RESPIRATION

Cellular respiration (or Tissue respiration) is the process by which food substances are broken down to release energy in body cells. Respiration mainly takes place in the mitochondria and is enzyme catalyzed to produce ATP (adenosine triphosphate). Since the release of energy occurs inside the cell, it is called **internal respiration**. The energy released from the food is used to attach a phosphate group to a compound called adenosine diphosphate (ADP) found in all cells to form adenosine triphosphate (ATP). **ATP formed is an energy store** i.e.

$ADP + P \rightarrow ATP$

All ATP stores energy for a short time and when the cells need energy, ATP is hydrolysed to release the energy stored. $ATP + H_2O \rightarrow ADP + P + Energy$

Uses of Energy

- It is used for muscle contraction in animals
- Energy is used for growth i.e. replacement of worn-out cells
- Used by plants for photosynthesis
- Movement of substances in and out of cells by active transport.
- Used for production of heat for maintenance of normal body temperature
- Carrying impulses along nerve cells in animals
- Absorption of water and mineral salts in plants.

Types of Tissue Respiration

There are two types of tissue respiration. These include:-

a) Aerobic respiration
b) Anaerobic respiration

Aerobic Respiration

This is the breakdown of food substances in presence of oxygen in the body cells to release energy. The respiratory substrates include mainly carbohydrates and lipids.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + Energy.$$

When an organism respires, it utilizes food to generate carbon dioxide, waterand energy. These are referred to as **products of aerobic respiration**. Experiments can be carried out to demonstrate that respiration is taking place in organisms through detection of products given off or through decrease in the dry weight of an organism.

Experiments of Respiration

Experiment 1: To show that germinating/respiring seeds give off carbon dioxide.

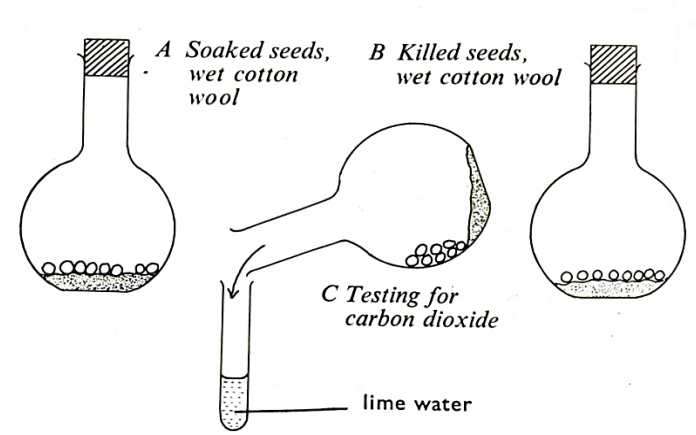
Materials

- Soaked been seeds
- Wet cotton wool
- Conical flasks
- Lime water or bicarbonate indicator
- Sodium hypochlorite or jik
- Heat source
- Boiled seeds

Procedure

- Wet cotton wool is placed in two flasks A and B.
- Soaked seeds are added to flask A and an equal number of boiled seeds to flask B.
- Both groups of seeds are soaked for 15 minutes in sodium hypochlorite solution to prevent fungal and bacterial growth which might produce carbon dioxide.
- The flasks are securely corked and left in the same conditions of light and temperature until germination is clearly observable in flask A. the seeds in flask B should not germinate.
- The gases in each flask are then tested by removing the cork and tilting the flask over a test tube of lime water and shaking up the test tube.

Set up



Results

The air from flask A turns lime water milky showing that carbon dioxide is present. Air from flask B has no effect on lime water.

Interpretation

The carbon dioxide must have been produced by the germinating seeds. B acts as a control experiment and proves that it is not the cotton wool or anything other than germinating seeds that give carbon dioxide.

Conclusion

Carbon dioxide is given off during germination as the germinating seeds respire.

Experiment 2: To show that carbon dioxide is produced by respiring animals

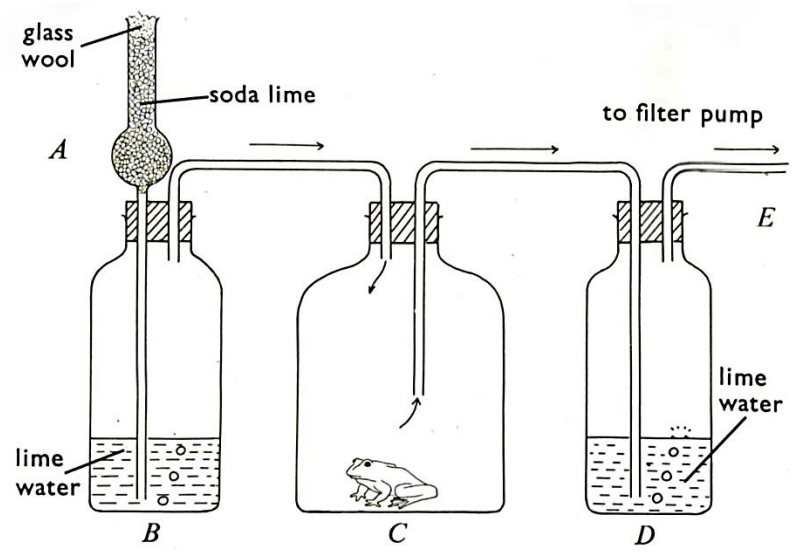
Materials

- Small animal such as frog or insect
- Conical flasks
- Lime water
- Suction pump
- Soda lime
- Delivery tubes
- Glass wool

Procedure

- Flasks are connected using capillary tubes and the setup is as shown below
- The animal is placed in vessel C. A stream of air is drawn slowly through the apparatus by means of the filter pump at E
- The soda lime at A absorbs carbon dioxide from the incoming air. The lime water at B should be clear to prove that carbon dioxide is absent from air going to vessel C.

Set up



Observation

The lime water in vessel D turns to white precipitate.

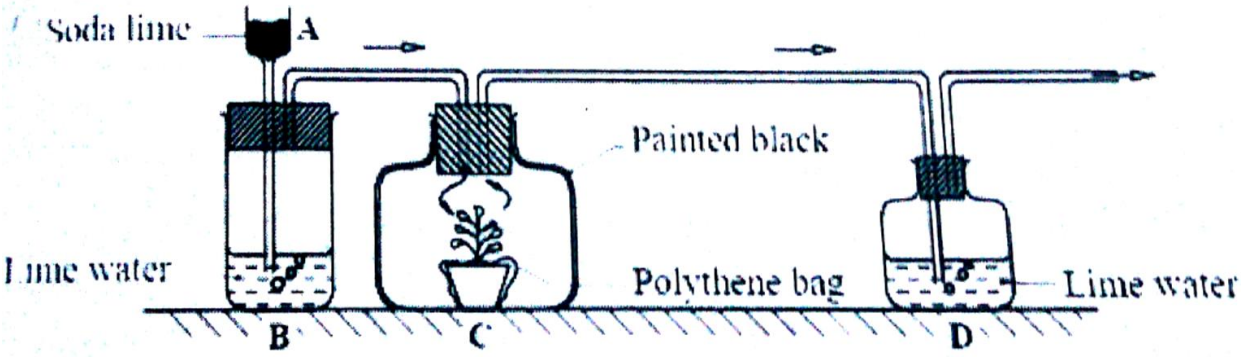
Conclusion

Carbon dioxide is given off by respiring organisms

Note

A potted plant can also be used in vessel C but must be blackened out to prevent photosynthesis from taking place. The pot must be enclosed impermeable material so that respiration of the organisms in soil does not affect the results.

Diagram for the Set up



Experiment 3: To determine rate of respiration in a small animal

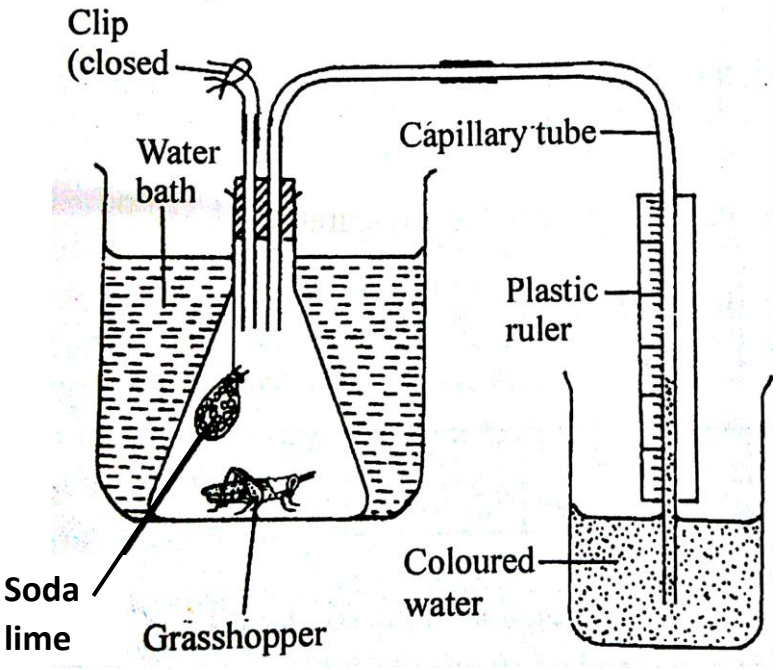
Materials

- Small animal
- Beaker
- Conical flask
- Cork
- Capillary tube
- Water bath
- Coloured water
- Plastic ruler
- Clip
- Soda lime

Procedure

- Small animal e.g. grasshopper is put in conical flask, containing soda lime to absorb carbon dioxide corked and connected to source of coloured water by capillary tube
- Conical flask with animal is put in water bath maintained at 25^{o}C
- A plastic ruler is tied onto the capillary tube to determine the uptake of coloured water
- The experiment is left to stand for about 30 minutes

Setup



Observations

The level of water in capillary tube rises

Explanation

The grasshopper absorbs oxygen for respiration and gives off carbon dioxide gas which is absorbed by the soda lime. Oxygen absorption causes coloured water to rise up the capillary tube. The distance moved by the coloured water divided by time taken is used to determine the rate of respiration.

Conclusion

Movement of coloured water shows that respiration is taking place.

Experiment 4: To show that germinating seeds release heat (energy) during respiration

Materials

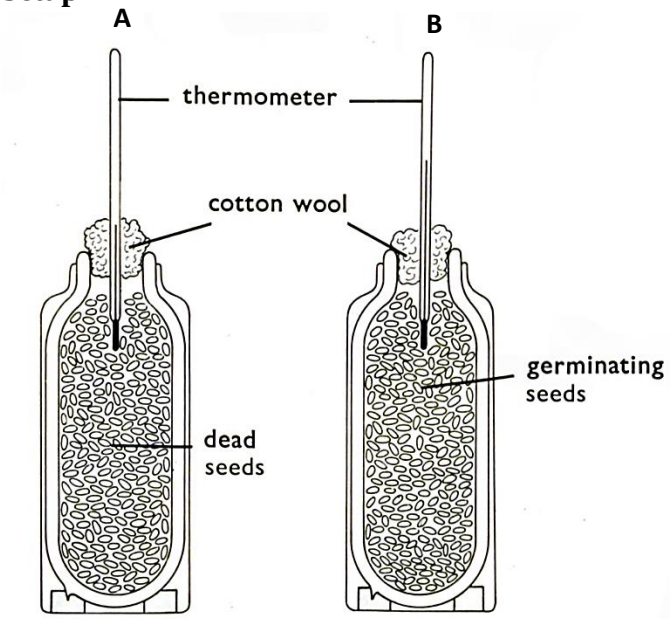
- Soaked bean seeds
- Vacuum flasks
- Thermometers
- Cotton wool
- Sodium hypochlorite or jik
- Heat source

Procedure

- Sufficient amount of seeds to fill two small vacuum flasks are soaked in water for 24 hours and half of them are killed by boiling for 10 minutes.

- Both lots of seeds are soaked for 15 minutes in a solution of sodium hypochlorite to kill fungal spores on the grains. The seeds are rinsed with tap water.
- The living seeds are placed in flask A and the dead in flask B. The thermometers are inserted and the mouths of flasks plugged with cotton wool.

Setup



Result

After a few days the temperature in the flask with living seeds will be considerably higher than the control.

Conclusion

During germination of seeds, heat energy is released

Experiment 5: To show that oxygen is used up during respiration

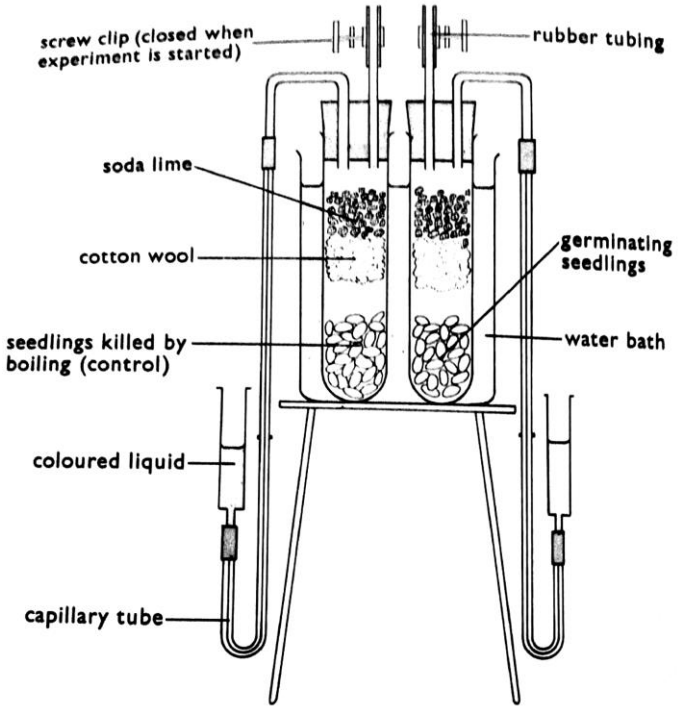
Materials

- Germinating been seeds
- Cotton wool
- Soda lime
- Coloured water
- Test tubes
- Water bath
- Capillary tubes
- Screw clip
- Rubber bang

Procedure

- Germinating been seeds are placed in one test tube and covered with cotton wool while boiled seeds are placed in another test tube and also covered with cotton wool.
- Soda lime is placed at the top of cotton wool in each test tube to absorb carbon dioxide gas from each test tube.
- A capillary tube is used to connect each test tube to the container containing coloured water. the setup is placed in a water bath to maintain favourable temperature for metabolism
- The setup is left to stand for 5 days

Setup



Observations

The coloured water rises in capillary tube from the container connected to the test tube with germinating seeds. No observable change in coloured water level from test tube with boiled seeds.

Explanation

Germinating seeds use up oxygen from the test tube and create a vacuum so the colored water rises in the capillary tube. Boiled seeds are metabolically inactive so no respiration and no use of oxygen so water level remains the same.

Conclusion

Germinating seeds use up oxygen.

Alternatively

Refer to experiment 3

Anaerobic respiration

This is the chemical breakdown of food materials in a cell to release energy in absence of oxygen.

The food substrate for anaerobic respiration is glucose and fat. The products are; lactic acid, water and energy in animals while in plants, ethanol (alcohol), carbon dioxide and energy are formed
i.e. in animals: Glucose → Lactic acid + Water +Energy
In plants: Glucose → carbon dioxide + Ethanol + Energy
Lactic acid in animals and ethanol in plants are formed due to incomplete break down of glucose. The incomplete breakdown of food means that less energy is made available during anaerobic respiration than is released during aerobic respiration. The first stage in the breakdown of glucose is anaerobic i.e. Glucose → Lactic acid + Water +Energy
The products of anaerobic respiration are then oxidised to carbon dioxide and water
i.e. **Lactic acid → carbon dioxide + Water**

Lactic Acid Fermentation in Muscles
This occurs during vigorous muscular activity when blood is unable to supply enough oxygen to the skeletal muscles. This results in muscle fibres producing lactic acid as a result of anaerobic respiration, resulting in pain and muscle cramps. Lactic acid is poisonous so must be removed. It is taken to the liver by blood where it is broken down into water and carbon dioxide and energy in presence of oxygen.
The extra oxygen required to breakdown lactic acid to carbon dioxide and water constitutes **oxygen debt** and results in rapid rate of breathing that arises after a race or any vigorous activity.
Question.
The concentration of lactic acid in blood during and after a ten minutes race was determined. The results are shown in the table below;

Time (minutes)	0	10	15	30	40	55
Lactic acid concentration (mg/100cm^3)	20	80	96	72	54	52

a) Plot a graph of lactic acid concentration against time (6 marks).
b) Describe the shape of the graph (4 marks).
c) Explain the variation of lactic acid as shown by the graph (6 marks).
d) Determine the lactic acid concentration at 25 minutes (1 mark).

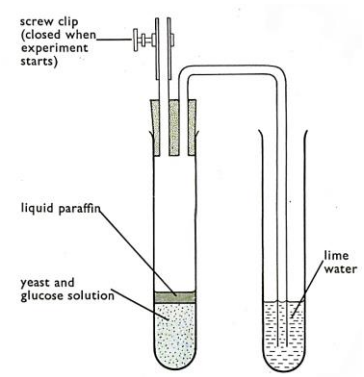
Anaerobic Respiration in Plants
Some plants can respire anaerobically and produce a different intermediate compound called ethanol i.e. Glucose → carbon dioxide + Ethanol + Energy. Certain bacteria and fungi like yeast also derive most of their energy from anaerobic respiration and the end products are frequently alcohol and carbon dioxide. This process is called **alcohol fermentation**.

Experiment to demonstrate that carbon dioxide is given off during anaerobic respiration
Materials
- Water
- Heat source
- Glucose
- Yeast
- Test tubes or boiling tubes
- Delivery tubes
- Lime water
- Liquid paraffin

Procedure

- A given amount of water is boiled to drive out all the dissolved oxygen
- The water is cooled and used to make up a 5% solution of glucose and a 10% suspension of dried yeast.
- A mixture of 5 cm^3 of the glucose solution and 1cm^3 of the yeast suspension are placed in a test tube
- a thin layer of liquid paraffin is poured into the mixture exclude atmospheric oxygen from entering the mixture.
- A delivery tube is fitted and allowed to dip into clear lime water. The experiment is left to stand for 20 minutes.

Setup



Observation

After 20 minutes bubbles of a gas are seen escaping from the mixture into the lime water and turn it milky. The gas is therefore carbon dioxide.

Conclusion

Carbon dioxide is given off during anaerobic respiration.

Note

A control experiment can be set up in the same way but this time using boiled yeast which does not ferment. The fact that living yeast produces carbon dioxide despite being deprived of oxygen is evidence to support the argument that anaerobic respiration is taking place.

Commercial Application of Anaerobic Respiration

- Production of organic acids such as vinegar and citric acid used for food processing.
- Baking of bread where CO2 is used to cause the dough to rise.
- Brewing of alcoholic drinks like beer, wine, spirits and other local drinks
- Dairy products like cheese and yoghurt
- Biogas production (methane) using anaerobic bacteria in cow dung and other organic materials.

Comparison between Aerobic & Anaerobic Respiration

SIMILARITIES

- Both require glucose as a raw material

- Both release energy
- B o t h release carbon dioxide
- Both take place in living cells

Differences

AEROBIC	ANAEROBIC
Occurs in most organisms	Occurs mainly in simple organisms e.g. yeast and internal parasites.
Goes on throughout life	Occurs temporarily in very active muscles in higher plants
Liberates large quantities of energy	Liberates less energy
Utilizes oxygen	Does not utilize oxygen
Products are water and carbon dioxide	Products are ethanol and carbon dioxide in plants and lactic acid in animals.
There is complete oxidation of food	There is incomplete oxidation of food.

Differences between Respiration & Photosynthesis

Respiration	Photosynthesis
Oxygen is absorbed in the process	Oxygen is liberated
Carbon dioxide is liberated	Carbon dioxide is absorbed
Takes place during day and night	Mostly occurs in presence of light
Light is not essential for the process	Light is essential for the process
Energy is released in the process	Energy is stored during the process
Chlorophyll is not necessary	Chlorophyll is necessary
There is loss of weight in plants	Gain in weight of plants
Takes place in animals and plants	Takes place in green plants only.

Question

a) Give 5 differences between respiration and photosynthesis

b) Give 3 ways in which respiration is important to living organisms

c) Name 2 commercial uses of anaerobic respiration