Oxygen and Carbon dioxide Transport

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Objectives:

Understand the forms of oxygen transport in the blood, the importance of each.

Differentiate between O_2 capacity, O_2 content and O_2 saturation.

Describe Oxygen- hemoglobin dissociation curve.

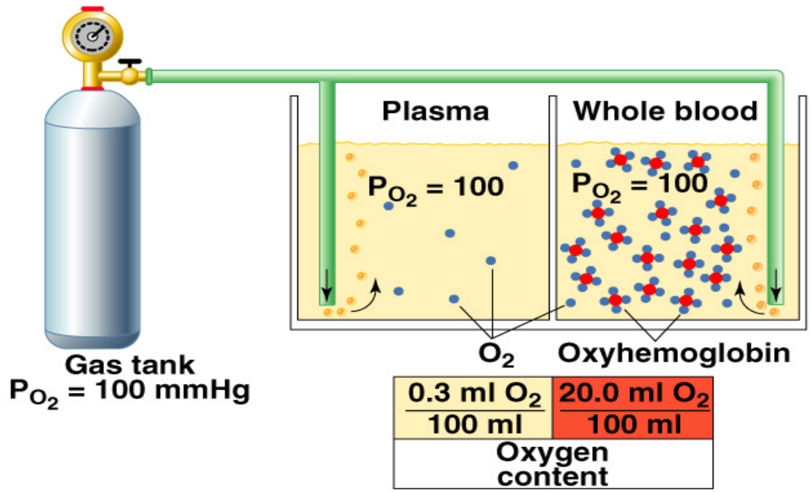
Define the P50 and its significance.

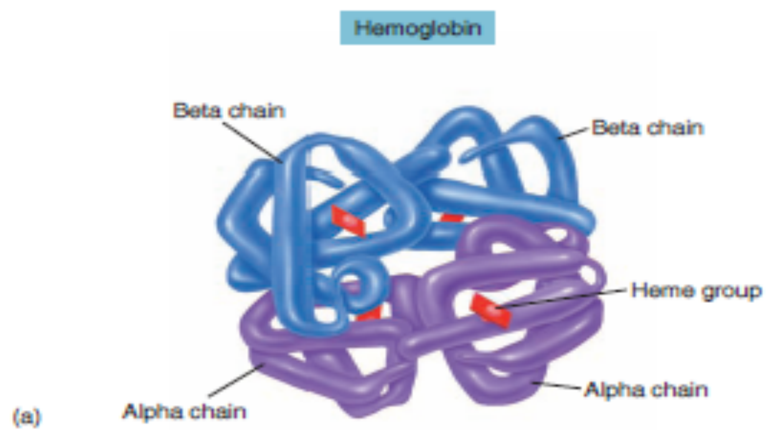
How DPG, temperature, H^+ ions and PCO_2 affect affinity of O_2 for Hemoglobin and the physiological importance of these effects.

Describe the three forms of carbon dioxide that are transported in the blood, and the chloride shift.

Forms of O2 transport

- O2 is mostly transported in the blood bound to hemoglobin and to a lesser extent in dissolved state.
- 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.
- 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
- Dissolved O2: Unbound O2 in blood (ml O2/100 ml blood).

Cont…transport of O2 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.

  When 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.

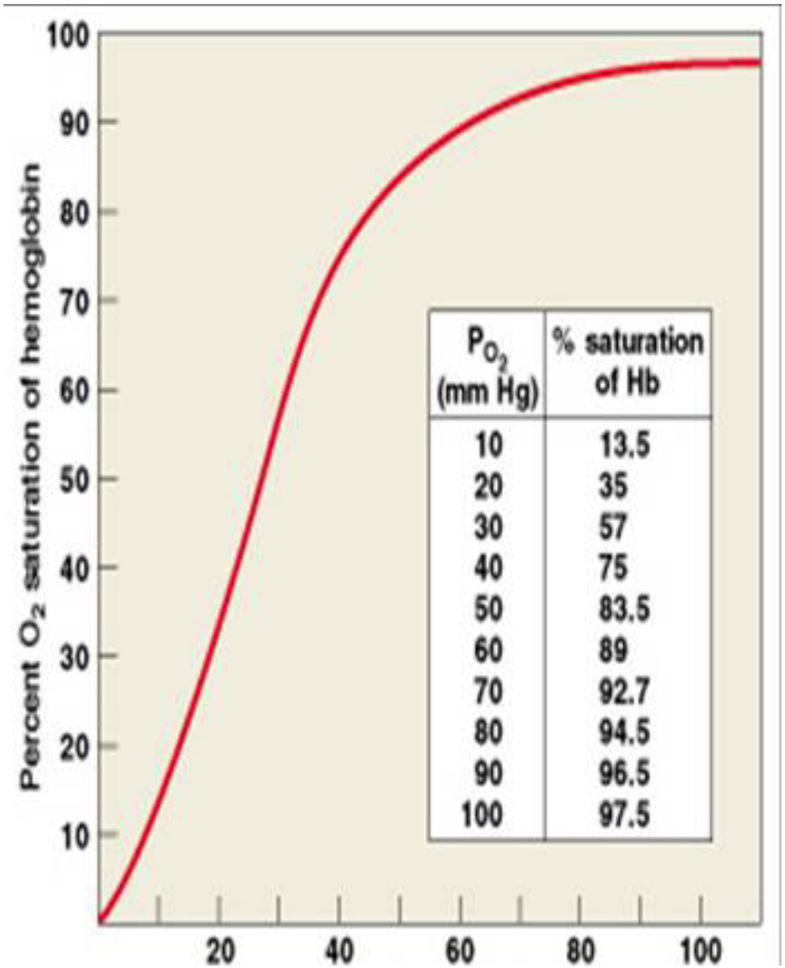
  15 ml O2 is given to the tissues /100 ml blood.

- 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 PO22 results in greater Hb saturation.
- The relation between PO2 and Hb-O2 is not linear. The curve is called: Oxygen hemoglobin Saturation Curve Which is S- shaped or sigmoidal.



P_{O_2} (mm Hg)	% saturation of Hb
10	13.5
20	35
30	57
40	75
50	83.5
60	89
70	92.7
80	94.5
90	96.5
100	97.5

Oxygen hemoglobin Dissociation Curve

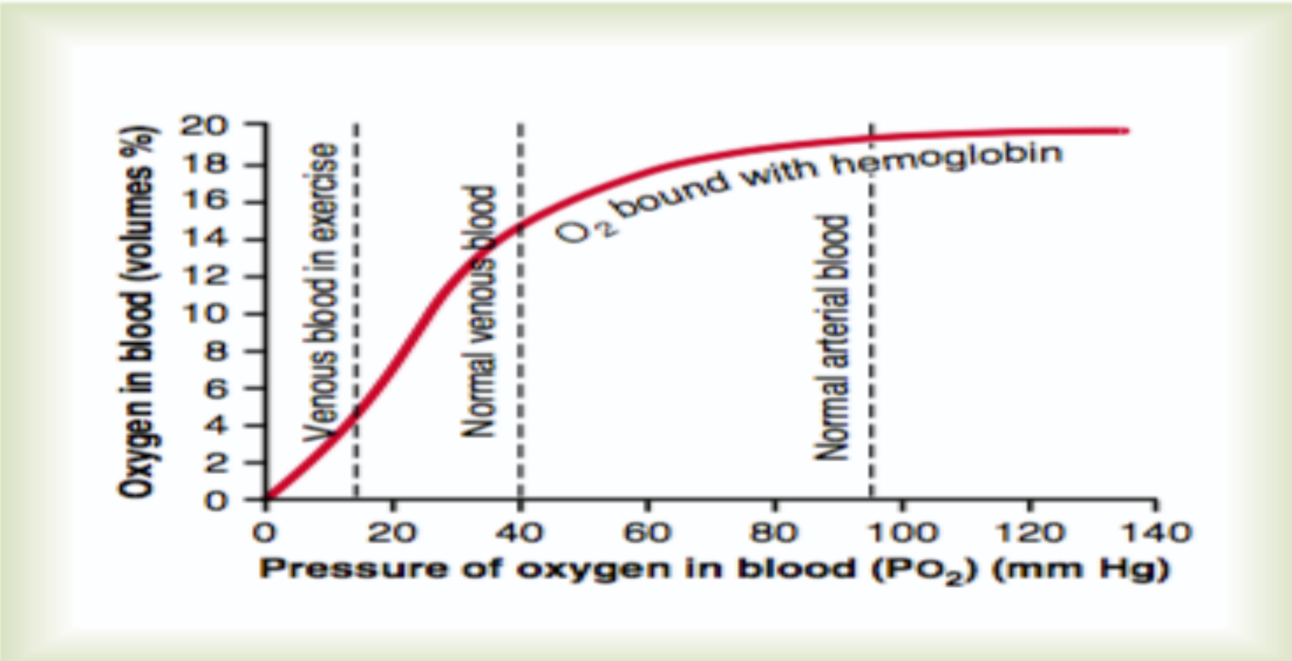


Figure 40–9

Effect of blood PO_2 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.

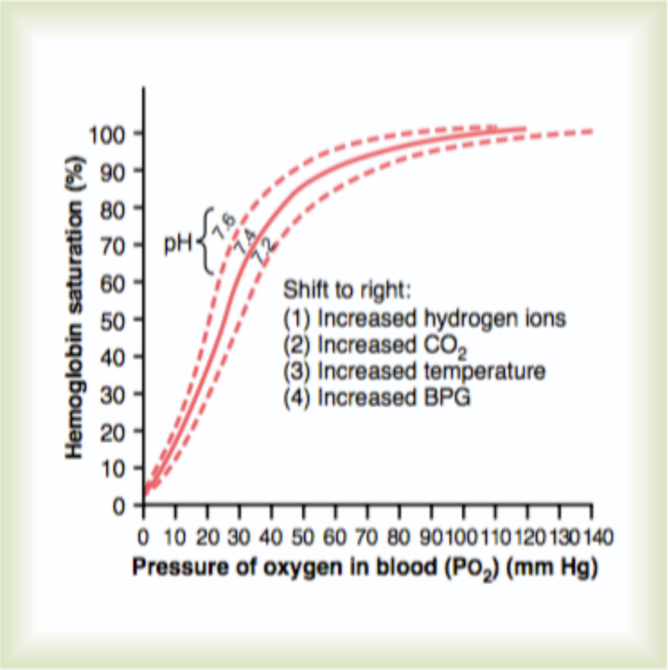
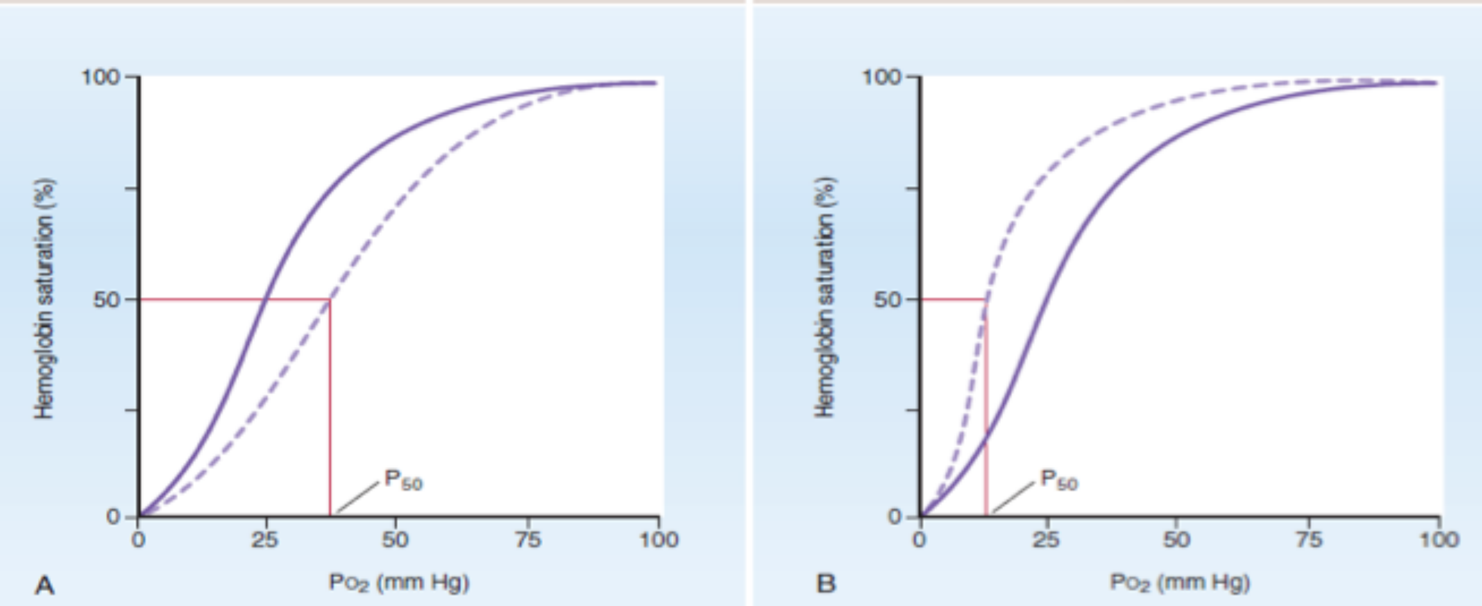


Figure 40–10

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	Causes of shift to the left
↑ P_{CO_2} ↓ pH ↑ Temperature ↑ 2,3-DPG	↓ P_{CO_2} ↑ pH ↓ Temperature ↓ 2,3-DPG Hemoglobin F



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.

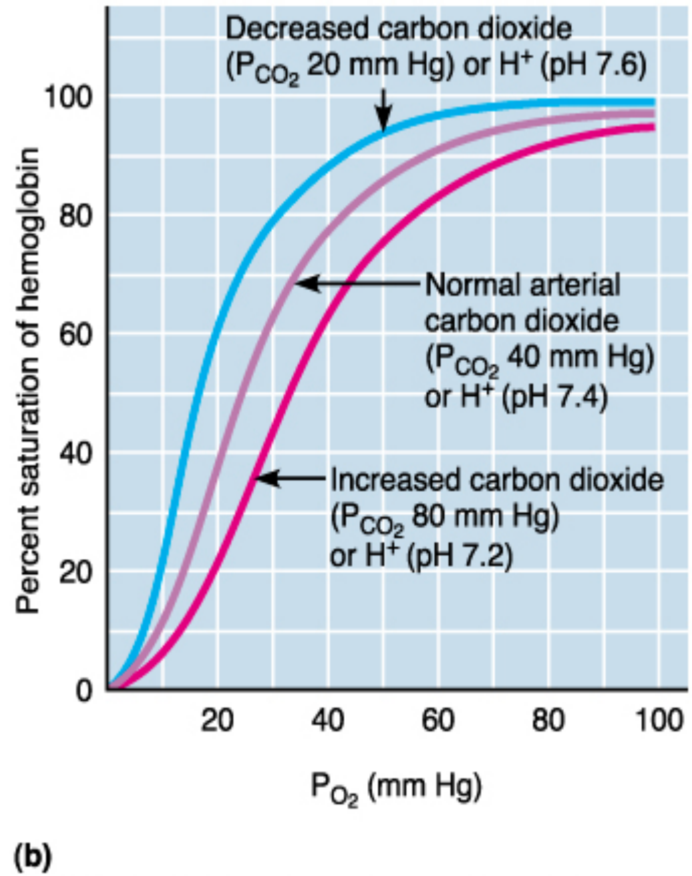
  Increased 2,3DPG, H+, Temperature , PCO2 shift the curve to right.
- 2,3DPG is synthesized in RBCs from the glycolytic pathway. Increased 2,3 DPG facilitates the oxygen release and shifts the dissociation curve to Rt.
- 2,3 DPG increases in the RBCs in anemia and hypoxemia, and thus serves as an important 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.



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 O_2 is transported in the dissolved state,
- At normal arterial PO_2 of 95 mmHg , about 0.29 ml of oxygen is dissolved in each 100ml of blood.
- When the PO_2 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)

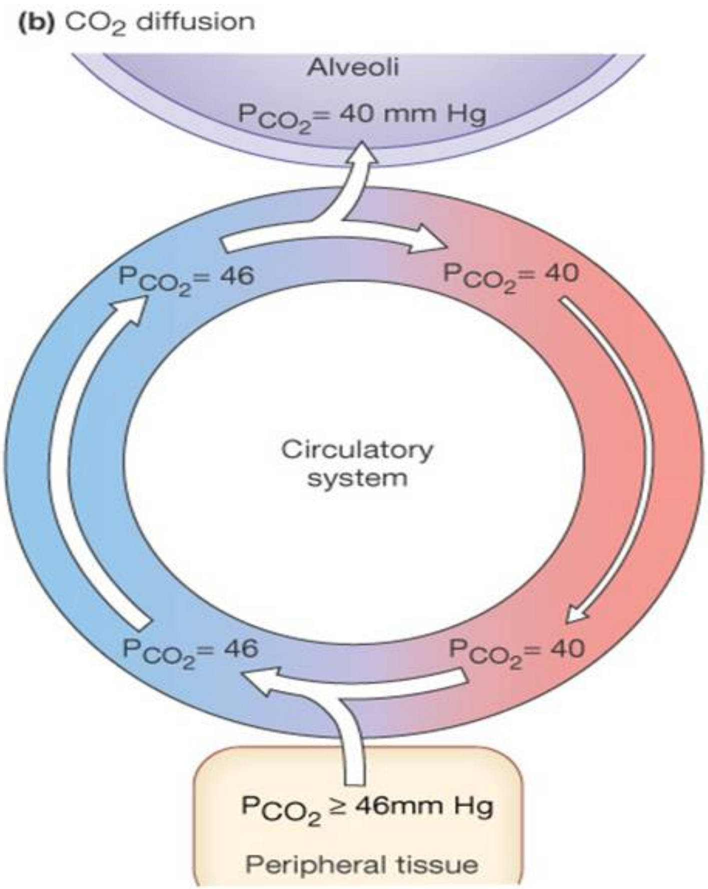
- CO combines with Hb at the same point on the Hb molecule as does oxygen.
- It binds with Hb about 250 times as much as O2 (affinity of Hb to CO is very high (250 times) that to O2.
- It causes Lt shift of the O2-Hb curve.

Transport of carbon dioxide in the blood

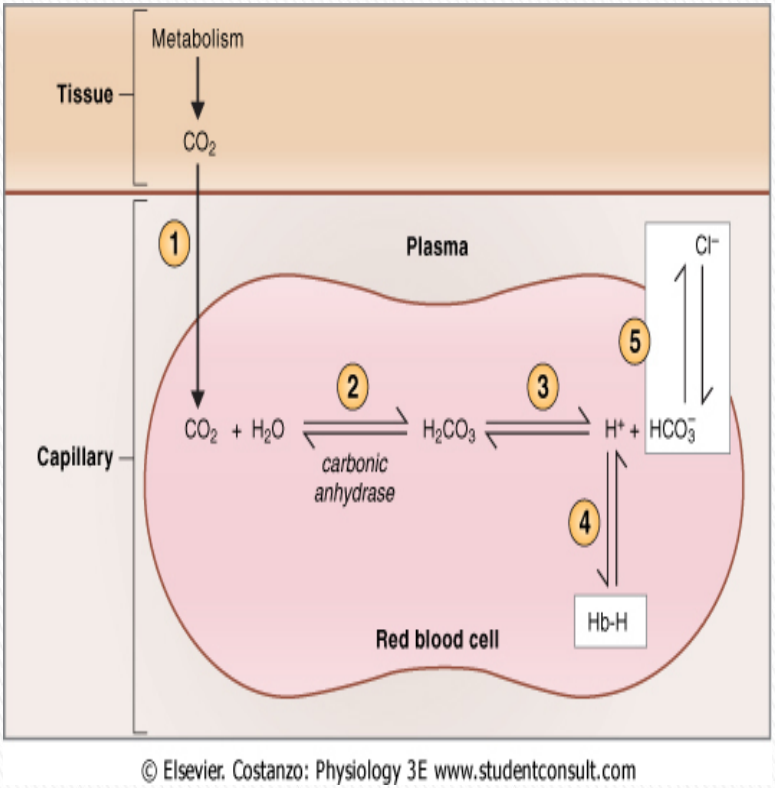
- **Carbon dioxide is transported in three forms:**

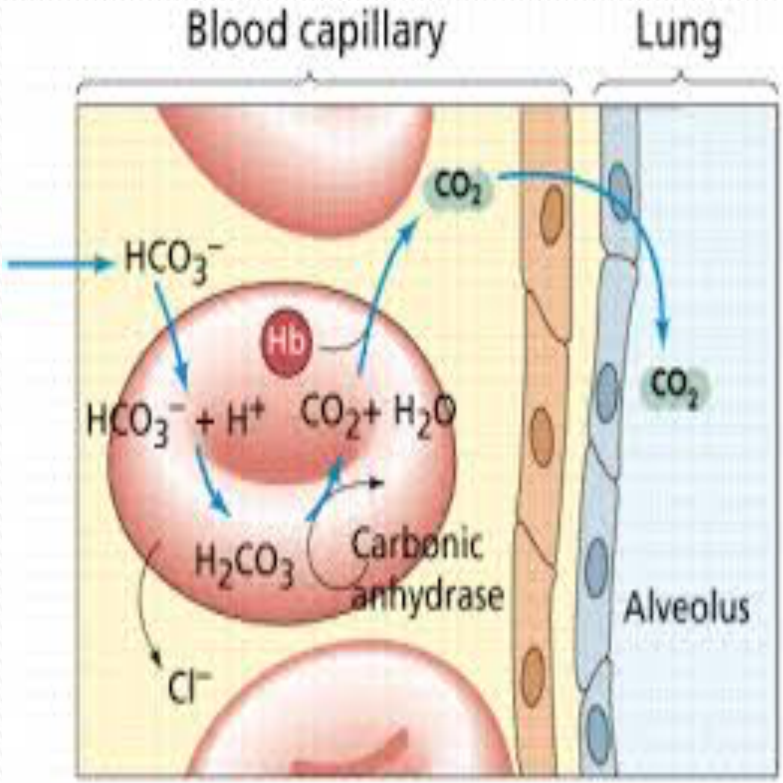
1.Dissolved CO2 (7%)
2.bicarbonate ions (70 %)
3.Carbaminohemoglobin (with Hb) (23%).

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



Formation of HCO3- & Chloride shift



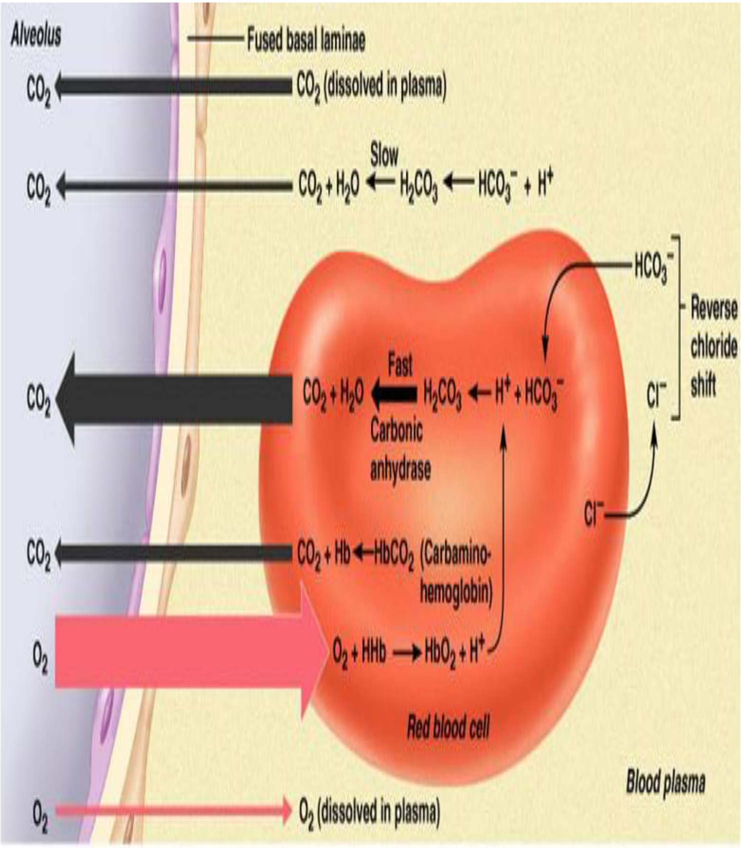


In Tissues

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



(b) Oxygen pickup and carbon dioxide release in the lungs

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 O2 is metabolized with carbohydrates, one molecule of CO2 is formed for each molecule of O2 consumed; when O2 reacts with fats, a large share of the O2 combines with hydrogen atoms from the fats to form water instead of CO2.