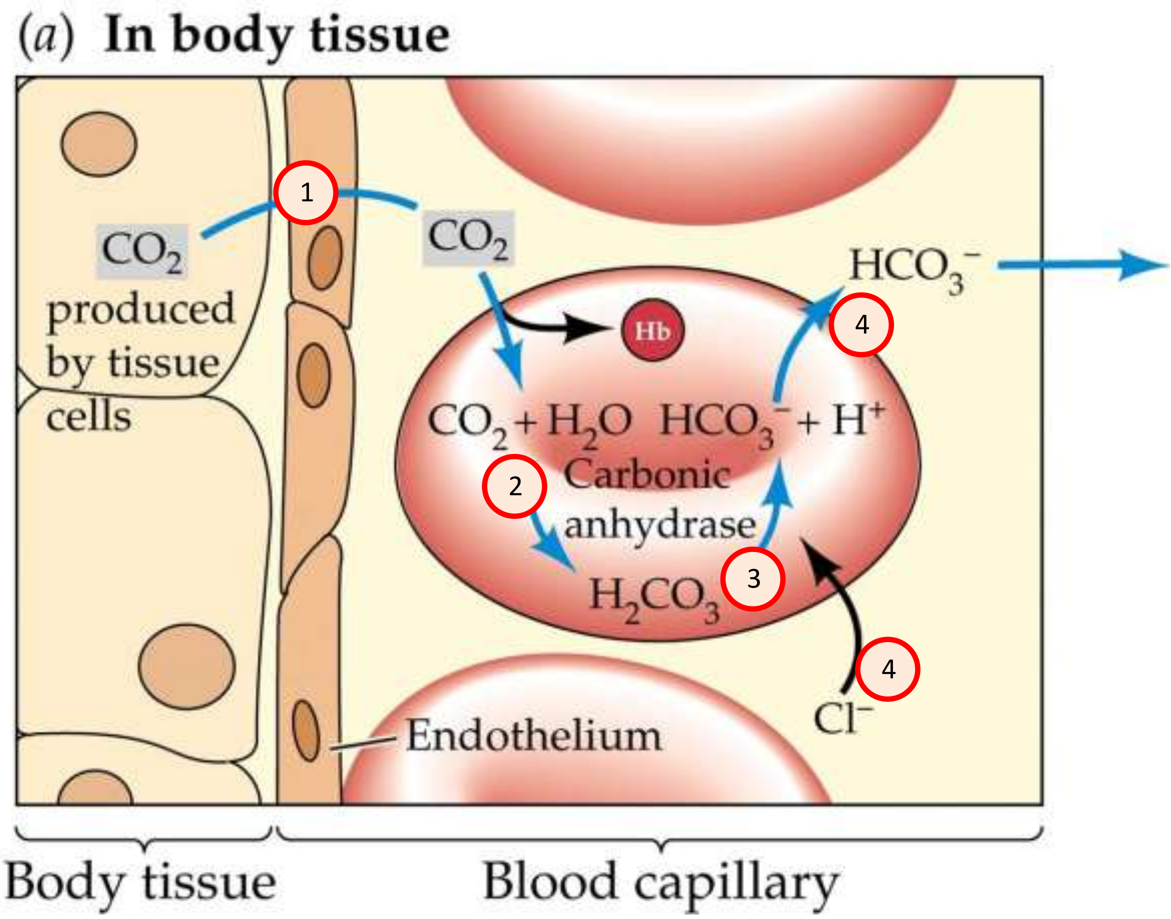
The formation of bicarbonate ions, (HCO_3^-) takes place by the following reactions:

2- Hydration of CO_2: $CO_2 + HOH === H_2CO_3$

3- Dissociation of H_2CO_3: $H_2CO_3 === H^+ + HCO_3^-$

* The H_2CO_3/HCO_3^- combination acts as the primary buffer of the blood.

4- Bicarbonate diffuses out of the red blood cells into the plasma in venous blood and Chloride ion always diffuses in an opposite direction of bicarbonate ion in order to maintain a charge balance. This is referred to as the "chloride shift".

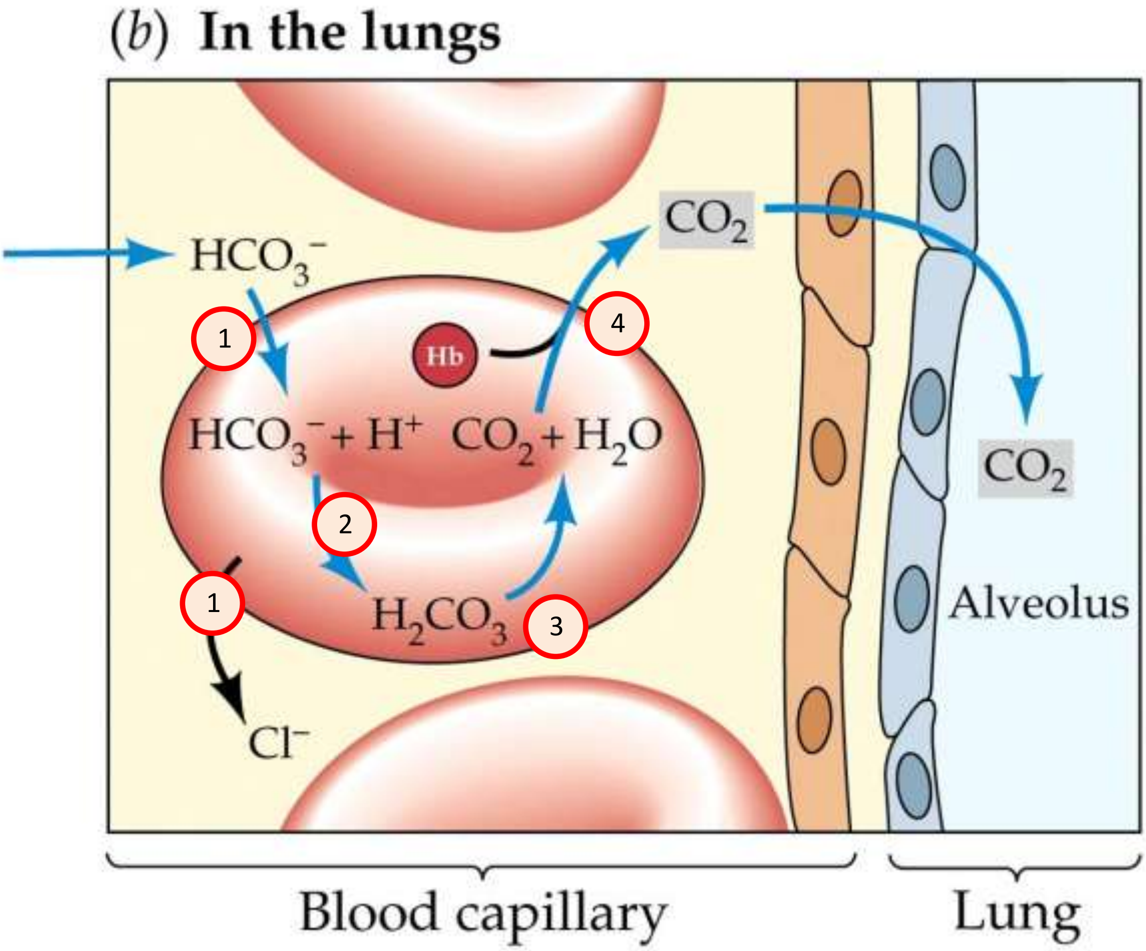


B- In the pulmonary capillaries:

1- Bicarbonate diffuses into the red blood cells and Chloride ion diffuses out "chloride shift".

The reformation of CO2 in step 2 & 3

4- Carbon dioxide produced in RBC diffuses into the blood plasma. Then to the alveoli.



❖ The Haldane effect :

- When O2 binds with HB, CO2 released
- This binding causes Hb to become stronger acid and this in turn displaces CO2 from blood into alveoli.

❖ Respiratory Exchange rate Ratio " quotient"

The ratio between the amount of CO_2 exhaled and O_2 inhaled in one breath.

$$R = \frac{rate\ of\ CO2\ output}{\text{rate of O2 uptake}}$$

- Normally = 4/5 = 82% or 0.82
- In a carbohydrate diet R=1, cause each O_2 molecule used in carbohydrate metabolism produce 1 molecule of CO_2

When fats only is used R=0.7