

Chapter 13

Gaseous Exchange

13.1 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 by which energy is released and supplied for the activities of living organisms.

Levels of Respiration

Respiration occurs at two levels i.e. organismic and cellular.

Organismic Respiration

Gaseous exchange between organism and environment is called organismic respiration. It is also called ***breathing or ventilation***.

Cellular Respiration

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.

13.2 ADVANTAGES AND DISADVANTAGES OF GAS EXCHANGE IN AIR AND WATER

Respiratory gases are exchanged between body fluid and outside medium, which may be water or air.

- Exchange of gases at organismic level is only by ***diffusion***.
- Active transport has no role in exchange of gases across biological membrane.
- Oxygen can be obtained more easily from air than from water. Air is better respiratory medium than water.

Reasons

Reasons for air being a better medium than water are as follows;

i) Oxygen Contents

Oxygen content of air is much higher than the oxygen content of equal volume of water. One litre of water contains 10ml of oxygen while one litre of air contains 200ml of oxygen.

ii) Rate of Diffusion

Oxygen diffuses about ***8000 times*** more quickly in air than in water.

iii) Density and Ventilation

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 denser*** than air.

iv) Viscosity

Water is 50 times more viscous than air. It makes the exchange of gases difficult.

QUESTION RELATED TO ABOVE ARTICLE

In what ways air is better respiratory medium than water? (Exercise Question i)

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13.3 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.
- The roots of the land plants get their oxygen form the air existing in the spaces between the soil particles.
- Aquatic plants obtain their oxygen by diffusion from dissolved oxygen in water.

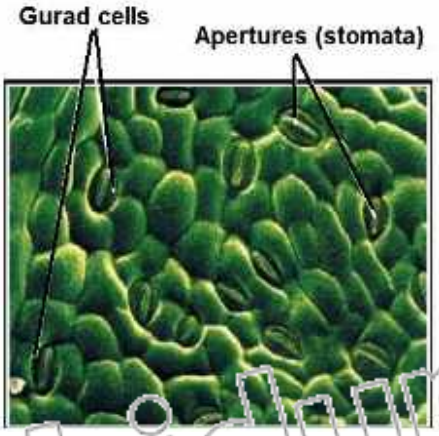


Fig 13.1 Stomata on leaf surface

QUESTION RELATED TO ABOVE ARTICLE

Describe gaseous exchange in plants. (GRW 2009)

13.3.(a) Photorespiration and its Consequences

Definition

Respiratory activity that occurs in plants during daytime is called photorespiration.

Basic Principle

In the process of photorespiration, carbon dioxide is released and oxygen is absorbed. It usually occurs when oxygen concentration increases in leaves during photosynthesis.

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Substances Involved

Various substances involved during photorespiration are as follows;

i) Ribulose 1,5-bisphosphate (RuBP)
ii) Oxygen
iii) Rubisco

Role of Rubisco

- Rubisco can act in two different ways i.e. ribulose bisphosphate carboxylase, which fixes CO_2 and ribulose bisphosphate oxygenase, which fixes oxygen.
- In photorespiration, ribulose bisphosphate oxygenase is involved.
- The most important factor, which decides when rubisco will act as an oxygenase or carboxylase is relative concentration of carbon dioxide and oxygen in leaf.

When more oxygen is present, it acts as oxygenase and photorespiration starts. On the other hand, if carbon dioxide is more then Calvin-Benson cycle starts.

Condition for Occurrence of Photorespiration

In a hot and dry day, level of oxygen inside the leaf rises. This is because the stomata close to prevent loss of water. 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.

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

Different steps involved during this process are as follows;

First Step

In first step, rubisco (most abundant protein in world out of which oxygenase comprises about 20% of all rubisco) oxygenase fixes O_2 to RuBP, which converts into two carbon compound glycolate.

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

Second Step

Glycolate diffuses into the Peroxisomes. In the Peroxisomes, the glycolate is converted into glycine, through a series of reactions.

$$\text{Glycolate} \rightarrow \text{Glycine}$$

Third Step

Glycine (simplest amino acid) diffuses into mitochondria where two glycine molecules are converted into serine and a molecule of CO_2 is formed.

$$2\ \text{Glycine} \rightarrow \text{Serine} + CO_2$$

Due to these processes, photorespiration is also called that process by which RuBP is converted into serine.

Advantage and Disadvantage of Photorespiration

- ***Advantage*** of photorespiration is that it reduces excess oxygen from plant body.
- ***Disadvantage*** of photorespiration is that during this process ATP molecules are not produced, so it reduces growth of plant.

Comparison of Photorespiration and Calvin Cycle

Both photorespiration and Calvin-Benson cycle use ATP and NADPH produced in the light reactions. But photorespiration is reverse of Calvin cycle.

Some of the differences are as follows.

Photorespiration	Calvin cycle
Oxygen is fixed	Carbon dioxide is fixed
Carbon dioxide is produced	Oxygen is produced
Oxygenase (rubisco) is involved	Carboxylase (rubisco) is involved
It retards growth	It promotes growth

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Relation of Photorespiration with Evolution

Photorespiration is not essential for plants, yet occurs in some plants. If photorespiration is inhibited chemically, the plant can still grow.

Initially when oxygen was less in atmosphere, it was not present. It started when the quantity of oxygen increased in plant body and atmosphere.

QUESTION RELATED TO ABOVE ARTICLE

Explain in detail the photorespiration.

What is photorespiration? Give its consequences. (Exercise Question ii)

13.4 RESPIRATORY ORGANS IN REPRESENTATIVE AQUATIC AND TERRESTRIAL ANIMALS

13.4 (a) Properties of respiratory surfaces in animals

Respiratory Surface

This is site where gaseous exchange takes place.

Features

The respiratory surface in most animals exhibits following features

1) Large Surface and Moisture

The surface area should be large and kept moist as it is seen in the lungs in the land vertebrates and in the gills in 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-celled 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 cross over all the time at an adequate speed. In this way steep diffusion gradient is maintained which helps in rapid diffusion of oxygen.

13.4.1 Respiration in Hydra

Hydra has no specialized organs for respiration.

Mechanism of Respiration

Gaseous exchange i.e. intake of oxygen and removal of carbon dioxide, occurs through the entire general surface in contact with water.

Exchange of gases also occurs in cells lining the digestive cavity. In this way surface lining of the enteron acts as an efficient respiratory surface.

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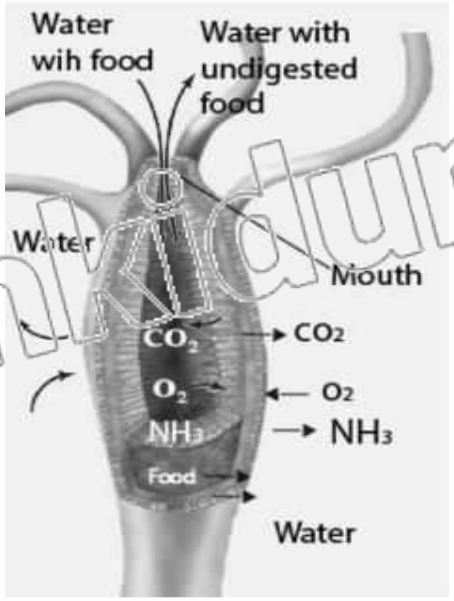


Fig 13.2: Respiration in Hydra

13.4.2 Respiration in Earthworm

Although earthworm is much complex than hydra, yet is does not have any specialized respiratory organs.

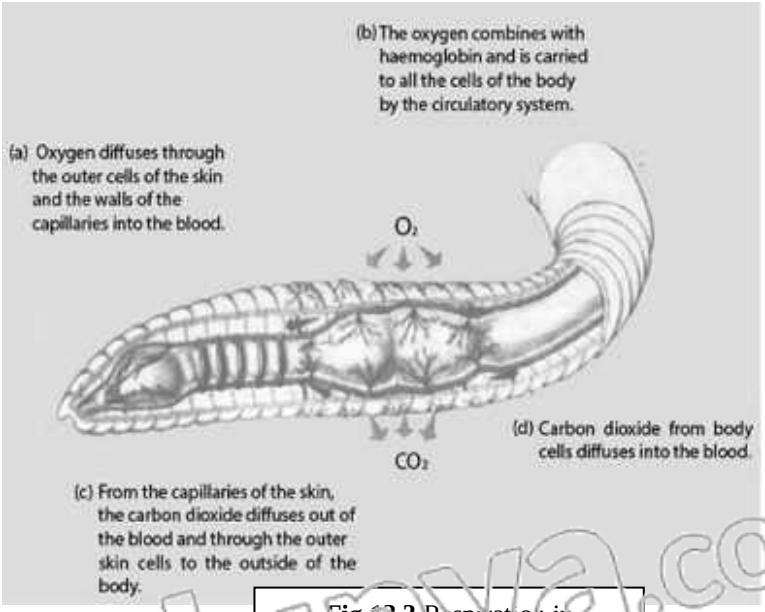


Fig 13.3 Respiration in

Mechanism of Respiration

Gaseous Exchange

Gaseous exchange mainly occurs through skin. Skin is richly supplied with blood capillaries and is always kept moist by the secretions of epidermal mucous gland cells and also by coelomic fluid through the dorsal pores.

Transport of Oxygen

Oxygen dissolved on the wet surface passes through the cuticle and epidermal cells into the blood. In the blood, oxygen combines with hemoglobin to form ***oxyhemoglobin***. Oxyhemoglobin releases oxygen at tissue level.

In earthworm blood does not come in direct contact with tissue cells so oxygen diffuses through tissue fluids and coelomic fluids.

Removal of Carbon Dioxide

Carbon dioxide is removed from the tissues by the blood and carried in plasma to skin, from where it is excreted.

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13.4.3 Respiration in Cockroach

Respiratory System

Cockroach has specialized organs for respiration. Its respiratory system is very specialized consisting of branching system of air tubules called ***tracheae*** lined by chitin.

Various components of tracheal system are explained as follows:

Spiracles

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.

Trachea

Main tracheal trunk is lined by chitin. Main trachea divides and subdivides forming very fine thin walled tubules called ***tracheoles***. These tracheoles end into blind ducts partly filled with fluid, in which the oxygen dissolves.

End Cells

These surround the organs and tissues and directly supply oxygen to the living cells.

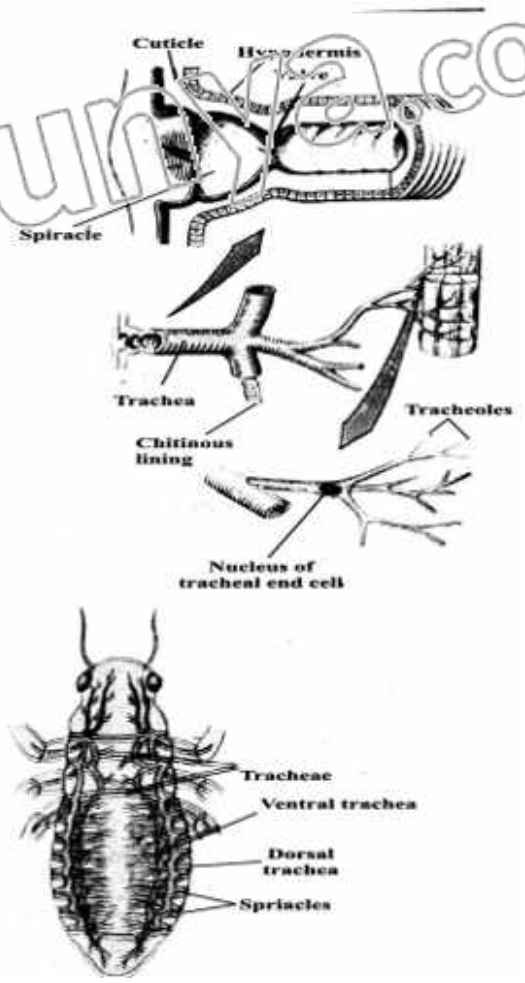


Fig 13.4 Respiration in Cockroach

Pathway of Gaseous Exchange

Air enters through spiracles into trachea. From trachea it moves to tracheoles where gaseous exchange between tissue cells and air in tracheole takes place.

Air is directly supplied to cells and ***blood is not involved.***

Mechanism of Gaseous Exchange

Air moves into and out of the spiracles due to two factors i.e.

- ***Concentration gradient*** between trachea and spiracles due to which air diffuses into trachea from outside.
- The movement of air through tracheal trunk is facilitated through contraction of ***abdominal muscles*** **(dorsoventral muscles)**.
- When abdomen expands, the **first four pairs** of spiracles open, air rushes in through these spiracles into tracheoles.
- When abdomen contracts, the anterior four pairs of spiracles close and posterior **six pairs** of spiracles open, due to which air is forced out of spiracles.

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13.4.4 Respiration in Fish

Respiratory Structures

Gills are most effective and highly modified for gaseous exchange in aquatic animals.

Features of Gills

- Gills are paired structures present on either side of the body almost at the junction of head and trunk.
- They are in ***four to five pairs***, which may open through gill slits and are visible on surface of pharynx (cartilaginous fishes) or are placed in bronchial cavities covered by operculum (bony fishes).
- They have ***great surface area*** for gaseous exchange. Their surface is all the time ventilated by constant flow of water.

Mechanism of Gaseous Exchange

Water carrying oxygen enters the mouth and after passing over the gills moves out of the body through the gill openings. At gills level, oxygen enters the blood and carbon dioxide escapes out.

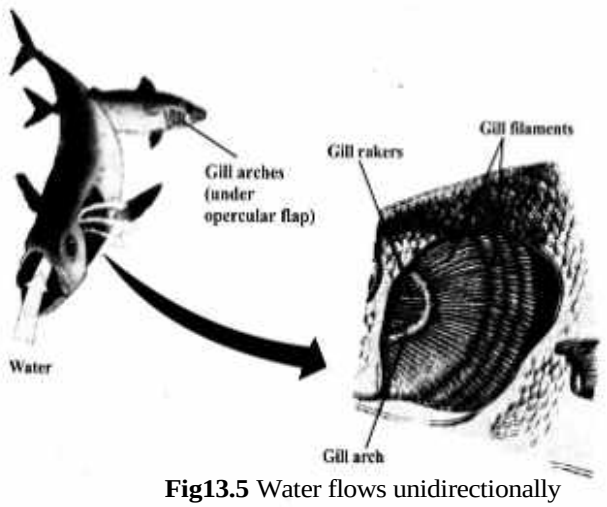


Fig13.5 Water flows unidirectionally over the gills of a fish.

Transport of Gases

- Heart pumps the blood to gills from where oxygenated blood is carried to all parts of the body.
- The deoxygenated blood from different parts of the body is received by heart. Heart of fish is single circuit and blood flows in one direction only.
- Blood enters in posterior side of heart and after passing through different chambers is pumped to gills.

13.4.5 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.
- 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**.

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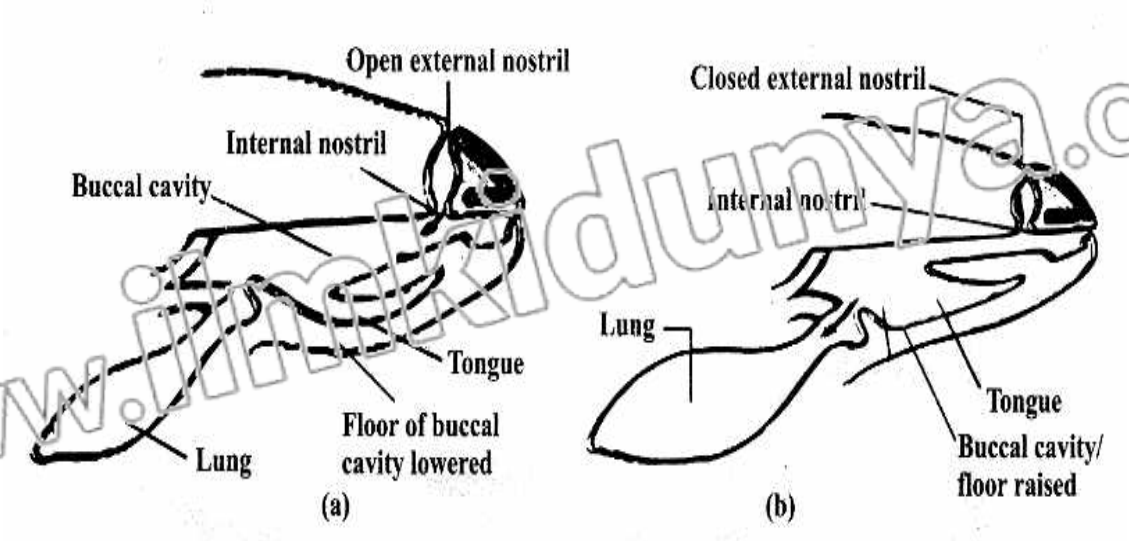


Fig 13.6 Two stages in inspiration (buccal respiration)

13.4.6 Respiration in Birds

Respiratory System

Respiratory system in birds is most efficient and elaborate.

Their respiratory system is arranged so that there is one-way flow of the air through the lungs and the air is renewed after inspiration.

Various features of respiratory structures in birds are as follows;

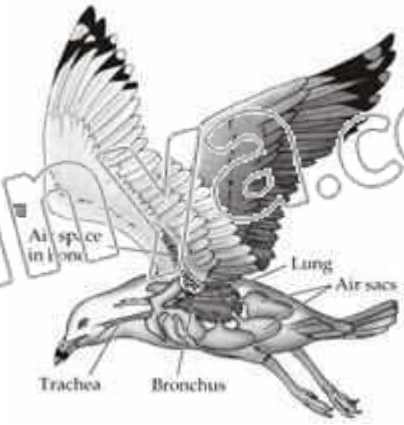
i) Lungs

There are two balloon-like lungs present in chest cavity.

Lungs of birds are very efficient in the respect that no stale air remains in the parabronchi.

ii) Air Sacs

- Lungs in birds have developed several extensions known as air sacs, which reach into all parts of the body and even penetrate some of the bones.
- In most birds, air sacs are **nine** in number, which become inflated by the atmospheric pressure when the ribs articulate and rotate forward and upward. Inflated air sacs act as bellows and send air into the parabronchi for gaseous exchange.



iii) Parabronchi

In lungs of birds, instead of alveoli tiny thin-walled ducts are present called parabronchi.

- Parabronchi are open at both ends and the air is constantly ventilated.
- Walls of parabronchi are chief sites of gaseous exchange.

Mechanism of Respiration

Air enters from nostrils to trachea and then to lungs, where gaseous exchange takes place. The direction of blood flow in the lungs is opposite to the airflow through the parabronchi. This ***counter current exchange*** increases the amount of oxygen, which enters the blood.

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QUESTION RELATED TO ABOVE ARTICLE

Explain the respiration in hydra.
Write note on the respiration in birds.
Describe the respiration in cockroach.
Describe the gases exchange in frog.
Describe the gases exchange in fishes.
Briefly describe the properties of respiratory surfaces in cockroach. (Exercise Question iii)
In what ways respiration in birds is the most efficient and elaborate? (Exercise Question iv)

13.5 RESPIRATION IN MAN

In man respiratory system includes;
Lungs
Air Passages
Which are responsible for carrying fresh air to the respiratory sites.

Air Passage Ways

Air passage ways consist of;

1. Nostrils
2. Nasal Cavities
3. Pharynx
4. Larynx
5. Trachea
6. Bronchi
7. Bronchioles
8. Alveolar ducts
9. Which ultimately lead into the alveolar sac.

Nasal cavities

10. Nasal cavities are lined with mucous membrane of ciliated epithelium.
11. Each nasal cavity is subdivided into three passage ways by the projection of bones from the walls of the internal nose.
12. Air enters the nasal cavity through nostril and the larger dust particles are trapped by the hair and mucus in the nostrils.
13. Air, while passing through the nasal cavity, becomes moist, warm and filtered of smaller foreign particles by mucous membrane.
14. The nasal cavity leads into the throat or pharynx by two internal openings.

Pharynx

The pharynx is a muscular passage lined with mucous membrane. The air is channelized from the pharynx into the larynx.

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.

Glottis

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.

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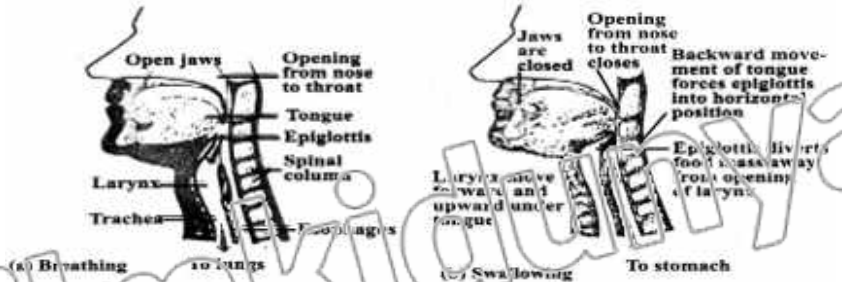


Fig. 13.8 Events in the throat associated with breathing (a) and swallowing (b). The commonly held belief that the epiglottis closes downward upon the larynx when food is swallowed is not quite true. The closure is probably never complete; the degree of closure is determined partly by the backward movement 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 to one side of the opening and safely down the esophagus.

Trachea

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.

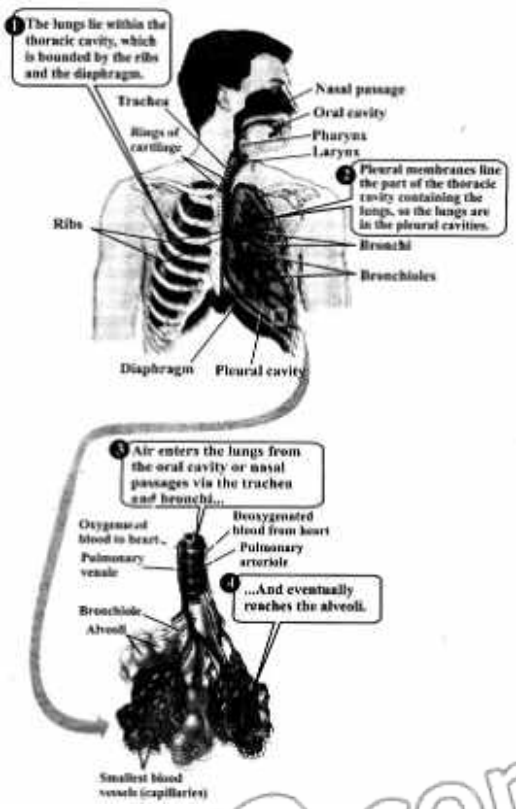


Fig. 13.9 Human respiratory organs

Bronchus and Bronchi

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 the same 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.

Air Sac

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.

Alveoli

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.

Lungs

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.

Diaphragm

Chest cavity is bounded by ribs and muscles on the sides. The floor of the chest is called ***diaphragm which is a sheet of skeletal muscles.***

Pleura

Lungs are covered with double layered thin membranous sacs called **pleura.**

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QUESTION RELATED TO ABOVE ARTICLE

List the air passage way in sequence from nostrils to alveoli. Describe the structure of alveolus in detail. **(Exercise Question vii)**

13.5.1 MECHANICS OF VOLUNTARY AND INVOLUNTARY REGULATION OF BREATHING IN MAN

Breathing

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
- Expiration

During inspiration, fresh air moves in and during 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 shape 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.

13.5.1 (a) 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.

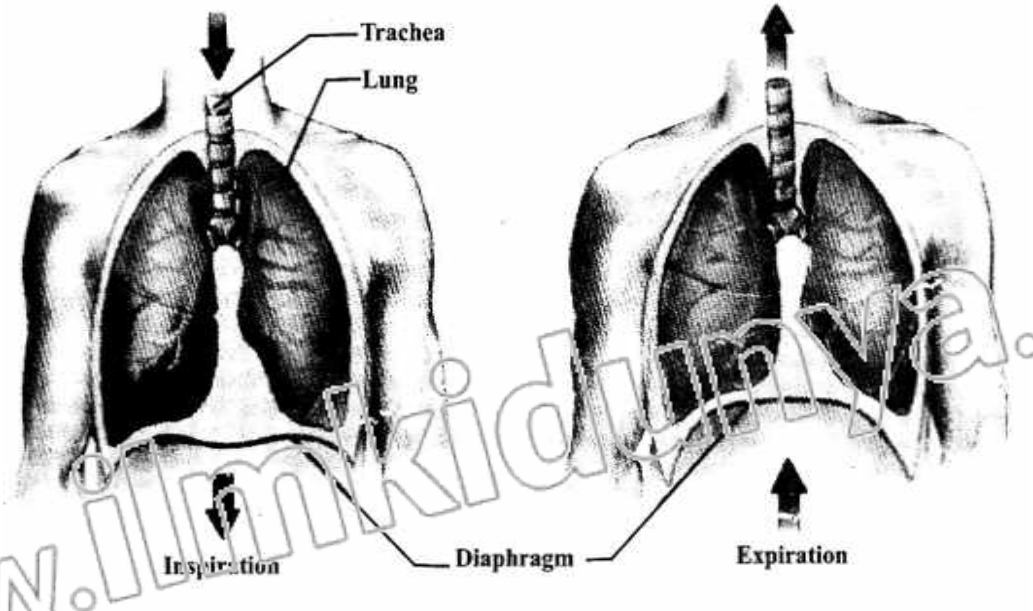


Fig. 13.10 Movement of Diaphragm

- Secondly, the muscles of diaphragm also contract and diaphragm becomes less domelike.

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- 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.**

13.5.1 (b) 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 air inside lungs moves out of the lungs and this is expiration.

Respiratory Distress Syndrome

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.

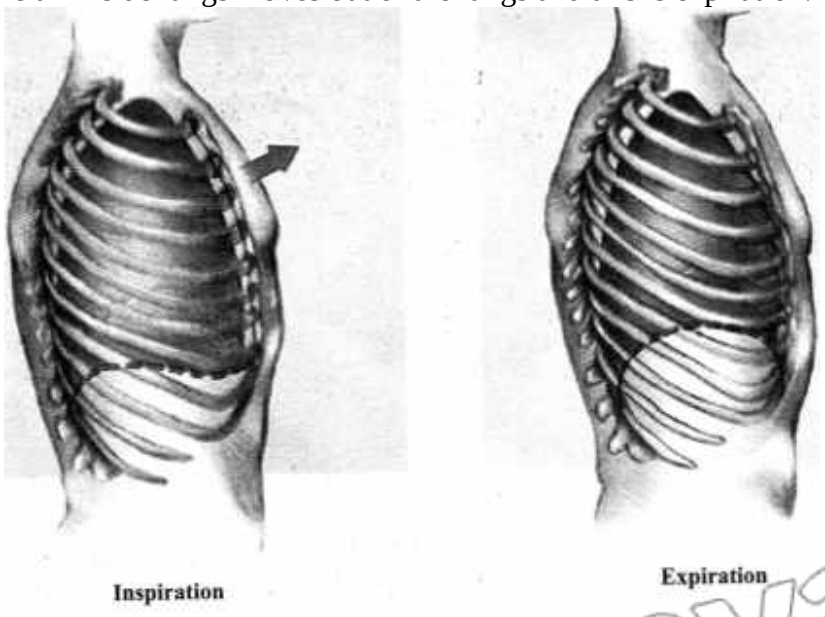


Fig. 13.11

QUESTION RELATED TO ABOVE ARTICLE

Discuss mechanical aspects of breathing in man. (Exercise Question v)

13.5.2 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.

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12.5.2 (a) Transport of Oxygen

Respiratory pigment is haemoglobin

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 unstable and splits into the normal purple-red coloured haemoglobin and oxygen in the conditions of low oxygen concentration and less pressure.

Carbonic Anhydrase

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.

$$Hb + O_2 \rightleftharpoons HbO_2$$

Absorbtion by Haemoglobin

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.

Factor Effecting Oxygen Transport

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.

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12.5.2 (b) 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 is transported in the blood in several different states.

> Carbon dioxide which is much more important than oxygen as a regulator of normal alveoler ventilation (Breathing) but under certain circumstances a reduced PO_2 (partial pressure of the oxygen) in the arterial blood does play an important stimulatory role especially during conditions of shock.

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.

$$CO_2 + H_2O \xrightarrow{\text{Carbonic anhydrase}} H_2CO_3$$

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

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

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.

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

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.

12.5.3 Respiratory Disorders

12.5.3.(a) 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 person 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.

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12.5.3 (b) 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.***

12.5.3 (c) 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 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.

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.

- The person suffering from emphysema cannot oxygenate his blood properly and least exertion makes him breathless and exhausted.
- 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.

QUESTION RELATED TO ABOVE ARTICLE

Explain the transport of oxygen and factor affecting it.

13.5.4 Role of Respiratory Pigments

Various types of respiratory pigments are present in animals. These combine with oxygen reversibly and increase oxygen carrying capacity of blood.

Two pigments are important in humans

Haemoglobin

It is most important protein present in many animals including man. It increases oxygen carrying capacity of blood to about **75 times.**

Myoglobin

It is hemoglobin-like iron containing protein occurring in muscle fibers. It is also known as ***muscle haemoglobin***. Affinity of myoglobin to combine with oxygen is much more than hemoglobin.

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Comparison between Hemoglobin and Myoglobin

Haemoglobin	Myoglobin
It is found in blood.	It is found in muscles.
It transfers oxygen from lungs to blood and then to tissues.	It transfers oxygen from hemoglobin to aerobically respiring muscle cells.
It cannot store oxygen.	It can store oxygen.
It consists of four polypeptide chains associated with an iron containing ring structure.	It consists of one polypeptide chain associated with an iron containing ring structure.

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, the consumption 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.

QUESTION RELATED TO ABOVE ARTICLE

Write a detailed note on respiratory pigments.

13.5.5 Lung Capacities

Total Lung Capacity

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.

Inspiratory and Expiratory Volume

The volume of the air taken inside and expelled out during exercise is about ***3.5 litres***.

Residual Volume

There is residual volume of ***1.5 litres,*** which remains in the lungs.

Effect of Exercise on Breathing

Normal breathing rate is ***15-20 times per minute.*** It ***increases to 30 times per minute*** during exercise. This increased rate allows more oxygen to dissolve in blood and supply it to active muscles. Extra carbon dioxide is removed by deep and fast breathing.

There is little change in composition of inhaled and exhaled air during rest or exercise in most of the constituents of the air as seen in the Table.

Changes in the composition of the breathed air

Component	Inhaled air (%)	Exhaled air (%)
Oxygen	21	16
Carbondioxide	0.04	4
Water vapours	Variable	Saturated
Nitrogen	79	79

QUESTION RELATED TO ABOVE ARTICLE

Write a detailed note on respiratory pigments. **(Exercise Question vi)**

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KEY POINTS

Gills:

Gills are special structures for aquatic respiration. The gills are composed of filaments called gill lamella. Each gill lamina has highly fold membrane called gill lamina. The gill lamina has a network or capillaries for the exchange of gases.

Gill Slits:

The gill slits are slit like openings in the wall of pharynx. Each gill is covered by gill filaments (lamella)

Respiration in Bird:

There is one way flow of the gases in the birds. During inhalation most of the air passes directly to air sacs through parabronchi. So a little exchange of gases takes place during inspiration. During expiration the air passes from air sacs into the lungs and finally come out through nostril. So most of exchange of gases takes place during expiration. Following is the path of air in birds.

External nostrils ⟹ trachea ⟹ bronchi ⟹ parabronchi ⟹ Air sacs ⟹ lungs ⟹ Bronchi

So air do not passes through alveoli of lungs. It directly moves into air sac through parabronchi. While in mammal there is two way passage of air.

Cancer:

An uncontrolled growth or cell division is called cancer. A tumor is formed during cancer. There are two types of tumors:

- **Benign Tumor:**
  In this case, the cells of the tumor remain at their original site. They are not transferred to other organs of the body. Such tumors do not cause any problem. It can be easily removed by surgery. Examples: common cysts on head and feet.
- **Malignant Tumor:**
  In this case, the cells of the tumors do not stay at their original site. They are transferred to the other parts of the body. So the uncontrolled growth is started in many parts of the body. It is called cancer tumor.

Metastasis:

In this case, the cells of the tumors do not stay at their original site. They are transferred to the other parts of the body. So the uncontrolled growth is started in many parts of the body. It is called cancer tumor.

Allergy:

The oversensitivity of the defense system of the body is called allergy.

Reflexes:

Spontaneous action without consciousness is called reflex

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EXERCISE

Q.1. Fill in the blanks

i) _____ is the most important protein in the world.

ii) Hemoglobin is a complex molecule, which contains _____ atoms and 574 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.

Ans: i) Rubisco ii) 9758
iii) Glottis iv) 1
v) 12,000

Q.2. Write Whether The Statement Is 'True' Or 'False' And Write The Correct Statement, If It Is False.

i) ATP is generated during organismic respiration.

ii) Water is 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.

Ans: i) False ii) False
iii) True iv) True

vi) False

Q.3. Encircle the correct answer form the multiple choices.

i) Air spaces between mesophyll cells of a leaf comprise _____ of the total volume:
(a) 20%
(b) 30%
(c) 40%
(d) 50%

ii) The respiratory system is most efficient in:
(a) Man
(b) Birds
(c) Fish
(d) Snake

iii) Respiratory pigment present in muscles is called:
(a) Myoglobin
(b) Globin
(c) Haemoglobin
(d) Haemocyanin

iv) Blood contains _____ oxygen when haemoglobin is 98% saturated per 100ml of blood:
(a) 19.6ml
(b) 18.6ml
(c) 17.6ml
(d) 16.6ml

v) How much air lungs can hold when they are fully inflated?
(a) 5 litres
(b) 4 litres
(c) 4.5 litres
(d) 3.5 litres

Answers Key:

i	c
ii	b
iii	a
iv	A
v	a

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Q.4. Short Questions

i) How does breathing differ from respiration?

Ans: **Breathing:**
Breathing is a mechanical process directly involved in exchange of gases. The fresh air containing more oxygen is pumped into the lungs and air with more carbon dioxide is pumped out of the lungs. It consists of two phases: inspiration and expiration.

Cellular Respiration:
Cellular respiration is the process by which cell utilizes oxygen, produces carbon dioxide, extracts and conserve the energy from food molecules in biologically useful form such as ATP.

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

Ans: Venous blood contains about 54ml of CO_2/100ml of blood while arterial blood contains 50ml of CO_2/100ml of blood.

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

Ans: When concentration of gases in lungs become equal to that in outer environment, exchange stops and further air is retained inside the lungs.

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

Ans: These are serine and carbon dioxide.

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

Ans: Water is 8000 times denser than air.

Q.5. Extensive Questions.

i) In what ways air is better respiratory medium than water?

Ans: (See article 13.2)

ii) What is photorespiration? Give its consequences.

Ans: (See article 13.3.(a)

iii) Briefly describe the properties of respiratory surfaces in cockroach.

Ans: (See article 13.4.3)

iv) In what ways respiration in birds is the most efficient and elaborate?

Ans: (See article 13.4.6)

v) Discuss mechanical aspects of breathing in man.

Ans: (See article 13.5.1)

vi) Write a detailed note on respiratory pigments.

Ans: (See article 13.5.4)

vii) List the air passage way in sequence from nostrils to alveoli. Describe the structure of alveolus in detail.

Ans: (See article 13.5)

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