Breathing and Exchange of Gases

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.

- **Respiration (breathing)**
- Respiration is the process of release of energy from the breakdown of organic substances.
- It involves the exchange of oxygen from atmosphere and carbon dioxide produced in the body.
- **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.
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- **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.
- The process of respiration involves five steps.

1. Breathing/ Pulmonary ventilation
2. Diffusion of gases across alveolar membrane
3. Transport of gases by blood
4. Diffusion of gases between blood and tissues
5. Cellular respiration

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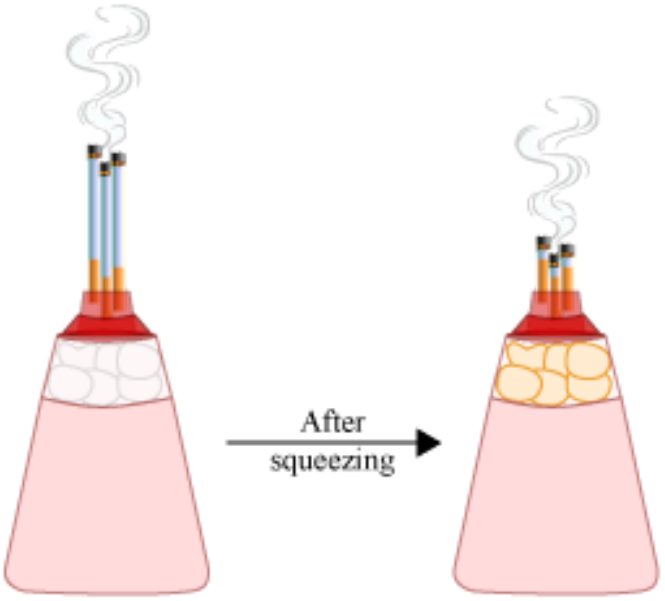
Do you know that tobacco contains harmful components? These components do not allow proper supply of oxygenated blood and results in many diseases.

Why is it so?

Let us perform the following activity to understand the harmful effects of smoking.



Take a clean, empty squeezable ketchup bottle.

Place a few cotton balls in the lid of the bottle and close its mouth with the help of the cap. Fit two or more cigarettes on the tip of the bottle.

Then, light the cigarette and simultaneously squeeze and release the body of the bottle slowly, till the cigarette burns out completely. Repeat this process with two or more cigarettes.

Open the cap of the bottle and remove the cotton balls. You will observe that the colour of the cotton balls change from white to brown or black.

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