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- **Lecture title: Transport of gas in the blood**

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Summary:

- **Transport of gas in the blood**

The respiratory and circulatory systems function together to transport oxygen (O2) from the lungs and transport carbon dioxide (CO2) from the tissues to the lungs for expiration. CO2, a product of active cellular metabolism, is transported from the tissues via systemic veins to the lungs, where it is expired. To enhance uptake and transport of these gases between the lungs and tissues, specialized mechanisms (e.g., binding of O2 and hemoglobin and HCO3- transport of CO2) have evolved that enable O2 uptake and CO2 expiration to occur simultaneously. Moreover, these specialized mechanisms facilitate uptake of O2 and expiration of CO2.

- **Gas diffusion: -**

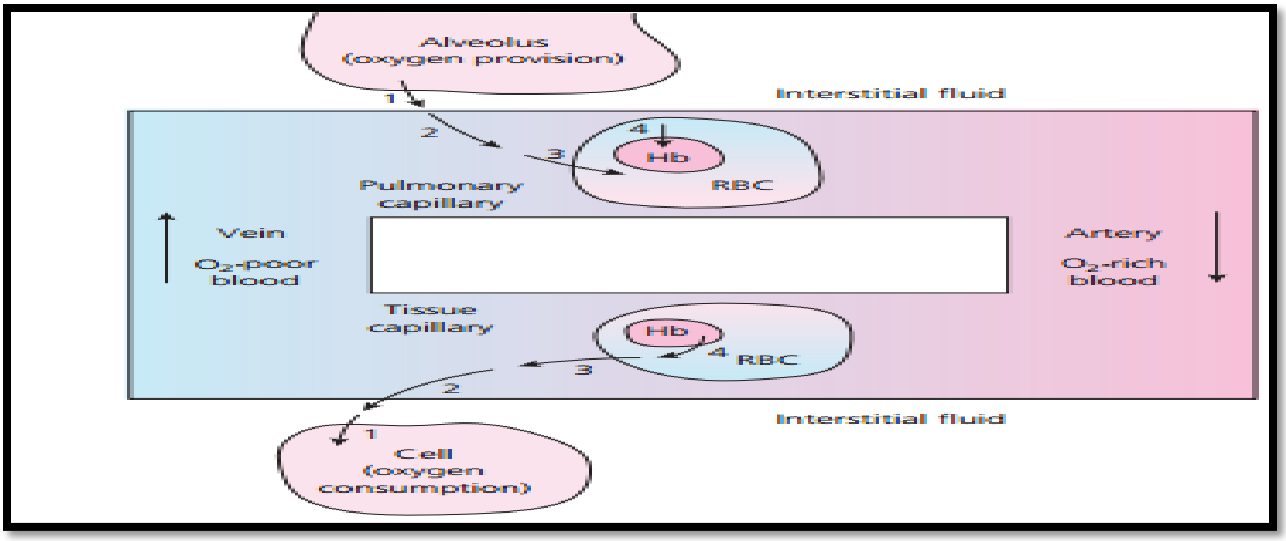
Gas movement throughout the respiratory system occurs predominantly via diffusion. The respiratory and circulatory system contain several unique anatomical and physiological features to facilitate gas diffusion: -

- (1) Large surface areas for gas exchange (alveolar to capillary and capillary to tissue membrane) with short distances to travel
- (2) Substantial partial pressure gradient differences
- (3) Gases with advantageous diffusion properties. Transport and delivery of O_2 from the lungs to the tissue and vice versa for CO_2 are dependent on basic gas diffusion laws.

- Transport of Oxygen

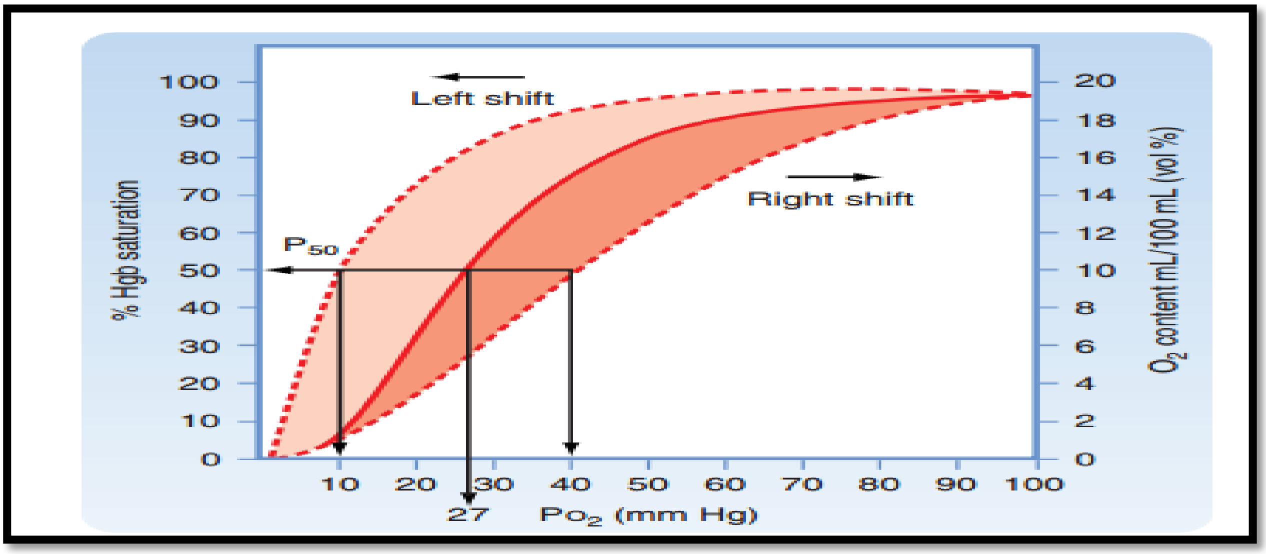
Oxygen is vital for life-sustaining aerobic respiration. Generally, there are two types of oxygen transfer in the body: convection and diffusion. Convection refers to the active process where oxygen is moved in circulation through mass transport. Diffusion refers to the passive movement of oxy-gen along a concentration gradient, for example from the microvasculature to tissues.

- General scheme of oxygen transport:- The transport of oxygen from alveoli to hemoglobin and from hemoglobin to tissues occurs via diffusion gradients. When oxygen-poor blood arrives at the lungs, the process of diffusion is from alveoli to erythrocytes. Reversal of the process occurs when oxygen-rich blood arrives at the tissues. The .The process of oxygen uptake by hemoglobin proceeds as follows: oxygen passes from air in the alveolus to successive solution in interstitial fluid (1), plasma (2), and erythrocyte fluid (3), and finally to combination with hemoglobin (4). The process of oxygen yield to the cells proceeds in the reverse direction. Diffusion of oxygen away from interstitial fluid lowers the Po_2 of the erythrocyte fluid and, just as an increased Po_2 increases the saturation of hemoglobin with oxygen, decreased Po_2 causes desaturation of hemoglobin.



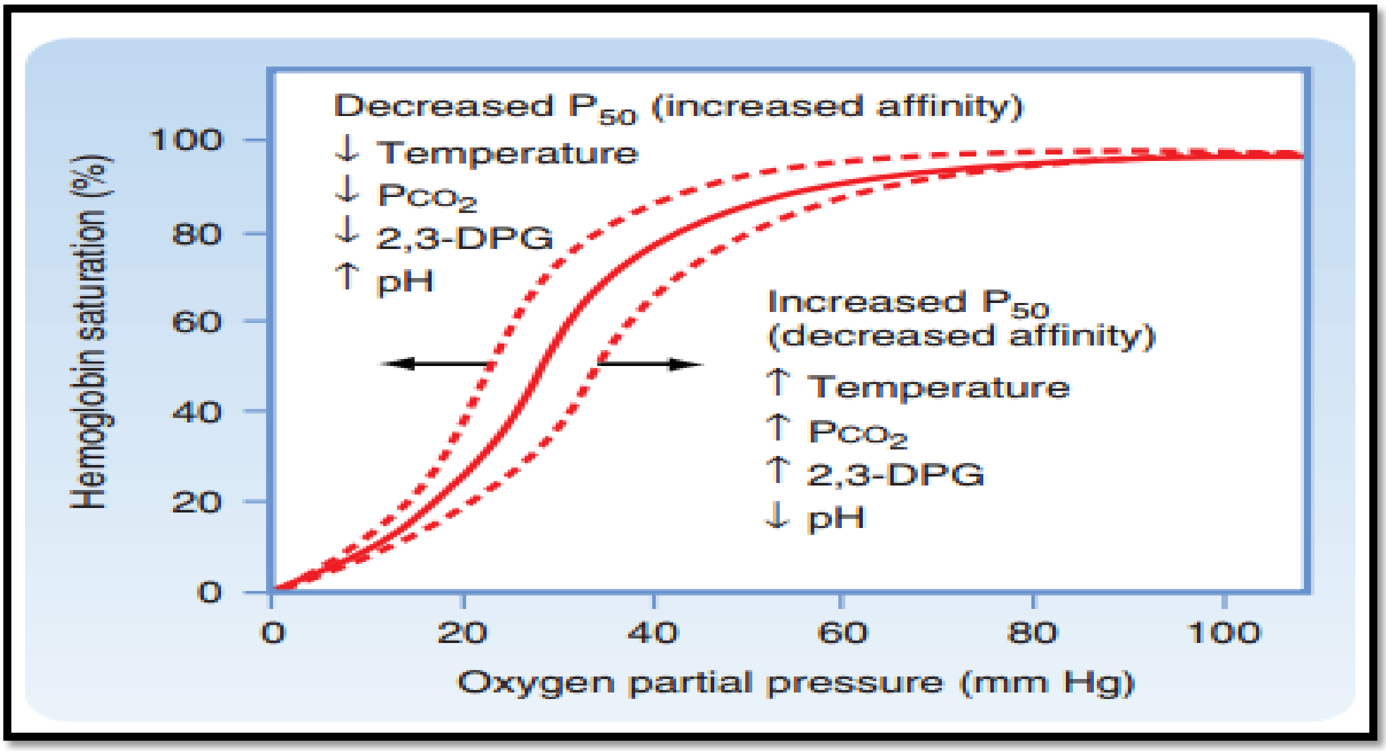
- The oxygen–hemoglobin dissociation curve: -

The loading and unloading of oxygen from hemoglobin are best described by the oxygen–hemoglobin dissociation curve. Which demonstrates a progressive increase in the percentage of hemoglobin bound with oxygen as blood Po_2 increases, which is called the percent saturation of hemoglobin. Because the blood leaving the lungs and entering the systemic arteries usually has a Po_2 of about 95 mm Hg, one can see from the dissociation curve that the usual oxygen saturation of systemic arterial blood averages 97%. Conversely in normal venous blood returning from the peripheral tissues, the Po_2 is about 40 mm Hg, and the saturation of hemoglobin averages 75%. The association of oxygen with hemoglobin and its dissociation from hemoglobin are not stable under all conditions. Different conditions change the equilibrium of the reaction between hemoglobin and oxygen that form oxyhemoglobin



Physiological Factors That Shift the Oxyhemoglobin Dissociation Curve

The oxyhemoglobin dissociation curve can shift in numerous clinical conditions, either to the right or to the left the curve is shifted to the right when the affinity of Hgb for O_2 decreases, which enhances O_2 dissociation. This results in decreased Hgb binding to O_2 at a given PO2, which causes the P50 to increase. When the affinity of Hb for O_2 increases, the curve is shifted to the left, which causes the P50 to decrease. In this state, O_2 dissociation and delivery to tissue are inhibited. Shifts to the right or left of the dissociation curve have little effect when they occur at O_2 partial pressures within the normal range (80 to 100 mm Hg). However, at O_2 partial pressures below 60 mm Hg (steep part of the curve), shifts in the oxyhemoglobin dissociation curve can dramatically influence O_2 transport



- ## Transport of Carbon Dioxide

The purpose of breathing is to supply oxygen to the tissues and get rid of the carbon dioxide (CO_2) produced during metabolism, which can sometimes be at the rate of 200 mL/ min, thus stabilizing the biochemical environment necessary to maintain the vital metabolic process. Carbon dioxide occurs in three different forms in the body, i.e. (a) dissolved, (b) as bicarbonate and (c) as carbamate.

General scheme of carbon dioxide transport: -

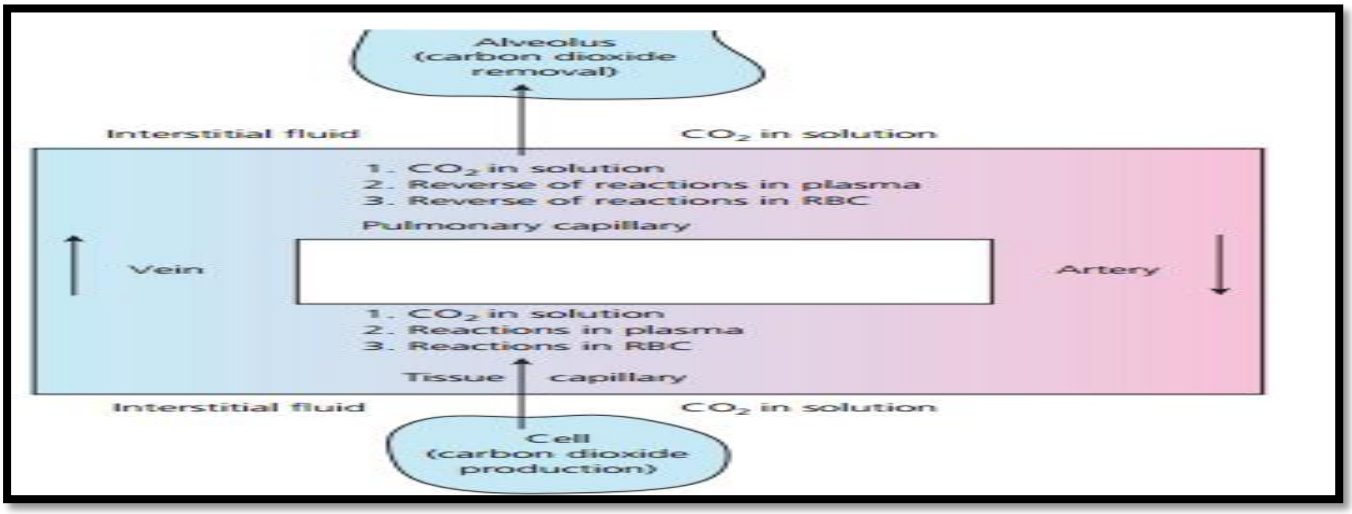
This scheme considers the following points: -

1- Carbon dioxide is highly soluble in body fluids and because of pressure gradients, readily diffuses from its production site, the body cells, through interstitial fluid, to the plasma of venous blood of the tissue capillaries.

2 -At this point, carbon dioxide is transported not only by that which is in solution, but also by reactions that occur in plasma, and by reactions that occur in red blood cells.

3- The venous blood circulates to the pulmonary capillaries and, because of pressure gradients that favor unloading of carbon dioxide, the carbon dioxide in solution diffuses from the pulmonary capillaries to the alveoli this is followed by a reversal of the reactions that accommodated the prior loading of carbon dioxide in plasma and red blood cells.

4- The venous blood now becomes arterial blood that exhibits a reduction in the partial pressure of carbon dioxide whereby diffusion gradients will again favor loading of carbon dioxide from its site of production.



Transport of carbon dioxide in plasma: -

Carbon dioxide that diffuses to plasma from the cells not only will exist as dissolved carbon dioxide but also will combine with terminal amino groups of plasma proteins to form carbamino compounds and will be hydrated to form ionization products of carbonic acid. This reaction does not account for a significant amount of transport because there are relatively few free or terminal amino groups on plasma proteins capable of combining with carbon dioxide. The hydration of carbon dioxide, forming ionization products of carbonic acid (H_2CO_3) proceeds as follows:-

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

The equilibrium of the hydration reaction in plasma is far to the left. In fact, the concentration of carbon dioxide in plasma is about 1000 times greater than the concentration of carbonic acid. In summary, the reactions that occur in plasma with carbon dioxide comprise only about 10% of carbon dioxide transport.

- **Carbon dioxide in erythrocytes (Role in acid-base homeostasis)** Carbon dioxide readily diffuses into erythrocytes, and reactions with water and amino groups are more significant than in plasma. There are greater numbers of terminal amino groups on hemoglobin than there are on plasma proteins, so that this form of carriage is more prominent. Also, the hydration reaction is facilitated by the presence of **carbonic anhydrase**, an enzyme found within erythrocytes. The carbonic acid that is formed ionizes to produce hydrogen ions and bicarbonate ions. Even though the equilibrium of the hydration reaction favors the formation of hydrogen ions and bicarbonate ions, it is rate- limited if the ionization products are not removed. However, the ionization products are removed by the buffering of hydrogen ions by hemoglobin and by the diffusion of bicarbonate ions from the erythrocytes to the plasma.