

BREATHING AND EXCHANGE OF GASES

Respiration is the oxidation of nutrients in the living cells to release energy for biological work.

Breathing is the exchange of O_2 from the atmosphere with CO_2 produced by the cells.

RESPIRATORY ORGANS

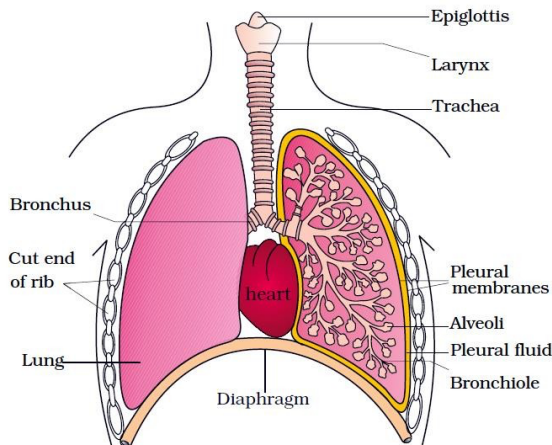
- **General body surface:** E.g. lower invertebrates (sponges,

coelenterates, flatworms etc).

- **Skin or moist cuticle (cutaneous respiration):** E.g. earthworms, leech, amphibians etc.
- **Tracheal tubes:** E.g. insects, centipede, millipede, spider.
- **Gills (Branchial respiration):** E.g. fishes, tadpoles, prawn.
- **Lungs (Pulmonary respiration):** E.g. most vertebrates.

HUMAN RESPIRATORY SYSTEM

It consists of a pair of *air passages (air tract)* and *lungs*.



1. Air passages

- **Conducting part** which transports the atmospheric air into the alveoli, clears it from foreign particles, humidifies and brings the air to body temperature.

External nostrils → *nasal passage* → *nasal chamber (cavity)* → *pharynx* → *glottis* → *larynx* → *trachea* → *primary bronchi* → *secondary bronchi* → *tertiary bronchi* → *bronchioles* → *terminal bronchioles* → *respiratory bronchiole* → *alveolar duct*.

- Each terminal bronchiole gives rise to many very thin and vascularised **alveoli** (in lungs).

- A cartilaginous **Larynx** (sound box or voice box) helps in sound production.
- During swallowing, **epiglottis** (a thin elastic cartilaginous flap) closes **glottis** to prevent entry of food into larynx.
- Trachea, all bronchi and initial bronchioles are supported by incomplete cartilaginous half rings.

2. Lungs

- Lungs situate in **thoracic chamber** and rest on **diaphragm**.
- Right lung has 3 lobes and left lung has 2 lobes.
- Lungs are covered by double-layered **pleura** (outer **parietal pleura** and inner **visceral pleura**).
- The **pleural fluid** present in between these 2 layers lubricates the surface of the lungs and prevents friction between the membranes.
- **Lungs = Bronchi + bronchioles + alveoli**.
- Alveoli and their ducts form the **respiratory or exchange part** of the respiratory system.
- **Alveoli are the structural and functional units of lungs**.

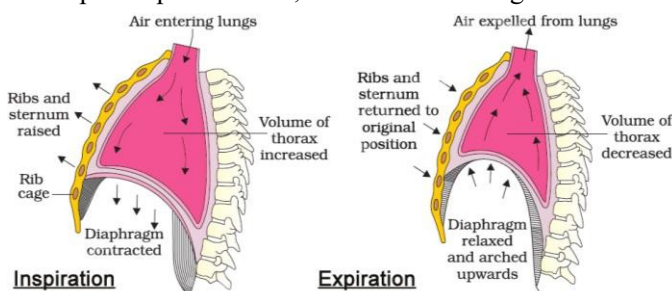
Steps of respiration

1. Pulmonary ventilation (breathing).
2. Gas exchange between lung alveoli & blood.
3. Gas transport (O_2 transport & CO_2 transport).
4. Gas exchange between blood & tissues.
5. Cellular or tissue respiration.

MECHANISM OF BREATHING (INSPIRATION & EXPIRATION)

a. Inspiration

- **Active** intake of air from atmosphere into lungs.
- During this, the **diaphragm contracts** (flattens) causing an increase in vertical thoracic volume (*antero-posterior axis*).
- Contraction of **external intercostal muscles** (muscles found between ribs) lifts up the ribs and sternum causing an increase in thoracic volume in the *dorso-ventral axis*.
- Increase in thoracic volume reduces thoracic pressure. So, lungs expand. Thus, pulmonary volume increases resulting in decrease of **intra-pulmonary pressure** to less than the atmospheric pressure. So, air moves into lungs.



b. Expiration

- **Passive** expelling of air from the lungs.
- During this, **intercostal muscles & diaphragm** relax causing a decrease in thoracic volume and thereby pulmonary volume. So, air moves out.
- During **forceful expiration**, **abdominal muscles** and **internal inter-costal muscles contract**.

Respiratory volumes and capacities

- **Tidal volume (TV):** Volume of air inspired or expired during a normal respiration. It is about **500 ml**. i.e., **6000-8000 ml** per minute.
- **Inspiratory reserve volume (IRV) or complementary air:** Additional volume of air that can inspire by forceful inspiration. It is **2500-3000 ml**.
- **Expiratory reserve volume (ERV) or supplemental air:** Additional volume of air that can expire by a forceful expiration. It is **1000-1100 ml**.
- **Residual volume (RV):** Volume of air remaining in lungs after a forcible expiration. It is **1100-1200 ml**.

- **Inspiratory capacity (IC):** Total volume of air inspired after a normal expiration (TV + IRV). It is **3000-3500 ml**.
- **Expiratory capacity (EC):** Total volume of air expired after a normal inspiration (TV + ERV). It is **1500-1600 ml**.
- **Functional residual capacity (FRC):** Volume of air remaining in the lungs after a normal expiration (ERV + RV). It is **2100-2300 ml**.
- **Vital capacity (VC):** Volume of air that can breathe in after a forced expiration or Volume of air that can breathe out after a forced inspiration (ERV + TV + IRV).

It is **3500-4500 ml**.

- **Total lung capacity (TLC):** Total volume of air in the lungs after a maximum inspiration. (RV + ERV + TV + IRV or VC + RV). It is **5000-6000 ml**.
- Part of respiratory tract (from nostrils to terminal bronchi) not involved in gaseous exchange is called **dead space**.
Dead air volume is about **150 ml**.

- **Respiratory cycle**= an inspiration + an expiration
- **Normal respiratory (breathing) rate:** 12-16 times/min
- **Spirometer (respirometer):** To measure respiratory rate.

GAS EXCHANGE

Gas exchange occurs between

1. Alveoli and blood 2. Blood and tissues

Alveoli are the primary sites of gas exchange.

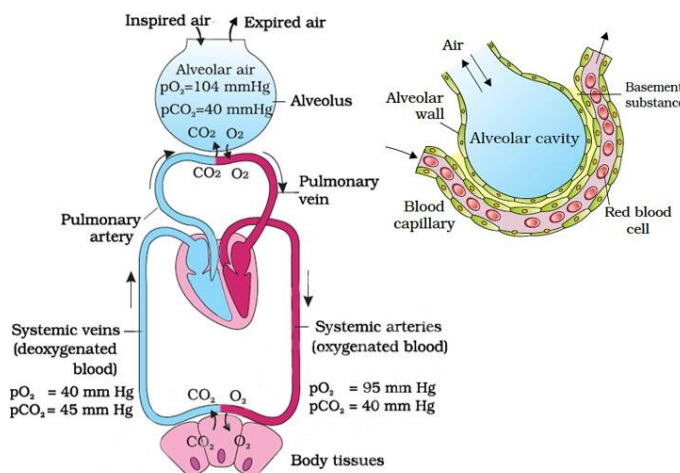
O₂ & CO₂ are exchanged by simple diffusion. It depends upon the following factors:

- **Pressure/ concentration gradient:** The **Partial pressures** (individual pressure of a gas in a gas mixture) of O₂ and CO₂ (pO₂ and pCO₂) are given below.

Respiratory gas	pO ₂ (in mm Hg)	pCO ₂ (in mm Hg)
Atmospheric air	159	0.3
Alveoli	104	40
Deoxygenated blood	40	45
Oxygenated blood	95	40
Tissues	40	45

- **pO₂ in alveoli** is more (**104 mm Hg**) than that in **blood capillaries (40 mm Hg)**. So O₂ diffuses into capillary blood. **pCO₂ in deoxygenated blood** is more (**45 mm Hg**) than that in alveoli (**40 mm Hg**). So, CO₂ diffuses to alveoli.
- **Solubility of gases:** Solubility of CO₂ is 20-25 times higher than that of O₂. So, the amount of CO₂ that can diffuse through the diffusion membrane per unit difference in partial pressure is higher than that of O₂.

- **Thickness of membranes:** The diffusion membrane is made up of 3 layers:
 - a) **Squamous epithelium** of alveoli.
 - b) **Endothelium** of alveolar capillaries.
 - c) **Basement substance** between them.
 Its total thickness is only 0.5 µm. It enables easy gas exchange.
- **Surface area:** Presence of alveoli increases the surface area of lungs. It increases the gas exchange.



GAS TRANSPORT (O₂ TRANSPORT & CO₂ TRANSPORT)

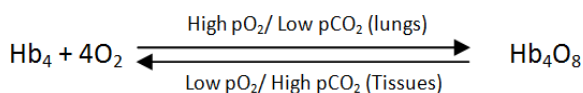
It is the transport of respiratory gases (O₂ & CO₂) from alveoli to the systemic tissues and vice versa.

1. O₂ TRANSPORT

It is the transport of O₂ from lungs to various tissues.

It occurs in 2 ways:

- In physical solution (blood plasma):** About **3%** of O₂ is carried in a dissolved state through plasma.
- As oxyhaemoglobin:** About **97%** of O₂ is transported by **haemoglobin** (red coloured iron containing pigment) on RBC. O₂ binds with haemoglobin (Hb) to form **oxyhaemoglobin**. This is called **oxygenation**. Hb has **4 haem units**. So, each Hb molecule can carry 4 oxygen molecules. Binding of O₂ depends upon pO₂, pCO₂, H⁺ ion concentration (pH) and temperature.

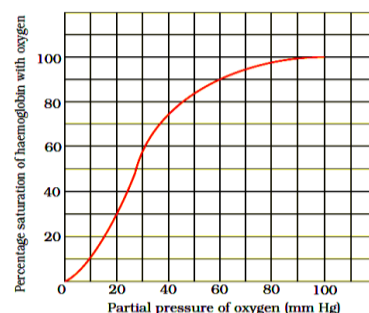


- In the alveoli, high pO₂, low pCO₂, lesser H⁺ ion concentration and lower temperature exist. These factors are favourable for the formation of oxyhaemoglobin.

- In tissues, low pO₂, high pCO₂, high H⁺ ions and high temperature exist. So Hb₄O₈ dissociates to release O₂.
- Every 100 ml of oxygenated blood can deliver around 5 ml of O₂ to the tissues under normal physiological conditions.

Oxygen-haemoglobin dissociation curve

It is a sigmoid curve obtained when percentage saturation of Hb with O₂ is plotted against the pO₂. It is used to study the effect of factors like pCO₂, H⁺ concentration etc., on binding of O₂ with Hb.



2. CO₂ TRANSPORT

It is the transport of CO₂ from tissues to lungs.

In tissues, pCO₂ is high due to catabolism and pO₂ is low. In lungs, pCO₂ is low and pO₂ is high. This favours CO₂ transport from tissues to lungs. It occurs in 3 ways:

- As carbonic acid:** In tissues, **7%** of CO_2 is dissolved in **plasma water** to form **carbonic acid** and carried to lungs.
- As carbamino-haemoglobin:** In tissues, **20-25%** of CO_2 binds to Hb to form **carbamino-haemoglobin**. In alveoli, CO_2 dissociates from carbamino-haemoglobin.
- As bicarbonates:** **70%** of CO_2 transported by this method. RBCs contain an enzyme, *carbonic anhydrase*. (It is slightly present in plasma too).

At tissue site, it facilitates the following reactions:



In alveoli, the above reaction proceeds in opposite direction leading to the formation of CO_2 and H_2O .

Every **100 ml of deoxygenated blood** delivers about **4 ml of CO_2** to the alveoli.

REGULATION OF RESPIRATION

In brain, there are the following **Respiratory centres**:

- Respiratory rhythm centre (Inspiratory & Expiratory centres):** In **medulla oblongata**. It regulates respiratory rhythms.
- Pneumotaxic centre:** In **Pons**. It moderates functions of respiratory rhythm centre. Impulse from this centre reduces the duration of inspiration and thereby alter respiratory rate.

- Chemosensitive area:** Seen adjacent to the rhythm centre. Increase in the concentration of CO_2 and H^+ activates this centre, which in turn signals rhythm centre. **Receptors** in **aortic arch & carotid artery** also recognize changes in CO_2 & H^+ concentration and send signals to rhythm centre. Role of oxygen in the regulation of respiratory rhythm is quite insignificant.

DISORDERS OF RESPIRATORY SYSTEM

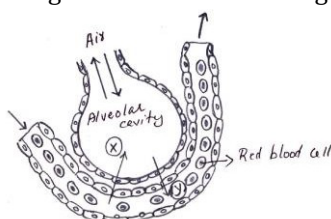
- Asthma:** Difficulty in breathing causing wheezing due to inflammation of bronchi and bronchioles.
- Emphysema:** Damage of alveolar walls. It decreases respiratory surface. Major cause is cigarette smoking.
- Occupational respiratory disorders:** Certain industries produce so much dust. So, the defense mechanism of the body cannot cope with the situation. Long exposure causes inflammation leading to **fibrosis** (proliferation of fibrous tissues). It results in lung damage. Workers in such industries should wear protective masks.

MODEL QUESTIONS

- Draw a flowchart showing the different parts of the air tract.
- Match the following

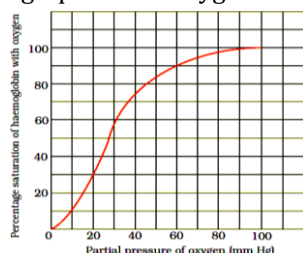
A	B	C
IC	TV + ERV	3500-4500 ml
EC	ERV + TV + IRV	2100-2300 ml
FRC	TV + IRV	3000-3500 ml
VC	ERV + RV	1500-1600 ml

- Note the relationship between first two words and fill up the fourth place.
 - TV: 500 ml IRV:..... b. Atmospheric air: 159 mm Hg Alveoli:
- The given diagram shows the exchange of gases between alveolus and alveolar capillary.



- Identify X and Y.
- Name the Physical Process involved in gas exchange.
- Mention the factors that favour this process.

- The given graph shows oxygen-haemoglobin dissociation curve.



- What is the nature of curve?
- Find out the pressure at which Haemoglobin is 50% saturated with O_2 ?
- What are the factors which influence it?

- Identify the two true statements from the statements given below and rewrite the two false statements correctly.
 - Pneumonia is a chronic disorder due to cigarette smoking.
 - Carbon dioxide combines with haemoglobin to form carbamino haemoglobin.
 - Respiratory rhythm is maintained by the respiratory centre in the heart.
 - Alveoli are the primary sites of exchange of gases.