CHAPTER 05

Breathing and Exchange of Gases

In this Chapter...

- Respiratory Organs
- Human Respiratory System
- Mechanism of Breathing
- Exchange of Gases
- Transport of Gases
- Regulation of Respiration
- Disorders of Respiratory System

- **Respiration** is an oxidative process involving the oxidation of food substances such as carbohydrates, fats and proteins within the tissues to form $\mathbf{CO_2}$, water and consequent release of energy.
- The respiratory system provides the route by which the oxygen present in our environment gains entry into the body and the carbon dioxide is excreted. This whole process of exchange of gases is called **breathing**.

Respiratory Organs

- Different animal groups have evolved different mechanisms of breathing for the exchange of gases.
- Lower animals like sponges, cnidarians, platyhelminths and free-living roundworms exhange $\mathbf{O_2}$ by simple diffusion through body surface.
- Earthworms respire through moist cuticle and insects have a network of tubes (tracheal tubes) to transport atmospheric air within the body.
- Special vascularised structures called **gills** (branchial respiration) are used by most of the aquatic arthropods and molluscs.
- The highly vascularised bags called **lungs** (pulmonary respiration) are used by the terrestrial forms for the exchange of gases, e.g. reptiles, birds and mammals.
- Amphibians (frog) respire through their skin (cutaneous respiration) as well as lungs.

Human Respiratory System

Human respiratory system may be divided into two major components, i.e. **conduction of gases** and **respiration** or **exchange of gases**.

Conduction of Gases

It is the passage for the air (transports the atmospheric air to the lung alveoli and return from lungs to the exterior). This portion clears air by removing foreign particles, humidifies it and also brings it to body temperature. In this part, gaseous exchange does not take place. It is also called **dead air space**. It starts with the external nostrils upto the terminal bronchioles.

The various parts are as follows

(i) **External Nares** (Nostrils) There is a pair of slits at the lower end of the nose, which opens into the nasal chamber through the nasal passage.

(ii) **Nasal Chambers** Pair of passage located at the back of nostrils just above the mouth cavity. **Nasal septum** is a median partition that separates the two chambers.

Each chamber has three regions, i.e. **vestibular, respiratory** and **olfactory**. The chambers has special pseudostratified ciliated epithelium by which air is filtered (by hairs) and moistened (by mucus).

(iii) **Internal Nares** These are the posterior openings of the nasal chambers that lead into the nasopharynx.

(iv) **Nasopharynx** It is the upper part of pharynx, into which internal nares open.

(v) **Larynx** It is the upper part of trachea. It allows the air to pass into lungs. Nasopharynx opens through **glottis** of the larynx into trachea. Glottis is a slit-like aperture that remains open except during swallowing. The glottis bears a leaf-like cartilaginous flap, the **epiglottis** at its anterior region. It closes the glottis to check the entry of food during swallowing. Larynx helps in sound production and hence, called the **sound box**.

Note *Larynx is often called the* ***Adam's apple*** *and is more prominent in men than in women.*

(vi) **Trachea** It is a thin-walled tube, about 11 cm long and 2.5 cm wide. It extends up to the mid-thoracic cavity. It passes the air to the alveoli.

(vii) **Primary and Secondary Bronchi** At the level of 5th thoracic vertebra, the trachea divides into two tubes, right and left primary bronchi.

Each bronchi further divides into **secondary bronchi**. The secondary bronchi subdivides into smaller tertiary bronchi, which is further divided into still smaller bronchioles. The small terminal bronchioles give off a number of thin, irregular walled, one cell thick, vascular bag-like structure called **lung alveoli.**

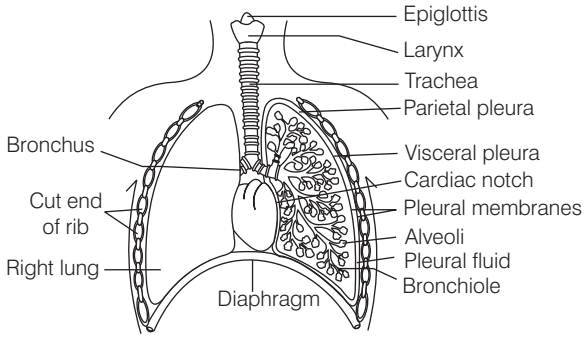
Cartilaginous rings support the walls of the trachea and the bronchi to prevent their collapse. Each terminal bronchiole gives rise to a number of thin irregular walled and vascularised bag-like structure called **alveoli**. The branching network of bronchi, bronchioles and alveoli form the lungs.

Respiratory/Exchange of Gases

The **alveoli** and their **ducts** form this part of the respiratory system. It is the site of actual diffusion of O_2 and CO_2 between blood and atmospheric air. The branching network of bronchi, bronchioles and alveoli comprises the **lungs**, which provide the surface for exchange of gases in humans.

Lungs

- Humans have two lungs one at right and other on left side in chest region. These are triangular bags that constitute the respiratory organ and are site for gaseous exchange (O_2 / CO_2).
- They lie in the **thoracic cavity** on the sides of the heart. It is an anatomically airtight chamber. The thoracic cavity is enclosed dorsally by **thoracic vertebrae**, laterally by the **ribs**, ventrally by the **sternum** and closed below by a dome-shaped **diaphragm**.
- The arrangement of lungs is such that any change in the volume of thoracic cavity will be manifested in the pulmonary cavity. This arrangement is necessary for breathing as the pulmonary volume cannot be altered directly.
- Each lung is enclosed by two membranes called the **pleura** (layers of peritoneum of the thorax). The inner membrane, called the **visceral pleuron**, which is firmly bound to the surface of lungs. The outer membrane, called the **parietal pleuron** is held to the thoracic wall and diaphragm by connective tissue.
- **Pleural cavity** is a very narrow space that exists between the two pleura. It contains the **pleural fluid** secreted by the pleura, for reducing friction on the lung surface.



Diagrammatic view of human respiratory system (sectional view on the left side)

External Features of Lungs

(i) The **left lung** has two lobes, i.e. superior lobe and inferior lobe separated by oblique fissure. It has a cardiac notch, a concave cavity where the heart lies. It is longer and narrower than right lung.

(ii) The **right lung** is bigger and has three lobes, i.e. superior lobe, middle lobe and inferior lobe separated by horizontal fissure and oblique fissure.

Respiration Processes : Breathing and Gaseous Exchange

The main mechanism of respiration is categorised into following three steps

(i) **Breathing** (pulmonary ventilation) is the inflow of atmospheric air and release (outflow) of CO_2 rich alveolar air.

(ii) **Exchange of gases** (O_2 and CO_2) across alveolar membrane as well as in tissues.

(iii) **Transport of gases** by the blood.

Breathing

Breathing is an extracellular, energy consuming and physical process. It involves movement of thorax, expansion (inflation) and deflation of lungs and flow of air into and from the lungs by creating a pressure gradient between the lungs and the atmosphere.

The movement of diaphragm and a specialised set of muscles (i.e. external and internal intercostals between the ribs) help in generation of such difference of pressure gradients between lungs and atmosphere. Breathing mainly involves two steps

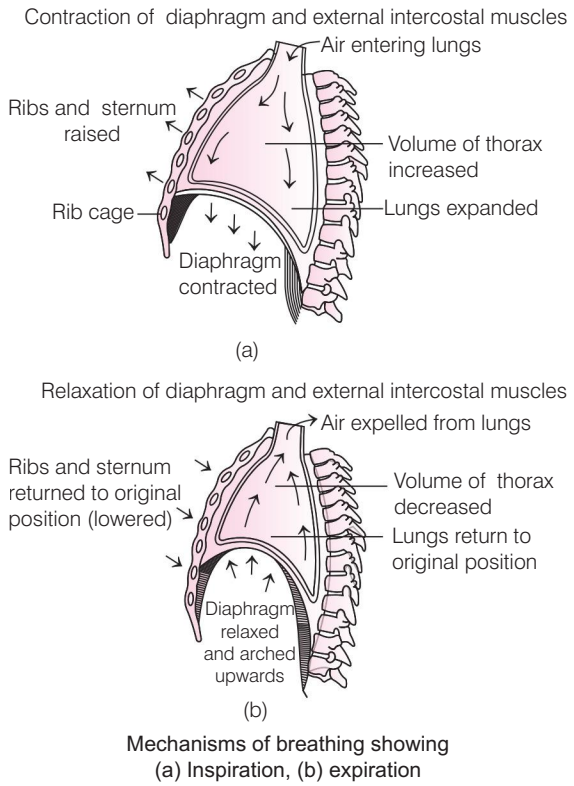
1. Inspiration

- It is an active process by which fresh air enters the lungs. It can occur if the pressure within the lungs (intrapulmonary pressure) is less than the atmospheric pressure, i.e. negative pressure in lungs with respect to atmospheric pressure.
- Following muscles play an important role
  (a) **Diaphragm** It is lowered by the contraction of its muscle fibres and becomes flat. This causes an increase in the volume of thoracic chamber in the antero-posterior axis.
  (b) **External Intercostal Muscles** They occur between the ribs (internal intercostal muscles are related to expiration). The external intercostal muscles contract and pull the **ribs** and the **sternum** upward and outward thus, increasing the volume of thoracic chamber in dorsoventral axis.
- Thus, the overall increase in the volume of thoracic cavity causes an increase in pulmonary volume. As a result, there is a decrease in the intrapulmonary pressure. The greater atmospheric pressure outside the body now causes air to flow rapidly into external nares, which sequentially leads to alveoli.

From the alveoli, $\mathbf{O_2}$ passes into blood of the capillaries and $\mathbf{CO_2}$ diffuses out from blood to alveoli's lumen.

2. Expiration

- It is a passive process by which $\mathbf{CO_2}$ is expelled out from the lungs. It takes place when the intrapulmonary pressure is higher than the atmospheric pressure.
- The movements of muscles involved in the breathing mechanism are as follows
  (a) **Diaphragm** The muscle fibres of the diaphragm relax making it convex, decreasing volume of the thoracic cavity.
  (b) **Internal Intercostal Muscles** These muscles contract thus, pulling the ribs downward and inward, decreasing the thoracic volume.
- The overall volume of the thoracic cavity thus, decreases thereby reducing the pulmonary volume. As a result, the intrapulmonary pressure increases slightly above the atmospheric pressure. This in turn causes the expulsion of the air from the lungs. The process of expiration is simpler than inspiration.



Mechanisms of breathing showing (a) Inspiration, (b) expiration

Respiratory Volumes and Capacities

- The quantity of air, the lungs can receive, hold or expel under different conditions are called **respiratory** (pulmonary) **volumes**. Combination of two or more pulmonary volumes are called **respiratory** (pulmonary) **capacities.**
- Different types of respiratory volumes and respiratory capacities are tabulated below

Respiratory Volumes		
Tidal volume	Volume of air inspired or expired during a normal respiration	500 mL
Inspiratory Reserve Volume (IRV)	Additional volume of air, a person can inspire by a forcible inspiration	2500-3000 mL
Expiratory Reserve Volume (ERV)	Additional volume of air, a person can expire by a forcible expiration	1000-1100 mL
Residual Volume (RV)	Remaining volume of air in lungs after a forcible expiration	1100-1200 mL
Respiratory Capacities		
Inspiratory Capacity (IC)	Total volume of air, a person can inspire after normal expiration	TV+IRV = 3500 mL

Tidal volume	Volume of air inspired or expired during a normal respiration	500 mL
Expiratory Capacity (EC)	Total volume of air, a person can expire after normal inspiration	TV + ERV = **1600** mL
Functional Residual Capacity (FRC)	Volume of air that will remain in lungs after normal expiration	ERV + RV = 2300 mL
Vital Capacity (VC)	Maximum volume of air, a person can breathe after forced expiration	ERV + TV + IRV = 4600 mL
Total Lung Capacity (TLC)	Total volume of air accommodated in the lungs at the end of a forced inspiration	VC + RV or RV + ERV + TV + IRV = 5800 mL

Exchange of Gases

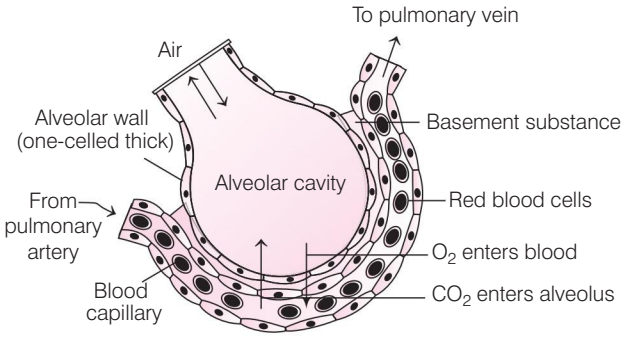
The primary sites for exchange of gases are the **alveoli** and **tissues.** It occurs by simple diffusion mainly based on pressure/concentration gradient.

The factors that affect rate of diffusion are

(i) Thinness of the membrane.
(ii) Surface area of the membrane.
(iii) Permeability of the membrane.
(iv) Solubility of the gases.
(v) Partial pressure gradient (difference) of gases on the two sides of the diffusing surfaces of lung alveoli.

1. Exchange of Gases between Alveoli and Blood

- This exchange between lung alveoli and pulmonary capillaries is called **external respiration**.
- The alveolar wall is very thin with a rich network of blood capillaries. It is also called as **respiratory membrane** (alveolar-capillary membrane).
  (a) Alveolar epithelium
  (b) Epithelial basement membrane
  (c) Their interstitial space
  (d) Capillary basement membrane
  (e) Capillary endothelium
- All these form a membrane of about 0.2 mm thickness. This membrane has a limit of gaseous exchange between alveoli and pulmonary blood. It is called **diffusing capacity**. It is the volume of gas that diffuses through membrane per minute for a pressure difference of 1 mm Hg.
- At a particular pressure difference, the diffusion of CO_2 is 20-25 times faster than oxygen. Thus, the amount of that can diffuse through the membrane per unit difference in partial pressure is much higher as compared to oxygen.

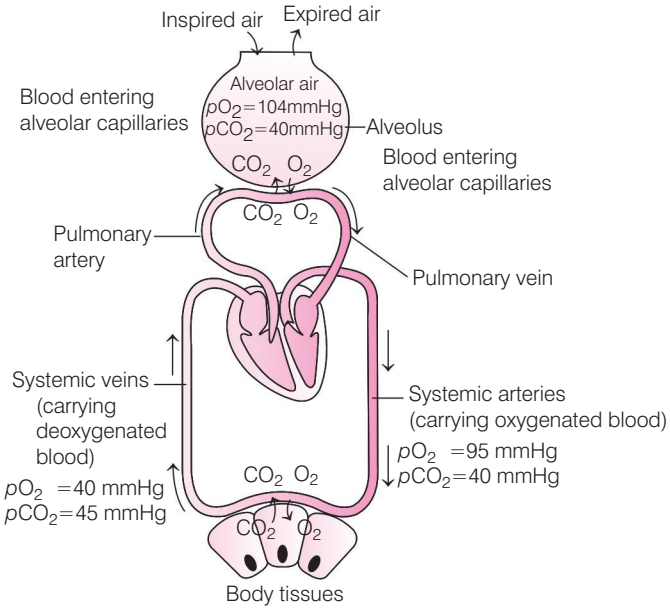


A diagram of a section of an alveolus with the pulmonary capillary

- Partial pressures (in mm Hg) of oxygen and carbon dioxide at different parts involved in diffusion in comparison to those in atmosphere are as follows

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

- As seen in the above table, pO_2 in the alveoli (104 mmHg) is higher than that in the deoxygenated blood in the capillaries of pulmonary arteries (95 mmHg). So, there is diffusion of O_2 from alveoli to the blood capillary. Also, pCO_2 is higher in deoxygenated blood (45 mmHg) than in alveoli, therefore CO_2 diffuses from blood to the alveoli.



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

2. Exchange of Gases between Blood and Tissue Cells

- This exchange between tissue blood capillaries and tissue cells is called **internal respiration.** $\mathbf{pO_2}$ in oxygenated blood (95 mmHg) > $\mathbf{pO_2}$ in body cells (40 mmHg) and $\mathbf{pCO_2}$ in oxygenated blood **(40 mmHg)** < $\mathbf{pCO_2}$ in body cells (45 mmHg).
- Due to this partial pressure differences, oxygen diffuses from the capillary blood to the body cells and $\mathbf{CO_2}$ diffuses from the body cells to the capillary blood *via* tissue fluid. Now, the blood becomes deoxygenated, which is further carried to the heart by veins and finally it goes to lungs for purification.

Transport of Gases

Blood carries oxygen from the lungs to tissue cells for oxidation and carbon dioxide from the tissue cells to the respiratory surface for elimination.

Transport of oxygen and carbon dioxide in detail is discussed below

Transport of Oxygen

- It is done in the following manner
  (i) **As Dissolved Gas** About 3% of oxygen in the blood is carried in a dissolved state through the plasma.
  (ii) **As Oxyhaemoglobin** About 97% of $\mathbf{O_2}$ is carried by RBCs in the blood.
- **Haemoglobin** is a **red** coloured **iron** containing pigment present in RBCs to which $\mathbf{O_2}$ can bind in a reversible manner to form **oxyhaemoglobin.** Four molecules of oxygen bind one molecule of haemoglobin.

$$\underset{\text{Haemoglobin}}{\mathbf{Hb}} + \underset{\text{Oxygen}}{\mathbf{O_2}} \underset{\text{In tissues}}{\overset{\text{In lungs}}{\rightleftharpoons}} \underset{\text{Oxyhaemoglobin}}{\mathbf{HbO_2}}$$

- Factors affecting the binding of oxygen with haemoglobin are
  (i) Partial pressure of oxygen
  (ii) Partial pressure of carbon dioxide
  (iii) Hydrogen ion concentration
  (iv) Temperature

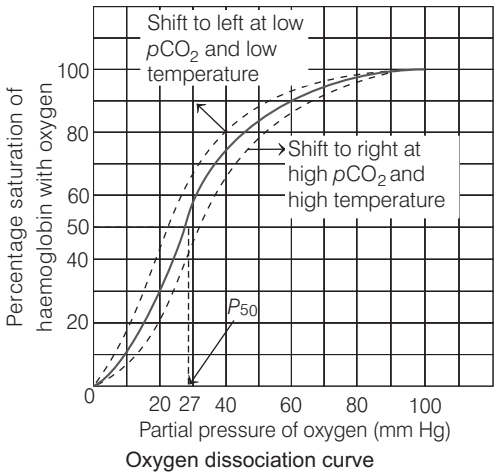
Oxygen Dissociation Curve or Oxyhaemoglobin Dissociation Curve

It is the curve obtained on plotting percentage saturation of Hb with $\mathbf{O_2}$ against $\mathbf{pO_2}$.

The curve thus, obtained is **sigmoid shaped** or **S-shaped,** under normal conditions.

(i) This curve is useful in studying the effect of factors like $\mathbf{pCO_2}$, H^+ concentration and temperature, etc., on binding of $\mathbf{O_2}$ with Hb.

(ii) The lower part of the curve indicates dissociation of oxygen from haemoglobin, while the upper part of the curve indicates the acceptance of $\mathbf{O_2}$ by Hb.



Oxygen dissociation curve

(iii) The oxygen haemoglobin dissociation curve is shifted either to left or right by various factors.

Shift to left indicates association of $\mathbf{O_2}$ by Hb. It occurs in the alveoli where there is low $\mathbf{pCO_2}$, high $\mathbf{pO_2}$, lesser H^+ concentration and low temperature.

Note *In the foetal blood, there is a shift to left because foetal haemoglobin has more affinity for oxygen than the adult Hb.*

(iv) **Shift to right** indicates dissociation of $\mathbf{O_2}$ from Hb. It occurs in the tissues where there is low $\mathbf{pO_2}$, high $\mathbf{pCO_2}$, low pH (high $\mathbf{H^+}$ concentration and higher temperature).

(v) This clearly indicates that $\mathbf{O_2}$ gets bound to Hb on the lung surface and gets dissociated at the tissue level.

(vi) Every 100 mL of oxygenated blood can deliver around 5 mL of $\mathbf{O_2}$ to the tissues under normal physiological conditions. People feel difficulty in breathing at hills because air pressure falls there at hills. So, less oxygen is diffused to lung blood vessels.

Transport of Carbon Dioxide

$\mathbf{CO_2}$ in gaseous form diffuses out of the cells into capillaries, where it is transported in following ways

(i) **Transport in Dissolved Form** About 7% $\mathbf{CO_2}$ is carried in dissolved form through the plasma because of its high solubility.

(ii) **Transport as Bicarbonate** The largest fraction (about 70%) is carried in plasma as bicarbonate ions (HCO_3^-). At the tissues site, where pCO_2 is high due to catabolism, CO_2 diffuses into the blood (RBCs and plasma) and forms HCO_3^- and H^+.

$$\underset{\text{Carbon dioxide}}{CO_2} + H_2O \xrightleftharpoons[\text{anhydrase}]{\text{Carbonic}} \underset{\text{Carbonic acid}}{H_2CO_3}$$

$$H_2CO_3 \xrightleftharpoons[\text{anhydrase}]{\text{Carbonic}} \underset{\text{Bicarbonate ion}}{HCO_3^-} + \underset{\text{Hydrogen ion}}{H^+}$$

This reaction is faster in RBCs because they contain an enzyme **carbonic anhydrase.** Hydrogen ion released during the reaction bind to Hb, triggering the **Bohr's effect**.

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

Hamburger's phenomenon

This is the phenomenon in which an exit of bicarbonate ions considerably changes ionic balance between the plasma and erythrocytes. This ionic balance is restored by the diffusion of chloride ions from the plasma into the **erythrocytes.**

(iii) **Transport as Carbaminohaemoglobin** Nearly 20-25% CO_2 is carried by haemoglobin as carbaminohaemoglobin. CO_2 entering the blood combines with the NH_2 group of the reduced Hb.

$$HbO_2 + CO_2 \rightleftharpoons \underset{\text{(Carbaminohaemoglobin)}}{HbCO_2} + H^+ + O_2$$

The reaction releases oxygen from oxyhaemoglobin. Factors affecting the binding of CO_2 and Hb are

(i) Partial pressure of CO_2.

(ii) Partial pressure of O_2 (major factor).

In tissues, pCO_2 is high and pO_2 is low, more binding of CO_2 occurs while, in the alveoli, pCO_2 is low and pO_2 is high, dissociation of CO_2 from $HbCO_2$ takes place, i.e. CO_2 which is bound to Hb from the tissues is delivered at the alveoli.

Every 100 mL of deoxygenated blood delivers approximately 4 mL of CO_2 to the alveoli.

Haldane effect states that binding of oxygen with Hb tends to displace CO_2 from the blood. It is quantitatively more important in promoting CO_2 transport than the Bohr effect in promoting O_2 transport. Thus, Haldane effect and Bohr effect complement each other.

Regulation of Respiration

The respiratory rhythm can be maintained and moderated by human beings to suit the demands of the body tissues. It is under dual control, i.e. nervous and chemical. This is explained below as

i. Neural Control

The **respiratory rhythm centre** is composed of a group of neurons located in the **medulla oblongata** and **pons Varolii**.

Pons Respiratory Centres

- Neural signal from **pneumotaxic centres** reduce the duration of inspiration, altering the respiratory rate.
- A chemosensitive area is located adjacent to rhythm centre that is highly sensitive to CO_2 and hydrogen ions. They increase activity of this centre, which in turn signals the respiratory centre to make necessary changes in order to eliminate these substances.
- Oxygen does not have a significantly direct effect on the respiratory centre of the brain in controlling respiration.

ii. Chemical Control

- Large number of **chemoreceptors** are located in the carotid bodies, which lie bilaterally in the bifurcations of the common **carotid arteries**. Their afferent nerve fibres pass through **glossopharyngeal cranial nerve** and thus, to dorsal respiratory area of the medulla oblongata.
- Receptors of aortic arch and carotid artery recognise change in CO_2 and H^+ concentration and send necessary signals to the rhythm centre for remedial actions.

Disorders of Respiratory System

Common respiratory disorders are tabulated below

Disorders	Characteristics
Asthma	• Difficulty in breathing caused due to allergens. • Wheezing due to the inflammation of bronchi and bronchioles. • Can be prevented by avoiding and treated by using inhalers.
Emphysema	• Decreased respiratory surface due to damaged alveolar walls. • Mainly caused due to cigarette smoking. • Avoiding cigarettes can be preventive measures.
Occupational respiratory disorder	• Mainly caused due to long exposure to grinding or stone breaking. • Inflammation leading to fibrosis of lungs. • Protective masks can reduce the risk.

Chapter Practice

PART 1
Objective Questions

• Multiple Choice Questions

1. Over the entire body surface, O_2 exchange with CO_2 by simple diffusion occurs in

(a) sponges (b) coelenterates

(c) flatworms (d) All of these

(***d***) Breathing mechanism varies among the different groups of animals depending on their habitats and level of organisation. Lower invertebrates like sponges, coelenterates, flatworms, etc., exchange air through simple diffusion over their entire body surface.

Thus, option (d) is correct.

2. Which of the following statements is correct about respiratory organs of different animals?

(a) The exchange of O_2 and CO_2 *via* simple diffusion across body surface occurs in aquatic arthropods

(b) A complex system of air tubes called trachea is present in earthworm for respiration

(c) Fishes have lungs for respiration

(d) Cutaneous respiration occurs in amphibians

(***d***) Statement in option (d) is correct.

3. Conducting part of the respiratory system comprises

(a) external nostrils upto the terminal bronchioles

(b) internal nostrils upto trachea

(c) epiglottis upto trachea

(d) larynx upto bronchi

(***a***) The conducting portion of the respiratory system consists of nasopharynx, larynx, trachea, bronchi, bronchioles and terminal bronchioles, i.e. all structures from external nostrils upto terminal bronchioles.

4. Which of the following statements is incorrect regarding respiratory system?

(a) Each terminal bronchiole gives rise to a network of bronchi

(b) The alveoli are highly vascularised

(c) The lungs are covered by a double-layered membrane

(d) The pleural fluid reduces friction on the lung surface

(***a***) Statement in option (a) is incorrect and can be corrected as

Each terminal bronchiole gives rise to a network of alveoli.

Rest other statements are correct.

5. Which of the following changes occurs in diaphragm and intercostal muscles when expiration of air takes place?

(a) External intercostal muscles relax and diaphragm contracts

(b) External intercostal muscles contract and diaphragm relaxes

(c) External intercostal muscles and diaphragm relax

(d) External intercostal muscles and diaphragm contract

(***c***) During expiration, muscle fibres of the diaphragm and external intercostal muscles get relaxed.

6. Match the items given in Column I with those in Column II and select the correct option given below.

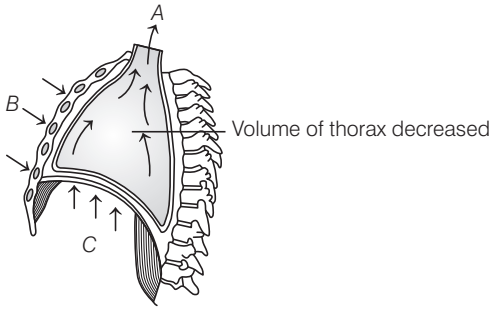
	Column I (Lung Volume)		**Column II** (Value)
A.	Tidal volume	1.	2500-3000 mL
B.	Inspiratory reserve volume	2.	1100-1200 mL
C.	Expiratory reserve volume	3.	500 mL
D.	Residual volume	4.	1000-1100 mL

Codes

	A	B	C	D
(a)	1	4	2	3
(b)	3	1	4	2
(c)	3	2	1	4
(d)	4	3	2	1

(***b***) A–3, B–1, C–4, D–2

7. In the given diagram of mechanism of breathing, what do **A, B** and **C** depict?



(a) *A*–Air goes inside to lungs, *B*–Ribs and sternum returned to original position, *C*– Diaphragm contracted

(b) *A*–Air expelled from lungs, *B*–Ribs and sternum returned to original position, *C*–Diaphragm relaxed and arched upward

(c) *A*–Air expelled from lungs, *B*–Ribs and sternum go upward, *C*–Diaphragm relaxed and arched upward

(d) *A*–Air goes inside to lungs, *B*–Ribs and sternum go upward, *C*–Diaphragm relaxed and arched upward

(***b***) When air is expelled from the lungs (label *A*), the internal intercostal muscles contract which pulls the ribs and sternum downward and inward, i.e. original position (label *B*). Also, the muscle fibres of the diaphragm relax which decreases the thoracic volume and makes the diaphragm arched upward (label *C*).

Thus, option (c) is correct.

8. Consider the following statements.

I. The partial pressure of oxygen in deoxygenated blood is 40 mmHg.

II. The partial pressure of oxygen in oxygenated blood is 95 mmHg.

III. The partial pressure of oxygen in alveolar air is 104 mmHg.

IV. The partial pressure of $\mathbf{CO_2}$ in the atmospheric air is 40 mmHg.

Choose the option containing incorrect statement(s) only.

(a) I and III

(b) Only IV

(c) Only II

(d) III and IV

(***b***) Statement IV is incorrect and can be corrected as

The partial pressure of CO_2 in deoxygenated blood is 40 mmHg while in atmospheric air, pCO_2 is 0.3 mmHg.

Rest other statements are correct.

9. What is Bohr's effect?

(a) A rise in levels of pCO_2 or fall in pH decreases the oxygen affinity of haemoglobin

(b) Decrease in levels of pCO_2 or fall in pH decreases the oxygen affinity of haemoglobin

(c) A rise in levels of pCO_2 or increase in pH decreases the oxygen affinity of haemoglobin

(d) Shifting of the oxygen-haemoglobin curve to left

(***a***) Bohr's effect is described as a rise in $\mathbf{pCO_2}$ (or fall in pH) which decreases the oxygen affinity of haemoglobin thus, raising the P_{50} value and shifts the curve to the right.

10. Partial pressure of O_2 and CO_2 in atmospheric air as compared to that in alveolar air is

	pO_2	pCO_2
(a)	Higher	Lower
(b)	Higher	Higher
(c)	Lower	Lower
(d)	Lower	Higher

(***a***) The $\mathbf{pO_2}$ is higher in the atmosphere as compared to alveoli and $\mathbf{pCO_2}$ is lower in the atmosphere as compared to alveoli.

11. Consider the following statements.

I. The percentage of haemoglobin that is bound with haemoglobin is called per cent saturation of haemoglobin.

II. Every 100 mL of oxygenated blood can deliver 60 mL O_2 to the tissues under normal conditions.

III. $\mathbf{P_{50}}$ value is the value of O_2 at which Hb is 50% saturated with oxygen.

IV. Unlike haemoglobin, myoglobin has three polypeptide chains.

Choose the option containing incorrect statements.

(a) I and III

(b) II and IV

(c) III and IV

(d) I and II

(***b***) Statements II and IV are incorrect and can be corrected as

- 100 mL arterial blood carries about 19-20 mL of oxygen but it delivers 4-6 mL of oxygen at tissue level in normal conditions.
- Unlike Hb, myoglobin contains only one polypeptide chain.

Rest other statements are correct.

12. When you hold your breathe, which of the following gas changes in blood would first lead to the urge to breathe?

(a) Falling CO_2 concentration

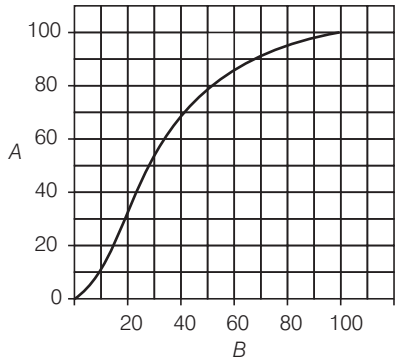
(b) Rising O_2 concentration

(c) Falling O_2 concentration

(d) Rising CO_2 concentration

(***d***) Rising $\mathbf{CO_2}$ concentration will lead to urge to breathe, this is because $\mathbf{CO_2}$ is toxic to human body and needs to be excreted.

13. Which of the following statements is incorrect about the given graph?



(a) The curve is called oxygen dissociation curve

(b) The part *A* represents percentage saturation of haemoglobin with oxygen

(c) The part *B* represents partial pressure of carbon dioxide

(d) This curve is highly useful in studying the effect of factors like $\mathbf{pCO_2}$, H^+ concentration, etc.

(***c***) Statement in option (c) is incorrect about the given graph. It can be corrected as

The part *B* represents partial pressure of oxygen.

14. Pneumotaxic centre of the brain, i.e. pons region can

(a) moderate the function of respiratory system

(b) decrease the heart rate

(c) increase the heart rate

(d) increase the flow of blood

(***a***) Respiratory centre present in the pons region of the brain is called pneumotaxic centre. It can moderate the functions of respiratory rhythm centre. Neural signal from this centre can reduce the duration of inspiration and thereby, alter the respiratory rate.

15. Name the pulmonary disease in which alveolar surface area involved in gas exchange is drastically reduced due to the damage in the alveolar walls.

(a) Pleurisy (b) Emphysema

(c) Pneumonia (d) Asthma

(***b***) Emphysema or inflation of alveolar sacs involves collapse of alveolar septa as a result of which the area for gaseous exchange is reduced and there is difficulty in breathing.

• Assertion-Reasoning MCQs

Direction (Q. Nos. 1-5) *Each of these questions contains two statements, Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.*

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true, but R is not the correct explanation of A

(c) A is true, but R is false

(d) A is false, but R is true

1. **Assertion** (A) Trachea and bronchioles are supported by cartilaginous ring.

Reason (R) Trachea can collapse during expiration.

(***c***) A is true, but R is false because

Trachea and initial bronchioles are supported by incomplete cartilaginous rings. These support the trachea and prevent it from being collapsed during breathing.

2. **Assertion** (A) Expiration is a passive process.

Reason (R) It occurs when the intrapulmonary pressure is higher than the atmospheric presssure.

(***b***) Both A and R are true, but R is not the correct explanation of A.

Expiration is a passive process since air leaves the lungs without using energy.
It occurs when intrapulmonary pressure is higher than the atmospheric pressure.

3. **Assertion** (A) High carbon monoxide (CO) levels can kill a person.

Reason (R) CO has greater affinity for haemoglobin.

(***a***) Both A and R are true and R is the correct explanation of A.

Carbon monoxide combines with haemoglobin far readily as compared to oxygen, since it has 200 times greater affinity for Hb. As a result, carboxyhaemoglobin is formed which causes reduced transport of $\mathbf{O_2}$ in body. As a result, nausea, suffocation and even death occurs.

4. **Assertion** (A) $\mathbf{pO_2}$ is the highest in alveoli.

Reason (R) Partial pressure of a gas is the pressure contributed by individual gas in a mixture.

(***b***) Both A and R are true, but R is not the correct explanation of A.

The $\mathbf{pO_2}$ is highest in the alveoli, i.e. 104 mm Hg because inspiration of oxygen from the atmosphere is by the lungs. Also $\mathbf{pO_2}$ of the blood capillaries around the alveoli is minimum, thus oxygen diffuse into the blood capillaries.

Partial pressure of a gas is the pressure contributed by individual gas in a mixture.

5. **Assertion** (A) The higher amount of CO_2 can diffuse through diffusion membrane per unit difference in partial pressure as compared to O_2.

Reason (R) Solubility of CO_2 is 20-25 times higher than that of O_2.

(***a***) Both A and R are true and R is the correct explanation of A.

As the solubility rate of CO_2 is 20-25 times higher than that of O_2 the amount of CO_2 to diffuse through the diffusion membrane per unit difference in partial pressure is much higher when compared to O_2.

• Case Based MCQ

Direction *Read the following passage and answer the questions that follows.*

The human respiratory system consists of a pair of lungs and a series of air passages which lead to lungs. The entire respiratory tract consists of nose, pharynx, larynx, trachea, bronchi and bronchioles. When air passes through the nose, it is warmed, moistened and filtered.

Hair present in the nose filter out particles in the incoming air. The air is moistened by the mucus present in the nose and gets warmed by the blood that flows through the capillaries.

Behind the nose, lies the pharynx with two passages, one for food and the other for air. The passage continues from pharynx to larynx and the opening that leads to larynx is called glottis, it is covered by epiglottis which prevents food from entering the passage to lungs. The total surface area through which gaseous exchange takes place can be about a hundred times that of the body.

(i) Which portion of the human respiratory system is called the sound box?

(a) Larynx (b) Trachea

(c) Nasopharynx (d) Glottis

(***a***) Larynx is a cartilaginous box that aids in sound production and is referred to as sound box.

(ii) In man, the total number of alveoli is

(a) 300 million

(b) 30,000

(c) 50,000

(d) 7000

(***a***) There are about 300 million alveoli in both lungs.

(iii) Trachea divides into right and left primary bronchi of which thoracic vertebra?

(a) 5 (b) 4

(c) 9 (d) 6

(***a***) Trachea extends upto the midthoracic cavity and divides at the level of 5th thoracic vertebra into right and left bronchi which end upto become bronchioles by repeated divisions.

(iv) Exchange part of the respiratory system comprises

(a) lungs and pleural membrane

(b) alveoli and their ducts

(c) bronchus and their protective covering

(d) diaphragm and alveoli

(***b***) The respiratory part consists of alveolar sacs and alveolar ducts.

(v) Identify the correct statement with regard to human respiratory system.

(a) Sternum is present in the dorsal side of the thoracic chamber

(b) Alveoli are lined by ciliated columnar epithelium

(c) Expiration occurs when there is a positive pressure in the lungs

(d) Larynx is found in between the epiglottis and trachea at the anterior side, at the level of 2nd to 4th cervical vertebrae

(***c***) Statement in option (c) is correct.

Expiration occurs when there is positive pressure in the lungs whereas inspiration occurs when lungs have negative pressure.

PART 2

Subjective Questions

• Short Answer (SA) Type Questions

1. Give the name of the organs of respiration in the following organisms. **(NCERT Exemplar)**

(i) Flatworm (ii) Birds
(iii) Frog (iv) Cockroach

(i) Body surface (ii) Lungs
(iii) Skin, buccopharyngeal lining and lungs
(iv) Trachea

2. Give two examples of each of the following

(i) Animals having internal gills.
(ii) Animal groups showing tracheal respiration.
(iii) Anaerobes.

(i) Fishes and *Pila,* etc.
(ii) Insects, centipedes and millipedes, etc.
(iii) Certain bacteria, parasitic worms (e.g. *Ascaris* and tapeworm), etc.

3. Complete the following sentences.

(i) Nasal chambers are separated from the oral cavity by ..... .
(ii) A film of ..... lines the alveoli to lower the surface tension.
(iii) Sound is produced by vibration of ..... located in the ..... .
(iv) Left lung has ..... lobes, while right lung has ..... lobes.

(i) palate (ii) lecithin
(iii) vocal cords, larynx (iv) two, three

4. What is Adam's apple? Is it more prominent in males or females?'

Larynx is often called as Adam's apple. It is more prominent in males than females.

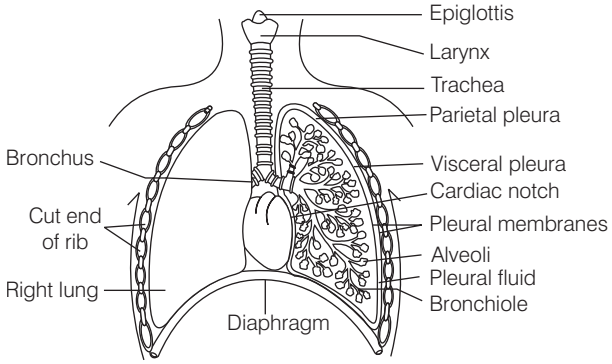
5. (i) What prevents the trachea and the bronchi from collapsing?

(ii) Name the epithelium and the cells present in the walls of trachea, bronchi and bronchioles.

(i) Cartilaginous rings are incomplete from behind which supports the walls of the trachea and the bronchi to prevent them from collapsing.
(ii) Pseudostratified ciliated columnar epithelial tissue lines the walls of trachea, bronchi and bronchioles and it is rich in mucus secreting cells.

6. Draw a labelled diagram of the human respiratory system.

Diagrammatic view of the human respiratory system is



The human respiratory system

7. A person dies in an accident in which his chest cavity was punctured, but no lung damage was there. Point out the cause of death.

The movement of air into and out of the lungs is carried out by creating a pressure gradient between the lungs and the atmosphere. The pressure within the lungs is less than the atmospheric pressure so, there is a negative pressure in the lungs with respect to atmospheric pressure.

The puncture in the chest affects this pressure gradient maintained by the lungs and thus, may cause cessation of breathing.

8. Give the condition of the following muscles during expiration.

(i) Diaphragm muscles
(ii) Internal intercostal muscles

(i) The muscles of the diaphragm are in a relaxed position, making it convex.
(ii) The internal intercostal muscles are contracting thus, pulling the ribs downward and inward.

9. Write the role of diaphragm and intercostal muscles in the inspiratory process.

The diaphragm and intercostal muscles (external and internal) present between the ribs help in generation of a pressure gradient between the lungs and the atmosphere.

During inspiration, diaphragm is lowered by contraction of its muscle fibres and becomes flat. The external intercostal muscles contract pulling the ribs and sternum upward and outward.

This increases the volume of thoracic cavity and thus, decrease the intrapulmonary pressure. The greater atmospheric pressure outside the body now causes the air to flow rapidly into external nares, which sequentially leads to alveoli. Thus, causing inspiration.

10. In normal breathing, which is the active process inspiration or expiration? Explain.

In normal breathing, inspiration is an active process as it is brought about by the contraction of diaphragm and external intercostal muscles, while expiration is a passive process as it simply involves relaxation of inspiratory muscles.

11. Fill in the blanks.

(i) During normal quiet breathing, on an average, approximately ..... mL of air is inspired or expired in each breathe, termed as ..... .

(ii) Actually, only about ..... mL of air enters the lung alveoli for the exchange of gases. The remaining fills the respiratory passage and is termed ..... .

(iii) Diaphragm contracts to helps in ..... while the contraction of abdominal muscles help in ..... .

(iv) Alveolar $\mathbf{pO_2}$ is ..... than the venous $\mathbf{pO_2}$ in lungs, while arterial $\mathbf{pO_2}$ is ..... than the alveolar $\mathbf{pO_2}$.

(i) 500, tidal volume.

(ii) 350, dead space air

(iii) inspiration, forced expiration

(iv) higher, lower.

12. Arrange the following terms based on their volumes in an ascending order.

(i) Tidal Volume (TV)

(ii) Residual Volume (RV)

(iii) Inspiratory Reserve Volume (IRV)

(iv) Expiratory Capacity (EC) **(NCERT Exemplar)**

Tidal volume → Residual volume →
(500 mL) (1100-1200 mL)
Expiratory capacity → IRV
(1500-1600 mL) (2500-3000 mL)

13. Define vital capacity. What is its significance? **(NCERT)**

Vital capacity is the maximum amount of air a person can breathe in after a forced expiration or breathe out after a forced inspiration. It represents the maximum amount of air one can renew in the respiratory system during a single respiration. Thus, the greater the VC, more is the energy available to the body. Vital capacity shows the optimum efficiency of lungs in a person. It promotes the act of supplying fresh air and getting rid of full air, thereby increasing the gaseous exchange between the tissues and the environment.

14. Complete the missing terms.

(i) Inspiratory Capacity (IC) = ... + ...

(ii) ..... = TV + ERV

(iii) Functional Residual Capacity (FRC) = ... + ...

(i) Tidal Volume (TV) + Inspiratory Reserve Volume (IRV).

(ii) Expiratory Capacity (EC).

(iii) Residual Volume (RV) + Expiratory Reserve Volume (ERV).

15. Distinguish between

(i) IRV and ERV

(ii) Vital capacity and Total lung capacity

(i) Distinguishes between IRV and ERV are as follows

IRV (Inspiratory Reserve Volume)	**ERV** (Expiratory Reserve Volume)
It is the additional amount of air that can be inspired forcibly after a normal inspiration.	It is the additional amount of air that can be expired forcibly after a normal expiration.
It is about 2500-3000 mL of air.	It is about 1000-1100 mL of air.

(ii) Differences between vital capacity and total lung capacity are as follows

Vital Capacity	**Total Lung Capacity**
It is the maximum volume of air a person can breathe in after a forced expiration or the maximum volume of air a person can breathe out after a forced inspiration.	It is the total volume of air present in the lungs after a forced inspiration.
It includes TV + IRV + ERV.	It includes RV + ERV + TV + IRV.

16. State the route of foul air from the lungs to outside. Also state whether TV increases or decreases during excitement and activity.

The foul air follows the route given below

Alveoli → Alveolar ducts → Bronchioles → Bronchi → Trachea → Larynx → Glottis → Pharynx → Internal nares → Nasal chambers → External nares → Atmosphere.

The tidal volume increases 4-10 times during excitement and activity.

17. For completion of respiration process, write the given steps in sequential manner.

(i) Diffusion of gases ($\mathbf{O_2}$ and $\mathbf{CO_2}$) across alveolar membrane.

(ii) Transport of gases by blood.

(iii) Utilisation of $\mathbf{O_2}$ by the cells for catabolic reactions and resultant release of $\mathbf{CO_2}$.

(iv) Pulmonary ventilation by which atmospheric air is drawn in and CO_2 rich alveolar air is released out.

(v) Diffusion of O_2 and CO_2 between blood and tissues. **(NCERT Exemplar)**

Steps in the process of respiration

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

(ii) Transport of gases by blood to the farthest tissues in body.

(iii) Utilisation of O_2 by the cell for catabolic reactions and resultant release of CO_2 and energy.

(iv) Pulmonary ventilation by which atmospheric air is drawn in and CO_2 rich alveolar air is released out.

(v) Diffusion of O_2 and CO_2 between blood and tissues.

18. Why is breathing of women regarded as thoracic, while that of male as abdominal? Also state who among the two has higher vital capacity.

In males, the lateral movement of thorax constitutes 25% of breathing, while the abdominal movement accounts for 75% breathing. Thus, it is regarded as abdominal breathing.

In women, particularly in pregnant women, the entire breathing is through lateral movement of thorax. Thus, breathing in women is regarded as thoracic.

The VC is higher in men than in women and in the young ones than in the old persons.

19. Diffusion of gases occurs in the alveolar region only and not in the other part of respiratory system. Why? **(NCERT)**

For efficient exchange of gases, respiratory surface must have certain characteristics such as

(i) it must be thin, moist and permeable to respiratory gases.

(ii) it must be large.

(iii) it must be highly vascular.

Only alveolar region has these characteristics. Thus, diffusion of gases occurs in this region only.

20. State the factors that affect the rate of diffusion.

Rate of diffusion is affected by the concentration gradient, membrane permeability, temperature and pressure. It will take place as long as the difference between the concentrations of substances across a barrier are maintained. Membrane permeability also affects the rate of diffusion. It increases with an increase in membrane permeability. Changes in temperatue and pressure also affect the rate of diffusion.

21. How does haemoglobin help in the transport of oxygen from lung to tissues?

Haemoglobin combines with O_2 in a reversible manner to form oxyhaemoglobin.

This oxygenated blood circulates in the body. When, it reaches the tissues having low pO_2, the oxygen is released into the tissues.

22. State the factors affecting the oxygen-haemoglobin binding.

Factors that affect the oxygen-haemoglobin binding are

(i) Partial pressure of oxygen

(ii) Partial pressure of carbon dioxide

(iii) Hydrogen ion concentration

(iv) Temperature

23. What is the effect of pCO_2 on oxygen transport? **(NCERT)**

Increase in pCO_2 tension in blood brings rightward shift of the oxygen-dissociation curve of haemoglobin thereby decreasing the affinity of Hb for O_2. This effect is called Bohr's effect.

It plays a crucial role in enhancing oxygenation of the blood in the lungs and in release of O_2 in the tissues.

24. What will be the pO_2 and pCO_2 in the atmospheric air compared to those in the alveolar air?

(i) pO_2 lesser and pCO_2 higher

(ii) pO_2 higher and pCO_2 lesser

(iii) pO_2 higher and pCO_2 higher

(iv) pO_2 lesser and pCO_2 lesser

(i) In the alveolar tissues, where low pO_2, high pCO_2, high H^+ concentration, these conditions are favourable for dissociation of oxygen from the oxyhaemoglobin.

(ii) When there is high pO_2, low pCO_2, less H^+ concentration and lesser temperature, the factors are all favourable for formation of oxyhaemoglobin.

(iii) When pO_2 is high in the alveoli and pCO_2 is high in the tissues then the oxygen diffuses into the blood and combines with oxygen forming oxyhaemoglobin and CO_2 diffuses out.

(iv) When pO_2 is low in the alveoli and pCO_2 is low in the tissues then these conditions are favourable for dissociation of oxygen from the oxyhaemoglobin.

25. What does the oxygen haemoglobin dissociation curve indicate?

The lower part of the curve indicates dissociation of oxygen from haemoglobin, while the upper part of the curve indicates acceptance of oxygen by Hb.

26. What happens to the oxygen dissociation curve in

(i) Alveoli (ii) Tissues

(i) In the alveoli, the oxygen dissociation curve shifts to left. It occurs because alveoli has low pCO_2, high pO_2, lesser H^+ concentration and low temperature.

(ii) In the tissues, the oxygen dissociation curve shifts to right. It occurs where there is low pO_2, high pCO_2, low pH, high H^+ concentration and higher temperature.

27. How is CO_2 transported in human body.

CO_2 is transported in the human body in the following ways

(i) In dissolved form about 7%.

(ii) As bicarbonate ions about 70%.

(iii) As carbaminohaemoglobin about 20-25%.

28. What is Hamburger's phenomenon?

The movement of bicarbonate ions out from the erythrocytes into the plasma, changes the ionic balance between plasma and erythrocytes. In order to restore the ionic balance, the chloride ions diffusion from plasma to the erythrocytes. This phenomenon is called chloride shift or Hamburger's phenomenon.

29. What is the role of carbonic anhydrase in humans?

Nearly 70% of CO_2 enters the RBCs and reacts with water to form carbonic acid in the presence of enzyme, carbonic anhydrase. This dissociates to form bicarbonate ions, which are circulated by plasma.

30. Write about Haldane effect. How does Haldane effect and Bohr's effect complement each other?

Haldane effect states that binding of oxygen with haemoglobin tends to displace CO_2 from the blood.

It is quantitatively more important in promoting CO_2 transport than the Bohr's effect in O_2 transport. Thus, Haldane effect and Bohr's effect complement each other.

31. Differentiate between oxyhaemoglobin and carbaminohaemoglobin.

Differences between oxyhaemoglobin and carbaminohaemoglobin are as follows

Oxyhaemoglobin	Carbaminohaemoglobin
It is formed by the combination of oxygen with the Fe^{2+} part of haemoglobin.	It is formed by the combination of CO_2 with the amino group of haemoglobin.
Its formation occurs on the alveolar surface.	Its formation occurs in the tissues.

32. What makes carbon monoxide more harmful to animals than carbon dioxide?

Haemoglobin consists of a protein globin and pigment haem. The four portions of iron in haem combine with molecule of oxygen. It is an easy reversible reaction to form oxyhaemoglobin.

$$Hb + O_2 \rightleftharpoons HbO_2$$

Whereas, the complex formed by the reaction of carbon monoxide and haemoglobin is incredibly strong

$$\underset{\text{(Haemoglobin)}}{Hb} + CO \longrightarrow \underset{\text{(Carboxyhaemoglobin)}}{HbCO}$$

As a result of this strong bonding between the haemoglobin and carbon monoxide, the haemoglobin looses its affinity to bind with oxygen thus, may lead to choking or even death.

33. Why is it not advisable to sleep in closed rooms warmed with burning of coals continuously?

A person sleeping in such room gets carbon monoxide poisoning. CO combines with Hb more readily than oxygen forming carboxyhaemoglobin. This reduces the amount of free Hb available for carrying O_2. Thus, the tissue is starved of O_2. This is the reason why it is not advisable to sleep in closed rooms warmed with coals.

34. How marine mammals are able to make long underwater dives? Explain.

Marine mammals (e.g. seals and whales) can make long underwater dives as they have

(i) more blood per kg of body weight.

(ii) can store more oxygen in blood and muscles.

(iii) have a large spleen with blood.

(iv) can reduce O_2 consumption rate when underwater.

35. What happens to the respiratory process in a man going up a hill? **(NCERT)**

At hills, the pressure of air falls and the person cannot get enough oxygen in the lungs for diffusion in blood. Due to deficiency of oxygen, the person feels breathlessness headache, dizziness, nausea, mental fatigue and a bluish colour on the skin, nails and lips.

36. Explain chemical control of respiratory rhythm.

Large number of chemoreceptors are located in the carotid bodies (lie bilaterally in the bifurcations of the common carotid arteries). Their afferent nerve fibres pass through glossopharyngeal cranial nerve and thus to dorsal respiratory area of the medulla oblongata, sizeable number of chemoreceptors are also located in the aortic bodies (which lie along the arch of aorta).
Their afferent nerve fibres pass through the vagus cranial nerve and thus, to dorsal respiratory group of neurons.

37. Which of the regulatory centre of respiration can reduce the inspiratory duration when it is stimulated?

Respiratory process is regulated by certain specialised centres present in hindbrain. Amongst them, pneumotaxis centre is located in the dorsal part of pons Varolii of the brain, can reduce the duration of inspiration and thus, alter the respiratory rate.

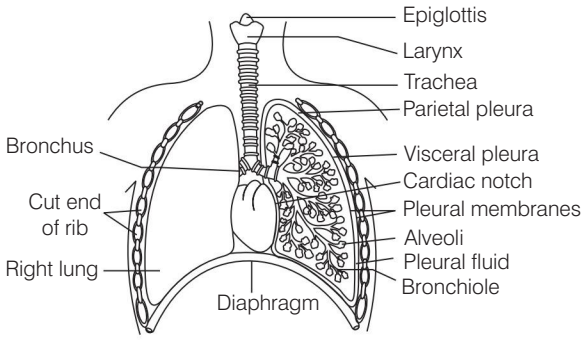
• Long Answer (LA) Type Questions

1. Describe the structure of lungs with suitable diagrams.

Humans have two lungs one at right and other on left side in chest region covered by a double-layered pleura with pleural fluid between them to reduce friction on the lung surface. These are triangular bags that constitute the respiratory organ and are site for gaseous exchange (O_2 / CO_2).

They are situated in the **thoracic cavity** which is an anatomically airtight chamber. The thoracic cavity is

enclosed dorsally by **thoracic vertebrae**, laterally by the **ribs**, ventrally by the **sternum** and closed below by a dome-shaped **diaphragm**. The arrangement of lungs is such that, any change in the volume of thoracic cavity will be manifested in the pulmonary cavity. This arrangement is necessary for breathing as the pulmonary volume cannot be altered directly. The inner membrane of the pleura called the **visceral pleuron**, which is firmly bound to the surface of lungs. The outer membrane, called the **parietal pleuron** is held to the thoracic wall and diaphragm by connective tissue.



Diagrammatic view of human respiratory system
(sectional view on the left side)

External Features of Lungs

(i) The **left lung** has two lobes, i.e. superior lobe and inferior lobe separated by oblique fissure. It has a cardiac notch, a concave cavity where the heart lies. It is longer and narrower than right lung.

(ii) The **right lung** is bigger and has three lobes, i.e. superior lobe, middle lobe and inferior lobe separated by horizontal fissure and oblique fissure.

2. Explain the process of inspiration under normal conditions.

It is an active process by which fresh air enters the lungs. It can occur if the pressure within the lungs (intrapulmonary pressure) is less than the atmospheric pressure, i.e. negative pressure in lungs with respect to atmospheric pressure.

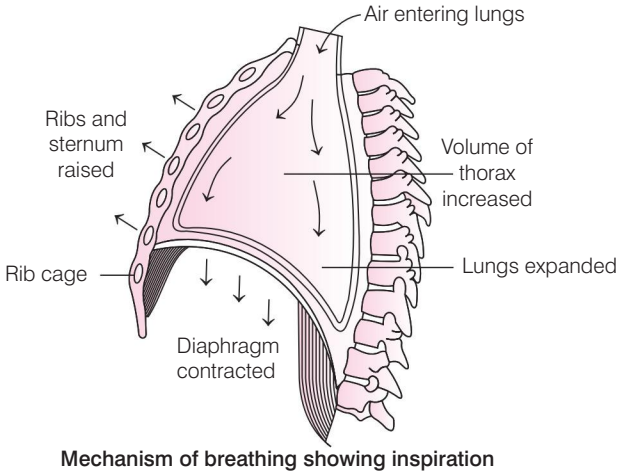
Following muscles play an important role

(a) **Diaphragm** It is lowered by the contraction of its muscle fibres and becomes flat. This causes an increase in the volume of thoracic chamber in the antero-posterior axis.

(b) **External Intercostal Muscles** They occur between the ribs (internal intercostal muscles are related to expiration). The external intercostal muscles contract and pull the **ribs** and the **sternum** upward and outward thus, increasing the volume of thoracic chamber in dorsoventral axis.

Thus, the overall increase in the volume of thoracic cavity causes an increase in pulmonary volume. As a result, there is a decrease in the intrapulmonary pressure. The greater atmospheric pressure outside the body now causes air to flow rapidly into external nares, which sequentially leads to alveoli.

From the alveoli, O_2 passes into blood of the capillaries and CO_2 diffuses out from blood to alveoli's lumen.



Mechanism of breathing showing inspiration

3. Explain the mechanism of expiration in humans. Also, give diagram of this process of breathing.

Expiration is a passive process by which CO_2 is expelled out from the lungs. It takes place when the intrapulmonary pressure is higher than the atmospheric pressure.

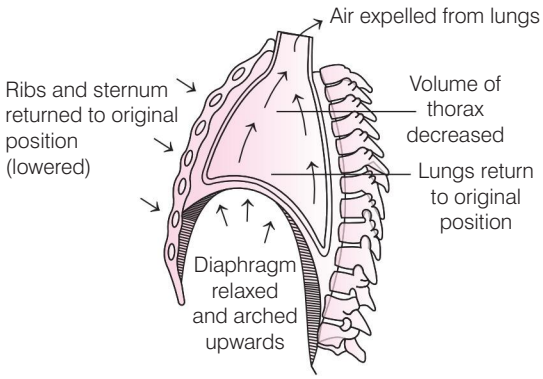
The movements of muscles involved in the breathing mechanism are as follows

(i) **Diaphragm** The muscle fibres of the diaphragm relax making it convex, decreasing volume of the thoracic cavity.

(ii) **Internal Intercostal Muscles** These muscles contract thus, pulling the ribs downward and inward, decreasing the thoracic volume.

The overall volume of the thoracic cavity thus, decreases thereby reducing the pulmonary volume.

As a result, the intrapulmonary pressure increases slightly above the atmospheric pressure. This in turn causes the expulsion of the air from the lungs. The process of expiration is simpler than inspiration.



Mechanism of breathing showing expiration

4. Explain the different respiratory volumes and capacities.

The different volumes and capacities are as follows

(i) **Tidal Volume** (TV) It is the volume of air inspired or expired during normal breathing in relaxed or resting position. It is about 500 mL. A healthy man can inspire or expire approximately 6000-8000 mL of air per minute.

(ii) **Inspiratory Reserve Volume** (IRV) It is the additional amount of air that can be inspired forcibly after a normal inspiration. It is about 2500-3000 mL of air.

(iii) **Expiratory Reserve Volume** (ERV) It is the additional volume of air that can be expired forcibly after a normal expiration. It is about 1000-1100 mL.

(iv) **Residual Volume** (RV) It is the volume of air remaining in the lungs even after a forcible expiration. It is about 1100-1200 mL. It cannot be measured by spirometry.

Various pulmonary capacities are derived from the above mentioned volumes. These are as follows

(i) **Inspiratory Capacity** (IC) It is the total volume of air a person can inspire after a normal expiration. It is about 2500-3000 mL. It includes

IC = TV + IRV

(ii) **Expiratory Capacity** (EC) It is the total volume of air a person can expire after a normal inspiration. It includes

EC = TV + ERV

(iii) **Functional Residual Capacity** (FRC) It is the volume of air that will remain in the lungs after a normal expiration. It includes

FRC = RV + ERV

(iv) **Vital Capacity** (VC) It is the maximum volume of air a person can breathe in after a forced expiration or the maximum volume of air a person can breathe out after a forced inspiration.

This includes

TV + IRV + ERV.

(v) **Total Lung Capacity** It is the total volume of air present in the lungs after a forced (maximum) inspiration. It includes

RV + ERV + TV + IRV or (VC + RV)

5. Give diagrammatic representation of exchange of gases at the alveolus and the body tissues with transport of $\mathbf{O_2}$ **and** $\mathbf{CO_2}$. Also, explain how does exchange of gases occur between blood and tissue cells.

Primary sites for gaseous exchange are the alveoli and tissues. Gaseous exchange occurs by simple diffusion based on concentration gradient. It occurs in two ways

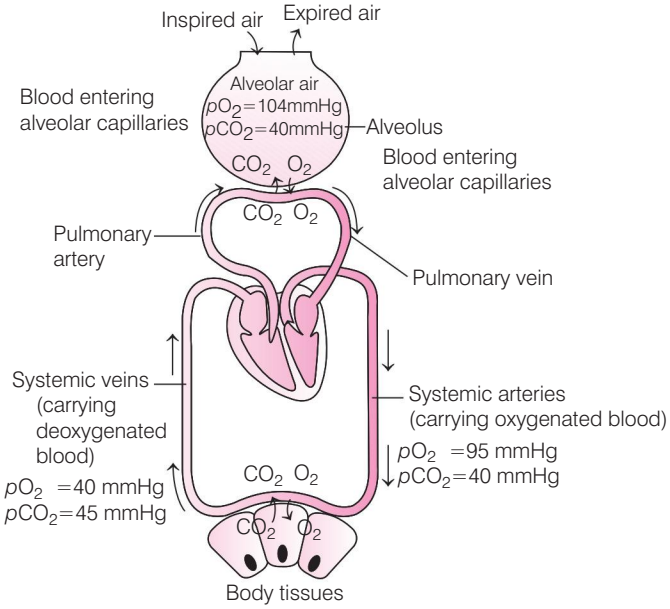
(i) Exchange of gases between alveoli and blood (external respiration).

(ii) Exchange of gases between blood and tissue cells (internal respiration).

The exchange of gas between tissue blood capillaries and tissue cells is called internal respiration. $\mathbf{pO_2}$ in oxygenated blood is more than that in body cells and $\mathbf{pCO_2}$ in oxygenated blood is less than that in body cells.

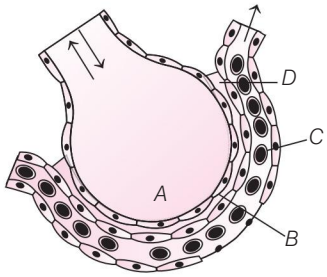
Due to the partial pressure differences created, oxygen diffuses from capillary blood to body cells and $\mathbf{CO_2}$ diffuses from body cells to the capillary blood. The deoxygenated blood formed is carried to the heart by veins and finally to lungs for purification.

The diagram below represents gaseous exchange at the alveolus and body tissues



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

6. What is tidal volume? Find out the tidal volume for a healthy human in an hour time?
Also, label the parts *A*, *B*, *C* and *D* in the given figure of alveolus.



Tidal volume is the volume of air inspired or expired during normal breathing in relaxed or resting position. Its volume is about 500 mL.

Amount of Tidal Volume (TV) in an hour

$$= \text{Respiratory rate} \times TV \times 60\,\text{min}$$
$$= (\mathbf{12-16}\ \text{breaths per minute}) \times \mathbf{500}\ \text{mL} \times \mathbf{60}$$
$$= 16 \times 500 \times 60 = \mathbf{480000}\ \text{mL}$$

$$\boxed{TV = \mathbf{360-480}\ \text{L}}$$

Therefore, the hourly tidal volume for healthy human is approximately $\mathbf{3.6 \times 10^5}$ mL to $\mathbf{4.8 \times 10^{-5}}$ mL.

In figure parts labelled as

A — Alveolar cavity,

B — Alveolar wall,

C — Red blood cells,

D — Basement substance.

7. What are the major transport mechanisms for CO_2? Explain. **(NCERT)**

CO_2 diffuses out of the cells into capillaries. Major transport mechanisms for CO_2 are

(i) **Transport in Dissolved Form** About 7% CO_2 is carried in a dissolved state through plasma due to high solubility.

(ii) **Transport as Bicarbonate** The largest fraction (about 70%) is carried in plasma as bicarbonate ions (HCO_3^-).

At the tissues site, where pCO_2 is high due to catabolism, CO_2 diffuses into the blood (RBCs and plasma) and forms HCO_3^- and H^+.

$$\underset{\text{(Carbon dioxide)}}{CO_2} + H_2O \xrightleftharpoons[\text{anhydrase}]{\text{Carbonic}} \underset{\text{(Carbonic acid)}}{H_2CO_3}$$

$$H_2CO_3 \xrightleftharpoons[\text{anhydrase}]{\text{Carbonic}} \underset{\text{(Bicarbonate ion)}}{HCO_3^-} + \underset{\text{(Hydrogen ion)}}{H^+}$$

This reaction is faster in RBCs because they contain an enzyme **carbonic anhydrase.** Hydrogen ion released during the reaction bind to Hb, triggering the **Bohr effect**.

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

(iii) **Transport as Carbaminohaemoglobin** Nearly 20-25% CO_2 is carried by haemoglobin as carbamino-haemoglobin. CO_2 entering the blood combines with the NH_2 group of the reduced Hb.

$$HbO_2 + CO_2 \rightleftharpoons \underset{\text{(Carbaminohaemoglobin)}}{HbCO_2} + H^+ + O_2$$

8. Explain the process of regulation of respiration.

The respiratory rhythm can be maintained and moderated by human beings to suit the demands of the body tissues.

It is under dual control, i.e. nervous and chemical. This is explained below as

i. **Neural Control**

The **respiratory rhythm centre** is composed of a group of neurons located in the **medulla oblongata** and **pons Varolii**.

Pons Respiratory Centres

Neural signal from **pneumotaxic centres** stimulated reduce the duration of inspiration, altering the respiratory rate.

A chemosensitive area is located adjacent to rhythm centre that is highly sensitive to CO_2 and hydrogen ions. They increase activity of this centre, which in turn signals the respiratory centre to make necessary changes in order to eliminate these substances. Oxygen does not have a significantly direct effect on the respiratory centre of the brain in controlling respiration.

ii. **Chemical Control**

Large number of **chemoreceptors** are located in the carotid bodies, which lie bilaterally in the bifurcations of the common **carotid arteries**. Their afferent nerve fibres pass through **glossopharyngeal cranial nerve** and thus, to dorsal respiratory area of the medulla oblongata. Receptors of aortic arch and carotid artery recognise change in CO_2 and H^+ concentration and send necessary signals to the rhythm centre for remedial actions.

9. Give cause, symptoms and preventions of the following disorders.

(i) Asthma (ii) Emphysema

(iii) Occupational respiratory disorder

The cause, symptoms and preventions of the disorders are as follows

(i) **Asthma** (difficulty in breathing)

Causes Allergens stimulate the release of histamine from the mast cells causing inflammation of bronchi and bronchioles.

Symptoms Coughing, wheezing, excess amount of mucus clog the bronchi and bronchioles.

Preventions By avoiding exposure to allergens.

(ii) **Emphysema** (inflation or distension of bronchioles or alveolar sacs)

Causes Cigarette smoking and inhalation of other smoke or toxic substances over a period of time leads to damage of alveolar walls.

Symptoms Due to collapse of alveolar septa, surface area for gas exchange is reduced, lungs inflated, exhalation becomes difficult.

Preventions Cigarette smoking and exposure to air pollutants must be avoided.

(iii) **Occupational Respiratory Disorders**
(it is due to occupation of individual especially those in grinding or stone breaking industry)

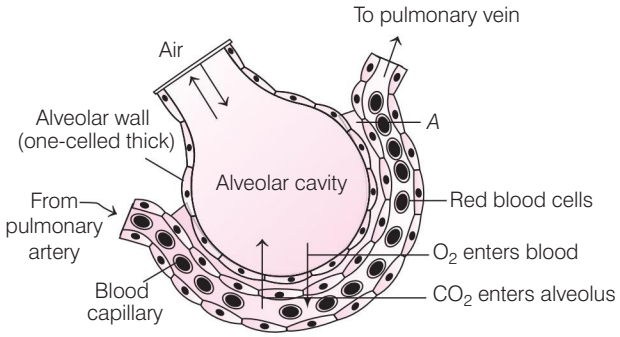
Causes Occur due to chronic exposure of harmful substances as silica, aesbestos, etc., (silicosis, asbestosis). The defence mechanism of body fails to cope with the situation.

Symptoms Proliferation of fibrous connective tissue (fibrosis) of upper part of lung causing inflammation.

Preventions Minimise use of harmful dust. Use of protective gears and clothing at work place. Regular health check up of workers.

• Case Based Questions

1. Observe the diagram given below and answer the questions that follows.



(i) What is being represented in the above diagram?

The above diagram represents a section of an alveolus with pulmonary capillary, showing gaseous exchange.

(ii) Which vein contains the oxygenated blood in humans?

Pulmonary vein is the only vein in the body that carries oxygenated blood, from the lungs to the left auricle and thereafter, it gets distributed to all parts of the body.

(iii) How is oxygen carried from alveoli into the blood in pulmonary capillaries?

Movement of oxygen from alveoli into the blood in pulmonary capillaries occurs by the process of simple diffusion.

(iv) Which factors affect the rate of diffusion?

Concentration/.pressure gradient, solubility of gases and the thickness of the membrane(s) involved in diffusion are some important factors which affect the rate of diffusion.

(v) Identify *A* and write its feature and/or function.

A is basement substance forming alveolar capillary membrane that allows gaseous exchange between blood and alveolar air.

2. **Direction** *Read the following passage and answer the questions that follows.*

Respiratory diseases are highly complex, being driven by host-environment interactions and manifested by structural, functional and inflammatory abnormalities which vary as per time and conditions. It is possible to study the collective behaviour of their symptoms in order to find appropriate measures to deal with them.

Asthma is one such disorder characterised by recurrent attacks of breathlessness and wheezing that varies from person to person in terms of severity and frequency symptoms of asthma include inability to breathe, coughing fits, wheezing fits. It is a condition with no known cures, but an effective management.

Occupational respiratory disease is any lung condition that one gets at work. It occurs due to repeated exposure to certain toxins.

Symptoms of ORD can vary. They depend on your work setting, type of disease and state of health.

(i) Name the chronic respiratory disorder caused mainly by cigarette smoking.

Emphysema is a destructure disease of the lungs in which alveoli get destroyed. The primary cause of emphysema is smoking as the toxins present in the cigarette damage the alveoli.

(ii) What step can be taken as a preventure measure to cure emphysema?

Emphysema is mainly caused due to cigarette smoking hence, avoiding cigarettes can be a preventive measure to cure emphysema.

(iii) How can asthma be effectively managed? .

Asthma can be effectively managed with the help of inhalers which open the swollen airways that block breathing. Also, medications are helpful in managing asthmatic conditions.

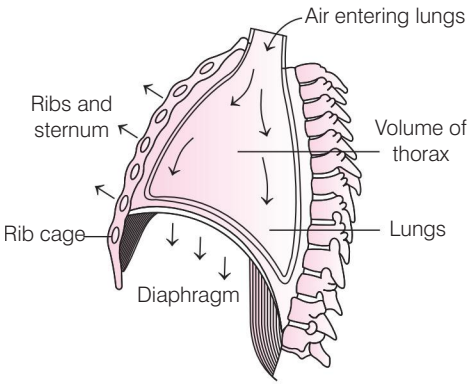
(iv) Give example of an occupational respiration disorder?

Occupational respiratory disorders arise due to repeated or prolong exposure to certain toxins at work places, e.g. silicosis.

(v) How can occupational respiratory disorders be prevented?

Occupational respiratory disorders can be prevented by avoiding areas with increased levels of dust and smoke, wearing protective masks and consuming antihistamine tablets daily.

3. Observe the diagram given below and answer the questions that follows.



(i) What happens to the diaphragm during the process shown above?

During inspiration (depicted above), the diaphragm contracts, putting backwards by the partial flattening.

(ii) In which respiratory volume, air inhaled and exhaled without any force?

The volume of air breathed in and out without any force in each breath is called Tidal Volume. It is about 500 mL or 0.5 L.

(iii) What is the causes of decreased intrapulmonary pressure during inspiration?

Inspiration is initiated by the contraction of diaphragm. It is achieved by the contraction of the external intercostal muscles which up lift the ribs and the sternum. The overall increase in the thoracic volume causes a similar increase in the pulmonary volume. This decreases the intrapulmonary pressure forcing the air from outside to move into the lungs (i.e. inspiration).

(iv) How is negative pressure breathing helpful for mammals?

If allows the mammals to eat and breathe at the same time.

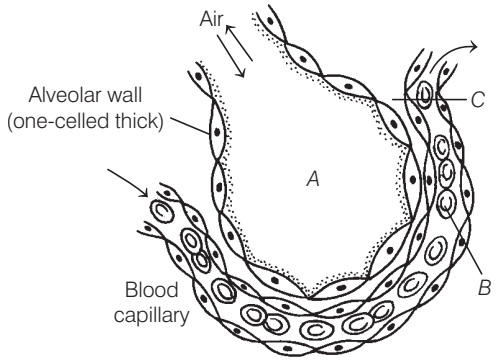
Chapter Test

Multiple Choice Questions

1. Correct sequence of the air passage in humans is
(a) Nose → Larynx → Pharynx → Bronchioles → Alveoli
(b) Nose → Pharynx → Larynx → Bronchioles → Bronchi
(c) Nose → Pharynx → Larynx → Bronchioles → Trachea
(d) External nostril → Nasal passage → Internal nostril → Pharynx → Larynx → Trachea → Bronchi → Bronchiole → Alveoli

2. Lungs do not collapse between breaths and some air always remains in the lungs which can never be expelled because
(a) there is negative pressure in the lungs
(b) there is negative intrapleural pressure pulling at the lung walls
(c) there is positive intrapleural pressure
(d) pressure in the lungs is higher than the atmospheric pressure

3. Identify *A*, *B* and *C* in the given diagram and choose the correct option accordingly.



(a) *A*–Alveolar cavity, *B*–WBC, *C*–Capillary wall
(b) *A*–Alveolar cavity, *B*–RBC, *C*–Systemic wall
(c) *A*–Alveolar cavity, *B*–RBC, *C*–Basement membrane
(d) *A*–Alveolar cavity, *B*–WBC, *C*–Systemic wall

4. Blood does not become acidic although it carries CO_2 because
(a) CO_2 is continuously diffused through tissues
(b) CO_2 combines with H_2O to form H_2CO_3
(c) in CO_2 transport, buffer plays an important role
(d) CO_2 is absorbed by WBC

5. Which one of the following options correctly represents the lung conditions in asthma and emphysema, respectively?
(a) Increased respiratory surface; Inflammation of bronchioles
(b) Increased number of bronchioles; Increased respiratory surface
(c) Inflammation of bronchioles; Decreased respiratory surface
(d) Decreased respiratory surface; Inflammation of bronchioles

Assertion-Reasoning MCQs

Direction (Q. Nos. 1-3) *Each of these questions contains two statements, Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.*

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true, but R is not the correct explanation of A
(c) A is true, but R is false
(d) A is false, but R is true

1. **Assertion** (A) Most fishes when out of water, die of suffocation.
Reason (R) Atmospheric air contains less oxygen content than oxygen dissolved in water.

2. **Assertion** (A) CO_2 transport occurs very fast through RBCs.
Reason (R) Enzyme carbonic anhydrase is absent in the blood plasma.

3. **Assertion** (A) Blood oxygen does not have significant effect on the respiratory centre of brain.
Reason (R) Increased pCO_2 and H^+ levels detected by chemoreceptors activate the respiratory centres to mediate the necessary adjustments.

Short Answer Type Questions

1. Write note on larynx.
2. What is meant by inspiration and expiration?
3. Name the factors that affect the rate of diffusion of gases in the lungs.
4. What happens to oxyhaemoglobin, when the blood reaches the tissues?
5. Draw a labelled diagram of a section of an alveolus with a pulmonary capillary.

Long Answer Type Questions

1. Explain human respiratory system.
2. How are gases (O_2 and CO_2) transported in blood?

Answers

Multiple Choice Questions

1. *(d)* ***2.*** *(b)* ***3.*** *(c)* ***4.*** *(c)* ***5.*** *(c)*

Assertion-Reasoning MCQs

1. *(c)* ***2.*** *(c)* ***3.*** *(a)*