CARBON DIOXIDE TRANSPORT

In lowly organized animals with a small oxygen requirement only a small amount of $CO_2$is produced as a bye-product of biological oxidation. In these animals, $CO_2$is kept as solution till its disposal through the respiratory surface. But in higher animals, increased amount of$CO_2$is produced due to increased activity with an increased demand of oxygen. Hence an efficient transport of $CO_2$to the respiratory surface facilitating its quick removal is required. The CO_2transport takes place by the corpuscles as well as by the plasma. CO_2 is 30 times more suitable in water than oxygen. During CO_2 transport by the plasma, blood functions as buffer solution and does not allow any great fluctuations in the pH value and hence does not become acidic.

The CO_2produced in the tissues is transported to the lungs or gills, where it is exchanged by diffusion. Little of the $CO_2$is in physical solution in the plasma, but rather is largely found in reversible chemical combinations, both in plasma and in the erythrocytes.

FACTS ABOUT CO_2 TRANSPORT

1. CO_2TENSION IN ARTERIAL BLOOD- 40 mm Hg.

2. CO_2 TENSION IN VENOUS BLOOD- 45 mm Hg.

3. ARTERIAL CO_2CONTENT-48ml/100 ml

4. VENOUSCO_2CONTENT-52ml/100 ml

5. So, 100 ml of blood transports 4 ml of $CO_2$from the tissues

CHEMICAL FORMS IN WHICH CO_2 IS TRANSPORTED

A. TRANSPORT OF CO_2 IN THE DISSOLVED STATE

A small portion of the CO_2 is transported in the dissolved state to the lungs. Only about 0.3 milliliter of CO_2 is transported in the form of dissolved CO_2 by each 100 milliliters of blood. This is only 7% of all the CO_2 normally transported.

B. TRANSPORT OF CO_2 IN THE FORM OF BICARBONATE ION

1. This is the principal form (70%) in which CO_2 is transported.
2. CO_2 reacts with water to form H_2CO_3 which breaks down into H^+ and HCO_3^-. However, in plasma, the reaction is too slow to be of any importance.
3. But this reaction proceeds with much greater speed inside the RBC due to two reasons:
   i. Presence of the enzyme carbonic anhydrase.
   ii. Presence od Hb- a proton acceptor in tissues.
4. Dissolved CO_2 in the bloodreacts with water to form carbonic acid. This reaction would occur much too slowly to be of importance were it not for the fact that inside the red blood cell is a protein enzyme called carbonic anhydrase, which catalyzes the reaction between CO_2 and water, accelerating its reaction rate about 5000-fold. Instead of requiring many seconds or minutes to occur, as is true in the plasma, the reaction occurs so rapidly in the red blood cells that it reaches almost complete equilibrium within a very small fraction of a second. This allows tremendous amounts of CO_2 to react with red blood cell water even before the blood leaves the tissue
5. In another fraction of a second, the carbonic acid formed in red blood cells (H_2CO_3) dissociates into hydrogen and bicarbonate ions (H^+ and HCO_3^-).
6. Most of the hydrogen ions then combine with the hemoglobin in the red blood cells because the hemoglobin protein is a powerful acid-base buffer.

7. As the reaction proceeds, there is gradual accumulation of HCO_3^- inside the RBC. Since the rise in the HCO_3^- content of red cells is much greater than in the plasma, about 70% of the HCO_3^- now comes out of the RBC into the plasma along the concentration gradient. This upsets the electrical balance of the cell interior.
8. Chloride ion (Cl^{-}) now moves into the RBC from the plasma to restore electroneutrality, i.e., HCO_3^- leaves the red blood cells in exchange for Cl^-
9. This is made possible by the presence of a special bicarbonate-chloride carrier protein in the red cell membrane that shuttles these 2 ions in opposite directions at rapid velocities.

   Thus, the chloride content of venous red blood cells is greater than that of arterial red blood cells, a phenomenon called the **chloride shift.** The chloride shift occurs rapidly and is essentially completed in 1 second.
10. The process of movement of excess HCO_3^- in exchange of Cl^- is mediated by **Band 3**, a major membrane protein.

    Note- The reversible combination of CO_2 with water in the red blood cells under the influence of carbonic anhydrase account for about 70% of the CO_2 transported from the tissues to the lungs. Thus, this means of transporting CO_2 is by far the most important of all the methods for transport. Indeed, when a carbonic anhydrase inhibitor, acetazolamide is administered to animal to block the action of carbonic anhydrase in the red blood cells, CO_2 transport from the tissues become so poor, that the tissue P CO_2 can be made to rise to 80 mm Hg instead of the normal 45 mm Hg.

C. TRANSPORT OF CO_2 IN COMBINATION WITH HEMOGLOBIN AND PLASMA PROTEIN CARBAMINOHEMOGLOBIN

1. In addition to reacting with water, CO_2 reacts directly with amine radicals of the hemoglobin molecule to form the compound carbaminohemoglobin (CO_2Hgb). This combination of CO_2 with the hemoglobin is a reversible reaction that occurs with a loose bond, so that the CO_2 is easily released into the alveoli, where the P CO_2 is lower than in the tissue capillaries.
2. A small amount of CO_2 also reacts in the same way with the plasma proteins, but this is much less significant because the quantity of these proteins is only one fourth as great as the quantity of hemoglobin.

REVERSE CHLORIDE SHIFT

1. In the lungs, the opposite sequence of reaction occurs, the hemoglobin is oxygenated.
2. HbO_2 is more acidic and releases H^+ ions inside the RBC, which combine with HCO_3^- to form H_2CO_3.
3. H_2CO_3 liberates CO_2 which escapes through lungs.
4. As HCO_3^- inside the RBC has become low, HCO_3^- from the plasma now enters into RBC.
5. In exchange of this HCO_3^-, Cl^- moves out from the RBC into the plasma to maintain electroneutrality. This is therefore, termed as **reverse chloride shift.**

HALDANE EFFECT

Release of oxygen in the tissues from HbO_2 with the formation of reduced Hb stimulates uptake of CO_2 by RBC. This is known as **Haldane effect**.

This is due to two reasons:

1. Deoxygenated Hb binds more CO_2 as carbaminohemoglobin.
2. Reduced hemoglobin is less acidic and therefore acts as a stronger proton acceptor. So, when oxygen is released in tissues forming reduced hemoglobin, this can mop up more H^+ and move the reaction.

$CO_2 + H_2O = H_2CO_3 = H^+ + HCO_3$ in rightward direction. This leads to greater uptake of CO_2.

Thus, Haldane Effect facilitates the uptake of CO_2 in the tissues and its release in the lungs.