CHAPTER

13

Gaseous Exchange

Animation 13.1: Gaseous Exchange
Source & Credit: Wikispaces

NEED OF RESPIRATORY GAS EXCHANGE

At all levels of activities in living organisms an uninterrupted supply of energy is required. Respiration is one of the most important metabolic activities of all organisms. Respiration occurs at two levels, i.e, organismic and cellular level. Organismic respiration is also known as breathing or ventilation. The cellular respiration is directly involved in the production of energy, necessary for all living activities. Cellular respiration is the process by which cell utilizes oxygen, produces carbon dioxide, extracts and conserves the energy from food molecules in biologically useful form, such as, ATP.

ADVANTAGES AND DISADVANTAGES OF GAS EXCHANGE IN AIR AND IN WATER

Exchange of gases during organismic respiration is carried out only by diffusion. Respiratory gases are exchanged between body fluid and outside medium which may be water or air. There is no active transport mechanism to move respiratory gases across biological membranes. For that matter, air is better respiratory' medium than water. Oxygen can be obtained more easily from air than from water because of many reasons.

Firstly, the oxygen content of air is much higher than the oxygen content of equal volume of water. A liter of water cannot contain even 10 ml of oxygen whereas oxygen content of fresh air is about 200 ml per liter. Secondly, oxygen diffuses about 8000 times more quickly in air than in water.

Breathing or ventilation is directly involved in the exchange of gases .The ventilation of water is far more difficult than the ventilation of air, because water is 8000 times more dense than air .In terms of viscosity the water is 50 times more viscous, which makes it more difficult for exchange of gases as compared to air.

GASEOUS EXCHANGE IN PLANTS

Plants like animals also get their energy from respiration. In plants, in contrast to animals, no special organ or system is present for gaseous exchange as they exist in higher animals. Every cell of plant carries out exchange of gases according to its needs. The transport system of plants which includes conducting tissues i.e. xylem and phloem is not involved in the transport of gases in the plants. In most cells of mesophyll which are specialized for photosynthesis, there are present large air spaces. These air spaces are directly involved in gaseous exchange. Stomata are the main sites of exchange of gases in plants. Stomata are largely present in the leaves and in young stem. In older stems, cork tissue is present which is formed of dead cells. The cork tissue has special pores called lenticels which are involved in gaseous exchange. Land plants get their oxygen directly from air which enters through stomata. Enormous number of stomata are. present on the leaves. It is estimated that there are 12000 stomata per square centimeter of leaf surface in Tobacco plant. These stomata lead to the intercellular spaces (spaces between cells) of mesophyll tissue. The air spaces are comparable to honey comb. These air spaces may comprise up to 40% of the total volume of the leaf. The exchange of gases between and the moist surface of mesophyll cells takes place promptly (Fig 13.1). The roots of the land plants get their oxygen from the air existing in the spaces between the soil particles. Aquatic plants obtain their oxygen by diffusion from dissolved oxygen in water.

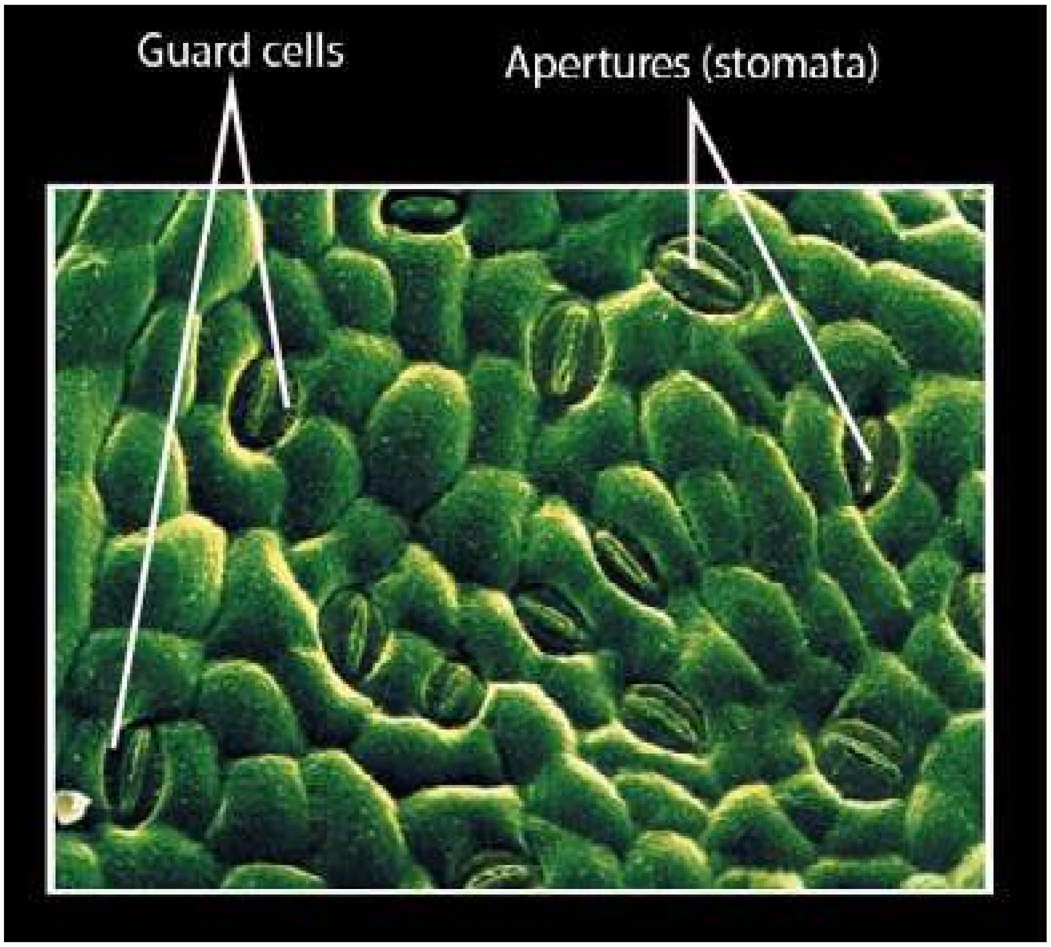


Fig. 13.1 Stomata on leaf surface

Photorespiration and its Consequences

Respiratory activity which occurs in plants during daytime is called **photorespiration**. In the process of photorespiration carbon dioxide is released and oxygen is absorbed. The oxygen absorbed is not useful to produce energy such as ATP. In other words photorespiration is a light dependent process during which oxygen is absorbed and carbon dioxide is released. This oxygen is derived from the early reaction of photosynthesis.

The photorespiration is a process in which ribulose bisphosphate carboxylase/oxygenase (rubisco) fixes oxygen instead of carbon dioxide which results in lowering the overall rate of carbon dioxide fixation and plant growth.

Ribulose 1,5 bisphosphate (RuBP) reacts with oxygen in photorespiration

The first step of photorespiration during which RuBP reacts with oxygen is carried out by rubisco, the most abundant protein in chloroplasts and probably the most abundant protein in the world. The rubisco is carboxylase as well as oxygenase. When rubisco acts as carboxylase it adds carbon dioxide to RuBP, which is an accepter molecule. On the other hand when rubisco is oxygenase it adds oxygen to RuBP. Both these reactions compete with each other. When RuBP reacts with oxygen, a two carbon compound glycolate is produced.

$$\text{RuBP} + O_2 \longmapsto \text{Glycolate}$$

The glycolate thus produced diffuses into the membrane bounded organelles known as **peroxisomes**. In the peroxisomes the glycolate is converted into glycine, through a series of reactions.

$$\text{Glycolate} \longmapsto \text{glycine}$$

The glycine is the simplest amino acid which soon after its formation diffuses into the **mitochondria** where two glycine molecules are converted into serine and synthesis a molecule of carbon dioxide is formed.

$$2\ \text{glycine} \longmapsto \text{serine} + CO_2$$

The pathway in which RuBP is converted into serine is called photorespiration. The process of photorespiration uses ATP and NADPH produced in the light reactions just like **Calvin-Benson cycle.** But, in fact, photorespiration is reverse of Calvin cycle. During photorespiration carbon dioxide is released instead of fixation into carbohydrates. In most plants photorespiration reduces the amount of carbon fixed into -carbohydrates by 25%.

In a hot and dry day the level of oxygen inside the leaf rises. This is because the stomata close to prevent the loss of water. The level of carbon dioxide falls because it is being consumed and the level of oxygen rises because closed stomata do not let it go out.

It is interesting that apparently the photorespiration reduces the photosynthetic process and it is not essential for plants and many plants grow normally without the process of photorespiration. It is also observed that if photorespiration is inhibited chemically, the plant can, still grow. Then why does photorespiration exist? The common simple answer to this question is that the active site of rubisco is evolved to bind both carbon dioxide and oxygen together. Originally it was not a problem as there was little oxygen in the atmosphere and the carbon dioxide binding activity was the only one used. The photorespiration started when the quantity of oxygen became more.

RESPIRATORY ORGANS IN REPRESENTATIVE AQUATIC AND TERRESTRIAL ANIMALS

Properties of respiratory surfaces in animals

Respiratory surfaces in animals are the sites where gaseous exchange takes place. The respiratory surfaces in most animals exhibit the following features :

1. Large surface and moisture:

The surface area should be extremely large and kept moist as it is seen in the lungs in the land vertebrates and in the gills in the case of fishes.

2. Thin epithelium:

The distance across which diffusion has to take place should be little. In most animals the epithelium which separates air and blood is only two cell thick. As a result the distance for diffusion is very short.

3. Ventilation:

Ventilation maintains a steep diffusion gradient. There is a big difference in the concentration of the gases at two points which brings about diffusion.

4. Capillary network:

The respiratory site should possess extensive network of capillaries through which blood should flow all the fime at an adequate speed. In this way steep diffusion gradient is maintained which helps in rapid diffusion of oxygen.

Respiration in Hydra

Hydra has no specialized organs for respiration. Exchange of gases i.e., intake of oxygen and removal of carbon dioxide, occurs through the entire general surface in contact with water. Exchange of oxygen in and carbon dioxide out also occurs in cells lining the digestive cavity. In this way the surface lining of the enteron acts., as an efficient respiratory surface (Fig. 13.2).

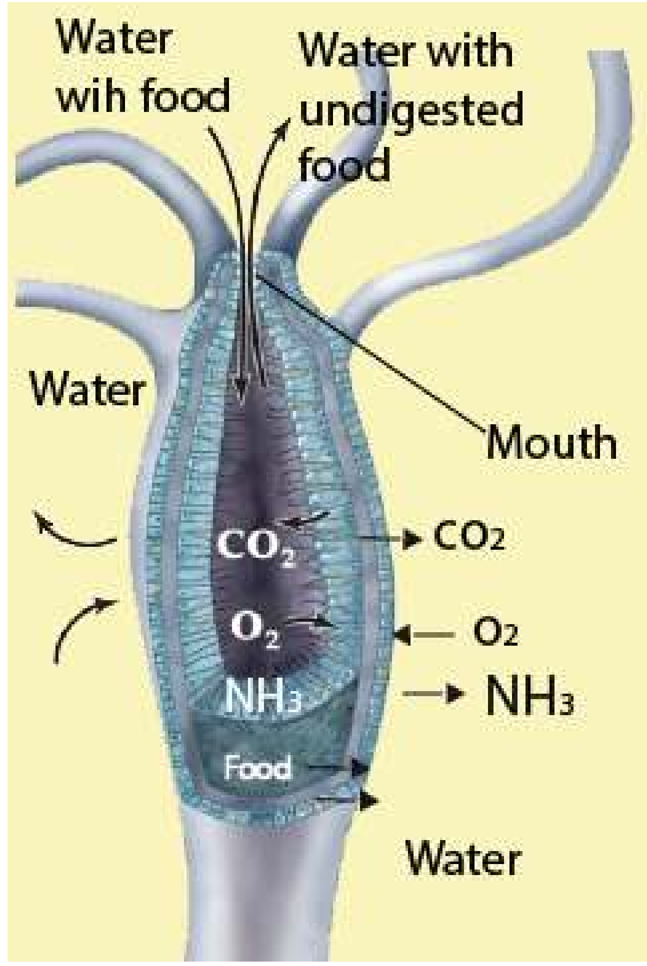


Fig 13.2 Respiration in Hydra

Animation 13.2: Hydra
Source and Credit: carnivoraforum

Animation 13.3: hydra
Source and Credit: gifsoup

Respiration in Earthworm

Although earthworm is much complex than hydra, yet it does not have any specialized respiratory organs. The exchange of gases occurs mainly through skin. Skin is richly supplied with blood capillaries and is always kept moist by the secretion of epidermal mucous gland cells and also by coelomic fluid exuding out through the dorsal pores. Oxygen dissolved on the wet surface passes through the cuticle and epidermal cells into the blood. In the blood, oxygen combines with haemoglobin to form oxyhaemoglobin.Oxyhaemoglobin releases up oxygen at the tissue level. In earthworm, blood does not come into direct contact with tissue cells so oxygen must diffuse through the tissue fluids and coelomic fluids. Carbon dioxide is removed from the tissues by the blood and carried in the plasma to skin, from where it is excreted ((Fig. 13.3)

Animation 13.4: Respiration in Earthworm
Source and Credit: waterwereld

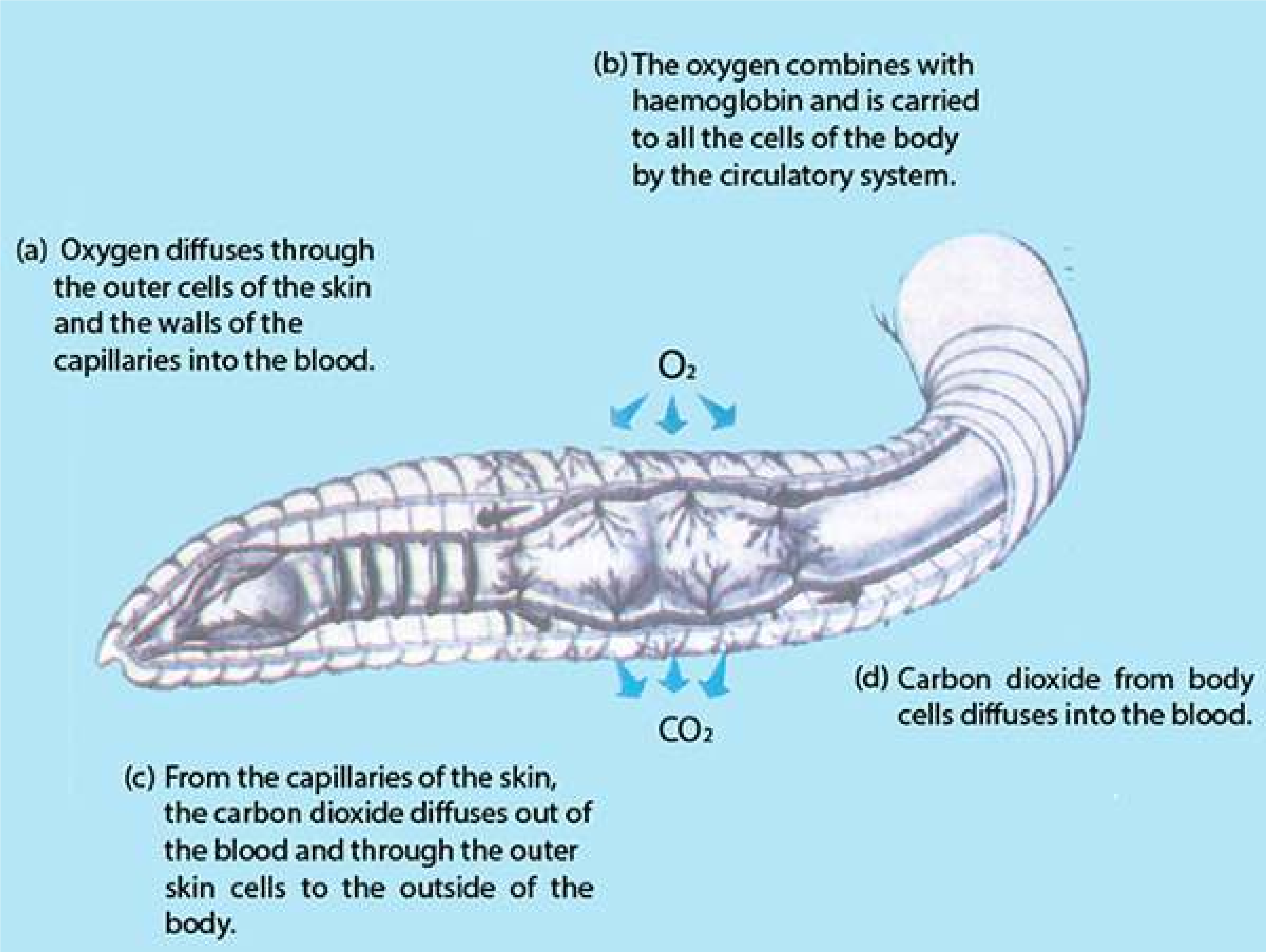


Fig. 13.3 Respiration in Earthworm

RESPIRATION IN COCKROACH

Cockroach has specialized organs for respiration. The respiratory system of the cockroach is very specialized. It consists of branching systems of air tubules called tracheae lined by chitin. The main tracheal trunk communicates with exterior by 10 pairs of apertures called **spiracles**, present on the lateral sides of the body. Two pairs are in thorax while the rest eight are in each of the eight abdominal segments. The main tracheae divide and subdivide forming very fine thin-walled tubules called **tracheoles**. These tracheoles end into blind ducts partly filled with fluid, in which the oxygen dissolves. These surround the organs and the tissues and directly supply oxygen to the living cells. A concentration gradient is set up between them and the spiracular openings and oxygen diffuses into the trachea from the outside air. The movement of the air through the tracheal trunks transfers gases through inspiration and expiration. Air is pumped in and out of the tracheae by the expansion and contraction of the abdominal muscles (Dorsoventral muscles). When abdomen expands, the first four pairs of spiracles open, air rushes in through these spiracles into tracheoles. Abdomen contracts, the anterior four pairs of spiracles close and posterior six pairs of spiracles open. This forces air through the tubes and eventually out of the body. In this way exhalation and inhalation take place. From the spiracles air enters into trachea and then tracheole, from where gaseous exchange between tissue cells and air in tracheole takes place. Thus air is directly supplied through tracheoles to the tissue cells. Blood is not involved in transport of gases(Fig.l3.4).

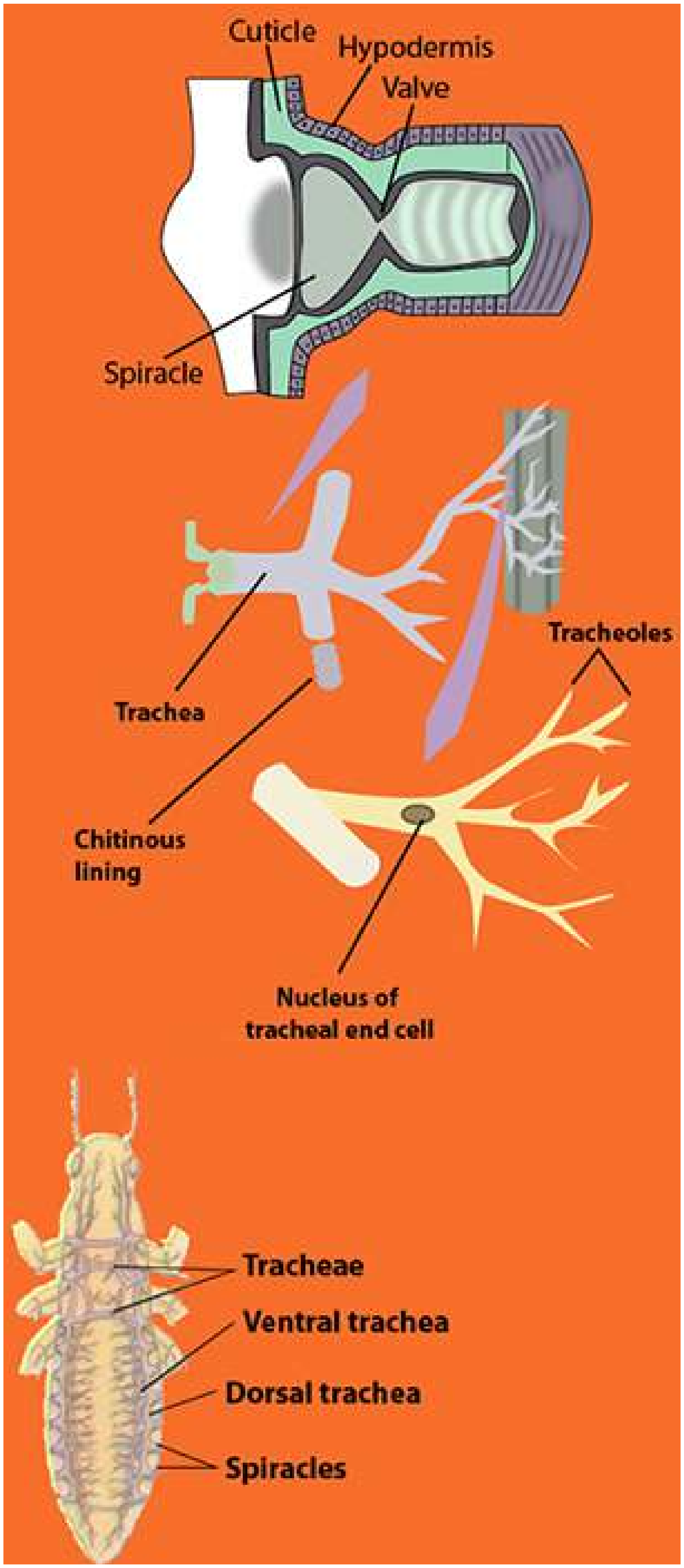


Fig. 13.4 Respiration in Cockroach

Animation 13.5: COCKROACH
Source and Credit: presentmam

Animation 13.6: Gas Exchange in Fish
Source and Credit: s-cool.co.uk

Respiration in fish

Fish respires through the gills which are paired structures present on either side of the body almost at the junction of head and trunk. Gills are most effective and highly modified for gaseous exchange in aquatic animals. They are in four to five pairs which may open through gill slits and are visible on the surface of the pharynx (cartilaginous fish) or are placed in bronchial cavities which are covered by **operculum**. Gills have great surface area for gaseous exchange. The gill surface is all the time ventilated by constant flow of water. Heart pumps the blood directly to the gills from where oxygenated blood is carried to all the parts of the body. The deoxygenated blood from different parts of the body is received by heart. The heart of the fish is single circuit and the blood flows in only one direction. The blood enters the posterior side of heart and after passing through different chambers it is pumped into the gills. Water enters through the mouth and after passing over the gills move out of the body through the gill openings (Fig. 13.5)

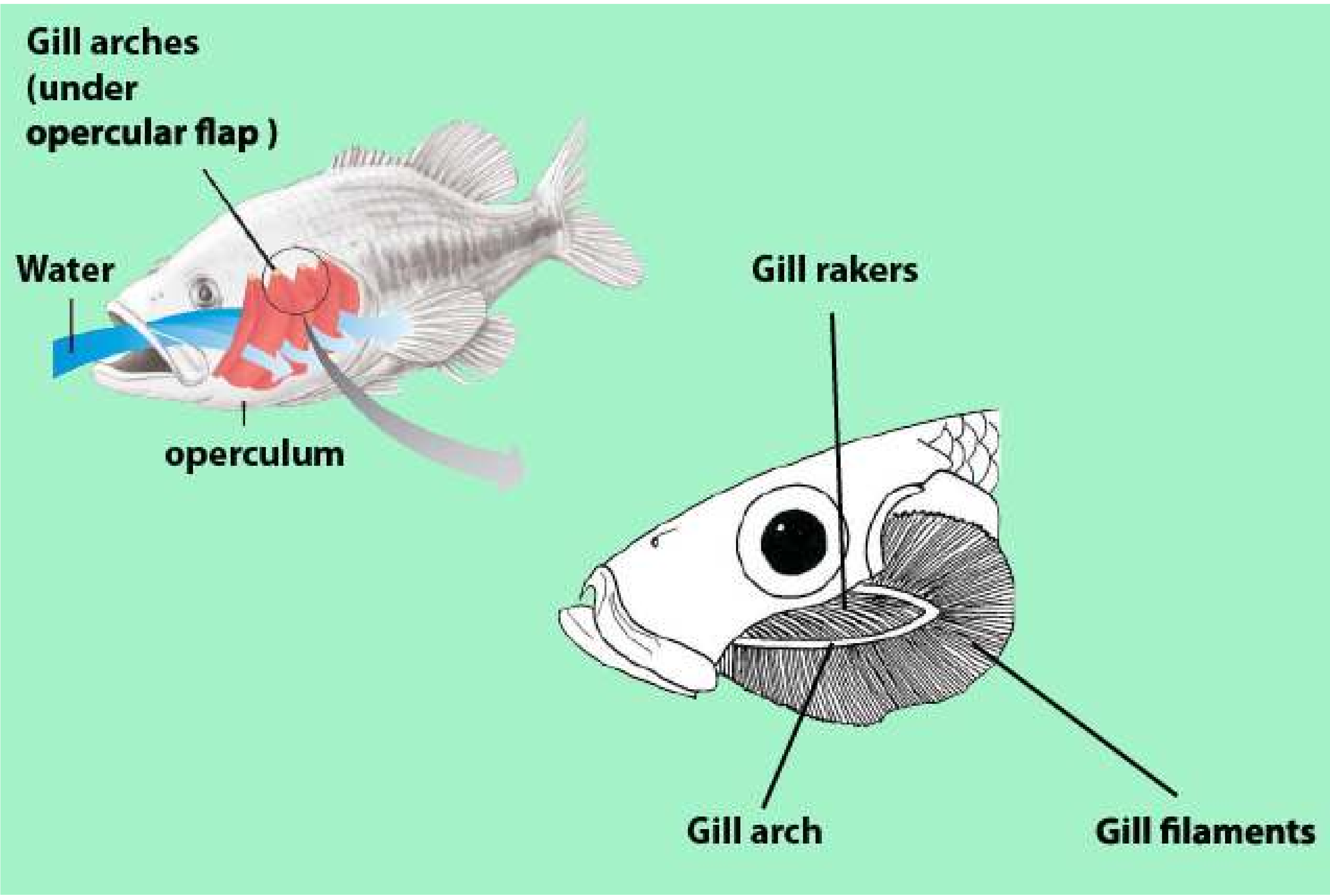


Fig. 13.5 Water flows unidirectionally over the gills of a fish.

Respiration in Frog

In frog, the gaseous exchange occurs through the lungs, by skin, and buccal chamber which are richly supplied with blood vessels. The gaseous exchange through the skin is known as cutaneous respiration.

Gaseous exchange through the lungs is called **pulmonary respiration**. In frog the air enters through the nostrils, when the nostrils are open; the mouth is closed. After entry of air the nostrils close, the floor of buccal cavity is raised, air is pushed into the lungs. This intake of air is known as **inhalation or inspiration**. Expiration occurs exactly in reverse order in sequence of inspiration.

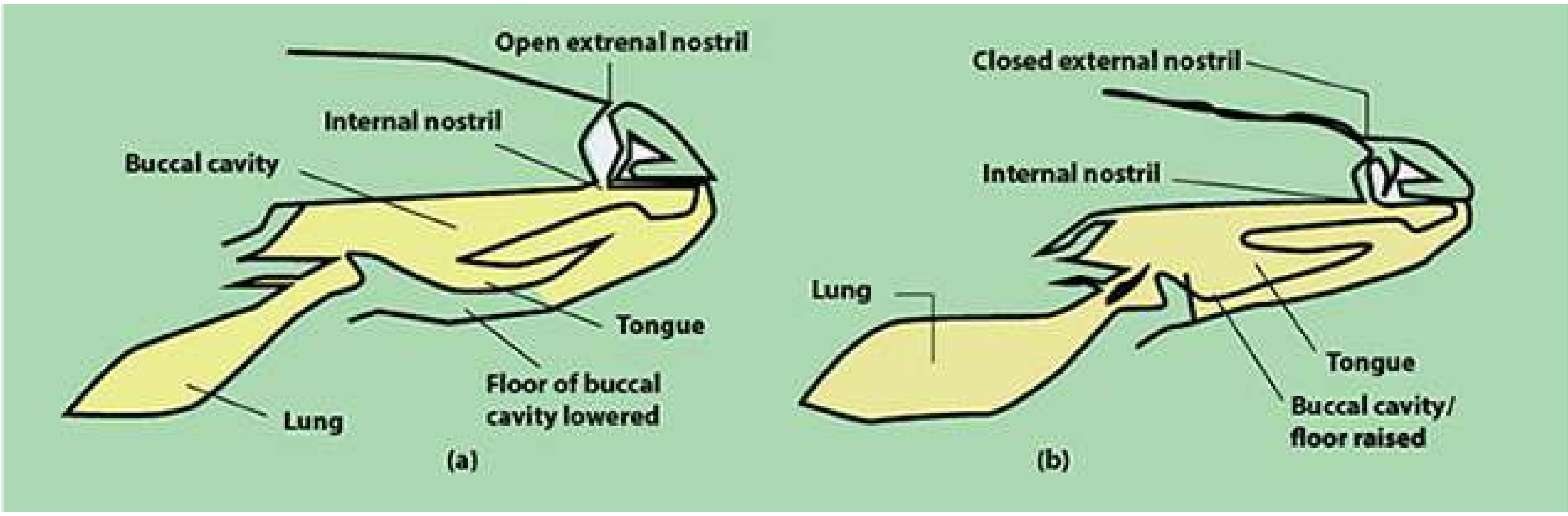


Fig. 13.6 Two stages in inspiration (buccal respiration)

Animation 13.7: Respiration in Frog
Source and Credit: clipartbest

Lungs in frog are simple sacs almost like balloon when they are fully expanded. The inner surface of lung is increased by thin walled air chambers. The walls of these air chambers are richly supplied with capillaries. These blood containing areas in the lungs are the main sites for gaseous exchange. The consumed air after gaseous exchange moves out of the lungs through the nostrils. The removal of consumed air out of the lungs, after gaseous exchange has occurred, is called **exhalation or expiration** (Fig. 13.6).

Respiration in birds

Respiratory system in birds is the most efficient and elaborate. The birds are very active animals with high metabolic rate, and thus need large amount of oxygen. The respiratory system in the birds is so arranged that there is one way flow of the air through the lungs and the air is renewed after inspiration. In the lungs of birds, tiny thin walled ducts called **parabronchi** are present instead of alveoli. These parabronchi are open at both ends and the air; is constantly ventilated. The walls of the parabronchi are chief sites of gaseous exchange. The direction of the blood flow in the lungs is opposite to that of the air flow through the parabronchi. This counter current exchange increases the amount of oxygen which enters blood. Lungs in birds are very efficient in this respect as well, because no stale of air remains in the parabronchi.

The lungs have also developed several extensions known as air sacs which reach all parts of the body and even penetrate some of the bones. In most birds the air sacs are nine in number which become inflated by air at atmospheric pressure when the rib articulations are rotated forward and upward. The inflated air sacs act as bellows and send air into the parabronchi for gaseous exchange.

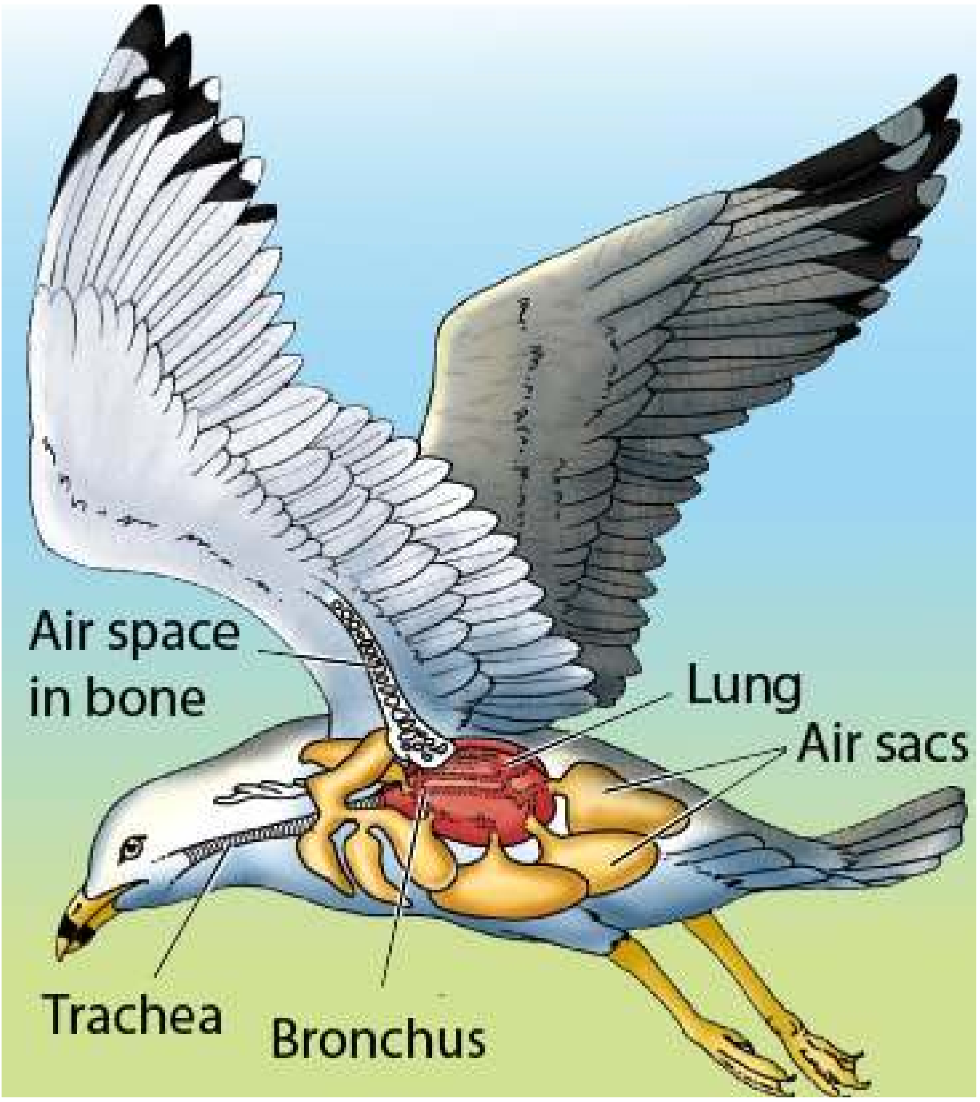
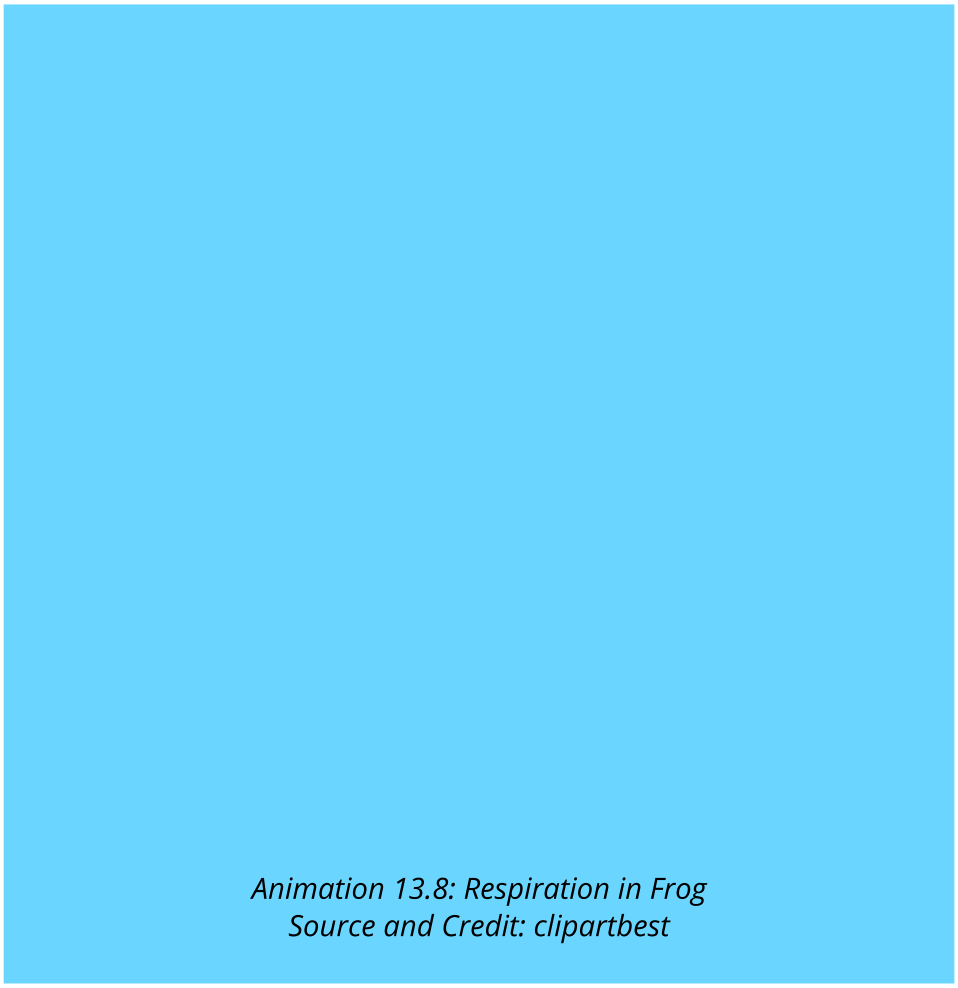


Fig. 13.7 The Respiratory System of Bird



Animation 13.8: Respiration in Frog
Source and Credit: clipartbest

Respiration in man

In man respiratory system includes lungs and air passages which are responsible for carrying fresh air to the respiratory sites.

Air Passage Ways

Air passage ways consist of nostrils, nasal cavities, pharynx, larynx, trachea, bronchi, bronchioles and alveolar ducts which ultimately lead into the alveolar sac. Nasal cavities are lined with mucous membrane of ciliated epithelium. Each nasal cavity is subdivided into three passage ways by the projection of bones from the walls of the internal nose. Air enters the nasal cavity through nostril and the larger dust particles are trapped by the hair and mucus in the nostrils. Air, while passing through the nasal cavity, becomes moist, warm and filtered of smaller foreign particles by mucous membrane. The nasal cavity leads into the throat or pharynx by two internal openings. The pharynx is a muscular passage lined with mucous membrane. The air is channelized from the pharynx into the larynx.

The **larynx** or voice box is a complex cartilaginous structure surrounding the upper end of the trachea. One of the cartilages, the epiglottis has a muscularly controlled, hinge-like action and serves as a lid which automatically covers the opening of the larynx during the act of swallowing so as to prevent the entry of food or liquids into the larynx. The opening of larynx is called glottis and is also lined with mucous membrane. In the glottis the mucous membrane is stretched across into two thin edged fibrous bands called **vocal cords,** which help in voice production, when vibrated by air.

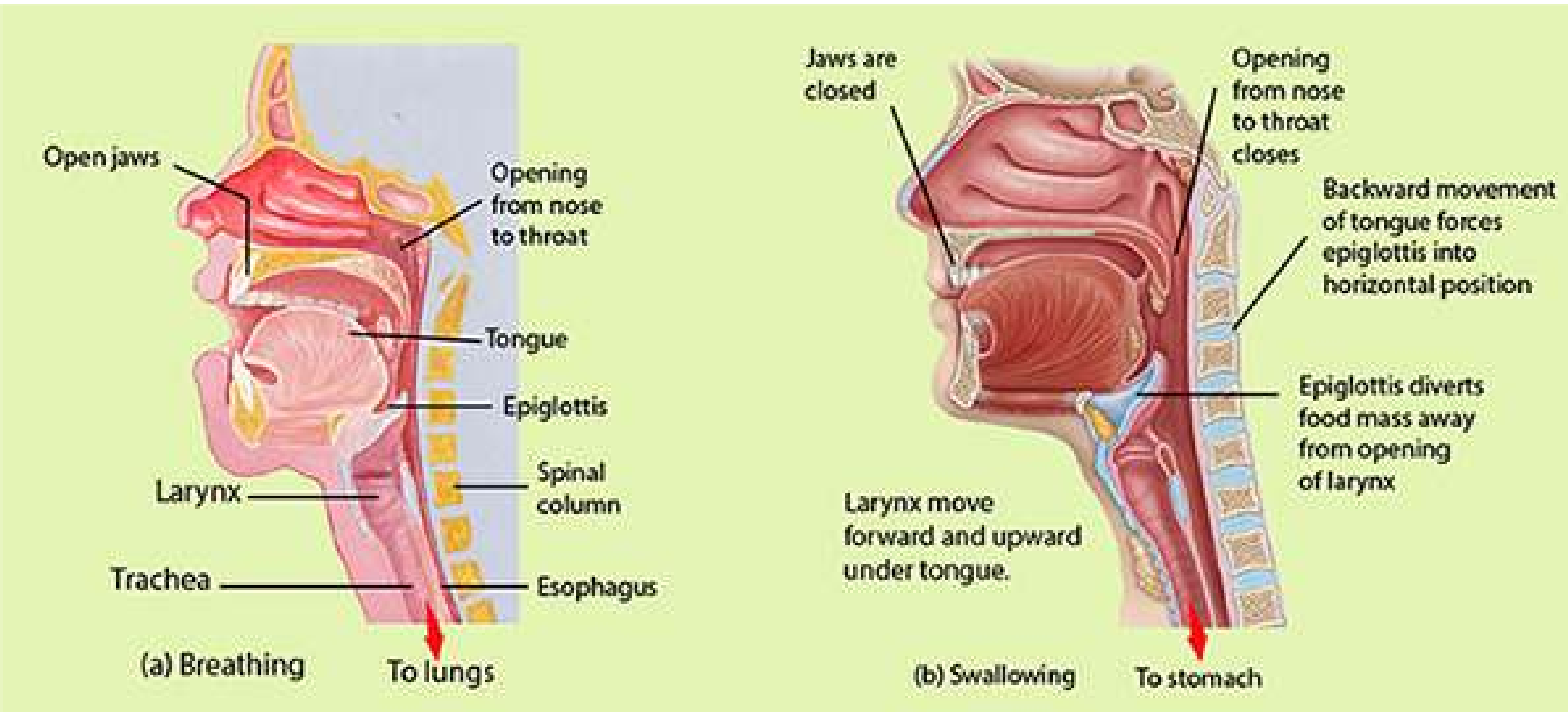


Fig. 13.8 Events in the throat associated with breathing (a) and swallowing (b). The commonly held belief that the epiglottis closes downward upon the larynx when food is swallowed is not quite true. The closure is probably never complete; the degree of closure is determined partly by the backward movement of the tongue during swallowing (which forces the epiglottis into a more or less horizontal position) and partly by the upward movement of the larynx (which brings it up under the epiglottis). Food does not enter the partly open larynx and obstruct breathing primarily because the epiglottis diverts the food mass to one side of the opening and safely down the esophagus.

The **trachea or wind Pipe** is a tubular structure lying ventral to the oesophagus and extends to the chest cavity or thorax where it is divided into right and left bronchi. In the wall of trachea there are a series of C shaped cartilage rings which prevent the trachea from collapsing and keep the passage of air open. Each bronchus on entering the lung divides and subdivides progressively into smaller and smaller **bronchi**. When the smaller bronchi attain a diameter of one mm or less, then they are called **bronchioles**. Bronchi have thesame cartilage rings as the trachea, but the rings are progressively replaced by irregularly distributed cartilage plates and the bronchioles totally lack cartilages. Bronchioles are made up of mainly circular smooth muscles.

The bronchioles continue to divide and subdivide deep into the lungs and finally open into a large number of air-sacs. Air-sac is the functional unit of the lungs. Each air-sac consists of several microscopic single layered structures called **alveoli**. Overlying the alveoli there is a rich network of blood capillaries to produce an excellent site for the exchange of gases.

The lungs are closed sacs that are connected to the outside by way of the trachea and the nostrils or mouth. Lungs are spongy because of the presence of millions of alveoli. Lungs are placed in the chest cavity. Chest cavity is bounded by ribs and muscles on the sides. The floor of the chest is called **diaphragm**.Diaphragm is a sheet of skeletal muscles. Lungs are covered with double layered thin membranous sacs called **pleura (Fig. 13.9).**

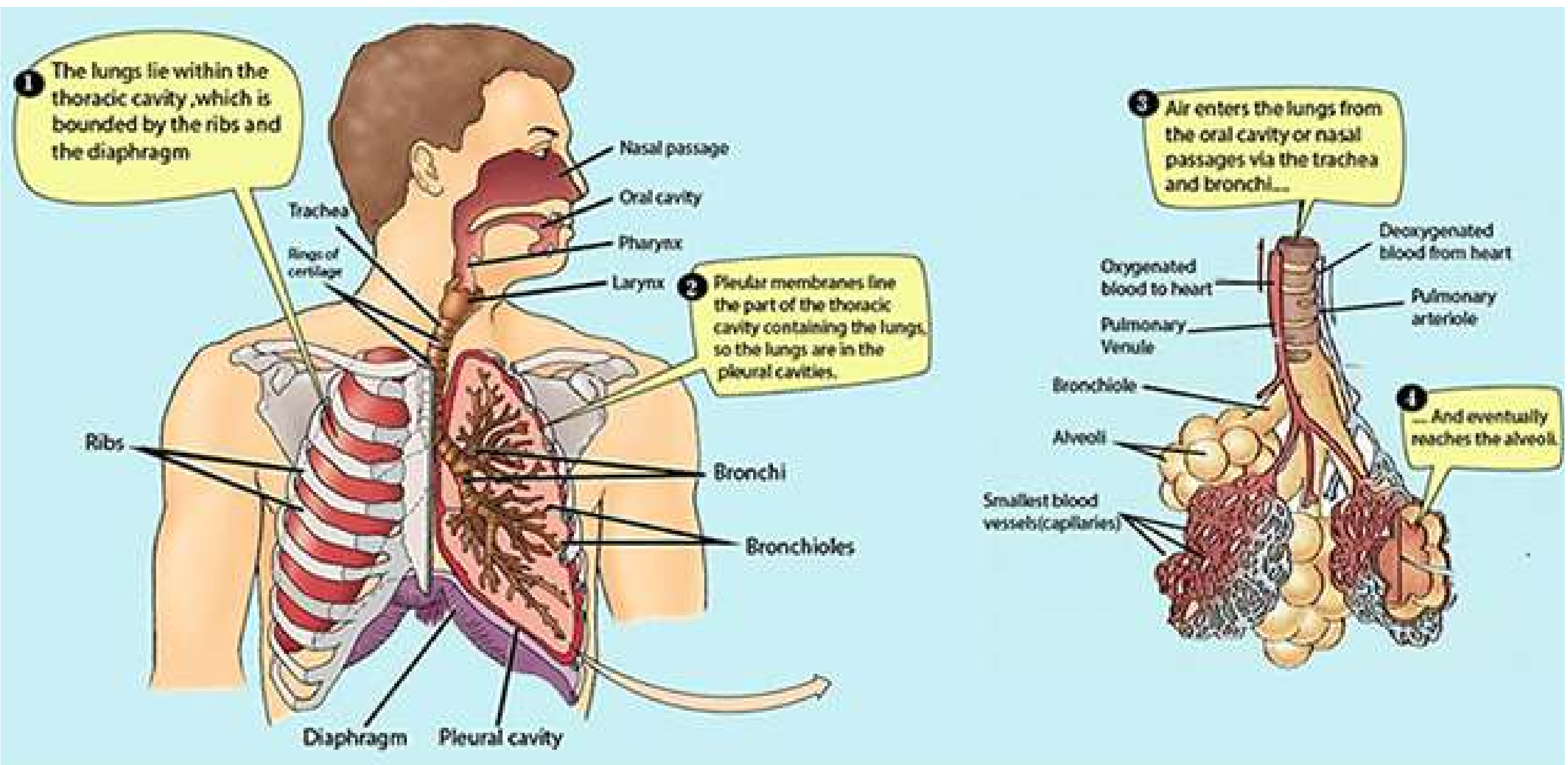


Fig. 13.9 Human respiratory organs

Animation 13.9: Respiratory System
Source and Credit: pleasanton.k12

MECHANICS OF VOLUNTARY AND INVOLUNTARY REGULATION OF BREATHING IN MAN

Breathing is a process in which fresh air containing more oxygen is pumped into the lungs and air with more carbon dioxide is pumped out of the lungs. In other words breathing is a mechanical process consisting of two phases, inspiration and expiration. During inspiration, fresh air moves in and in expiration air with low O_2 and high CO_2 content moves out of the lungs. During rest breathing occurs rhythmically at the frequency of 15 to 20 times per minute in humans. To understand the mechanism of breathing we should keep in mind three aspects related to lungs and associated structures.

1. Lungs are spongy in nature. The lungs themselves neither pull air in nor can they push it out. During inspiration passive expansion of elastic lungs occurs and expiration is due to a passive contraction of lungs.

2. The floor of the chest cavity is diaphragm, which is a muscular sheet. The snape of the diaphragm is more domelike when its muscles are relaxed. On the other hand when the muscles of the diaphragm contract its shape becomes less domelike.

3. Walls of the chest cavity are composed of ribs and intercostal muscles. When muscles between the ribs contract, the ribs are elevated and when muscles between ribs are relaxed the ribs settle down.

Inspiration

During inspiration the space inside the chest cavity is increased in two ways. Firstly, the muscles of ribs contract and elevate the ribs upwards and forwards and secondly, the muscles of diaphragm

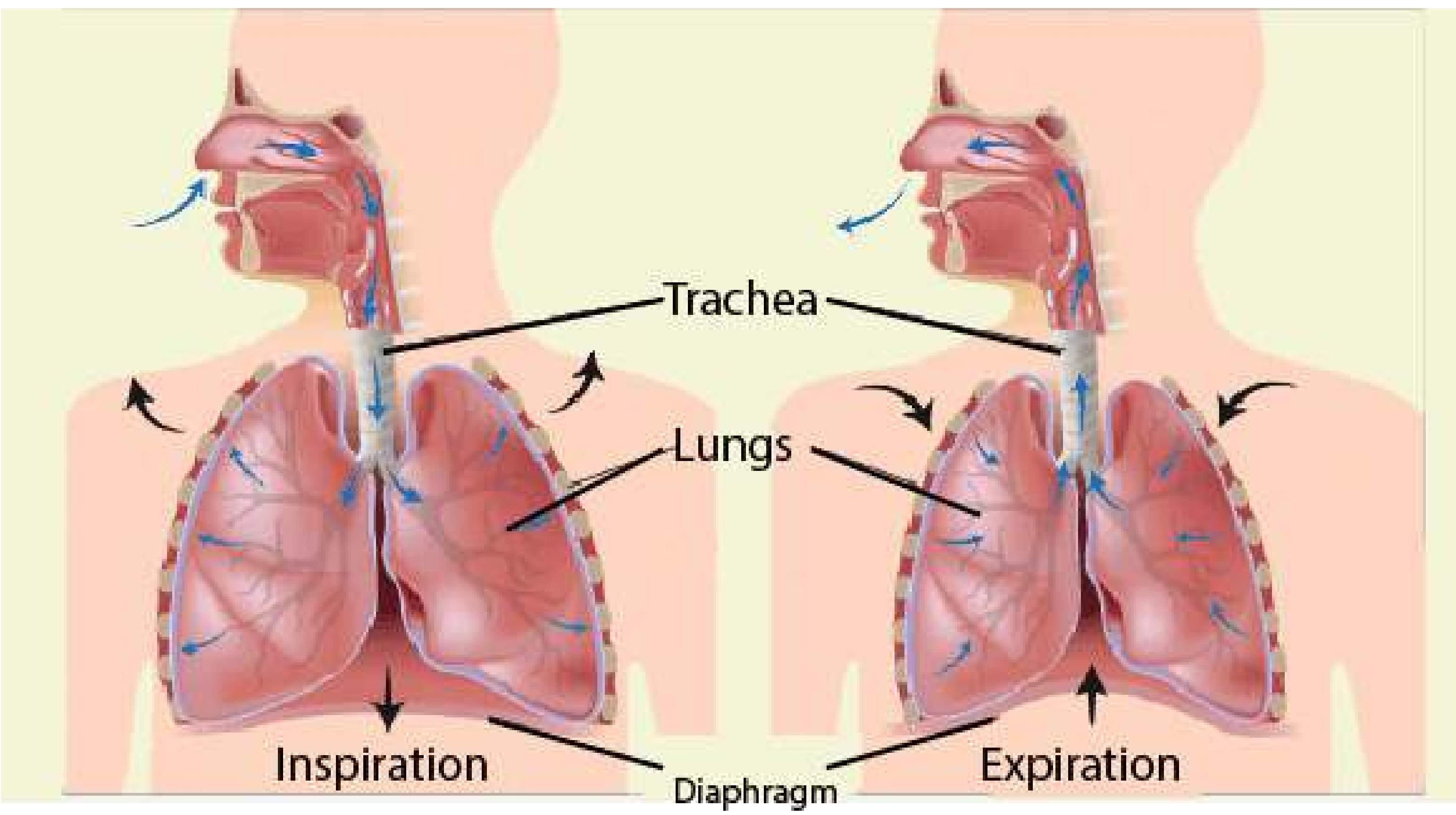


Fig. 13.10 Movement of Diaphragm

also contract and diaphragm becomes less domelike. This downward movement of diaphragm and outward and upward movement of the ribs causes increase in the chest cavity and reduces pressure. When the pressure from the lungs is removed they expand. With the expansion of the lungs vacuum is created inside the lungs in which the air rushes from the outside due to higher atmospheric pressure. This is called inspiration (Fig. 13.10,13.11)

Expiration

During expiration the muscles of ribs are relaxed and the ribs move downward and inward. In this way from the sides of chest cavity the space becomes less. At the same time the muscles of diaphragm also relax becoming more domelike and the chest cavity is also reduced from the floor. This reduction in space of the chest cavity exerts pressure on the lungs. When lungs are pressed the qir inside lungs moves out of the lungs and this is expiration. (Fig. 13.10, 13.11)

In Premature infant, **respiratory distress syndrome** *is common, especially for infant with a gestation age of less than 7 months. This occurs because enough surfactant (mixture of lipoprotein molecules produced by the secretary cells of the alveolar epithelium which forms a layer over the surface of the fluid within the alveoli to reduce the surface tension) is not produced to reduce the tendency of the lungs to collapse.*

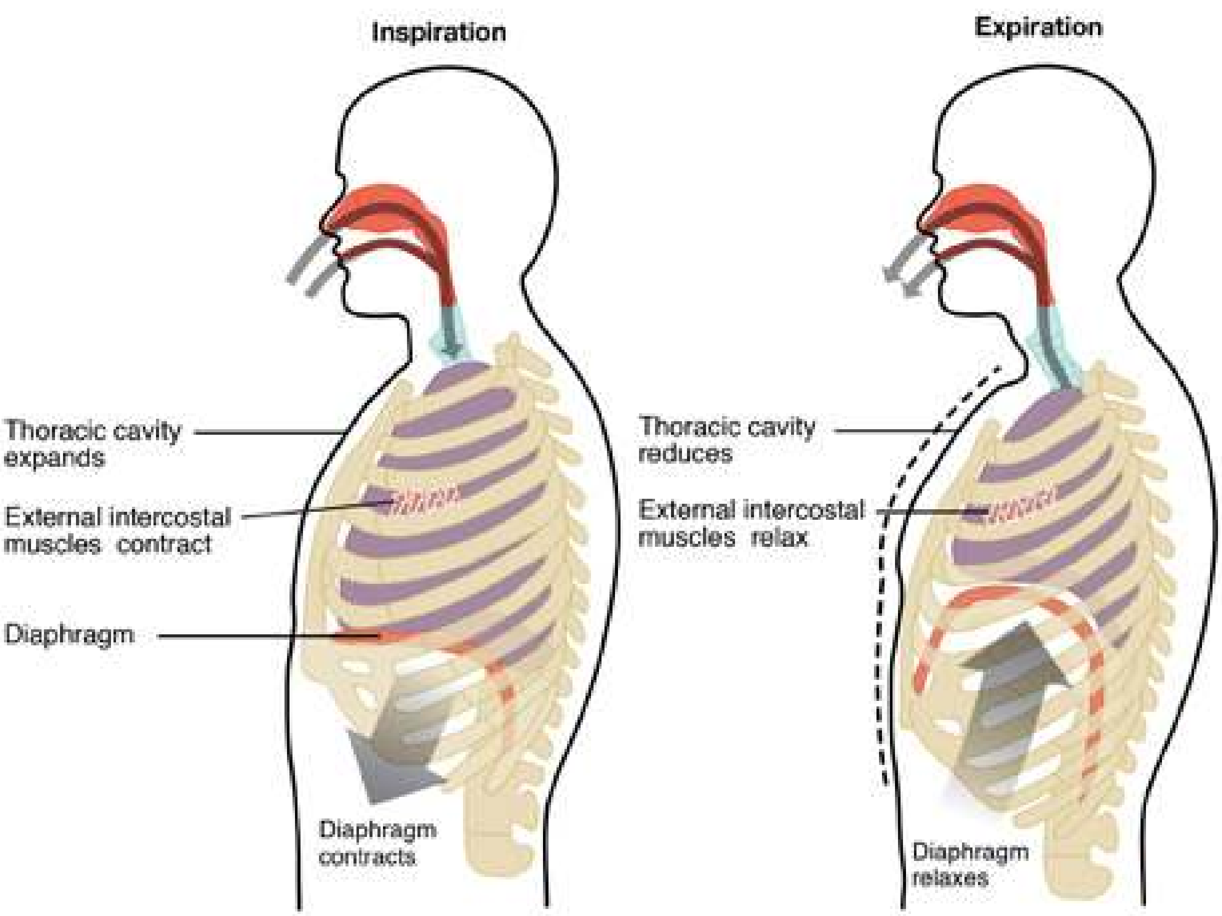


Fig. 13.11

TRANSPORT OF RESPIRATORY GASES

Intake of oxygen and release of carbon dioxide by blood passing through capillaries of alveoli is brought about by the following factors.

1. Diffusion of oxygen in and carbon dioxide out occurs because of difference in partial pressures of these gases.

2. Within the rich network of capillaries surrounding the alveoli, blood is distributed in extremely thin layers and, therefore, exposed to large alveolar surface.

3. Blood in the lungs is separated from the alveolar air by extremely thin membranes of the capillaries and alveoli.

Transport of Oxygen

In human beings the respiratory pigment is haemoglobin. It is contained in the red blood corpuscles. Haemoglobin readily combines with oxygen to form bright red oxyhaemoglobin. Oxyhaemoglobin is unistable and splits into the normal purple-red coloured haemoglobin and oxygen in the conditions of low oxygen concentration and less pressure.Carbonic anhydrase enzyme present in R.B.C. facilitates this activity. In this way haemoglobin acts as an efficient oxygen carrier. A small proportion of oxygen also gets dissolved in the blood plasma.

$$Hb + O_2 \rightleftharpoons HbO_2$$

Haemoglobin can absorb maximum oxygen at the sea level. The maximum amount of oxygen which normal human blood absorbs and carries at the sea-level is about 20ml/100ml of blood. This is the maximum capacity of haemoglobin for oxygen when it is fully oxygenated. Under normal conditions, blood of alveoli of the lungs is not completely oxygenated. When an oxygen tension is 115mm mercury, haemoglobin is 98 percent saturated and, therefore, contains 19.6 ml of oxygen per 100ml of blood. This means that haemoglobin can be almost completely oxygenated by an oxygen pressure of 100 mm mercury, which is present in the lungs. Any higher oxygen pressure would have the same result. When oxygen pressure falls below 60 mm mercury, as in many cells and tissues, the oxygen saturation of haemoglobin decreases very sharply. This results in the liberation of large quantities of oxygen from haemoglobin. In this way in the tissue where oxygen tension is low oxyhaemoglobin dissociates rapidly.

As a scuba diver descends in the sea, the pressure of the water on his body prevents normal expansion of the lungs. To compensate, the diver breaths pressurized air from air cylinders, which has a greater pressure than sea level air pressure.

There are three important factors which affect the capacity of haemoglobin to combine with oxygen.

1. Carbon dioxide

When carbon dioxide pressure increases, the oxygen tension decreases, the capacity of haemoglobin to hold oxygen becomes less. In this way increased carbon dioxide tension favours the greater liberation of oxygen from the blood to the tissue.

2. Temperature

Rise in temperature also causes a decrease in the oxygen-carrying capacity of blood, e.g., in the increased muscular activity.

3. pH

The pH of blood also influences the degree to which oxygen binds to haemoglobin. As the pH of the blood declines, the amount of oxygen bound to haemoglobin also declines. This occurs because decreased pH results from an increase in hydrogen ions, and the hydrogen ions combine with the protein part of the haemoglobin molecules, causing a decrease in the ability of haemoglobin to bind oxygen. Conversely, an increase in blood pH results in an increased ability of haemoglobin to bind oxygen.

Transport of Carbon Dioxide

Carbon dioxide is more soluble than oxygen and dissolves freely in the tissue fluid surrounding the cells. From the tissue fluid, dissolved carbon dioxide passes to the plasma within the blood capillaries.

Carbon dioxide which is much more important than oxygen as a regulator of normal alveoler ventilation (Breathing) but under certain circumstances a reduced $P0_2$ (partial pressure of the oxygen) in the arterial blood does play an important stimulatory role especially during conditions of shock.

Carbon dioxide is transported in the blood in several different states.

1. Some of the carbon dioxide (about 20%) is carried as carboxyhaemoglobin. Carboxyhaemoglobin is formed when carbon dioxide combines with amino group of haemoglobin.

2. Other plasma proteins also carry about 5% carbon dioxide from the body fluids to the capillaries of lungs.

3. About 70% carbon dioxide is carried as bicarbonate ion combined with sodium in the plasma. As carbon dioxide from tissue fluid enters the capillaries it combines to form carbonic acid.

$$CO_2 + h_2O \xrightarrow{\text{Corbonic anhydrase}} H_2CO_3$$

The carbonic acid splits quickly and ionizes to produce hydrogen ions and bicarbonate ions.

$$H_2CO_3 \longmapsto H^+ + HCO_3^-$$

When blood leaves the capillary bed most of the carbon dioxide is in the form of bicarbonate ions. All these reactions are reversible. In the lungs bicarbonate ions combine with hydrogen ions to form carbonic acid which splits into water and carbon dioxide. It is this carbon dioxide which diffuses out from the capillaries of the lungs into the space of alveolar sac.

$$HCO_3^- + H^+ \longmapsto H_2CO_3 \longmapsto CO_2 + H_2O$$

4. Small amount of carbon dioxide is also carried by corpuscles combined with potassium.

Carbon Dioxide Concentration in Arterial And Venous Blood

It has been found that arterial blood contains about 50 ml of carbon dioxide per 100 ml of blood whereas venous blood has 54 ml of carbon dioxide per 100 ml of blood. In this way each 100 ml of blood takes up just 4 ml of carbon dioxide as it passes through the tissues and gives off 4 ml of carbon dioxide per 100 ml of blood as it passes through the lungs.

Respiratory Disorders

Cancer

Many problems in the respiratory system can take place if inside lining is exposed continuously to unhealthy air, containing smoke and other pollutants. Lung cancer is one of the most serious diseases of respiratory system. Cancer or carcinoma is basically malignant tumor of potentially unlimited growth that expands locally by invasion and systemically by metastasis. Cancer can occlude respiratory passages as the tumor replaces lung tissue. Smoking especially in young adults is the most potential threat of lung cancer. The chances of lung cancer are ten times more in those persons who smoke or live in smoky and congested areas as compared to those who do not smoke. It is now estimated that 90% of lung cancer is caused by smoking. Recent research indicates that more than ten compounds of tar of tobacco smoke are involved in causing cancer.

Tuberculosis

Tuberculosis is a disorder of respiratory system. In fact, it is the general name of a group of diseases caused by *Mycobacterium tuberculosis*. Pulmonary tuberculosis is a disease of lungs in which inside of the lung is damaged resulting in cough and fever. It is more common in poor people. Malnutrition and poor living conditions facilitate *Mycobacterium* to grow. The disease is curable with proper medical attention. It is a contagious disease.

Asthma

Asthma is a serious respiratory disease associated with severe paroxysm of difficult breathing, usually followed by a period of complete relief, with recurrence of attack at more or less frequent intervals. It is an allergic reaction to pollen, spores, cold, humidity, pollution etc which manifests itself by spasmodic contraction of small bronchiole tubes. Asthma results in the release of inflammatory chemicals such as histamines into the circulatory system that cause severe contraction of the bronchiole.

Emphysema

Emphysema is a break down of alveoli. This respiratory problem is more common among smokers. The substances present in the smoke of the tobacco weaken the wall of alveoli. The irritant substances of smoke generally cause "smoker's cough" and coughing bursts some of the weakened alveoli. In the result of constant coughing the absorbing surface of the lung is greatly reduced. The person suffering from emphysema cannot oxygenate his blood properly and least exertion makes him breathless and exhausted.

In patients with emphysema, alveolar walls degenerate and small alveoli combine to form larger alveoli. The result is fewer alveoli, but alveoli with an increased volume and decreased surface area. Although the enlarged alveoli are still ventilated, there is inadequate surface area for complete gas exchange, and the physiological dead air space is increased.

Emphysema produces increased airway resistance because the bronchioles are obstructed as a result of inflammation and because damaged bronchioles collapse during expiration, trapping air within the alveolar sacs.

Role of Respiratory Pigments

Various types of respiratory pigments are present in different animals. The pigment combines with oxygen reversibly and increase the oxygen carrying capacity of the blood. Haemoglobin is the most important protein present in many animals including man. Haemoglobin in man increases the oxygen carrying capacity of the blood to about 75 times. You are familiar with its chemical composition.

Myoglobin is haemoglobin-like iron-containipg protein pigment occurring in muscle fibers. Myoglobin is also known as muscle haemoglobin. It serves as an intermediate compound for the transfer of oxygen from haemoglobin to aerobic metabolic processes of the muscle cells. It can also store some oxygen. Myoglobin consists of just one polypeptide chain associated with an iron-containing ring structure which can bind with one molecule of oxygen. The affinity of myoglobins to combine with oxygen is much higher as compared to haemoglobin.

Diving reflex

Aquatic mammals especially cetaceans can stay in the depth of the ocean for about two hours without coming up for air.

Diving mammals have almost twice the volume of blood in relation to their body weight as compared to non divers. Most of the diving mammals have high concentration of myoglobin in their muscles. Myoglobin binds extra oxygen.

When a mammal dives to its limit the diving reflex is activated. The breathing stops, the rate of heart beat slows down to one tenth of the normal rate, theconsumption of oxygen and energy is reduced. The blood is redistributed but most of the blood goes to the brain and heart which can least withstand anoxia. Skin muscles and digestive organs and other internal organs receive very little blood while an animal is submerged because these areas can survive with less oxygen. Muscles shift from aerobic to anaerobic respiration.

Lung capacities

In an adult human being when the lungs are fully inflated the total inside capacity of lungs is about 5 litres. Normally when we are at rest or asleep the exchange is only about half a litre. The volume of air taken inside the lungs and expelled during exercise is about 3.5 litres. In other words, there is a residual volume of 1.5 litres even during exercise which cannot be expelled.

Normally, at rest we inhale and exhale 15-20 times per minute. During exercise the breathing rate may rise to 30 times per minute. The increased rate and depth of breathing during exercise allows more oxygen to dissolve in blood and supplied be to the active muscles. The extra carbon dioxide which the muscle puts into the blood is removed by deep and fast breathing. There is a little change in the composition of inhaled and exhaled air during rest or exercise in most of the constituents of the air as seen in the Table 13.1

Table 13.1. Changes in the composition of the breathed air

	Inhaled %	Exhaled %
Oxygen	21	16
Carbon dioxide	0.04	4
Water vapours	variable	saturated
Nitrogen	79	79

EXERCISE

Q .1 Fill in the blanks

(i) ____________ is the most abundant protein in the world.

(ii) Haemoglobin is a complex molecule which contains 9512 atoms and _________amino acids.

(iii) The opening of larynx is called ____________________.

(iv) When the smaller bronchi attain the diameter of___________mm or less they are called bronchioles

(v) There are about ___________ stomata per square centimeter of leaf surface of tobacco plant

Q.2. Write whether the statement is true or false. Correct the statement if it is false.

(i) ATP is generated during organismic respiration .
(ii) Water is a better respiratory medium than air.
(iii) The earthworm does not possess specialized organs for respiration.
(iv) In parabronchi of birds, the blood flows in the opposite direction of air flow.
(v) Ring shaped cartilages are present in trachea of man.

Q.3. Short questions

(i) How does breathing differ from respiration?

(ii) How much carbon dioxide is present in venous and arterial blood?

(iii) How does air always remain in the lungs of human beings?

(iv) What are the products which are produced during photorespiration?

(v) How much denser is a water medium than air medium for exchange of respiratory gases?

Q.4 Extensive questions

(i) In what ways is air a better respiratory medium than water?
(ii) What is photorespiration? Give its consequences.
(iii) Describe briefly the properties of respiratory surfaces in cockroach.
(iv) In what ways is respiration in birds the most efficient and elaborate?
(v) Discuss the mechanical aspects of breathing in man.
(vi) Write a detailed note on respiratory pigments.
(vii) List the air passage way in sequence from nostrils to alveoli. Describe the structure of alveolus in detail.