TRANSPORT OF GASES

(A) Oxygen transfer:-

Transfer of O_2 takes place with the help of Haemoglobin. About 97% O_2 is transferred in the form of HbO_2 & Rest 3% transferred by plasma in soluble form.

The Hb has the high affinity for O_2, it binds with the O_2 at its higher conc. (i.e. lungs) & release it at the site of low O_2 conc. (i.e. tissue).

~~The affinity of O_2 for the~~

The binding capacity is due to presence of certain blood protein or respiratory protein. They are usually coloured hence are known as pigment. The most widely distributed pigment is Haemoglobin, the other are myoglobin, Haemocyanin, Chlorocruorin, Haemerythrin Vanadium etc.

* The binding affinity of pigment to O_2 is depends upon its protein part. like globin in case of Hb.

The amount of O_2 which binds with Hb depends upon the partial pressure of O_2. If all the sites of Hb molecule bind with O_2, the blood is 100% saturated & the O_2 content of blood is equal to its O_2 capacity.

One millimole of heme can bind one millimole of O_2, which is equal to 22.4 vol of O_2. Human blood contains about 0.9 millimole of heme/100ml blood. Hence the O_2 capacity is $0.9 \times 22.4 = 20.2$ vol% This vol. of blood includes the O_2 in physical solution as well as that of combined Hb, but in most cases the O_2 in physical sol. is only a small fraction of the total O_2 content.

Each Hb can bind with $4O_2$.

Oxygenation of the 1st heme gp. facilates oxygenation of other heme gp. One heme gp. occupied by an O_2 increasing the affinity of the remain heme gp for O_2. This is called Remi-haem effect

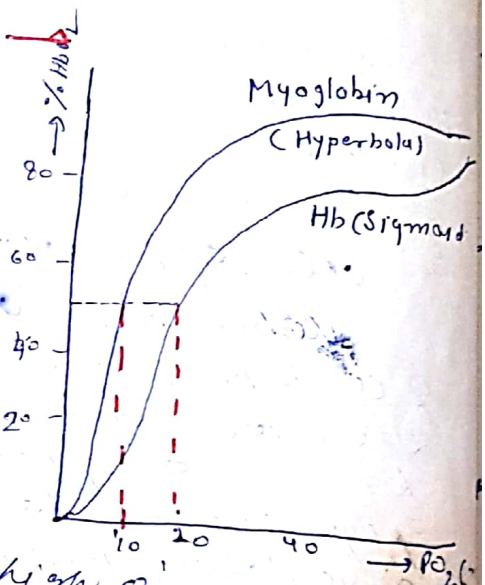
Oxygen Dissociation Curve & Bhor's Eff

The O.D.C describe the relationship between percent saturation and partial pressure of O_2. In this we plotted the saturated Hb (HbO_2) at y-axis and partial pressure of O_2 at x-axis.

Examples of different O.D.C.

① The O.D.C of Myoglobin & lamprey haemoglobin is hyperbola, because both have single Hb. And the O.D.C of Hb is Sigmaid.

The Myoglobin has greater affinity for O_2 than Hb. and its PO_{50} is less than Hb.

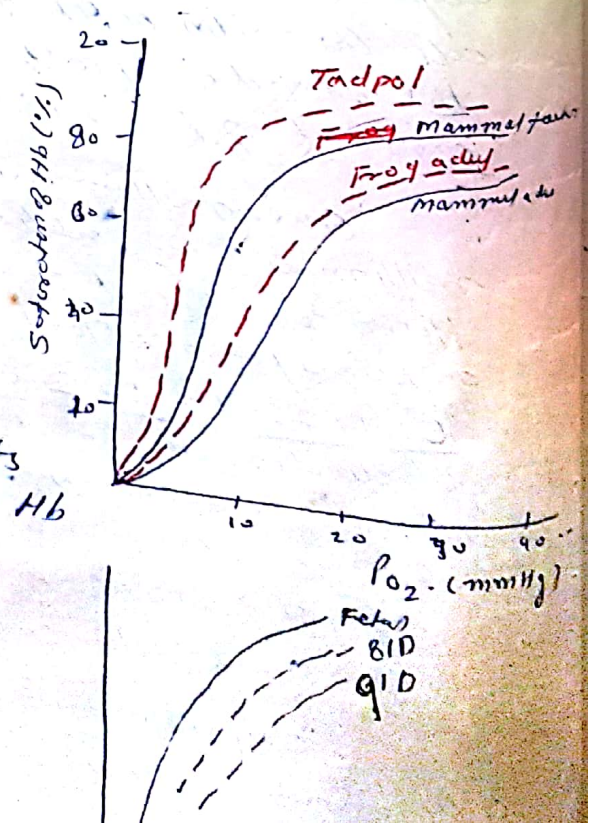


* The Hb that have high O_2 affinity are saturated at low PO_2 where as Hb with low affinity saturated at high P_{O_2}. The difference in O_2 affinity is not due to the difference in heme gp. rather it is related to difference in properties of globin protein

② O.D.C. factus :-

The foetus Hb has high affinity than adult at the same PO_2 level. The foetus O.D.C therefore lies to the left of materna O.D.C.

** No difference exists between foetal & adult Hb of cat.

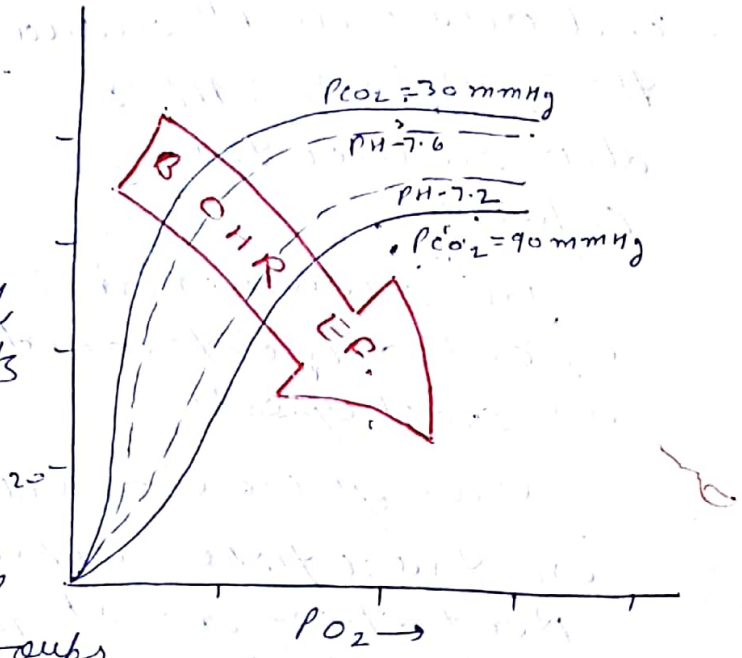


(iii) O.D.C of fishes:- The O.D.C of fishes living in O_2 poor water lies on the left of ODC of fishes living in better aerated water.

Bohr's Effect

The effect of P_{CO_2} or PH on the form & position of the ODC is known as Bohr effect.

* The release of CO_2, less pH, acidity, & high temp shifts the ODC towards the right side.



* The B.E. depends upon the sulphydril (-SH) groups in the globulin protein. The A.A. cysteine has a -SH group.

* The magnitude of B.E. is given by the change in P_{50} (Pressure of O_2 at which 50% saturation occurs) per PH unit or.

$$\frac{\Delta \log P_{50}}{\Delta P_H} = \text{no of } H^+ \text{ released per } O_2 \text{ per mole of haem.}$$

✓ For human Hb the change in P_{50} is 1.1 / PH unit from PH 6.5 to 9.5 ✗

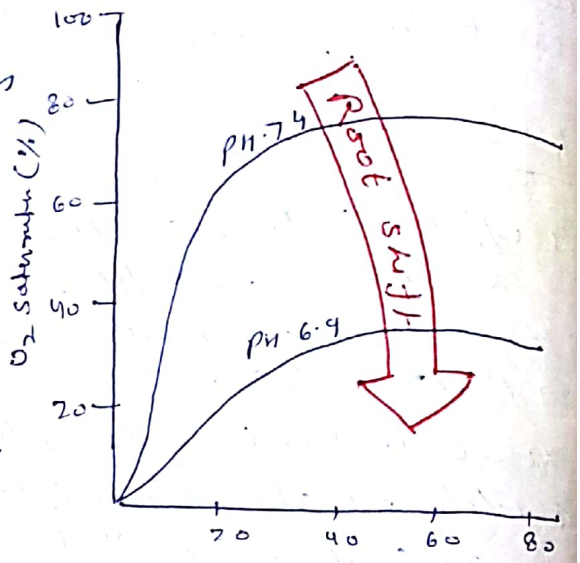
* The magnitude of the B.E. is greater in small mammals than in large ones.

Ex- $\Delta \log P_{50} / \Delta PH$ is 0.9 → Mouse
0.65 → Men
0.45 → elephant

Root Effect or Root Shift:→

In some fishes, cephalopods & Crustaceans an increase in CO_2 or decrease in pH reduce the O_2 affinity of Hb & also reduce the O_2 capacity.

This reduction in O_2 capacity is termed as root effect.



This effect is more common in those fishes which have swim bladder. Root effect is not present in those fishes which lack swim bladder.

In other words we can say root effect is one in which Hb can not be saturated with O_2 at any P_{O_2}. That at lower pH value less O_2 is carried/unit vol. of blood than at the higher pH values.

Reverse Bohr effect:-

A decrease in pH results in an increase in O_2 affinity in Haemocyanin from several gastropods, horse shoe crab, Limulus. The greater affinity in less pH is referred as reverse Bohr effect.

O.D.C. in such condition shifts towards the left resulting when high CO_2, less pH is resulted.

Factors affecting the ODC →

① Effect of pH on O_2 transport →

Decrease in pH shifts the O.D.C towards the right side, and shows less saturation.

② Effect of temp :-

An increase in temp. shifts the ODC towards the right side.

In general temp affects the behaviour of poikilotherms by shifting the ODC. As temp. increased the P_{50} also goes up. A species which shows less increase in P_{50} with increase in temp. are more adaptive to temp. changes in its environment assuming all other factors are constant.

A rise in temp not only reduce the O_2 solubility in water but also decrease Hb-O_2 affinity, making O_2 transfer between water & blood more difficult. Unfortunately this occurs at a time when tissue O_2 requirements are increasing also as a result of the rise in temp.

③ Effects of some other factors on ODC.

- ★ Dilution shifts the ODC to left whereas decreasing salt conc. shifts it to right
- ★ Hb-O_2 affinity is reduced by organic phosphate legends for ex- 2,3 diphosphoglycerate (DPG) or ATP
- ★ DPG binds to the β-chains of deoxygenated haemoglobin & reduce O_2 affinity. (Right shift)
- ★ Mammalian blood cells contains high amount of DPG
- ★ As rise in altitude O_2 pressure falls in air and also rise in DPG (3000 mt → 10% increase in DPG). As a result of this O_2 affinity reduced, enhance O_2 transfer to tissue, but adversely effects O_2 uptake to lungs.
- ★ ATP → Birds, inositol phosphate → Birds, are in high conc. & affect O_2 affinity.

Transfer of CO_2 :→ CO_2 diffuse into blood from tissue transported in the blood & diffuse across the respiratory surface into the enviornment.
It is mainly takes place by following methods-

① A small amount of CO_2 reacts with H_2O in the plasma to form H_2CO_3 (carbonic acid) But the rate of H_2CO_3 formation is low in plasma, so very little CO_2 is transfer in this form.

The H_2CO_3 that formed react with various buffer system in the blood, so that it does not upset the pH of the blo

Ex —

$$Na_2HPO_4 + H_2CO_3 \longrightarrow NaHCO_3 + NaH_2$$

② CO_2 transport → plasma – 7%
Carbaminocompound – 23%
Bicarbonate – 70%.

** The CO_2 react with H_2O to form H_2CO_3, a weak acid, which dissociates into HCO_3^- &

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^{--}$$

The ratio of CO_2, HCO_3^- & CO_3^{-2} in solution depends upon pH, temp & ionic strength of solution.

- In blood ratio of CO_2 to H_2CO_3 is about 1000 : 1
" " CO_2 to HCO_3^- " 1 : 2

So HCO_3^- is the predominant form of CO_2 in the blood at normal pH. The CO_3^{-2} content is usually negligible in birds & mammals. But in poikilotherms with low temp & high pH the CO_3^{-2} content may be upto 5% of the total CO_2 content of the blood, but bicarbonate is still predominant form of CO_2

* R.BCs membrane is permeable to -ve ions & gases.

* Most of the dissolved CO_2 diffuse from the plasma in to the RBCs where the formation of H_2CO_3 is very fast due to presence of ~~enzyme~~ carbonic anhydrase in R.B.Cs.

$$RBCs \rightarrow H_2O + CO_2 \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

* Although plasma have higher conc. of CO_2 than RBCs, most of the CO_2 entering & leaving the plasma via R.B.Cs, it is because —
  ① Presence of CA in red RBCs. which increase the formation of $H^+ + HCO_3^-$ rapidly
  ② The deoxygenated Hb acts as H^+ acceptor facilitating the formation of HCO_3^-

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- + HbO_2 \rightleftharpoons HHb + O_2$$

So pH is not affected because H^+ combined with Hb after release of O_2.

* On entering the blood CO_2 diffuse into R.BCs. where in the presence of CA, H_2CO_3 formed v. fast. and H_2CO_3 dissociated into H^+, HCO_3^-, ~~So~~ This HCO_3^- leaves the RBCs into plasma. To maintain electrochemical blance across PM there is simultaneous influx of Cl^- into R.BCs (PM is permeable to -ve ion). This influx of chloride ion is called chloride shift or Hamberger effect.

* The rate of movement of CO_2, HCO_3^-, Cl^- and O_2 into or out of RBC will determined by the surface/volume ratio of the cell and the diffusion coefficient of these substances through red cells. The

* The size of RBC varies among species. The small RBC with lower surface/vol ratio are oxygenated faster than larger cell

* Water enters the RBCs with the CO_2 & thus increases the RBCs volume. For this reason the RBC ~~etc~~ of venous blood are slightly larger than arterial blood

** Some of the H_2CO_3 formed in RBC remain there and react with Hb. Oxy-Hb & deoxy Hb together form an effective buffer system which prevents this H_2CO_3 from upsetting the pH within RBCs.

$$KHb + H_2CO_3 \rightleftharpoons KHCO_3 + HHb$$

** Some of the dissolved CO_2 entering in RBC react directly with amino ($-NH_2$) group of deoxy-Hb to form carbamino compound called carbhaemoglobin.

20%. $$Hb-N\begin{matrix}H\\H\end{matrix} + CO_2 \rightleftharpoons Hb-N\begin{matrix}H\\COOH\end{matrix}$$

The formation of carbamino haemoglobin formation will depends on the number of avilable $-NH_2$ gp. as well as blood pH & pCO_2.

About 20-23% CO_2 transfered by this

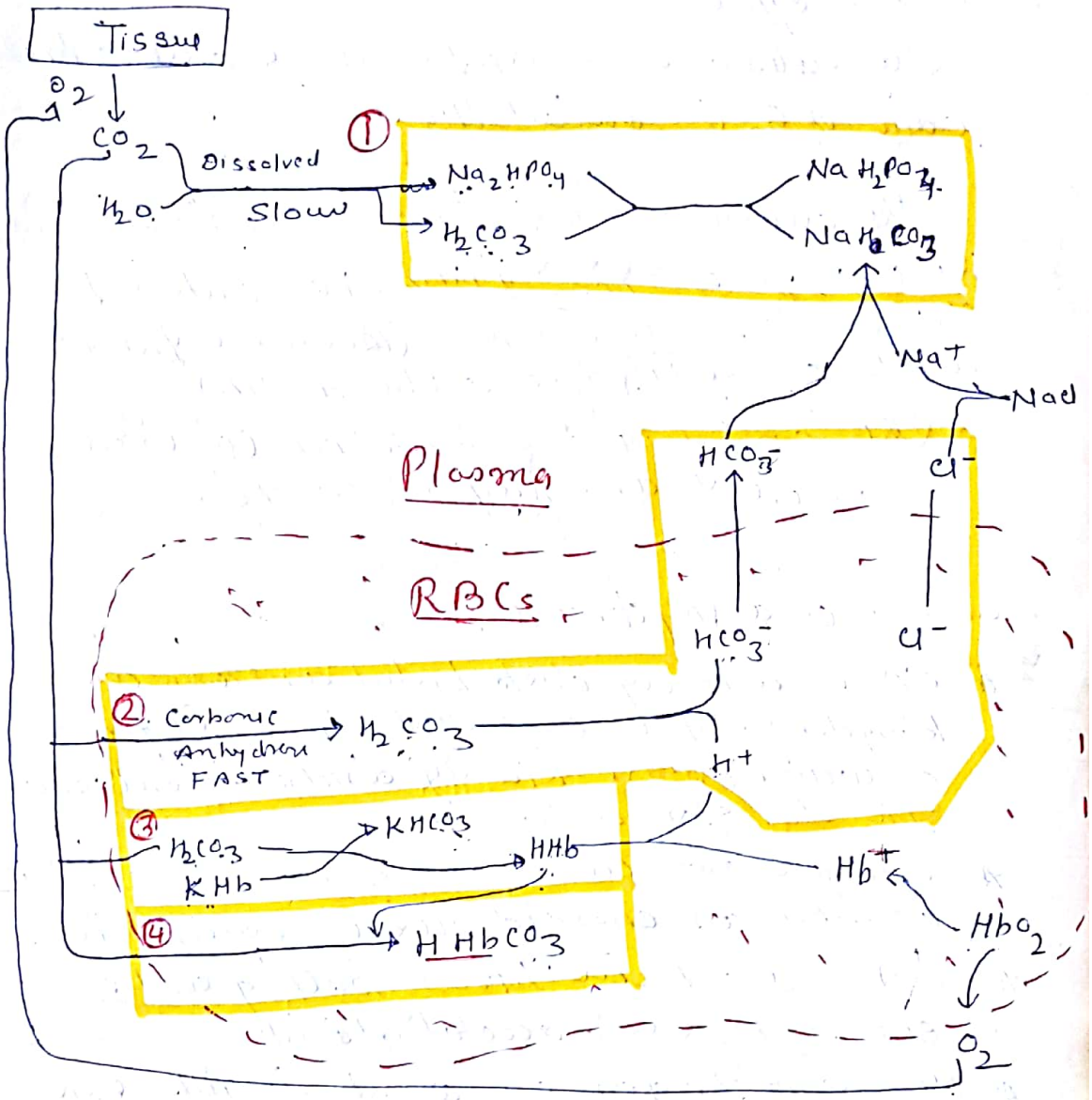
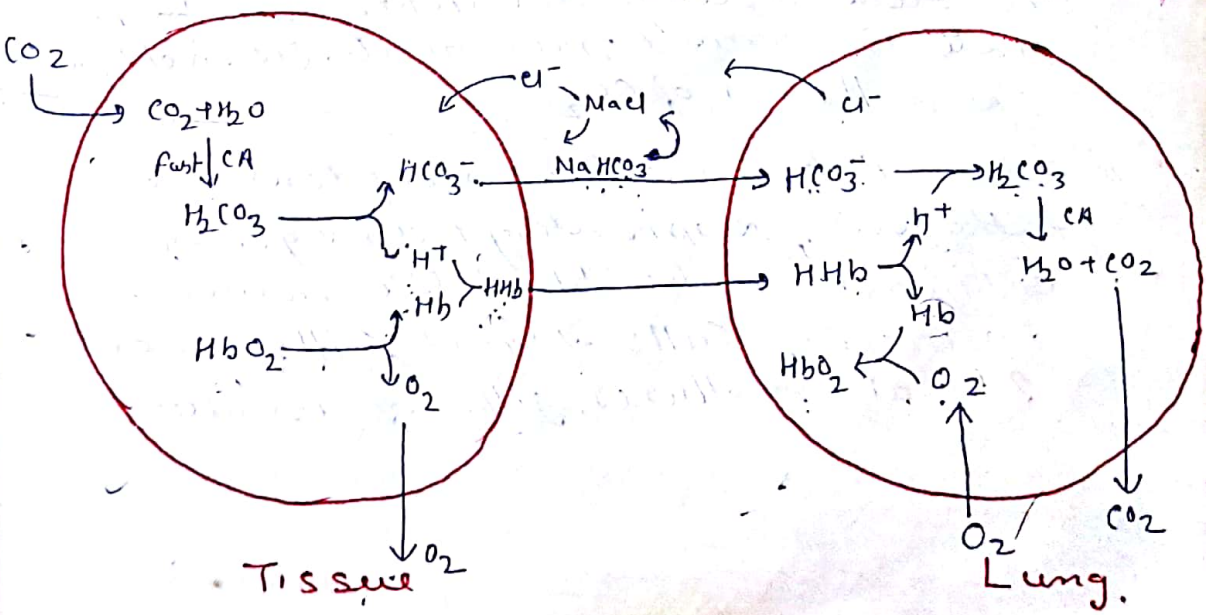


fig: Showing all 4 types of CO_2 transport mech.



Haldane Effect:-

The release of CO_2 at the lungs due to high conc. of O_2 is called H.E.

The deoxygenation of Hb in the tissue reduces the change in P_{CO_2} & pH as CO_2 enters the blood this is termed as H.E. (Because the H^+ binds with deoxy Hb after releasing Hb)

The carbaminohaemoglobin CO_2 is responsible for more than half of the HE.

The binding of H^+ to Hb after release of O_2 to form HHb is called HE.

Carbonic anhydrase:—

- ✱ CA is widely distributed among animal kingdom. It is essential in acidification of urine in the kidney and in acid secretion in the stomach.
- ✱ CA present in the eye of all vertebrates as well as choroid plexus & pancreas.
- ✱ CA present in birds salt gland & elasmobranch rectal gland.
- ✱ It is present in larger amount in gills & kidney of fresh water fish (but not in marine)
- ✱ The CA activity is greater in red cells of small mammals than that of large species. It is related with the higher metabolic rate in small mammals. It facilitates the diffusion of CO_2
- ✱ CA is present in coelentrates (tentacle of Anthozoa), Respiratory trees & gonads of echinoderms, blood of earthworm & nereids, Gills of squid, gills & mental of bivalve molluscs, gills of Limulus.

* CA in human RBC occurs in 3 isozymal forms, which are separable by electrophoresis CA of sepia gills & muscles occurs in 2 forms. Each of 3 forms of human CA contains 0.2 % Zn also in turtle 0.2%. but in duck this is 0.14 % only
* Unsaturated aromatic sulfonamides are known as CA inhibitors.