RESPIRATION AND GASEOUS EXCHANGE

TISSUE RESPIRATION

This is the breakdown of food substances to release energy. It occurs with the help of enzymes. The major food respired (respiratory substrate) is a carbohydrate (glucose). All other compounds are converted into a carbohydrate before they are respired.
The energy released is stored as ATP (Adenosine tri phosphate).
ATP is highly energy rich compound formed between a chemical bond between ADP (Adenosine di phosphate) and inorganic phosphate groups, i.e.

$$ADP + Pi \longrightarrow ATP$$

If the energy stored as ATP is required by the body, ATP is suddenly broken down into ADP and Pi to release energy for the body activities i.e.

$$ATP \xrightarrow{\text{ATPase enzyme}} ADP + Pi + \text{energy}$$

The energy released is used by the body for various activities i.e.

- Maintaining blood circulation
- Bring about breathing movement
- For producing sound
- Transmission of nerve impulses from one part to another.
- Synthesis of blood proteins
- Maintaining the constant blood temperature
- Cell division either mitosis or meiosis leading to growth
- Active transport of materials into or outside the cell.
- Secretion of various materials like hormones, enzymes, etc.

Stages of respiration

Respiration occurs in a series of reaction which are divided into 2 stages

1. Glycolysis

It involves breaking down of six carbon compounds (glucose) into 2 small 3 carbon compounds. This occurs in the cell cytoplasm.

2. Krebs cycle

It involves the breaking down of 3 carbon compounds further to release more energy than glycolysis. It occurs in the mitochondria.

There are two types of respiration.

1. Aerobic respiration.
2. Anaerobic respiration

AEROBIC RESPIRATION

This is the breakdown of food to release energy in the presence of oxygen. This type of respiration produces energy, Carbon dioxide and water. This is the most efficient process by which energy is produced because there is complete breakdown of food and it therefore produces more energy.

Equation for aerobic respiration

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \longrightarrow \underset{\text{Carbondioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{Energy}$$

The Carbondioxide produced diffuses from the tissues into the blood and it is transported to the lungs for expiration through the trachea and nostrils. In plants the Carbondioxide produced is either lost to the atmosphere through stomata on leaves or lenticels in stems or used in photosynthesis to produce food.

EXPERIMENT TO DEMOSTRATE THAT LIVING ORGANISMS USE OXYGEN IN AEROBIC RESPIRATION

Materials:

Conical flask
Delivery tube
Beaker
Sodium hydroxide solution
Water
Germinating seeds

Procedure:

- Some germinating seeds are placed in a conical flask in which a test tube containing sodium hydroxide is enclosed.
- A delivery tube is then connected to the conical flask with one end deeped in a beaker containing water.
- The setup is left to stand and observations are made on the level of water in the delivery tube.

Setup of the experiment

Observation:

After some time, water is seen to have risen in the delivery tube.

Conclusion:

Oxygen is used in aerobic respiration.

Explanation:

As the seeds respire, they use oxygen and produce CO_2. However, the CO_2 is absorbed by the sodium hydroxide solution thus it's not added back to the air in the flask hence there's a decrease in the original volume of air in the flask.

EXPERIMENT TO SHOW THAT LIVING ORGANISMS LIBERATE CO_2 DURING AEROBIC RESPIRATION

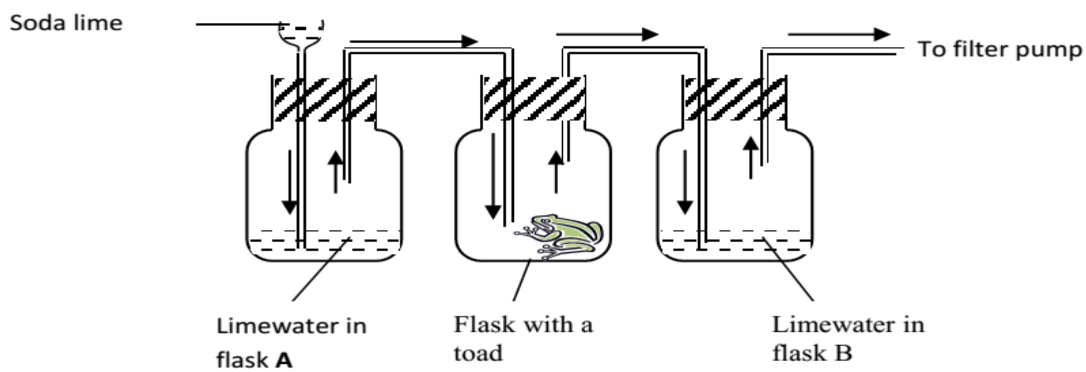
Materials

- Soda lime (sodium hydroxide),
- Lime water,
- Filter pump,
- Toad ,
- Two delivery tubes,
- Three flasks and Corks.

Procedure

- A rat is used as an aerobe and the experiment is fixed as shown below and left to stand for 40 minutes.
- The purpose of sodium hydroxide is to absorb CO_2 from the incoming air.
- Lime water in flask A is used to confirm the absence of CO_2 in the incoming air.
- Lime water in flask C is used to test for the presence of CO_2 in exhaled air.
- The filter pump ensures one direction of air.

Setup



Observation

Limewater in flask B turned milky while that in flask A remained clear.

Conclusion

The living organism gives out Carbondioxide during respiration.

ANAEROBIC RESPIRATION

This is the breakdown of food to release energy in absence of oxygen.

In this process the food is not completely broken down but part of it remains in form of alcohol in plants and lactic acid in animals.

This process releases Carbondioxide, energy and lactic acid in animals or ethanol in plants.

The incomplete break down of food results into less energy released from the same amount of food.

Most of the energy remains blocked in the intermediate substances (ethanol and lactic acid). When oxygen is provided lactic acid can be further broken down to release the remaining energy.

Equation to show anaerobic respiration in plants

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{enzyme}} \underset{\text{ethanol}}{C_2H_5OH} + \underset{\text{Carbondioxide}}{CO_2} + \text{Energy}$$

OXYGEN DEBT

During vigorous activities the oxygen supply to muscles may not be enough to meet the energy demands of the organism. In the process the products of anaerobic respiration accumulate. As a result the rate of breathing of the individual increases even after an exercise to provide extra oxygen required to oxidise the accumulated lactic acid to CO_2, water and energy.

In this condition the organism is said to be in an oxygen debt. **Oxygen debt** therefore is the amount of oxygen needed to break down the accumulated lactic acid in muscles after vigorous exercises.

Equation for anaerobic respiration in animals

$$C_6H_{12}O_6 \longrightarrow 2CH_3CH(OH)COOH + CO_2 + 150kj\ (energy)$$

Graph showing change in lactic acid and concentration during and after exercise

Lactic acid increases rapidly during an exercise till the end. This is due to increased rate of anaerobic respiration due to lack of enough oxygen supply.

At the end of the exercise, lactic acid content in muscles drops suddenly because it is being oxidized to CO_2, water and more energy in the liver. The oxygen used in breaking down this lactic acid is attained by breathing deeply.

Anaerobic respiration in plants

When plants respire without oxygen, glucose is broken down into ethanol, CO_2, water and energy.

$C_6H_{12}O_6 \xrightarrow{enzyme} C_2H_5OH + CO_2 + \text{Energy (118kj)}$

Glucose ethanol Carbondioxide

Little energy is produced, much of it still locked in the partially broken ethanol.

Anaerobic respiration in yeast

- The form of anaerobic respiration carried out by yeast is known as fermentation.
- Fermentation is any form of anaerobic respiration in solution form.
- In yeast, fermentation leads to production of ethanol, CO_2 and energy which is a chief product. The enzyme which is involved is zymase.

$C_6H_{12}O_6 \xrightarrow{enzyme} C_2H_5OH + CO_2 + \text{Energy (118kj)}$

Glucose ethanol Carbondioxide

Application of anaerobic respiration

- The process is commercially exploited in beer brewing to produce alcohol
- It is also used in baking of bread to raise dough.

Experiment to show that CO_2 is given off during anaerobic respiration/fermentation

Materials:

- Two test tubes,
- Delivery tubes,
- Yeast,
- Glucose,
- Oil and
- Lime water.

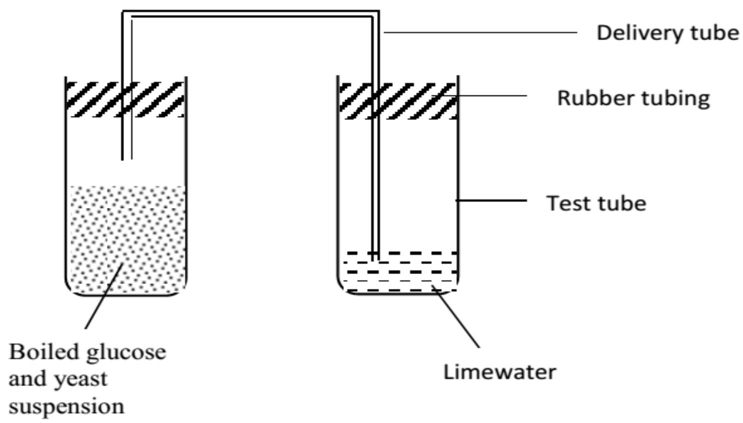
Procedure

1. Boil about 20 cm^3 of glucose solution ***to drive off oxygen*** from it and allow it to cool to room temperature.
2. Add a layer of oil over glucose solution to prevent oxygen from dissolving in it.
3. Add a small quantity of yeast suspension to the glucose solution using a pipette.
4. Pour limewater in one test tube.

5. Using a delivery tube and rubber bangs fix the delivery tube in the test tube as shown below.

6. Leave the experiment to stand in a warm place for an hour.

Setup



Set up a control experiment in the same way but using a boiled yeast suspension or without yeast or without glucose.

Observation

Bubbles of a gas are seen in limewater and limewater turns milky.

Conclusion

Carbon dioxide is produced during anaerobic respiration.

Explanation

Yeast breaks down glucose in absence of oxygen to produce ethanol, CO_2 and some heat.

The CO_2 produced turns lime water milky by reacting with calcium hydroxide to form insoluble calcium carbonate.

Experiment to demonstrate the liberation of heat during fermentation of yeast OR

Experiment to show the production of energy in absence of oxygen (anaerobic respiration)

Materials:

- 10% glucose solution
- 10% yeast suspension
- 2 vacuum/thermos flasks
- 2 thermometers

- Cooking oil
- Cotton wool
- Water bath

Procedure:

100cc of glucose solution is boiled in a beaker over a water bath so as to drive out any dissolved oxygen and then allowed to cool.

50cc of glucose solution is each poured in each flask and small quantities of oil are added to prevent entry of oxygen into the glucose solution.

Yeast solution is added below the oil layer of one of the flasks using a dropper/pipette.

A thermometer is placed in each flask and kept in solution with cotton wool as shown below.

The thermometer readings are recorded hourly at intervals for some time.

Observation:

After some time, the temperature rises in flask. A steadily while in B, the temperature remains the same.

Conclusion:

The temperature rises in flask A due to anaerobic respiration of glucose by producing heat.

In B, there’s no yeast to respire anaerobically hence no heat is produced.

Experiment to show that energy (heat) is released by germinating seeds during respiration

Materials:

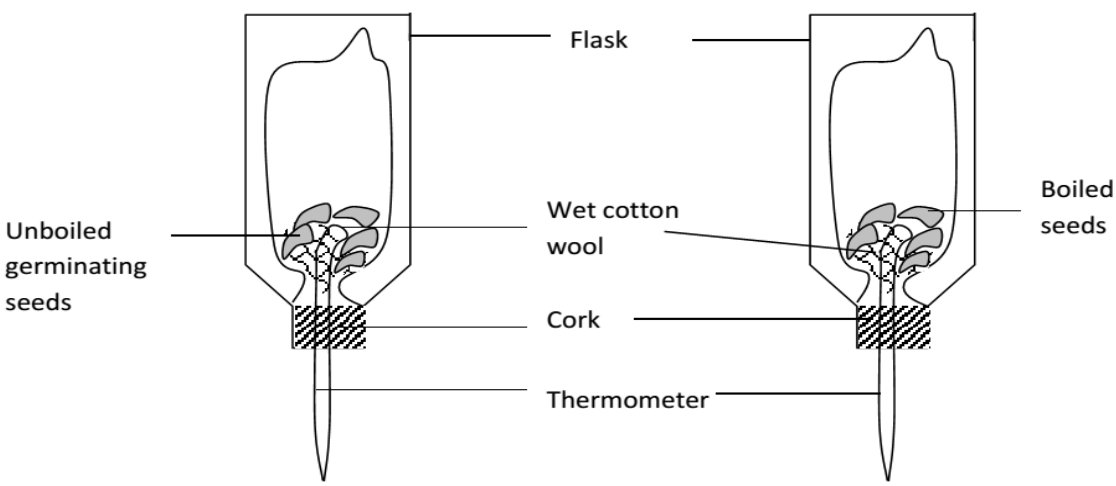
- Vacuum flask,
- Germinating seeds,
- Cotton wool and

- Thermometer.
- Sodium hypochlorite solution

Procedure

- The seeds are socked in water for 24 hours.
- One group of seeds is then killed by boiling them in water.
- Both sets of seeds are socked in formalin for 15 minutes in order to kill any bacterial and fungal spores.
- Place moist germinating seeds in one flask.
- Place the boiled seeds in another flask.
- Insert a thermometer in each of the flasks plugged with cotton wool.
- Fix the two flasks on a retort stand in an upside down position so that the seeds are near the thermometer bulb as shown below.

Setup



Observation

After three days the temperature in the germinating seeds is higher than that of the boiled seeds. That of the boiled seeds remains constant.

Conclusion

Germinating seeds give out heat.

Explanation

During germination oxygen is absorbed to carry out respiration, which gives out energy in form of heat.

Similarities between aerobic and anaerobic respiration

1) Both require glucose as a raw material.
2) Both produce energy.
3) Both produce Carbondioxide.
4) Both take place in living cells.

Differences between aerobic and anaerobic respiration

Aerobic respiration	Anaerobic respiration
A common mode of respiration in both plants and animals	Rare process limited to few plants and animals
Produces more Carbondioxide	Produces less Carbondioxide.
Occurs throughout life	Occurs temporary in very active muscles
Liberates large quantities of energy	Liberates less energy
Products are water, Carbondioxide and energy	Products are Carbondioxide, energy and alcohol or lactic acid.
Complete breakdown of food	Incomplete break down of food.
Oxygen is used	Oxygen is not used.

Respiration quotient: This is the ratio of CO_2 produced to oxygen used:

$$RQ = \frac{CO_2 \text{ produced}}{O_2 \text{ used}}$$

Importance of respiration

1) Respiration produces energy that is used to run the various activities in the body.
2) It is exploited commercially in baking, brewing and making of dairy products such as cheese, yoghurt and butter.

Similarities between respiration and photosynthesis

1) Both take place in living cells.
2) Both involve enzymes.
3) Both involve oxygen, Carbondioxide and glucose.
4) Both involve energy.

Differences between respiration and photosynthesis

Respiration	Photosynthesis
Oxygen is absorbed	Oxygen is released
Carbondioxide is released	Carbondioxide is absorbed
Takes place in light and darkness	Needs light to take place
Energy is released	Energy is absorbed
Does not require chlorophyll	It requires chlorophyll
Take place in plants and animals	Takes place in plants only.

GASEOUS EXCHANGE

This is the exchange of respiratory gases between the organism and the environment. It takes place across specialized surfaces called respiratory surfaces. Gaseous exchange helps an organism to get rid of CO_2 produced during respiration within cells and at the same time obtain oxygen needed for aerobic respiration to occur.

Note:*Breathing is an **active process** involving movement of air in and out of the body whereas gaseous exchange is a **passive process** involving passage of air through respiratory surfaces/gaseous exchange surfaces.*

Characteristics of a good respiratory surface

Respiratory surfaces are sites where gaseous exchange takes place in the body of the organism. Respiratory surfaces possess the following characteristics:

1) They have a large surface area to volume ratio to enable rapid diffusion of gases. This is achieved by folding or branching of structures to form alveoli in lungs, gill filaments in the gills and tracheoles in insects.
2) They are moist to allow easy diffusion of gases.
3) They are thin walled to reduce on the distance over which diffusion has to take place.
4) They have a good network of blood capillaries for easy transportation of gases to the respiring tissues.
5) They are well ventilated to maintain a high concentration gradient that favours diffusion of gases.

Note; respiratory surfaces of insects are not supplied with a network of blood capillaries because the blood of insects does not transport gases. The gases are transported in the tracheole tubes.

GASEOUS EXCHANGE IN PLANTS

Plants do not have a special respiratory surface for gaseous exchange. They use simple pores i.e. stomata of the leaves and lenticels of the stems for gaseous exchange.

Gases circulate in the plant by simple process of diffusion due to abundant large intercellular spaces that make diffusion faster.

Plants do not need special respiratory surfaces and blood transport system because:

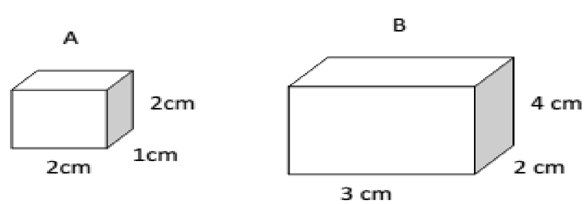
- They utilize CO_2 produced by the plant cells for photosynthesis thus preventing accumulation.
- Plants produce oxygen as a bi-product of photosynthesis which is then used in respiration.
- Plants have numerous stomata and lenticels that favour fast gaseous exchange.
- They have large intercellular spaces that favour fast circulation of gases without blood.
- They have low demand for oxygen due to their low metabolic rate because they are less active since they are immobile.

Gaseous exchange in simple organisms

Small organisms like amoeba, paramecium, hydra and jellyfish have a large surface area to volume ratio. In such organisms gaseous exchange takes place over the whole body surface. Because of their small body volume, diffusion alone is enough to transport oxygen and Carbondioxide into, around and out of their bodies.
Larger organisms such as insects and vertebrates have a small surface area to volume ratio. In these organisms, gaseous exchange takes place in a specialized region of the body known as a respiratory surface. The respiratory surface is part of the respiratory organ. It is the actual site where gaseous exchange takes place.

Surface area to volume ratio and gaseous exchange

Surface area to volume ratio is an important aspect in gaseous exchange. It is obtained by calculating the total surface area and dividing it by the volume of the object in question.
Consider two boxes A and B below



Box A is smaller than box B. we can work out the surface area to volume ratio of each box to prove that smaller objects have a larger surface area to volume ratio than big ones.
Starting with box A

Total surface area.

$$A = 2(2X1) + 2(1X2) + 2(2X2)$$
$$A = 4 + 4 + 8$$
$$A = 16cm^2$$

Volume of A

$$V = LXWXH$$
$$V = 2X1X2$$
$$V = 4\ cm^3$$

Surface area to volume ratio of A

$$\frac{16}{\quad}$$

$$= 4$$

Box B

Total surface area.

$$A = 2(3X2) + 2(3X4) + 2(2X4)$$
$$A = 12 + 24 + 16$$
$$A = 52cm^2$$

Volume of B

$$V = LXWXH$$
$$V = 4X2X3$$
$$V = 24\ cm^3$$

Surface area to volume ratio of B

$$\frac{52}{\quad}$$

$$= 2.3$$

The surface area to volume ratio of A is larger than that of B.

- Therefore the surface area to volume ratio of smaller organisms is larger than that of larger organisms. This facilitates a faster rate of diffusion to ensure that all body tissues are supplied with respiratory gases.
- Smaller organisms also have a short diffusion distance i.e. it takes less time for gases to move to all parts of their body. Most of them are single celled and some have only one layer of cells.
- Larger organisms on the other hand have a smaller surface area to volume ratio. This reduces the rate of diffusion and diffusion alone cannot meet the respiratory demands of their large bodies.
- They also have a large diffusion distance because they have very many layers of cells. Due to this large organisms have developed mechanisms, which reduce on the diffusion distance and increase the surface area to volume ratio.
- Mammals have developed a blood circulatory system, which transports blood containing respiratory gases through highly branched blood vessels to all cells of the body.
- Insects have developed a tracheal system, which has finely divided tubes known as tracheoles, which carry respiratory gases to and from all cells in the body of the insect.

Examples of respiratory surfaces and corresponding respiratory organs

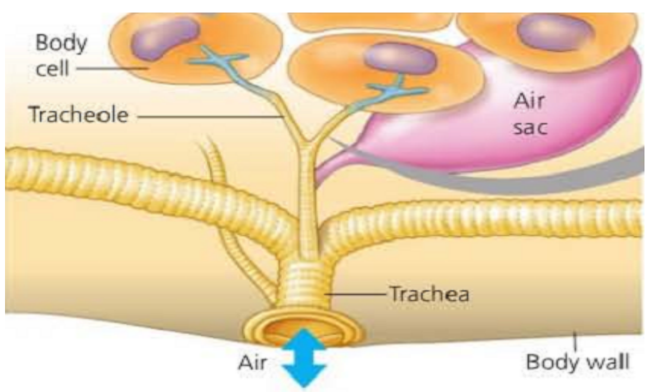
Animal	Respiratory organ	Respiratory surface
Amphibians	Lungs	Alveolus
Amphibians	Skin	Skin surface
Amphibians	Buccal cavity	Buccal cavity epithelium
Birds	Lungs	Alveolus
Fish	Gills	Gill filaments
Insects	Tracheal system	Tracheoles
Mammals	Lungs	Alveolus
Tadpoles	Gills	Gill filaments

NB: the movement of gases and water to and from respiratory surface is called ventilation (breathing).

GASEOUS EXCHANGE IN INSECTS

The respiratory organs of insects consist of a network of tubes known as tracheal tubes, which make up the tracheal system. These tubes reach all the body tissues like the capillaries.

The tracheal system of insects



Ventilation mechanism

Inhalation:

- When the abdominal wall expands, the internal pressure reduces and the volume increases.

- This forces air containing oxygen in to the insect through the spiracles, to the trachea and then the tracheoles.
- Between the tracheoles and muscles of the insect, gaseous exchange occurs with oxygen entering in to the tissues and CO_2 released from tissues, diffusing into the fluid in the tracheoles

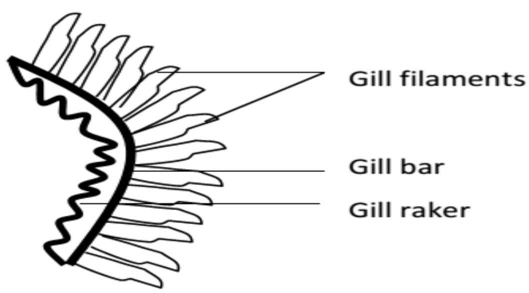
Exhalation:

Abdominal wall contracts, internal volume decreases while pressure increases, forcing air with a high concentration of carbon dioxide in the tracheoles out of the insect through the spiracles.

GASEOUS EXCHANGE IN FISH

Fish uses water as a medium of gaseous exchange and their respiratory surface is the internal gill.
Fish absorb dissolved oxygen from water by use of gills. In most fish there is a pair of gills on each side of the body and in bony fish the gills are covered by a gill plate also called the operculum.

Structure of the gill



Parts of the gill:

1. **Gill bar**: this provides an attachment and support to the gill filaments.
2. **Gill raker**: These are hard projections from the gill bar.
    - They trap food suspended in water.
    - They protect the gill filament by filtering out sand particles in water before reaching the gill filament.
3. **Gill filaments:**

These are sites of gaseous exchange in the fish.

- They are finger-like projections that increase the surface area for gaseous exchange.
- They have a network of capillaries whose blood moves in the opposite direction with water (counter current flow) to maintain a high concentration gradient by carrying away the diffused gases.

- Filaments have a thin membrane
- They are well ventilated.
- They are numerous to increase the surface area.

Mechanism of ventilation in bony fish

Ventilation in bony fish occurs in two phases i.e. inhalation and exhalation.

Inward movement of water

- This is the process by which water containing dissolved oxygen is allowed into the body of the fish.
- The fish closes the operculum (gill cover) and opens the mouth.
- It then lowers the floor of the mouth cavity. This increases volume of the mouth cavity and lowers its pressure below that of the surrounding water.
- The mouth then opens to let in water into the mouth cavity (buccal cavity)
- Water flows into the mouth cavity through the mouth.
- It then closes the mouth and rises the buccal cavity to decrease the volume and increase the pressure in the buccal cavity.
- Meanwhile the gullet is closed.
- This makes the water current to flow into the gill chamber.
- As water passes over the gill filament, gaseous exchange takes place i.e. oxygen diffuses into blood while CO_2 diffuses from blood into the water.

Out ward movement of water:

- For water to flow out after gaseous exchange, the operculum muscle relax then water flows out.
- Meanwhile the buccal floor is still raised and the mouth is still closed.
- The buccal floor then lowers to repeat the cycle.

GASEOUS EXCHANGE IN AMPHIBIANS

a) Tad pole

- Tad poles first use external gills and later internal gills as surface of gaseous exchange.
- The tad pole takes in water through the mouth and the water passes over the gills and then out of the body through the gill slit.
- The oxygen diffuses from the water into the blood while CO_2 diffuses from blood into water.

b) Adult amphibians

In adults gaseous exchange takes place through the;

1. Skin.
2. Lining of the mouth cavity.
3. Lungs.

Amphibians depend mostly on their skin and buccal cavity for their gaseous exchange while they are in water. Lungs are only used when on land or when the water dries and the amphibian has to remain in mud.

1. The skin

The skin is thin walled, moist and has a good network of blood capillaries. The skin acts as a respiratory surface when the amphibian is in and out of water. It's used when the oxygen need is low.

On land, the atmospheric oxygen dissolves in the layer of moisture and then diffuses across the skin into the blood.
At the same time, CO_2 diffuses from the blood into the atmospheric air.
In water, the oxygen dissolved in it, diffuses from the water across the skin into blood. CO_2 diffuses from blood into water.

2. The buccal cavity

The buccal cavity has a thin lining which is kept moist. It also has a good network of blood capillaries. The cavity is ventilated in the following ways.

During inhalation:

- The mouth floor lowers when it closes.
- This increases the volume of the buccal cavity reducing the pressure within.
- This forces the air from the atmosphere through the nostrils into the buccal cavity.
- Oxygen diffuses through the thin cavity membrane into blood while Carbondioxide diffuses from blood into the buccal cavity.

During exhalation:

- The muscles of the floor of the buccal cavity relax raising the floor of the mouth.
- This leads to a reduction in volume and an increase in pressure within the mouth cavity.
- Air then moves out to the atmosphere through the nostrils.

3. The lungs

- The lungs consist of sacs supplied by a good network of blood capillaries.
- They have a large surface area.
- It is supplied with a lot of blood capillaries
- It is thin walled.

- Ventilation of the lungs occurs in the following stages;

Inspiration:

- The mouth closes and the nostrils open.
- Muscles of the floor of the buccal cavity contract to lower the mouth floor. This increases the volume and reduces the pressure within the buccal cavity.
- Air enters through the nostrils into the buccal cavity.
- The nostrils close, the muscles of the floor of the buccal cavity relax to raise the floor of the buccal cavity, while those of the abdominal cavity contract.
- This causes the volume of the buccal cavity to reduce and that of the abdominal cavity to increase.
- Pressure in the buccal cavity increases and that in the lungs decreases.
- It opens the glottis and air moves from the mouth cavity into the lungs through the trachea.
- Oxygen diffuses from the lungs into blood and Carbondioxide from the blood into the lungs.

Exhalation:

- For exhalation, the abdominal muscles relax to reduce the volume of the lungs while the floor of the mouth cavity is lowered to increase its volume.
- This creates a higher pressure in the lungs and low pressure in the buccal cavity.
- Waste air is forced from the lungs into the buccal cavity
- The valve to the lungs (glottis) closes and nostrils open.
- Muscles of the floor of the mouth cavity relax raising the floor and increasing pressure in the buccal cavity.
- Waste air is forced from the cavity through the nostrils to the atmosphere.

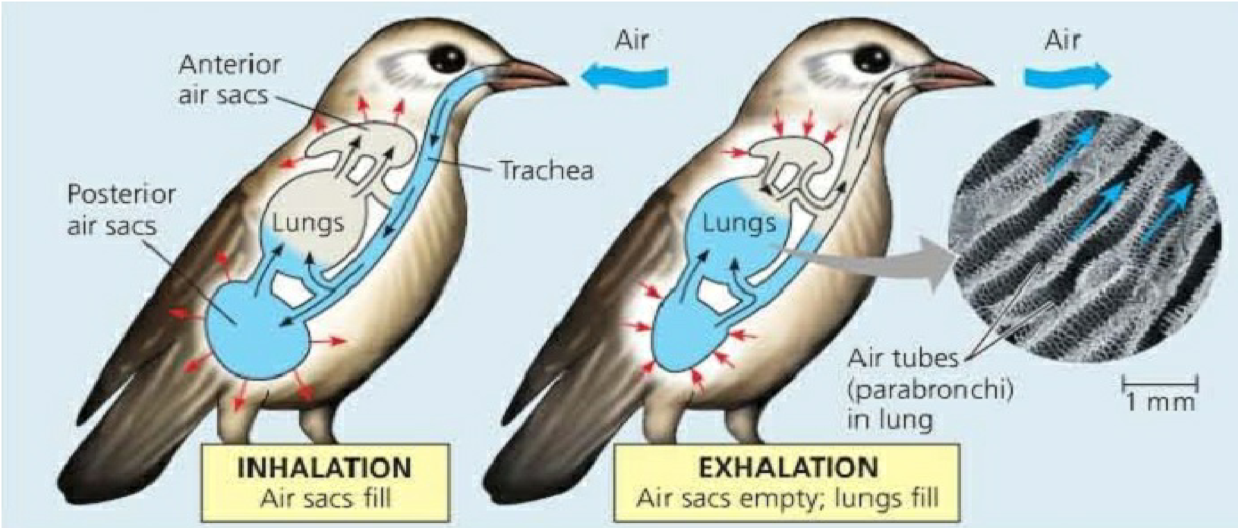
GASEOUS EXCHANGE IN BIRDS

Due to metabolic rate, birds need high supply of oxygen and an efficient gaseous exchange mechanism.

The respiratory system is made up of lungs and air sacs.

During inhalation, air enters through the trachea, bronchus and to the posterior air sac to the lings, then to the anterior air sac and finally to the exterior (atmosphere) through the trachea.

Illustration



GASEOUS EXCHANGE IN MAMMALS e.g. man

The respiratory organs in man are lungs and the respiratory surfaces are the sac like structures called alveoli.

The respiratory tract (air passage)

Air enters through the nostrils into the nasal cavity where it is warmed to body temperature.
It begins from the nostrils into the back of the mouth, then into the pharynx from which it goes into the larynx and then to the trachea. From here, it travels through the bronchus, bronchioles and lastly to the alveolus.
The membrane of the nasal cavity is covered with cilia between which are goblet cells, which produce mucus.
Dust and germs inhaled from the atmosphere are trapped in mucus and are carried by the beating action of cilia towards the back of the mouth where they are swallowed.
This helps to prevent dust and germs from entering the lungs. Therefore, by the time air reaches the lungs it is dust and germ free, warm and moist. It is drawn from the nasal cavity into the trachea (wind pipe).

The trachea

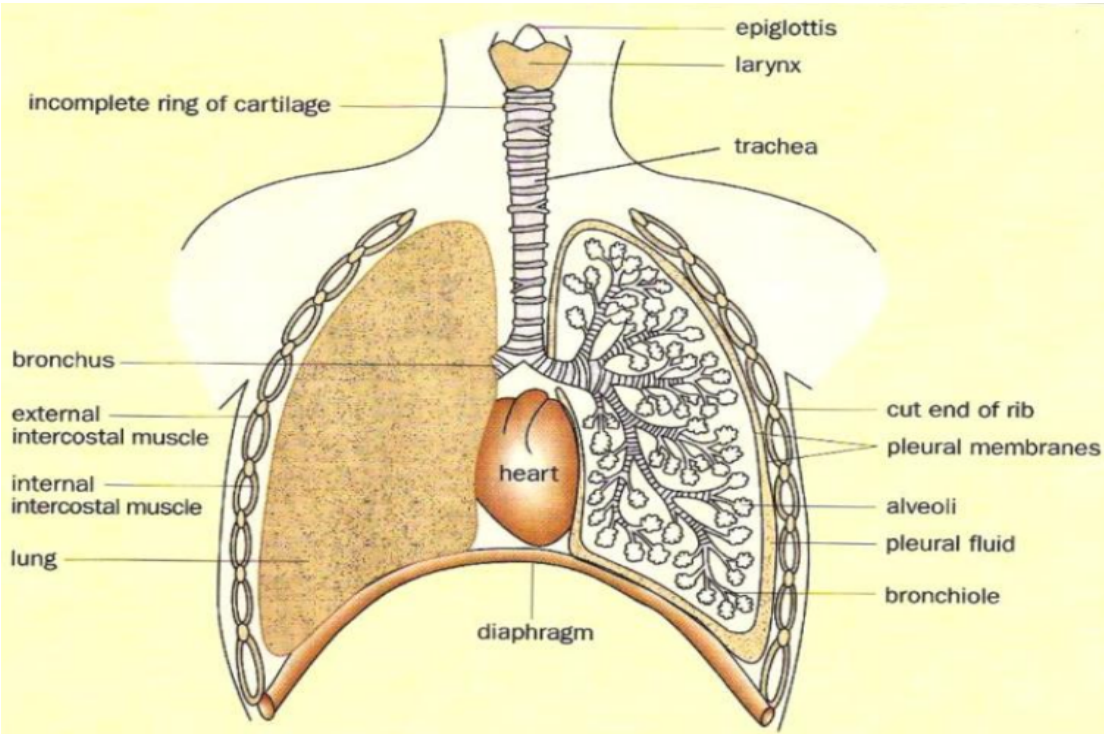
This is a tube running from the pharynx to the lungs. It is always kept open by the circular rings of cartilage within it. The cartilage prevents the trachea from collapsing in case there is no air.
Cilia and goblet cells extend into the trachea to draw germs and dust out of trachea into the mouth where they are lost.
At the lower end, the trachea divides into sub tubes called bronchi, which penetrate further into the lungs and divide repeatedly to form small tubes called bronchioles.

The bronchioles divide into many small tubes called alveolar ducts, which end in air sacs called alveoli.

The alveoli are the respiratory surfaces of mammals. There are about 300 million alveoli in a human lung. This increases the surface area over which gaseous exchange takes place.

Location of the lungs in the body

They are located in the thoracic cavity, enclosed by thorax wall and diaphragm.



The alveoli

An alveolus is a sac-like structure. The outer surface of the alveolus is covered with a network of blood capillaries. The alveolus is moist and thin walled. The oxygen in the alveolus diffuses into blood in the capillaries and it is carried around the body. At the same time, Carbondioxide diffuses from blood into the alveolus and travels through the alveolar duct to the bronchioles then to the bronchi and trachea and out through the nostrils.

The mammalian lung

These are two elastic spongy-like structures located within the thoracic cavity and protected by the rib cage. Between the ribs are intercostal muscles, which move the rib cage. Below the lungs is a muscular sheet of tissue called the diaphragm.

Breathing mechanism in mammals/ lung ventilation

The breathing mechanism in mammals involves two sub-processes that are inspiration and expiration.

Inspiration:

This is the process by which air is allowed into the respiratory organs (lungs).

- The external intercostal muscles contract while the internal intercostal ones relax.
- This makes the rib cage to move outwards and upwards. The diaphragm contracts and flattens.
- This increases the volume of the thoracic cavity and reduces the pressure in it below that of the atmosphere.
- This causes air to enter from the atmosphere through the nostril, trachea, bronchi, and bronchioles until it reaches the alveoli.

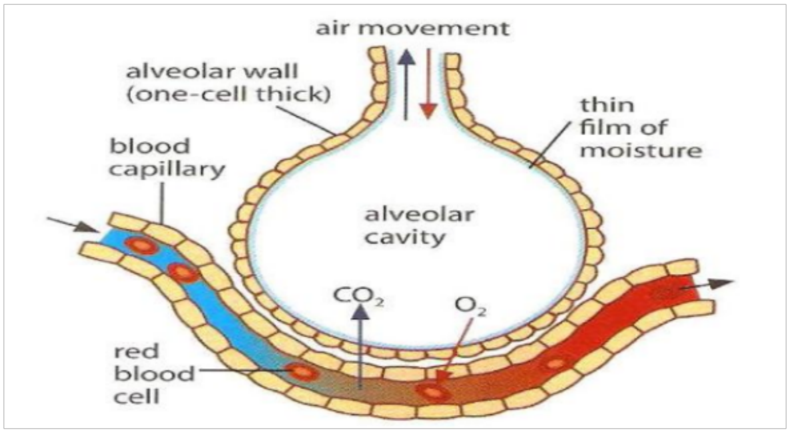
Expiration:

- The internal intercostal muscles contract and the external ones relax.
- This makes the rib cage to move downwards and inwards and the diaphragm becomes dome-shaped.
- This reduces the volume of the thoracic cavity and increases its pressure beyond that of the atmosphere.
- This forces the lungs to contract and release Carbondioxide through the bronchi, trachea and out through the nostrils.

Gaseous exchange in the alveolus

This take place across walls of alveoli and blood capillaries by diffusion.

During inspiration, air is taken into the lungs filling the alveoli. This air contains more oxygen and low CO_2 concentration. Oxygen in inspired air dissolves in the moisture of the alveolar epithelium and diffuses across this and capillary walls into the red blood cells of blood. Inside the red blood cell, oxygen combines with haemoglobin to form oxyhaemoglobin and carried in this form. At the same time, CO_2 which was carried as bicarbonate ion in blood diffuses from it through the capillary walls into the alveoli. It leaves the lungs in expired air.



Changes in the composition of gases in blood across the alveolus

Volume of gas carried by 100cc of blood

Gas	Entering lungs	Leaving lungs

Nitrogen	0.9cc	0.9cc
Oxygen	10.6cc	19.0cc
Carbon dioxide	58.0cc	50.0cc

The blood that flows towards the lungs contains a larger volume of carbondioxide and less oxygen. But as it leaves the lungs, oxygen is added into it and some CO_2 is given off in the lungs. This indicates exchange of gases within the lungs.

Changes in approximate air composition during breathing

Component	Inhaled	Exhaled
Nitrogen	79%	79%
Oxygen	21%	17%
Carbon dioxide	0.03%	4%
Water vapour	Less saturated (variable)	Saturated
Temperature	Atmospheric temperature	Body temperature

Although nitrogen is exchanged within the lungs and blood plasma, it plays no part in chemical reactions of the body hence its composition remains the same in inspired and expired air.

Inhaled air has more oxygen compared to exhaled air because it is taken up for the process of respiration, which produces out CO_2. Hence exhaled air contains more CO_2 than inhaled air. However the process of gaseous exchange in alveoli does not remove all the carbon dioxide and oxygen in air.

Experiment to demonstrate breathing in mammals

Materials

- Glass tubing,
- Cork,
- Rubber tubing,
- Y tube,
- Bell jar,
- Two balloons,
- Rubber sheet and
- Thread.

Procedure

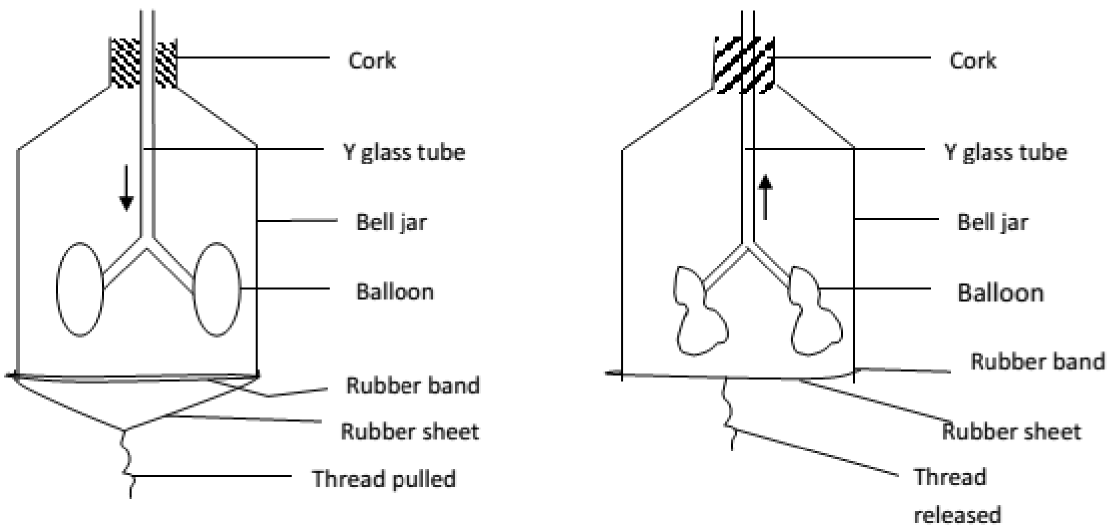
- Get a bell jar and fix a cork with glass tubing in its mouth.
- Use a rubber tubing to connect a Y tube to the glass tubing inside the bell jar.
- Tie balloons on each end of the Y tube to act as lungs.
- Tie a rubber sheet using a rubber band at the open end of the bell jar to act as a diaphragm.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

Note

The bell jar acts as the thoracic cavity and its walls as the rib cage. The glass tubing acts as the trachea and the ends of the Y tube act as the bronchi.

- Pull the end of the rubber sheet using the thread to represent inhalation and release it to represent 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: Pulling of the thread represents inspiration and its release represents expiration.

Important terms related with breathing.

Lung capacity: This refers to the total volume of the lungs when fully inflated. In an adult man, this is about 5 liters. When breathing at rest only a small volume of the lung is used. This is called the **tidal volume**. Tidal volume is the volume of air breathed in and out at rest. When the body is very active, a larger volume of air is taken into the lungs. This volume is called the **vital lung capacity.** However, even at maximum expiration some air remains inside the lungs to prevent the lungs from collapsing. This air makes up the **residual volume**.

Experiment to show that expired air contains Carbondioxide.

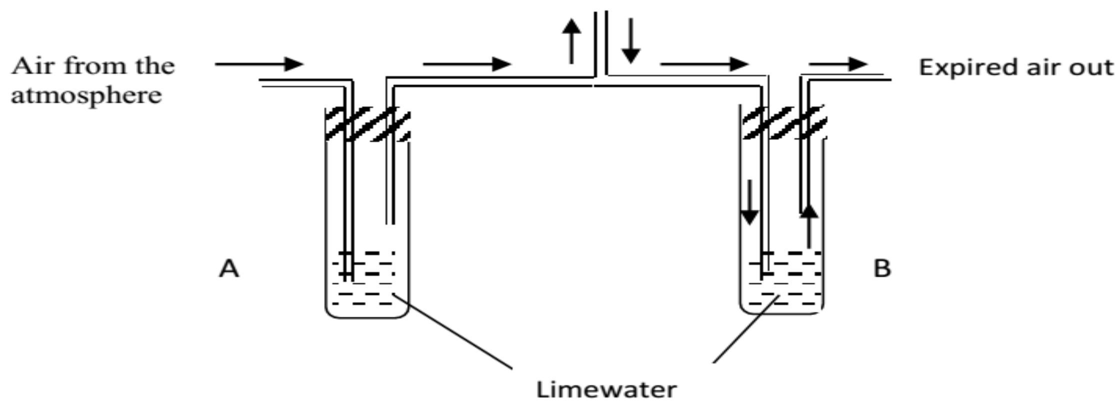
Materials

- Two test tubes,
- Two corks,
- T- Tube,
- Two right angled capillary tubes and
- Lime water

Procedure

- Place the T tube in the mouth and breathe in and out normally.
- Air is made to pass into the lungs from test tube A and out through test tube B. inhalation air is got from the atmosphere through the capillary tube and lime water in tube A.
- Exhaled air passes through lime water and capillary tube at the B end.

Set up of the experiment



Observation

Lime water in tube B turns milky while that in A remains clear.

Conclusion

Expired air contains Carbondioxide.

Explanation

It is only Carbondioxide, which can change the colourless limewater to milky. Therefore since B had expired air, it proves it.

Experiment to measure the volume of expired air/depth of breathing

Materials:

- Trough
- Calibrated Bell jar

- Cork
- Glass tube
- Rubber tube
- Water

Procedure:

- A bell jar calibrated in liters is completely filled with water and placed in a trough.
- One end of the rubber tube is then inserted in the bell jar while the other end is connected to a glass tube.
- The demonstrator (person) then breathes out once into the bell jar via the glass tube.
- This is done at 2 different occasions namely, at rest and immediately after an exercise.

Observation:

- Some amount of water is displaced from the bell jar when the person breathes out.
- However, the volume of water displaced at rest is lower than the volume of water displaced after an exercise.
- The volume of water displaced is recorded and equal to the volume of air expired.

Conclusion:

The volume of expired air is greater immediately after an exercise than at rest, this shows that exercise increases the depth of breathing.