Breathing and Exchange of Gases

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1 BREATING/RESPIRATION

Atmospheric oxygen $\xrightleftharpoons{\text{Exchange}}$ CO_2 produced by cells

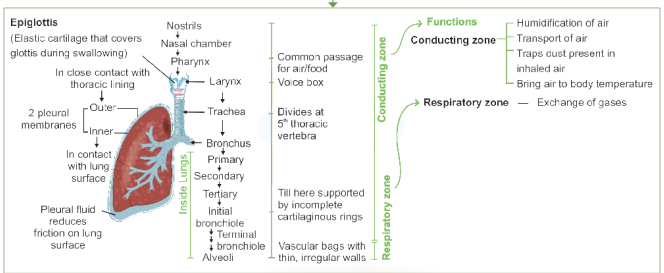
2 RESPIRATORY ORGANS

- Based on: Habitats; Levels of organisation

Organism	Mechanism
Sponges, coelenterates flatworms	Simple diffusion
Earthworm	Moist skin
Insects	Tracheal tubes
Aquatic, arthropods, molluscs, fish	Branchial/ Gills
Amphibians, reptiles, aves, mammals	Pulmonary/lungs

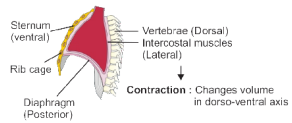
Amphibians show cutaneous respiration all the time

3 OUTLOOK OF HUMAN RESPIRATORY SYSTEM



4 MECHANISM OF BREATHING

- Lungs, enclosed in an anatomically air tight thoracic chamber: essential for breathing as we cannot alter pulmonary volumes directly.
- Movement of air follows the pressure gradient
- **Specialised set of structures involved in breathing:**



Contraction: Changes volume in antero- posterior axis

Normal rate of breating 12-16 times/minute in adult human

Involve

	Inspiration	Expiration
Intrapulmonary pressure	Low	High
Pressure in the lungs w.r.t. atmosphere	–ve	+ve
Shape of diaphragm	Flat	Dome-shaped

Additional muscles involved in expiration : Abdominal muscles

5 EXCHANGE OF GASES

- Partial pressure drives respiration
- Site of exchange
  - Alveoli (Primary)
  - Between blood and tissues
- Partial pressure:
  - Pressure contributed by an individual gas in a mixture of gases

Respiration steps	Atmosphere	Partial pressure of gases (mm Hg) O_2	CO_2
1. Breathing/pulmonary ventilation	CO_2 O_2	159	0.3
2. Diffusion across alveolar membrane (less than 1 mm thick)		104	40
3. Transport of gases by blood		95	45
4. Diffusion b/w blood and tissues			
5. Cellular respiration	CO_2 O_2	40	45

- Exchange of gases is based on:
  - Concentration gradient
  - Thickness of membrane
  - Solubility of gases - CO_2 is 20–25% more soluble than O_2
  - Any factor that affects diffusion rate

Diffusion membrane comprises of 3 layers: thin squamous epithelium of alveoli, endothelium of capillaries and basement substances in between

6 RESPIRATORY VOLUME AND CAPACITES

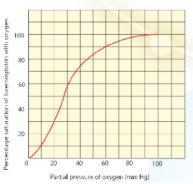
- **Instrument** - Spirometer
- **Significance** - Clinical assessment of pulmonary functions

Standard volumes	Values in ml	Standard capacities
1. Tidal volume/air inhaled or exhaled per breath	TV-500	IC, VC, TLC
2. Inspiratory reserve volume/forceful inhalation	IRV- 2500-3000	IC, VC, TLC
EC ← 3. Expiratory reserve volume/forceful exhalation	ERV- 1000-1100	FRC
4. Residual volume/air left in lungs after forceful exhalation	RV-1100-1200	FRC

Minute volume : TV × respiratory rate i.e., 500 × 12 = 6000–8000 ml
Pulmonary capacity : Addition of various repiratory volumes e.g., FRC = RV + ERV

7 TRANSPORT OF GASES

O_2: Lungs → Blood → Tissue; CO_2: Tissue → Blood → Lungs



Oxygen

- 5 ml of O_2 is delivered to the tissues by 100 ml of oxygenated blood
- 3 % dissolved in plasma
- 97 % as **oxyhaemoglobin**
- Binding of O_2 with Hb is primarily related to pO_2

$Hb + O_2 \rightleftharpoons$ Oxyhaemoglobin

Carbon dioxide

- 4 ml of CO_2 is delivered to alveoli by 100 ml of deoxygenated blood
- 7 % dissolved in plasma
- 20-25 % as **carbamino Hb**
- Binding of CO_2 with Hb is related to pCO_2 as well as pO_2

$Hb + CO_2 \rightleftharpoons$ Carbaminohaemoglobin

Parameter	Association	Dissociation	Association	Dissociation
High pO_2	↑	↓	↓	↑
Low pCO_2	↓	↑	↑	↓
High H^+	↓	↑	↑	↓
High temperature	↓	↑	↑	↓
Location	Lungs (Alveoli)	Tissue	Tissue	Lungs (Alveoli)

- Each Hb. molecule carries or binds 4 oxygen molecules in a **reversible** manner.
- Oxygen dissociation curve obtained is **sigmoid**
- Maximum (70%) CO2 is transported as bicarbonates facilitated by enzyme **carbonic anhydrase**, which exists more in RBCs and minute quantities in plasma

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

8 REGULATION OF RESPIRATION

- Humans have significant ability to maintain and moderate the respiratory rhythm to suit the demands of the body tissues

Regions involved	Pneumotaxic center	Chemosensitive Area	Aortic receptors	Carotid receptors
Location	Pons	Medulla oblongata	Aortic arch	Carotid artery
	Reduces duration of inspiration	Respiratory adjustments		

Sensitive to: ↑pCO_2, ↑ H^+

Influence: Medulla oblongata

Primary respiratory rhythm center

The role of oxygen in the regulation of respiratory rhythm is quite insignificant

9 DISORDERS

Diseases	Impact zone	Characteristic(s)
Asthma	- Inflammation of bronchi, bronchioles	- Wheezing sound
Emphysema	- Alveolar wall damage in chronic cigarette smokers	- Respiratory surface decreased
Occupational respiratory disorder	- Lungs	- Fibrosis, lungs damage

Masks give protection to workers engaged in industries that are involved in dust producing, grinding and stone breaking.