

Biology

Textbook for Cass XI

17. Breathing and Exchange of Gases

Question 1. Define vital capacity. What is its significance?

Answer: Vital capacity: This is the maximum volume of air that a person can exhale out after a maximum inspiration is called Vital Capacity. It is about 3.5 – 4.5 litres in a normal adult person. Significance of Vital Capacity: It allows the intake of maximum amount of fresh air and to get rid of the foul air in a single stroke of respiration. Hence, it increases the gaseous exchange between the various tissues of the body, thereby increasing the amount of energy available to the body.

Question 2. State the volume of air remaining in the lungs after a normal breathing.

Answer: The volume of air remaining in the lungs after a normal expiration is known as functional residual capacity (FRC). It includes expiratory reserve volume (ERV) and residual volume (RV). ERV is the maximum volume of air that can be exhaled after a normal expiration. It is about 1000 mL to 1500 mL. RV is the volume of air remaining in the lungs after maximum expiration. It is about 1100 mL to 1500 mL.

$$\begin{aligned}\therefore \text{FRC} &= \text{ERV} + \text{RV} \\ &\cong 1500 + 1500 \\ &\cong 3000 \text{ mL}\end{aligned}$$

The functional residual capacity of the human lungs is about 2500 – 3000 mL.

Question 3. Diffusion of gases occurs in the alveolar region only and not in the other parts of respiratory system. Why?

Answer: Each alveolus is made up of highly-permeable and thin layers of squamous epithelial cells. Similarly, the blood capillaries have layers of squamous epithelial cells. Oxygen-rich air enters the body through the nose and reaches the alveoli. The deoxygenated (carbon dioxide-rich) blood from the body is brought to the heart by the veins. The heart pumps it to the lungs for oxygenation. The exchange of O₂ and CO₂ takes place between the blood capillaries surrounding the alveoli and the gases present in the alveoli.

Thus, the alveoli are the sites for gaseous exchange. The exchange of gases takes place by simple diffusion because of pressure or concentration differences. The barrier between the alveoli and the capillaries is thin and the diffusion of gases takes place from higher partial pressure to lower partial pressure. The venous blood that reaches the alveoli has lower partial pressure of O₂ and higher partial

pressure of CO_2 as compared to alveolar air. Hence, oxygen diffuses into blood. Simultaneously, carbon dioxide diffuses out of blood and into the alveoli.

Question 4. What are the major transport mechanisms for CO_2 ? Explain.

Answer: The transport mechanism of CO_2 takes place mainly by the haemoglobin. The carbon dioxide dissolved in the blood combines with the haemoglobin to form carbamino-haemoglobin (about 20-25 per cent), which is carried to the alveoli from the tissue. This binding is related to the partial pressure of CO_2 . Partial pressure of O_2 is a major factor, which could affect this binding. When pCO_2 is high and pO_2 is low as in the tissues, more binding of carbon dioxide occurs whereas, when the pCO_2 is low and pO_2 is high as in the alveoli, dissociation of CO_2 from carbamino-haemoglobin takes place. During the dissociation of carbamino-haemoglobin the CO_2 bound to haemoglobin from the tissues is delivered at the alveoli. RBCs contain a very high concentration of the enzyme, carbonic anhydrase and minute quantities of the same is present in the plasma too. This enzyme facilitates the following reaction in both directions. $CO_2 + H_2O \rightarrow H_2CO_3 \rightleftharpoons HCO_3^- + H^+$ In the above reaction CO_2 combines with H_2O in the presence of carbonic anhydrase to form H_2CO_3 this is further split into $HCO_3^- + H^+$. At the alveolar site where pCO_2 is low, the reaction proceeds in the opposite direction leading to the formation of CO_2 and H_2O . Thus, CO_2 trapped as bicarbonate at the tissue level and transported to the alveoli is released out as CO_2 . By these methods every 100 ml of blood transports about 4ml of carbon dioxide to the alveoli to be exhaled.

Question 5. What will be the pO_2 and pCO_2 in the atmospheric air compared to those in the alveolar air?

- (i) pO_2 lesser, pCO_2 higher
- (ii) pO_2 higher, pCO_2 lesser
- (iii) pO_2 higher, pCO_2 higher
- (iv) pO_2 lesser, pCO_2 lesser

Answer: (ii) The pO_2 (partial pressure of oxygen) will be higher in the atmospheric air compared to that in the alveolar air. The pCO_2 (partial pressure of carbon dioxide) will be lesser in the atmospheric air compared to that in the alveolar air. In atmospheric air, pO_2 is about 159 mm Hg. In alveolar air, it is about 104 mm Hg. In atmospheric air, pCO_2 is about 0.3 mm Hg. In alveolar air, it is about 40 mm Hg.

Question 6. Explain the process of inspiration under normal conditions.

Answer: Inspiration is the process of breathing in air from outside the body into the lungs. It is carried out by creating a air pressure gradient between the lungs and the atmosphere. When air enters the lungs, the diaphragm contracts toward the abdominal cavity, thereby increasing the space in the thoracic cavity for accommodating the inhaled air. Simultaneously, the volume of the thoracic chamber in the anteroposterior axis increases with the contraction of the external intercostal muscles. This causes the ribs and the sternum to move out, thereby increasing the volume of the thoracic chamber in the dorsoventral axis.

Thus, the overall increase in the thoracic volume leads to a similar increase in the pulmonary volume. Due to this increase, the intra-pulmonary pressure becomes lesser than the atmospheric pressure, and hence leads to the movement of air from outside the body into the lungs.

Question 7. How is respiration regulated?

Answer: A specialised centre present in the medulla region of the brain called respiratory rhythm centre is primarily responsible for the regulation of respiration. Another centre present in the pons region of the brain called pneumotaxic centre can moderate the functions of the respiratory rhythm centre. Neural signal from this centre can reduce the duration of inspiration and thereby, alter the respiratory rate.

Question 8. What is the effect of pCO_2 on oxygen transport?

Answer: Partial pressure of CO_2 (pCO_2) can interfere the binding of oxygen with haemoglobin, i.e., to form oxyhaemoglobin. (i) In the alveoli, where there is high pO_2 and low pCO_2 , less H^+ concentration and low temperature., more formation of oxyhaemoglobin occur. (ii) In the tissues, where low pO_2 , high pCO_2 , high H^+ concentration and high temperature exist, the conditions are responsible for dissociation of oxygen from the oxyhaemoglobin.

Question 9. What happens to the respiratory process in a man going up a hill?

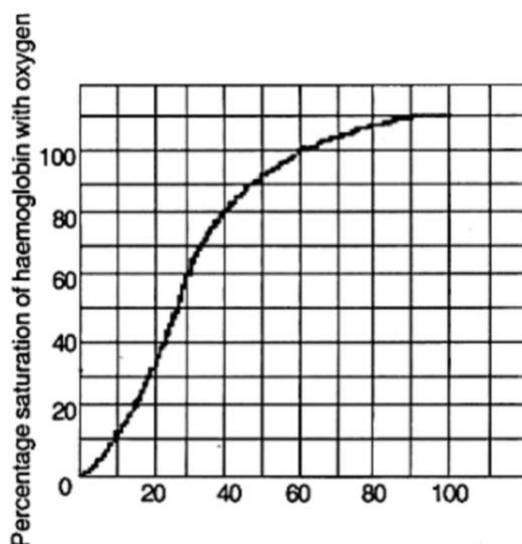
Answer: As the altitude increases, the oxygen level in the atmosphere decreases. Therefore, as a man goes uphill, he will suffer from oxygen deficiency. The causes the amount of oxygen in the blood to decline. The respiratory rate increases to compensate for the decrease in the oxygen level of the blood. Simultaneously, the rate of heart beat increases to increase the supply of oxygen to blood.

Question 10. What is the site of gaseous exchange in an insect?

Answer: Gaseous exchange in insects occurs through a system of air-filled internal tubes, the tracheal system, the finer branches of which extend to all parts of the body and may become functionally intracellular in muscle fibers. Thus oxygen is carried in the gas phase directly to its sites of utilization. While the blood is not concerned with oxygen transport in most insects, some insects have now been shown to have hemocyanin, an oxygen-carrying pigment, in the blood. In terrestrial insects and some aquatic species, the tracheae open to the outside through segmental pores, the spiracles, which generally have some filter structures and a closing mechanism reducing water loss from the respiratory surfaces. Other aquatic species have no functional spiracles, and gaseous exchange with the water involves arrays of tracheae close beneath the surface of thin, permeable cuticle.

Question 11. Define oxygen dissociation curve. Can you suggest any reason for its sigmoidal pattern?

Answer: The curve in which percentage saturation of haemoglobin with O_2 is plotted against the partial pressure of oxygen (PO_2) is called the oxygen dissociation curve. At a PO_2 of 100 mm Hg, 100 percent saturation of Hb takes place. 90% saturation of Hb takes place even at a PO_2 of 60mm Hg. An I fall of PCX, from 100 to 60mm Hg will cause only 10% decrease in saturation of Hb. Hence the curve takes the shape of a sigmoid.



Question 12. Have you heard about hypoxia? Try to gather information about it, and discuss with your friends.

Answer: Hypoxia is a condition characterised by an inadequate or decreased supply of oxygen to the lungs. It is caused by several extrinsic factors such as reduction in pO_2 , inadequate oxygen, etc. The different types of hypoxia are discussed below.

(i) Hypoxemic hypoxia:

In this condition, there is a reduction in the oxygen content of blood as a result of the low partial pressure of oxygen in the arterial blood.

(ii) Anemic hypoxia:

In this condition, there is a reduction in the concentration of haemoglobin.

(iii) Stagnant or ischemic hypoxia:

In this condition, there is a deficiency in the oxygen content of blood because of poor blood circulation. It occurs when a person is exposed to cold temperature for a prolonged period of time.

(iv) Histotoxic hypoxia:

In this condition, tissues are unable to use oxygen. This occurs during carbon monoxide or cyanide poisoning.

Question 13. Distinguish between

(a) IRV and ERV

(b) Inspiratory capacity and Expiratory capacity.

(c) Vital capacity and Total lung capacity.

Answer:

(a) IRV and ERV

Inspiratory reserve volume	Expiratory reserve volume
It is the maximum volume of air that can be inhaled after a normal inspiration.	It is the maximum volume of air that can be exhaled after a normal expiration.
It is about 2500 – 3500 mL in the human lungs.	It is about 1000 – 1100 mL in the human lungs.

(b) Inspiratory and expiratory capacity

Inspiratory capacity	Expiratory capacity
It is the volume of air that can be inhaled after a normal expiration.	It is the volume of air that can be exhaled after a normal inspiration.
It includes tidal volume and inspiratory reserve volume. $IC = TV + IRV$	It includes tidal volume and expiratory reserve volume. $EC = TV + ERV$

(c) Vital capacity and total lung capacity

Vital capacity	Total lung capacity
It is the maximum volume of air that can be exhaled after a maximum inspiration. It includes IC and ERV.	It is the volume of air in the lungs after maximum inspiration. It includes IC, ERV, and residual volume.
It is about 4000 mL in the human lungs.	It is about 5000 – 6000 mL in the human lungs.

Question 14. What is Tidal volume? Find out the Tidal volume (approximate value) for a healthy human in an hour.

Answer: Tidal volume is the volume of air that is transported into and out of the lungs (inspired or expired) with each normal respiratory cycle. Tidal volume is approximately 6000 to 8000 mL of air per minute for a healthy human.

We can calculate the hourly tidal volume for a healthy human.

If, Tidal volume = 6000 to 8000 mL/minute

So, the Tidal volume in an hour will be:

$$= 6000 \text{ to } 8000 \text{ mL} \times (60 \text{ min})$$

$$= 3.6 \times 10^5 \text{ mL to } 4.8 \times 10^5 \text{ mL}$$

Hence, the hourly tidal volume for a healthy human is approximately 360000 ml-480000 ml.