13. Human Respiration

Respiration
Respiration is a chemical process in which glucose is breakdown to release energy for carrying out other life processes. The basic respiration process can be represented as:
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Energy

Types of Respiration

- Aerobic respiration: Respiration occurring in presence of oxygen. Most common type of respiration process in animals.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + 38 ATP + Heat energy

- Anaerobic Respiration: Respiration occurring in absence of oxygen. Very few animals can respire anaerobically, example tapeworms

$C_6H_{12}O_6 \rightarrow$ Lactic acid + 2 ATP + Heat energy

Parts of Respiration

- Breathing: It is a physical process in which oxygen-rich air is taken in and CO_2 rich air (from our body's internal organs) is expelled out.
- Gaseous transport: Firstly, the exchange of gases occurs in the lungs. The oxygen absorbed by the blood in lungs is then carried to other body parts as oxyhaemoglobin. The CO_2 from the tissues is transported to the lungs through blood either as bicarbonates dissolved in plasms, or as carbamino-haemoglobin (by combining with haemoglobin).
- Tissue respiration: The capillaries deliver the oxygen to the body cells and pick up the carbon dioxide released by them. This exchange of gases occurs by diffusion through thin walls of capillaries.
- Cellular respiration: It involves complex chemical reactions inside the cell in which oxygen is utilised to breakdown the glucose to release energy.

Human respiratory organs

- Human respiratory system extends from nose to lungs.
- It includes nose, nasopharynx, trachea, bronchi, bronchioles, and lungs.
- **Nasopharynx** acts as a common passage for food and air. It opens through glottis into the trachea.
- **Epiglottis** is the covering of glottis which prevents the entry of food into the larynx.
- **Larynx** (sound box) is a cartilaginous structure located at the top of trachea. It helps in sound production
- **Trachea** is a straight tube which is divided into right and left primary bronchi. Bronchi are then further divided into secondary and tertiary bronchi.
- **Bronchi** are then divided into bronchioles, which end into terminal bronchioles.
- **Terminal Bronchioles** give rise to several tiny air sacs called alveoli.
- **Nostrils, trachea, bronchi, and bronchioles** form the conducting part of respiratory system. They transport atmospheric air to alveoli (the exchange part), which clears off any foreign particles from inhaled air.
- **Alveoli** are the site of exchange of gases. They do not play any role in conduction of air. They hold air in the lungs.
- The exchange of gases takes place between the blood capillaries and gases present in alveoli.

Mechanism of Breathing

- The process of breathing involves taking in of atmospheric air **(inspiration)** and giving out of alveolar air **(expiration).**
- **Inspiration**
- It occurs when intra-pulmonary pressure is lower than atmospheric pressure, which means there is negative pressure in lungs.
- Diaphragm moves down and ribs move upwards and outwards, thereby leading the movement of air into the lungs.
- The volume of air in the thoracic chamber increases.
- **Expiration**
- It occurs when intra-pulmonary pressure is higher than atmospheric pressure, which means that there is positive pressure in lungs.
- Diaphragm moves to its former position and the ribs move downward and inward. This reduces the size of chest cavity and leads to the movement of air out of lungs.
- The volume of air in the thoracic chamber decreases.
- An adult human respires at the rate of 12-16 times/minute. Spirometre helps in clinical assessment of pulmonary function.

- **Respiratory volume and capacities**
- **Tidal volume (TV):** It is the volume of air that is inspired or expired in a single breath during regular breathing. Its value is about 500 mL. Hence, it is about 6000 to 8000 mL of air/minute.
- **Inspiratory reserve volume (IRV) –** It is the additional volume of air that can be inspired by a person in a forcible inspiration. It is about 2500 – 3000 mL.
- **Expiratory reserve volume (ERV) –** It is the additional volume of air that can be expired by a person in a forcible expiration. It is about 1000 – 1100 mL.
- **Residual volume (RV) –** It is the amount of air remaining in the lungs after maximum expiratory effort. It is about 1100 – 1200 mL.
- **Inspiratory capacity (IC) –** It is the total amount of air that can be inhaled by a person after normal exhalation. It includes TV + IRV.
- **Expiratory capacity (EC) –** It is the amount of air that a person can exhale after a normal inhalation. It includes TV + ERV.
- **Functional residual volume (FRV) –** It is the amount of air that remains in lungs after normal exhalation. It includes ERV + RV.

- **Vital capacity (VC) –** It is the maximum volume of air that a person can breathe in after maximum exhalation. It is equal to ERV+TV+IRV.
- **Total lung capacity (TLC) –** It is the total amount of air accommodated in lungs after forced inhalation. It includes VC + RV.

- **Gaseous exchange**
- Exchange of gases (O_2 and CO_2) at alveolar and tissue region occurs by **diffusion.**
- The partial pressure of O_2 in atmospheric air is higher than that of oxygen in alveolar air. In atmospheric air, pO_2 is about 159 mm Hg; while in alveolar air, it is about 104 mm Hg.
- The partial pressure of CO_2 in atmospheric air is lower than that of CO_2 in alveolar air. In atmospheric air, pCO_2 is about 0.3 mm Hg; while in alveolar air, it is about 40 mm Hg.

- **Hypoxia:** Condition of deficiency of oxygen reaching the tissues. It may occur due to poor ventilation or at higher altitudes.
- **Asphyxiation:** Condition in which blood becomes venous due to accumulation of carbon dioxide and diminished oxygen supply.

Factors Affecting Gaseous Exchange in Tissues

Gaseous exchange

- Exchange of gases (O_2 and CO_2) at alveolar and tissue region occurs by **diffusion**.
- **Factors affecting diffusion of gases are:-**
- Thickness of membrane involved
- **Solubility of gases**
- Solubility of CO_2 is 20 - 25 times higher than that of oxygen.
- **Partial pressure**
- The partial pressure of O_2 in atmospheric air is higher than that of oxygen in alveolar air. In atmospheric air, pO_2 is about 159 mm Hg; while in alveolar air, it is about 104 mm Hg. The pO_2 in oxygenated blood is 95 mm Hg while it is 40 mm Hg in tissues.
- The partial pressure of CO_2 in atmospheric air is lower than that of CO_2 in alveolar air. In atmospheric air, pCO_2 is about 0.3 mm Hg; while in alveolar air, it is about 40 mm Hg. The pCO_2 in oxygenated blood is 40 mm Hg and 45 mm Hg in tissues.

Transport of Gases

- **Transport of oxygen**

1. Oxygen is mainly transported as oxy-haemoglobin**.**
2. **In lungs,** the pO_2 is high while low pCO_2, low H^+ and temperature. Therefore, haemoglobin binds to oxygen and forms oxy-haemoglobin.
3. **Tissues** have low pO_2, high pCO_2, high H^+, and higher temperature. Therefore, oxy-haemoglobin releases oxygen to form haemoglobin.
4. Under physiological conditions, every 100 mL of oxygenated blood delivers around 5 mL of O_2 to tissues.
5. An oxygen dissociation curve is formed when percentage saturation of haemoglobin with O_2 is plotted against the pO_2. This curve is called the Oxygen dissociation curve.

- **Transport of carbon dioxide**

1. About 7% of CO_2 is carried in dissolved state through **plasma.**
2. About 20 – 25 % of CO_2 is transported by RBCs as **carbamino haemoglobin.**
3. About 70% of CO_2 is transported as **bicarbonate.**

$$CO_2 + H_2O \xrightleftharpoons{\text{Carbonic anhydrase}} H_2CO_3 \xrightleftharpoons{\text{Carbonic anhydrase}} HCO_3^- + H^+$$

1. When pCO_2 is high, HCO_3^- forms in tissues
2. When pCO_2 is low, $CO_2 + H_2O$ forms in Alveoli.
3. CO_2 is trapped in tissue as HCO_3^- and released from alveoli as $CO_2 + H_2O$.

1. Every 100 mL of deoxygenated blood delivers 4 mL of CO_2 to alveoli.

Respiratory Volume and Capacities

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Regulation of Respiration and Respiratory Disorders

1. **Regulation of Respiration**

The respiratory rhythm centre in the medulla region of brain regulates respiration. This system is associated with

- **Pneumotaxic centre** that moderates the function of respiratory rhythm centre
- **Chemo sensitive area** which gets activated when the conc. of CO_2 and H^+ increases and provide signals to eliminate them.

1. **Respiratory disorders**

- **Asthma –** It is caused due to inflammation of bronchi and bronchioles.
- **Emphysema –** It is characterized by loss of elasticity of alveolar wall.
- **Occupational respiratory disorders –** Long exposure to dust leads to inflammation. Example: Fibrosis