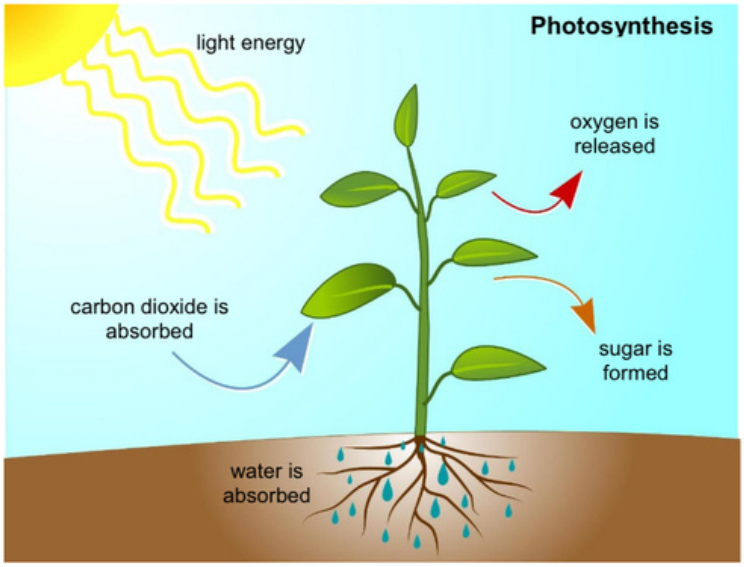
Photosynthesis Scope

Topic	Breakdown
Photosynthesis	Definition of photosynthesis Requirements and products of photosynthesis The structure and function of the **chloroplast** – using diagram The process of photosynthesis: •Light phase/light dependent phase: Occurs in the grana of the chloroplast Chlorophyll molecules absorb radiant energy from the sun This energy is used to split water into hydrogen and oxygen Some energy is used to form ATP (energy-carrier) Energised hydrogen atoms are released and used in the dark phase Oxygen is released into the atmosphere • Dark phase /Light independent phase: Occurs in the stroma of the chloroplast Carbon dioxide from the atmosphere combines hydrogen atoms to form carbohydrates such as glucose and starch using energy in the form of ATP from the light phase Biological importance of photosynthesis: • Provision of energy for all living organisms • Maintaining the correct balance of O2 and CO2 in the atmosphere • Oxygen is released as a by-product The factors affecting the rate of photosynthesis: • Carbon dioxide concentration • Light intensity • Temperature Greenhouse Systems • Definition of the greenhouse •Improve crop yields in greenhouse system - Carbon dioxide enrichment - Optimum light - Optimum temperature **INVESTIGATIONS** - Light is essential for photosynthesis - Chlorophyll is needed for photosynthesis - Carbon dioxide is needed for photosynthesis - Oxygen is produced during photosynthesis

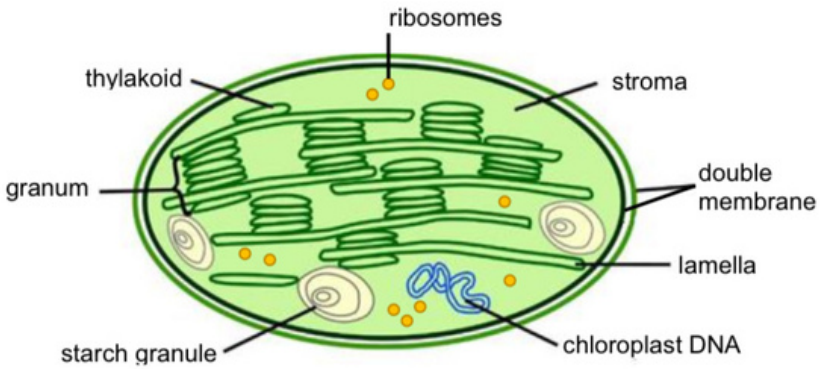
Photosynthesis

The term **photosynthesis** means light is used (photo) to manufacture (synthesis) energy.

Photosynthesis occurs in **green plants** and takes place in the **chloroplast** of a cell.



Chloroplast



Part of the chloroplast	Function
thylakoid	disc shaped membranes that that contain chlorophyll
granum	a stack of thylakoids
lamella	membranes that make up the thylakoids
stroma	liquid part of the chloroplast
starch granule	glucose produced is stored as starch in this structure
chloroplast DNA	contains genetic information
double membrane	protects the chloroplast and allows substances to move in and out

Requirements
Carbon dioxide: Diffuses into the leaves of plants
Water: Inorganic substance absorbed from soil by the roots of plants
Radiant energy/ light energy: Absorbed from the sun by leaves of plants
Chlorophyll: Green pigment found inside the **chloroplasts**
Enzymes: Found inside the chloroplasts

Products
Glucose: Carbohydrate formed. It is converted and stored as starch in plants or glycogen in animals
Oxygen: Gas that is released back into the atmosphere from the leaves

Plants are *adapted* to obtain what is required for photosynthesis as well as to release the products.
<u>The requirements for and products of photosynthesis can be represented in the equations given below:</u>

Word Equation

Carbon dioxide + Water + Radiant energy $\xrightarrow[\text{Enzymes}]{\text{Chlorophyll}}$ Glucose + Oxygen

Chemical Equation:

$$CO_2 + H_2O + \text{radiant energy} \xrightarrow[\text{Enzymes}]{\text{Chlorophyll}} C_6H_{12}O_6 + O_2$$

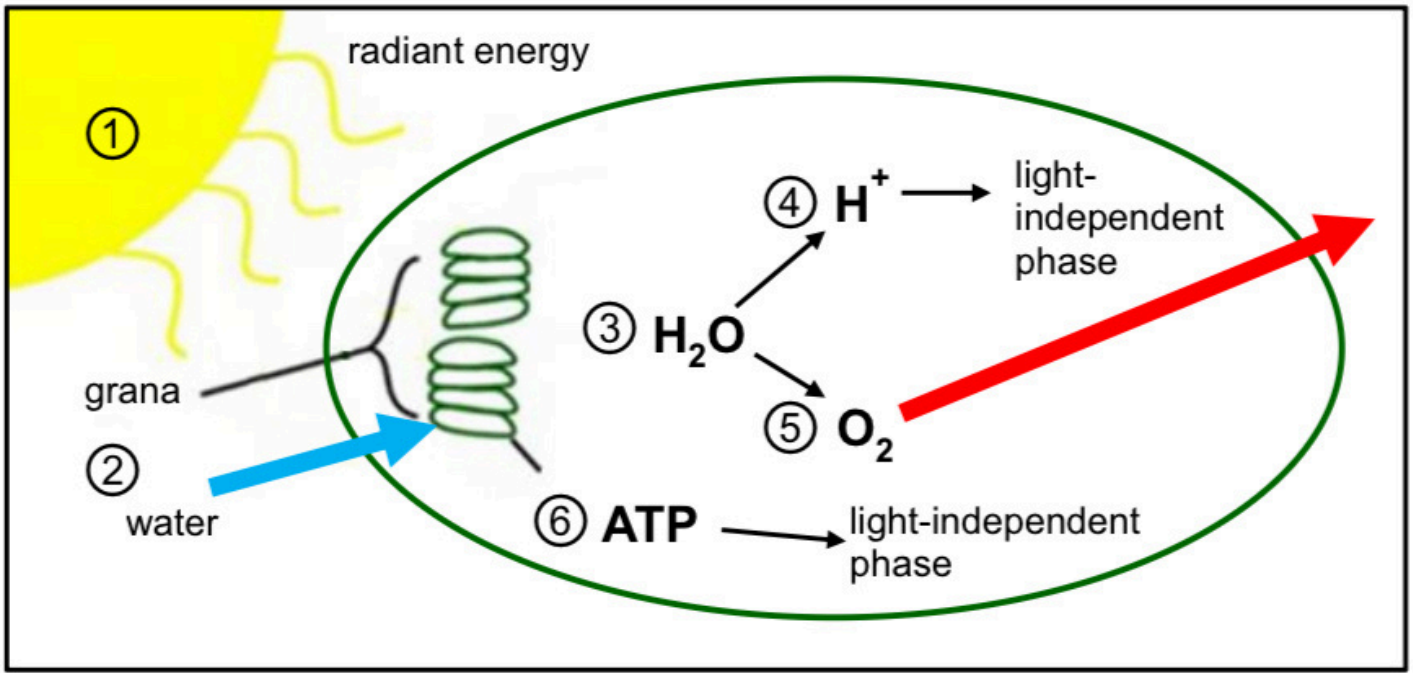
Photosynthesis Process

The process of photosynthesis occurs in two phases:
- **Light dependent phase**: light is required
- **Light independent phase**: no light is required

Light phase

The **light dependent phase** of photosynthesis takes place in the **grana** of chloroplasts as follows:

1. The required **radiant energy** is absorbed by chlorophyll in the grana.
2. **Water** is absorbed into the grana of the chloroplast
3. Radiant energy causes the water molecule to split (**photolysis**), releasing:
4. **Energy rich hydrogen** (H+) ions which are taken into the **light-independent phase**, and
5. **Oxygen** which is released back into the atmosphere
6. Radiant energy also causes the **energy carrier ATP** to be formed (**phosphorylation**) which will be used in the light-independent phase.



Phosphorylation

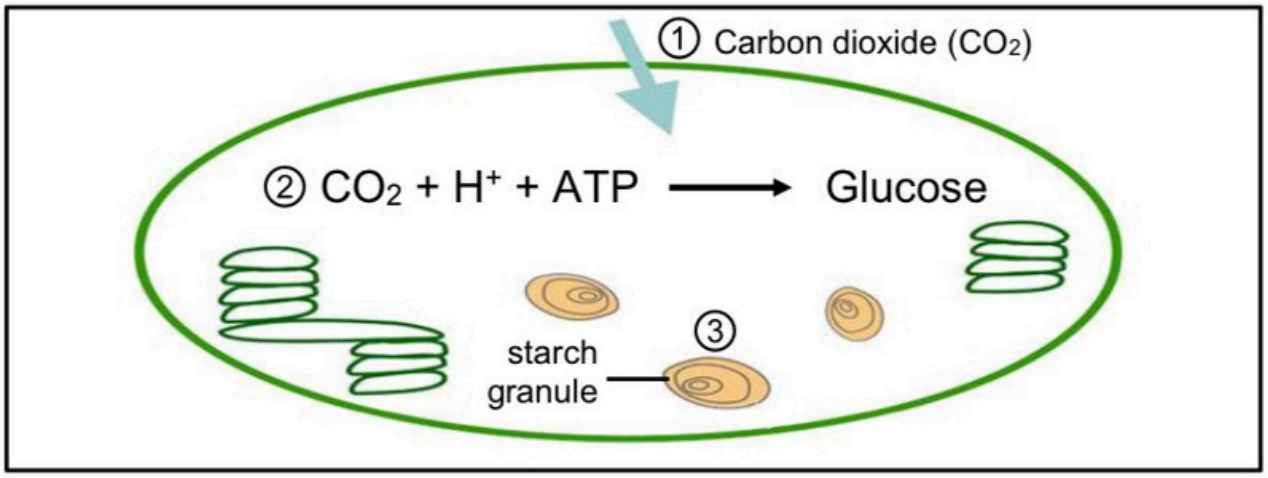
Equation: ADP + P → ATP
ATP stands for **Adenosine triphosphate**

Photosynthesis Process

Dark phase

The **light independent phase** of photosynthesis takes place in the **stroma** of chloroplasts as follows:

1. Carbon dioxide is absorbed from the atmosphere
2. Carbon dioxide and energy rich Hydrogen (H+) atoms, from the light dependent phase, are combined by using ATP, from the light dependent phase to from carbohydrates (glucose)
3. Excess glucose is stored as starch in starch granules



Light dependent phase	Light independent phase
Occurs in the grana	Occurs in the stroma
Light is required	Light is not required
Radiant energy is absorbed and used for the reactions of photolysis & phosphorylation	Carbon dioxide is absorbed from the atmosphere
Photolysis occurs: hydrogen is released and oxygen is returned to the atmosphere	Hydrogen and carbon dioxide combine by using atp to form glucose
Phosphorylation occurs: ATP is produced	Excess glucose is stored as starch

Importance

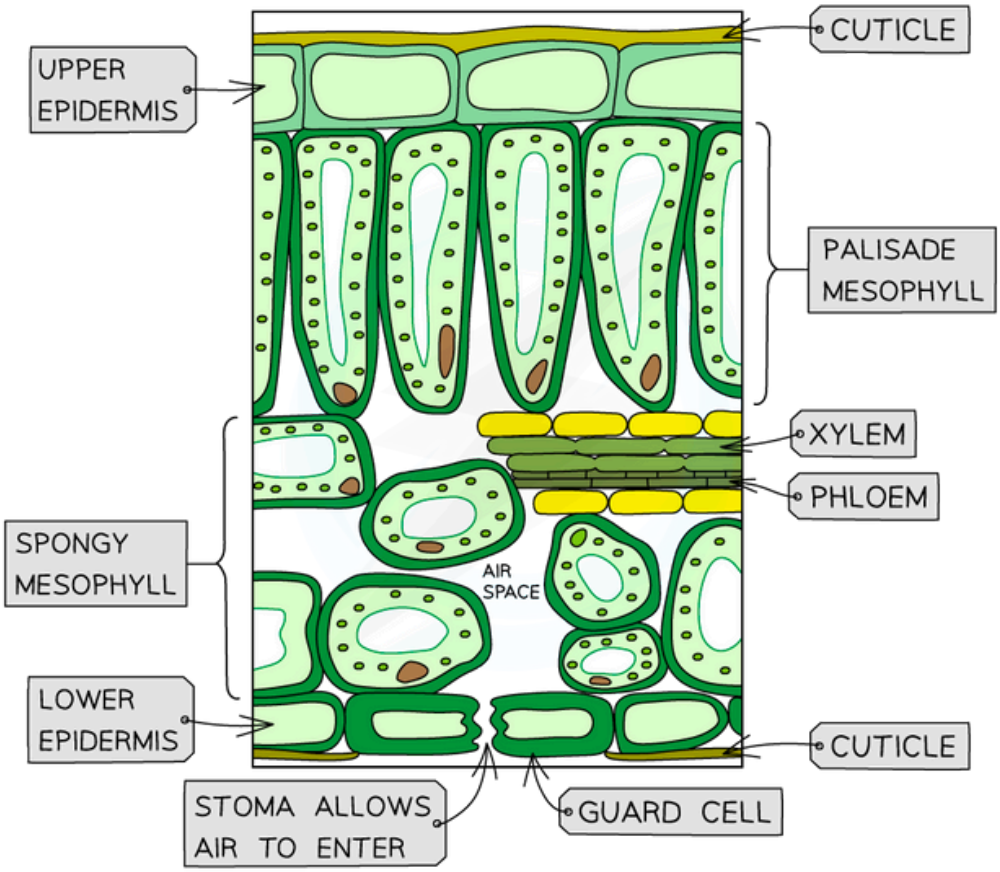
Photosynthesis is important for the following reasons:

- It balances the levels of carbon dioxide and oxygen in the atmosphere.
- The process uses carbon dioxide and releases oxygen.
- It uses radiant energy to produce chemical potential energy in the form of glucose which serves as food for other organisms.
- Proteins and lipids are made by using the stored starch.

Photosynthesis Factors

Factors affecting photosynthesis can be **internal** or **external**

Internal factors



Note

Cuticle - Waxy to reduce water loss
Epidermis - Transperent to allow light to pass through
Mesophyll tissues - Contain chloroplasts to trap sunlight
Palisade mesophyll - Has intercellular air spaces to allow for gaseous exchange
Stomata/Stoma - Allow for gaseous exchange. Closes to reduce transpiration rate

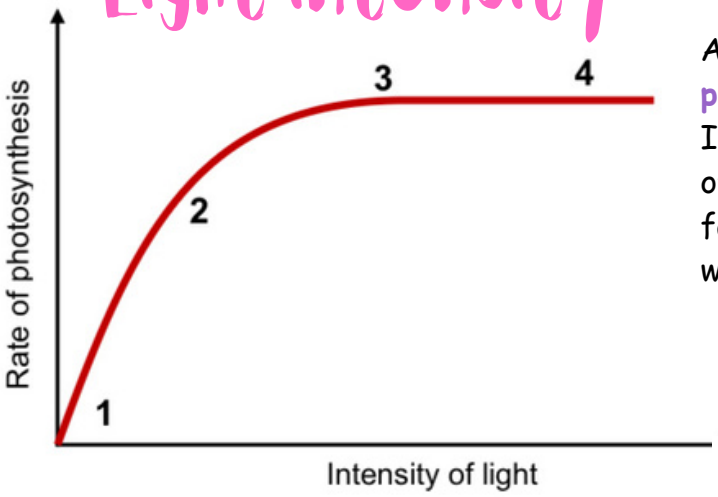
Photosynthesis Factors

External factors

The factors that affect the rate of photosynthesis (how slowly or quickly it takes place) are:

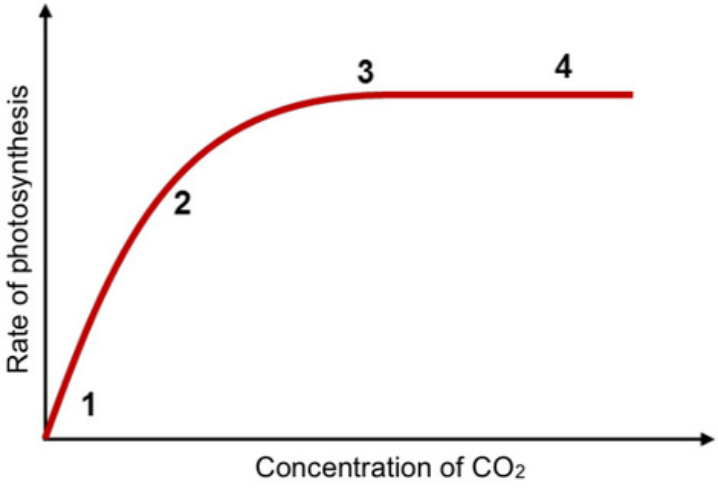
- The intensity of light
- The concentration of carbon dioxide
- The temperature

Light intensity



As **light intensity increases**, the **rate of photosynthesis will increase** until optimum amount(3). If light intensity increases past the optimum, the rate of photosynthesis will **remain constant**. The other factors such as carbon dioxide become **limiting factors** which reduces the rate of photosynthesis.

CO_2 concentration



As **CO_2 concentrations increases**, the **rate of photosynthesis will increase** until optimum amount(3).
If CO_2 increases **past the optimum**, the rate of photosynthesis will **remain constant**. The light independent phase cannot take place more quickly than what it does at the optimum level of carbon dioxide concentration.

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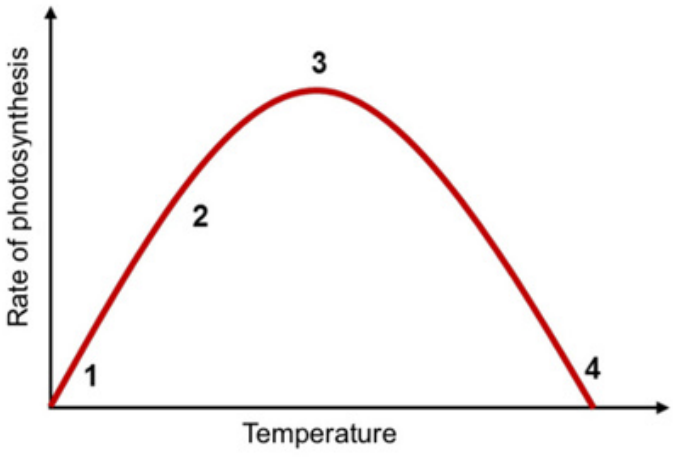
Temperature

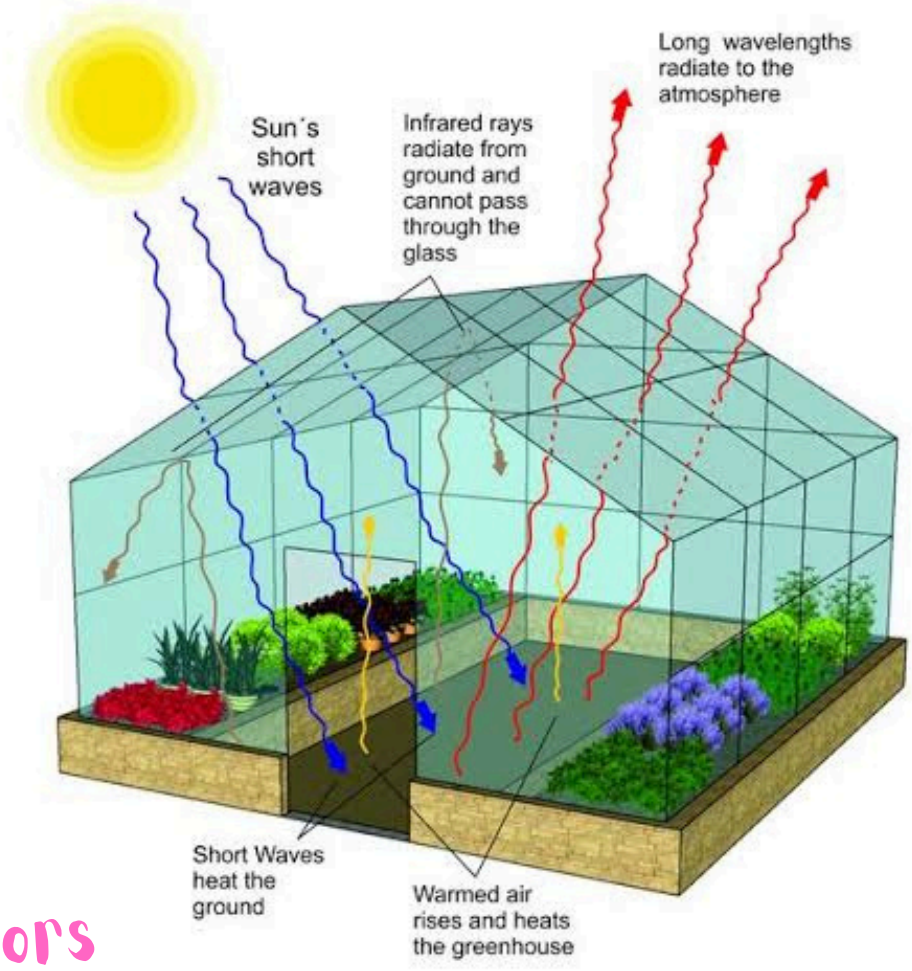


As **temperature increases,** the **rate of photosynthesis also increases.**
When temperature is at the optimum amount(3), the **rate of photosynthesis will reach a maximum.**
If the temperature is higher than the optimum amount, then photosynthesis will decrease in rate. **The enzymes used in the process will denature at high temperatures** and will no longer function.

Photosynthesis
Greenhouse

A **greenhouse** is a structure with a transparent roof and walls, and is used to grow plants.

Light enters the greenhouse through the roof and heat is trapped inside the structure. Greenhouses can be used to maintain the optimal levels of the factors affecting the rate of photosynthesis.



Factors

- **Light** passes through the transparent structure. Artificial lights can be used to allow the plants to photosynthesis for longer periods of time.
- **Carbon dioxide** is present in the atmosphere but more can be pumped into the greenhouse or be produced by burning gas lamps.
- The **temperature** can be kept at the optimum level by using heating and cooling devices.

The greenhouse effect is a natural phenomenon where heat is trapped in the atmosphere of the Earth by carbon dioxide.

Investigations

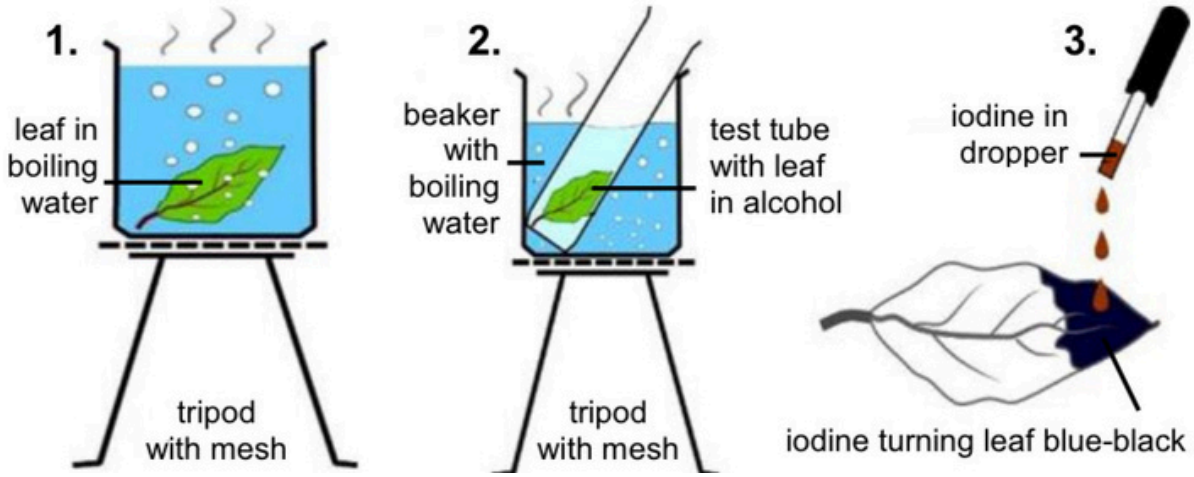
There are investigations which can be performed to determine if a factor is required for photosynthesis or to determine the rate at which photosynthesis is occurring. In the investigations, one plant (**the experiment**) is given all of the requirements *except for the factor being tested*. Another plant is given all of the requirements in the same investigation and is referred to as the **control**. **In most of the investigations, a test for starch is performed at the end to prove that photosynthesis took place.**

Before starting the investigations, *starch must be removed from the plant*. To do this:
- the plant is placed in a **dark cupboard for 48 hours**
- the plant uses the stored starch during the 48 hour period
- it can be proved that the starch present at the end of the investigation is due to photosynthesis occurring.

The **starch test can be used to prove that starch is a product of photosynthesis**

The starch test

If starch is present, then it can be concluded that **photosynthesis** occurred. If starch is not present, then it can be concluded that photosynthesis did not occur.



Method

- Place leaf in boiling water to soften it and stop metabolism.
- Place leaf in a testube with ethanol and place testube in a water bath. (chlorophyll will be extracted & leaf will turn white)
- Rinse leaf in water to soften it.
- Spread leaf in a tile and add iodine solution

Results

The leaf turns **blue black** which proves that starch has been produced by photosynthesis.

Investigations

Light is required for photosynthesis

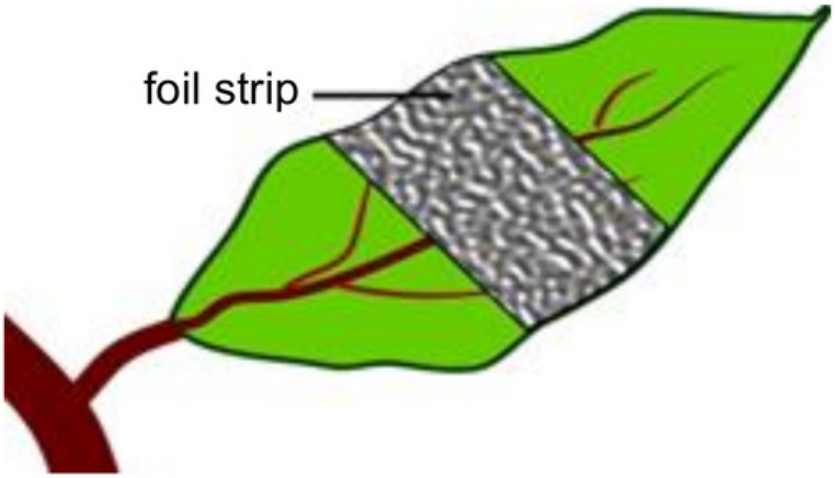
An investigation can be performed to show that without light, starch will not be produced and therefore no photosynthesis took place.

Aim

To prove that light is required for photosynthesis

Method

- Destarch a potted plant by placing it in a dark cupboard for 48 hours
- Cover a portion of the leaf, still attached to the plant, with aluminium foil
- Place the plant in a sunny area for 48 hours
- Pick the leaf and remove the foil
- Test for the presence of starch using the starch test.



The experiment is the part of the leaf covered by the foil, as it does not receive light. The part of the leaf left uncovered is the control as it receives all of the requirements for photosynthesis, including light.

Results

Experiment (leaf covered with tinfoil): the iodine solution remains **light brown**.
Control (leaf left uncovered): the iodine solution turns **blue-black**.

Conclusion

Light is essential for photosynthesis to take place.

Investigations

Carbon dioxide is required for photosynthesis

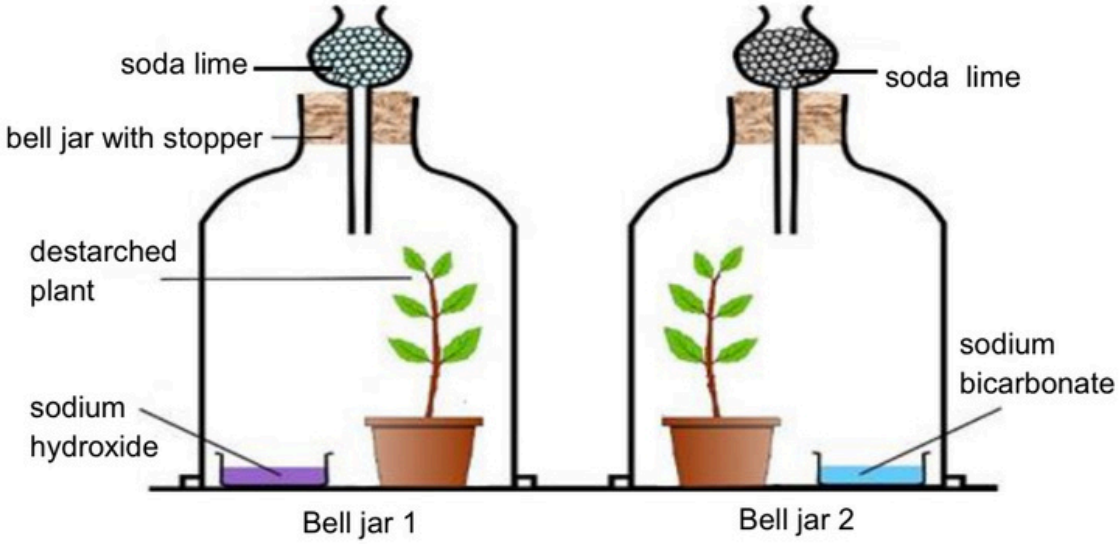
An investigation can be performed to show that without carbon dioxide, starch will not be produced and no photosynthesis will take place.

Aim

To prove that **carbon dioxide** is required for **photosynthesis**

Method

- Destarch two potted plants by placing them in a dark cupboard for 48 hours
- Set up the apparatus as shown in Figure 11 above and water plants well.
- Sodium hydroxide is used to absorb carbon dioxide from the air in bell jar 1
- Sodium bicarbonate releases carbon dioxide into bell jar
- Place the sealed bell jars into a sunny area for 48 hours
- Pick a leaf from each plant and test for the presence of starch



sodium hydroxide, potassium hydroxide or soda lime can be used to remove carbon dioxide. Sodium bicarbonate or potassium bicarbonate can be used to add carbon dioxide.

Results

- **Bell jar 1 leaf**: iodine solution remains **light brown.**
- **Bell jar 2 leaf**: iodine solution turns from light brown to **blue-black.**

Conclusion

- **Bell jar 1 leaf**: No starch is produced. No photosynthesis can take place in the absence of carbon dioxide.
- **Bell jar 2 leaf**: Starch is produced. Photosynthesis takes place in the presence of carbon dioxide.

Investigations

Chlorophyll is required for photosynthesis

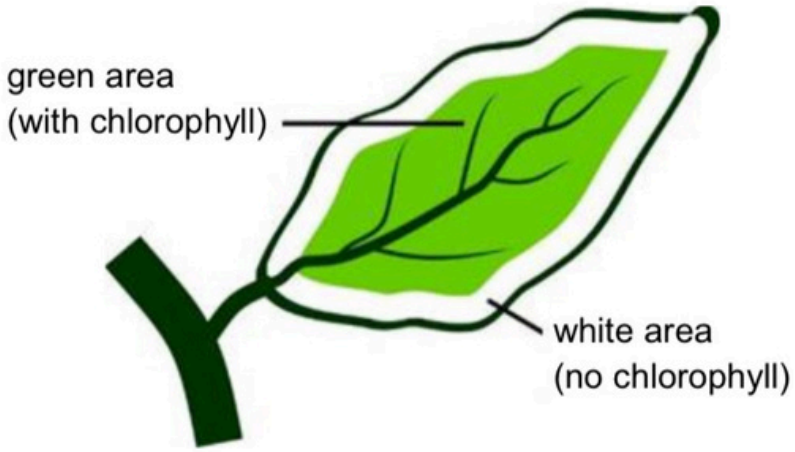
A **variegated leaf** is used to prove that without chlorophyll, starch will not be produced and therefore no photosynthesis took place. A variegated leaf contains green parts (**with chlorophyll**) and white parts (**without chlorophyll**)

Aim

To prove that **chlorophyll** is required for **photosynthesis**

Method

- Place a potted plant with variegated leaves (white and green parts) in a sunny place for a few hours
- Remove a leaf from the potted plant
- Test for the presence of starch



This leaf does not require destarching as the experiment and control are on the same leaf.

Results

- **Experiment** (White part): iodine solution remains **light brown.**
- **Control** (Green part): iodine solution turns from light brown to **blue-black.**

Conclusion

- **Experiment** (White part): Contains no starch. No photosynthesis can occur without chlorophyll.
- **Control** (Green part): Contains starch. Photosynthesis takes place using chlorophyll.
- **Chlorophyll** is essential for photosynthesis.

Investigations

Photosynthesis produces oxygen

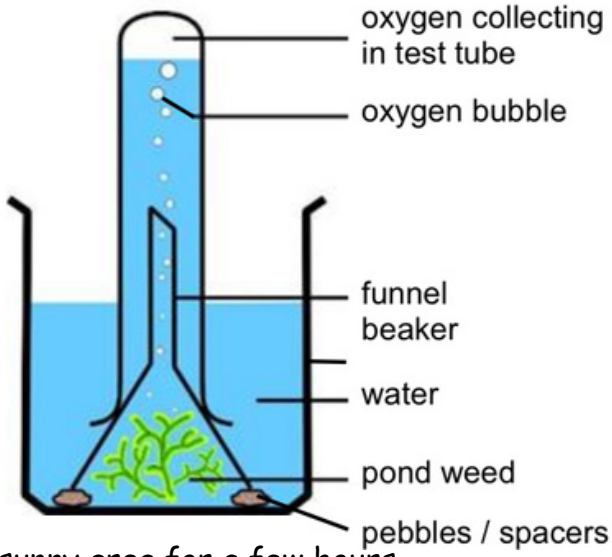
A **glowing splint** test is used to show that oxygen is produced during photosynthesis. A test uses a *small wooden stick that has been lit.* The splint glows more brightly or re-ignites in the presence of oxygen.

Aim

To prove that **oxygen** is produced during **photosynthesis**

Method

Set up the apparatus as shown the diagram



- Place the apparatus in a sunny area for a few hours
- A small amount of sodium bicarbonate can be dissolved in the water. Sodium bicarbonate will add carbon dioxide to the water
- After a while gas bubbles will start to form. These gas bubbles will collect in the test tube.
- Once enough gas has been trapped in the test tube, remove the test tube from the funnel but keep the opening of the test tube submerged under the water
- Seal the test tube using a rubber stopper while under the water
- Once it has been sealed, remove the test tube from the water
- Insert a glowing wooden splint into the test tube

Results

The glowing splint **re-ignites or burns more brightly.**
Oxygen is present in the test tube.

Conclusion

Oxygen is produced during photosynthesis.

Photosynthesis Terminology

Key terminology

metabolism	chemical processes in organisms controlled by enzymes
anabolism	building up chemical reactions
catabolism	breaking down chemical reactions
iodine solution	chemical used to test for starch – a positive test results in the colour changing from brown to blue-black
autotrophic	green plants that produce their own food through photosynthesis
heterotrophic	organisms that cannot photosynthesize and obtain food from other organisms

radiant energy	energy from the sun, needed by plants for photosynthesis
chloroplast	organelle in plants, site for photosynthesis
chlorophyll	green pigment needed for photosynthesis
thylakoids	part of the chloroplast that contains chlorophyll
grana	stacks of thylakoids, light dependent phase of photosynthesis takes place here
stroma	liquid part of the chloroplast, light independent phase of photosynthesis takes place here

photolysis	splitting of water molecules into oxygen atoms and hydrogen atoms. photo = light, lysis = split
phosphorylation	formation of energy transporting molecules called ATP
ATP	adenosine triphosphate, energy carriers in cells
Calvin cycle	cyclical process during light independent phase of photosynthesis
glucose	carbohydrate formed during photosynthesis
starch	stored form of glucose in plants
glycogen	stored form of glucose in animals

greenhouse	a glass or plastic structure that traps heat and allows light to enter, used to grow plants
greenhouse effect	phenomenon where heat from the sun is trapped on Earth by CO_2 in the atmosphere