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CHAPTER 06

BREATHING AND EXCHANGE OF GASES

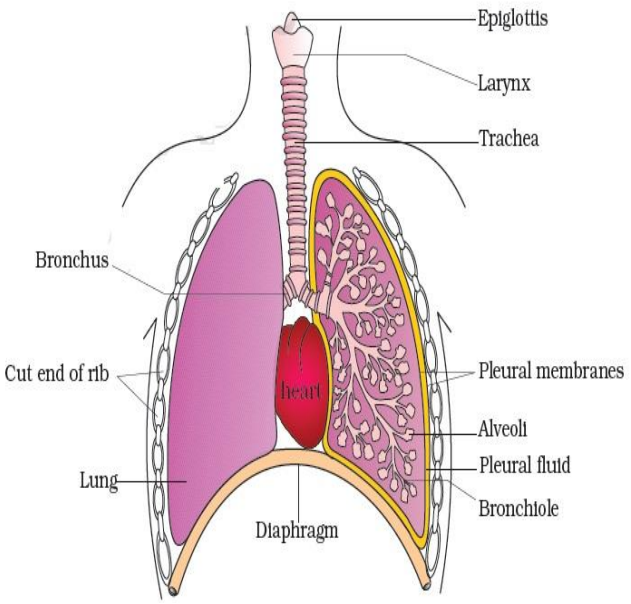
Breathing:

process of exchange of O_2 from the atmosphere with CO_2 produced by the cells is called **breathing,** commonly known as **respiration.**

RESPIRATORY ORGANS

Respiratory organs	Examples
sponges, coelenterates, flatworms	exchange of O_2 with CO_2 by **simple diffusion** over their entire body surface
Earthworms	moist cuticle
Insects	Tracheal system
aquatic arthropods and mollusks, fish	Gills (branchial respiration)
Frogs	Skin(cutaneous respiration)
Man	Lungs(Pulmonary respiration)

Human Respiratory System

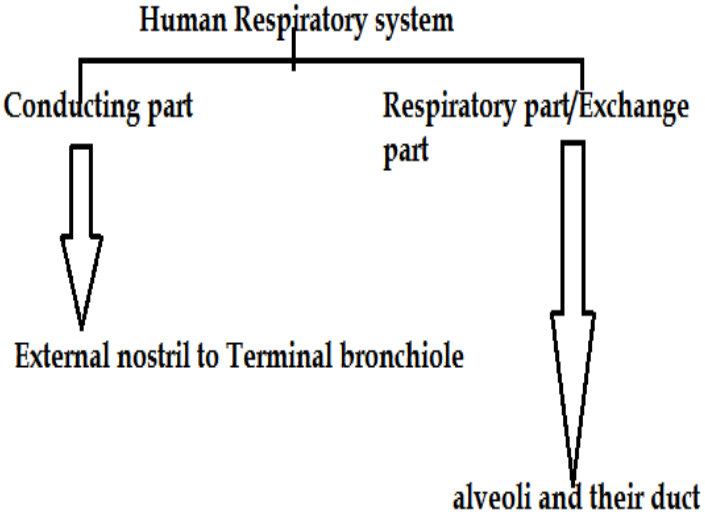


- Human respiratory system starts with a **pair of external nostrils** opening out above the upper lips.
- It leads to a **nasal chamber** through the nasal passage.
- The nasal chamber opens into the **pharynx**, a portion of which is the common passage for food and air.
- The pharynx opens through the **larynx** region into the trachea.
- Larynx is a **cartilaginous box which helps in sound production** and hence called the **sound box. / Voice box**
- During swallowing glottis can be covered by a thin elastic cartilaginous flap called **epiglottis** to prevent the entry of food into the larynx.
- **Trachea** is a straight tube extending up to the mid-thoracic cavity, which divides at the level of 5th thoracic vertebra into a right and left primary **bronchi**.
- Each bronchi undergoes repeated divisions to form the **secondary and tertiary bronchi and bronchioles ending up in very thin terminal bronchioles**.
- The tracheae, primary, secondary and tertiary bronchi, and initial bronchioles are supported by incomplete cartilaginous rings.
- Each terminal bronchiole gives rise to a number of very thin, irregular-walled and vascularised bag-like structures called **alveoli.**

LUNGS

- The branching network of **bronchi, bronchioles and alveoli comprise the lungs.**
- They are covered by a double layered **pleura**, with **pleural fluid** between them. It reduces friction on the lung-surface.
- The outer pleural membrane is in close contact with the thoracic lining whereas the inner pleural membrane is in contact with the lung surface.
- The lungs are situated in the thoracic chamber which is anatomically an air-tight chamber.
- The thoracic chamber is formed **dorsally by the vertebral column**, **ventrally by the sternum, laterally by the ribs and on the lower side by the dome-shaped diaphragm**

❖ **Human respiratory system has two parts**



A-Conducting part of respiratory system

❖ **The part starting with the external nostrils up to the terminal bronchioles constitute the conducting par**t

❖ The **main function** of the conducting part is
1. Transports the atmospheric air to the alveoli
2. Clears it from foreign particles
3. Humidification of the air
4. Brings the air to body temperature

B-Respiratory or exchange part

❖ **The alveoli and their ducts form the respiratory or exchange part of the respiratory system.**

❖ Exchange part is the site of actual diffusion of O_2 and CO_2 between blood and atmospheric air.

Respiration involves the following steps:

(i) Breathing or pulmonary ventilation 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

EXCHANGE OF GAS

❖ Alveoli are the **primary sites** of exchange of gases.

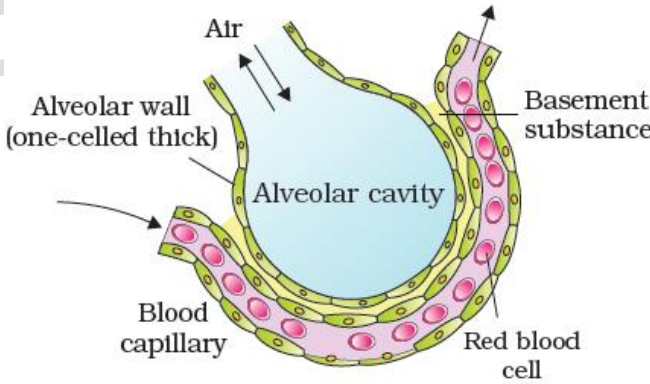
❖ Exchange of gases also occur between blood and tissues.

❖ O2 and CO2 are exchanged in these sites by **simple diffusion** mainly based on pressure/concentration gradient.

Factors affecting rate of diffusion

1.Solubility of the gases
2. The thickness of the membranes involved in diffusion

- The solubility of CO2 is **20-25 times** higher than that of O2, the amount of CO2 that can diffuse through the diffusion membrane per unit difference in partial pressure is much higher compared to that of O2



❖ The diffusion membrane is made up of **three major layers** namely,
- the thin squamous epithelium of alveoli,
- the endothelium of alveolar capillaries and
- the basement substance in between them.

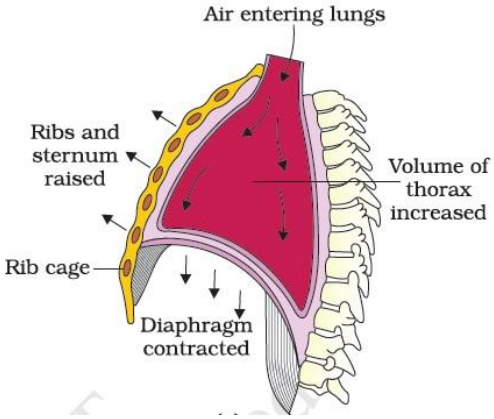
❖ total thickness of diffusion membrane is **much less than a millimetre**

MECHANISM OF BREATHING

- Muscles involved in respirations are **Diaphragm, Intercostal muscle (Muscles between ribs)Abdominal muscle**
- Breathing involve two stages

a)Inspiration
b)expiration

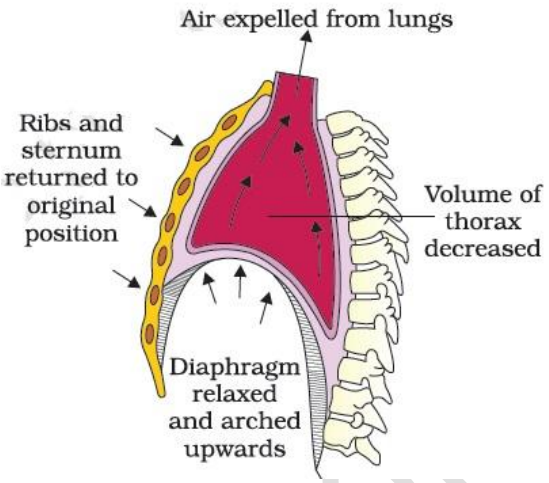
a)Inspiration



- It is the process by which during which atmospheric air is **drawn in.**
- Inspiration can occur if the pressure within the lungs (intra-pulmonary pressure) is less than the atmospheric pressure, i.e., there is a negative pressure in the lungs with respect to atmospheric pressure.
- Inspiration is initiated by the **contraction of diaphragm which increases the volume of thoracic chamber in the antero-posterior axis.**
- **The contraction of external inter-costal muscles lifts up the ribs and the sternum causing an increase in the volume of the thoracic chamber in the dorso-ventral axis.**
- The overall increase in the thoracic volume causes a similar increase in pulmonary volume. An increase in pulmonary volume decreases the intra-pulmonary pressure to less than the atmospheric pressure which forces the air from outside to move into the lungs, i.e., inspiration.

b)Expiration

- it is the process by which the alveolar air is released out. expiration takes place when the intra-pulmonary pressure is higher than the atmospheric pressure



- **Relaxation of the diaphragm and the inter-costal muscles returns the diaphragm and sternum to their normal positions and reduce the thoracic volume and thereby the pulmonary volume**.
- This leads to an increase in intra-pulmonary pressure to slightly above the atmospheric pressure causing the expulsion of air from the lungs, i.e., expiration

  - We have the ability to increase the strength of inspiration and expiration with the help **of additional muscles in the abdomen.**

- On an average, a healthy human breathes **12-16 times/minute**. The volume of air involved in breathing movements can be estimated by using a **spirometer**

Respiratory Volumes

a)Tidal Volume (TV):
Volume of air inspired or expired during a normal respiration. It is approx. 500 mL.,
i.e., a healthy man can inspire or expire approximately 6000 to 8000 mL of air per minute.

b)Inspiratory Reserve Volume (IRV):
Additional volume of air, a person can inspire by a forcible inspiration.
This averages 2500 mL to 3000 mL.

c)Expiratory Reserve Volume (ERV):
Additional volume of air, a person can expire by a forcible expiration.
This averages 1000 mL to 1100 mL.

d)Residual Volume (RV):
Volume of air remaining in the lungs even after a forcible expiration.
This averages 1100 mL to 1200 mL

Pulmonary Capacities

By adding up a few respiratory volumes we can derive various pulmonary capacities

a)Inspiratory Capacity (IC):
Total volume of air a person can inspire after a normal expiration.
This includes tidal volume and inspiratory reserve volume

IC =TV+IRV

b)Expiratory Capacity (EC):
Total volume of air a person can expire after a normal inspiration. This includes tidal volume and expiratory reserve volume

EC=TV+ERV

c)Functional Residual Capacity (FRC):
Volume of air that will remain in the lungs after a normal expiration.

FRC=ERV+RV.

d)Vital Capacity (VC):
The maximum volume of air a person can breathe in after a forced expiration. This includes ERV, TV and IRV or the maximum volume of air a person can breathe out after a forced inspiration.

e)Total Lung capacity (TLC): Total volume of air accommodated in the lungs at the end of a forced inspiration.
This includes RV, ER , TV and IRV or vital capacity + residual volume

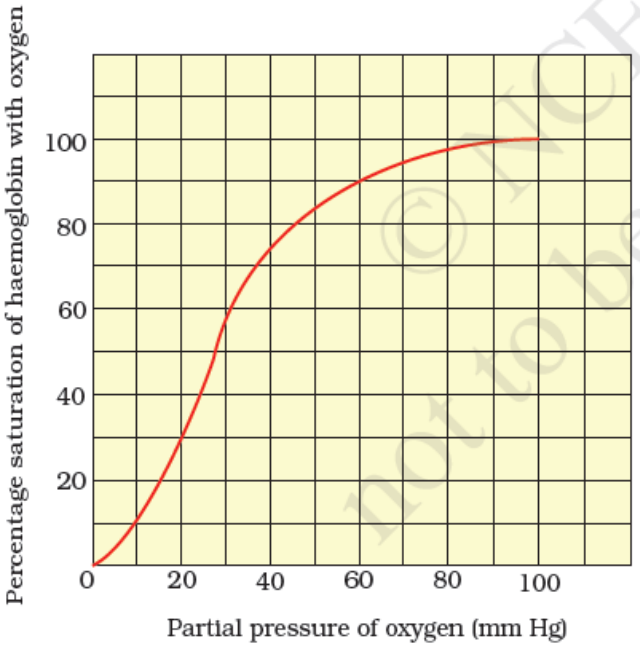
TRANSPORT OF GASES

a) Transport of oxygen

- About **97 per cent** of O_2 is transported by **RBCs** in the blood. The remaining **3 per cent** of O_2 is carried in a **dissolved state** through the **plasma**.
- **Haemoglobin is a red coloured iron containing pigment present in the RBCs.** O_2 can bind with haemoglobin in a **reversible** manner to form oxyhaemoglobin.
- Each haemoglobin molecule can carry a maximum of **four molecules of O2 .**
- **In the alveoli, there is high pO_2, low pCO_2, lesser H+ concentration and lower temperature, the factors are all favourable for the formation of oxyhaemoglobin.**
- In the tissues, **low pO_2, high pCO_2 , high H+ concentration and higher temperature exist,** this conditions are favourable for **dissociation of oxygen from the oxyhaemoglobin.**

Every 100 ml of oxygenated blood can deliver around **5 ml of O_2** to the tissues under normal physiological conditions.

Oxygen dissociation curve



- **A sigmoid curve** is obtained when **percentage saturation of haemoglobin with O_2 is plotted against the pO_2** .
- **This curve is called the Oxygen dissociation curve and is highly useful in studying the effect of factors like pCO_2, H+ concentration, etc., on binding of O_2 with haemoglobin.**

b)Transport of Co_2

- Nearly **20-25** per cent of CO_2 is transported by RBCs
- **70** per cent is carried as bicarbonate.
- About **7** per cent of CO_2 is carried in a dissolved state through plasma.

i)In the form of carbamino- hemoglobin

- About **20-25 % CO_2** is carried by haemoglobin as carbamino-haemoglobin .
- When pCO2 is high and pO_2 is low as in the tissues, more binding of carbon dioxide occurs whereas, when the pCO_2 is low and pO_2 is high as in the alveoli, dissociation of CO_2 from carbamino-haemoglobin takes place, i.e., CO_2 which is bound to haemoglobin from the tissues is delivered at the alveoli.

ii)In the form of bicarbonate ions

- RBCs contain a very high concentration of the enzyme, **carbonic anhydrase** and minute quantities of the same is present in the plasma too.
- At the tissue site where partial pressure of CO2 is high **due to catabolism**, CO2 diffuses into blood (RBCs and plasma) and forms HCO3- and H+,.
- At the alveolar site where pCO2 is low, the reaction proceeds in the opposite direction leading to the formation of CO2 and H2O.

Every 100 ml of deoxygenated blood delivers approximately **4 ml of CO_2** to the alveoli

REGULATION OF RESPIRATION

⇒ A specialised centre present in the **medulla region** of the brain called **respiratory rhythm centre** is primarily responsible for respiratorty regulation.

⇒ Another centre present in the **pons region** of the brain called **pneumotaxic centr**e can moderate the functions of the respiratory rhythm centre. Neural signal from this centre can reduce the duration of inspiration and thereby alter the respiratory rate.

⇒ A chemosensitive area is situated adjacent to the rhythm centre which is **highly sensitive to CO_2 and hydrogen ions.** Increase in these substances can activate this centre, which in 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+ concentration and send necessary signals to the rhythm centre for remedial actions.

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

DISORDERS OF RESPIRATORY SYSTEM

1.Asthma

It is a difficulty in breathing causing wheezing due to **inflammation of bronchi and bronchiole**s.

2.Emphysema

It is a chronic disorder in which alveolar walls are damaged due to which respiratory surface is decreased. One of the major causes of this is **cigarette smoking.**

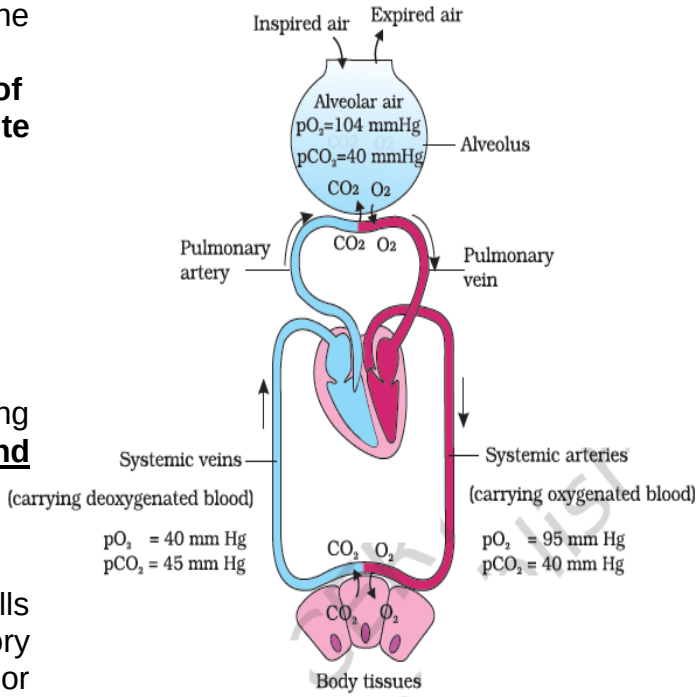


Figure 17.3 Diagrammatic representation of exchange of gases at the alveolus and the body tissues with blood and transport of oxygen and carbon dioxide

3. Occupational Respiratory Disorders:

In certain industries, especially those involving grinding or stone-breaking, so much dust is produced that the defense mechanism of the body cannot fully cope with the situation. Long exposure can give rise to inflammation leading to **fibrosis** (proliferation of fibrous tissues) and thus causing serious lung damage. **Workers in such industries should wear protective masks**.

Eg: Silicosis
Asbestosis

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

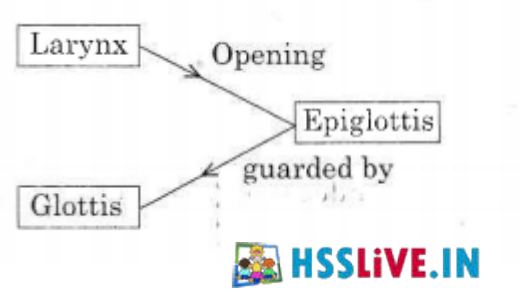
Respiratory Gas	Atmospheric Air	Alveoli	Blood (Deoxygenated)	Blood (Oxygenated)	Tissues
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

Previous years question papers

1. List the major factors affecting the dissociation of oxygen from oxyhaemoglobin in the tissues?
(HSE-July-2019)(2)
2. Distinguish between :
(HSE-March-2019)(2)

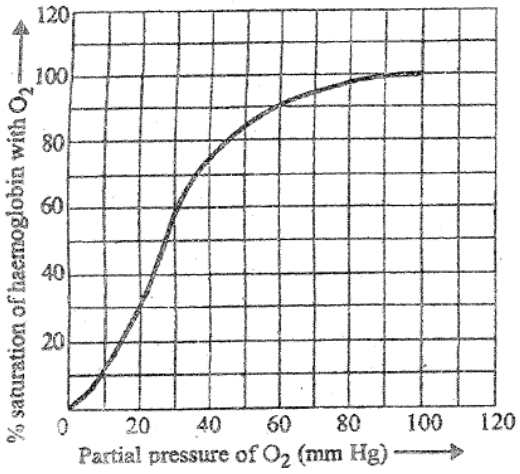
a)	Tidal volume and Residual volume
b)	Vital capacity and Total lung capacity

3. Analyze the concept map given below and if have mistake, reconstruct it
(HSE-Model-2019)(2)



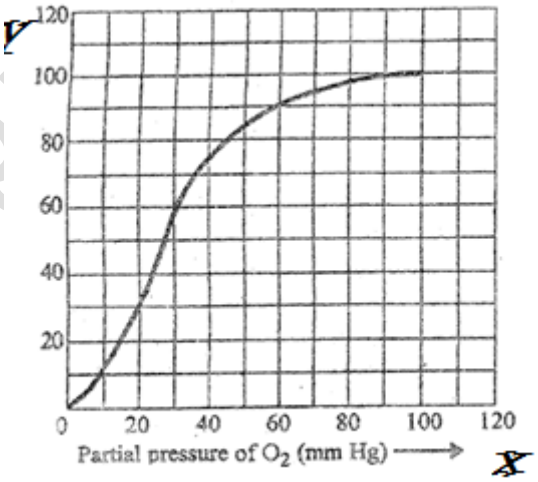
4. a) Identify the graph given below
(HSE-Aug-2018)(2)

Inspiration	Expiration
.....	.....
.....	.....

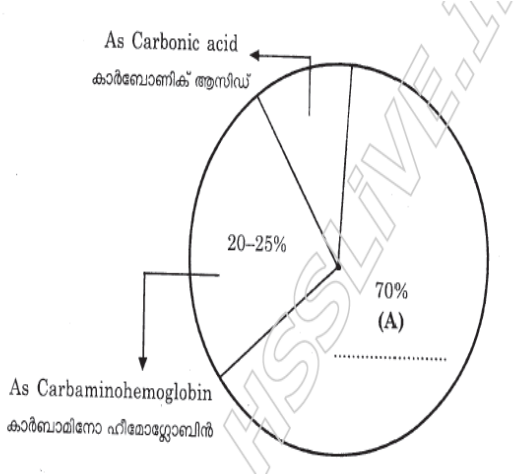


b) List the factors responsible for the formation and dissociation of oxyhaemoglobin

5. Distinguish between following :
a) IRV and ERV b) IC and EC
(HSE-March-2018)(2)
6. "In the tissues, the conditions are favorable for dissociation of oxygen from the oxyhaemoglobin '' Write any four favourable conditions in the tissues for the dissociation of O2 from oxyhaemoglobin (HSE-Model-2018)(2)
7. In the given graph of oxygen, Haemoglobin dissociation curve 'X' axis denote partial pressure of oxygen. What does 'Y ' axis indicate ? write any 2 factors which affect the sigmoid curve ? (HSE-July-2017)(2)



8. Differentiate the process of inspiration and expiration. (HSE-March-2017)(2)
9. Diagramatic representation of CO_2 in man is given. Observe and answer the following ? (HSE-Sept-2016)(2)

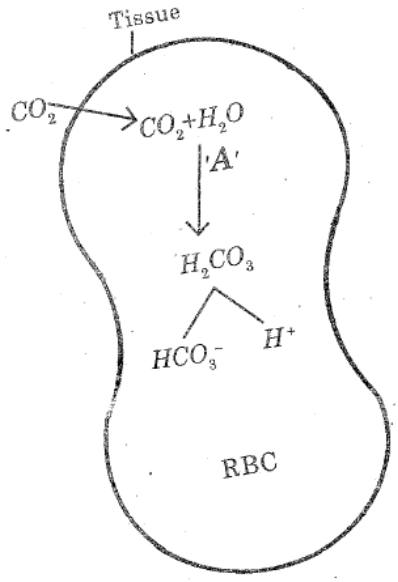


a)Name the method of CO2 transport indicated as A

b)Write the name of enzyme involved in the process A

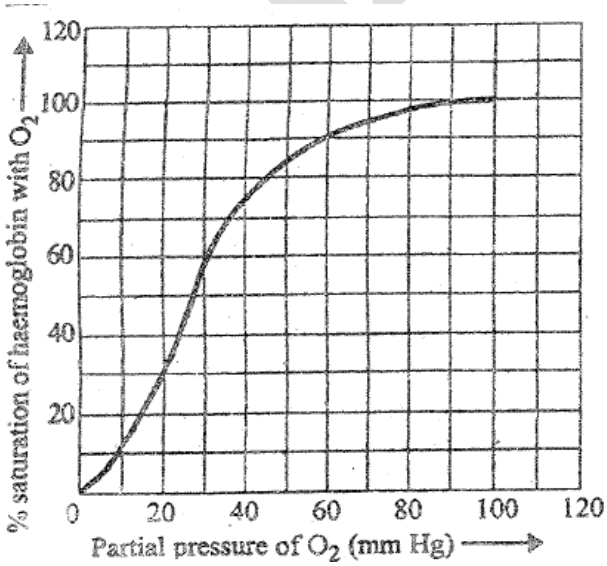
10. CO_2 Transport in the form of bicarbonate ion is picturized below. Observe the diagram and identify the enzyme noted as "A"

(HSE-MARCH-2016)(1)



11. Carefully observe the given sigmoid curve on the graph and answer the following questions

(HSE-MARCH-2016)(2)



a)What does the graph indicates?

b)What are the 3 factors affecting the sigmoid patterns of the graph?

12. Correct the following misconception of a student regading the human respiration (HSE-Septemer-2015)(2)

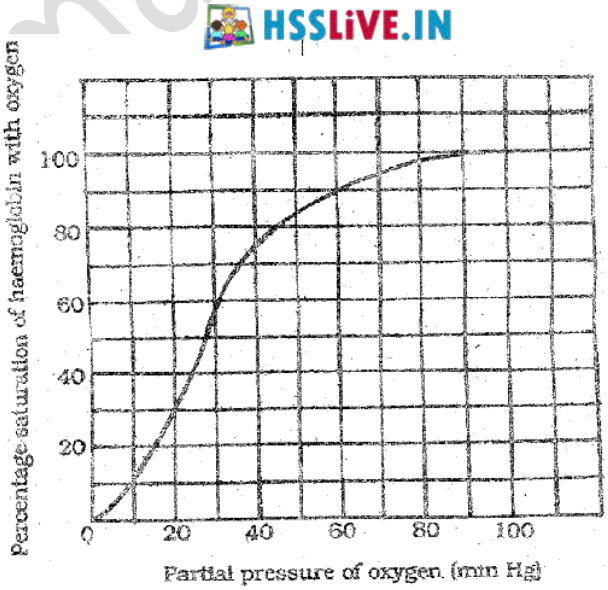
a)Vital capacity include, tidal volume residual volume and dead air

b)Respiration is controlled by nerve centres located in the hypothalamus and cerebrum

13. Asthma and emphysema are two disorders of human respiratory system, mention their causes and symptoms?

(HSE-March-2015)(2)

14.



a)What is presented by the above graph?

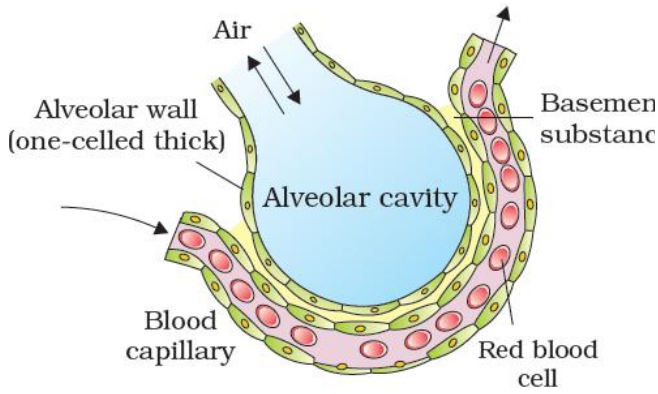
b)Write any three factors which can influence the sigmoid curve of this graph? (HSE-august-2014)(2)

15. Blood transports CO_2 from tissues to lungs by avrious means.Mention any two methods of the same

(HSE-MARCH-2014)(2)

16. Observe the diagram and answer the folllowing question

(HSE-September-2013)(2)



a)Name the biological process involved in the gas exchange shown in the figure?

b)How the oxygen is transported to the cells from the alveoli?

17. Pick out the wrong one and justify your selection (HSE march-2013)(2)

a)VC=ERV+IRV+TV

b)TLC=VC+RV

c)TV=500ml

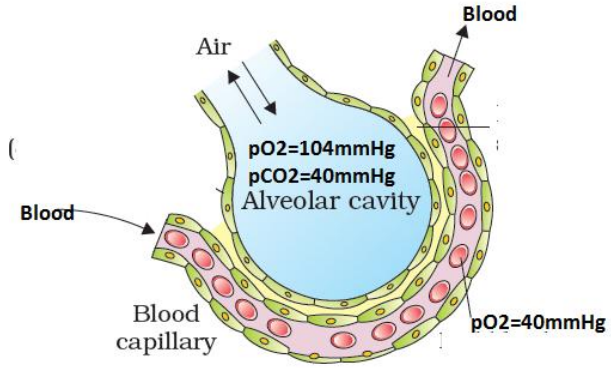
d)ERV=3000ml

18. Prepare an equation for a chemical reaction suing the ollowing components

Carbonic anhydrase ,carbonic acid, water, carbon dioxide

(HSE september-2012)(1)

19. Observe the Figure and answer the question (HSE september-2012)(2)



a)What is the partial pressure of Oxygen in the alveolar capillary?

b)Name the biological principles involved in the exchange of gases in the above structure?

c)What happen when partial presure of oxygen becomes same in the alveoli and alveolar capillary?

20. Identify the two true statements from the statement given below and rewrite the two false statement correctly (HSE march-2012)(2)

a)Pneumonia is a chronic diosrder due to cigarette smoking

b)CO2 combine with Hb to form carbamino hameoglobin

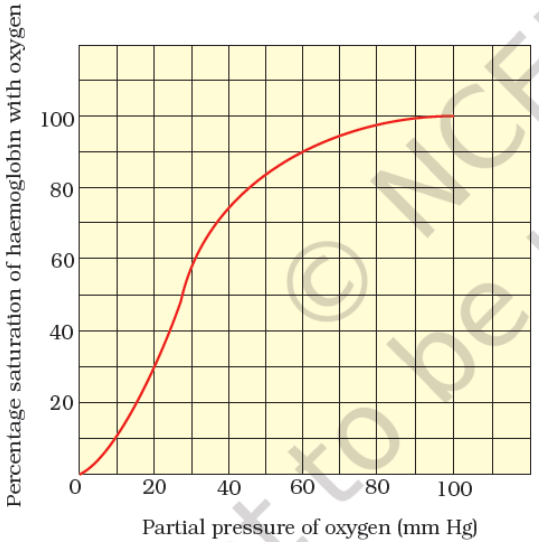
c)Respiratory rhythm is maintained by the respiratory center in the heart

d)Alveoli are the primary sites of exchange of gases

21. Observe the graph (HSE-march-2011)(2)

a)Identify the pO2 where 50% saturation of Hb with oxygen

b)Mention the factors favourale for the formation of oxyhaemoglobin in alveoli



22. In a 400m race competititon ,Athira won the first palce. Her friends commented that it is due to her vital capacity (HSE-March-2010)(2)
    a)What do you understand by the term vital capacity?
    b)Suggest the ways to improve the vital capacity?
23. Oxyhaemogloin is formed when pO2 is high. BUt oxyhaemogloin dissociate when the pCO2 is high,High H+ concentration and high temperature.
    Write what happens to oxyhaemoglobin in the alveoli and body tissues (HSE-march 2009)(2)