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B.Sc Part-III Paper-V

Topic - Physiology of Respiration in Mammals.

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Q. . Give an account of Physiology of respiration in Mammal.

Ans. Transport of gases includes (i) transport of O_2 from lungs to tissues and (ii) transport of CO_2 from tissues (cells) to alveoli of lungs.

Importance of blood circulatory system in the transport of gases :

The O_2 which enters the lungs must reach the animal cells for cellular respiration. As cells are situated quite away from the respiratory surface (lung) the O_2 is carried by circulating blood to the cells. Thus the circulatory system along with respiratory system performs the major work of O_2 distribution. The importance of blood is easily understood when we compare the solubility of O_2 and CO_2 in the same volume of blood and water. This is due to the presence of a complex chemical compound called haemoglobin in the RBC of blood and this is responsible for transporting O_2.

Role of haemoglobin in the transport of O_2 : Haemoglobin is present in the blood of all vertebrates due to which the colour of the blood is red. It is situated within the RBC and is responsible for the transport of gases. In the absence of haemoglobin respiration is impossible. So it is also called respiratory pigment. It is formed of two parts :

(i) Harm formed by iron prophyrin having Fe atom at the centre. This gives the red colour to the blood and has strong affinity for both O_2 and CO_2. It forms only 5% of haemoglobin.

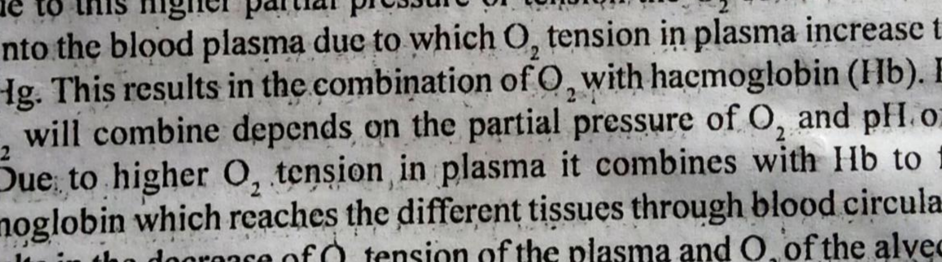
(ii) The second part of the haemoglobin is the globin forming 95% of haemoglobin. It is a colourless protein. The function of haemoglobin is not only to combine loosely with O_2 but combines with O_3 in huge amount for its proper functioning and to provide O_2 to places where it is present in lower concentration. In lungs where the partial pressure (tension) of O_2 is very high almost all haemoglobin molecules combine with O_2 In the tissues where the globin and enters into it (i.e. in tissues).

Dissociation curve : This partial pressure of O_2 on which haemoglobin is saturated by O_2 is very much variable. This indicates that the proportion of Oxy-haemoglobin and haemoglobin in the blood at any time is based on the oxygen tension in the blood. This is known as dissociation curve.

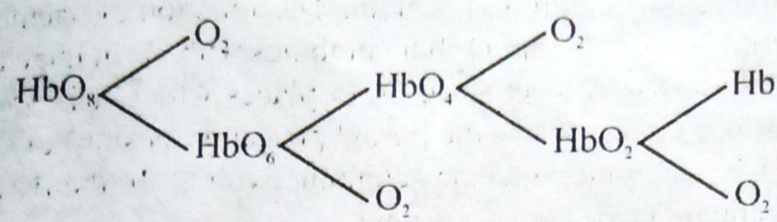
1. Oxygen transport : When various blood reaches the blood capillaries of the lungs it has O_2 tension of 40 mm of Hg and that of CO_2 46 mm. of H. In the alveolar air the tension of O_2 is 100 m.m. of Hg and that of CO_2 40 mm of Hg.

	PO_2	PCO_2
Alveolar air	100 m.m. Hg	40 m.m. Hg
Venous blood	40 m. m. Hg	46 m.m. Hg

Due to this higher partial pressure or tension the O_2 of the alveolar air diffues into the blood plasma due to which O_2 tension in plasma increase to 90 mm. of Hg. This results in the combination of O_2 with haemoglobin (Hb). How much O_2 will combine depends on the partial pressure of O_2 and pH of the blood. Due to higher O_2 tension in plasma it combines with Hb to form oxyhaemoglobin which reaches the different tissues through blood circulation. This results in the decrease of O_3 tension of the plasma and O_2 of the alvecAar air further diffues into RBC where it forms oxyhaemoglobin with Hb of the RBC. This diffusion of O_2 is continued until the Hb of the RBC is completely saturated with O_2. Each Hb is molecules contains 4 atoms of Fe^{++} and each of this iron atom is capable of uniting with one molecule of oxygen. So one molecule of Hb may combine with 1-4 molecules of O_2 to form different types of weak oxyhaemoglobin molecules as shown below :



In cells the partial pressure of O_2 is lower and so oxyhaemoglobin breaks up to oxygen and haemoglobin. Due to this pressure gradient O_2 from the blood diffuses into the tissues. Oxyhaemoglobin HbO_8 looses one molecule of O_2 to form HbO_6 and again by loosing another O_2 molecule forms HbO_4 and ultimately from one molecule of HbO_8 (Oxyhaemoglobin: four molecules of O_2 and one molecule of haemoglobin are formed shown below :



Mechanism of interchange of gases in tissue : When the O_2 tension is 90 mm. of and CO_2 tension is 40 m.m. of Hg in the arterial blood then the O_2 tension is 35 m. of Hg and CO_2 tension is only 45 mm. of Hg in the tissues. This pressure gradient result in the gaseous diffusion between systemic capillaries and the tissuses as shown below :

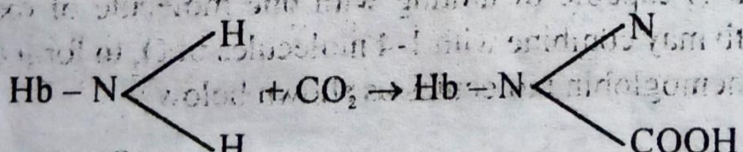
	O_2	CO_2
Arterial blood	90 m.m. Hg	40 m.m. Hg
Tissue	35 m.m. Hg	46 m.m Hg

Due to this pressure gradient the of the blood diffuses to the tissue and CO_2 of the tissues diffuses to blood.

(ii) Transport of CO_2 : During cellular respiration CO_2 and H_2O are formed and energy is liberated. This CO_2 is also transported to lungs by blood circulatory system. O_2 is mostly transported by haemoglobin but only about 5.10% of CO_2 is transported by Hb. So transport of CO_2 is done by blood circulation in different forms as described below :

(a) As Physical Solutin : About 5% CO_2 is transported as carbonic acid by blood plasma. The water present in plasma combines with CO_2 to form carbonic acid.

(b) As Carbamino Compound : About 10% of CO_2 combines with NH_2 group of haemoglobin to form carboxy. haemoglobin or with plasma proteins forming carbomino proteins and are transported as such



(c) As Bicarbonates : About 85% CO_2 transported as bicarbonates CO_2 with water forms carbonic acid which is ionised as follows—

$$CO_2 + H_2O \rightarrow H_2CO_3$$
$$H_2CO_2 \rightarrow H^+ + HCO_3$$

Carbonic acid is very weak acid and so very small amount of it is ionised which means it is scantly solutile in water. So in this form very little of CO_2 is transported but if carbonic acid is transformed into another compound the amount of transported carbonic acid will increase. This happens by forming bicarbonates in blood plasma and RBC.

(i) Formation of Bicarbonates in RBC : In RBC haemoglobin is present in the form of protein and KCl as salt. The negatively charged haemoglobin (Hb) unites with positively charged potassium (K^+). This combines with carbonic acid ($H^+ + HCO_3^-$) as follows to form potassium bicarbonate ($KHCO_3$) and haemoglobinic acid–

$$K^{+-}Hb + H^+ + HC_3^- \rightarrow KHCO_3 + H.Hb$$

Carbonic anhydrase an enzyme present in RBC accelerates the formation of more bicarbonate.

(ii) Formation of Bicarbonate in Plasma : Plasma protein is generally united with Na^+ which reacts with carbonic acid to form bicarbonate as shown below–

$$Napr + H^+ + HCO_3^- = Hpr + NaHCO_3$$

Plasma protein Sodium bicarbonate.

As carbonic anhydrase is absent in plasma small amount of bicarbonate is formed in plasma. Exchange of CO_2 in blood takes place between plasma and RBC. The plasma membrane of RBC allows only negatively charged anions like Cl^- and HCO_2^- to enter inside the cell but it does not allow positively charged K anions like Na^+ and K^+ to enter the cell. According to Donnon's law of ionic concentration both sides of the membrane should be in equilibrium. When HCO_3^- enters the RBC it forms bicarbonate. If the amount of bicarbonate in the cells is increased the cellular reactions become alkaline. So to maintain the pH (hydrogen ion concentration) it is necessary that either basic ions (K^+) come out of RBC of acidic ion of plasma (Cl^-) enters into RBC.

But K^+ ion cannot come out through plasma membrane so Cl^- ions of plasma enter the RBC. It combines with $KHCO_3$ and forms KCl and HCO_3^-. This HCO_3 combines with Cl^- ion of NaCl and forms $NaHCO_3$ which is highly soluble.

The Na^+ ion of NaCl remains free in the plasma due to shift of Cl^- inside the RBC. Due to this shift of Cl^- the amount of Cl^- ions in plasma decreases. As Cl^- is shifted into the RBC its place should be taken by some other negatively charged ion so the ionic concentration of both the sides of the membrane remains constant and the pH of blood is maintained. This is done by HCO_3. This shifting of Cl- ions from plasma to cell is called chlorine shift or Hamburger phenomenon after the name of discoverer.

Entry of CO_2 in Alveoli from blood : When O_2 passed from alveoli to blood then the partial pressure of CO_2 in the blood capillaries is higher than alveoli air and so CO_2 diffuses from blood capillaries into alveoli. This diminisbes the amount of CO_2 in the blood plasma and the diffusion rate is reduced.

In the mean time O_2 combines with Hb to form strong acidic compound the oxyhaemoglobin. It has greater affinity for base than reduced Hb and this disturbs the chemical equilibrium of the blood. When the bicarbonates break down it combines with the bases to form haemoglobinate and proteinate and CO_2.

When bicarbonates reach the lungs direction of movement of chloride ion (Cl^-) is changed i.e., comes out of RBC and combines with $NaHCO_3$ to form NaCl and HCO_3^-. This carbonic acid forms H_2O and CO_2.

This CO_2 cannot remain in the blood because blood contains as much CO_2 as it can hold and so CO_2 diffuse into alveolar air which is expelled out during expiration.