Chapter 13

GASEOUS EXCHANGE

No work can be done without energy. Likewise this universal truth, the body of an organisms cannot perform various activities without energy. The process of respiration resolves the mystery of releasing energy contained within chemical bonds of some bio-molecules.

All living organisms require energy to perform various activities. In order to obtain energy, they oxidize energy-rich molecules like ATP (Adenosine tri phosphate). The continuous supply of ATP to living cells is made possible through the process of respiration. It is a complex process of oxidation-reduction in which food is oxidized to release energy. An organism can generate greater number of ATP using oxygen molecules, which can be obtained from its external environment. But during the chemical pathway, carbon dioxide is released as by-product. Carbon dioxide must be given out of organism, as it is harmful if remained in cell. Thus, living organisms are always in need of gaseous exchange (take in oxygen and give out carbon dioxide) with their environment.

In addition to the process of respiration, autotrophs like plants perform gaseous exchange for the process of photosynthesis. During this process, plants obtain carbon dioxide and release oxygen into their environment. But in the following discussion, we will consider the exchange of respiratory gases, only.

The gas exchange in organisms takes place by the process of diffusion. Efficient gas exchange depends upon following factors:

(i) Maintenance of diffusion gradient,

(ii) Large surface area in relation to the volume of organism, and

(iii) Presence of moist membrane or **respiratory surface** for exchange of gases.

13.1 RESPIRATORY MEDIA

The source of oxygen called **respiratory media** for aquatic and terrestrial organisms are water and air, respectively. Aquatic organisms obtain oxygen dissolved in water while terrestrial organisms obtain it from the atmospheric air. The latter is the main source of oxygen on earth, which contains about 21% oxygen. On the contrary, same volume of water when fully saturated with oxygen contains about 5% oxygen. Moreover, water is denser than air. Thus it is more difficult for aquatic organisms particularly animals to obtain oxygen.

13.2 GASEOUS EXCHANGE IN PLANTS

All plants exchange gases for respiration as well as photosynthesis. The process of respiration occurs constantly day and night in all living cells of plants. However, photosynthesis occurs during daytime, and in chlorophyll containing cells only.

Gas exchange in unicellular organisms and lower plants especially the aquatic ones, takes place by diffusion across a moist cell membrane and wet body surface, respectively. Surface area in such organisms is greater than their volume so diffusion alone is sufficient for the transport of gases from surface cells to inner ones. But in higher land plants gas exchange through entire surface of leaves and stem is prevented due to external, waxy covering called **cuticle.** It is an adaptation to avoid excessive evaporation of water. However, the cutilarized epidermis of leaves has numerous pores called **stomata** (singular-stoma) for the exchange of gases as well as evaporation of water. Each stoma (Fig. 13.1) is formed by two modified epidermal bean-shaped, **guard cells**. Unlike other epidermal cells, guard cells bear chloroplast with thicker inner and thinner outer walls. Stomata can be opened or closed depending upon the turgidity of guard cells.

In woody stems, epidermis is replaced by impervious layer of closely packed cork cells that hamper the diffusion of gases through it. But the problem is overcome by numerous **lenticels** which are localized regions of loosely arranged cells with intercellular air spaces between them (Fig. 13.2). Through lenticels, respiratory gases can move freely in and out of stem. Gas exchange also occurs in roots by diffusion through epidermal cells and root hair in presence of moisture in the soil.

Though all living cells of different organs like stem, root. etc. constantly respire, yet there is no transport system within plants for respiratory gases. Such gases are therefore, transported by diffusion only. In order to facilitate the process of diffusion of gases, plant tissues are permeated by air spaces.

13.2.1 Photorespiration:

It is a metabolic process that occurs commonly in plants like wheat, rice, sugar cane, etc. Such plants are termed biochemically, as C_3 plants. It occurs during hot and dry days. In this process, C_3 plants consume oxygen and produce carbon dioxide during daytime, in chloroplast without production, of energy, so it is termed as **photorespiration**.

During hot and dry days, stomata are closed to conserve water. But due to the on going process of photosynthesis, the concentration of oxygen increases than the concentration of carbon dioxide inside the leaves. Under such condition, oxygen competes with carbon dioxide to combine with an enzyme called **Ribulose biphosphate carboxylase/oxygenase** or **Rubisco**. Normally, during photosynthesis, rubisco is involved in catalyzing the fixation of carbon dioxide with Ribulose biphosphate (RuBP) to form an unstable hexose sugar. But now RuBP combines with oxygen rather than carbon dioxide and breaks into one molecule of Phospho-Glyceric Acid (PGA) and one molecule of Phosphoglycolate. The latter rapidly breaks down to release carbon dioxide. The process of photorespiration can be summarized by the following equation.

Thus photorespiration is an oxidation process similar to respiration in which oxygen is consumed and carbon dioxide is released. But unlike respiration, it does not produce any ATP. So from the energy point of view, it is a useless and wasteful process. Moreover, it reduces photosynthetic output, which is ultimately related to decline in the crop yield.

13.3 GASEOUS EXCHANGE IN ANIMALS

Like other living organisms, animals also exchange gases with their environment during respiration. They take in oxygen and give out carbon dioxide continuously through their moist, respiratory surfaces. Respiratory gases move across moist, respiratory surfaces by diffusion. The concentration gradient is maintained across the respiratory surface as oxygen is consumed and carbon dioxide is liberated constantly. Thus, there is greater concentration of oxygen and lesser concentration of carbon dioxide, outside the respiratory surface than inside. The respiratory gases are passed across the respiratory surface by dissolving in water. Moreover, respiratory surfaces must be large enough in relation to the volume of that animal for efficient gas exchange.

13.3.1 Properties of respiratory surfaces:

Respiratory surface of animals bear following properties: (i) Permeable, (ii) large surface area in relation to volume, (iii) wet, and (iv) thin.

Respiratory surface in animals depends upon the structure, habitat and activity of animal. In order to maintain greater surface to volume ratio for efficient gas exchange, animals have evolved different adaptations in their respiratory surfaces. In unicellular organisms, gas exchange occurs over the entire surface area (plasma membrane).

13.3.2 Respiratory organs of aquatic and terrestrial animals:

1. Respiratory organs of Hydra:

Hydra is a multicellular animal with tissue level of organization but has no organs. It has a large surface area in relation to its volume. Being diploblastic, it has two layers of cells in its body. Since most of its cells are in direct contact with water, so the ectodermal cells exchange gases with external water while endodermal cells with water that comes within gastro-vascular cavity (Fig. 13.3).

2. Respiratory organs of earth worm:

Earthworm has a tubular body pattern with developed organs and systems but there are no specialized respiratory organs so it uses its wet skin as respiratory surface (Fig. 13.4) that offers enough surface area for efficient gas exchange. In order to keep the skin moist, earthworm has to live in damp soil. The moisture is absorbed by mucous secreted from the goblet glands in the skin of earth worm. However, due to larger size and complexity of the body of earthworm, distribution of respiratory gases from skin to each cell of the body and vice versa posses a problem since diffusion alone can not distribute gases rapidly to distant cells within the animal. So the earthworm has developed a blood vascular system, which can efficiently and rapidly transport respiratory gases within the body.

3. Respiratory organs of cockroach:

Cockroach (as well as other insects) has evolved a special type of invaginated respiratory system, called **tracheal system**. It is specially adapted for intake of oxygen, terrestrial mode of life, high metabolic rate and the compact body of aninsect.

The tracheal system consists of number of internal tubes called **tracheae**, which on side, open outside the body through minute, slit-like pores known as **spiracles** while on the other side ramify throughout the body into fine branches or **tracheoles**. Both, the trachea and the tracheoles are lined internally by thin cuticle. There are ten (10) pairs of spiracles on lateral sides of the cockroach; two (2) lie in the thoracic segments while eight (8) in the first abdominal segments. Spiracles are opened or closed by valves which are operated by special muscles. Tracheoles, finally end as blind, fluid filled, fine branches which are attached with the cells of the tissues.

The cockroach takes in air directly from the atmosphere into the tracheae through spiracles. Since oxygen diffuses directly into the cells of the tissues at the level of fluid filled tracheoles hence their blood vascular system is devoid of haemoglobin. However, the removal of carbon dioxide from the cells of the body is largely dependent upon plasma of the blood, which takes up carbon dioxide for its ultimate removal through the body surface via the cuticle.

4. Respiratory system of fish:

Respiratory organs in fish are called **gills** (Fig. 13.6). They are formed as outgrowth of pharynx and lie internally within the body so that they are protected from mechanical injuries. Each gill is a highly vascularized structure. It is composed of two rows of hundreds of **filaments,** which are arranged in V-shape and are supported by a cartilage or a long curved bone, the **gill bar** or **gill arch**. Each filament is folded to form numerous plate-like **lamellae** which greatly increase the surface area of the gill. Each lamella is provided by a dense network of blood capillaries.

In bony fishes ventilation is brought about by the combined effect of mouth and **opercula** (sing. Operculum). Water is drawn into mouth. It passes over the gills through pharynx and ultimately exits at the back of opercula. Since concentration of oxygen in water is low and also water is denser than air, fish must use considerable energy to ventilate its gills. Gas exchange is also facilitated in gills due to **counter current flow** of water and blood. In the capillaries of each lamella, blood flows in direction opposite to the movement of water across the gills. Thus the most highly oxygenated blood is brought close to the water that is just entering the gills and that has even higher oxygen content than the blood. As the water flows over the lamellae, gradually losing its oxygen to the blood, it encounters blood that is also increasingly low in oxygen. In this way, the gradient encouraging oxygen to move from water into the blood is maintained across all the lamellae. Counter current flow is very effective as it enables the fish to extract up to 80%-90% of the oxygen from water that flows over the gills.

5. Respiratory organs of frog:

Frog can live in water as well as on land. Although, its larval stages respire by gills, the adult has to develop some special respiratory organs adapted for terrestrial mode of life. Like other terrestrial vertebrates, frog has evolved vascularized, paired out growths from the lower part of pharynx known as **lungs**. They are located inside the body and are simple sac-like structures with shallow internal folds that increase the inner surface to form many chambers called **alveoli.** These are separated from each other through septa. The inner surface of alveoli is single cell layer and attached with blood capillaries. Alveoli are the site of exchange of gases. Each lung is connected to outside by system of hollow tubes. From each lung arises a tube or **bronchus**. Both bronchi open into the **larynx** or sound box which leads into the buccal cavity through **glottis** (Fig. 13.7).

Like all other amphibians, in frog, ventilation is a single, two-way path. Frog uses positive pressure (i.e. it pushes the air into the lungs) to move air in and out of lungs. The frog draws air into the buccal cavity by lowering its buccopharyngeal floor. During this process, it opens the nares and closes the glottis. Then with the nostrils closed and glottis opened, it raises the buccopharyngeal floor, thus pushing the air into the lungs. This type of ventilation does not allow the lungs to be completely emptied or refilled by air, hence termed as **incomplete ventilation**. Thus the air forced into the lungs mixes with the air already in lungs and depleted in oxygen. The exchange of gases on land through lungs is termed as **pulmonary respiration**. However, when frog goes into water or buries itself in mud, it exchanges gases by its moist and highly vascularized, thin skin. This is known as **cutaneous respiration**. Moreover, it can also exchange gases through its thin, vascularized lining of the buccal cavity. It is called **bucco-pharyngeal respiration.**

6. Respiratory system of Bird:

Birds are exclusively lung breathers. The lungs of a bird are internally subdivided into numerous, small, highly vascularized, thin membranous channels called**parabronchi.** These channels are responsible for continuous flow of air in one direction. In addition to a pair of lungs, a bird has 8 to 9 thin walled, non-muscular, non-vascular **air sacs** (Fig. 13.8) that penetrate the abdomen, neck and even the wings. The air sacs work as bellows that ensure the unidirectional flow of air or **complete ventilation**. Thus a bird must take two breaths to move air completely through the system of air sacs and lungs. The first breath draws fresh air into the posterior air sacs of the lungs. The second breath pushes the first breath into anterior air sacs and then out of the body. This one way flow of air enables a bird to fly at very high altitude without any shortage of oxygen, as the air coming in lungs is always oxygen-rich.

13.4 RESPIRATORY SYSTEM OF MAN

The respiratory system of man consists of paired lungs and the air passage ways. Paired lungs of man are situated in the thoracic cavity. The walls of thoracic cavity are formed of inter-costal muscles, which are attached with a bony cage formed by 12 pairs of ribs, vertebral column, and sternum bone. The thoracic cavity is separated from the abdomen by a muscular partition called **diaphragm** (Fig. 13.9).

13.4.1 Air Passage ways:

Air is drawn into the lungs by inter-connected system of branching ducts. Atmospheric air enters into these ducts through a pair of openings called **external nares** (nostrils), which lead separately into **nasal cavity**. It is lined internally by vascularized, ciliated epithelium containing mucous secreting cells. Hairs are also present in nasal cavity. Thus the air drawn in becomes warm, moist and filtered out of dust particles and microorganisms. It also contains sensory cells for smell. The air then leads through the **internal nostrils** into the **pharynx.** It is a common passage for food as well as air. The openings of nostrils into pharynx are guarded by soft palate.

Pharynx leads air into **larynx** through an opening called **glottis**. Glottis is guarded by a flap of tissue called **epiglottis.** During swallowing, soft palate and epiglottis close the nostril opening and glottis, respectively so the food is prevented to go either into the nasal cavity or glottis. Larynx or sound box is a small chamber. It consists of a pair of vocal cords for producing sound. Larynx leads the air into a flexible air duct or **trachea** that lies in thoracic cavity. It bears C-shaped cartilage rings, which prevent it from collapsing during drawing air in. Its internal lining is ciliated and bears mucus secreting **goblet cells**. Due to mucus and upward beating of cilia, any residues of dust and germs are always pushed outside the trachea into the oesophagus through pharynx. At its lower end, trachea bifurcates into two smaller branches called **bronchi.**Each bronchus leads the air into lung of its side. Bronchi are also supported by C-shaped cartilage rings in their walls upto the point where they enter into lungs.

The air passage way described above is normal way, but sometimes air can be drawn in through mouth also.

13.4.2 Lungs:

Lungs are paired, soft, spongy, and highly vascularized structures. The right lung is partitioned into three lobes while the left lung into two lobes. The lungs occupy most of the chest cavity. Each lung is enclosed by two, thin membranes known as **pleural membranes.** Within the pleural membranes, there is a fluid filled, narrow cavity called **pleural cavity**. This fluid acts as a lubricant.

Inside each lung, each bronchus progressively divides into very fine branches called **bronchioles.** Each bronchiole terminates at a tiny, hollow sac-like alveolar duct (Fig. 13.10) containing a number of **air sacs** or **alveoli.** The alveoli are considered as the **respiratory surfaces** of lung. A single alveolus is composed of single layer of epithelial cells with a slightly larger diameter than the blood capillary. Each alveolus is surrounded by extensive network of blood capillaries. It is the site of exchange of respiratory gases. The internal area of an alveolus is provided with a thin layer of fluid containing **surfactant**. It reduces the internal surface tension to prevent it from collapsing during gas exchange.

It has been estimated that both lungs contain about 700 million alveoli with a surface area equal to that of tennis court or 20 times the body's entire skin surface.

13.5 BREATHING IN MAN

13.5.1 Mechanism of breathing:

Breathing is the process of taking in **(inspiration / inhalation)** and giving out of air **(expiration / exhalation)** from the atmosphere up to the respiratory surface and vice versa. In man including other mammals, breathing is termed as **negative pressure breathing**. In this kind of breathing, air is drawn into the lungs due to negative pressure (decrease in pressure in thoracic cavity in relation to atmospheric pressure) (Fig. 13.11).

Inspiration (Inhalation): Inspiration or the process of taking in of air is energy consuming process in which volume of thoracic cavity is increased due to contraction of inter-costal muscles and diaphragm. Contraction of external inter-costal muscles moves the ribs as well as sternum outward and upward while contraction of the diaphragm makes it flat. As a consequence, the thoracic cavity enlarges and a negative pressure is developed inside the thoracic cavity and ultimately in the lungs. So the air through the respiratory passage rushes into the lungs up to alveoli where exchange of gases occurs.

Expiration (Exhalation): Expiration or the process of giving out of air is just reverse of inspiration. It is a passive process, which takes place due to increased pressure in thoracic cavity as well as lungs. It is caused by relaxation of external inter-costal muscles and the contraction of internal inter-costal muscles, which move ribs as well as sternum inward and downward. Similarly, diaphragm also relaxes which makes it dome shaped thus reducing the volume of the thoracic cavity. As a consequence, lungs are compressed so the air along with water vapors is exhaled outside through respiratory passage.

13.5.2 Rate of breathing:

It can be observed that we can hold our breath for a short time or can breathe faster and deeper at our will. This is termed as **voluntary control.** But mostly, rate of breathing is controlled automatically. This is termed as **involuntary control** (Fig. 13.12). This automatic control is maintained by coordination of respiratory and cardiovascular systems. It has been found that increased concentration of carbon dioxide and H^+ in blood are the basic stimuli to increase the rate of breathing. Their concentrations are monitored by chemo-receptors known as **aortic** and **carotid bodies** situated in aorta and carotid arteries, respectively. Any change in the concentrations of carbon dioxide and H^+ are detected by medulla oblongata (a part of brain). Moreover, medulla oblongata is itself sensory to changes in the concentrations of carbon dioxide and H^+ present in the cerebro-spinal fluid. In response to increased concentrations of carbon di oxide and H^+, it sends impulses to inter-costal muscles and diaphram to increase breathing rate.

13.5.3 Disorders of respiratory tract:

i) Lung cancer: It is usually a consequence of smoking either actively or passively. As the smoke passes through the respiratory passage, its toxic contents like nicotine, SO_2, etc, cause gradual loss of cilia of epithelial cells of the respiratory passage so that dust and germs are settled inside the lungs. Later, cells with abnormal nuclei appear in the thickened epithelial lining, which start dividing rapidly without following normal cell cycle. Finally, these cells with abnormal nuclei break the thickened epithelial lining and penetrate into the other tissues causing cancer.

ii) Emphysema: It is a degenerative disease in which alveoli gradually deteriorate. It happens when some toxic substance such as nitrogen oxides, sulfur di oxide, etc. are constantly inhaled. Due to such toxic substances, the elasticity of the lungs decreases. As a consequence, alveoli are ruptured and lungs become harder. So the tissues of the body including brain are supplied less and less oxygen. Thus, the victim's breathing becomes labored day by day. It also makes him depressed, irritable and sluggish.

iii) Asthma: It is another respiratory tract disorder in which there are recurrent attacks of breathlessness, characteristically accompanied by wheezing when breathing out. It may be caused by external factors like pollens, dust, animal fur, common cold, cough, smoke, etc. In many cases, there is no apparent cause. Heredity is a major factor in the development of asthma. Severe case of asthmatic attack can be fatal.

iv) Tuberculosis: It is an infectious disease of the lungs. It is caused by a bacterium called Mycobacterium tuberculosis. Commonly known as T.B., was once a major killer disease of human. Main symptoms are coughing (sometimes with blood in sputum), pain in chest, shortness of breath, fever, sweating at night, weight loss and poor appetite. It can cause complication leading to death. Infection is passed from person to person in air-borne droplets produced by coughing or sneezing.

13.6 TRANSPORT OF GASES IN MAN

13.6.1 Oxygen and carbon dioxide carrying capacities of blood and factors affecting these capacities:

Oxygen and carbon dioxide are exchanged in alveoli of lungs by the simple process of diffusion. Blood returning into lungs from all parts of the body is depleted from oxygen. This deoxygenated blood is dark maroon in color and appears bluish through the skin. The air inhaled into lungs has greater concentration of oxygen. Thus due to the difference in concentration across the respiratory surfaces, oxygen moves into blood flowing into capillaries around alveoli. Now the blood becomes oxygenated. It is bright red in color.

Blood returning from tissues contains carbon dioxide, which is a respiratory by-product. Due to its higher concentration, carbon dioxide diffuses from the tissues into the blood, which is brought in the lungs. In lungs, due to greater concentration of carbon dioxide in blood, it moves out into alveoli where its concentration is lower.

Blood takes in oxygen much more rapidly than water. Thus it can transport enough oxygen to tissues to meet their demand of oxygen. Many factors (e.g. concentration gradient presence of any competitor such as carbon/mono oxide, moisture, surfactant etc.) influence this transport of respiratory gases across the alveolar wall.

13.6.2 Lung capacities:

The total average lung capacity of adult human being is about 5 liters (5000 cm^3) of air. During normal breathing a person takes in and gives out air approximately half of a litre (450 cm^3 to 500cm^3). This is called **tidal volume.** It is only about 10% of the total capacity of lungs. With an extra deep breath, the maximum volume of air inspired and expired called **vital capacity** averages about 4 liters. The remaining volume approximately 1 liter of air remained in the lungs is termed as **residual volume**. It remains in there due to the fact that thorax cannot collapse completely. Residual volume is not stagnant since inspired air mixes with it at each time. Aging, emphysema, etc. can increase the residual volume at the expense of vital capacity.

13.6.3 Role of haemoglobin and myoglobin:

i) Haemoglobin, an iron containing protein is a respiratory pigment present in the red blood corpuscles of vertebrates. Each haemoglobin molecule has 4 iron containing groups called heme. It is the iron, which reversibly binds with oxygen. Nearly, all oxygen carried by blood is bound to Hb. Thus due to Hb, blood could carry 70 times more oxygen than plasma. So it plays an important role in maintaining a high concentration gradient of oxygen from air to blood. Hb binds to oxygen to form a loose compound called oxyhaemoglobin. It is carried to the tissues where due to low concentration of oxygen in tissues, oxyhaemoglobin dissociates releasing oxygen, which enters in tissues. The whole process can be represented by the following equation.

Each haemoglobin molecule binds up to 4 oxygen molecules. Since there are about 280 million Hb molecules in each R.B.C. so each R.B.C. is capable of carrying more than a billion molecules of oxygen.

ii) Myoglobin, a smaller protein than haemoglobin, found in the musclescan bind to oxygen more tightly than haemoglobin. It gives red colour to muscles.
Haemoglobin is also involved in the partial (35%) transport of carbon dioxide from tissues to alveolar blood capillaries in alveoli. Carbon dioxide due to its higher concentration in tissues diffuses out into the blood where it combines with amino group of haemoglobin to form a molecule called carbaminohaemoglobin. In alveoli, it breaks and carbon dioxide diffuses out into alveoli.
Rest of the carbon dioxide is transported by the water of plasma and also by the water of RB.C. as shown by the following equations.
Water of R.B.C. transports 60% carbon dioxide
Water of plasma transports 05% carbon dioxide
These reactions are facilitated by an enzyme called carbonic anhydrase present in the RBCs.

KEY POINTS

- Energy is required by living organisms to do different activities.
- Gaseous exchange plays key role in release of energy from food.
- Gaseous exchange depends upon maintenance of concentration gradient and large surface to volume ratio.
- Gaseous exchange and cellular respiration contribute to oxidation of food.
- Air is better medium for exchange of gases than water.
- Gaseous exchange occurs in all plants for respiration as well as photosynthesis.
- In plants there is not transport system for the respiratory gases.
- Plants during hot and humid days consume oxygen and release CO_2, a process termed as photorespiration.
- Photorespiration does not produce any ATP. It reduces crop yield.
- Like other insects cockroach respires by tracheal system.
- Fish respire through gills.
- Gaseous exchange in gills is facilitated by counter current flow of blood and water.
- Frog respires through skin, lungs and buccal cavity.
- Frog uses positive pressure breathing.
- Lungs of a bird are internally divided into numerous parabronchi.
- In addition to lungs, birds have air sacs that work as bellows.
- In man, breathing is termed as negative pressure breathing.
- Smoking is the major cause of lung cancer.
- Dust, pollens, smoke, etc may contribute in the development of asthma.
- Blood takes in oxygen much more rapidly than water.
- In vertebrates, haemoglobin is involved in the transport of nearly all oxygen and some carbon dioxide.
- Muscle fibers have a respiratory pigment or myoglobin.
- Myoglobin gives red color to muscles.

EXERCISE

1. Encircle the correct choice:

i) __________ cells have chloroplast.
(a) Goblet cells (b) RB.C.
(c) Guard cells (d) None of these

ii) __________ have the most efficient respiratory system.
(a) Fish (b) Amphibia
(c) Birds (d) Mammals

iii) Haemoglobin carries ___________ times more oxygen than plasma.
(a) 20 (b) 50
(c) 70 (d) 100

(iv) T.B. is caused by ___________
(a) Allergy (b) Bacterium
(c) Nicotine (d) All of these

(v) Rate of breathing is increased due to increase in concentration of _______ in blood:
(a) Oxygen and hydrogen (b) Oxygen and CO_2
(c) CO_2 and proton (d) CO and oxygen

(vi) Which of the following has complete ventelation?
(a) Frog (b) Bird
(c) Man (d) All of these

(vii) The average lung capacity of human is:
(a) 2 Litres (b) 3 Litres
(c) 4 Litres (d) 5 Litres

(viii) Each haemoglobin molecule carries oxygen molecule:
(a) 2 (b) 3
(c) 4 (d) 5

(ix) Lungs of bird consist of:
(a) Alveoli (b) Parabronchi
(c) Both a and B (d) None of the these

(x) Which of the following transports more CO_2?
(a) H_2O (b) Sodium ion
(c) Potassium ion. (d) None of these

2. Write detailed answers of the following questions

(i) Give an account on exchange of gases in plants.
(ii) Explain the respiratory system of cockroach.
(iii) State and explain the respiratory system of man.
(iv) What is breathing? Explain its mechanism and control in man.
(v) Discuss the process of transport of gases in man.
(vi) Explain the common respiratory tract disorders.

3. Write short answers of the following questions:

(i) What are the factors affecting gas exchange?
(ii) Why air is better respiratory medium than water?
(iii) What do you understand by 'counter current flow' of water and blood in gills of fish?
(iv) Differentiate between positive pressure breathing and negative pressure breathing.
(v) What are lung capacities?
(vi) Distinguish between inspiration and expiration.
(vii) what is the role of air sacs in birds.