Cellular respiration *Scope*

Topic	Topic Breakdown
Cellular respiration	The process of respiration and uses of energy for living cells. Aerobic respiration in cytoplasm and mitochondria - Glycolysis - Krebs cycle and - oxidative phosphorylation Anaerobic respiration production of: - lactic acid in muscles during exercise - Alcohol fermentation The role of anaerobic respiration in the industry e.g. beer brewing and bread making. A comparison between aerobic respiration and anaerobic respiration in terms of **raw materials** required and **energy** produced. Investigations - Oxygen is required during cellular respiration - Carbon dioxide is released during cellular respiration

Cellular respiration

Cellular respiration is the chemical process where glucose is broken down gradually, in the presence of oxygen (aerobic respiration) or in the absence of oxygen (anaerobic respiration), to release energy.

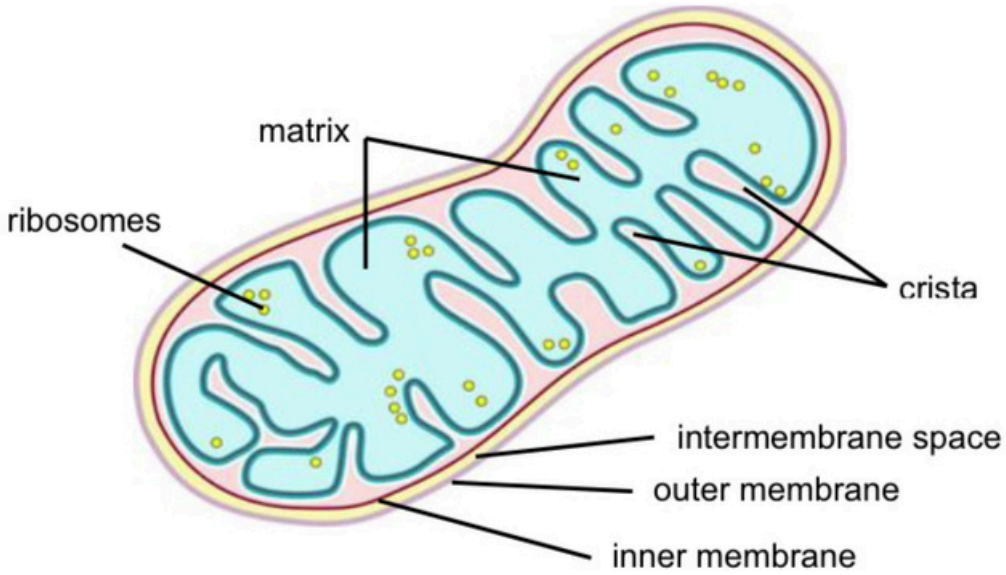
Celllular respiration occurs in plants and animals and takes place in the mitochondrion of a cell.

Uses of energy

Energy is used by organisms in various ways. Some of the main ways in which energy is used include the following:

- growth
- cell division
- movement
- transport of substances
- active transport

Mitochondrion



The requirements for the process are oxygen and glucose and the by-products released are carbon dioxide and water as well as ATP energy.

This can be shown in the following word equation:

Glucose + Oxygen ⟶ Carbon Dioxide + Water + ATP

Cellular respiration Process

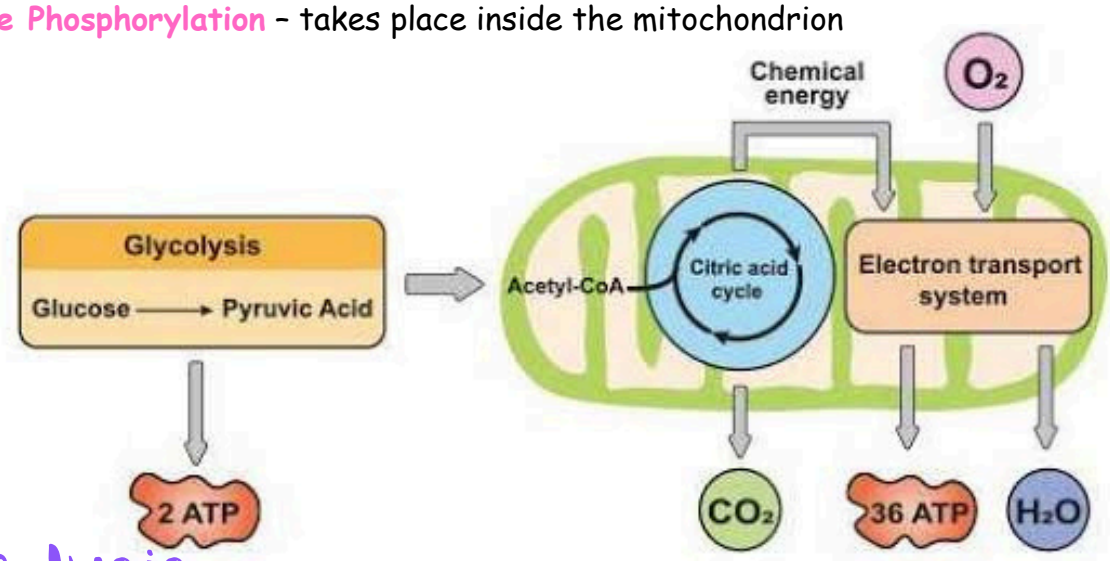
The process of cellular respiration occurs in two ways:
- **Aerobic**: oxygen is required
- **Anaerobic**: no light is required

Aerobic respiration

takes place in the **presence of oxygen**, inside the cytoplasm and mitochondria of cells.

Aerobic respiration takes place in three stages:

1. **Glycolysis** – takes place in the cytoplasm
2. **Krebs Cycle** – takes place inside the mitochondrion
3. **Oxidative Phosphorylation** – takes place inside the mitochondrion



Glycolysis

takes place **outside the mitochondrion**, in the **cytoplasm** of the cell
- **no oxygen** is required
- glucose is broken down into smaller molecules (**pyruvic acid**), releasing a small amount of energy that is stored in energy-rich ATP molecules
- releases high **energy hydrogen ions** (H+) that are used in the third stage of cellular respiration (**oxidative phosphorylation**)

Kreb's cycle

- also known as **citric acid cycle**
- can only take place if **oxygen is present**
- occurs inside of the mitochondrion in the **matrix**
- releases **carbon dioxide** and high energy **hydrogen ions** (H+)
- transports hydrogen atoms to the third stage (**oxidative phosphorylation**) via hydrogen carrier enzymes ($NADH^+$ and $FADH^+$)

Oxidative phosphorylation

takes place inside of the mitochondrion (**cristae**) and **requires oxygen**
- passes high energy hydrogen atoms from one hydrogen carrier enzyme to the next, releasing energy in the process
- uses released energy to combine a phosphate molecule to an ADP (Adenosine Di-phosphate) molecule to form ATP – called **phosphorylation** is represented in the formula: **ADP + P → ATP**
- oxygen acts as a **final hydrogen acceptor** binding with the hydrogen forming water which is released as a **waste** product of cellular respiration

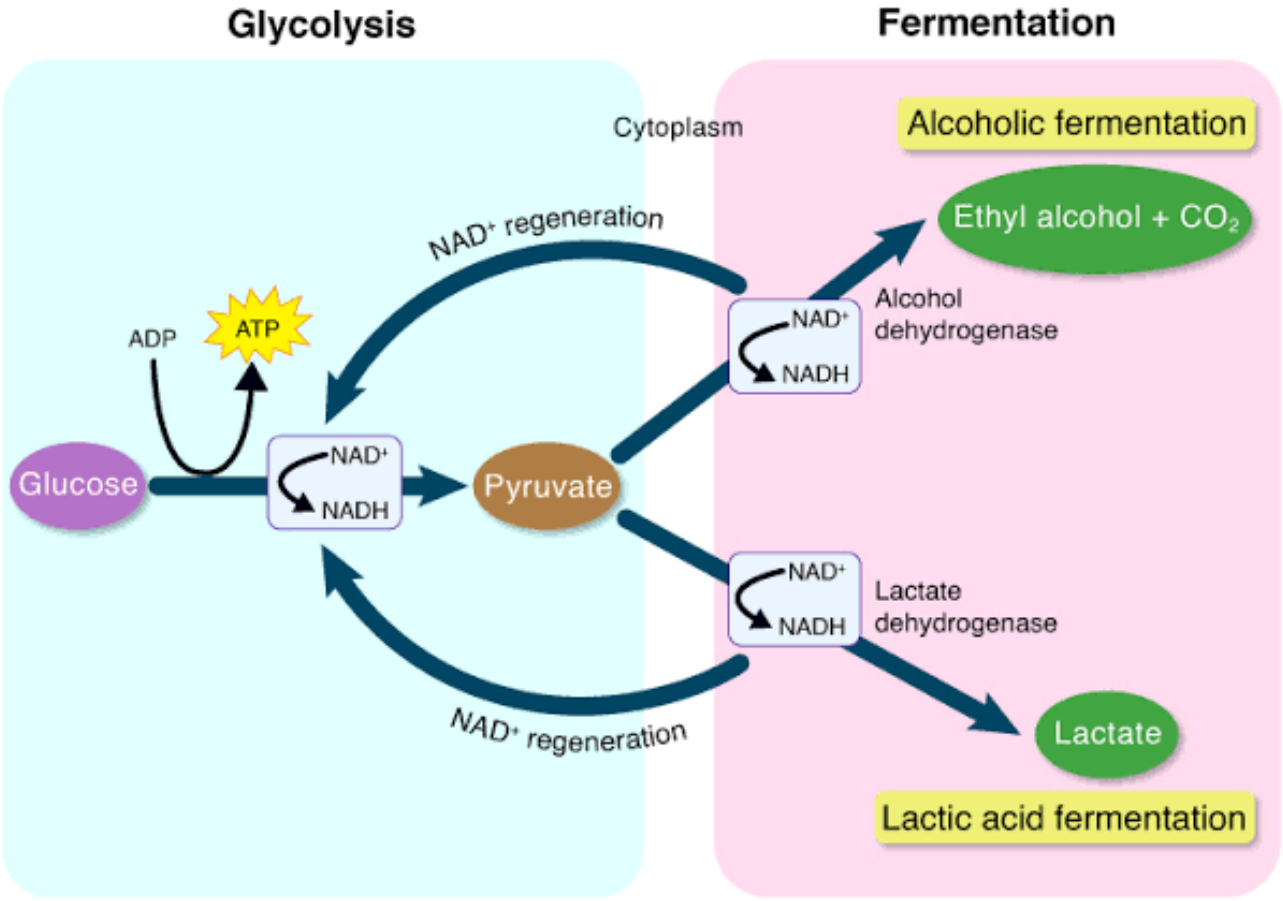
Cellular respiration Process

Anaerobic respiration

takes place in the **absence of oxygen,** inside the mitochondria of cells.

Anaerobic respiration takes place:

- without oxygen being present
- it occurs for short periods of time, mainly during physical exercise
- occurs differently in plants and animals
- produces **less ATP** than aerobic respiration



In animals

is known as lactic acid fermentation

- occurs in muscles during intense exercise
- enables glycolysis in the cytoplasm of animal cells
- results in the accumulation of lactic acid *causing the muscles to become tired and painful*
- produces only a small amount of ATP

The lactic acid can be converted back to pyruvic acid when the muscles receive oxygen.

In plants

- is known as alcoholic fermentation
- enables glycolysis in the cytoplasm of plant cells
- results in the accumulation of pyruvic acid
- breaks down pyruvic acid forming ethanol (alcohol) and releasing carbon dioxide in the process
- can be summarised as:

glucose → ATP + pyruvic acid → ethanol + carbon dioxide

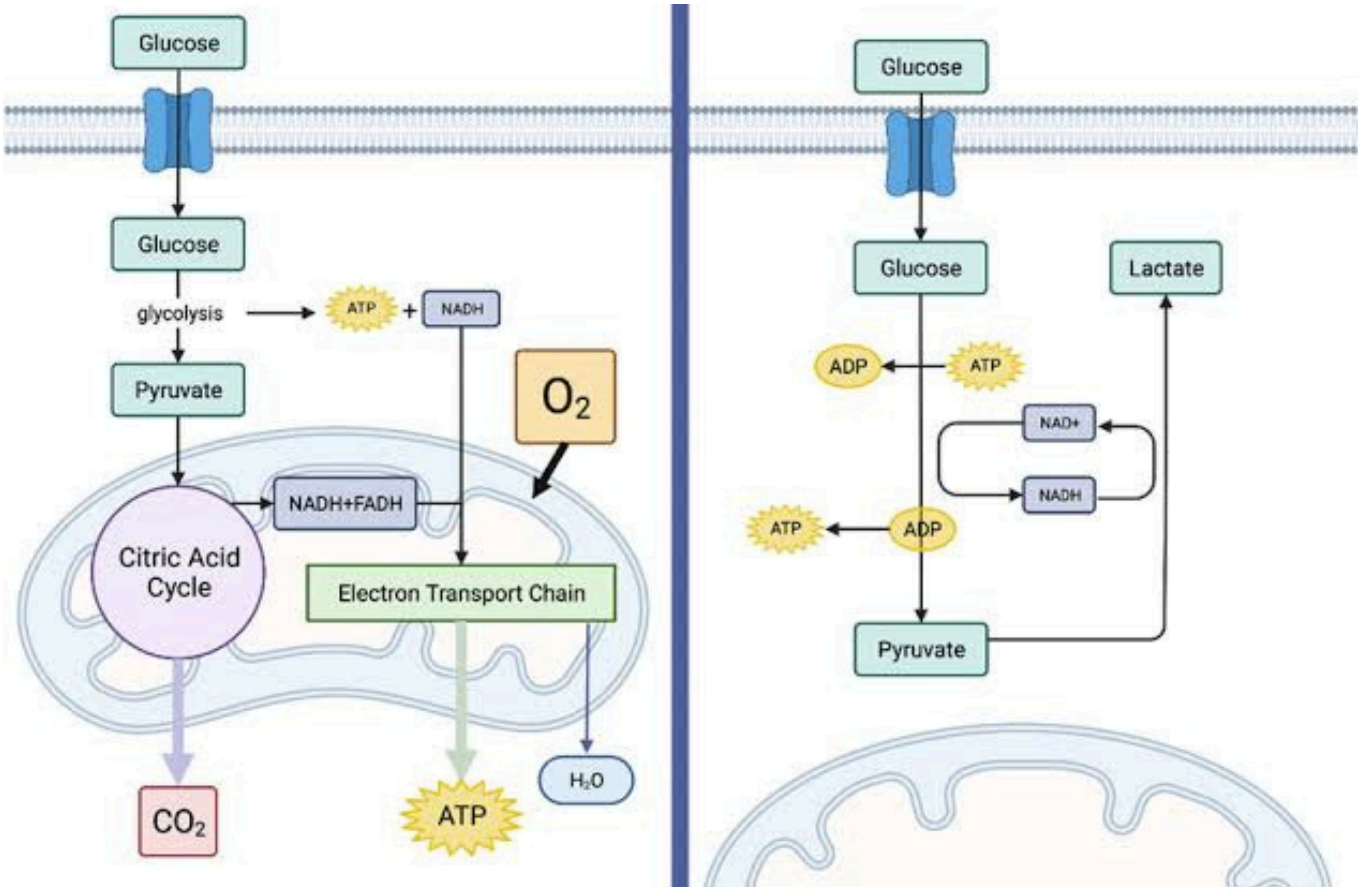
Cellular respiration

Uses

Yeast and other fungi respire anaerobically and are used to produce alcoholic beverages such as beer and wine. Yeast cells are also used to cause bread to rise during the baking process.
The fermentation process is also used to produce cheese

Comparison between aerobic & anaerobic respiration

Aerobic	Anaerobic
oxygen is required	oxygen is not required
products: carbon dioxide + water	products: lactic acid (animals) or carbon dioxide + alcohol (plants /yeast)
occurs in the cytoplasm and mitochondria	occurs in the cytoplasm
large amount of ATP energy is released, glucose is completely broken down	small amount of ATP energy is released, glucose is only partially broken down



Investigations

There are a number of Investigations to show the requirements and products of cellular respiration.

To test for oxygen

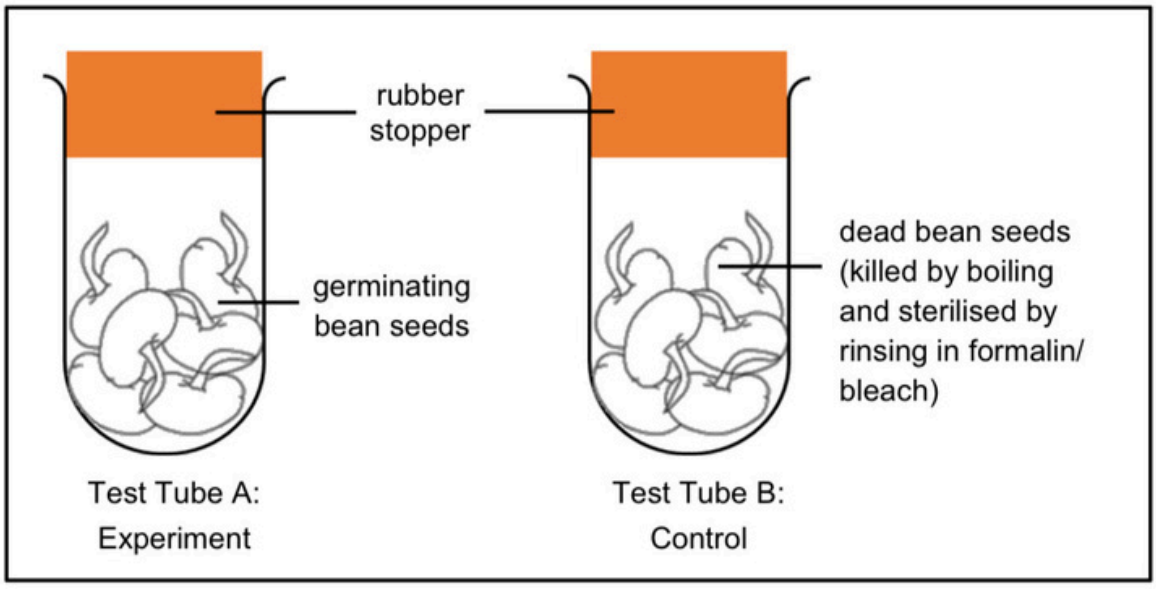
A glowing splint test can be used to test for the presence of oxygen. A wooden splint/ stick is lit and then extinguished. In the presence of oxygen, the glowing end of the splint will re-ignite or glow brighter.

To test for carbon dioxide

A clear lime water solution will turn milky in the presence of carbon dioxide

Oxygen is used

Micro-organisms need oxygen for cellular respiration. In germinating beans, cellular respiration takes place at a high rate releasing large amounts of **energy for growth**. In beans that have been killed by boiling them, **cellular respiration cannot take place and these serve as a control.**



Aim

to show that **oxygen** is used during **cellular respiration**

Method

Use germinating beans.

- Sterilise the equipment so that no micro-organisms are present.
- Place some of the beans into boiling water to kill them, so that cellular respiration cannot take place.
- Set-up the apparatus as shown above, making sure that the test tubes are tightly sealed.
- Leave the test tubes set-up overnight.
- Take the stoppers off of the test tubes the next morning and insert a glowing splint into each one.

Results

- **Test tube A** (the experiment): the glowing splint **dies out** - **no oxygen** is present, it has been used up by the germinating beans during cellular respiration.
- **Test tube B** (the control): the glowing splint **ignites** or **burns brighter** - oxygen is present, it has not been used since cellular respiration did not take place.

Conclusion

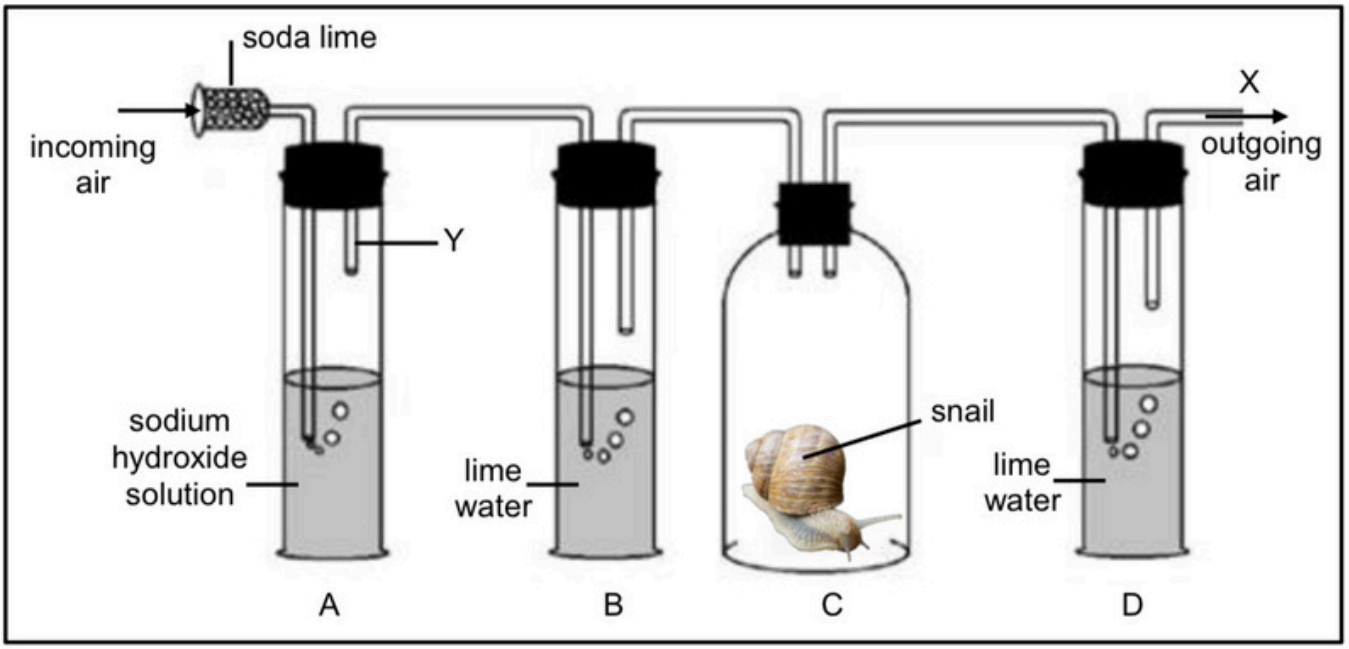
Oxygen is used by living organisms during cellular respiration.

Investigations

Carbon dioxide is produced

Living organisms produce carbon dioxide as a by-product of aerobic respiration.

Soda lime can be used to **remove carbon dioxide** from the **atmosphere** and **sodium hydroxide** can be added to a solution to **remove carbon dioxide** found in a **liquid**. This will ensure that no carbon dioxide can enter into any experiment so that we can prove the carbon dioxide is a result of aerobic respiration performed by an organism.



Aim

To prove that **carbon dioxide** is produced during **aerobic respiration**

Method

Use a small organism (e.g. snail).

- Sterilise the equipment so that no micro-organisms can influence the result.
- Place the snail into a large jar.
- Set- up the apparatus as shown above, making sure that the test tubes are tightly sealed.
- Examine the test tubes the following day and record the results

Results

- **Test tube B**: the lime water **remains clear**, carbon dioxide is removed by the soda lime and sodium hydroxide.y
- **Test tube D**: the lime water **turns milky** due to carbon dioxide produced by the snail.

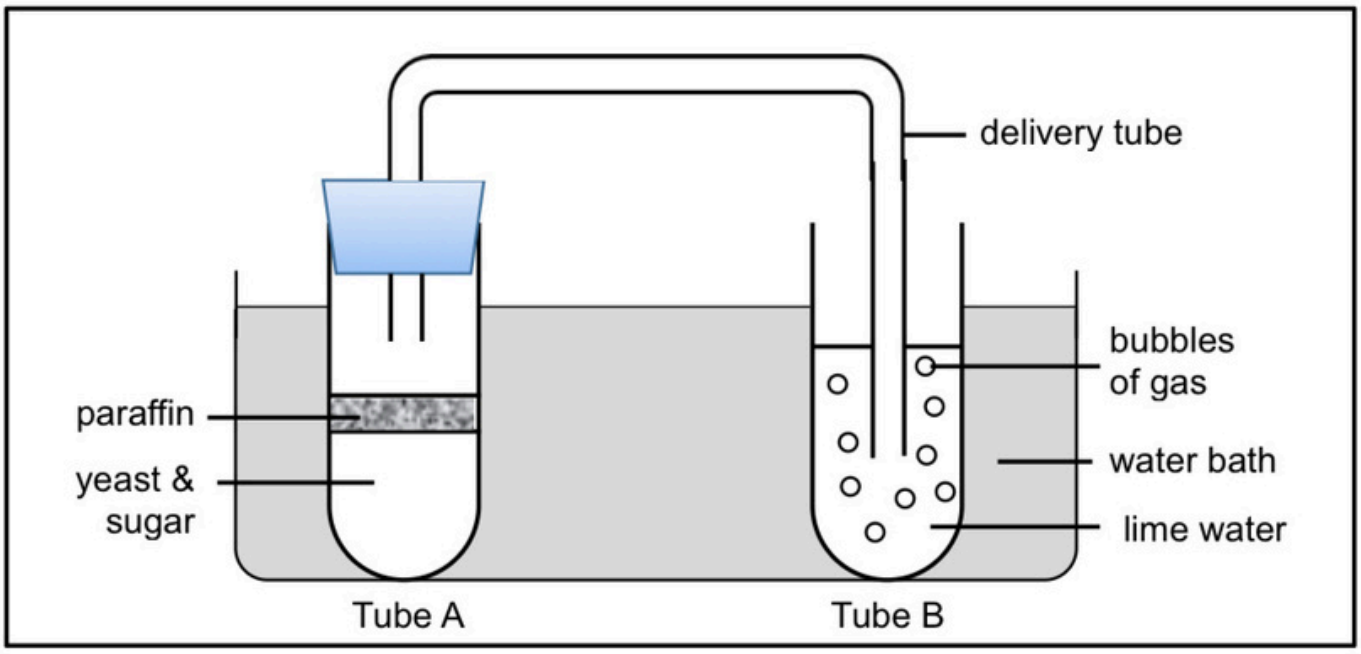
Conclusion

Carbon dioxide is produced during aerobic respiration by living organisms (the snail).

Investigations

Carbon dioxide is produced

Living organisms produce carbon dioxide as a by-product of aerobic respiration.



Aim

To prove that carbon dioxide is produced during aerobic respiration

Method

- Sterilise the equipment so that no micro-organisms can influence the result.
- Boil the sugar solution ahead of time to ensure that all of the oxygen is removed from the solution.
- Set-up the apparatus as shown above.
- The yeast and sugar solution should be in Test Tube A and clear lime water should be in Test Tube B.
- Cover the sugar solution with a thin layer of paraffin so that no oxygen from the air can dissolve into the solution. Make sure that the test tube is tightly sealed.
- The apparatus must be placed in a warm water bath because yeast grows quickly in warm conditions.
- Record the results after a few hours.

Results

The clear lime water becomes **milky** in colour.

Conclusion

Carbon dioxide is produced during aerobic respiration by living organisms (the yeast).

Cellular respiration Terminology

Key terminology

metabolism	chemical processes in organisms which are controlled by enzymes
catabolic	a metabolic process in which complex molecules are broken down into simple ones to release energy
anabolic	the synthesis of more complex substances from simple molecules
aerobic respiration	respiration in the presence of oxygen
mitochondrion	organelle / site for respiration
ATP	general energy carrier molecule in cells
anaerobic respiration	respiration in absence of oxygen
fermentation	type of anaerobic respiration in yeast (and other) cells
alcoholic fermentation	breaking down of glucose in absence of oxygen, to give rise to the production of alcohol in plant cells
lactic acid fermentation	breaking down of glucose in absence of oxygen to form lactic acid in animal cells
lactic acid	acid formed in muscle cells, during anaerobic respiration; leads to muscle exhaustion / cramping
lime water	solution used to test for carbon dioxide
glycogen	form in which glucose is stored in animal cells
germination	the process where a plant grows from a seed