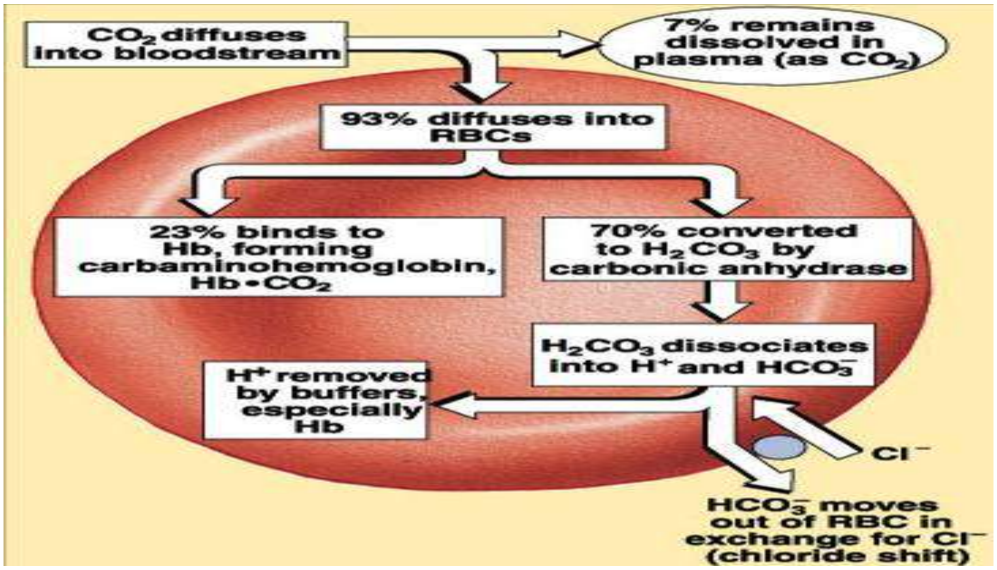

Lecture 13: Transport of CO_2 transport in the blood

Code: RRS-209

By

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Learning Objectives:

Knowledge:

- ✓ Know the forms of Co_2 in the blood.
- ✓ Explain mechanism by which CO_2 is transported in the blood.
- ✓ Describe the CO_2 dissociation curve and know its significance.
- ✓ Know the effect of Haldane on the Co_2 on its dissociation curve .

Intellectual:

- ✓ Compare between O and CO Dissociation curve.

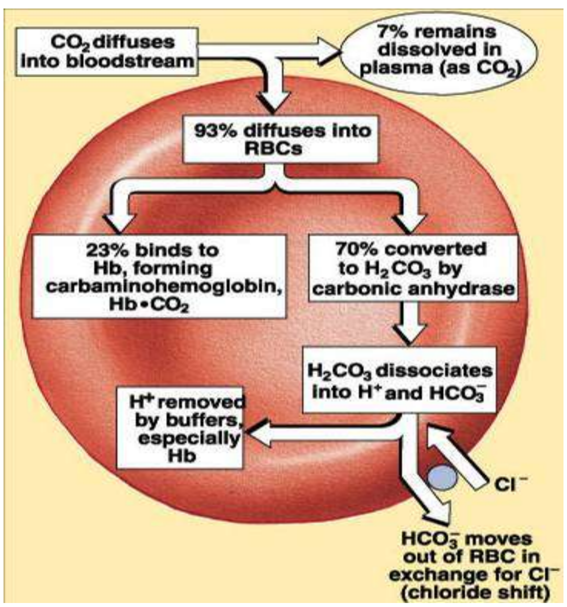
Carbon dioxide transport in the blood

- CO_2 is an acid product of metabolism which must be removed, it is a major determinant of blood pH.
- The PCO_2 of ECF is affected by: the metabolic formation of CO_2 and the rate of pulmonary ventilation. As metabolic formation of CO_2 normally is constant, SO PCO_2 chiefly depends on alveolar ventilation.
- Carbon dioxide is transported in the blood from the tissues to the lungs where it is excreted from the body.
- In order to transport all of the CO_2 produced in the tissues to the lung, CO2 in transported by the blood in three ways as:

In venous blood, As dissolved CO_2 7 %

In the form of HCO_3 70%

Carbamino CO2 23% : Complexed to the terminal amine groups of blood proteins.



1-Physical Form (Dissolved CO_2)

- Dissolved CO_2 is carried in the blood in both intracellular and extracellular compartments.
- The solubility of CO_2 is 20 times greater than that of O_2 so blood carries more dissolved carbon dioxide than dissolved oxygen (Compare)
- At Pco_2 of venous blood is **45** mmHg, 2.7ml/dl.
- At Pco_2 of arterial blood is **40** mmHg, the CO_2 amount is 2.4 ml/dl. SO, 0.3 ml of CO_2 is added to each 100 ml of blood when it passes to the tissues.

2- Carbaminohemoglobin ($HbCO_2$):

- Hb is the most significant protein for carrying CO2 which binds to the terminal amine groups of proteins in blood cells and plasma.
- 23% of the CO_2 entering the blood react reversibly with the amino groups of hemoglobin to form carbamino hemoglobin $HbCO_2$

3- In the form of Bicarbonate : Chloride shift:

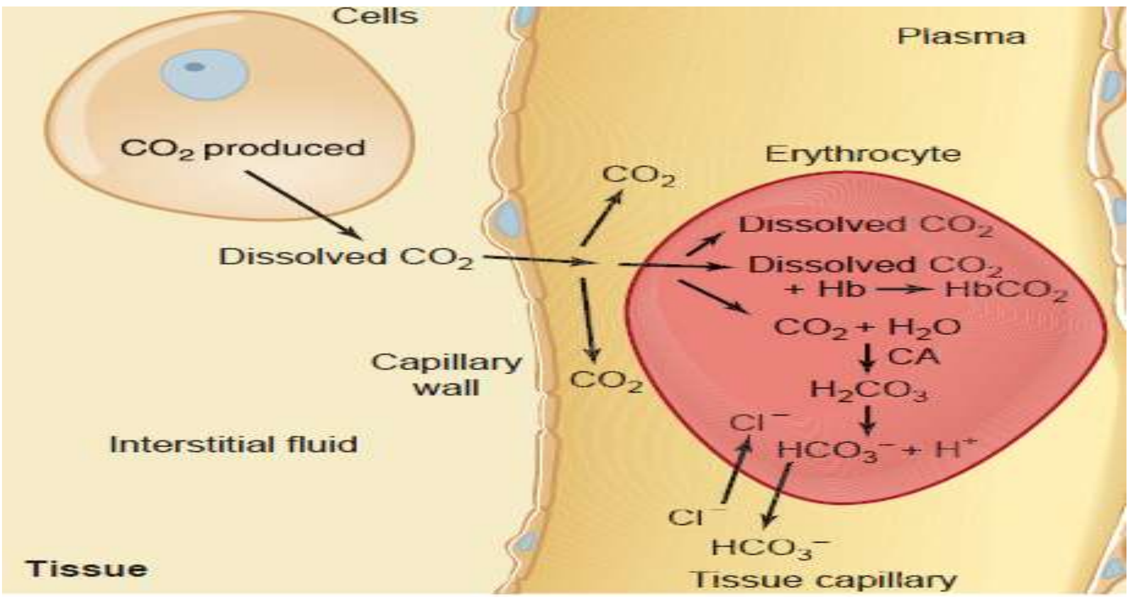
At the tissues,

- CO_2 diffuses from the tissues into erythrocytes. Hb releases O_2 to tissues. **WHY?**
- CO_2 is hydrated to form carbonic acid: $\mathbf{H_20 + C0_2 \Leftrightarrow H_2C0_3 \Leftrightarrow H^+ + HC0_3^-}$
- This reaction is rate-limiting and is <u>very slow</u> unless catalyzed by the enzyme **carbonic anhydrase.** This enzyme is present in the erythrocytes ***but not in the plasma***; therefore, this reaction occurs mainly in the erythrocytes.
- In contrast, carbonic acid dissociates very rapidly into a bicarbonate ion and a hydrogen ion without any enzyme assistance.
- Once HCO_3^- is formed, most of the bicarbonate moves out of the erythrocytes into the plasma via a transporter that exchanges one bicarbonate for one chloride ion this is called the ***("chloride shift").***

- ***N.B.*** *HCO_3^- diffuses into the blood to prevent its accumulation which would stop the reaction.*

- RBC becomes more +ve, so Cl^- attracted inside the RBCs for electrical neutrality through carrier protein (Cl^- shift).

- The H^+ formed in the red cells from the reaction is buffered by combining with deoxyhemoglobin, because deoxygenated Hb is a weaker acid than HbO_2 as it has more sites available to accept H^+.



TIME TO THINK *What is the net result of Cl^- shift phenomena?*

Reverse of Cl^- shift

At the lungs,

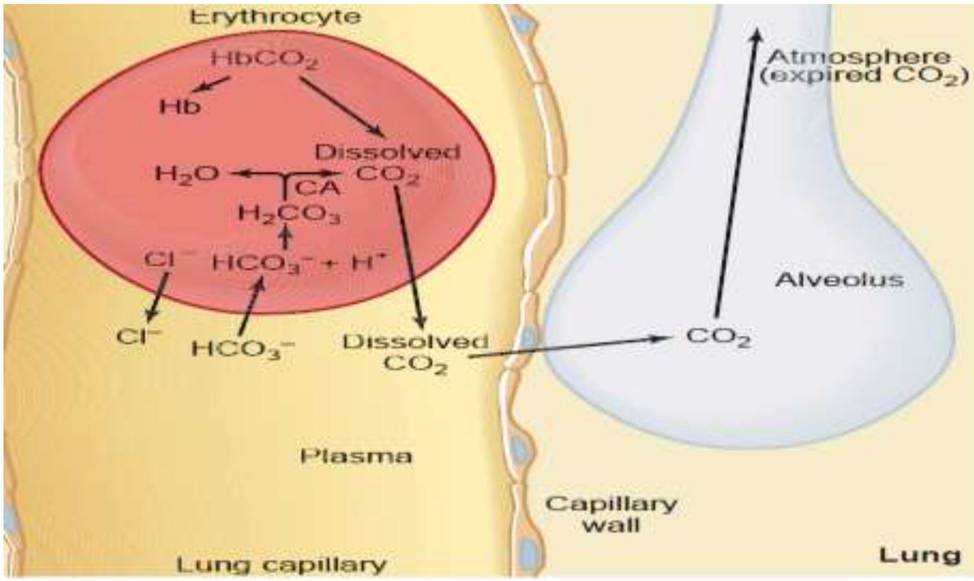
- The reverse sequence of events occurs.

- Because the venous blood *PCO_2 is higher than alveolar PCO2, a net diffusion of* CO_2 from blood into alveoli occurs. This loss of CO_2 from the blood lowers the blood *PCO_2 and drives reactions* (How this help Oxygenation of the blood?)

- HCO_3^- and H^+ combine to produce H_2CO_3, which then dissociates to CO_2 and H_2O.

- Normally, as fast as CO_2 is generated, it diffuses into the alveoli.

- Intracellular [Cl^-] is therefore higher for venous erythrocytes than for arterial erythrocytes (chloride shift).
- Decreased [$HC0_3^-$] in RBC, makes $HC0_3^-$ diffuses into the RBC. ***WHY.*** RBC becomes more –ve, so Cl^- diffuses out (reverse Cl^- shift).
- Similarly, $HbCO_2$ free CO_2. So, Deoxyhemoglobin converted to oxyhemoglobin.
- In this manner, all the CO_2 delivered into the blood in the tissues is now delivered into the alveoli, from where it is eliminated during expiration.

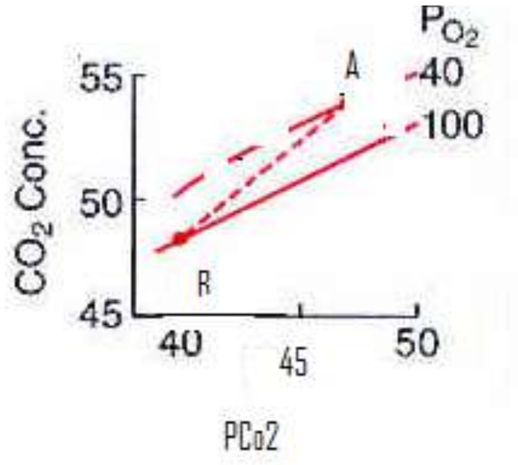


The CO_2 dissociation curve

- It is the relationship between *P* CO_2 and the concentration of CO_2 in whole blood.
- Discover the difference between it and O_2DC
- The curve is approximately linear over the physiological range of *PCO_2* (*The normal blood PCO_2 ranges between the limits of* ***40*** *mmHg in arterial blood* and ***46*** mmHg in venous blood.

From the curve we can observe that:

- The total amount of Co_2 concentration in the blood depends on the PCO_2.
- So, venous blood with PCO_2 46 mmHg, CO_2 content is of 52 ml/100ml, While, arterial blood with PCO_2 40 mmHg with CO_2 content of 48 ml/100ml.



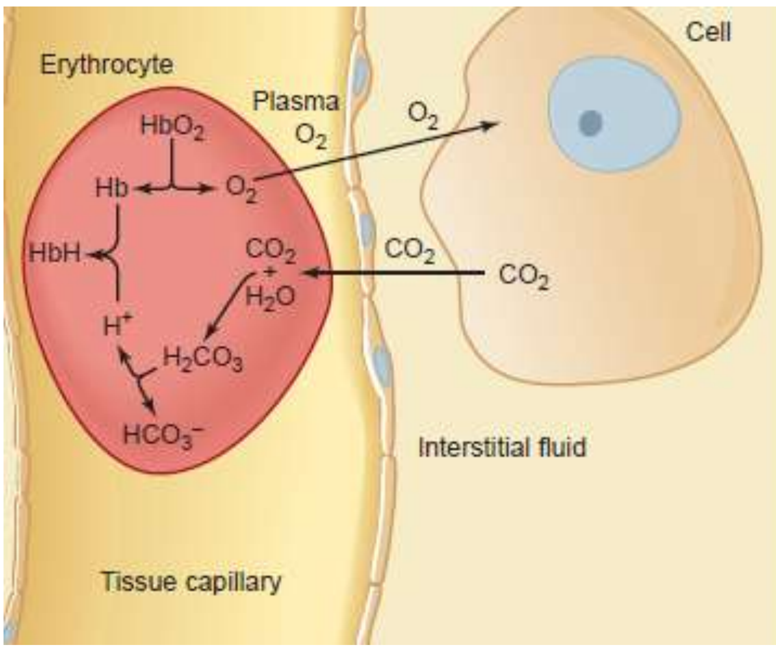
Effect of Haldane effect on CO2 dissociation curve:

- **Haldane effect**: Binding of O_2 with Hb tends to displace CO2 from the blood
- **Mechanism**:
- Combination of oxygen with hemoglobin in the lungs cause the hemoglobin to becomes a stronger acid which has a weaker affinity for CO_2. So, oxyhemoglobin releases CO_2
- The increased acidity of the hemoglobin also causes it to release hydrogen ions and hydrogen irons.
- This should be considered along with the ***Bohr effect*** as the interaction of these two effects augment the transport of the two most important respiratory gases.
- *Significance of Haldane effect;*
- 1- **Point A** on the dashed curve shows that in venous blood where normal PO_2 is 40 mmHg and PCO_2 is 45 mmHg, the volume of Co2 is 52 ml/100ml.
- 2- **Point B**: shows that arterial blood the PO_2 is 100mmHg and PCO_2 falls to 40 mmHg with volume of $CO_{2} =$ 48 ml/100ml.
- This means that venous blood (deoxygenated blood) can carry more Co_2 than arterial blood (fully oxygenated blood) which helps unloading of CO_2 from the tissues and more CO_2 to be discharged into the alveoli.

So Note that for any given PCO_2, CO2 content of blood, increases as PO2 falls

Transport Of hydrogen ions between Tissues and lung:

- As blood flows through the tissues, a fraction of oxyhemoglobin loses its oxygen to become deoxyhemoglobin, while simultaneously a large quantity of carbon dioxide enters the blood and undergoes the reactions that generate bicarbonate and hydrogen ions. *What happens to these hydrogen ions?*
- Deoxyhemoglobin has a much greater affinity for H^+ than does oxyhemoglobin, so it binds (buffers) most of the hydrogen ions. This explains why venous blood (pH = 7.36) is only slightly more acidic than arterial blood (pH = 7.40).



- As the venous blood passes through the lungs, this reaction is reversed. Deoxyhemoglobin becomes converted to oxyhemoglobin which, releases the hydrogen ions it picked up in the tissues.
- The hydrogen ions react with bicarbonate to produce carbonic acid, which, under the Influence of carbonic anhydrase, dissociates to form carbon dioxide and water.
- The carbon dioxide diffuses into the alveoli to be expired.

- Normally all the hydrogen ions that are generated in the tissue capillaries recombine with bicarbonate to form carbon dioxide and water in the pulmonary capillaries.

Important notes of the lecture:

- CO_2 is mainly transported in the plasma as HCO_3^- which is first formed in the red corpuscles. Just as the change in levels of CO_2 in the blood between lungs and tissues improves the carriage of O_2 so the changes in levels of O 2 improves the carriage of CO_2
- Most of the bicarbonate then moves out of the erythrocytes into the plasma in exchange for chloride ions.
- As venous blood flows through lung capillaries, blood PCO_2 decreases because of the diffusion of carbon dioxide out of the blood into the alveoli, and the reactions are reversed.
- The dissociation curve for CO 2 from the blood is almost a straight line, quite different from the S-shape for O_2.
- Most of the hydrogen ions generated in the erythrocytes from carbonic acid during blood passage through tissue capillaries bind to deoxyhemoglobin because deoxyhemoglobin, formed as oxygen unloads from oxyhemoglobin, has a high affinity for hydrogen ions.

End OF the Lecure