Unit V: Animal physiology (18 marks)

Chapter 17

BREATHING AND EXCHANGE OF GASES

By

Pragya Ranjan

PRAGYA KIE PARHAIE

Ray towards Success

Visit **https://pkp6.godaddysites.com/**

BREATHING:

It is the inflow (inspiration) and outflow (expiration) of air between atmosphere and the alveoli of the lungs.

RESPIRATION:

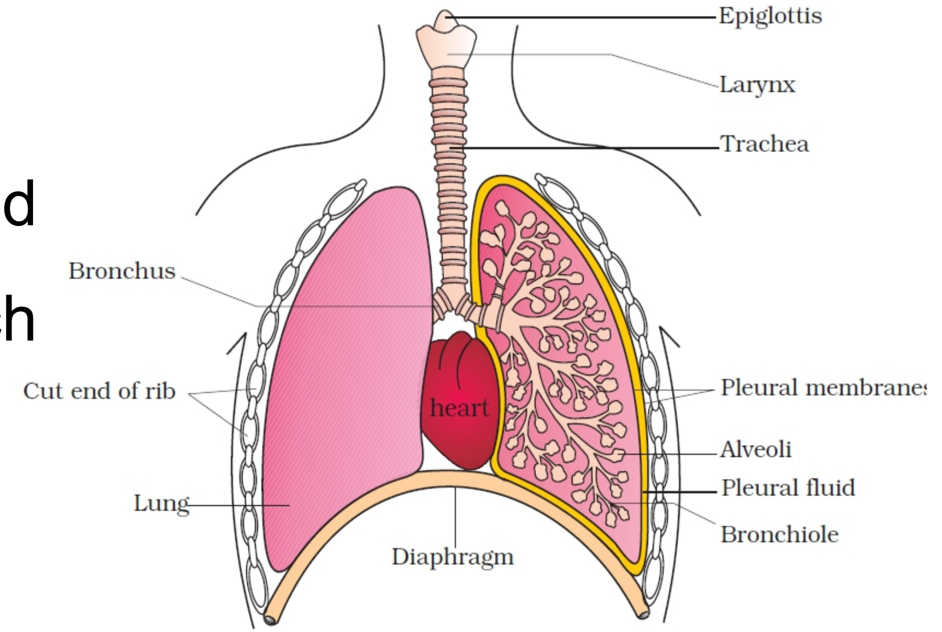
It is an oxidation process of food substances within the cells to form CO_2, water and consequent release of energy

RESPIRATORY ORGANS IN ANIMALS

SL. NO.	ORGANISM	GASEOUS EXCHANGE/ RESPIRATION
1	Protozoans, Sponges, Coelentrates	Direct respiration – Surrounding environment and plasma membrane by **diffusion**
2	Free living flat worms	General body surface by **diffusion**
3	Round worms	No exchange of gases (anaerobic respiration)
4	Earthworm	Cutaneous respiration
5	Cockroach	The respiratory system includes- **spiracles, tracheae and tracheoles**
6	Scorpion, Spiders	Book lungs
7	Fishes	Gills

RESPIRATORY SYSTEM IN HUMANS

- It comprises of ***nostrils, nasal chamber, pharynx, larynx, trachea, bronchi and bronchioles***.



1. Nostrils:

- Holes of nose are called nostrils (external nares) which leads to nasal chamber.

2. Nasal chamber:

- **Nasal septum** divides nasal cavity into 2 nasal chambers.
- The nasal chamber opens into the pharynx.

3. Pharynx

- It is a passage to both air and food.
- The pharynx leads to *larynx.*

4. Larynx (voice box):

- Larynx is a cartilaginous box which helps in sound production and hence called the **sound box.**
- During swallowing **glottis** (a slit like aperture in larynx) is closed by a thin elastic cartilaginous flap **called epiglottis** to prevent the entry of food into the larynx.
- The larynx leads to trachea.

(5) Trachea:

- Trachea is a straight tube extending up to the mid-thoracic cavity.
- It is supported by C-shaped ring cartilage.
- When there is no air, trachea does not collapse due to cartilaginous rings.

(**6**) **Bronchi and Bronchioles:**

- The trachea branches into 2 primary bronchi, one to each lung.
- The primary bronchi are subdivided into *secondary bronchi, tertiary bronchi, bronchioles, terminal bronchioles, and finally alveoli.*
- Alveoli are the primary site where the exchange of O_2 and CO_2 between blood and atmospheric air takes place.

Lungs

- The branching network of bronchi, bronchioles and alveoli comprise the lungs.
- There is a pair of lungs
- Lung has 2 membranes called **pleurae or pleural membranes**.
- The space between the two is known as **pleural cavity** and contains **pleural fluid**.

Nostril → Nasal chamber → Pharynx → Glottis → Larynx → Trachea → Bronchi → Bronchioles → Alveoli

Respiration involves the following steps:

i. Breathing by which atmospheric air is drawn in and CO_2 rich alveolar air is released out.

ii. Diffusion of gases (O_2 and CO_2) across alveolar membrane.

iii. Transport of gases by the blood.

iv. Diffusion of O_2 and CO_2 between blood and tissues.

v. Utilisation of O_2 by the cells for catabolic reactions and resultant release of CO_2.

MECHANISM OF BREATHING:

- It involves

  (i) *inspiration* (ii) *expiration*

- The main muscles of respiration in normal quiet breathing are:

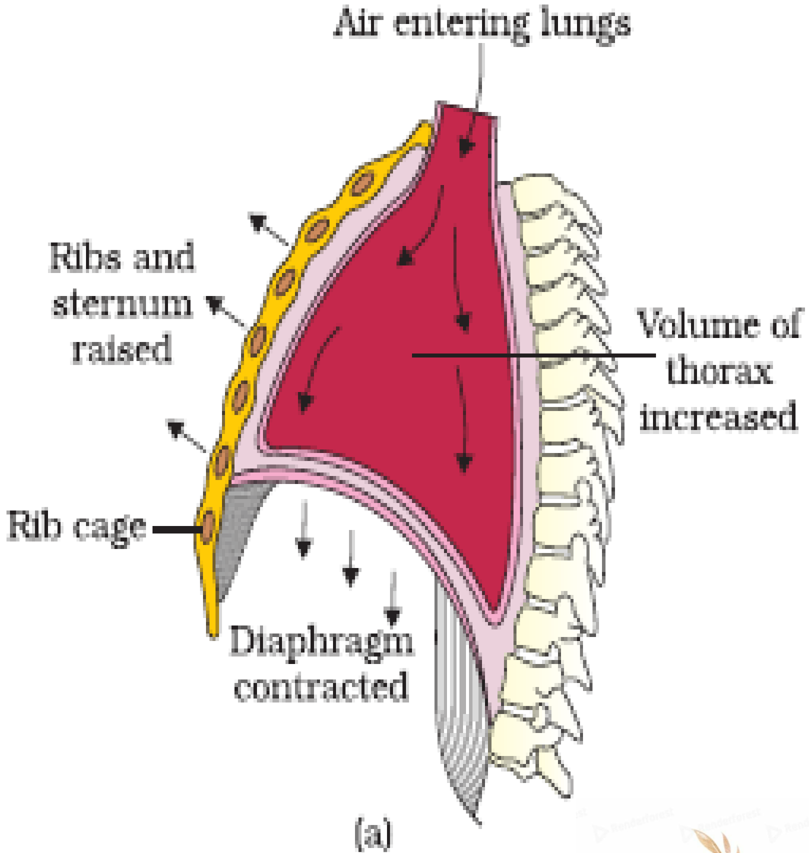
i. Diaphragm,

ii. Intercostals muscles of ribs

iii. Abdominal muscles.

Inspiration

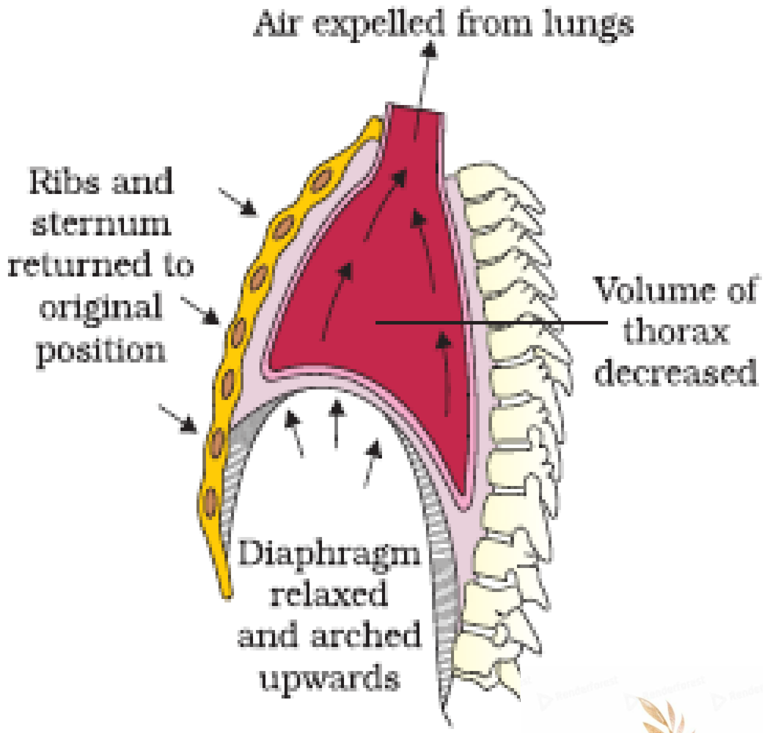
- During inspiration atmospheric air is drawn in.
- Inspiration occurs if the pressure within the lungs is less than the atmospheric pressure.
- During inspiration, the *diaphragm becomes flat, external intercostals muscles contract* and *abdominal muscle relaxes* simultaneously.



PKP
PRAGYA KIE PARHAIE

- This moves the lateral thoracic walls outward and upward increasing the thoracic cavity which increases pulmonary volume and decreases the intra-pulmonary pressure to less than the atmospheric pressure which forces the air from outside to move into the lungs.

Expiration



- During expiration the alveolar air is released out.

- During expiration, the *diaphragm becomes dome-shaped* and *internal intercostals muscles contract* and *abdominal muscle contract* simultaneously;

- Resulting in downward and inward movement of the thoracic wall decreasing the thoracic cavity which decreases pulmonary volume and increases the intra-pulmonary pressure to slightly above the atmospheric pressure which forces the air to move out of the lungs to outside.

Pulmonary/respiratory volumes and capacities

Pulmonary volume: The quantities of air the lungs can receive, hold or expel under different conditions are called pulmonary volumes.

(1) Tidal volume (TV):

- Amount of air inspired or expired with each normal breath (approx 500 ml).

(2) Inspiratory reserve volume (IRV):

- Extra amount of air that can be inspired forcibly after a normal respiration (approx 3100 ml).

(3) Expiratory reserve volume (ERV):

- Extra amount of air that can be expired forcibly after a normal respiration (approx 1200 ml).

(4) Residual volume (RV):

- Amount of air left in lungs after forceful expiration (approx 1200 ml).

Pulmonary capacities

- It is the combination of two or more pulmonary volumes.

(1) **Inspiratory capacity (IC):**

- Total volume of air a person can inspire after a normal expiration.
- TV + IRV = IC; (500 + 3100) ml = 3600 ml

(2) Expiratory capacity (EC):

- Total volume of air a person can expire after a normal inspiration.
- TV + ERV = EC; (500 + 1200) ml = 1700 ml

(**3) Functional residual capacity (FRC):**

- Volume of air that will remain in the lungs after a normal expiration.
- RV + ERV = FRC; (1200 + 1200) ml = 2400 ml

(**4) Vital capacity (VC)**

- The maximum volume of air a person can breathe in after a forced expiration.
- TV + IRV + ERV = VC; (500 + 3100 + 1200) ml = 4800 ml

(4) Total lung capacity (TLC):

- Total volume of air accommodated in the lungs at the end of a forced inspiration
- VC + RV = TLC; (4800 + 1200) ml = 6000 ml

EXCHANGE OF GASES

- Exchange of gases occurs in lungs and body tissues by diffusion.

Partial pressure

- Pressure contributed by an individual gas in a mixture of gases is called partial pressure (pO_2 for O_2; $_PCO_2$ for CO_2)

Partial Pressures (in mm Hg) of Oxygen and Carbon dioxide at Different Parts Involved in Diffusion in Comparison to those in Atmosphere

Respiratory Gas	Atmospheric Air	Alveoli	Blood (Deoxygenated)	Blood (Oxygenated)	Tissues
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

Exchange of Gases in Lungs:

- In lungs, the exchange of gases (O_2 and CO_2) between lung alveoli and pulmonary capillaries take place.
- The pO_2 is higher in alveoli (104 mm Hg) than the deoxygenated blood in the capillaries of pulmonary artery (40 mm Hg). Therefore, O_2 moves (diffuses) from alveoli to capillaries.
- On the other hand, pCO_2 is higher in deoxygenated blood in the capillaries of pulmonary artery (45 mm Hg) than the alveoli (40 mm Hg). Therefore, CO_2 moves (diffuses) from capillaries to alveoli.
- Blood becomes oxygenated, and moves to heart and then to tissues.

Exchange of Gases in tissues:

- In tissues, the exchange of gases (O_2 and CO_2) between tissue blood capillaries and tissue cells take place.
- The pO_2 is higher in oxygenated blood in the capillaries (95 mm Hg) than the body cells (40 mm Hg). Therefore, O_2 moves (diffuses) from capillaries to body cells.
- pCO_2 is higher in the body cells 45 mm Hg) than the blood in the capillaries (40 mm Hg). Therefore, CO_2 moves (diffuses) from body cells to capillaries.
- The blood becomes deoxygenated, and moves to heart and then to lungs.

TRANSPORT OF GASES IN BLOOD:

- Blood is the medium of transport for O_2 and CO_2

Transport of O_2

(1) As dissolve gas

- **3%** of O_2 is carried by blood plasma

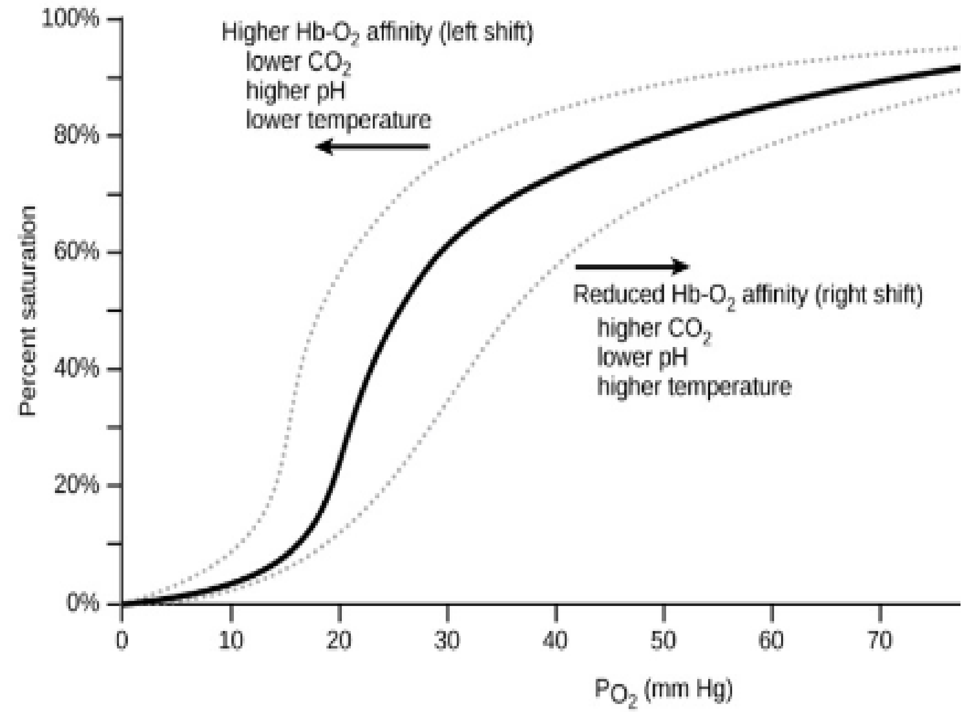
(2) As oxyhaemoglobin:

- **97%** of O_2 is carried by binding to haemoglobin (Hb).
- Haemoglobin consists of a protein called globin and a haeme group.
- Four iron atoms are present in haeme group.
- Each iron has the capacity to bind to one O_2.
- One haemoglobin molecule can carry four molecules of O_2
- 100 ml of oxygenated blood can carry around 5 ml of O_2.

OXYGEN-HAEMOGLOBIN DISSOCIATION CURVE:

- The percentage of haemoglobin i.e. bound with O_2 is called **percentage saturation of haemoglobin**.
- The relationship between the pO_2 and percentage saturation of haemoglobin is graphically presented by a curve called **Oxygen-haemoglobin dissociation curve.**
- The curve is “sigmoid” in shape.
- The oxygen-haemoglobin dissociation curve is useful in studying the effect of factors like pCO_2, H+ concentration, etc., on binding of O_2 with haemoglobin.

- In the alveoli, high pO_2, low pCO_2, lesser H+ concentration and lower temperature, makes the condition favourable for formation of oxyhaemoglobin.



- In the tissues, low pO_2, high pCO_2, high H+ concentration and higher temperature makes the condition favourable for dissociation of oxygen from the oxyhaemoglobin.
- Shifting of curve to the right indicates dissociation of O_2 from haemoglobin
- Shifting of curve to the left indicates association of O_2 to haemoglobin.

BOHR EFFECT

- Shifting of O_2 - haemoglobin dissociation curve to the right by increasing CO_2 partial pressure.

- Increased CO_2 concentration causing dissociation of O_2-haemoglobin

Transport of CO_2

- 7% of CO_2 in dissolved state in plasma
- 23% of CO_2 as carbamino-haemoglobin
- 70% of CO_2 as bicarbonates.

As dissolved state in plasma

$$CO_2 + H_2O \leftrightharpoons H_2CO_3$$

As carbamino-haemoglobin

- CO_2 reacts directly with haemoglobin to form **carbamino-haemoglobin.**

As bicarbonates

- At the tissue site where partial pressure of CO_2 is high, CO_2 diffuses into blood (RBCs and plasma) and reacts with water to form carbonic acid.
- This reaction is very slow in blood plasma, but occurs very rapidly inside RBC because of the presence of **carbonic anhydrase**.

$$CO_2 + H_2O \xrightleftharpoons{\text{Carbonic anhydrase}} H_2CO_3$$

$$H_2CO_3 \leftrightharpoons H^+ + HCO_3^-$$

CHLORIDE SHIFT

- Most of the bicarbonates (HCO_3^-) formed inside RBC diffuse out in the blood plasma along a concentration gradient

- To balance ionic concentration, Cl^- diffuse from plasma into the RBCs.

- This shifting of Chloride ions and bicarbonates between plasma and RBC is called Chloride shift.

Release of CO_2 in alveoli

At the alveolar site where pCO_2 is low, the reaction proceeds in the opposite direction leading to the formation of CO_2 and H_2O. Thus, CO_2 trapped as bicarbonate at the tissue level and transported to the alveoli is released out as CO_2.

Haldane effect

Binding of O_2 with haemoglobin displaces CO_2 from blood

Bohr effect	Haldane effect
• Increased CO2 concentration causing dissociation of O2-haemoglobin • Helps in release of O2 from arterial blood to the tissue cells	• Binding of O_2 with haemoglobin displaces CO_2 from blood • Helps in release of CO2from blood to the alveoli of lungs

REGULATION OF RESPIRATION:

- Respiration is controlled by specialised centre present in the brain called **respiratory rhythm centre**
- The respiratory centre is composed of neurons present in **medulla oblongata (dorsal respiratory centre)** and ***pons varolli (ventral respiratory centre)***
- The functions of the respiratory rhythm centres are again moderated by another centre near pons called **pneumotaxic centre**
- Neural signal from this pneumotaxic centre can **reduce the duration of inspiration** and thereby alter the respiratory rate

Chemosensitive area

- Situated adjacent to the rhythm centre
- Highly sensitive to CO_2 and hydrogen ions.
- Increase in CO_2 and hydrogen ions can activate this centre
- Activation sends signal to the respiratory centre
- Necessary adjustments in the respiratory process is made by which these substances can be eliminated (expiration)
- **Chemoreceptors** associated with **aortic arch** and **carotid artery** also can recognise changes in CO2 and H+ concentration and send necessary signals to the rhythm centre for remedial actions