RESPIRATION

- The term **respiration** means exchange of gases (particularly oxygen and carbon dioxide) between an organism and its medium.
- Physiologically, the term respiration may be defined as a biochemical activity taking place in the protoplasm of a cell and results in the liberation of energy.
- Aerobic respiration yields more energy.
- Aerobic respiration requires oxygen. Cells must be supplied with oxygen to oxidise food to release energy
- Carbon dioxide produced as a result of cellular respiration combines with water to form carbonic acid. That will lower the pH threatening homeostasis. So CO_2 must be eliminated from the body.
- In protozoans and lower metazoans respiration takes place through simple diffusion
- Respiration occurs in animals in four phases, namely, external respiration, transport of gases, internal respiration and Cellular respiration.

1. External respiration (breathing or ventilation):

- In this phase, oxygen diffuses into the blood and carbon dioxide is liberated out. This process takes place in respiratory organs (e.g., lungs, gills).
- Exchange of gases between air in the alveoli and blood in pulmonary capillaries is external respiration

2. Transport of gases:

- The oxygen that is diffused into the blood in respiratory organs is transported to all tissues of the body. At the same time blood returns the carbon dioxide from various tissues to respiratory organs.

3. **Internal respiration:**
   Exchange of gases between the blood in systemic capillaries and the tissue cells is internal respiration
4. **Cellular respiration:** In this phase, oxidation of food material takes place within the cells liberating energy, carbon dioxide and water.

RESPIRATORY SYSTEM OF RABBIT:

- Rabbit is a terrestrial animal. It respires through lungs. The respiratory system of rabbit consists of a respiratory tract and a pair of lungs.

1. **Respiratory tract**:

- It includes the following parts:

a. External nostrils (external nares):

- Rabbit has a pair of oval external nostrils obliquely placed at the tip of the **snout.** They open into nasal chambers.

b. Nasal chambers:

- These are paired long passages above the palate separated from each other by a **nasal septum.**
- Each nasal chamber is divisible into anterior vestibular part, middle respiratory part and posterior olfactory part.
- **i. Vestibular parts** are within the external nostrils and are lined by stratified squamous cell epithelium. It bears hair (which act as a sieve) and have sebaceous glands.
- **ii. Respiratory parts** form the major portion of nasal chambers. They contain three thin, twisted bony plates called **turbinals** or **conchae**.
- These are superior, middle and inferior conchae.
- They are lined by **ciliated columnar epithelium** which is highly vascular, and has numerous mucous cells.
- Their secretions keep it moist. The respiratory parts of nasal chambers act as natural air conditioners.
- **iii. Olfactory parts** are lined with sensory epithelium which is olfactory in function.

c. Internal nostrils:

- Nasal passages open into the nasopharynx through a pair of internal nostrils located above the soft palate.

d. Pharynx:

- It is a common passage for food and air which cross each other in it.
- Nasopharynx is lined by pseudo stratified ciliated epithelium.
- Laryngo pharynx is lined by non keratinised stratified squamous epithelium.

- At the hind end of pharynx there is a slit like pore called **glottis.**
- It has a lid called **epiglottis** made up of elastic cartilage.
- It closes the glottis during swallowing of food or water. At other times, glottis remains open.
- Glottis opens into the larynx.

e. Larynx:

- It is the voice producing part. It is a short, tube like structure, supported by four cartilages.
- They are a thyroid cartilage, a cricoid and a pair of arytenoids.
- Among them, the **thyroid cartilage** is the largest one. Thyroid cartilage forms the ventral and lateral walls of the larynx and is incomplete dorsally.
- Epiglottis arises from thyroid cartilage. Behind the thyroid cartilage is a ring like cricoid cartilage.
- On the dorsal side of larynx is a pair of arytenoid cartilages.
- The tips of arytenoids in their turn bear a pair of cartilages known as **santorini.** Extending between thyroid and arytenoid cartilages, are two fibro- elastic strands called **vocal cords.**
- The space between two vocal cards is **Rima glottidis**
- Sound is produced due to their vibrations. Posteriorly, larynx opens into the trachea.

f. Trachea (wind pipe):

- Trachea is a wide, thin walled tube that passes through the neck (on the ventral side of the oesophagus).
- It is supported by C- shaped cartilaginous rings, which are incomplete dorsally.
- Their free ends are joined by fibrous and muscular tissue. They keep the trachea always open. Internally trachea is lined by **pseudo stratified ciliated epithelium**.

g. Bronchi and their branches:

- On entering into the thorax, trachea bifurcates into two bronchi. Each bronchus enters into the corresponding lung. Bronchi are also supported by incomplete cartilaginous rings.
- Internally, they are lined by pseudo stratified and ciliated columnar epithelium with many **goblet cells**.
- Mucus secreted by them traps the dust and bacteria.
- Inside the lung, each bronchus divides secondary bronchi. They are further divided into tertiary bronchi.

f. Bronchioles:

- Tertiary bronchi are divided into many branches called bronchioles, primary bronchioles, secondary bronchioles, tertiary bronchioles, terminal bronchioles and respiratory bronchioles.
- Each respiratory bronchiole terminates in a cluster of alveolar ducts.
- Larger bronchioles are lined by simple ciliated columnar epithelium.
- Smaller bronchioles are lined by simple nonciliated cuboidal epithelium.
- Alveolar ducts end in thin walled, highly vascular alveolar sacs. Each alveolar sac is formed of many small round or oval chambers called alveoli. Actually exchange of gases takes place in alveoli.

2. Lungs:

- In rabbit, a pair of pinkish, spongy lungs is present in the thoracic cavity, one on either side of heart.
- Each lung is enclosed in a double layered pleuroperitoneum in which outer layer is known as **parietal layer** and the inner layer is called as **visceral layer**.
- These two layers are separated by **pleural cavity** which contains pleural fluid. This fluid protects the lungs from shocks and friction.
- Right lung of rabbit has four lobes, namely, anterior azygous, right anterior lobe, right posterior lobe and posterior azygous lobe.
- Left lung has two lobes, namely, the left anterior and left posterior lobes. Inside each lung, bronchioles end as alveolar ducts and finally terminate in clusters of alveoli.
- Each alveolus is lined by simple squamous epithelium that rests on basement membrane.
- Thickness of the membrane is 0.5mm

MECHANISM OF BREATHING:

- Alternate expansion and contraction of thoracic cavity results in breathing movements.
- These cyclical events occur about 12-16 times per minute in man.
- Thoracic cavity is dorsally bound by vertebral column, ventrally by sternum, posteriorly by a dome shaped muscular diaphragm and laterally by twelve pairs of ribs.
- Ribs are movably attached to thoracic vertebrae and sternum. Breathing movements are brought about by two types of muscles: 1) Intercostal muscles and 2) Phrenic muscles.

1. Intercostal muscles :

- Muscles that extend between successive ribs are called intercostal muscles. They are of two types, namely, external intercostal muscles and internal intercostal muscles.

2. Phrenic muscles :

- These are also known as **radial muscles,** found in diaphragm. The process of breathing involves two events, namely, inspiration and expiration.

A. Inspiration :

- The process of taking in air into lungs is known as inspiration, which is an active process. During this process, external intercostal muscles contract.
- Thus the ribs are pulled up and the sternum moves forward. At the same time, radial muscles of diaphragm also contract and the diaphragm becomes flat.
- As a result, size of thoraic cavity is increased, in the directions permitting the lungs to expand.
- Air pressure in alveoli and respiratory passages decreases.
- This results in air being drawn into the alveoli of lungs, where, exchange of oxygen and carbondioxide take place.
- Contraction of diaphragm accounts for 75% of air entering into lungs

B. Expiration :

- The process of elimination of used air from lungs is known as expiration, which is a passive process. In this process, internal inter costal muscles contract, external inter costal muscles and radial muscles of diaphragm relax. Ribs, diaphragm and sternum reach their original places.
- The size of thoracic cavity is reduced. As a result, lungs are compressed forcing the air to come out.
- Human lungs have about 750 millions of alveoli, which have a total surface area of 100 sq.m., which is about 50 times to that of skin's surface.

Exchange of Gases:

Normal atmospheric pressure 760mm Hg

Percentage of O_2 in the atmosphere 20.95%

Po_2 in atmosphere 159mm Hg

Pulmonary gas exchange-external respiration

Differences in Po_2 and Pco_2 favour diffusion of O_2 and CO_2 in opposite direction

Lung volumes and Capacities in Human:

Tidal Volume (TV) volume moved in and out of the lungs during respiratory cycle (500ml)

Inspiratory reserve volume (IRV) volume that can be inhaled during forced breathing in addition to tidal volume (3000ml)

Expiratory reserve volume (ERV) volume that can be exhaled during forced breathing in addition to the tudal volume ((1,100 ml)

Residual volume (RV) volume that remains in the lungs all the time (1,200ml)

Inspiratory capacity (IC) maximum volume of air that can be inhaled following following exhalation of tidal volume IC=TV+IRV

Functional residual capacity (FRC) volume of air that remains in the lungs following exhalation of tidal volume FRC=ERV+RV

Vital Capacity (VC) maximum volume of air that can be exhaled after taking the deepest breath possible VC=TV+IRV+ERV

Total Lung capacity (TLC) total volume of air that lungs can hold TLC=VC+RV

Partial pressure of gases:

GAS	O_2	Co_2
Atmospheric	159	0.3
Alveoli	104	40
Deoxygenated blood	40	45
Oxygenated blood	95	40
Tissues	40	45

TRANSPORT OF GASES :

- Every 100 ml of oxygenated blood can deliver 5ml of oxygen to tissues
- Blood transports oxygen, that is diffused into it in alveoli of lungs to various tissues and returns carbondioxide to the alveoli for elimination. These gases (oxygen and carbondioxide) are transported as compounds or in the form of salts.

I. Transport of oxygen

- Oxygen from lungs is transported to various tissues in two forms. 1. Through plasma and 2. Red blood cells.

1. Through plasma :

- Very little amount 3% of oxygen is transported by plasma in dissolved state.

Through red blood cells :

- Major part of oxygen is transported by the red blood cells. They contain an oxygen carrier substance, **haemoglobin.** Haemoglobin contains a protein, globin consisting of four polypeptide chains (two α-chains and two β-chains).
- Each chain is attached to a prosthetic haem group. Hence one molecule of haemoglobin contains four haem groups and it can carry four oxygen molecules.
- Haemoglobin has great affinity for oxygen. As the partial pressure of oxygen is more in alveoli, it diffuses into the blood and binds with haemoglobin forming an unstable **oxyhaemoglobin.**
- $Hb + 4O_2 \rightleftharpoons Hb(O_2)_4$ (oxyhaemoglobin)
- Haemoglobin is a dark red pigment. When it is combined with oxygen *(i.e.,* oxyhaemoglobin), it becomes bright red.
- Formation of oxyhaemoglobin in lungs is affected by three factors, namely, normal pH of blood *(i.e.,* 7.4), low temperature in lungs and high oxygen concentration and low carbondioxide concentration in inspired air.
- It has been observed that the presence of more carbondioxide tends to reduce the amount of oxygen carried by the blood. This effect of carbondioxide on oxygen carrying capacity is known as **Bohr effect.**
- In tissues, where oxygen concentration is less, oxyhaemoglobin dissociates and releases oxygen.
- The dissociation of oxyhaemoglobin is affected by decrease in pH (due to increase of H^+ ions), rise in temperature in tissues, high tension of carbondioxide and low tension of oxygen.

Oxygen dissociation curve :

- The relationship between the oxygen tension and saturation of haemoglobin can be studied by observing the oxygen dissociation curve.
- It is a sigmoid curve, which can be drawn on a graph paper by plotting partial pressure of oxygen on x-axis and percentage of saturation of haemoglobin on y-axis.
- The curve shows a progressive increase in percentage of saturation of haemoglobin with increase of partial pressure of oxygen upto a certain extent, where it becomes constant.
- When the partial pressure of oxygen is 100 mm / Hg, the haemoglobin is 95-98% saturated.
- As the oxygen tension falls, the saturation of haemoglobin falls slowly until oxygen partial pressure drops to about 50mm Hg, at which rapid evolution of oxygen occurs (unloading tension).
- In the tissues partial pressure of oxygen is about 40 mm Hg and thus oxyhaemoglobin dissociates and oxygen is readily made available to tissues.

Transport of carbondioxide

- Carbon dioxide is formed in tissues during metabolism and diffuses into the blood. Then it is transported to lungs in the following ways:

1. As carbamino compounds :

- About 23% of carbondioxide is transported in this form.
- Carbondioxide, that is diffused into the blood combines with haemoglobin and forms an unstable **carbamino haemoglobin.**
- In lungs where carbondioxide tension is low, it dissociates and releases carbondioxide.

$CO_2 + Hb \rightleftharpoons$ Carbamino haemoglobin

2. As physical solution :

- About 7% of carbondioxide is transported in this way.
- Carbondioxide reacts with water present in plasma of blood and forms an unstable - compound called carbonic acid. (If all the carbondioxide is transported in this way, the pH of blood become lowered from 7.4 to 4.4, which cause fatal effects. Hence only about 10% of it is transported as carbonic acid).
- In lungs carbonic acid is dissociated into carbon dioxide and water.

$CO_2 + H_2O$ (of plasma) $\rightleftharpoons H_2CO_3$

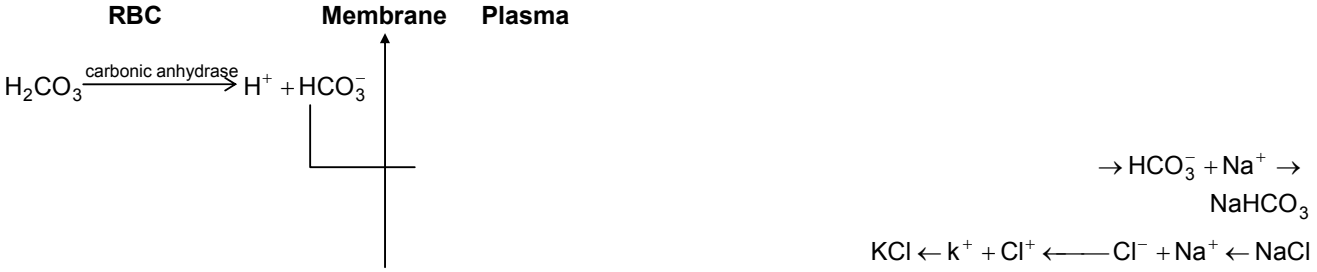
3. As bicarbonates :

- About 70% of carbon dioxide is transported in this way.
- The carbon dioxide, that is diffused into blood from tissues enters the cytoplasm of red blood cells and combines with water (of cytoplasm) and forms carbonic acid in presence of **carbonic anhydrase.**
- Soon, the carbonic acid is dissociated into H+ ions and HCO_3^- ions.
- In the red blood cells, haemoglobin remains combined with potassium.
- This potassium combines with HCO_3 and forms potassium bicarbonate and H^+ ions combine with haemoglobin forming haemoglobin acidic.

- $CO_2 + H_2O$ (of RBC) $\rightleftharpoons H_2CO_3$
- $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
- $H^+ + HCO_3^- + KHb \rightleftharpoons KHCO_3 + HHb$.

Chloride shift (Hamberger's phenomenon)

- In RBC, Carbonic anhydrase catalyses the formation of carbonic acid and its dissociation into H^+ and HCO_3^-. Hence these HCO_3^- ions increase in RBC.
- Under normal conditions the cell membranes of red blood cells are impermeable to cations (K^+, Na^+ etc.) and haemoglobin and are permeable to anions (HCO_3^-, Cl^- etc.).
- So these HCO_3^- ions diffuse into the plasma.
- To maintain neutrally, for each HCO_3^- ion one Cl^- diffuses into RBC.
- These Cl^- ions are formed in the plasma due to the dissociation of NaCl in plasma.
- HCO_3^- ions in plasma combine with sodium ions forming $NaHCO_3$.
- Cl^- combines with K^+ to form KCl in RBC.



- The exchange of Cl^- and HCO_3^- between plasma and red blood cells is described as chloride shift which permits the transport of additional amounts of carbondioxide as sodium bicarbonate by the plasma.
- All the events of chloride shift are reversible. In lungs, chloride shifts back into plasma, thus, liberating K^+ to buffer the newly formed oxyhaemoglobin.
- In plasma Cl^- ions neutralise the Na liberated by the dissociation of $NaHCO_3$.