Breathing and Exchange of Gases

Process of exchange of O_2 from the atmosphere with CO_2 produced by the cells is called breathing/respiration (physical, chemical & biological process).

Respiratory Organs

- Lower invertebrates like sponges, coelenterates, flatworms exchange gases via their entire body surface.
- Earthworms use their moist cuticle & insects have a network of tubes (tracheal tubes) to transport atmospheric air within the body.
- Aquatic arthropods (prawns/crustaceans) and molluscs use vascularized structures called gills (branchial respiration).
- Vascularised bags called lungs (pulmonary respiration) are use by terrestial forms.
- Among vertebrates fishes use gills, amphibia, reptilia, birds, mammals use lungs. Frogs can respire through their skin (cutaneous respiration).

Human Respiratory System

External nostrils→nasal passage→nasal chamber→pharynx (nasopharynx) →lysngopharynx→ larynx region in trachea→trachea divides at 5th vertebra (thoracic) into right & left primary bronchi →secondary & tertiary bronchi & bronchioles →terminal bronchioles (thin)→ irregular walled vascularised bag like structure called alveoli (the branching network of bronchi, bronchioles & alveoli comprise the lungs)

- Larynx is a cartilaginous box helps in sound production\& hence called the sound box.
- Trachea, primary, secondary, tertiary bronchi and initial bronchioles are supported by incomplete cartilaginous rings.
- We have 2 lungs, surounded by double layered wall called as pleural membrane with pleural fluid filled between them. It reduces friction on the lung surface the outer pleural membrane is in contact with the thoracic lining whereas the inner layer is in contact with the lung surface.

Respiratory System

CONDUCTING PART
(External nostrils to terminal bronchioles)
- Conducts atmospheric air to alveoli
- clears foreign particles
- humidifies air
- brings air to body temperature

RESPIRATORY/EXCHANGE PART
(Alveoli & their ducts)
- site of actual diffusion of O_2 & CO_2 b/w blood & atmospheric air.

- Lungs are situated in the thoracic chamber which is an anatomically air tight chamber.
- Any change in the volume of the thoracic cavity will be reflected in lung (pulmonary) cavity. It is very important as we cannot directly alter the pulmonary volume.

Steps of Respiration

- Breathing (intake of O_2 & exhalation of CO_2)
- Diffusion of gases across alveolar membrane
- Transport of gases by the blood
- Diffusion of gases b/w blood & tissues.
- Utilisation of O_2 by cells in deriving energy and of CO_2 (cellular respiration)

Mechanism of Breathing

Pressure gradient b/w lungs & atmosphere

Inspiration

- Atmospheric air is moved in
- There is a negative pressure in the lungs with respect to atmospheric pressure.
- Diaphragm contracts (increases volume of anterio posterior axis)
- External intercostal muscles contract & ribs/ sternum moves upwards which increases volume of the thoracic chamber in the dorso-ventral axis.
- Intrapulmonary pressure is decreased.

We have ability to increase the strength of breathing with the help of additional muscles in abdomen. Healthy man breaths 12-16 times per minute. The volume of air involved in breathing movements can be estimated by using spirometer helps in clinical assessment of pulmonary functions.

Expiration

- Alveolar air is released out.
- Intrapulmonary pressure is higher than the atmospheric pressure.
- Relaxation of diaphragm and the intercostal muscle return to their original position & reduce the thoracic volume.
- Intrapulmonary pressure is increased
- Causes expulsion of air from the lungs.

Respiratory Volumes & Capacities

Tidal Volume(TV)

Volume of air inspired or expired during a normal respiration. It is approx 500 ml. i.e. healthy man can inspire or expire approximately 6000 to 8000 ml per minute.

Inspiratory Reserve Volume (IRV)

Additional volume of air, a person can inspire by a forcible inspiration. This averages 2500 ml to 3000 ml.

Expiratory Reserve Volume (ERV)

Additional volume of air a person can expire forcefully. This averages 1000 ml to 1100 ml.

Residual Volume (RV)

Volume of air remaining in lungs even after forceful expiration. This averages 1100 to 1200 ml.

Inspiratory Capacity (IC)

Total volume of air a person can inspire after a normal expiration. Sum of tidal volume and inspiratory reserve volume (TV+IRV).

Expiratory Capacity (EC)

Total volume of air a person can inspire after a normal expiration. Sum of tidal volume and inspiratory reserve volume (TV+IRV).

Functional Residual Capacity (FRC)	Vital Capacity (VC)	Total Lung Capacity
Volume of air that will remain in lungs after a normal expiration. This includes ERV+RV. FRC = ERV+RV	Maximum volume of air a person can breath in or out after a forced expiration/inhalation. Includes ERV+TV+IRV. VC = ERV+TV+IRV	Total volume of air accomodated in the lungs at the end of a forced inspiration. Includes RV, ERV TV, IRV or VC+RV TLC = RV+TV+ERV+TV+IRV OR TLC = VC+RV

Exchange of Gases

It is based on pressure and concentration gradient.

Factors Responsible

Solubility of gases, thickness of membrane.

Pressure contributed by an individual gas in a mixture of gases is known as partial pressure and is denoted as pO_2 & pCO_2 for O_2 & CO_2 respectively.

As the solubility of CO_2 is 20-25 times higher than that of O_2, the amount of CO_2 that can diffuse through the diffusion membrane per unit difference in partial pressure is much higher compared to that of O_2.

Diffusion membrane is made of 3 Layers

- Thin squamous epithelium of alveoli
- Endothelium of alveolar capillaries
- Basement substance b/w them
- Its total thickness is less than 1 mm. Hence every condition is favourable for respiration in our body.

Transport of gases

Transport of O_2

- Oxygen - 97 % by RBC + 3 % by Plasma
- Oxygen bind with Hb to form oxyhaemoglobin (reversible reaction).

Then each Hb molecule carries four O_2 molecules.

- **Factors Responsible for Binding of Hb With O_2:**

pO_2, pCO_2, hydrogen ion concentration, temperature.

- Oxygen dissociation curve is sigmoid in shape (graph b/w % saturation of Hb with O_2 against O_2.
- **Factors favourable for the formation of oxyhemoglobin**

In alveoli high pO_2, less pCO_2, less H_2+, less temp

- **Factors responsible for breaking of HbO_2**

In tissues less pO_2, high pCO_2, High H_2+, high temperature.

- Every 100 ml of oxygenated blood can deliver around 5 ml of $O_2$to tissues.

Transport of CO_2

- CO_2 - 70 % by bicarbonate +20-25 % by RBC +7 % By plasma
- CO_2 carried by Hb (20-25%) thus carbamino haemoglobin is formed.
- **Conditions for formation of carbaminohaemoglobin**

high pCO_2, less pO_2 in tissues.

- **Conditions for dissociation of Carbaminohaemoglobin**

less pCO_2, High pO_2 in alveoli.

- RBC Contain a very high concentration of enzyme carbonic anhydrase and some quantity in plasma too. Hence the following reaction takes place.

$$CO_2 + H_2O \xrightleftharpoons{\text{carbonic anhydrase}} H_2CO_3 \xrightleftharpoons{\text{carbonic anhydrase}} HCO^-_3 + H^+$$

- At tissue the reaction forward in right direction and at alveoli reaction forward in opposite direction.
- Every 100 ml of deoxygenated blood delivers approximately 4 ml of CO_2 to the alveoli.

Regulation of Respiration

Performed by neural system

- Respiratory rythm centre present in the medulla is responsible for the regulation.
- Another centre present in the pons region of the brain called pneumotaxic centre can moderate the functions of the respiratory rythm.
- Neural signal from this centre can reduce the duration of inspiration and thereby alter the respiratory rate.
- A chemosensitive area is situated adjacent to the rythm centre which is highly sensitive to CO_2 and H_2+ ion increase in these substance can activate this center which in turn can signal the rythm centre to make necessary adjustment in the respiratory process by which these substance can be eliminated.
- Receptors associated with aortic arch and carotid artery also recognise changes in CO_2 & H_2+ conc. And send necessary signals to the rhythm centre for remedial actions the role of oxygen in the regulation of respiratory rhythm is quite insignificant.

Disorders of respiratory system

Asthma

• Difficulty in breathing causing wheeziness due to inflammation of bronchi & bronchioles.

Emphysema

• Chronic (cannot be easily cured) disorder in which alveolar walls are damaged due to which respiratory surface is decreased.
• Reason is cigarette smoking.

Occupational respiratory disorder

• In stone breaking industry, so much dust is produced, long exposure can give rise to inflammation leading to fibrosis (proliferation of fibrous tissue) and causes serious lung damage.
• Workers in such industries should wear protective masks.