RESPIRATORY BLOCK

كلية الطب البشري
السنة الأولى

1432 – 1431

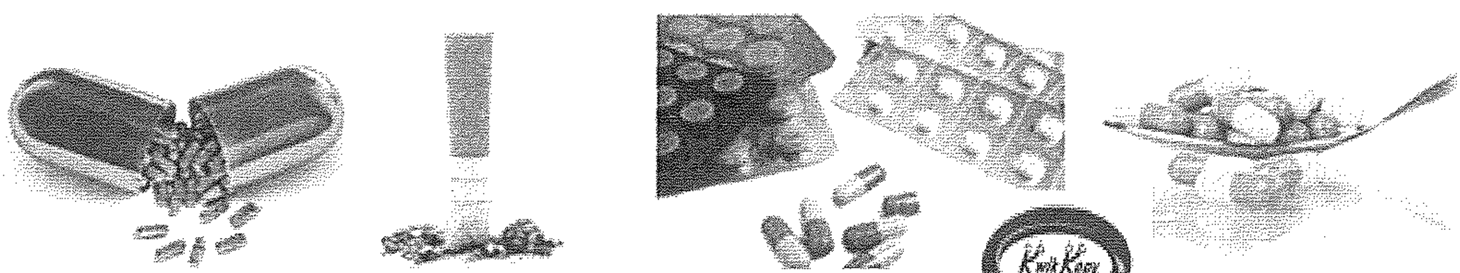
رقم المذكرة
15

عدد الصفحات
18

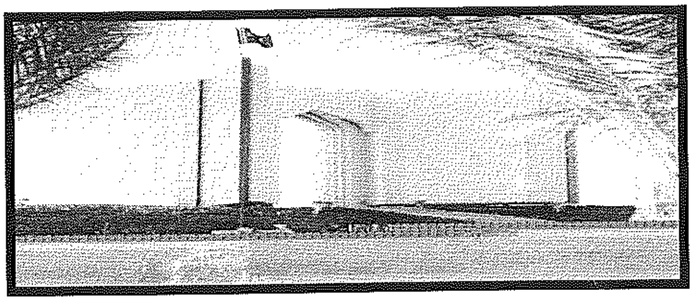
Transport of oxygen- and carbondioxide

Dr.sultan

Physiology



TRANSPORT OF OXYGEN AND CARBON DIOXIDE



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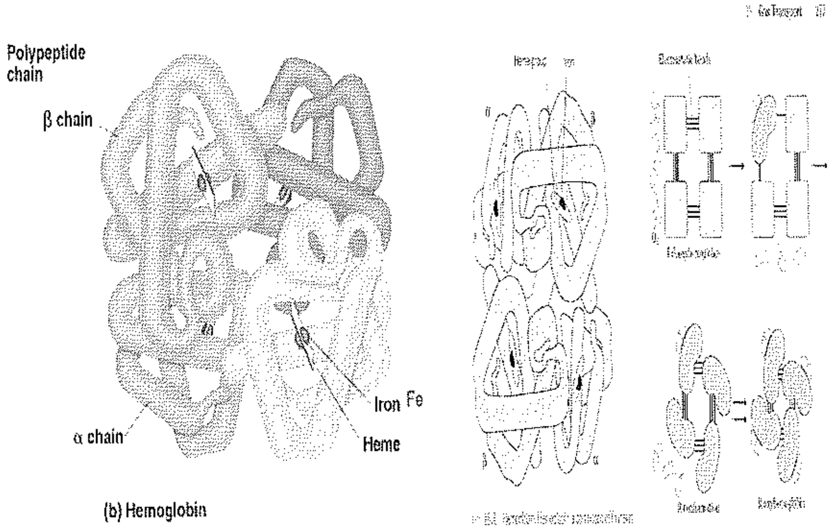
HEMOGLOBIN



(b) Hemoglobin

HEMOGLOBIN

Oxygen molecule combines loosely and reversibly with the heme portion of hemoglobin.

When Po2 is high, as in the pulmonary capillaries, oxygen binds with the hemoglobin.

when Po2 is low, as in the tissue capillaries, oxygen is released from the hemoglobin.

HEMOGLOBIN

- Oxyhemoglobin:
  - Normal heme contains iron in the reduced form (Fe^{2+}).
  - Fe^{2+} shares electrons and bonds with oxygen.
- Deoxyhemoglobin:
  - When oxyhemoglobin dissociates to release oxygen, the heme iron is still in the reduced form.

HEMOGLOBIN

- Methemoglobin:
  - Has iron in the oxidized form (Fe^{3+}).
    - Lacks electrons and cannot bind with 0_2.
    - Blood normally contains a small amount.
- Carboxyhemoglobin:
  - The reduced heme is combined with carbon monoxide.
  - The bond with carbon monoxide is **210** times stronger than the bond with oxygen.
  - Transport of 0_2 to tissues is impaired.

HEMOGLOBIN

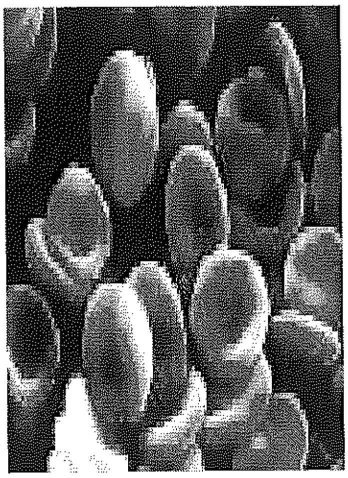
- Oxygen-carrying capacity of blood determined by its [hemoglobin].
  - Anemia:
    - [Hemoglobin] below normal.
  - Polycythemia:
    - [Hemoglobin] above normal.
  - Hemoglobin production controlled by erythropoietin.
    - Production stimulated by P_{CO_2} delivery to kidneys.
- Loading/unloading depends:
  - P_{O_2} of environment.
  - Affinity between hemoglobin and 0_2.

TRANSPORT OF O2

Transport of respiratory gases between the lungs and body tissues is the main function of blood.

■ 97 % of the oxygen transported from the lungs to the tissues is carried in chemical combination with hemoglobin

■ 3 % iscarried by physically being dissolved in plasma.



$Hb + 4O_2 \rightarrow Hb(O_2)_4$

TRANSPORT OF O2

Transport of O_2 by haemoglobin: Hb combines with oxygen the compound formed is called oxyhaemoglobin.

The amount of O_2 carried in the blood in oxyhaemoglobin depends on the amount of Hb present in the blood.

The normal amount of Hb in young adults is about 16 gm/dl of the blood.Each gram of Hb can bind with 1.34 ml of O_2.Thus, if a person has a Hb is 16 gm/dl of blood his blood can carry

16 x 1.34 = 21.44 ml of O_2/dl.

TRANSPORT OF O2

The haem part of the hemoglobin contains 4 atoms of iron, each capable of combining with a molecule of oxygen. Oxygen can combine loosely and reversibly with hemoglobin.

- $Hb + O_2$ HbO_2

The important factor which determines how much oxygen combines with Hb when the haemoglobin (deoxygenated Hb) is converted to HbO_2, is the PO_2. When the PO_2 is high, it binds with Hb, but when the PO_2 is low O_2 is released from Hb.

TRANSPORT OF O2

Partial Pressure Difference
1. High Partial Pressure of O_2 (Po_2)in Alveoli
2. Low Po_2 in Capillary

- Concentration Gradient
  1. High Concentration of O_2 in Alveoli
  2. Low Concentration of O_2 in Capillary O_2

TRANSPORT OF O2

- Diffusion Difference-Very Short
- O_2 Diffusion-Very Rapid
- O_2 Diffuses from Alveoli Into RBC
- Attaches to Heme Molecule→HbO
- Carried To Tissues

TRANSPORT OF CO2

- Large amount of CO_2 is continuously produced in the body. Under normal resting conditions each 100 ml of deoxygenated blood contains 4 ml of CO_2 which is carried in the blood in three forms:
- 70% of CO_2 is transported in bicarbonate form.
- 23% combines with the globin part of haemoglobin to form carbamino haemoglobin
- 7% is dissolved in plasma

TRANSPORT OF CO2

Transport of CO_2 dissolved in plasma: Little carbon dioxide is transported in the dissolved state to the lungs. $PCO_2$of venous blood is 45 mm Hg and the PCO_2 of arterial blood is 40 mmHg. The amount of CO_2 dissolved in the blood at 45 mmHg is 2.7 ml/dl (2.7%). The amount of CO_2 dissolved at 40 mmHg is about 2.4 ml. The difference between 2.7 and 2.4 is only 0.3 ml. About 0.3 ml CO_2 is transported in the form of dissolved CO_2 by each 100 ml of blood. Itis about 7 % of all CO_2 is transported in this form.

TRANSPORT OF CO2

- Transport of CO_2 in Bicarbonate form: As CO_2 diffuses into the tissue capillaries it then enters the red blood cells. CO_2 reacts with water to form carbonic acid in the presence of carbonic anhydrase enzyme. This enzyme accelerates the reaction 4800 times more, so it occurs within a fractions of second. The carbonic acid is then dissociated into hydrogen ions (H^+) and bicarbonate ions. Hydrogen ions combine with haemoglobin to form H,Hb, and the bicarbonate ions (HCO_3^-) leave RBCs and enter the plasma. To maintain the negativity of RBCs, chloride ions (Cl^-) enter from the plasma into the RBCs. The exchange of bicarbonate ions from RBCs to plasma and Cl^- ions from plasma to RBCs is called the bicarbonate chloride shift phenomenon.

TRANSPORT OF CO2

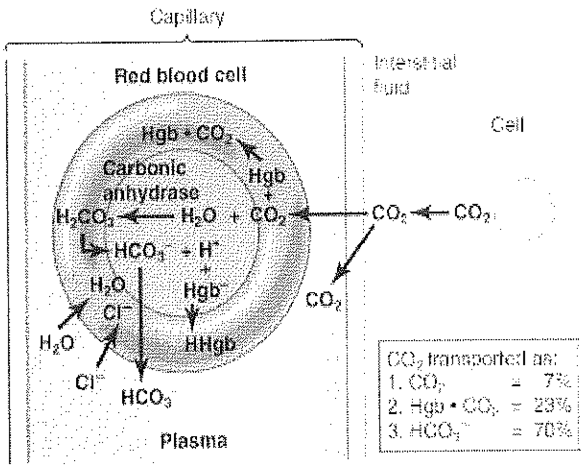
Diffusion Effected By

- Partial Pressure of CO_2 (Pco_2)-Higher In Tissues Than In Capillary
- Concentration Gradient-CO_2 Higher In Tissues Than In Capillary
- Distance-Very Short

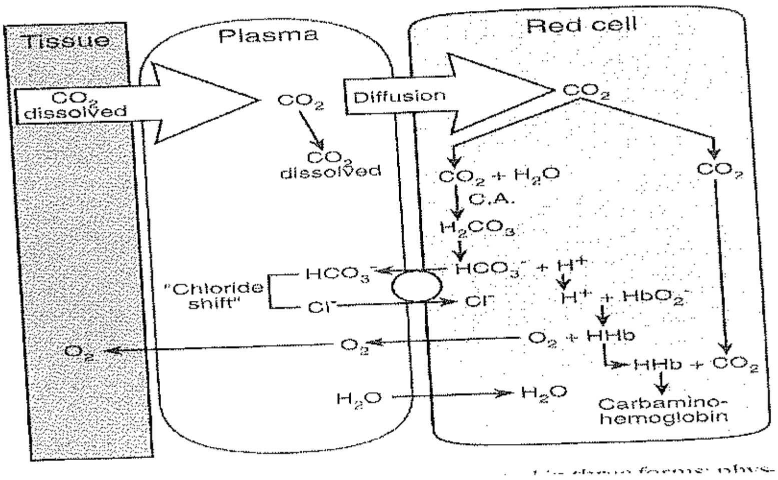
TRANSPORT OF CO2

- **$H_20 + C0_2$ H_2C0_3 $H^+ + HC0_3^-$**
- At the tissues, $C0_2$ diffuses into the RBC; shifts the reaction to the right.
  - Increased [$HC0_3^-$] produced in RBC:
    - $HC0_3^-$ diffuses into the blood.
  - RBC becomes more +.
    - Cl^- attracted in (Cl^- shift).
  - H^+ released buffered by combining with deoxyhemoglobin.
- $HbC0_2$ formed.
  - Unloading of 0_2.

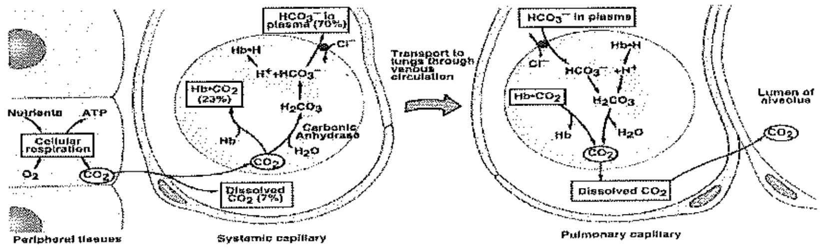
TRANSPORT OF CO2



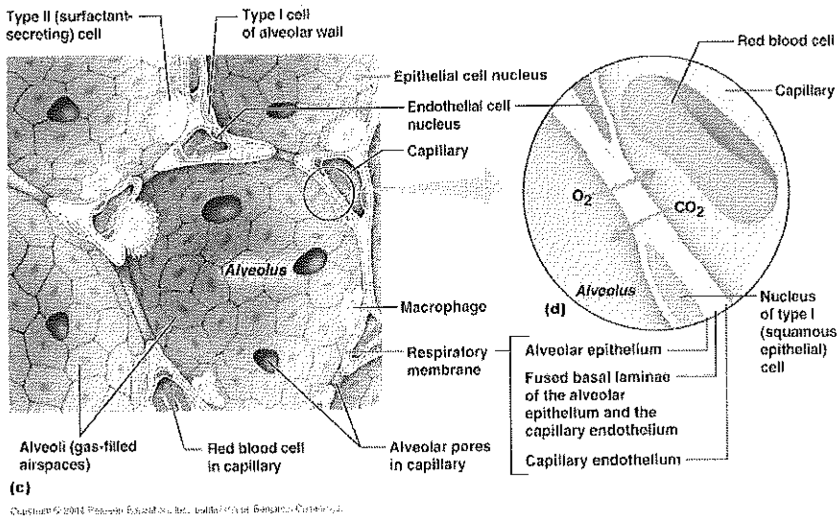
TRANSPORT OF CO2



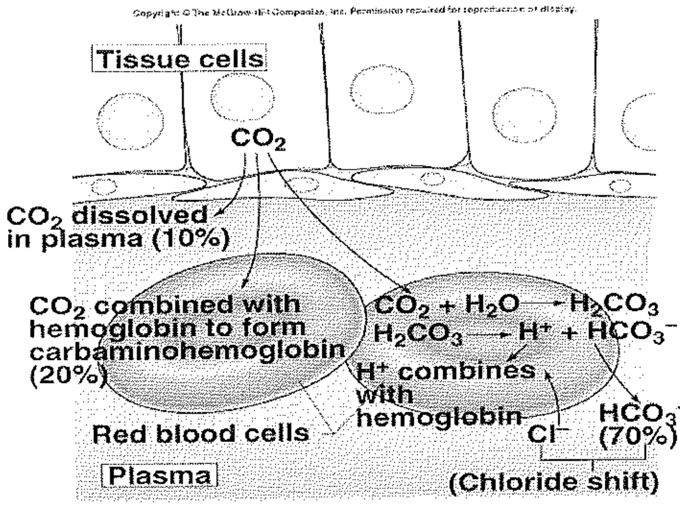
TRANSPORT OF CO2



CARBON DIOXIDE TRANSPORT AND CHLORIDE SHIFT



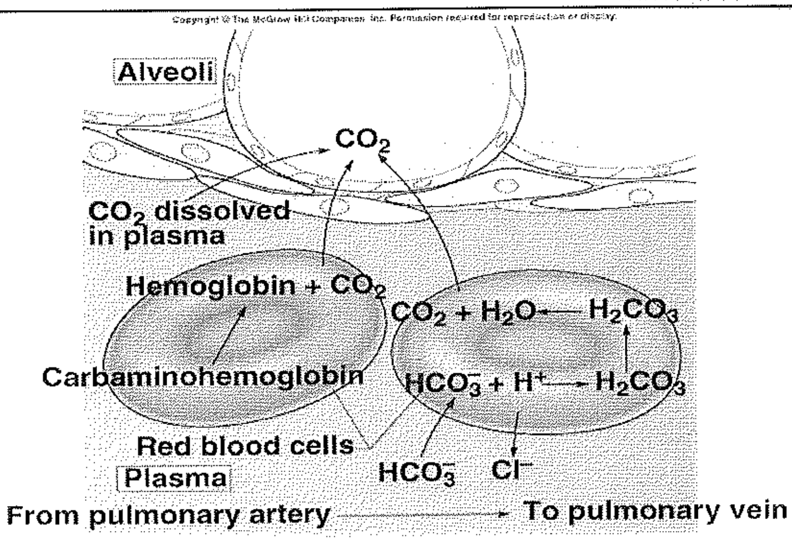
CARBON DIOXIDE TRANSPORT AND CHLORIDE SHIFT



AT PULMONARY CAPILLARIES

- $H_20 + C0_2$ H_2C0_3 $H^+ + HC0_3^-$
- At the alveoli, $C0_2$ diffuses into the alveoli; reaction shifts to the left.
- Decreased $[HC0_3^-]$ in RBC, $HC0_3^-$ diffuses into the RBC.
  - RBC becomes more -.
    - Cl^- diffuses out (reverse Cl^- shift).
- Deoxyhemoglobin converted to oxyhemoglobin.
  - Has weak affinity for H^+.
- Gives off $HbC0_2$.

REVERSE CHLORIDE SHIFT IN LUNGS



OXYHEMOGLOBIN DISSOCIATION CURVE

This is a curve which denotes the relationship between the percent O_2 saturation of Hb and the partial pressure of O_2.

Right shift of oxy-Hb-dissociation curve: When the oxy-haemoglobin dissociation curve is shifted to the right, it means oxygen is dissociated or released from haemoglobin.

Factors shifting the curve to the right: Increase H^+ concentration or decrease pH, Increase CO_2, Increase temperature, Increase 2, 3 DPG

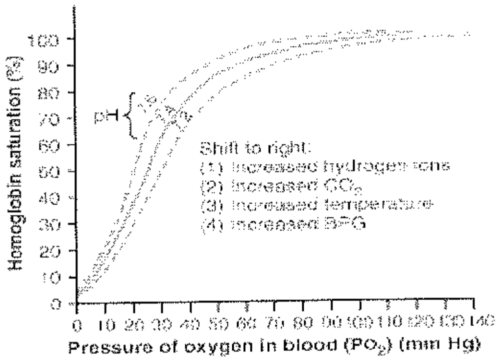
OXYHEMOGLOBIN DISSOCIATION CURVE

- **Left shift of oxy-haemoglobin dissociation curve:** When the oxy-hemoglobin dissociation curve is shifted to the left. It shows that hemoglobin affinity for oxygen is increased.
- **Factors shifting the curve to the left:**
- Decrease H^+ concentration or increase pH
- Decrease CO_2
- Decrease temperature
- Decrease 2, 3 DPG
- Fetal haemoglobin

OXYHEMOGLOBIN DISSOCIATION CURVE

- Graphic illustration of the % oxyhemoglobin saturation at different values of P_{O_2}.
  - Loading and unloading of 0_2.
    - Steep portion of the sigmoidal curve, small changes in P_{O_2} produce large differences in % saturation (unload more 0_2).
- Decreased pH, increased temperature, and increased 2,3 DPG:
  - Affinity of hemoglobin for 0_2 decreases.
    - Greater unloading of 0_2:
      - Shift to the curve to the right.

FACTORS EFFECTING OXYHEMOGLOBIN DISSOCIATION CURVE



FACTORS EFFECTING OXYHEMOGLOBIN DISSOCIATION CURVE

Table 16.9 Factors That Affect the Affinity of Hemoglobin for Oxygen and the Position of the Oxyhemoglobin Dissociation Curve

Factor	Affinity	Position of Curve	Comments
↓pH	Decreased	Shift to the right	Called the Bohr effect; increases oxygen delivery during hypercapnia
↑Temperature	Decreased	Shift to the right	Increases oxygen unloading during exercise and fever
↑2,3-DPG	Decreased	Shift to the right	Increases oxygen unloading when there is a decrease in total hemoglobin or total oxygen content; an adaptation to anemia and high-altitude living

FACTORS EFFECTING OXYHEMOGLOBIN DISSOCIATION CURVE

Table 16.8 Effect of pH on Hemoglobin Affinity for Oxygen and Unloading of Oxygen to the Tissues

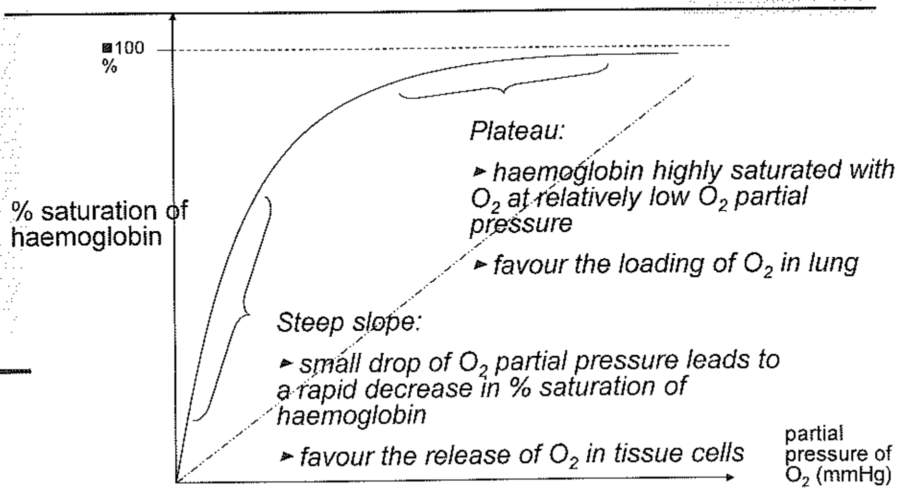
pH	Affinity	Arterial O_2 Content per 100 ml	Venous O_2 Content per 100 ml	O_2 Unloaded to Tissues per 100 ml
7.40	Normal	19.8 ml O_2	14.8 ml O_2	5.0 ml O_2
7.60	Increased	20.0 ml O_2	17.0 ml O_2	3.0 ml O_2
7.20	Decreased	19.2 ml O_2	12.6 ml O_2	6.6 ml O_2

FACTORS EFFECTING OXYHEMOGLOBIN DISSOCIATION CURVE

Table 16.10 Effect of Lung Function on Blood Acid-Base Balance

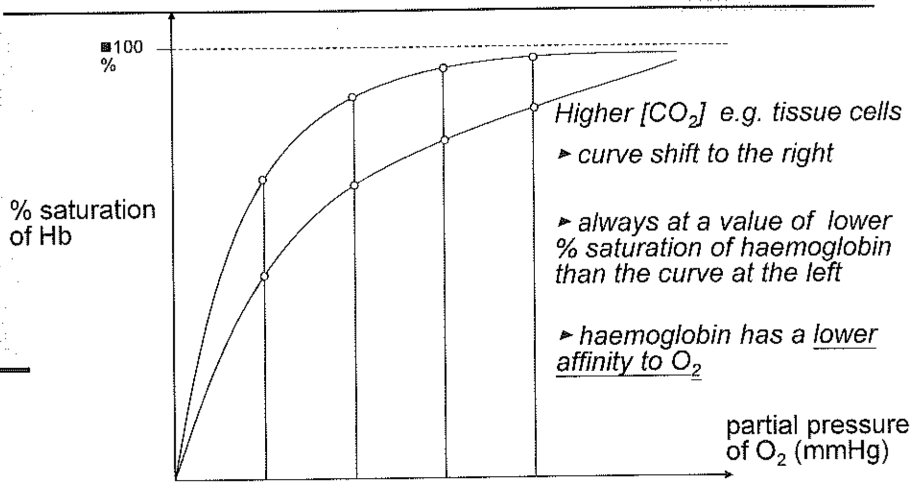
Condition	pH	P_{CO_2}	Ventilation	Cause of Compensation
Normal	7.35-7.45	39-41 mmHg	Normal	Not applicable
Respiratory acidosis	Low	High	Hypoventilation	Cause of the acidosis
Respiratory alkalosis	High	Low	Hyperventilation	Cause of the alkalosis
Metabolic acidosis	Low	Low	Hyperventilation	Compensation for acidosis
Metabolic alkalosis	High	High	Hypoventilation	Compensation for alkalosis

SIGNIFICANCE OF THE S-SHAPE CURVE



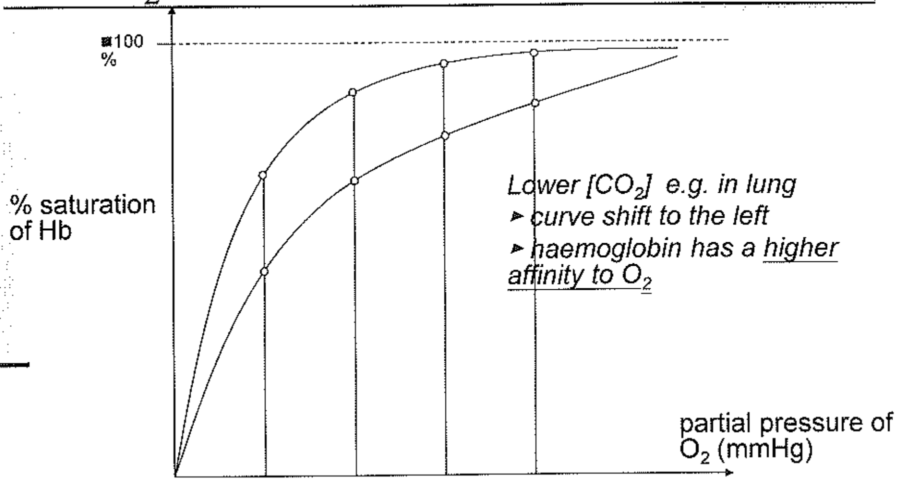
highly effective in the uptake large amount of O_2 from environment but release it so easily to the tissue cells !

BOHR EFFECT: THE EFFECT OF CO_2 ON HAEMOGLOBIN



■∴ in actively respiring tissue cells, O_2 is more easily released by haemoglobin !

BOHR EFFECT: THE EFFECT OF CO_2 ON HAEMOGLOBIN



■∴ in well-ventilated alveolus, O_2 is more easily taken up by haemoglobin !

TRANSPORT OF CO2

Table 18.1 **THE BASICS OF THE BOHR AND HALDANE EFFECTS**

Bohr Effect	Haldane Effect
CO_2 and H^+ binding to Hb → decreased Hb affinity for O_2	Deoxygenation of Hb → increased Hb affinity for CO_2
Shifts O_2-hemoglobin curve RIGHT	Shifts CO_2-blood curve LEFT

THANK YOU