GASEOUS EXCHANGE

This is the process by which respiratory gases are exchanged between external media and the body cells. It is also known as ***external respiration****.* Gaseous exchange is however different from ventilation.

Ventilation is a special mechanism by which the gaseous exchange medium flows over a respiratory surface. In higher animals such as humans, ventilation is an active process while in lower animals like earthworms, it is a passive process

Need for Gaseous Exchange

- Enables organisms to get oxygen for respiration.
- To get rid of waste products of respiration like carbon dioxide
- Enables green plants to obtain carbon dioxide for photosynthesis

NOTE: *Across all respiratory surfaces, gaseous exchange occurs by diffusion, thus, factors that affect the rate of diffusion are the same factors that affect gaseous exchange as shown below;*

Factors Affecting Rate of Gaseous Exchange

- The total surface area available for diffusion of gases. Gaseous exchange occurs rapidly over large surface areas and slowly over small surface areas. Compared to volume however, smaller animals tend to have a larger surface area than larger animals.
- The distance over which diffusion of gases has to occur. The rate of diffusion is inversely proportional to the diffusion distance.
- The concentration gradient across the gas exchange surface. The greater the concentration gradient of a gas between the external medium and the blood, the greater its rate of diffusion and faster the process of gaseous exchange.
- The temperature. This affects the speed at which molecules move such that when temperature is high, rate of gaseous exchange is higher and lower when temperature is low.
- Solubility of diffusing gas. Along respiratory surfaces, gases dissolve before diffusing. The higher the solubility of the gas, the higher the rate of gaseous exchange and with low solubility of the gas, the rate of gaseous exchange is low.
- The size of molecules of diffusing gases. Smaller molecules diffuse faster than larger molecules resulting into a higher rate of gaseous exchange.

Characteristics of Respiratory Surfaces

- They are moist. Moisture dissolves the respiratory gases so they diffuse easily over respiratory surfaces.
- Have thin membranes. This reduces the distance moved by the respiratory gases so that the gases diffuse rapidly.
- Are permeable to enable gases to easily pass through them easily.
- Possess large surface area to volume ratio to enable rapid diffusion of more respiratory gases.
- Have a rich blood supply to facilitate the movement of the respiratory gases to and from the surface so as to maintain a concentration gradient.

Effect of Size and Surface Area

A large organism like a mammal which has a low surface area to volume ratio has problems with gaseous exchange compared to smaller organisms like protozoa.

This is because of the large diffusion distance and the large volume of the organism as compared to the external surface area over which diffusion can occur. So oxygen can't easily get to all cells.

The large multicellular organisms have had to develop means of bringing the external medium with which gases are exchanged nearer the cells. Hence the development of the respiratory system with specialized respiratory surfaces to solve the problem of surface area to volume ratio and a circulatory system with blood to solve the problem of diffusion distance.

Question.

How does each of the following characteristics of a respiratory surface aid diffusion of gases at the surface?

a) Thin epithelium (02 marks)
b) Dense network of blood capillaries (03 marks)
c) Moist surface (03 marks)
d) Large surface area (02 marks)

RESPIRATORY MEDIA (GASEOUS EXCHANGE MEDIA)

A gaseous exchange medium is a substance from which respiratory gases can either be obtained or deposited. Gaseous exchange media in organisms are air and water

Comparison between air and water as gaseous exchange media.

AIR	WATER
• Has a higher concentration of oxygen	• Has a lower concentration of oxygen
• Has a higher diffusion rate	• Has a lower diffusion rate
• Lower density	• higher density
• doesn't offers support to respiratory surface	• offers support to respiratory surface
• less energy required for ventilation due to low viscosity	• more energy required for ventilation due to high viscosity

Table showing Gaseous Exchange Surfaces of Animals

Animal	Respiratory organ	Respiratory surface
Amphibians	Lungs	Alveolus
Amphibians	Skin	Skin surface
Amphibians	Buccal cavity	Buccal cavity epithelium
Birds	Lungs	Alveolus
Fish	Gills	Gill filaments
Insects	Tracheal system	Tracheoles
Mammals	Lungs	Alveolus
Tadpoles	Gills	Gill filaments

Note: Tadpoles use external gills while the old toads use lungs.

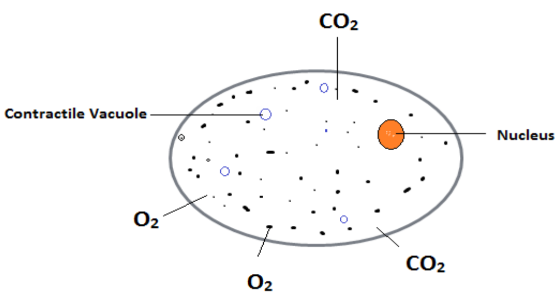
Gaseous Exchange in Unicellular Organisms

These don't require a special respiratory organ such as gills or lungs because they have a large surface area to volume ratio as a result of their small size. These animals use their exterior body surface membrane to carryout gaseous exchange effectively by simple diffusion.

During inspiration, oxygen gas being at high concentration in the water diffuses into the interior of amoeba over the thin cell membrane. Simple diffusion of oxygen is enough to satisfy the oxygen requirements of amoeba.

During expiration, carbon dioxide diffuses from the interior of the amoeba over the thin cell membrane to the exterior. Simple diffusion is also enough to remove all the carbon dioxide produced.

Diagram to Show Gaseous Exchange in Amoeba



Question.

a) Describe the process of gaseous exchange in amoeba (04 marks)
b) Explain why an amoeba does not have a respiratory system (5 marks)

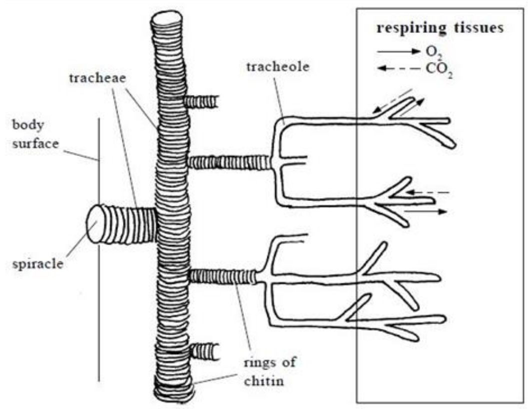
Gaseous Exchange in Insects

Running through the bodies of insects are tubes called **trachea** which contain air. They open to the outside by pores called **spiracles**. Gases enter and leave through spiracles which may be closed by valves. Spiracles are surrounded by hairs to retain water vapour thus reduce water loss.

Spiracles close when the insect is not active and needs less oxygen so as to reduce the evaporation of water hence conserve moisture.

The tracheae are lined with cuticle which is thickened in spiral bands of chitin. These keep the trachea open against the internal pressure of the body fluids.

The trachea branch repeatedly until they terminate in very fine **tracheoles** which penetrate the tissues and organs in the body. The walls of the tracheoles are permeable to gases since they are not lined with chitin, so oxygen is able to diffuse through them to reach the living cells and carbon dioxide from living cells into them.



Mechanism of Gaseous Exchange in Insects

In small and less active insects, the movement of oxygen from the atmosphere through the spiracles up to the trachea and tracheoles to the body tissues is by simple diffusion. The passage of carbon dioxide in the opposite direction is also by simple diffusion.

However, in large and highly active insects such as grass hoppers, locusts and cockroaches, gaseous exchange is brought about by a ventilation mechanism as described below;

Inspiration

Internal muscles in the abdomen relax causing the abdomen and trachea to expand, pressure inside tracheal system decreases below atmospheric pressure so air containing more oxygen enters via the thoracic spiracles which are open at that time. Oxygen in inhaled air moves through the trachea, tracheoles, dissolving in the fluid within and then diffuses directly to body organs.

Expiration

Internal muscles of the abdomen contract and compress the abdomen and the tracheal system. This reduces volume and increases pressure within the tracheal system. Air containing more carbon dioxide is forced out through the open posterior spiracles of the abdomen.

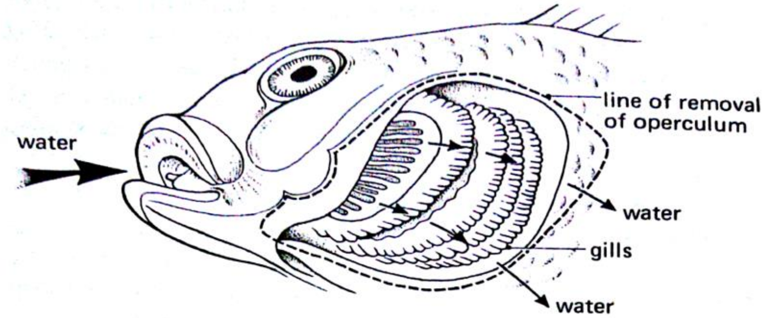
Question

a) Describe the process of gaseous exchange in a named insect? (10 marks)
b) How does gaseous exchange in insects differ from that in mammals? (05 marks)

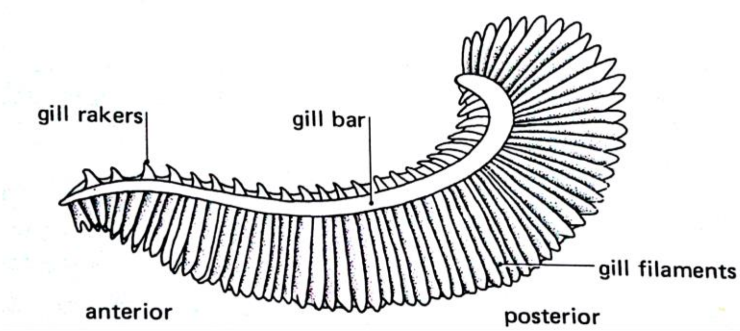
Gaseous Exchange in Fish

Fish use the gills for gaseous exchange. The gills are able to obtain oxygen dissolved in the water. There are usually four gills on each side of protected by the operculum, a bonny flap.

Head of Tilapia with Operculum Removed To Expose Gills



Structure of Gills



Functions of Parts

Gill Bar

This is a piece of bone which supports the gills. It also provides a structure for the attachment of the gill filaments and rakers.

Gill Rakers

They are found on the gill bar. They trap suspended food particles. They also protect the gill filament by filtering out large suspended materials in the water before reaching the gill filament.

Gill Filament

These are small flaps which are the sites for gaseous exchange in the fish.

Adaptations of Gills

- Have numerous gill filaments to increase the surface area for gaseous exchange
- Presence of gill bar for attachment of gill filaments and rakers
- Has numerous blood capillaries in gill filaments to enable quick transportation of gases
- Have gill rakers on one side of gill bar to sieve out dirty particles from water, preventing clogging of gill filaments.
- Thin epithelium lining on gill filament to reduce the distance of diffusion of gases

Ventilation in Bony Fish

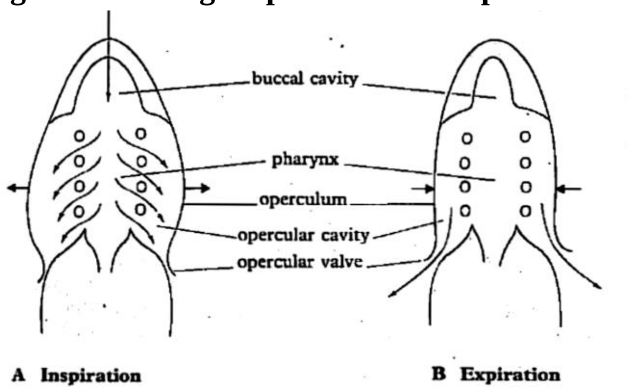
- **Inspiration**

The floor of the buccal cavity is lowered by contraction of muscles of the buccal cavity, volume of the buccal cavity is increased and pressure is reduced. The mouth opens and water flows through the mouth into the buccal cavity. At the same time, the opercular valves close, the operculum bulges outwards increasing the volume but reducing pressure in opercular cavity. Water containing more oxygen flows from the mouth cavity over gills where oxygen dissolved into the water diffuses into the blood of the capillaries lining the filaments and is carried to other body tissues. The carbon dioxide from blood diffuses into the water.

- **Expiration**

The floor of the buccal cavity is raises, mouth is closed, reducing the volume and increasing pressure within buccal cavity above water pressure. The operculum relaxes and water pressure forces opercular valves to open, allowing water containing more carbon dioxide out through the valves

Diagrams showing Inspiration and Expiration



Gaseous Exchange across Gills

As water passes over the gills, the oxygen dissolved in the water diffuses into the gill filaments and finally into the blood capillaries where it is carried to actively respiring tissues. Carbon dioxide diffuses out of blood into the outgoing water.

The direction of flow of the blood in the **gill lamellae** is opposite to the flow of water. This is called **counter current flow**. This arrangement ensures that blood extracts maximum oxygen from the water as it passes over the gills, but also a high concentration of carbon dioxide is released into water. This is because a high concentration gradient of oxygen and carbon dioxide is maintained.

A graph showing efficiency of oxygen extraction from water during countercurrent Flow

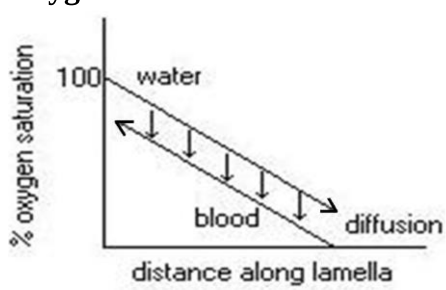
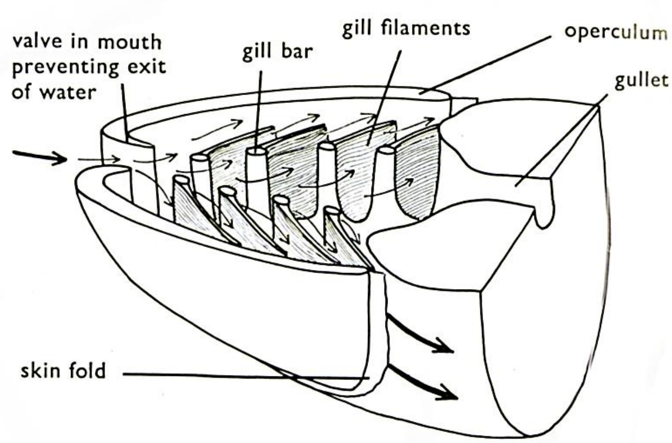


Diagram Showing Respiratory Currents in Fish



Question

a) How does gaseous exchange occur in bony fish? (11marks)
b) How are gills of a bony fish adapted for their function? (04 marks)

Gaseous Exchange in Amphibians

Amphibians are animals that live on land and in water. Examples include frogs, toads, newts, salamanders.

The young amphibians e.g. tadpoles carryout gaseous exchange through the external gills. Here oxygen and carbon dioxide are exchanged in and out of the gills respectively through simple diffusion in the water.

In adult amphibians gaseous exchange occurs using the lining of the buccal cavity, skin and lungs.

Use of Skin

When amphibians are in water, they respire mainly using the skin. Their skin is moist, thin and richly supplied with blood vessels which allows diffusion of gases between water and blood. Oxygen dissolves in the moisture and diffuses into the underlying blood capillaries and is transported to body tissues.

NB: gaseous exchange in toads is restricted to skin on ventral surface. The frogs usually have moist skin. It is kept moist by secretion from glands hence mostly use skin for gaseous exchange.

Use of Buccal cavity

The lining of the buccal cavity is used when the amphibians are on land. The mouth cavity is thin, kept moist by mucus secretions and contains numerous blood capillaries where gaseous exchange occurs between the air that enters the mouth and the blood capillaries. Ventilation mechanisms through the mouth include inspiration and expiration

Inspiration

Muscles of the buccal cavity contract, mouth opens, floor of the buccal cavity is lowered increasing its volume and lowering the pressure within below atmospheric pressure so air containing more oxygen rushes into the mouth. Oxygen diffuses into the moisture lining of the mouth and diffuses into the capillary blood vessels and is carried away in the blood while the carbon dioxide from the blood diffuses out from blood in capillaries into the air.

Expiration

The muscles of the mouth cavity relax, rising the flow of the buccal cavity, the mouth closes, volume of the buccal cavity is lowered and its pressure is raised. This forces air containing more carbon dioxide to be expelled out of the body via the open nostrils.

Use of Lungs

Lungs of frogs are a pair of thin-walled sacs suspended in the body cavity. Lungs are commonly used on land. The ventilation of the lungs is also involves inspiration and expiration.

Inspiration

Mouth opens and floor of mouth cavity is lowered by contraction of muscles of the buccal cavity. This results into increased volume of mouth cavity and reducing pressure in it below air pressure. High air pressure forces nostrils to open such that air containing more oxygen enters into the enlarged mouth cavity from the nostrils. The nostrils then close as the floor of mouth cavity is raised increasing the pressure in buccal cavity which forces air through the pharynx into the lungs where gaseous exchange occurs.

Expiration

The muscles of the mouth cavity relax, volume of the buccal cavity is lowered and its pressure is raised. This forces air containing carbon dioxide to be expelled out of the lungs via the nostrils to the atmosphere.

Question.

a) Describe gaseous exchange in a frog (10marks).
b) How does gaseous exchange occur in amphibians in aquatic and terrestrial environment? (05marks)

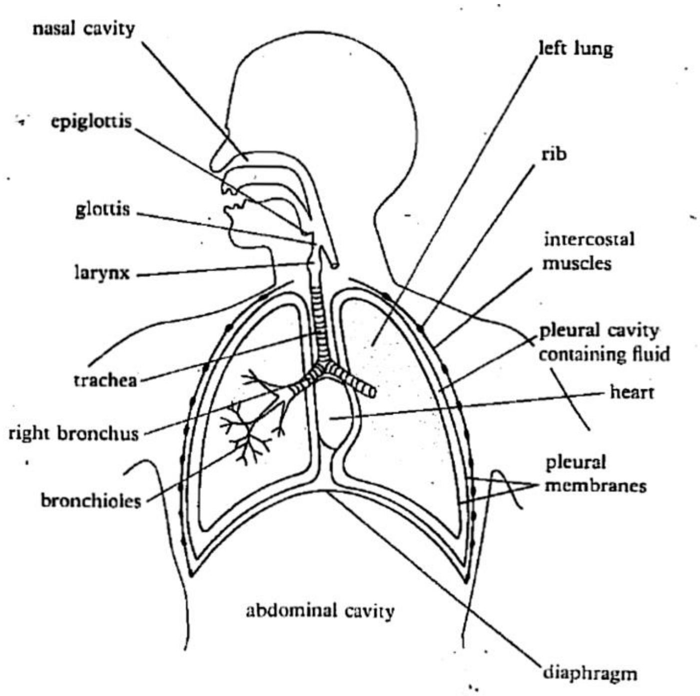
GASEOUS EXCHANGE IN MAN

This takes place in the lungs. Lungs are the most advanced organs for gaseous exchange in terrestrial animals.

Structure of Lungs

These are two spongy-like structures within the thoracic cavity that are protected by the **ribs** which are lined by the **intercostal muscles** (internal and external). A sheet of muscular tissue separates the abdominal cavity from the thoracic cavity and this muscle is called the **diaphragm**. Each lung is completely surrounded by a two-layered membrane called **pleural membrane**. Between the two layers is the **pleural cavity**, which contains a lubricating fluid called **pleural fluid**.

Structures of Gaseous Exchange system in Man



Functions of Parts

- **Nose**

This is a point where air enters and leaves the respiratory surface although the mouth can do the same. The walls of the nose are lined with hairs which trap dust and other foreign materials that may come along with the respiratory gases.

- **Pharynx**

This is the back of the mouth where the nasal cavity and the mouth cavity join together. It is at the pharynx that the oesophagus and trachea meet.

- **Larynx**

This is a cavity at the top of the trachea. It contains the vocal cords which vibrate to produce sound when air passes over them. Near the larynx is a flap of cartilage known as the epiglottis which prevents dust and other foreign particles from entering the trachea during swallowing.

- **Trachea**

This is a tube running from the pharynx to the lungs. Its walls contain ring-like cartilage which prevents the trachea from collapsing when pressure in it falls.

Adaptations of Trachea

- It is hollow so readily allows gases to pass through
- It is kept open by rings of cartilage
- Secretes mucus which traps dust particles
- Has cilia which beats to move mucus and dust up to the larynx.

- **Bronchi**

There are two bronchi tubes branching from the trachea. They also have rings of cartilage which keep them permanently open. Each bronchus leads to one lung and divides to form a mass of fine tubes called the bronchioles.

- **Bronchioles**

These are tiny tubes branching form the bronchi without rings of cartilage. Bronchioles end in bag-like sacks called alveoli.

- **Alveoli**

These are the sites of actual gaseous exchange in the lungs. They are numerous and composed of thin walls. Their membranes are completely moistened to dissolve respiratory gases.

Mechanism of Breathing in Man

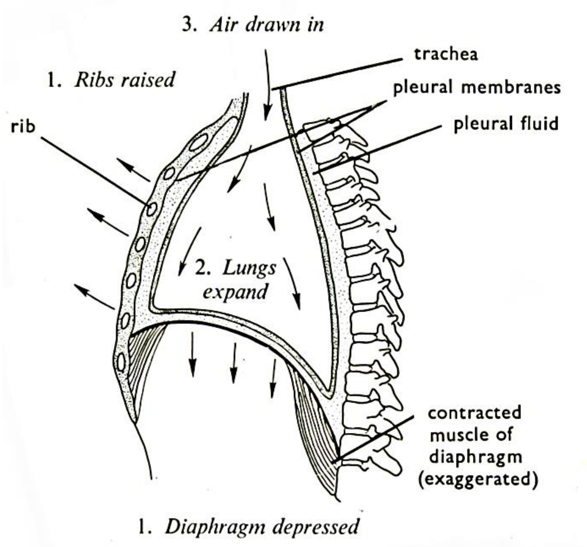
Breathing in man occurs in two phase i.e.

a) Inspiration
b) Expiration

Inspiration

The external intercostal muscles contract as internal intercostal muscles relax. The rib cage moves upward and outward. The muscles of the diaphragm contract and cause it to flatten. The sternum bone is moved forward. These movements increase the volume of the thoracic cavity. The pressure within the lungs is lowered below atmospheric pressure and this forces air containing more oxygen into the lungs and to the bronchioles leading to alveoli where oxygen diffuses into blood.

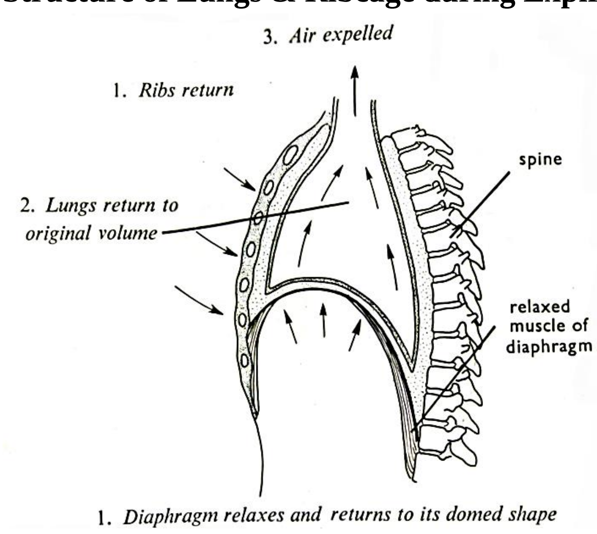
Structure of Lungs & Ribcage during Inspiration



Expiration

The external intercostal muscles relax while the internal intercostal muscles contract. This moves the rib cage downward and inward. The diaphragm muscles relax and it becomes dome shaped. The sternum bone also moves inward so volume of the thoracic cavity decreases. The increased pressure inside the thorax and due to the elasticity of lungs results into reduces volume and increased pressure in lungs causing air rich in carbon dioxide to be forced out of the lungs into the trachea, pharynx and to the atmosphere through the nose.

Structure of Lungs & Ribcage during Expiration



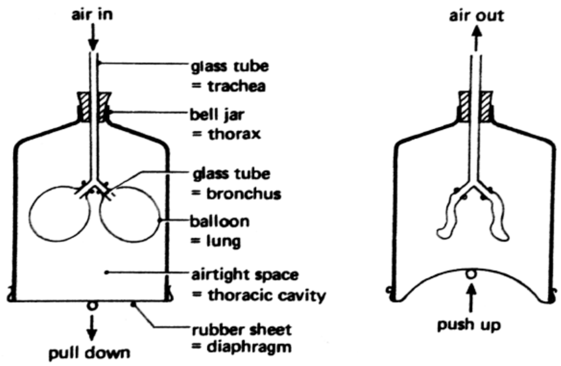
Model to Demonstrate Gaseous Exchange in Man

Procedure

- Get a bell jar and fix a cork with glass tubing in its mouth.
- Use a rubber tubing to connect a Y tube to the glass tubing inside the bell jar.
- Tie balloons on each end of the Y tube to act as lungs. Tie a rubber sheet using a rubber band at the open end of the bell jar to act as a diaphragm.

- Tie a piece of thread in the middle of the rubber sheet. Pull the end of the rubber sheet using the thread (inhalation) and then release it (exhalation).

Setup



Observation

- When the thread is pulled, the rubber sheet stretches. This increases the volume in the bell jar and reduces the pressure. Air enters from out through the glass tube to the Y tube and inflates the balloons.
- When the thread is released, the rubber sheet returns to its normal flat shape. This reduces the volume in the bell jar and increases the pressure. Air is forced out of the balloons through the Y tube and glass tubing. This deflates the balloons.

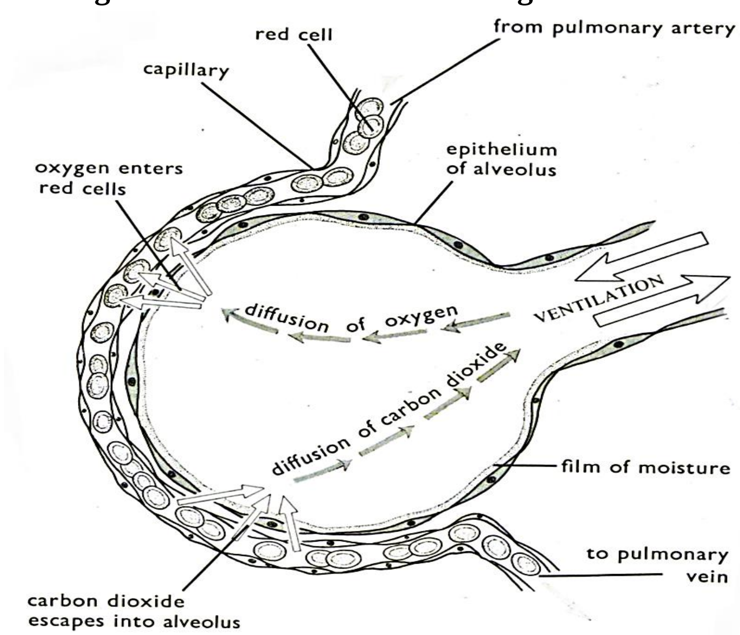
Conclusion

During inspiration, air is taken in while during expiration, air is taken out

Gaseous Exchange at Alveolus

The alveoli have thin elastic walls consisting internally of a single cell layer or epithelium. Below the alveolus is a dense network of blood capillaries supplied with de-oxygenated blood from the right ventricle of the heart through the pulmonary artery. In human lungs, there are about 350 million alveoli with an absorbing surface area of about $90m^2$

Diagram to Show Gaseous Exchange at Alveolus



How Oxygen Reaches Tissues

Oxygen is at higher concentration in the alveolar air than in the blood capillaries so it dissolves into the film of moisture and diffuses into the capillaries. Due to the concentration gradient, oxygen diffuses into the red blood cells and combines with haemoglobin to form oxyhaemoglobin. Oxyhaemoglobin is then transported in the blood from the lung capillaries through the pulmonary vein, left atrium, left ventricle where it is pumped by the heart through the aorta, arteries and into capillaries of the body tissues. In active body tissues, oxygen is at lower concentration and this causes the breakdown of oxyhaemoglobin into oxygen and haemoglobin. Oxygen then diffuses out of the red blood cells and enters the body cells by diffusion. The carbon dioxide from the tissues diffuses into the blood in capillaries.

Question

a) Explain how the action of muscles cause air to pass from the atmosphere into the lungs (05 marks)
b) How does oxygen move from the air in alveolus and cells and tissues? (07 marks)
c) Give 3 characteristics of an efficient respiratory organ. (03 marks)

Components of Inhaled & Exhaled Air

Component	Inhaled	Exhaled
Nitrogen	79%	79%
Oxygen	21%	17%
Carbon dioxide	0.03%	4%
Water vapour	Variable	Saturated

Explanation

Inspired air contains more oxygen than expired air. This is because of the higher concentration of oxygen in atmosphere while in expired air, much of the oxygen has diffused into tissues.

Expired air contains more carbon dioxide than inspired air. This is because during respiration in the body tissues, carbon dioxide is produced which increases the amount of carbon dioxide given off in expired air, compared to the low carbon dioxide concentration in air from atmosphere that is inhaled.

Although nitrogen diffuses in the blood plasma, it plays no part in the chemical reactions of the body so the rates of its diffusion in and out of the body are the same. Nitrogen is also not produced anywhere in the body.

Water vapour is produced as a bi-product of many metabolic processes in the body so expired air contains saturated water vapour.

Lung Capacity

The total capacity of the lungs in an adult man is about 5 liters. In normal breathing only 500cm^3 of air is breathed in and out. This is known as **tidal air**.

Tidal air is the volume of air breathed in and out during normal breathing.

Again in humans not all the air breathed can be expelled out. There is a certain volume of air which remains in the alveoli. This is called **residual air**. Other terms used to describe lung volumes include;

- **Ventilation rate**. This refers to the volume of air breathed per minute and is equal to tidal volume multiplied by number of inspirations per minute.

- **Inspiratory reserve volume**. This is the volume of air one can inhale above the tidal volume.
- **Expiratory reserve volume**. Volume of air that can be exhaled after the end of normal expiration.
- **Dead space air**. Part of the tidal volume air which does not get to the alveoli but remains in the air passages of trachea and bronchi.

Control of Breathing

The rhythmic breathing movements are usually carried out quite unconsciously. These movements are controlled by **medulla oblongata** of the brain. Chemoreceptors present in the medulla are very sensitive to high carbon dioxide concentration in the blood. Impulses from the chemoreceptors stimulate the respiratory centre in the medulla which controls ventilation rate and heartbeat.

If there is a rise in the carbon dioxide concentration of the blood reaching this region of the brain, chemoreceptors send nerve impulses automatically to the diaphragm and the rib muscles. These contract and relax rapidly causing an increase the rate and depth of breathing. The accelerated rate of breathing expels the excess carbon dioxide and increases the amount of oxygen in the blood so as to meet the demands of increases tissue respiration.

The breathing rate soon returns to normal once the carbon dioxide concentrations have reduced to normal.

Factors Affecting Rate of Breathing

- Body activity. The rate of breathing increases with increase in the activities of the body to supply more oxygen for tissue respiration and remove carbon dioxide.
- State of mind. Fear and anxiety cause a rise in breathing rate due to secretion of adrenaline hormone in the body.
- Health status. Diseases destabilize body activities. Some sicknesses such as malaria increase rate of breathing while other lower rate of breathing.
- Age. Young children are actively growing so need more energy. This increases their rate of breathing to satisfy metabolic requirements of oxygen.
- Altitude. At high altitude, the oxygen concentration is low hence require faster rate of breathing for people who have been previous at lower altitude to supply tissues with enough oxygen. People who have been living at high altitude have increased number of red blood cells to transport more oxygen so they breathe normally at high altitude i.e. acclimatized.

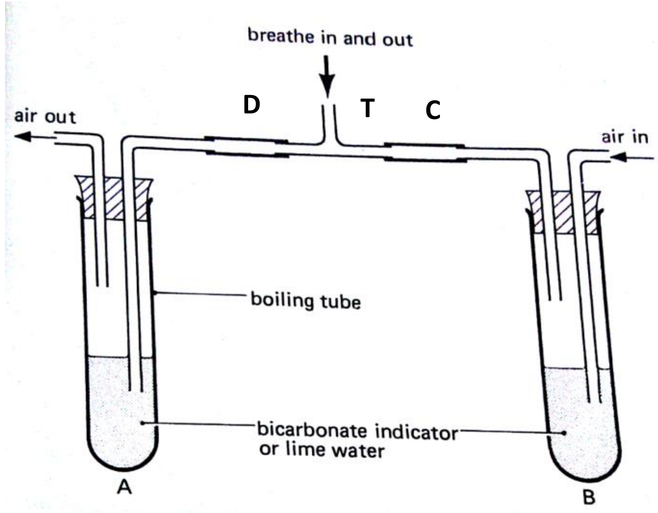
Note: Respiratory system diseases include whooping cough, asthma, tuberculosis, pneumonia, emphysema, flu, bronchitis and COVID-19. Most of these are air borne.

Experiment to Show that Exhaled Air contains Carbon Dioxide

Apparatus

- ✓ Two test tubes
- ✓ 2 Capillary tubes
- ✓ 2 rubber tubes
- ✓ T-tube
- ✓ cork
- ✓ Lime water/bicarbonate indicator
- ✓ 2 Delivery tubes
- ✓ Man

Diagram for Setup



Procedure

i. Equal volumes of lime water are placed in each test tube A and B
ii. A T-tube is connected by rubber tubing to capillary tubes from both test tube A and B as shown in the setup above. The rubber tubes function as valves.
iii. By pressing rubber tube D between fingers, man breathes in gently at point T
iv. Rubber tube D is released and now C is pressed between two fingers, man gently exhales
v. Procedures (iii) and (iv) are repeated simultaneously for 5 minutes.

Observation

Lime water in test tube A forms a white precipitate while lime water in test tube B remains colourless

Conclusion

Exhaled air contains higher concentration of CO_2 than inhaled air

Gaseous Exchange in Plants

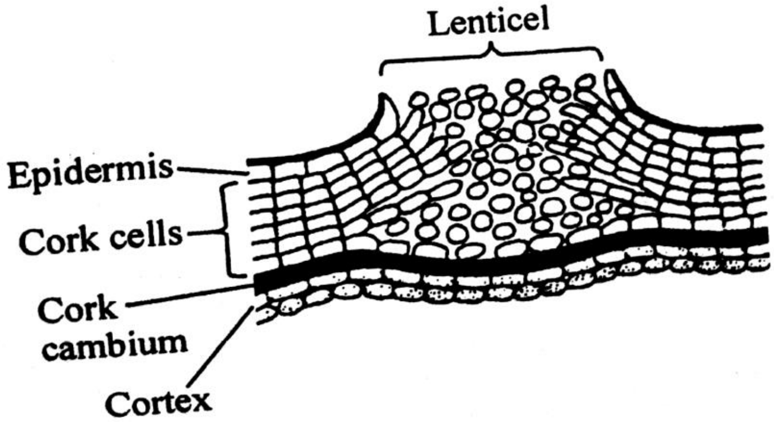
In terrestrial plants, gaseous exchange occurs mainly in the leaves. Gaseous exchange can also take place in roots such as breathing roots of mangrove and stems through **lenticels**. In leaves the structures for gaseous exchange are the **stomata** with facilitation of spongy mesophyll tissues.

The leaves and stems of plants exchange oxygen and carbon dioxide with the atmosphere by diffusion while the roots obtain their oxygen from the air dissolved in soil or from water.

Lenticels

These are structures of gaseous exchange in woody stems and roots. They are specialized pores which externally appear as raised pits on the bark of a woody stem. Lenticels form due to loose packing of cells of bark, leaving gaps which communicate with the air spaces in the cortex. Gases diffuse through the porous tissue that is formed by loose cork cells underlying the cork cambium.

Structure of Lenticel

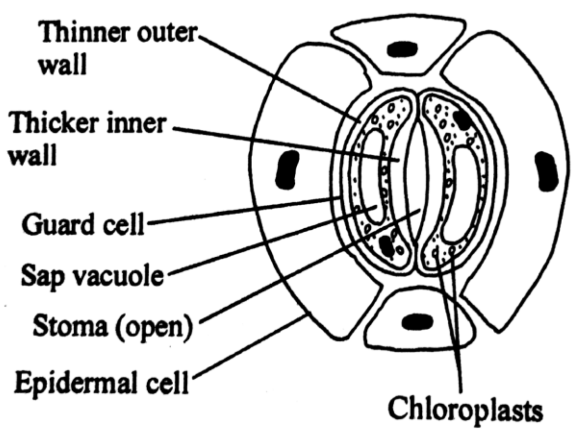


Stomata

These are openings in the epidermis. Stoma comprise of a stomatal pore and two specialised epidermal cells called **guard cells**. Guard cells join at the internal end walls to leave a pore in the middle. The guard cells are structurally adapted to their function by;

- Have chloroplasts
- Inner wall is thicker and inelastic
- Outer wall is thinner and elastic

Structure of Stoma



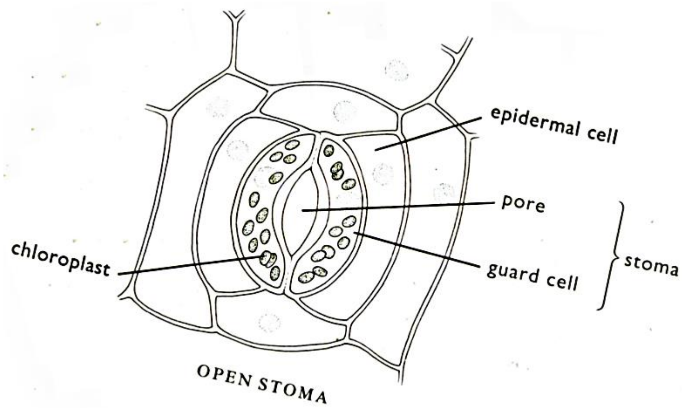
Stomata Movements

The stomata close and open depending on the light intensity and concentration of sugars in the cell sap of the vacuoles of the guard cells. Stomata open during day light when carbon dioxide is needed for photosynthesis and closed at night when there is low light intensity such that photosynthesis ceases.

Opening of Stomata

During daylight rate of photosynthesis is high. The concentration of sugars accumulates in the cell sap of the guard cells hence water potential of the cell sap decreases. The guard cells obtain water from their neighbouring cells by osmosis. This increases the turgor pressure in the guard cells so that the outer elastic wall expands more than the inner inelastic wall and stomata opens.

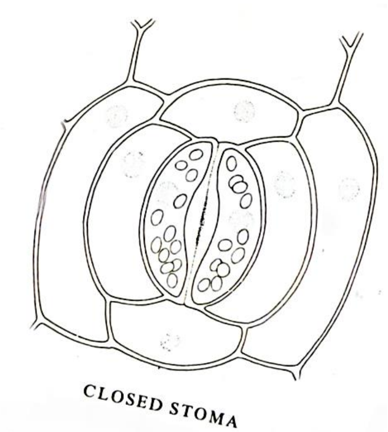
Structure of Open Stomata



Closing Stomata

At night, photosynthesis ceases hence the concentration of sugars reduce in the cell sap of the guard cells. The water potential of the cell cytoplasm increases as compared to that of neighbouring epidermal cells. The guard cells loose water to the neighbouring cells by osmosis. Guard cells become flaccid such that the inner wall retracts more than outer wall and stomata close.

Structure of Closed Stomata



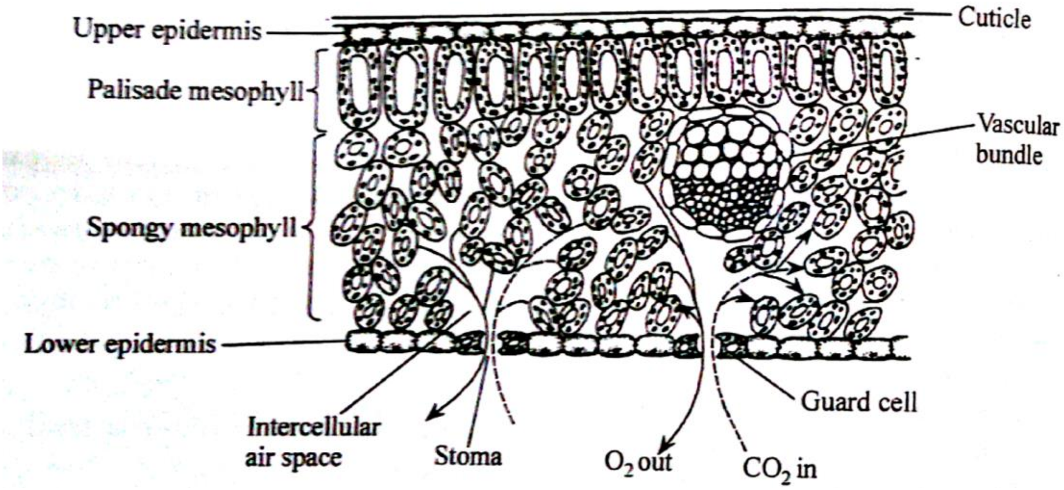
Movement in & out of Carbon dioxide and Oxygen Gas

During day, carbon dioxide from the atmospheric air diffuses into the large intercellular air spaces of the spongy mesophyll through the stomata. The carbon dioxide dissolves in the film of moisture on the cell wall and in this form it diffuses into the photosynthetic cells (palisade). Here it is used for photosynthesis and oxygen is released by the cells.

Some of the oxygen produced is used by the plant for respiration. Excess oxygen diffuses from the leaf down a concentration gradient through the stomata into the atmosphere.

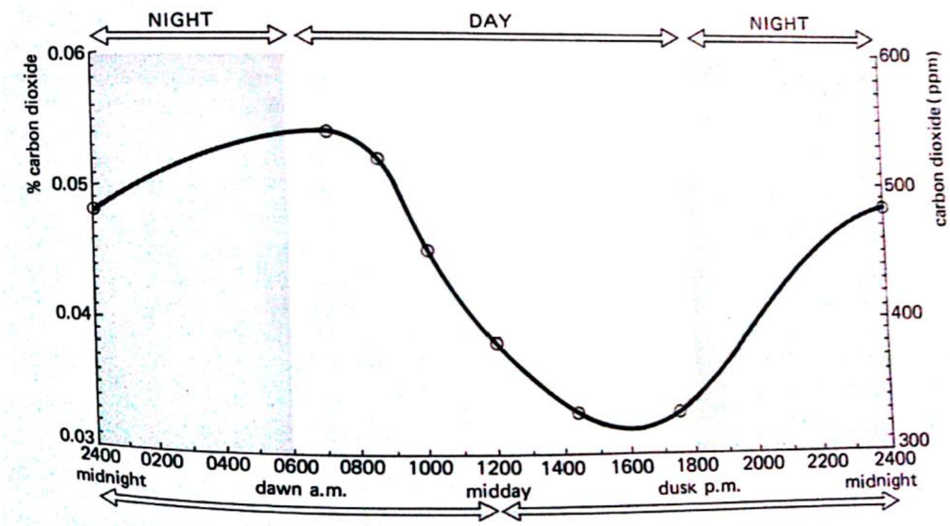
At night, oxygen in the air diffuses into the intercellular air spaces of the spongy mesophyll. It dissolves in the film of moisture and in this form it diffuses into the cells. The cells use oxygen in respiration and releases carbon dioxide. Since there are no light for photosynthesis, carbon dioxide accumulates in the leaves. Due to the concentration gradient, the carbon dioxide diffuses out of the leaves through the stomata.

Diagrammatic Illustration



Note: Some gaseous exchange occurs through the thin cuticle and the epidermis of young leaves and stems. Epidermal cells of the root hairs also allow gaseous exchange by simple diffusion. Plant growth is poor in poorly aerated soils such as waterlogged soils.

Graph Showing Carbon dioxide Concentration in Air in a Rain Forest over 24 Hours



Gaseous Exchange in Aquatic Plants

In a fully submerged plants, gases move into and out of the stem and leaf surface by diffusion. Aquatic plants have the following features;

- They do not have stomata
- Their epidermis have thin or no cuticles to reduce diffusion distance of respiratory gases.
- Have aerenchyma tissues with several air spaces which store oxygen and keep the plant buoyant.
- The leaves are branched, small and flattened which provides a large surface area for light absorption.
- Have numerous chloroplasts for light absorption.
- Many air spaces which encourage loss of excess water through transpiration.

Note: In partly submerged plants like water lily, gaseous exchange takes place mainly at the exposed surface of the leaves. The surface is water proof layer of waxy cuticle and numerous stomata.

Adaptations of aquatic animals for gaseous exchange

i. Have haemoglobin with a higher affinity of oxygen to extract more oxygen from water with lower oxygen concentration than the air for example mu fish
ii. Have an efficient ventilation system such that oxygen is extracted from water both during inspiration and expiration e.g. fresh water fish (tilapia).
iii. Some store a high concentration of oxygen by a unique pigment in muscles called myoglobin e.g. whales
iv. They stock pile a high concentration of oxygen in blood as compared to terrestrial animals e.g. whales
v. Have a countercurrent flow system in the gill lamellae which maintains a steep concentration gradient for oxygen uptake.