Breathing & Exchange of Gases

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INTRODUCTION

- It is a process of oxidation of organic compounds in cell in which energy is released.
- According to scientist **G.S. Carter,** there are 3 steps in respiration :

1. **External respiration :** Gaseous exchange between environment and lungs.
2. **Internal respiration :** Gaseous exchange between lungs and blood & blood with tissue cells.
3. **Cellular respiration :** Oxidation of organic compounds in cell, in which energy is released.

TYPE OF RESPIRATION

- **Respiration is of two types :**

1. **Anerobic Respiration**

- Oxygen is not required.
- Process occur in cytoplasm
- Due to incomplete oxidation of organic compounds less energy is released.
- Final products are lactic acid and alcohol. **e.g.** – RBC, muscles, internal parasites [Tapeworm, Ascaris, parasites of intestine]

Note : Parasites of blood like plasmodium respire by aerobic respiration.

2. **Aerobic respiration :**

- Oxygen is must.
- Process occur in cytoplasm and mitochondria.
- Due to complete oxidation of organic compounds more energy is released.
- Final products are carbon dioxide & water. **e.g.**– most of Animals & Plants
- Aerobic respiration are of two type :

(a) **Direct respiration :** In this case environmental oxygen is exchanged with the carbon dioxide of the body cells without special respiratory organs and without the aid of blood. Eg. Aerobic bacteria, protists, plants, sponges, cnidarians, flatworms, and most arthropods.

(b) **Indirect respiration :** It involves special respiratory organs such as skin, buccopharyngeal lining, lungs and it need the help of blood.

RESPIRATORY ORGANS

Mechanisms of breathing vary among different groups of animals depending mainly on their habitats and levels of organisation. Lower invertebrates like sponges, coelenterates,

flatworms, etc., exchange O_2 with CO_2 by simple diffusion over their entire body surface. Earthworms use their moist cuticle and insects have a network of tubes (tracheal tubes) to transport atmospheric air within the body. Special vascularised structures called gills are used by most of the aquatic arthropods and molluscs whereas vascularised bags called lungs are used by the terrestrial forms for the exchange of gases. Among vertebrates, fishes use gills whereas reptiles, birds and mammals respire through lungs. Amphibians like frogs can respire through their moist skin also. Mammals have a well developed respiratory system.

HUMAN RESPIRATORY SYSTEM

- The human respiratory system consists of two parts

  (A) Respiratory tract **(B)** Lungs

(A) Respiratory tract :

- A passage from which environmental air enter into lungs.

  Or

  A passage from external nostrils to lungs is called respiratory tract.

External nares → Vestibule → Nasal chamber ↓ Nasopharynx ← Pharynx ← Larynx ← Trachea ↓ Alveoli of Lungs → Respiratory Tree → Bronchiole Tree

1. External nostrils :

- In human two separates external nostrils are present. It is called as Dirhynous condition.

2. Nasal cavity :

- External nostrils open in vestibule, which is present in anterior part of nasal passage.
- Complete nasal passage is divide in two parts by the help of nasal septum.
- In vestibule region this septum is composed of Hyaline cartilage.
- Complete nasal passage is divided in 3 structural & functional regions :

(a) Vestibule region : (Vestibular)

- It is present in anterior part of nasal passage.
- It is composed of skin so derivatives of skin are also present like hairs & sebaceous glands.
- Hairs of vestibule region filtrate inspired air.

(b) Respiratory region :

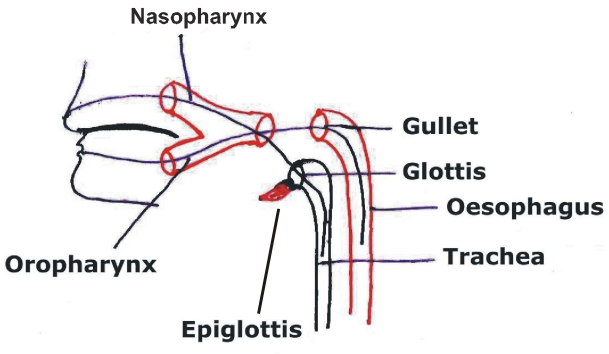
- Epithelial lining of respiratory region is composed of PSCGE in which goblet cells are present, which secret mucous, and makes nasal passage moist.It act as a air conditioning and filtering unit in breathing.

(c) Olfactory region :

- Epithelial linings of olfactory region called **neurosensory epithelium** which receive smell sensation.

3. Internal nares = (choanae)

- Nasal chamber open in nasopharynx through internal nares :



4. Pharynx

- Due to presence of palate in mammals, anterior part of pharynx is divide in two chambers.

(1) On Dorsal surface nasopharynx

(2) On ventral surface oropharynx

- Posteriorly both these chambers open in pharynx, so pharynx is a common chamber for food and air. Therefore mammals can breath through mouth.

- In posterior part of pharynx 2 openings are present :

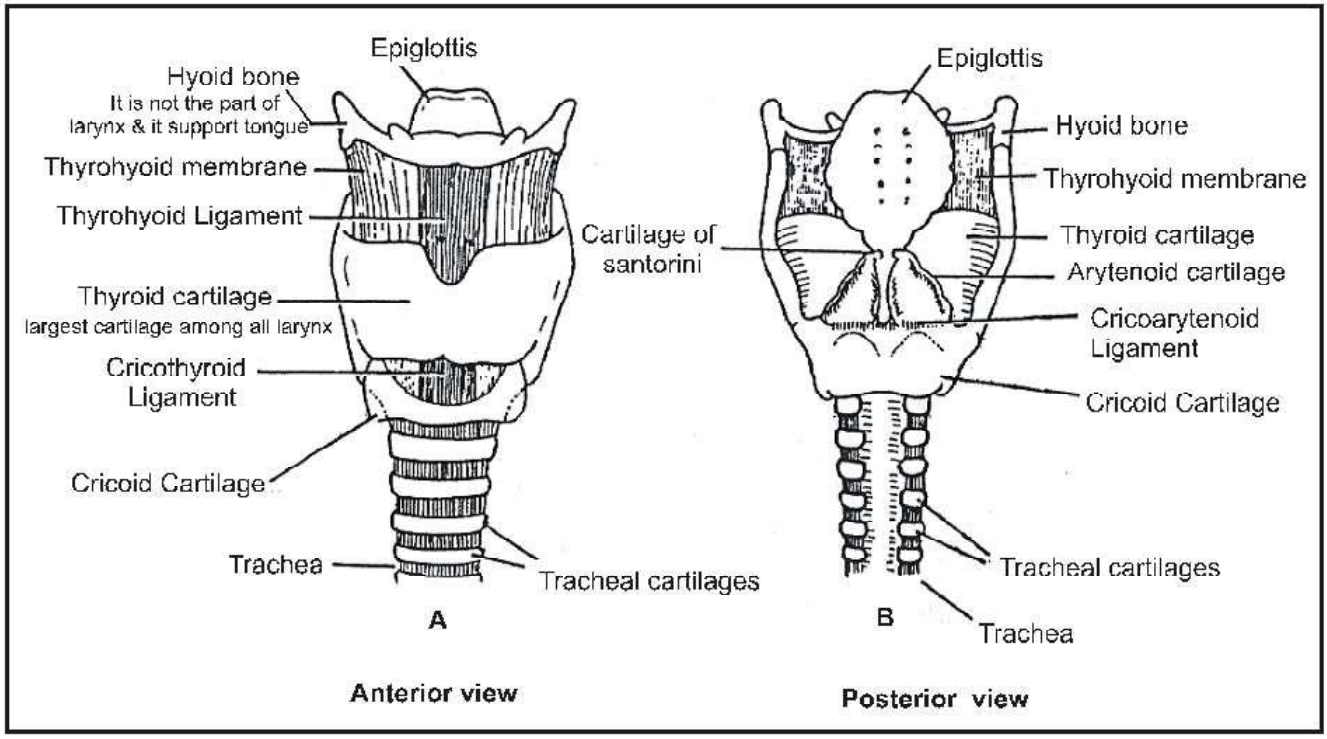
(1) Upper opening is called **Gullet** through which pharynx open in oesophagus.

(2) Lower opening is called **Glottis** through which pharynx open in Larynx/Trachea**.**

- On glottis leaf shape septum **Epiglottis (thin elastic cartilage)** is present which close glottis at the time of swallowing. So at this moment breathing stops or breathing rate become zero.
- Pharynx is only body part in which both food and air passage intersect each-other.

5. LARYNX (voice box: voice producing organ):

- It is present in the anterior part of Trachea, so is considered as modification of Trachea.
- Composed of Nine cartilage.
- These cartilage of larynx attach by ligaments & membranes.



(1) Thyroid cartilage

(2) Cricoid cartilage

(3) Arytenoids Cartilage

(4) Cartilage of Santorini

(5) Other cartilages : Cuneiform and Corniculate are also present.

Vocal cords : In Larynx two pairs of vocal cords are present

(1) Anterior vocal cords : false vocal cord :

- They are composed of membranes.
- They are pink in colour.
- They do not help in Phonation.

(2) Posterior pair : True vocal cord :

- They are composed of yellow fibrous C.T., so they are yellow in colour.
- Usually they are present in relax position, so when air pass through vocal cord, no sound is produced.
- By the contraction in laryngeal muscle vocal cord comes in stretch position, so when air pass through these vocal cords, due to vibration, sound is produced in the form of Laryngeal voice (AA and E) which is converted into true speech by the help of lips and tongue.

6. Trachea :

- Its 12 cm long tube with diameter 2.5 cm, which is present in complete length of neck and upto middle part of thoracic cavity **(at the level of 5th thoracic vertebra divide into right and left primary bronchi).**
- In complete length of Trachea 16-20 'C-shaped' cartilaginous rings are present which are composed of cartilage.
- These rings are incomplete on dorsal surface of Trachea which prevent trachea to collapse.
- In the absence of cartilage on dorsal surface **Trachealis** muscles are present which help in dialation of Trachea during forceful breathing.

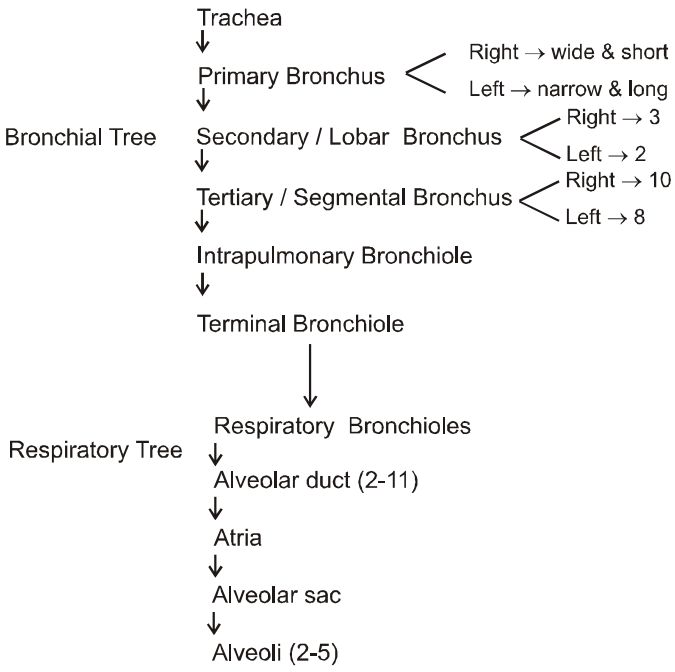
7. Bronchial Tree (B.T.) and Respiratory Tree (R.T.) :

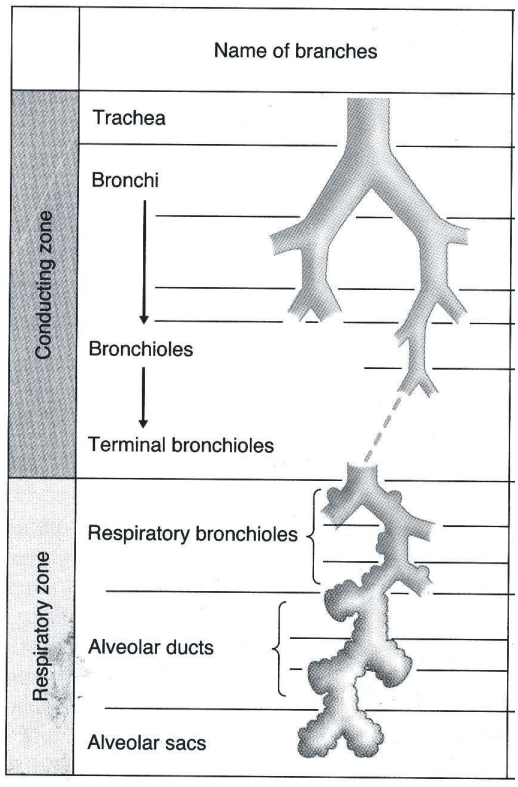
- When trachea enter into thoracic cavity it divides in two branches called as primary bronchus. Branches of primary bronchus upto Terminal bronchioles make **Bronchial Tree**.
- Terminal bronchioles divide to form respiratory bronchiole and its branches make **Respiratory Tree.**

Note: (i) Cartilagenous rings are present in the wall of bronchial tree while absent in respiratory tree.

(ii) Gaseous exchange occur in Respiratory tree while absent in Bronchial Tree.

(iii) Volume of air which is present in bronchial tree is a part of Dead space volume.





Note : (i) Alveoli is structural and functional unit of lungs.

(ii) In two lungs 300 million alveoli are present.

(iii) Wall of alveoli consist of two layers:

(1) Outer layer is composed of sheet of yellow fibrous C.T. in which network of blood capillaries is present.

(2) Inner layer is composed of **simple squamous epithelium**. Squamous cells of alveoli are called as **Pneumocytes.**

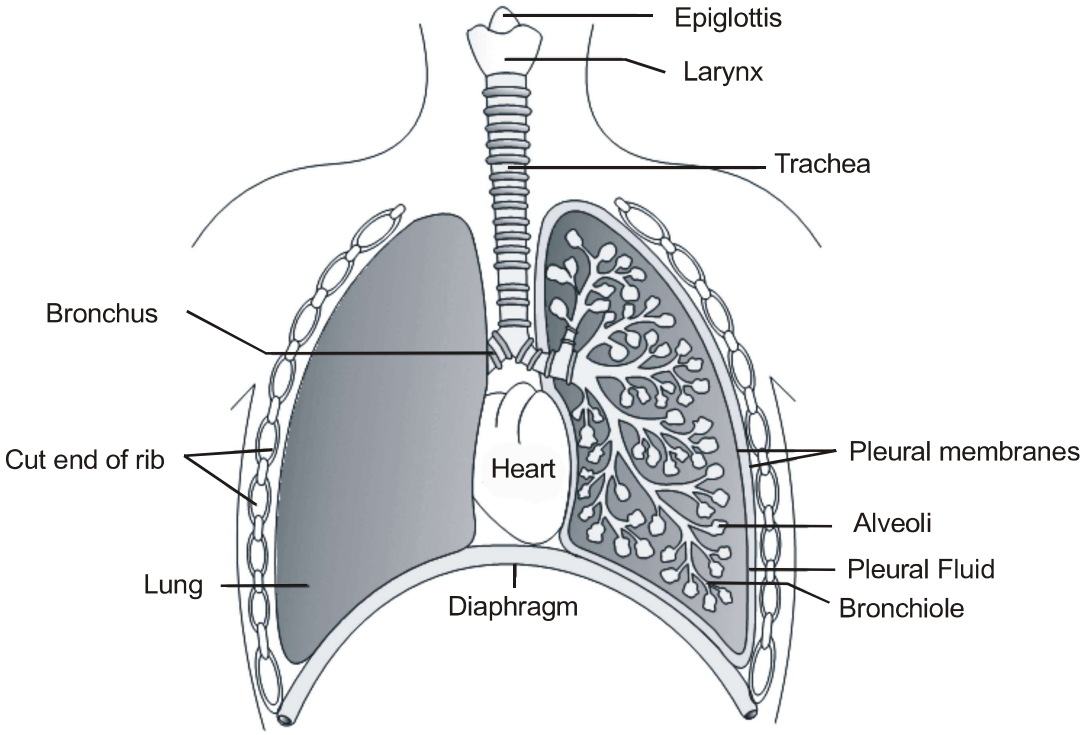
(iv) Most of these pneumocytes help in gaseous exchange while few pneumocytes which are larger in size they secret **Lecithin which is also called surfactant which prevent alveolar collapse.** The lecithin lining

(1) lowers the surface tension of alveoli and keeps them open preventing collapse.

(2) Speeds up the diffusion of gases between air and blood.

(3) kills bacteria that may reach the lungs.

(B) Lungs :



Diagrammatic view the human respiratory system (Sectional view of the left lung is also shown)

- In human two light, spongy & pink in colour lungs are present.
- Around lungs **pleural cavity** is present which is a space between parietal pleura & visceral pleura .
- Both pleura are composed of simple squamous epithelium.
- **In this cavity pleural fluid is filled which is 2 ml in amount.**
- By infection when amount of this fluid is increase it is called as **pleurisy** which causes chest pain & breathing become painful.
- Space between two lungs is called as Mediastinum in which heart, oesophagus, Aorta, posterior venacava, Thymus gland & lymph vessels are present.
- Right lung is bigger than left lung.
- In inner surface of left lung a permanent concavity is present called as **Cardiac notch**, which is formed by compression of heart

Human	
Right lung 3 lobes	**Left lung 2 lobes**
Superior lobe	Left Anterior
middle lobe	Left Posterior
inferior	

Note:

(i) Thoracic cage :

Covering of thoracic cavity makes thoracic cage.

Anterior surface : Neck & Clavicle

Posterior surface : Diaphragm

Ventral surface : Sternum & Ribs

Dorsal surface : Vertebral column & Ribs

Lateral surface : Ribs

(ii) Diaphragm :

♦ A muscular septum which is found in only mammals.

exception : crocodiles

♦ It is dome-shape septum which divide body cavity in two parts.

(1) Upper thoracic cavity

(2) Lower abdominal cavity.

(iii) Intercostals Muscles (ICM) :

♦ Space between two ribs is called as intercostals space in which two types of muscles are present.

(1) External Intercostals Muscles (EICM) :

♦ The fibres of an EICM originate from Posterior border of the dorsal part of a rib and insert upon anterior border of the ventral part of the rib behind crossing the IICM at right angle. Contraction of these muscles assist in **inspiration.**

(2) Internal intercostals muscles [IICM] :

♦ They originates from dorsal surface of lower rib and inserted on ventral surface of upper rib.

♦ By the contraction in these muscles ribs and sternum shifts downwards and inwards.They help in only **forceful expiration.** So they are under control of cerebrum.

MECHANISM OF RESPIRATION

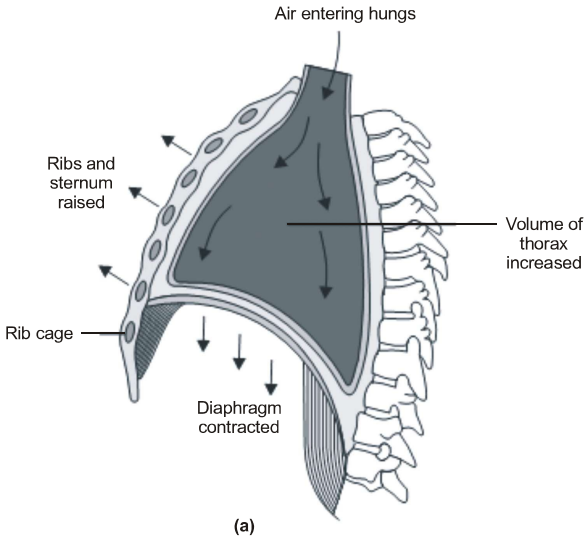
1. Breathing :

♦ In take of fresh air from environment and expulsion of fawl air from lungs is called breathing, so there are two steps in breathing :

(a) Inspiration

(b) Expiration

(a) Inspiration



♦ In take of fresh air

♦ It is an active process.

♦ Completes in 2 sec.

♦ Inspiration occur by contraction in inspiratory muscles

which are of two types :

(i) Radial muscles of diaphragm

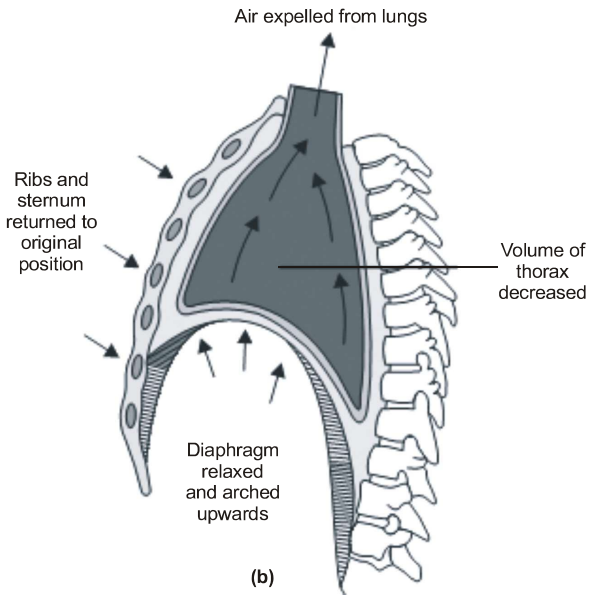
(ii) EICM

♦ When radial muscles contract diaphragm become **flattened** in shaped so volume of thoracic cavity increase between anterior & posterior surface.

♦ When EICM contract sternum comes outward and ribs goes upward.

♦ By the contraction in both muscles volume of thoracic cavity increase and intrapulmonary pressure decrease by 1-3 mm Hg. So, environmental air enter into lungs through respiratory tract called inspiration

(b) Expiration :



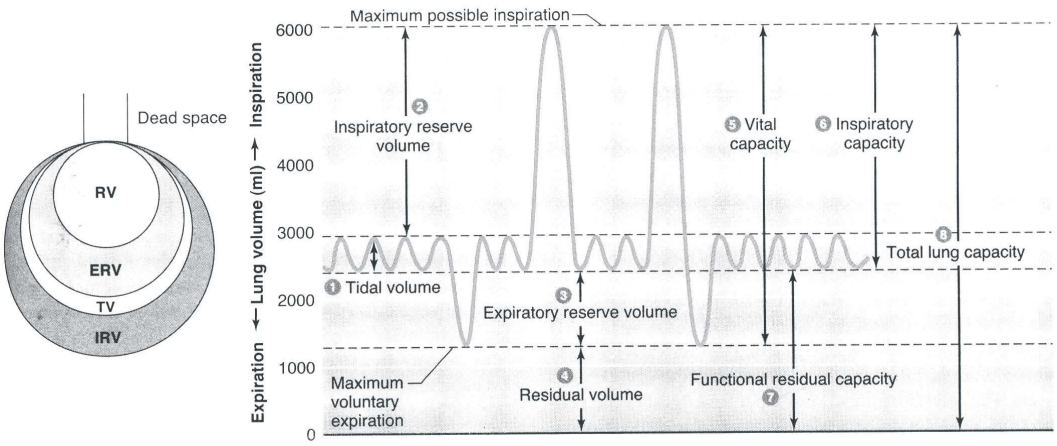
Mechanism of breathing showing : (a) inspiration (b) expiration

- Explusion is flow of air.
- It is a passive process.
- It takes 3 sec.
- Expiration occur by relaxation in inspiratory muscles.
- By relaxation in radial muscle diaphragm become normal dome-shape.
- When EICM relax, then ribs and sternum comes to their normal position.

So by relaxation in both muscles volume of thoracic cavity decrease and intrapulmonary pressure increase 1-3 mm Hg. So expulsion of air occur through respiratory tract called expiration.

- Expiration during sneezing, coughing and yogabhyas is called **forceful expiration**. It is an active process. During forceful expiration, Internal intercostal muscles contract. At this time these contracted muscle pull the ribs inwards, thus the volume of thoracic cavity is highly decreased and the air which was filled in lungs rushes towards outside. Normal breathing is also called **Abdominal breathing**.

SPIROMETRY (PULMONARY AIR VOLUMES & CAPACITIES)



Measurement of volume of inspired and expired air by the help of **Spirometer instrument**.

(1) Tidal Volume (TV) :

Volume of air which is inspired or expired in normal breathing. It is 500 ml.

(2) Inspiratory reserve volume [IRV] :

Volume of air which inspired forceful beyond Tidal volume. It is 3000 ml

(3) Expiratory reserve volume [ERV] :

Volume of air which expired forcefully beyond Tidal volume. It is 1100 ml

(4) Residual volume [RV] :

Volume of air which always remain in lungs after forceful expiration. It can not expired in any condition.

It is 1200 ml. So, **Functional residual volume** is ERV + RV = 2300 ml

(5) Vital capacity of lungs [VC] :

Volume of air which expired forcefully after forceful inspiration.

Vital capacity = IRV + ERV + TV
= 3000 + 1100 + 500
= 4600 ml

(6) Inspiratory Capacity [IC] : IRV + TV
= 3000 + 500 = 3500 ml

(7) Functional Residual Capacity (FRC) :

Volume of air that will remain in the lungs after a normal expiration. This includes ERV + RV
1100 + 1200 = 2300 ml

(8) Total capacity of lungs :

Volume of air which can be filled in lungs.

Total capacity = Vital capacity + RV
= 4600 + 1200 = 5800 ml

(9) Dead Space Volume :

Complete volume of fresh air do not take part in gaseous exchange, while a part of this air retain in respiratory tract from external nostrils to terminal bronchiole called dead space volume. It is 150ml.

(10) Minute respiratory volume :

Volume of air which is inspired or expired per minute in normal breathing.

It is 500 × 12 = 6000 ml.

(11) Alveolar ventilation :

Volume of fresh air which take part in gaseous exchange per minute.

It is 350 × 12 = 4200 ml.

(12) Expiratory Capacity (EC) :

Total volume of air a person can expire after a normal inspiration. This includes tidal volume and expiratory reserve volume (TV + ERV)

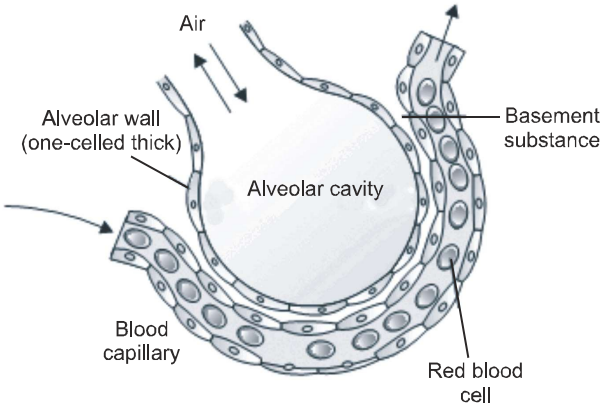
EXCHANGE OF GASES

Gaseous exchange between lungs and blood and blood with tissue fluid occur by **simple diffusion** due to partial pressure difference.

1. Gaseous Exchange in Lungs

At alveoli level gaseous exchange occur through respiratory membrane which is 0.2 mm thick and consist of three layers:

(1) Alveolar epithelium (2) Basement membrane
(3) Capillary endothelium



A Diagram of a section of an alveolar with a pulmonary capillary

- The respiratory membrane has a limit of gaseous exchange between alveoli and pulmonary blood. It is called **diffusing capacity**. The diffusing capacity is defined as the volume of gas, that diffuses through the membrane per minute for a pressure difference of 1 mm Hg.
- It is further dependent on the solubility of the diffusing gases.
- As the solubility of CO_2 is 20-25 times higher than that of O_2, the amount CO_2 that can diffuse through the diffusion membrane per unit difference in partial pressure is much higher compared to that of O_2.
- The partial pressure of oxygen (P_{O_2}) in the alveoli is higher (104 mm Hg) than that in the deoxygenated blood in the capillaries of the pulmonary arteries (40 mm Hg). As the gases diffuse from a higher to a lower concentration, the movement of oxygen is from the alveoli to the blood.
- The reverse is the case in relation to carbon dioxide.

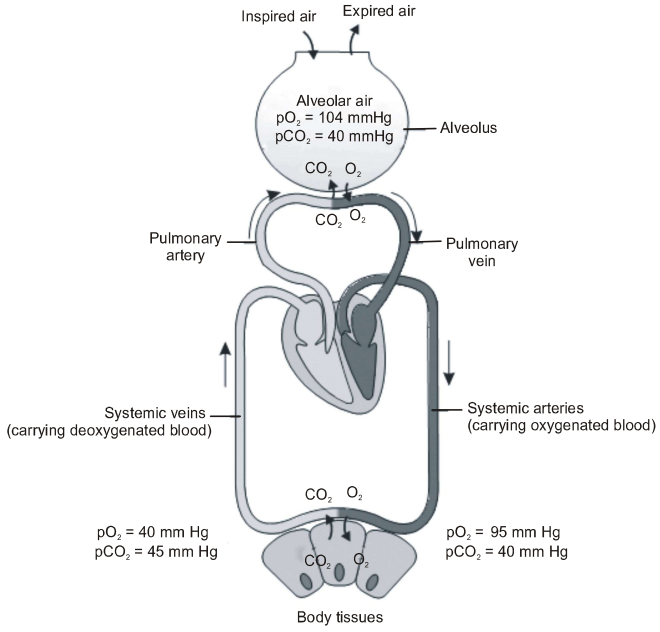
The partial pressure of carbon dioxide (P_{CO_2}) is higher in deoxygenated blood (45 mm Hg) than in alveoli (40 mm Hg). Therefore, carbon dioxide passes from the blood to the alveoli.

Partial Preseures (In mm Hg) of O_2 and CO_2 at Different Parts involved in Diffusion

Respiratory Gas	Atmospheric Air	Alveoli	Blood Deoxygenated	Blood oxyenated	Tissues
Oxygen	159	104	40	95	40
Carbon dioxide	0.3	40	45	40	45

2. Gaseous Exchange in Tissues :

- The partial pressure of oxygen in the oxygenated blood is higher (95mm Hg) than that of the tissue cells (40mm Hg) and the partial pressure ofcarbondioxide in the oxygenated blood is lesser (40mm Hg) than that of the tissue cells (45mm Hg).
- Therefore, oxygen diffuses from the capillary blood to the tissue cells through tissue fluid and carbon dioxide diffuses form the tissue cells of the capillary blood through tissue fluid.



Diagrammatic representation of exchange of gases at the alveolus and the body tissues with blood and transport of oxygen and carbon dioxide

TRANSPORT OF GASES

1. Transport of oxygen :

(a) 97% to 99% oxygen is transported as oxyhaemoglobin and

(b) 1-3 % O_2 transported as dissolve form in water of plasma.

- Haemoglobin is a red coloured pigment present in RBC. O_2 can bind with Hb in a reversible manner to form oxyhaemoglobin.
- One molecule of Hb contains four molecule of O_2.

Note: (i) OXYHAEMOGLOBIN DISSOCIATION CURVE :

- This curve is plotted between partial pressure of oxygen and percentage saturation of haemoglobin with O_2.
- It is sigmoid in shape.
- P_{50} : It is defined as partial pressure of O_2 at which Hb is half saturated.

(1) In oxygenated blood haemoglobin is 97% saturated with oxygen in which partial pressure of oxygen is 100 mm Hg.

(2) Deoxygenated blood in which partial pressure of O_2 is 40 mm Hg, haemoglobin is 75% saturated with oxygen. So, in a single circulation Hb release 22% [20-25%] oxygen to tissue fluid.

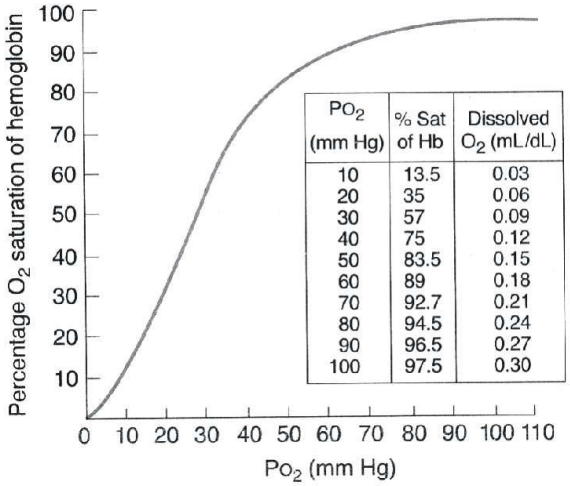
OR

100 ml blood release 5 ml oxygen to tissue fluid.

(3) During vigorous exercise, due to more demand of oxygen haemoglobin delivers 75% oxygen to tissue fluid

OR

100 ml blood release 15 ml to tissue fluid.



PO_2 (mm Hg)	% Sat of Hb	Dissolved O_2 (mL/dL)
10	13.5	0.03
20	35	0.06
30	57	0.09
40	75	0.12
50	83.5	0.15
60	89	0.18
70	92.7	0.21
80	94.5	0.24
90	96.5	0.27
100	97.5	0.30

- **If body temperature increase, CO_2 conc. increase, pH decrease, Acidity increase.Then dissocia tion curve of oxyhaemoglobin shift to right means more dissociation of oxyhaemoglobin take place.**
- Oxygen dissociation curve of myoglobin is hyperbolic. Function of myoglobin is to store oxygen in muscles

2. Transport of CO_2 : Occur in three forms :

(a) As dissolve form : 7% CO_2 is transported as dissolved form in water of plasma.

(b) As carbamino haemoglobin : 23% Hb. NH_2 + CO_2 $\longrightarrow$ Hb. NH. COOH

This percentage of CO_2 combine with amino group of globin protein of haemoglobin to form carbaminohaemoglobin

(c) As bicarbonate compound (70% CO_2)

- This percentage of CO_2 diffuse in RBC and dissolve in water of cytoplasm to form carbonic acid.Formation of carbonic acid is occur in presence of **carbonic anhydrase enzyme** which increase rate of formation of carbonic acid 5000 times.
- Carbonic acid now dissociates into H^+ ions and Bicarbonate (HCO_3^-) ions.
- To regulate pH of blood haemoglobin act as buffer and combine with H^+ ion to form **Haemoglobinic acid.**
- Bicarbonate ions are highly diffusible ions. They diffuse in plasma from RBC and combine with Na^+ ions to form Sodium Bicarbonate.
- To maintain ion equilibrium, in the same of HCO_3^- ions Cl^- ions also diffuse in RBC from plasma. It is called **chloride shift** or **Hamburger phenomena**.
- Cl^- ions combine with K^+ ion to form potassium chloride.

REGULATION OF RESPIRATION

1. Nervous control of breathing :

- There are four centers in brain which regulate breathing :
  - **(a)** Inspiratory centre
  - **(b)** Apneustic center
  - **(c)** Pneumotaxic centre
  - **(d)** Expiratory centre

(a) Inspiratory centre :

It is located on dorsal surface of medulla, so called as Dorsal group of neuron.

- This centre is under chemical control.
- When CO_2 concentration increase means O_2 conc. decrease, this centre stimulate and generate impulse of contraction.These impulse goes to diaphragm through phrenic nerve and through inter coastal nerve they goes to EICM. So by contraction in these muscles inspiration takes place.

(b) Apneustic center :

Located in pons. Apneusis refers to inspiratory gaps. It facilitates inspiration, for example it can prolong inspiration when our O_2 requirement is increased, as during exercise. In this sense the apneustic centre control depth of respiration.

(c) Pneumotaxic centre :

- It is located on dorsal surface of Pons veroli. This area control other two centers and cuts of inspiration at a certain point to make sure that inspiration does not continue too long.
- In this sense pneumotaxic center helps to control rate of respiration. For example it shuts off the hyperstimulated inspiratory centre in response to strenuous exercise preventing over inflation of lungs.

(d) Expiratory centre :

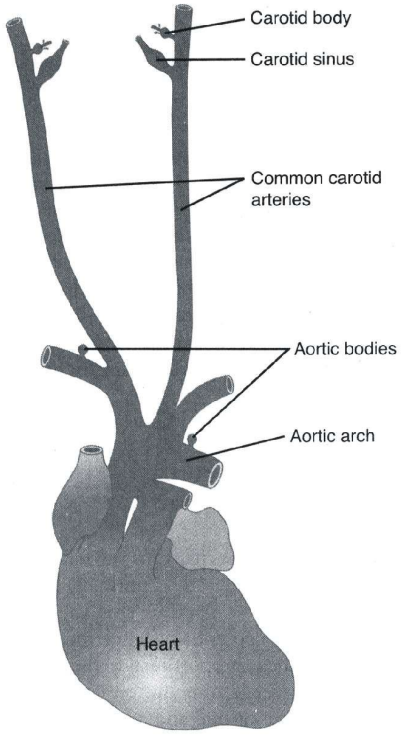
It is located on ventral surface of Medulla, so called as ventral group of neuron.

- This centre is responsible for forceful breathing.
- In this centre few group of neuron generate impulse for forceful inspiration and few group of neuron for forceful Expiration.

Note: This centre do not play any role in normal breathing.

2. Chemical control :

- A chemosensitive area is situated adjacent to the respiratory rhythm centre which is highly sensitive to **CO_2 and hydrogen ions (H^+ ions)**. Increase in these substances can activate this centre, which is turn can signal the rhythm centre to make necessary adjustments in the respiratory process by which these substances can be eliminated.
- Receptors associated with aortic arch and carotid artery also can recognise changes in CO_2 and H^+ ion concentration and send necessary signals to the respiratory rhythm centre for remedial actions.



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

DISOEDER OF RESPIRATORY SYSTEM

(1) Bronchial Asthma :

It is an allergy caused by some allergens like pollen grain, dust particle. allergen stimulate mast cells to produce histamine that causes contraction of smooth muscles of bronchi.

Symptoms : coughing, difficulty in breathing mainaly during expiration, breathing with wheezing sound, excess mucus secretion from respiratory tract that may clog bronchi and bronchiole.

(2) Emphysema :

Emphysema = inflation = full of air.

- Emphysema is an abnormal distension of bronchi, bronchiole and alveolar sac of the lungs mainaly due to cigarette smoking.
- the septa between alveoli are dissolved and elastic tissue replaced by fibrous connective tissue so that lung become non-elastic. Respiratory surface of lung reduced, bronchiole become non- elastic, alveoli remain filled with air even after exhalation.

(3) Bronchitis :

Inflammation of the bronchi due to cigaratte somking air pollutant like CO and Microbial infection

(4) Pneumonia :

It is an acute infection and inflammation of the lung alveoli by *S.pneumonae*, *Mycoplasma*, some false yeast. Infant, young ones, HIV patient are more sensitive for pneumonia.

Symptoms : The alveoli become acutely inflammated, most of the air space filled with mucus and fluid with W.B.C.

(5) Occupational lung diseases :

These disorders are caused due to exposure of potentially harmful substances, such as gas, fumes or dusts, present in the environment where a person works.