PLANTS

4.1 PHOTOSYNTHESIS

Photosynthesis Experiments

Objectives :

- Explain the process of photosynthesis

- *Light- dependent reaction*
- *Light independent reaction*

- Practical skills: Design experiments about photosynthesis.

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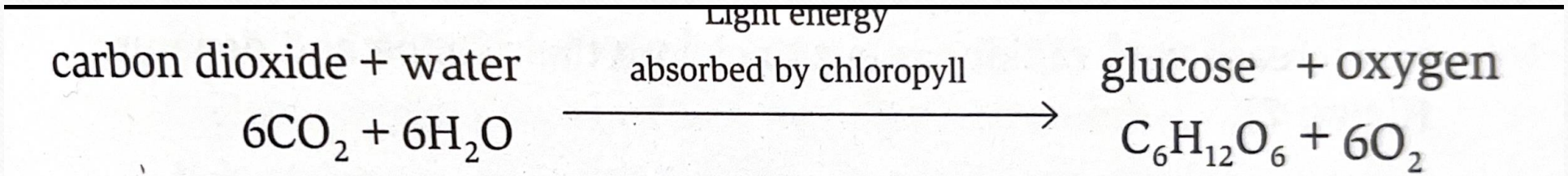
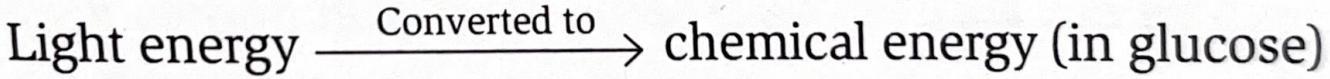
The process of photosynthesis

Photosynthesis is the process by which plants make use of inorganic water and carbon dioxide to produce organic compounds (carbon compounds) in cells using light energy.



Photosynthesis involves the conversion of light energy into chemical energy.



There are two reactions that take place during photosynthesis, the light-dependent reaction and the light-independent reaction.

Stage 1: Light-dependent reaction

During the light-dependent reaction, light energy is absorbed by chlorophyll and is used for two main functions:

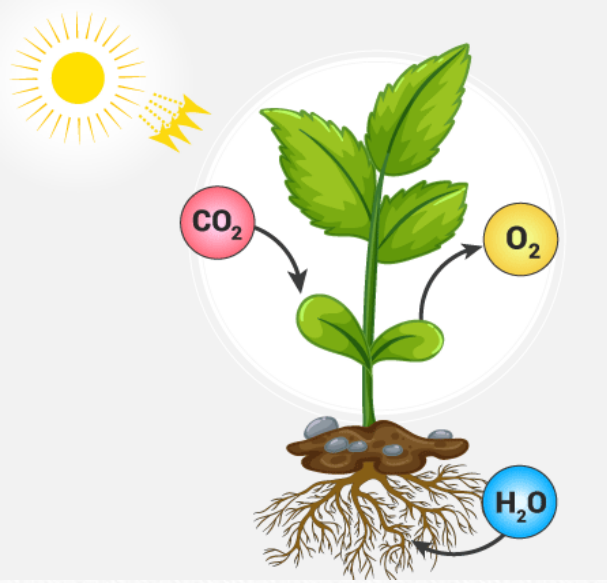
- To produce ATP, which is needed for the light-independent reaction
- Photolysis of water, where water molecules split to form hydrogen ions (H*) and oxygen. Oxygen is lost as a waste product and hydrogen ions are needed for the light-independent reaction.

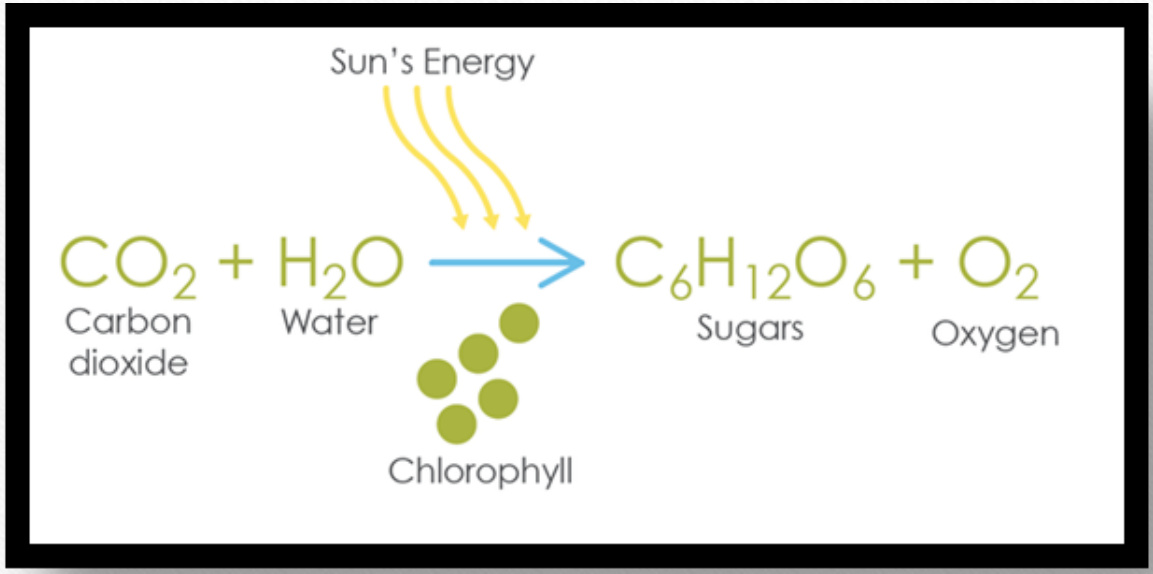
Stage 2: Light-independent reaction

During the light-independent reaction, energy (in the form of ATP) and hydrogen ions produced in the light-dependent reaction are used to produce carbohydrates from carbon dioxide.

$$\text{carbon dioxide} + \text{hydrogen ions} \xrightarrow{\text{ATP}} \text{glucose}$$

Photosynthesis experiments





The main aim of these experiments is to prove that photosynthesis needs **chlorophyll, carbon dioxide and light.**

If you want to test that a factor is necessary , the only way to do this is to eliminate this factor and check if photosynthesis takes place without it , if it does then the factor studied is **not necessary** and photosynthesis can take place whether it is present or not . But if photosynthesis doesn't take place then this factor is **certainly necessary for the reaction to occur.**

There are two things that we must do **before** and **after** performing a photosynthesis experiment:

Principles of photosynthesis experiments :

- **Investigations need controls**

Control plant has all substances it needs.

A control is an experiment which is done to make a comparison and to make sure that only the condition being investigated has affected the result.

Test plant lacks one substance (light/chlorophyll/CO_2)

- Before we perform the experiment:

We must **destarch** (remove starch) the plant that we are going to use in the experiment.

How to destarch ? SIMPLY

By leaving the plant in the darkness (inside a dark cupboard) for 48-72 hours. In the darkness , the plants cannot photosynthesize since there is no light (only respiration will take place), so they will use up their stores of starch .

Why do we need to destarch the plant before the photosynthesis experiment?

This makes sure that all the starch present in the leaf is newly synthesized and is produced during our photosynthesis experiment.

- After the experiment:

We should test the presence of starch to see whether or not starch was produced. If starch was produced this means that photosynthesis took place.

How can we know that photosynthesis took place?

Our only evidence is the **Presence of starch**

As learned in photosynthesis, glucose formed during photosynthesis is quickly built up into starch to maintain the osmotic potential of cells.

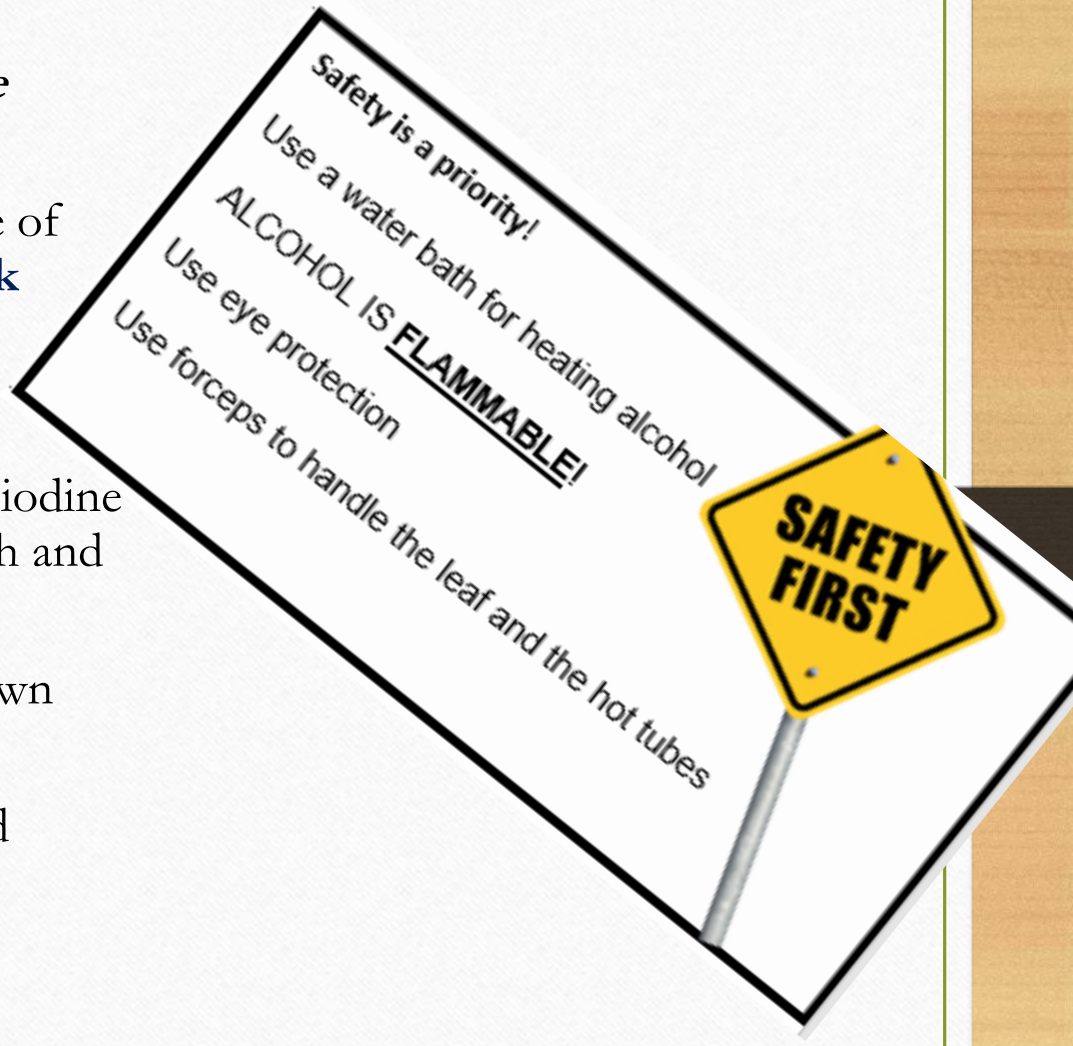
You have encountered previously that we can test for the presence of starch by using Iodine that will change its colour into **bluish black** indicating the presence of starch.

But you can't add Iodine directly to the leaf!

This is because starch is stored inside the chloroplasts in cells, the iodine solution cannot get through the cell membranes to reach the starch and react with it!

Another problem is that the green colour of the leaf with the brown colour of iodine can look **black all together**!

So a specific procedure must be done to **break the cell walls** and **remove the green colour**→ it's carried out at the end of each experiment to detect if photosynthesis took place or not.



How do we test for the presence of starch (after the experiment)

1. Heat some water to boiling point in a beaker and then turn out the Bunsen burner.

2. Use the forceps to dip the leaf in the hot water for about 30 seconds. This **breaks the cell walls, denatures the enzymes** and makes the leaf more permeable to Iodine solution.

3. Push the leaf to the bottom of the test tube and cover it with alcohol.

Alcohol will **dissolve most of the chlorophyll and decolourize the leaf** / **Why?**

Because chlorophyll **masks** the colour change, so we remove chlorophyll to be able **to better detect the colour change of Iodine when it reacts with starch** (if present).

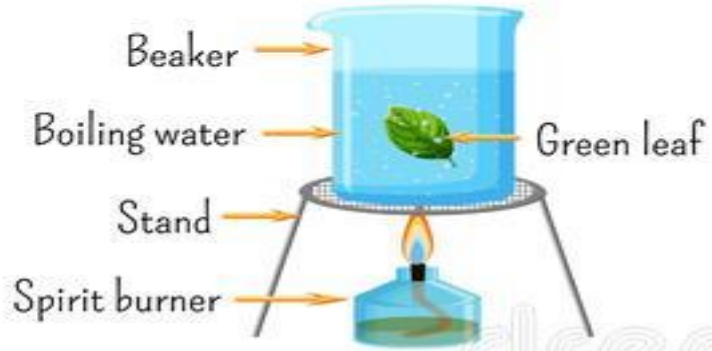
4. Pour the green alcohol and get rid of it, remove the leaf and dip it once more into hot water to **soften it**.

5. Spread the decolorized leaf on a white surface (to be able to observe any colour change) and add few drops of Iodine on it. The parts containing starch will turn blue; the parts without starch will remain yellow or brown.

LEAF STARCH TEST

https://www.youtube.com/watch?v=Uz7JnVUWCZQ

Video test for starch



1. Leaf in boiling water

2. Leaf in boiling alcohol

3. Leaf in cold water

4. Starch test with iodine solution

Check your understanding

Q1.Why is starch tested for and not glucose?

Because glucose is stored as starch

Q2. Explain why boiling the leaf in water is important.

breaks the cell walls, denatures the enzymes

Q3.Explain why boiling the leaf in ethanol is important.

To dissolve most of the chlorophyll to better detect the colour change of Iodine when it reacts with starch (if present).

Experiment1 : Is chlorophyll necessary for photosynthesis

This is done using a **variegated** leaf, which contains chlorophyll in patches. The white parts don't contain chlorophyll and the green parts contain chlorophyll. So this seems perfect for our experiment.

The green parts are the control experiment.

Procedure:

1) First, Destarch the leaves of the plant (as previously described)

2) The experiment is simply done by placing the leaves (still attached to the plant) in sunlight for few hours.

3) Then the presence of starch is tested using Iodine (following the procedure mentioned previously).

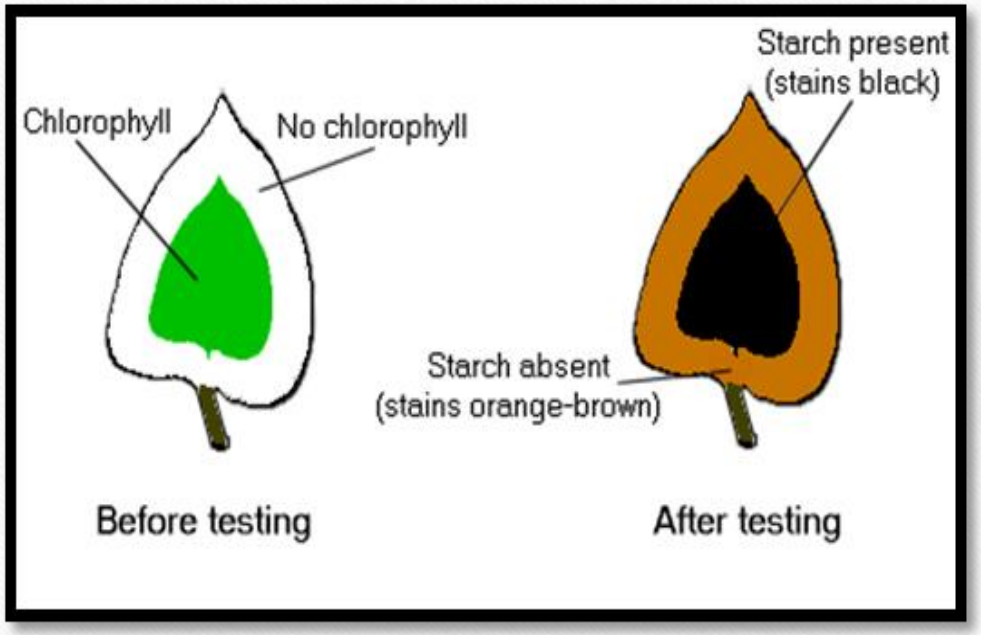
Results :

The parts that turn bluish black are the parts that **contain starch** and are the parts that were able to **undergo photosynthesis** → you will notice that these are the parts that were previously green (contain chlorophyll)

The parts that remained yellowish brown weren't able to photosynthesize and so no starch is produced in these areas → these are the parts that were previously white (don't contain chlorophyll)

We conclude from these results that without chlorophyll no photosynthesis will take place. So chlorophyll is essential for photosynthesis to take place

variegated leaf



Experiment 2:Is light necessary for photosynthesis?

Eliminate light → The check if photosynthesis took place by testing the presence of starch

Procedure:

1. First destarching is performed.

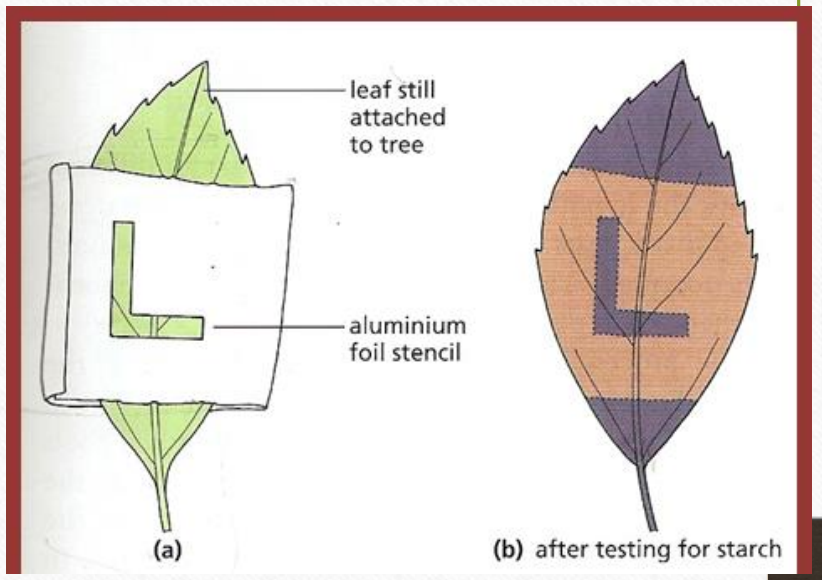
2. This experiment is done using an aluminum foil placed in the way shown the figure.

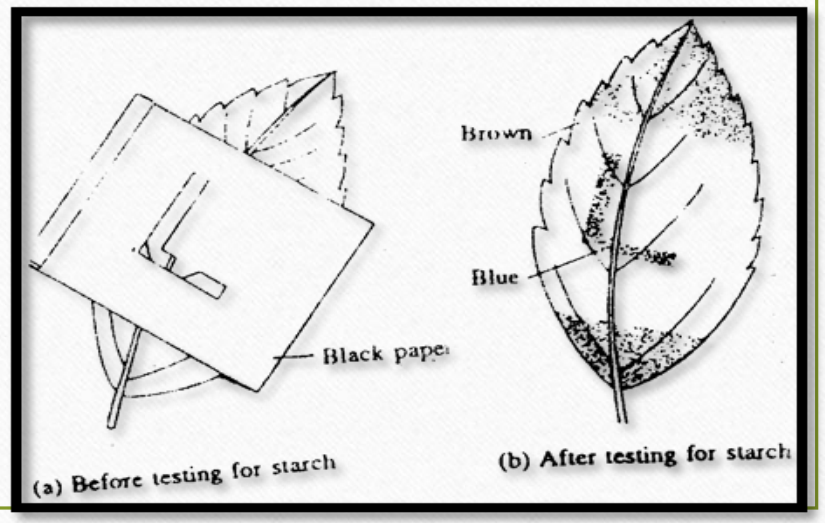
Aluminum foil will block light from reaching the covered areas.

The uncovered areas are the control experiment

3. Let the leaves stand in sunlight for few hours

4. Test for the presence of starch





Results:

You will notice that the parts that were covered **will not change the colour of Iodine to bluish black,** whereas the parts that were exposed to light will produce a colour change to bluish black, this is because photosynthesis occurred in these areas and starch was produced.

So we conclude that light is needed for photosynthesis and without light no photosynthesis will take place.

One might argue that the aluminum foil had stopped carbon dioxide from entering the leaf and that it was the shortage of carbon dioxide that prevented photosynthesis from taking place. You can disprove this by using a **transparent material** instead of aluminum foil. Photosynthesis will still take place in all parts of the leaf which disproves that carbon dioxide shortage was the reason that prevented photosynthesis in the case of aluminum foil.

A student placed a plant into a dark cupboard and then partially covered one leaf (leaf A) with a piece of card. After two days, she carried out a test for starch on leaf A and one other leaf, as shown below.

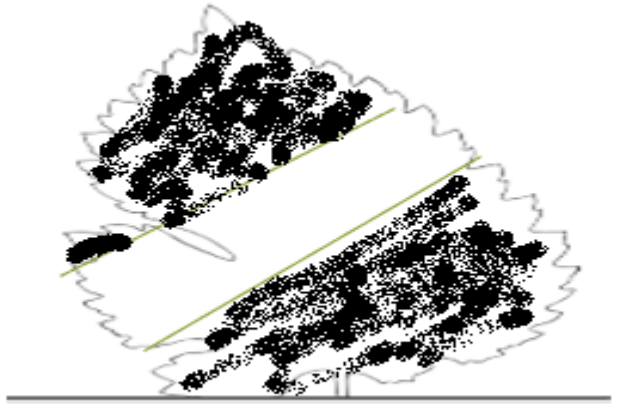
Leaf A

Leaf B

When iodine was added to leaf B it turned completely black.

Which parts of leaf A would turn black? The uncovered parts

Shade these areas on the leaf below, and explain your answer.



The parts that were covered will not change the colour of Iodine to bluish black, whereas the parts that were exposed to light will produce a colour change to bluish black, this is because photosynthesis occurred in these areas and starch was produced.

Experiment 3. Is carbon dioxide needed for photosynthesis?

Procedure :

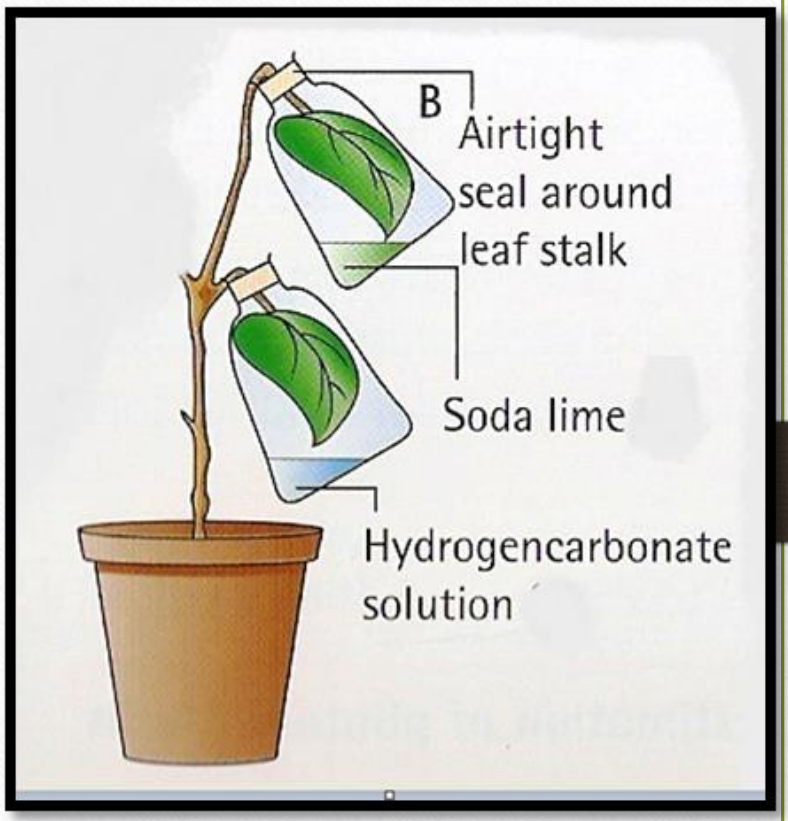
Destarch the plant.

Set the apparatus just as shown in the figure

Hydrogen carbonate →used to produce carbon dioxide → this is the **control experiment**

Soda lime (or potassium hydroxide) → absorbs carbon dioxide

5) Test for the presence of starch



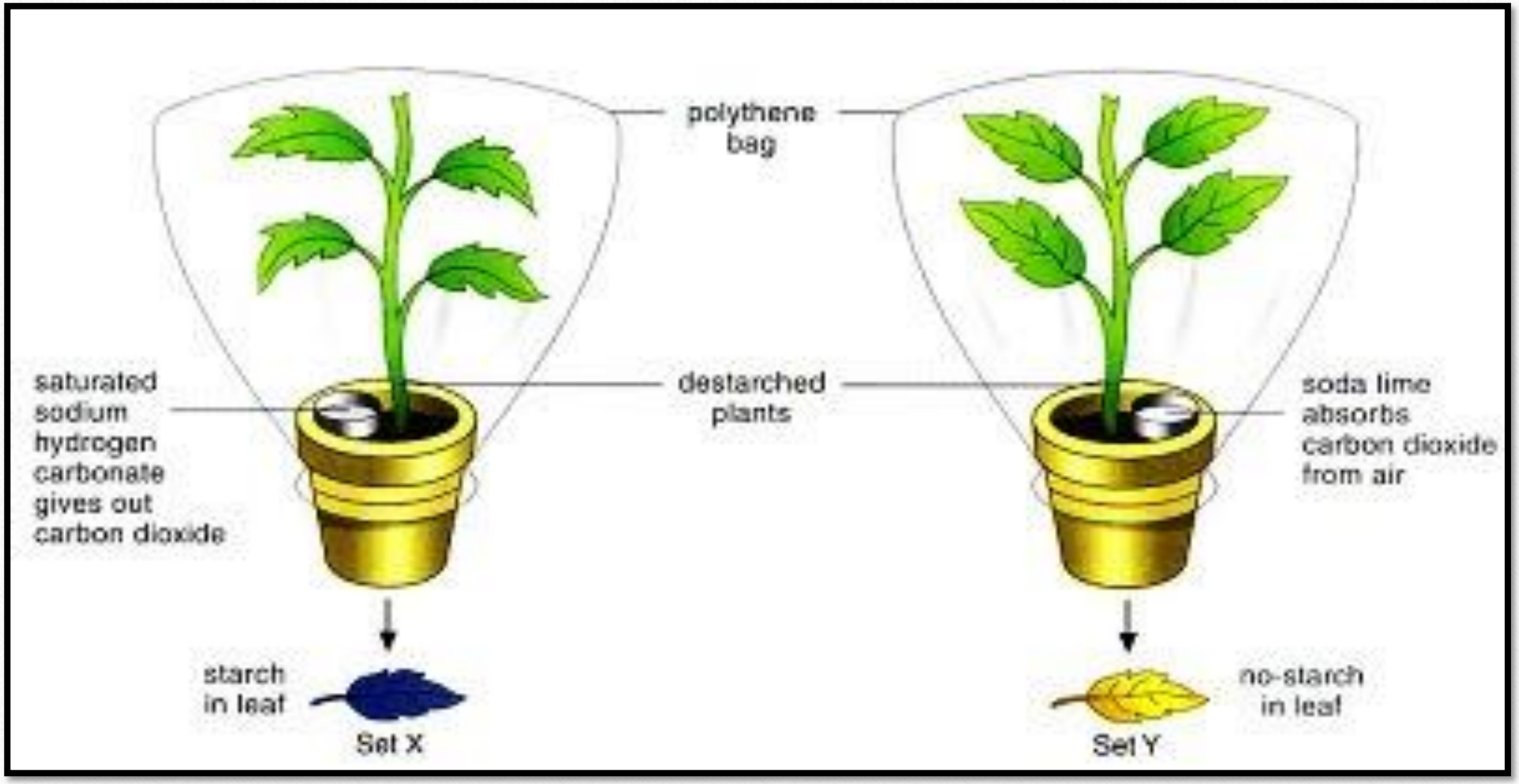
Result:

The leaf with the plastic bag containing hydrogen carbonate will change the color of Iodine to bluish black indicating that starch was produced due to photosynthesis taking place.

Leaf with the plastic bag containing soda lime will not change the colour of Iodine which proves that no starch was produced because photosynthesis didn't occur **due to the lack of CO_2.**

This proves that carbon dioxide is needed for photosynthesis.

The presence of the control experiment that contained hydrogencarbonate rules out the possibility that high humidity caused by the plastic bag prevented normal photosynthesis.


polythene bag
saturated sodium hydrogen carbonate gives out carbon dioxide
destarched plants
soda lime absorbs carbon dioxide from air
starch in leaf
Set X
no-starch in leaf
Set Y

Experiment 4. https://www.youtube.com/shorts/oHDTWLPyKN0

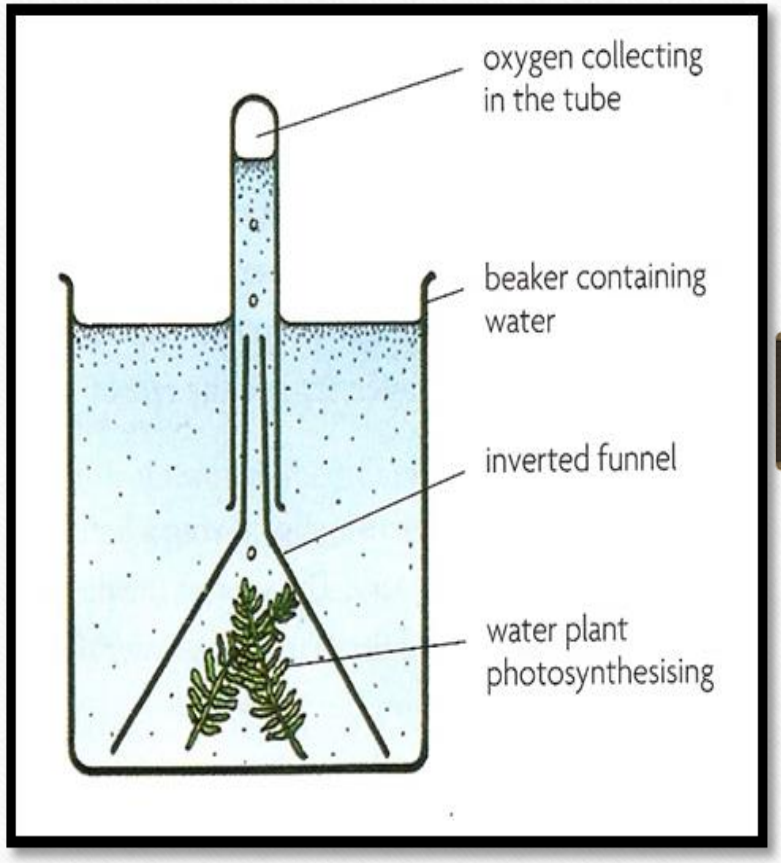
Is oxygen produced during photosynthesis?

We all know that oxygen is produced during photosynthesis, but we have to prove it!

This is done using **a Canadian pond** weed, this plant lives in water.

Set the apparatus as shown in the figure below.

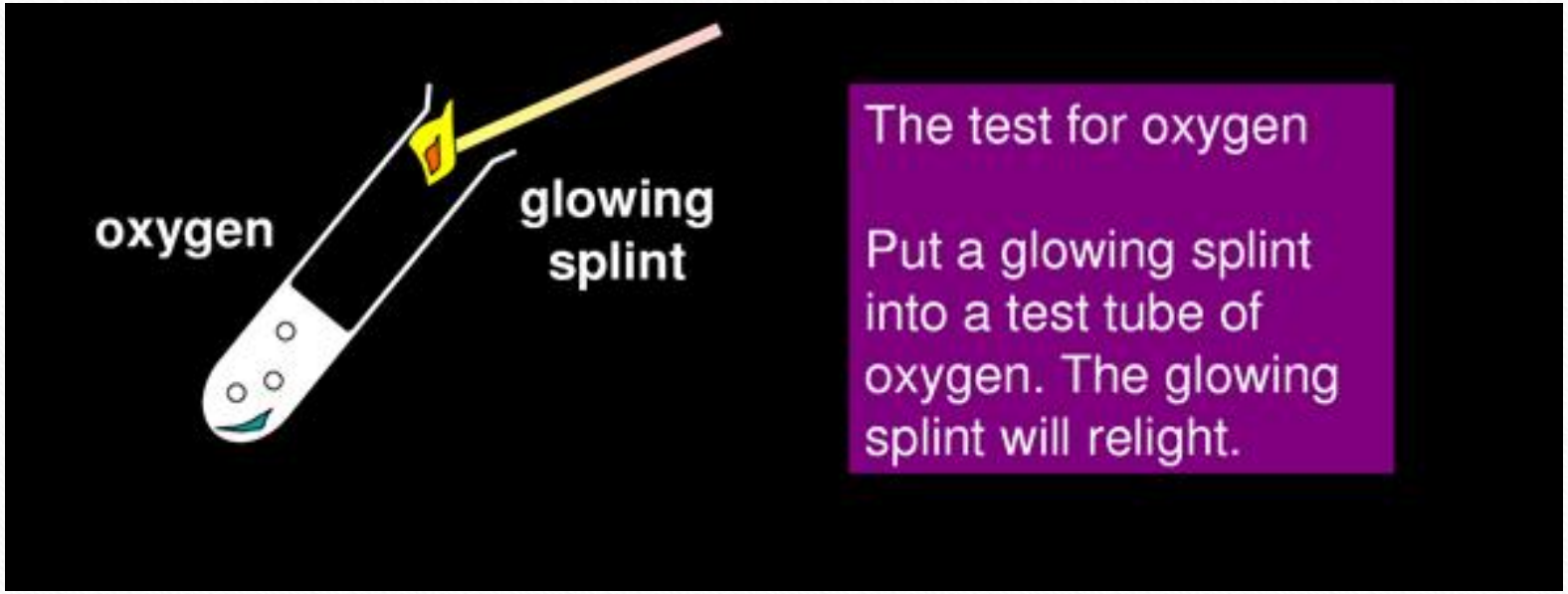
Place the plant in sunlight, in the presence of sunlight the plant will be able to photosynthesize and produce oxygen as a product, the oxygen in turn displaces the water in the tube. So at the end of the experiment there will be an empty space at the top of the tube, this empty space represents the oxygen produced during photosynthesis.



How can we be sure that this gas is oxygen?

The test for Oxygen in done by adding a glowing splint, if Oxygen was present the splint will relight.

What is a glowing splint? Light a wooden splint, then blow it out so that it's glowing, put it into the gas in the test tube, if it relights →then this gas is oxygen



Experiment 5: Gaseous exchange during photosynthesis:

Gaseous exchange in plants takes place for **carbon dioxide, oxygen and water vapour** through tiny pores in the epidermis of the leaves called **stomatal pores**.

Hydrogencarbonate has a red\orange colour in neutral conditions

Rate of photosynthesis = rate of respiration

Increase in carbon dioxide makes it more acidic → Color change from orange to **yellow**. Carbon dioxide is an acidic gas that forms **carbonic acid** (H_2CO_3) when dissolved in water

Happens when the rate of photosynthesis < rate of respiration

Decrease in carbon dioxide makes it less acidic → Color change from orange to purple.

Happens when rate of photosynthesis > rate of respiration

Hydrogen carbonate is often used because it is non-toxic and can be used with living organisms

Yellow	Purple	Yellow	Red\orange