CLASS – 11

BIOLOGY

Chapter – 17

Breathing and Exchange of gases

By ~Shahanshah Shahid

PGT- Biology

Chandra Public School, Mau (U.P)

BREATHING AND EXCHANGE OF GASES

- Breathing occurs in two stages- **inspiration** (*i.e. active process*) and **expiration** (*i.e. passive process*).
- Respiration is biochemical process by which ***organic compound are oxidized to liberate chemical energy*** in step wise process (*i.e. in the form of ATP*) from the food.
- ATP molecules are called **universal energy carriers** which hydrolyzed and convert into ADP.

Kind of Respiration

1. **Anaerobic respiration:**

- It is oxidation of food without oxygen molecules in which only 2 ATP molecules are released from one glucose molecules so it is **less efficient than aerobic respiration**.
- The final product of anaerobic respiration is differing in different organism as they produce different enzymes.

Example: In animal tissue (*i.e. skeletal muscle cells) produce* lactic acid during vigorous exercise which carried out by blood to liver where a part o it channeled back into the aerobic respiratory pathway.

2. **Aerobic respiration:**

- In all higher organism the molecules oxygen is utilized for oxidation of food.
- It is efficient process and produces **38 ATP molecules** from one molecule of glucose.

Phases of aerobic respiration in Animals

- Aerobic respiration consists of a series of physical and chemical processes which grouped into two phases:

1. **External respiration:**

- It is also called gaseous exchange and is a **physical process** (*i.e. Involve an exchange of gases between the organism and the surrounding medium which could be gaseous or liquid*).
- It involve ***taking in of oxygen and elimination of carbon dioxide*** where the exchange of gases occurs ***across a respiratory surface***,

- The gaseous exchange takes place by physical process (*i.e. through diffusion*).

Example: Breathing

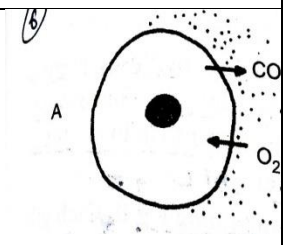
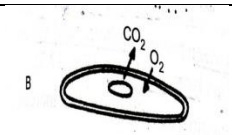
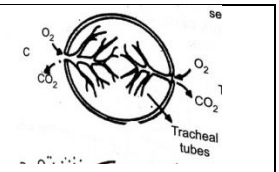
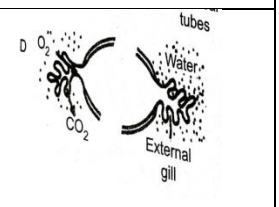
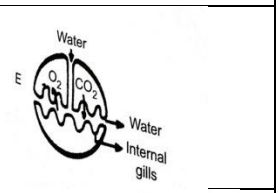
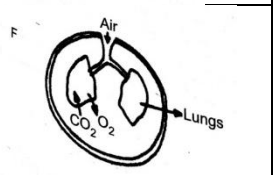
2. **Internal respiration:**

- It is also known as cell or tissue respiration.
- It is a **chemical process** that *involves the breakdown of organic molecules and release energy*.
- It could be ***aerobic or anerobic***

Difference between photosynthesis and Respiration

Photosynthesis	Aerobic Respiration
It is anabolic process	It is catabolic process
CO_2 and H_2O are used for synthesizing carbohydrate molecules	CO_2 and H_2O are released during breakdown of carbohydrate molecules.
CO_2 is taken and O_2 is given out	O_2 is taken inn and CO_2 is given out.
It takes place only in the presence of light	It takes place continuously throughout the life time in all the cells.
Takes place in chloroplast.	It takes place in mitochondria.
It results increase in dry mass	It results in decease in dry mass.

Respiratory Organs

Environment	Respiratory surface	Example	
Aquatic	**General membrane**	**Protistans like Amoeba and coelenterates like Hydra**	
Aquatic or semi-aquatic	**General surface (moist skin)**	**Flatworm like Planaria earthworms and leeches.**	
Terrestrial	**Terminal ends of tracheal tubes**	**Insects some arthopods.**	
Aquatic	**External gills**	**Somme molluscs, amphibians and larval stage of some animals**	
Aquatic	**Internal gills**	**Fish**	
Terrestrial	**Lungs**	**Adult amphibians, reptiles, birds and mammals.**	

Respiratory surface:

- Respiratory surface have the following features:

1. It should have a large surface area
2. It should be thin
3. It should be highly vascular and permeable to allow exchange of gases.
4. It should be constantly kept moist.

Diffusion of gases:

- Diffusion of oxygen and carbon dioxide takes place *due to difference in the partial pressure of oxygen (pO_2) and carbon dioxide (pCO_2) in the surrounding medium and the animals*.
- As the gases always ***move from high partial pressure to low partial pressure***.

Example: when the **pO_2 of air is more than pO_2 of venous blood** *then oxygen from air moves into the blood* and at the same time **pCO_2 of venous blood is more than pCO_2 of air** and so *carbon dioxide moves out from the blood*.

Respiration by gills

- In number of aquatic organism the animal respire by gills.
- As water have low diffusion rate than air so they have **series of gills** and one way current of water.

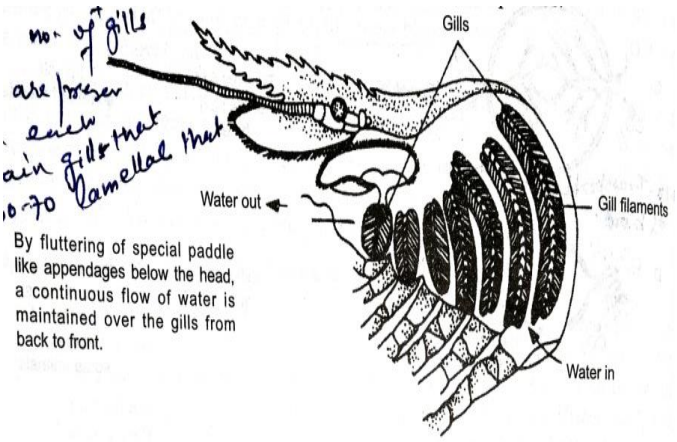
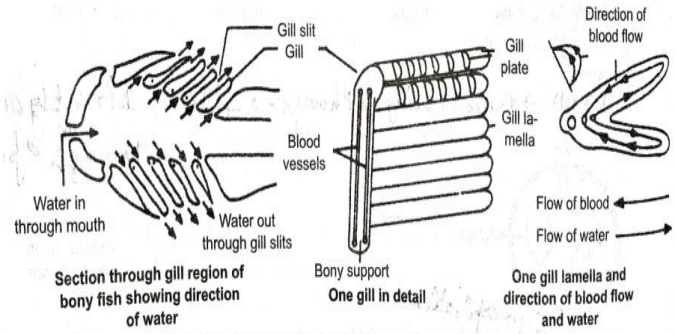
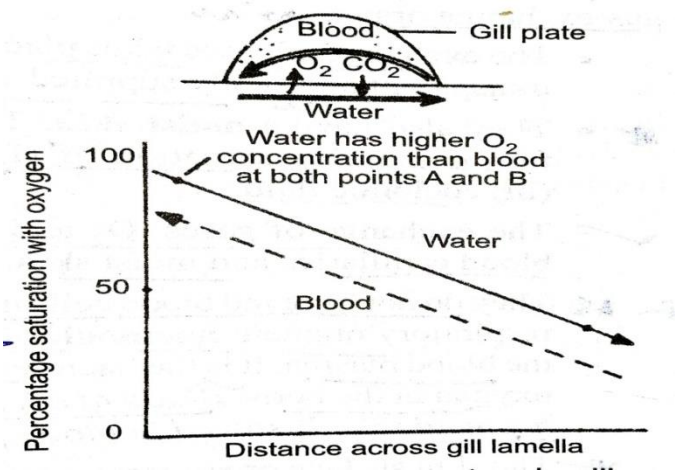


Fig. 17.2 Gills of a prawn



- Fish –have number of gills pouches that contain **gill** (*i.e. each have 60-70 lamella that projecting horizontally from bronchial arch*).
- Mouth buccal cavity pharynx gills directly outside or through operculum.

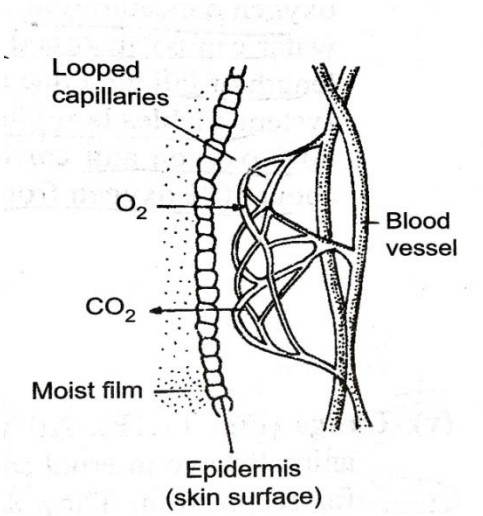


- It have **counter flow system** (*i.e. the flow of water and the flow of blood are in opposite direction*) which ensure that **blood constantly meet with water** (*i.e. have relative higher oxygen concentration*) so that oxygen from water can be absorbed through entire length of gill lamellae and gill plate.

 # 80% absorption in bony fishes, and 50% in cartilaginous fishes.

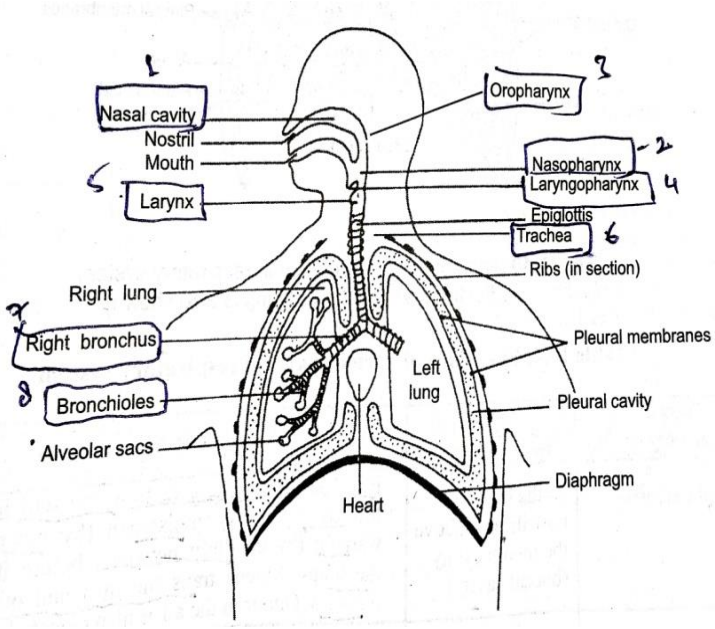
Gaseous exchange in Earthworm

- It does not have special respiratory organs and us entire **outer skin** (*as gaseous exchange where gaseous exchange takes place through their skin*) that have looped blood capillaries and moist skin which covered with mist film containing secretion of – *epidermal mucous gland, excretory wastes and coelomic fluid*.

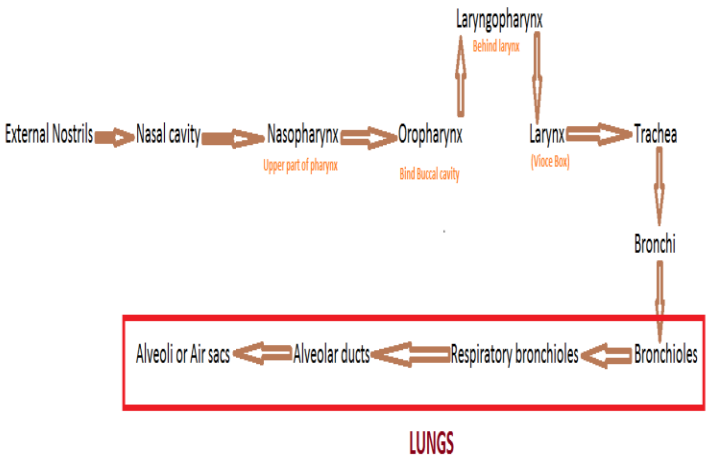


- They do ***not have blood cells in their blood*** so the ***hemoglobin*** is dissolved in blood plasma that carries oxygen in the body.
- Skin surface acts as a permeable membrane and the *pO2 in blood plasma is low so O2 diffused into the blood from the moist skin* and bind with hemoglobin, simultaneously CO2 diffused outside.
- The contractile pumping of blood vessels facilitates the transport of blood and dissolved gases round the body.

Human Respiratory System



- Human have lungs as respiratory organs and respiration occurs by lungs that known as pulmonary respiration.
- The passages of air in human respiratory system follow the following pathway:



Part of Respiratory System

Parts of respiratory system	Location	Importance and functions
Nasal cavity	Just above the mouth cavity	Has nasal epithelium by which air filtered (i.e. by hairs) moistened (i.e. by mucus – trap dust and other fine particle) and warmed (i.e. by capillary network) before enter in lungs.
Nasopharynx	Upper part of the pharynx	Air enter through two internal opening
Oropharynx Laryngopharynx	Behind buccal cavity Behind larynx	Air passes through oropharynx and laryngopharynx to enter larynx
Larynx	It cartilaginous structure present at opening of trachea	It produce different sound by varying the tension of vocal cords.
Glottis	Slit like opening to larynx	Through which air s passed into trachea via larynx.
Epiglottis	Triangular flap of cartilage present at the glottis	Common passage for food and air and closed the opening of the larynx at the time of swallowing.
Trachea	Runs through the neck in front of oesophagous and extends into the thoracic ccavity	- Connect lungs to nasopharynx . - Has c-shaped rings of cartilage (i.e. prevent the collapse of trachea during inspiration). - linked with ciliated pseudostratified columnar epithelium (i.e. keep unwanted particle away from lungs by beating the cilia towards the

		buccal cavity). It divide into two bronchi as it enters the thoracic cavity (at the level of 5th thoracic vertebra).
Bronchi	Right one enter into right lungs and left one enters into left lungs.	- Right one enter into right lungs and left one enters into left lungs.

Part of respiratory system	**Importance and functions**
Bronchioles	- Network of branching tubes in lungs. - Carry air to and from the alveoli. Branch into respiratory bronchioles.
Respiratory bronchioles	- - First and smallest tube which lack cartilage rings. - - Epithelium lack mucus cells. - - Divide repeatedly into a number o alveolar tubes.
Alveolar ducts	- - It lead into number of air sacs or alveoli which lined with cubical epithelium.
Alveoli	- - It is surrounded by capillary network have thin, simple squamous non-ciliated epithelium and are site of gaseous exchange.
Lungs	- - Spongy elastic roughly triangular bags that enclosed in pleural cavity.
Pleural cavity	- - Lined by two pleural membrane – inner pleura (i.e. tightly attached to the lung surface) and outer pleura (lines the wall of thorax and diaphragm). - - Plural cavity contains pleural fluid (i.e. lubricate the pleura and reduce the friction as the membranes rub against each other during expiration and inspiration).

Mechanism of Respiration

- Pulmonary respiration involve the following steps:

1. Breathing or pulmonary ventilation.
2. Exchange of gases between alveolar air and lungs capillaries.
3. Transport of gases into the blood.
4. Release of gases into the tissue and at the lungs level.
5. Regulation of breathing.

Pulmonary Ventilation

- It is simple process in which the air is taken in from the atmosphere and given out from the lungs which carriedout by constantly breathing that renews the air present in the lungs.
- It involves two processes – inspiration and expiration.
- During inspiration the volume of thoracic cavity increased by two contraction of two sets of muscles –

1. External intercostals
2. Diaphragm

- The respiratory rate (i.e. number of breaths taken per minute) is 12 – 14 breath per minute.

- During forced expiration the expiratory muscles along with abdominal muscle contact and reduce the volume of thoracic cavity to breathe out a large volume of air.

Respiratory volume and capacity

Tidal volume:

- It is a volume of air breathed in and out during normal breathing or in each respiratory cycle.

  TV = 500mL (0.5L)

Inspiration reserve volume:

- It is extra volume of air over and above the tidal volume that can be taken during deep breath.

IRV = 2500 – 3000 ml (2.5 – 3.5 l).

Expiratory reserve volume:

- It is the volume of air that can still expel after a normal expiration.

ERV = 1000 – 1100 (1.0 – 1.2 l).

Residual volume:

- It is amount of air left in in the lungs even after the maximum expiratory effort and can not be force out of lungs.

RV = About 1100 – 1200ml

Pulmonary capacities:

When two or more pulmonary volume (i.e. mention above) are considered together then such combination is called pulmonary capacities.

Inspiratory capacity:

It is the total amount of air of a person that can take in by distending the lungs to the maximum.

It is equal to TV and IVR

TV = TV + IVR

= 500 + (2500 -3000)

= 3000 – 3500 mL of air

Expiratory capacity:

It is the total volume of air of a person that can expire after a normal inspiration.

It include tidal volume and expiratory reserve volume.

EC = TV + ERV

= 1000 + 1500 = 2500 mL of air.

Functional residual capacity :

when a person breath normally then the amount of air that remains in the lungs after normal expiration .

ERC = expiratory reserve volume + Residual volume

= ERV + RV

= 1000 + 1500 = about 2500 ml.

Vital capacity:

It is the total volume of air expired after a maximum inspiration that followed by maximum expiration.

Vital capacity of adult = TV + IRV + ERV

= 500 + (2500 – 3000) + 1000

= 4000 – 4500 mL

- It is maximum capacity of a individual to renew the air in his respiratory system.

Total lung capacity:

- It is the amount of air that present in the lungs after the maximum inhalation.
- It is equivalent to 5500 – 6000 mL (5.5 – 6L).
- It is sum of vital capacity and residual volume.

Dead space air:

- It is amount of respiratory tube where gaseous exchange does not occurs.
- Out of 500ml tidal volume, 150ml remain in respiratory tubes as dead space air and rest 350

ml is present in alveolar sacs in the lungs for exchange of gases.

Exchange of gases between alveolar air and lung capillaries
OR
Pulmonary Exchange of Gases

Composition of alveolar air

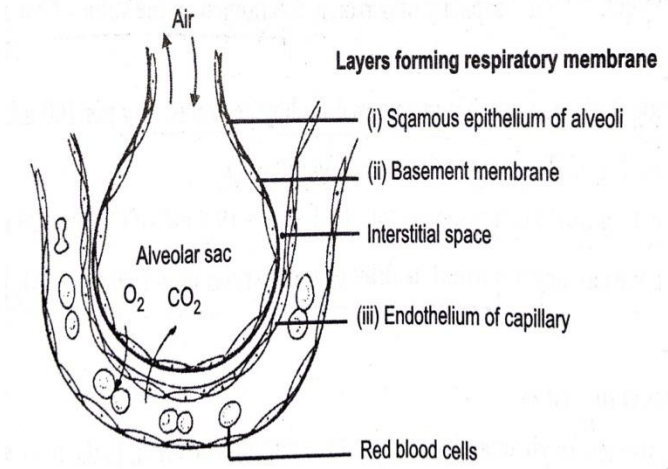
As 3000 mL (RV+ERV) air is already present in lungs so the ***air which inspired*** in and reaches the lungs get mixed and composition of air change as the inspired air.

The composition of alveolar sacs is relative constant (i.e. 13.8 % of oxygen and 5.5% of carbon dioxide).

Gas	Inspired air	Alveolar air	Expired air
o_2	20.95%	13.8%	16.4%
Co_2	0.04%	5.5%	4.0%
N_2	76.01%	80.7%	79.6%

Exchange along the alveolar surface

- Due to alveolar wall is very thin and rich supplied with blood capillaries the alveolar is very close contact with blood.
- The exchange of gases between alveolar sacs and blood occurs through a thin diffusion or respiratory membrane that consist of 3 layers:



1. Thin squamous epithelium of alveoli
2. Basement membrane
3. Endothelium of blood capillaries.

- The partial pressure of oxygen's and carbon dioxide at different parts which involve in diffusion in comparison to atmosphere.

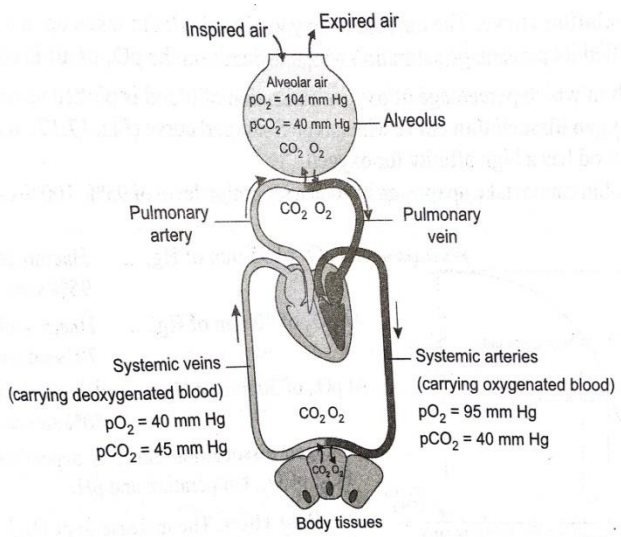
Diffusion Capacity

- Volume of gas that diffuse through the respiratory membrane per minute for a pressure difference of 1mm of Hg.
- It depends upon the **solubility of the diffusing gases** (*i.e. gas is more soluble ten it diffuse faster across the membrane*).
- Across the respiratory membrane the diffusion of gases takes place ***from higher partial pressure to lower partial pressure***.
- The blood reach to **alveolus or venous blood** (*i.e. have lower pO2 and higher pCo2*) results *oxygen diffusion into the blood and carbon dioxide out of the blood into the alveolus*.

 # By the time blood leaves the alveolus it has almost the same pO2 and pCo2 as the alveolar air.

Oxygen level in tissue

- As oxyhaemoglobin gives away part of its oxygen so the concentration of oxygen in blood is reduced to **14.4 mL per 100 mL of blood**.
- As arterial blood carrying O2 to tissue has **19.4 mL pr 100mL of blood** and the venous blood leaving the tissue after giving O2 has **14.4 mL per 100 mL of blood** that mean approximately ***5 mL of oxygen is given away by 100 mL of blood***.



 # so the venous blood picks up approaximately 5mL of O2 per 100 mL of blood when it reach the lungs from the alveoli.

Transport of gases in blood

- Blood is medium of transport of both O2 and CO2.
- Where O2 is transported from lungs to different tissues and Co2 is transported from tissue to the lungs.

Transport of oxygen:

- Oxygen carried out by blood cell as it contain **haemoglobin** which combined with oxygen form **oxyhaemoglobin** (*i.e. a reversible compounds)that form in pulmonary capillary and the bond holding the oxygen to haemoglobin breaks ad release oxygen in the tissue (i.e. tissue have lower pO2*).
- Normal carrying capacity of O2 in healthy person is deterined by *the value of haemogobulin of that person*.
- In healthy person the amount of haemoglobin is **15g /100mL** and 1 gm of haemoglobin can combine with **1.34 mL of O2** .
- 15 gm of Hb can combine with 1.34 x 15 = **19.4 mL of O2**.

 # a normal healthy person carries about 20mL of O2 per 100 mL of blood.

Structure of haemoglobin molecules

- A heamoglobn molecule is made up of ***4 polypeptide chain with four heme groups*** in which each contain **an iro**n atom to which an oxygen can attach.
- The haemoglobin molecules that carrying oxygen molecules according to its ***degree of saturation*** (*i. e. depend upon the pO2 in alveolus and pCo2 in the blood*).
- Oxyhaemoglobin formed in lungs and are quickly released in the tissues.

Hb + 4O2 → Hb(4O2)

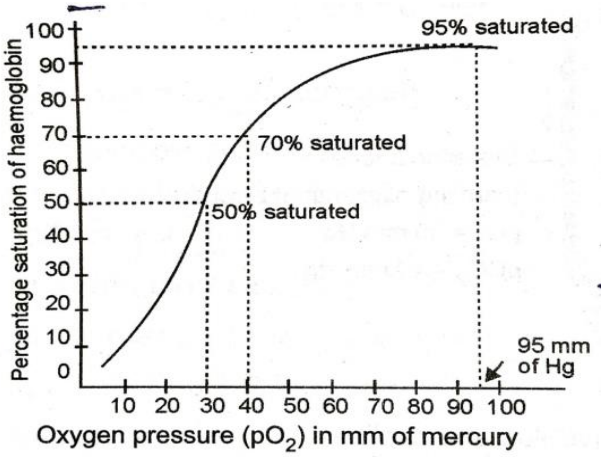
Haemoglobulin Oxygen Oxyhaemoglobin

- Haemoglobin has high affinity for the oxygen and this ***affinity is enhanced by fall in pCo2 of blood***.
- **At the alveolus in lungs** – the blood has *low oxygen and expose to high pCo2 of alveolus so oxygen diffused in red blood cells and form oxyhaemoglobin*.
- As Co2 diffuse from blood to alveolus then the *pCo2 in blood falls and enhancing the further uptake of oxygen*.

 # Oxyhhaemoglobin remain unchanged till it reaches the tissue (i.e. where it dissociate readily to release its oxygen).

Oxygen dissociation curve

- The amount of oxygen hemoglobin takes up at particular time is caballed percentage saturation.
- Percentage saturation is depend upon the pO2 in contact.
- Oxygen dissociation curve is graph in which percentage of oxygen saturation of blood is plotted against pO2 and it is an S-shaped curve.



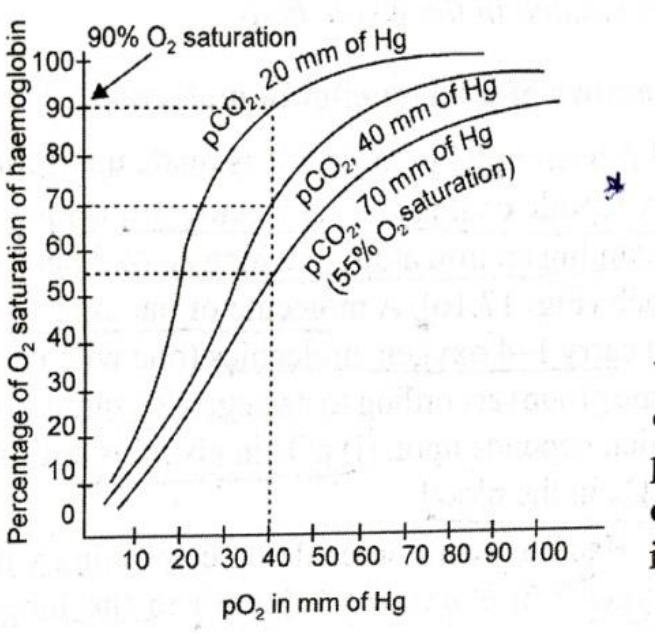
- It indicates that blood has higher affinity with oxygen.
- Hemoglobin cannot takes beyond the 95% saturation level:

1. At pO2 of 95 mm of Hg Hb is 95%
2. At pO2 of 40 mm of Hg Hb is 70%
3. At pO2 of 30mm of Hg Hb is 50%

- Oxygen dissociation curve is depend upon the pO2 , pCo2, temperature and pH

Bohr Effect

- Increase in pCo2 shift the oxygen dissociation curve downwards and this effect is called Bohr Effect.
- As pCo2 is lower in lungs than tissue so haemoglobin has higher affinity for oxygen.



- In the tissue pO2 is between 0 and 40 mm of Hg and pCo2 is comparatively very high around 46 mm of Hg.
- An active tissue have relatively high pCo2 , low pH and raise temperature and all these change lead to more dissociation of oxygen.

 # Inactive oxygenated blood does not give up oxygen even if its pO2 is low by in active cells it readily give oxygen as pCo2 is very high.

Myoglobin

- Myoglobin (oxygen carrier) is found abundantly in skeletal muscle cells of animals.
- The oxygen dissociation curve of myoglobin which far left to haemoglobin curve clear that myoglobin has grate affinity with oxygen.
- The pO2 has to be below 20mm of Hg for dissociation of O2 from myoglobin.
- At this pO2 (i.e. 20mm of Hg) has already given off more than 50% of oxygen.
- Myoglobin act as store of oxygen in muscle at rest and dissociate only when pO2 falls considerably which is advantageous for the muscles.

Carbon monoxide poisoning

- Haemoglobin has 250 times more affinity for carbon monoxide than oxygen.
- In presence of carbon monoxide – Hb combines and form carboxyhaemoglobin.
- When tissue suffer from oxygen starvation then the oxygen combining power decreases and lead to asphyxiation and in extreme cases to death.
- The person with asphyxiation need to administered with pure oxygen-carbon dioxide mixture (i.e. have a very high pO2 level) to dissociate carbon monoxide from haemoglobin.
- Carbon mono oxide poisoning occurs in closed room with open stove burners or furnaces or in garages having running automobile engines.

Transport of carbon dioxide

- A carbon dioxide is radial soluble in wateer that carried both by plasma and red blood cells.
- In active cells the Co2 gives out and enters in the blood where 5- 8% dorm solution in blood plasma and rest enter in blood cells where it transported by two mean-

1. **As carbonic acid by plasma in solution form:**

In this Co2 commbine with water and form carbonic acid (H2Co3) and is very slow process so that very low amount is carried by this way.

$$Co2 + H2O \rightarrow H2CO3$$

2. **As carbaminohaemogobin by the RBCs :**

- Some CO2 that entter in RBCs forms reversible compound with amino group of the globulin part o hemoglobin and form carbaminohaemoglobin.

$HHbNH2 + CO2 \rightarrow HbNHCOOH + H^+$

- Through this way 22 -25% of carbon dioxide is used.

3. <u>As sodium bicarbonate:</u>

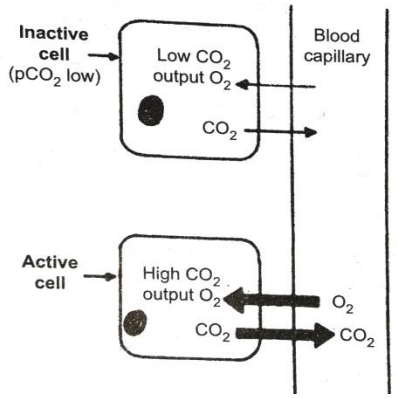
- As Co2 diffuse into the blood plasma then only a part combines with waater and form carbonic acid and large part enter RBCs where carbonic anhydrase speed u the formation of carbonic acid .
- Now the carbonic acid dissociate into bicarbonate (HCo3) (i.e. accumulate inside the RBCs) and hydrogen ions (i.e. buffered by haemoglobin and form haemoglobinic acid).
- Some amount diffuse out into plasma where they combine with sodium ions to form sodium bicarbonate (NaHCo3).
- In exchange the loss of bicarbonate ions is balanced by chloride ions diffusing onto the RBCs from the plasma and called chloride shift.
- The chloride ions inside the RBCs combine with potassium ions and for potassium chloride (KCl).
- Sodium bicarbonate in plasma forms an important buffering system that helps neutralize any acids or bases formed.

<u>Release of gases at the tissue and ay the lungs level</u>

- **At the tissue level oxygen is released** from oxyhaemoglobin and **carbon dioxide** is picked by plasma and red blood cells.
- **At the lungs level** the **carbon dioxide** is released from its *three state* so as to expire it out from blood to the alveoli and oxygen is picked up by haemoglobin.

<u>Release of O2 from oxyhaemoglobin at the tissue level:</u>

- The dissociation of oxyhaemoglobin depends on ***pO2 and pCo2 of the cell*** where it give off ***oxygaemoglobin gives off its oxygen*** more *redially in the presence of increased pCO2*.



- Increased Co2 - increases the acidity and lowered the pH value by the ***formation of carbonic acid***.
- ***An active cell have low pO2 and high pCo2*** and low pO2 so they get more oxygen than an active cells even if it has low pO2

<u>Released of Co2 from all its three state at the lungs</u>

- At the lungs of alveolus – situation is just opposite of at tissue level and blood capillaries are subjected to high oxygen and low carbon dioxide concentration

1. Co_2 dissolve in plasma diffusion into alveoli

   H2Co3 Co2 + H2O

2. Carbaminohaemoglobin also split into carbon dioxide and haemoglobin

   HbNHCOOH HbNH2 + Co2

3. For release of Co2 from bicarbonate the following series of reverse reactions take place:

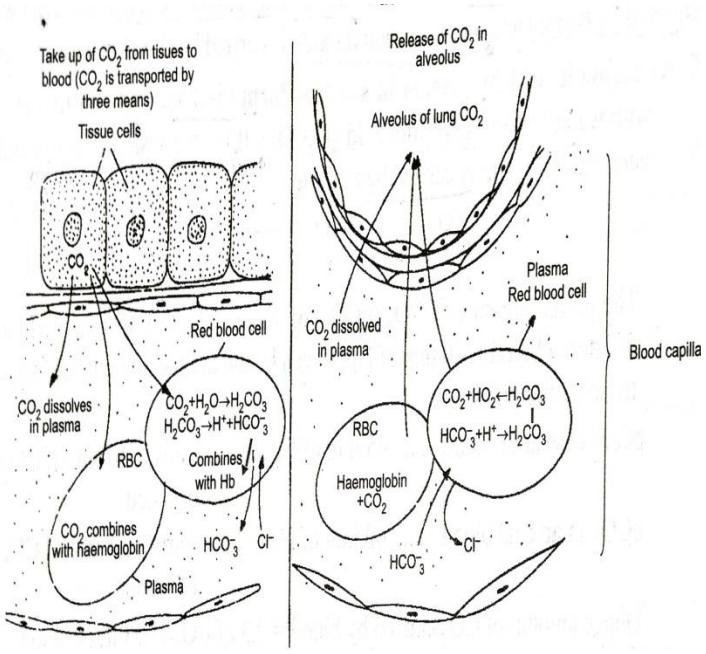
- When reduced haemoglobin in pulmonary blood takes up O2 then H^+ is released from it:

  $HHB + O2 \rightarrow HbO2 + H^+$

- Cl^- **are also release from Kcl** and $HCo3^-$ fro NaHCo3 in the RBCs:

  KCl $K^+ + Cl^-$

  NaHCo3 $Na + HCo3^-$



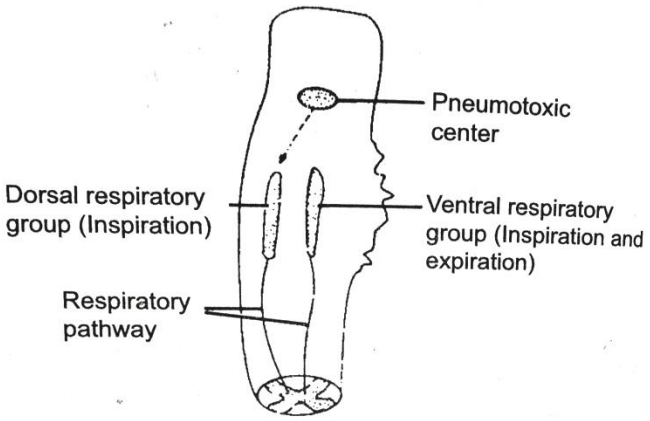
- $HCo3^-$ reacts with H^+ to form H2Co3 which ultimately split into Co2 and water in the presence of carbonic anhydrase enzyme and Co_2 is release into the lungs.

  $HCo3^- + H^+ \rightarrow H2Co3$

  $H2Co3 \rightarrow H2O + Co2$

Regulation of Respiration

- At some extent of breathing is an ***involuntary function of the body*** and occurs rhythmically without having to think about it.
- Breathing can *temporarily interrupted as voluntary muscles are involves but can but stopped completely.*



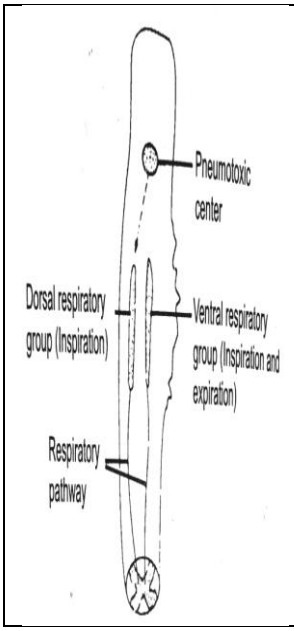
- The respiratory rhythm is controlled by **respiratory centers** (*i.e. a group of neurons*) which are located in the ***brain in the medulla oblongata regions***.
- There are 3 group of respiratory centers have been identified:

1. ***Dorsal respiratory group***
2. ***Ventral respiratory group***
3. ***Pneumatic center***

- All these center influence by ***increase in Co2 and H^+ concentration*** which direct by ***chemoreceptor*** *(i.e. present in the carotid and aortic arches*).
- **On stimulation** (*i.e. increase in pCO2*) send nerve impulses to respiratory centers to increase *the rate of contraction and relaxation*.

Location and function of different respiratory centers

Group of respiratory centers	**Location**	**Function**
Dorsal respiratory group	Dorsa part of medulla oblongata	- It generate the basic respiratory rhythm and transmitted to the diaphragm which is the primary inspiratory muscle.
Ventral respiratory group	Anteroletral to the dorsal respiratory group	- Remain inactive during normal respiration and plays no role in basic respiratory rhythm.
Pneumotaxic center	Dorsally in the upper pons	- Transmits signals to

	regions	inspiratory area and control the switch off point of inspiration. - Storing signal fro here - 1) lead inspiration lasting for 0. 5 seconds and lungs are partially filled. 2) lead to increase rate of breathing because inspiration as well as expiration are shortened. - Week signal lead inspiration lasting for 5 seconds or more and lungs are completely filled.

Disorder of respiratory system

Name of respiratory disorder	Cause	Symptom	Prevention and cure
1. Bronchitis	- due to viral infections. - Acute bronchitis is due to secondary bacterial infection. - Chronic bronchitis mostly seen in cigarette smokers. Could be due to pollutants like carbon mono-oxide.	- Inflammation of bronchi. - Characterized by hypertrophy and hyperplasia of sero-mucus gland and goblet cells lining bronchi. Frequently coughing with thick greenish yellow sputum which indicates bacterial infection.	- Avoid expose of smoke, chemicals and pollutants. - Treat underlying infection with suitable antibiotics. Bronchodilator drugs.
2. Bronchial asthma	- Hypersensitivity of the bronchioles to foreign substance in air - Allergy to certain substance called allergens.	- Spasm of the smooth muscles present in the walls of the bronchioles. - Coughing, difficulty in breathing mainly during expiration. - Excessive secretion of mucous membranes which may clog the bronchi and	- Best to avoid exposure to foreign substance or allergens. - Hypo sensitization (i.e. exposing small doses of the specific allergens. - Treatment include antibiotic therapy to combat infection. - Use of bronchodilator drugs and inhalers for symptomatic relief.

		bronchioles	
3. Emphysema	- Cigarette smoking for a long time and chronic exposure of lung tissue to smoke and air pollutants.	- Destruction of lungs tissue along with inflation - Alveolar walls ruptured and lose elasticity. - Alveolar sacs remain filled with air even after expiration (i.e. Cut off from the renewed oxygen supply and air with in them). - Loose the elasticity makes breathing difficult which lead breathlessness, cough and forced expiration.	- It is chronic obstructive disease of lungs due to irreversible distension and loss of elasticity of alveoli which can not be cured fully. - Bronchodilators, antibiotics and oxygen therapy may slow the progression of the disease. - It can be prevented by avoiding exposure to smoke (like cigarette) and pollutants.