

Oxygen and Carbon dioxide Transport

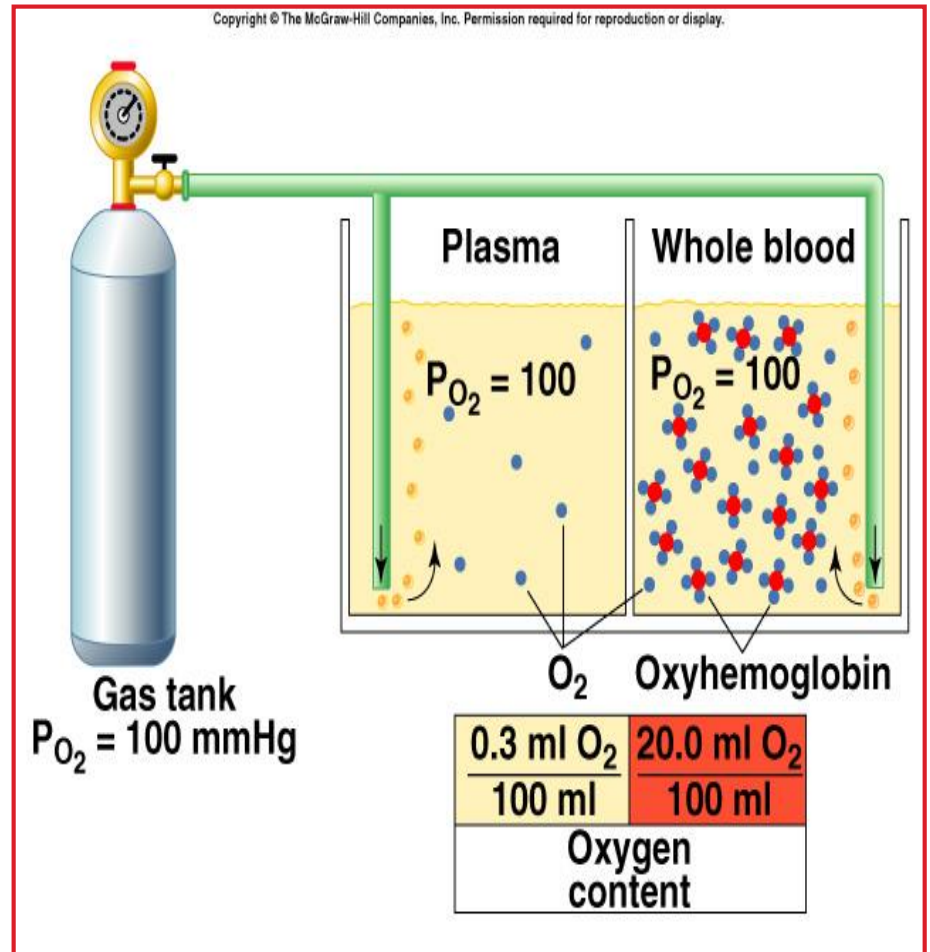
Dr.Thamir Al-khlaiwi
Physiology department
College of medicine

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.

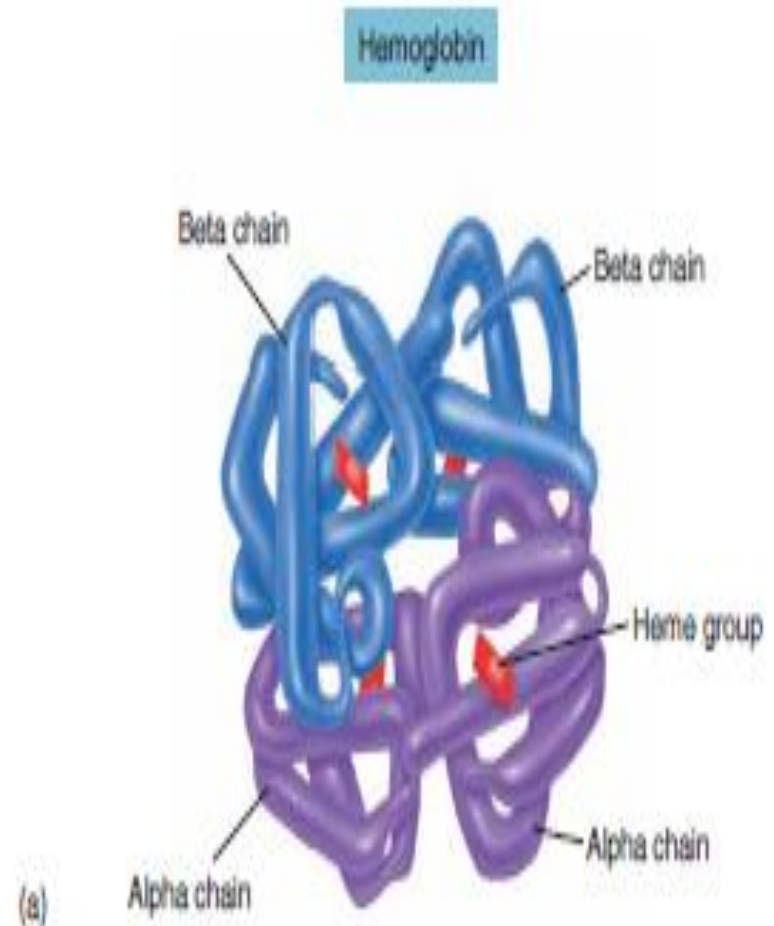
Forms of O₂ transport

- ▶ The presence of hemoglobin in the red blood cells allows the blood to transport 30 to 100 times as much oxygen as could be transported in the form of dissolved oxygen in the water of the blood.



Transport of O₂ and CO₂ in the blood and body fluids

- ▶ O₂ is mostly transported in the blood bound to hemoglobin and to a lesser extent in dissolved state.
- ▶ If the P_{O₂} increases Hb binds O₂.
- ▶ If P_{O₂} decreases Hb releases O₂.
- ▶ O₂ binds to the heme group on hemoglobin, with 4 oxygens /Hb.



Terminology:

- **O₂ content:** amount of O₂ in blood (ml O₂/100 ml blood)
- **O₂-binding capacity:** maximum amount of O₂ bound to hemoglobin (ml O₂/100 ml blood) measured at 100% saturation.
- **Percent saturation:** % of heme groups bound to O₂
$$\% \text{ saturation of Hb} = \frac{\text{oxygen content}}{\text{O}_2\text{-binding capacity}} \times 100$$
- **Dissolved O₂:** Unbound O₂ in blood (ml O₂/100 ml blood).

Cont...transport of oxygen in arterial blood

- ▶ **When blood is 100% saturated:** each gram of Hb carries 1.34 ml O₂.

O₂-binding capacity = 15g Hb x 1.34 O₂=20.1 ml.

But when the blood is only 97% saturated: each 100 ml blood contain 19.4 ml O₂.

- ▶ Amount of oxygen released from hemoglobin to the tissues is: 5ml/100ml blood.

O₂-binding capacity in venous blood =19.4-5= 14.4 ml.

- ▶ **During strenuous exercise:** oxygen uptake by the tissue increases 3-5 folds.

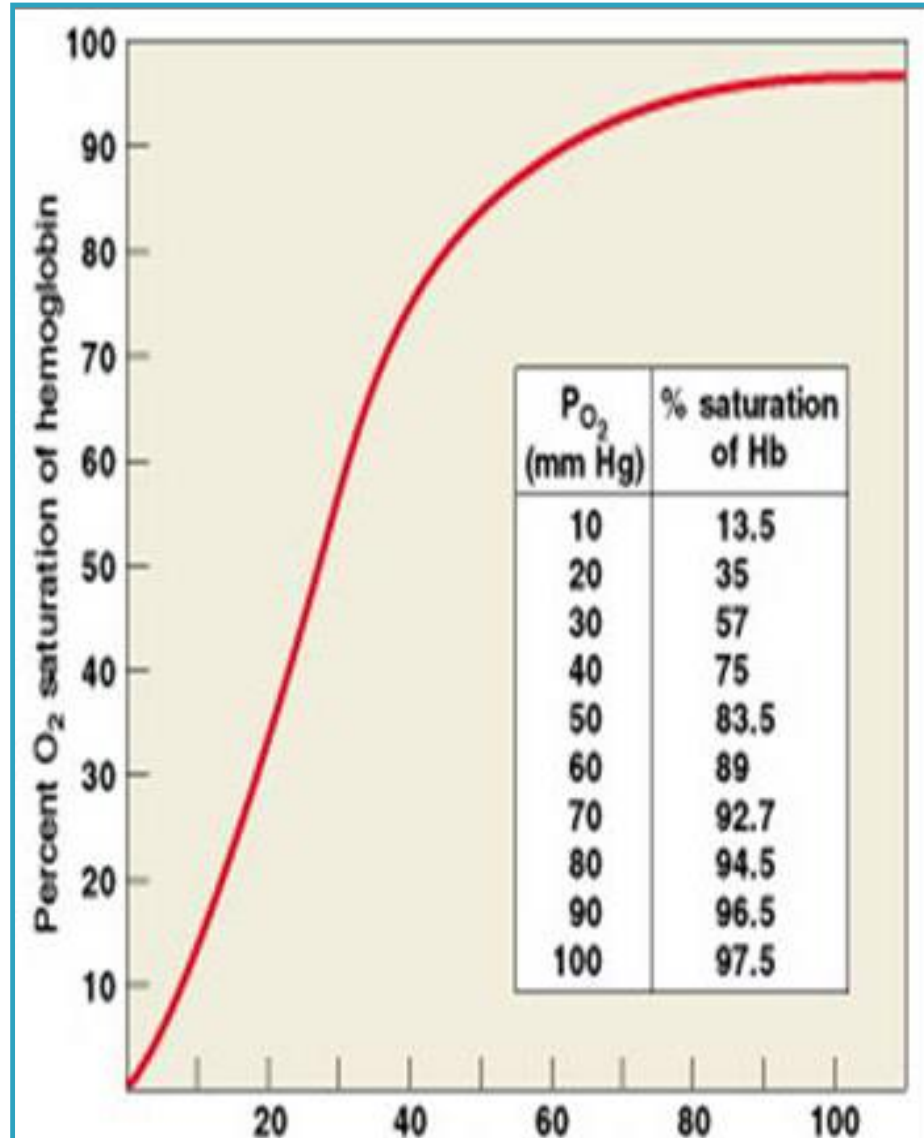
15 ml O₂ is given to the tissues /100 ml blood.

- ▶ **O₂ binding capacity in venous blood** =19.4-15=4.4 ml O₂ /100ml blood.

- ▶ **At rest, tissues consume 250 ml O₂ /min and produce 200ml CO₂.**

Oxygen transport in Blood

- 3% **dissolved** in plasma.
- 97% bound to hemoglobin (**oxyhemoglobin**).
- Higher PO_2 results in greater Hb saturation.
- The relation between PO_2 and Hb- O_2 is not linear. The curve is called: Oxygen hemoglobin Saturation Curve Which is S- shaped or sigmoidal.



Oxygen hemoglobin Dissociation Curve

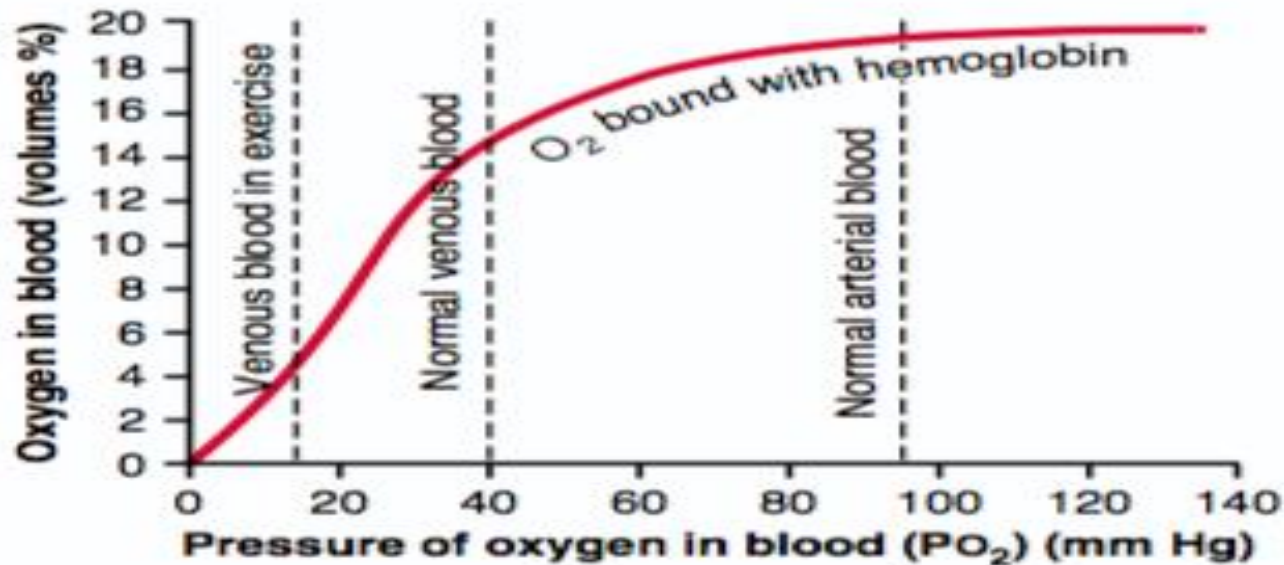


Figure 40-9

Effect of blood PO₂ on the quantity of oxygen bound with hemoglobin in each 100 milliliters of blood.

Factors that shift the O₂- Hb dissociation curve

- ▶ The position of the dissociation curve can be determined by measuring the P₅₀.
- ▶ **P₅₀**: The arterial PO₂ at which 50% of the Hb is saturated with O₂, normally P₅₀= 26.5
- ▶ **Decreased P₅₀**: means increased affinity of Hb to O₂ or shift of the curve to left.
- ▶ **Increased P₅₀**: means decreased affinity or shift of the curve to right.

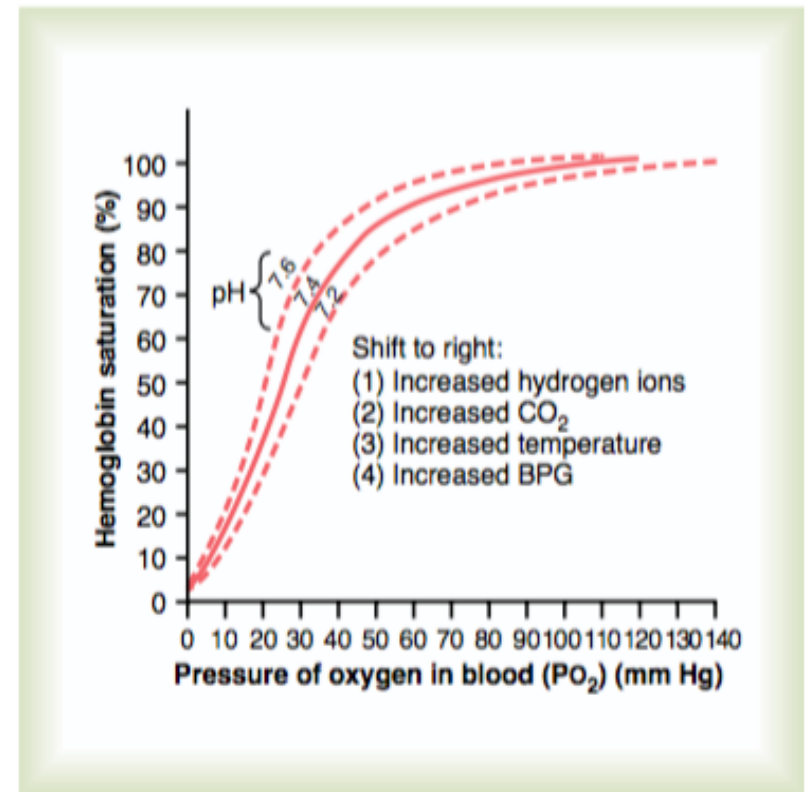


Figure 40-10

Shift of the oxygen-hemoglobin dissociation curve to the right caused by an increase in hydrogen ion concentration (decrease in pH). BPG, 2,3-biphosphoglycerate.

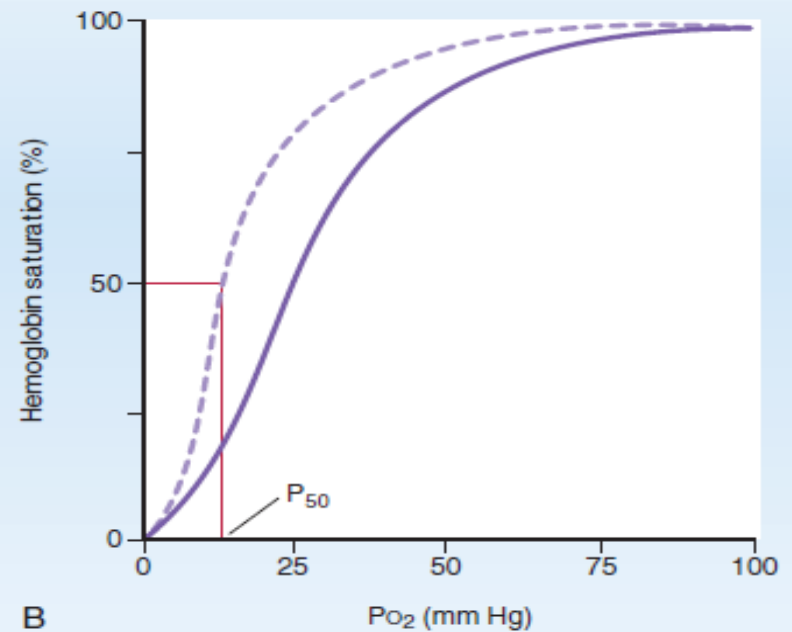
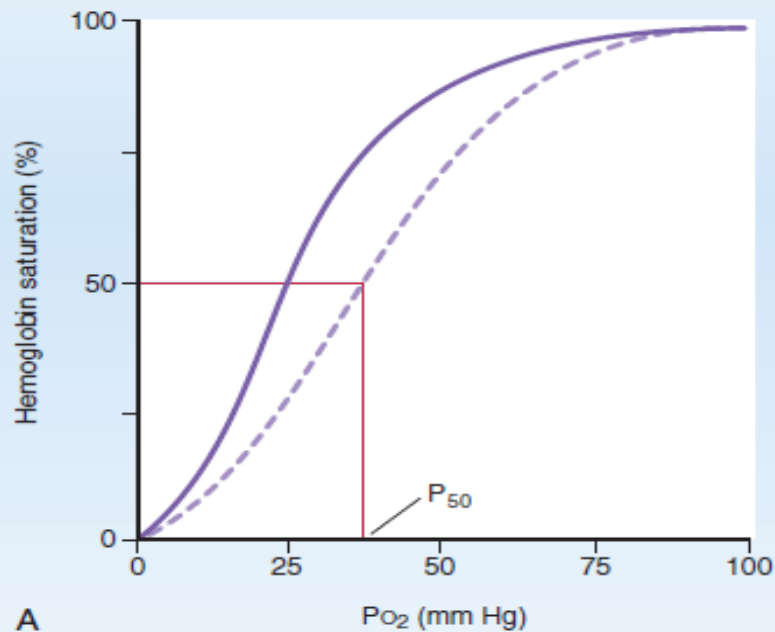
Shifts of O₂-hemoglobin dissociation curve

Causes of shift to the right

- ↑ P_{CO₂}
- ↓ pH
- ↑ Temperature
- ↑ 2,3-DPG

Causes of shift to the left

- ↓ P_{CO₂}
- ↑ pH
- ↓ Temperature
- ↓ 2,3-DPG
- Hemoglobin F



The Rt and Lt shifts:

- ▶ **Rt shift** means the oxygen is unloaded to the tissues from Hb, while **Lt shift means** loading or attachment of oxygen to Hb.

Increased 2,3DPG, H⁺, Temperature , PCO₂ shift the curve to right.

- ▶ 2,3DPG is synthesized in RBCs from the glycolytic pathway , it binds tightly to reduced Hb. increased 2,3 DPG facilitate the oxygen release and shifts the dissociation curve to Rt.
- ▶ **2,3 DPG increases in the RBCs** in anemia and hypoxemia, and thus serves as an important adaptive response in maintaining tissue oxygenation
- ▶ **Fetal Hb:** has a P50 of 20 mmHg in comparison to 26.5 mmHg of adult Hb.

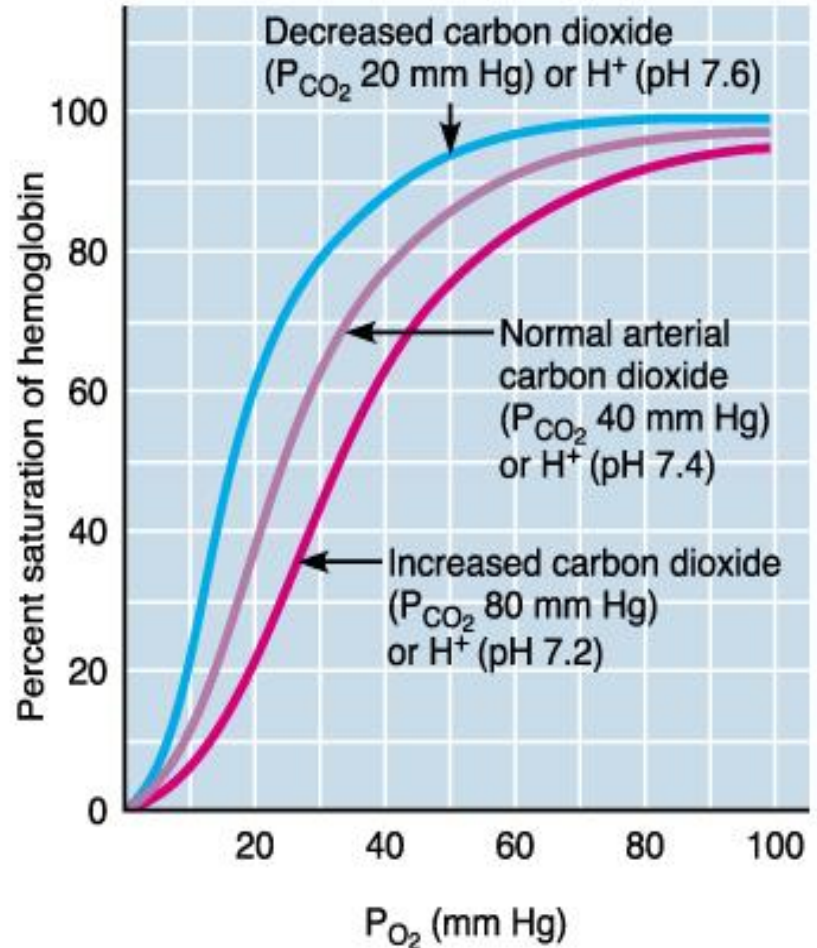
Bohr Effect:

➤ Effect of carbon dioxide and hydrogen ions on the curve

(Bohr effect)

➤ At lung: movement of CO₂ from blood to alveoli will decrease blood CO₂ & H⁺ → shift the curve to left and increase O₂ affinity to Hb allowing more O₂ transport to tissues.

➤ At tissues: the reverse occurs.



(b)

Pulse Oximetry

- Measures % saturation of arterial blood (e.g., of the finger) using dual-wavelength spectrophotometry. Because oxyhemoglobin and deoxyhemoglobin have different absorbance characteristics, the machine calculates % saturation from absorbance at two different wavelengths.
- Pulse oximetry measures arterial % saturation because arterial blood “pulses,” whereas venous and capillary blood do not; background absorbance from venous and capillary blood is subtracted out.
- Pulse oximetry does not directly measure PaO₂. However, knowing % saturation, one can estimate PaO₂ from the O₂-hemoglobin dissociation curve.

Transport of oxygen in dissolved state

- ▶ Only 3% of O₂ is transported in the dissolved state,
- ▶ At normal arterial PO₂ of 95 mmHg , about 0.29 ml of oxygen is dissolved in each 100ml of blood.
- ▶ When the PO₂ of the blood falls to 40 mmHg in tissue capillaries, only 0.12 of oxygen remains dissolved.
- ▶ 0.17 ml of oxygen is normally transported in the dissolved state to the tissues per each 100 ml of blood.

Combination of Hb with CO (displacement of oxygen)

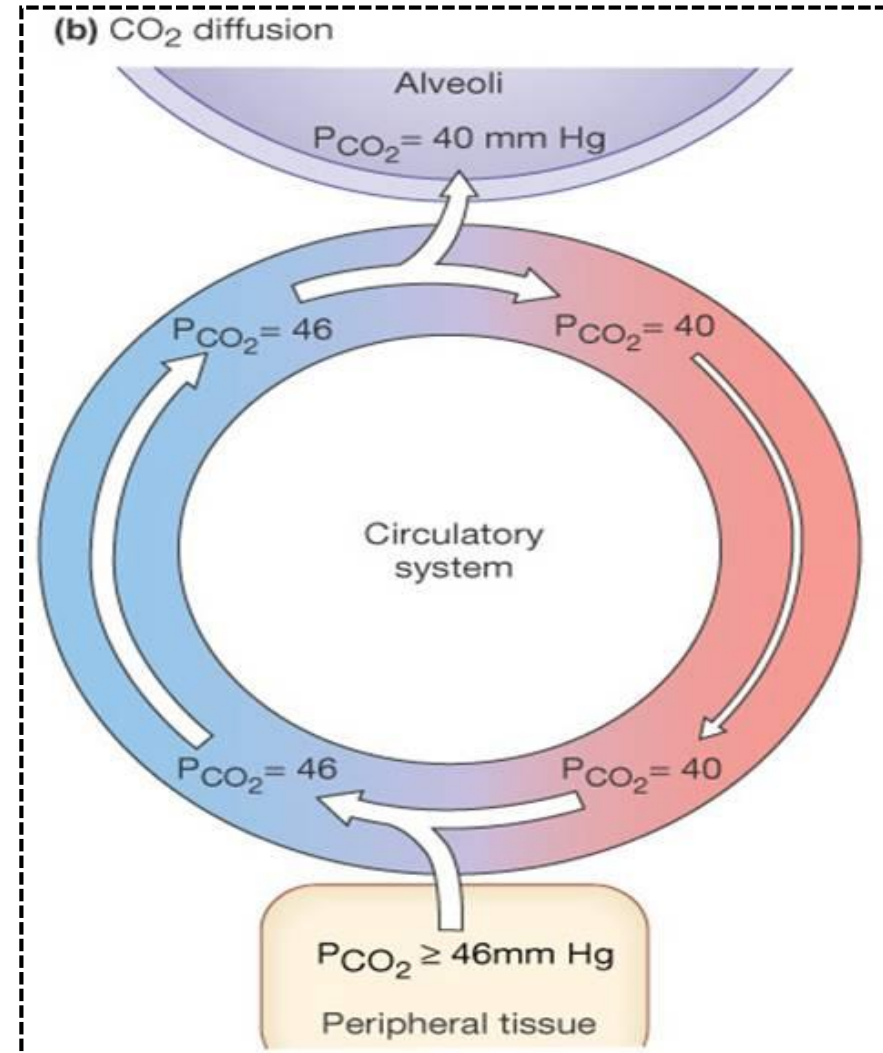
- ▶ CO combines with Hb at the same point on the Hb molecule as does oxygen.
- ▶ It binds with Hb about 250 times as much as O₂ (affinity of Hb to CO is very high (250 times) that to O₂).
- ▶ It causes Lt shift of the O₂-Hb curve.

Transport of carbon dioxide in the blood

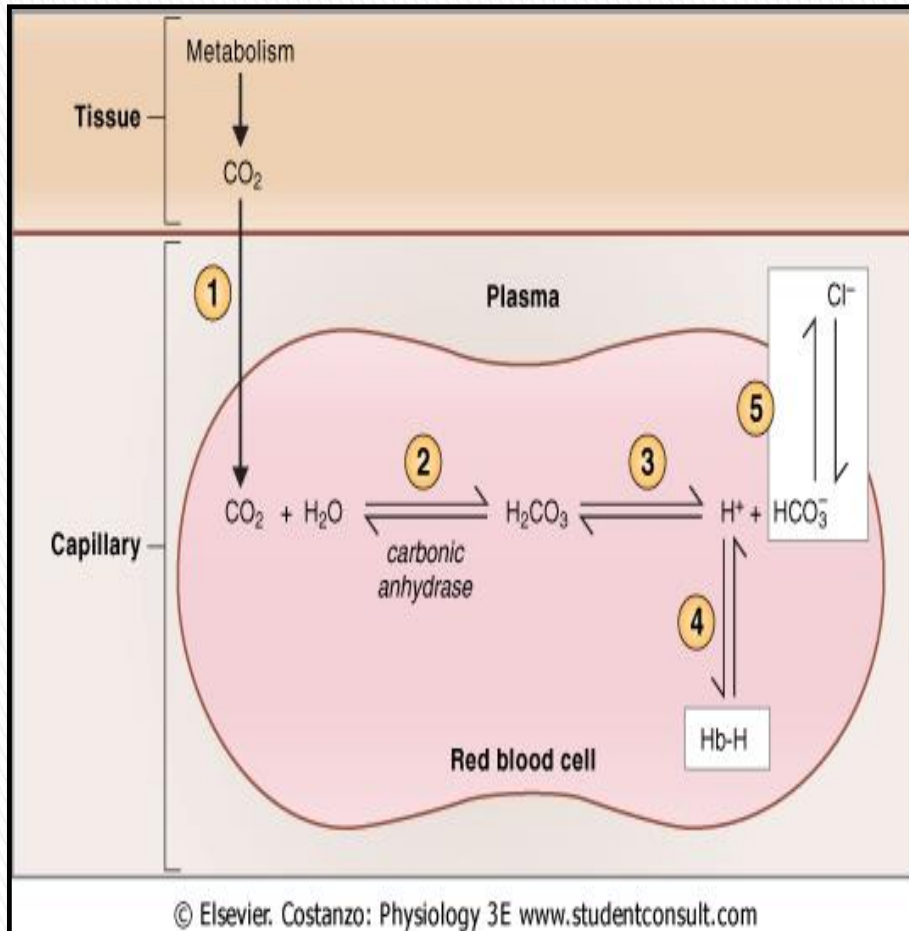
➤ **Carbon dioxide is transported in three forms:**

1. Dissolved CO₂ 7%
2. bicarbonate ions 70 %
3. Carbaminohemoglobin (with Hb) 23%.

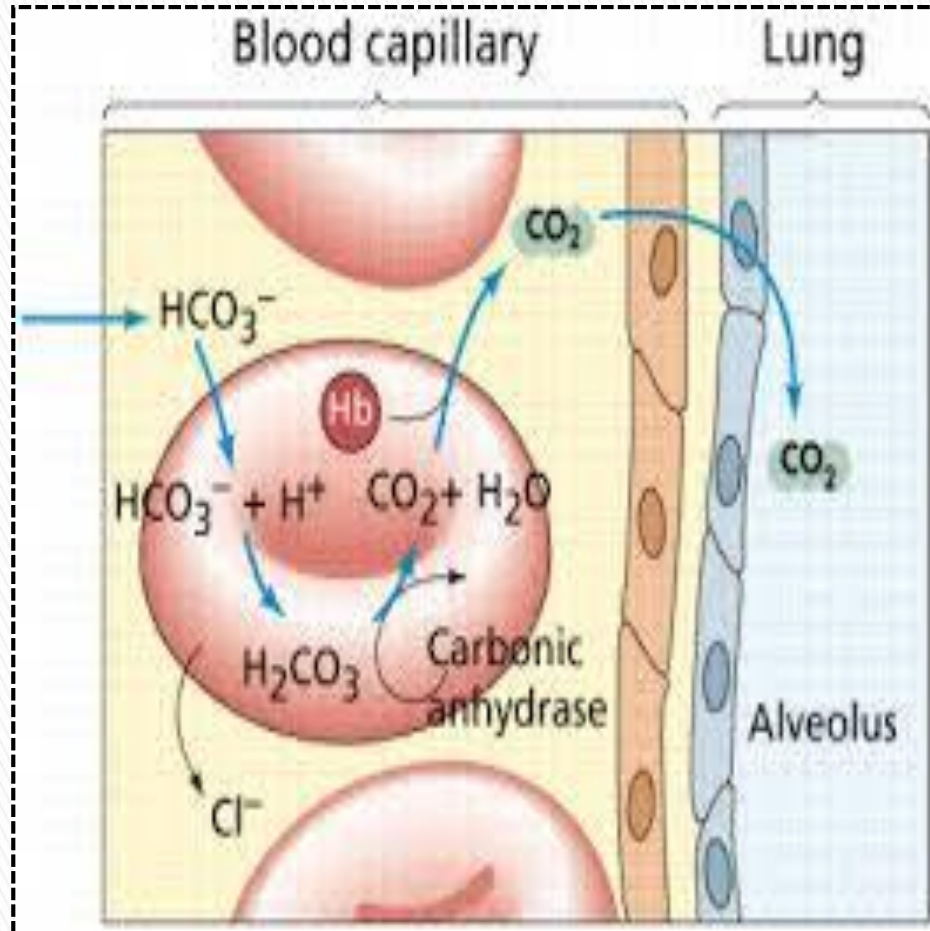
Each 100 ml of blood carry 4 ml of CO₂ from the tissues.



Formation of HCO_3^- & Chloride shift



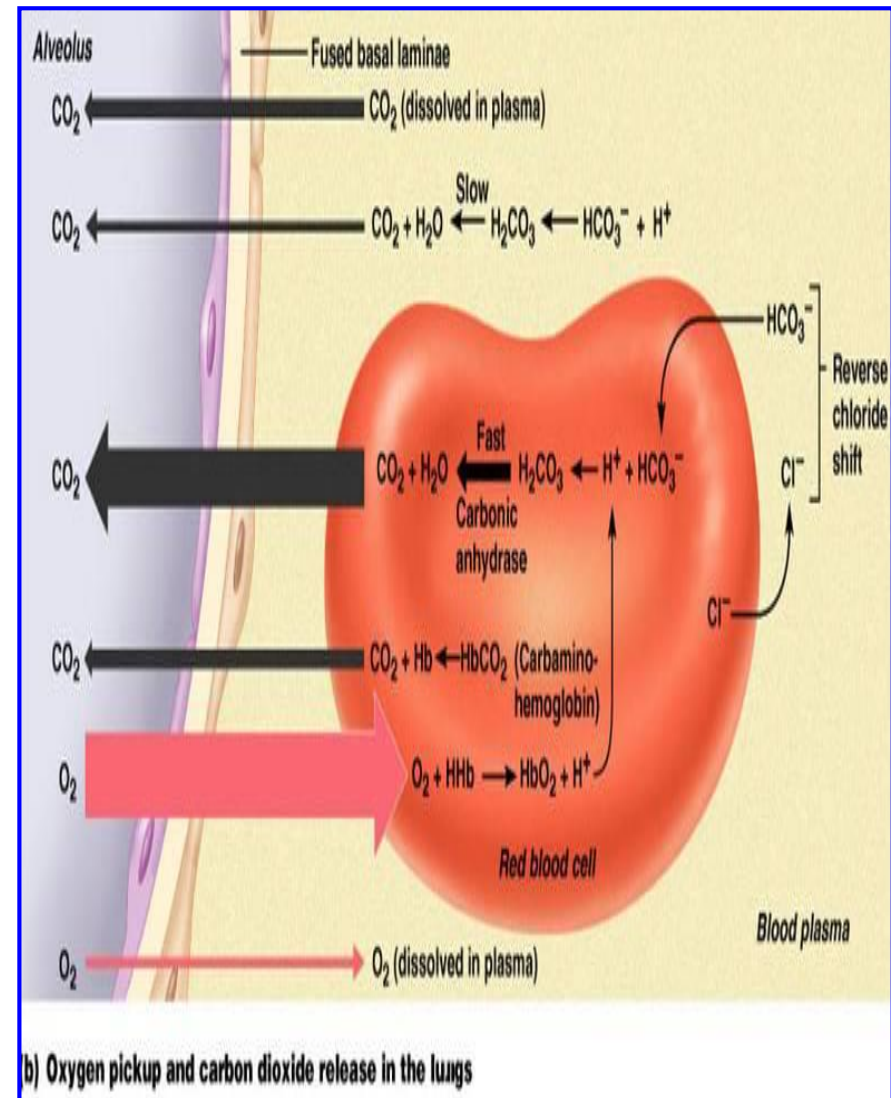
In Tissues



In Pulmonary capillaries

The Haldane effect

- ▶ When oxygen binds with hemoglobin, carbon dioxide is released- to increase CO₂ transport.
- ▶ Binding of Hb with O₂ at the lung causes the Hb to become a stronger acid and, this in turn displaces CO₂ from the blood and into the alveoli



Respiratory Exchange ratio (Respiratory Quotient)

$$R = \frac{\text{Rate of carbon dioxide output}}{\text{Rate of oxygen uptake}}$$

- A person on normal diet: $R=0.825$
- When Carbohydrate diet is used: $R = 1$
- When fats only is used: $R=0.7$
- The reason for this difference is that when O_2 is metabolized with carbohydrates, one molecule of CO_2 is formed for each molecule of O_2 consumed; when O_2 reacts with fats, a large share of the O_2 combines with hydrogen atoms from the fats to form water instead of CO_2 .