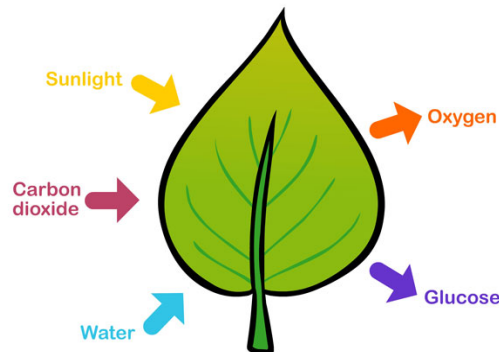


Chapter 11 - Photosynthesis

Learning objectives

- To define the term 'photosynthesis' and represent it as a balanced equation
- To describe simply the process of photosynthesis
- To describe the location of chlorophyll in cells
- To identify the sources of light, carbon dioxide and water for photosynthesis
- To describe the use of artificial light and added carbon dioxide for crop production in greenhouses
- To describe photosynthesis in detail as a two-stage process
- To investigate how light intensity OR carbon dioxide influence the rate of photosynthesis.

HIGHER ▶



Chapter 11 - Photosynthesis



The **sun** is the main source of energy for the earth.

Autotrophs make their own food and most are green plants.

They make food by carrying out **photosynthesis**.

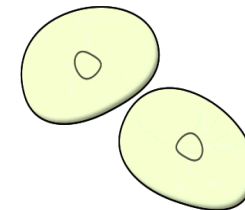


Cells need energy to carry out their functions.

This energy is in the form of ATP.

ATP (Adenosine Tri Phosphate) is a small package containing energy.

In photosynthesis light is first used to make ATP.



The Role of Photosynthesis

1. Plants use it to make **food**
2. Animals get their **food** from plants, so get their food from photosynthesis
3. It produces **Oxygen**, that most living things need to respire and live
4. It was responsible for forming some **fossil fuels** (e.g. oil, peat and coal)



Main events in Photosynthesis

1. **Light is trapped** by chlorophyll and provides the energy for photosynthesis.



2. **Water is split** - the sunlight energy is used to split water in half (**photolysis**)

The *Protons* (H⁺) are stored in a storage pool for the chloroplast to use later on

The *Electrons* (e⁻) are passed to chlorophyll

The *Oxygen* may pass from the chloroplast, into the cytoplasm and out of the leaf or the Oxygen may be used inside the leaf for *respiration*



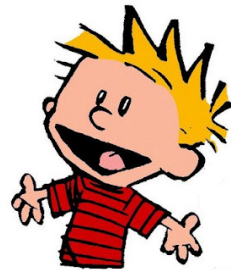
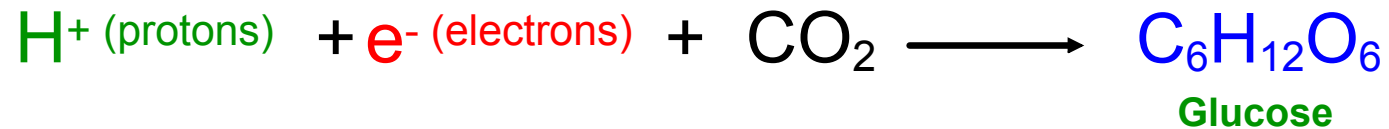
3. **The products** from splitting water are,

Protons - passed to a **storage pool** for later use.

Electrons - passed to **chlorophyll**.

Oxygen - can be used in **respiration** or **released** out of the leaf.

4. **Light energises electrons** and turns them into **high-energy** electrons. These have even more energy to do more work.
5. **Glucose is formed** when the high-energy electrons, protons from the storage pool and Carbon Dioxide from the air are combined. This is called the **Calvin cycle**.



What's Needed?

Light

Sunlight is normal source of light for photosynthesis but artificial light can be used. Countries near the poles can use artificial light in greenhouses to grow crops.



Carbon Dioxide

Plants have 2 sources of Carbon Dioxide, one external and one internal.

External - Most of the carbon dioxide used by plants comes from the outside air.

Internal – Some carbon dioxide used in photosynthesis comes from respiration.

Water

Water is absorbed from the soil by the roots by osmosis, passes up the xylem in stem and into the leaves.



Detailed Study of Photosynthesis - Higher Level

Photosynthesis is split into 2 main stages, the Light and the Dark Stage.

Light Stage

This happens in the **Chloroplast**. It involves electrons (electricity) so reactions happen very **quickly**.

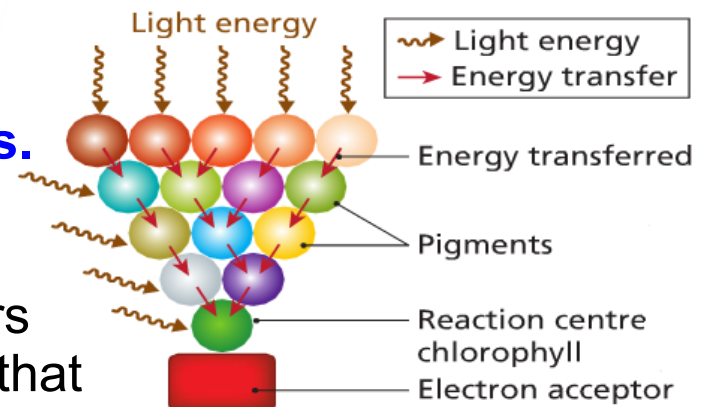
1. Light is absorbed.

Light is made up of 7 colours. Plants absorb all colours of light except green.

2. Light energy is transferred to electrons.

Pigments are arranged in clusters with a **chlorophyll and an electron acceptor**.

Different pigments absorb different colours and pass the electrons to the chlorophyll that has the electron acceptor attached. The electrons get more energy and become high-energy electrons. From here the electrons can go down either of **2 pathways**.



3. Electron flow - Pathway 1.

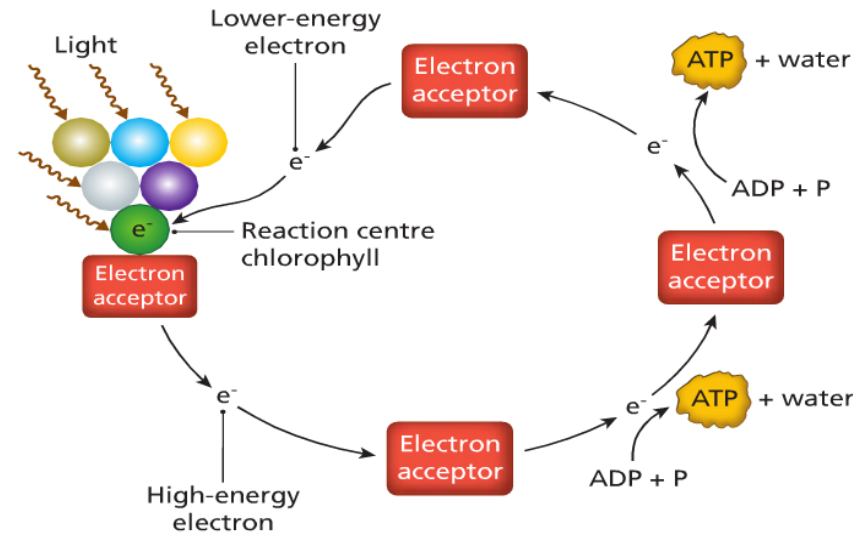
In pathway 1 the high-energy electrons move from the electron acceptor to other electron acceptors. They travel in a **circle** and back to where they started.

As they move they lose energy and this energy forms ATP.

ATP stores energy.



Because the light is involved, a Phosphate is added to the ADP and the electrons move in a circle this is called **Cyclic Photophosphorylation** or **Cyclic electron flow**.



4. Electron flow - Pathway 2.

In pathway 2 **two** high-energy electrons move from the electron acceptor to other electron acceptors. They **don't** travel in a circle.

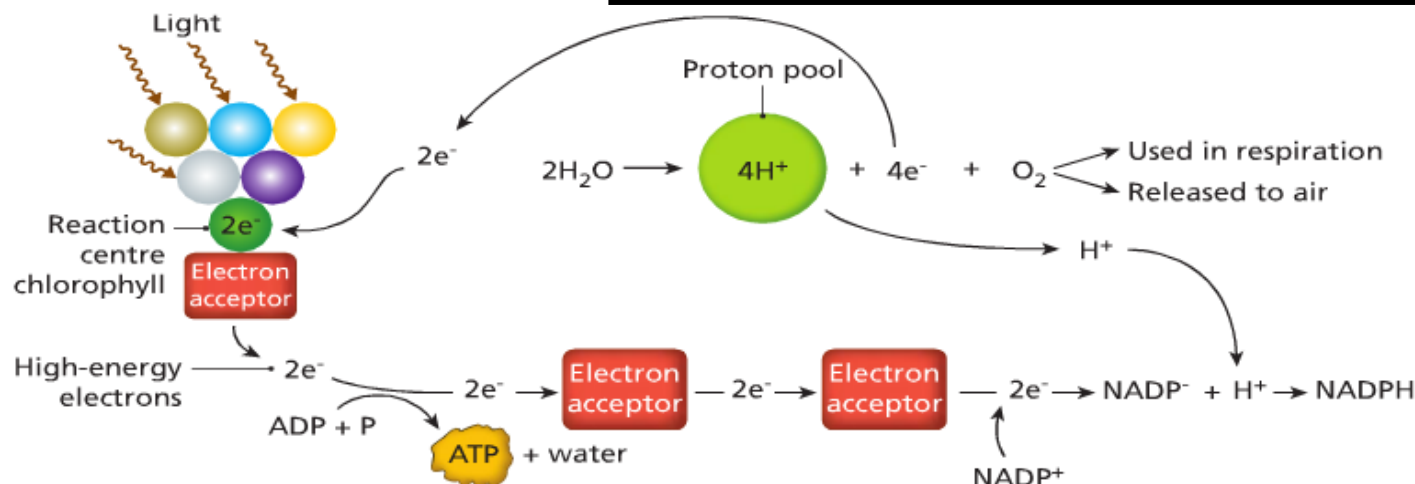
As they move they lose energy and this energy forms **ATP**.

Eventually the 2 electrons join to **NADP⁺** and make **NADP⁻**.

The **H⁺** from the storage pool is now used and stuck to the **NADP⁻** to form **NADPH**.

This is also called Non-Cyclic Photophosphorylation or Non Cyclic electron flow.

At the end of this pathway **ATP** and **NADPH** have been made. Both of these carry energy into the Dark Stage to make Glucose.



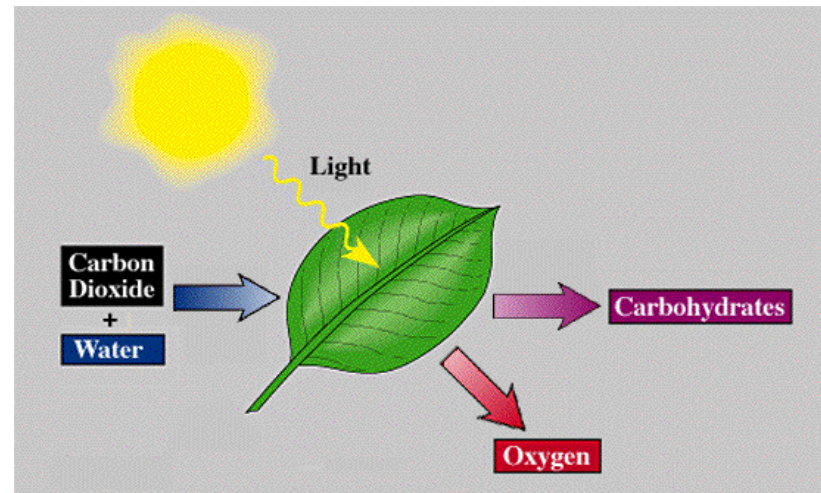
End products of the Light Stage

NADPH, ATP and Oxygen are the end products of the Light Stage.

ATP - will provide energy for reactions in the Dark Stage.

NADPH - will also provide energy but also the H_{12} for **Glucose**.

Oxygen - is made from the split water and released from the leaf or recycled in Respiration.



The Dark Stage

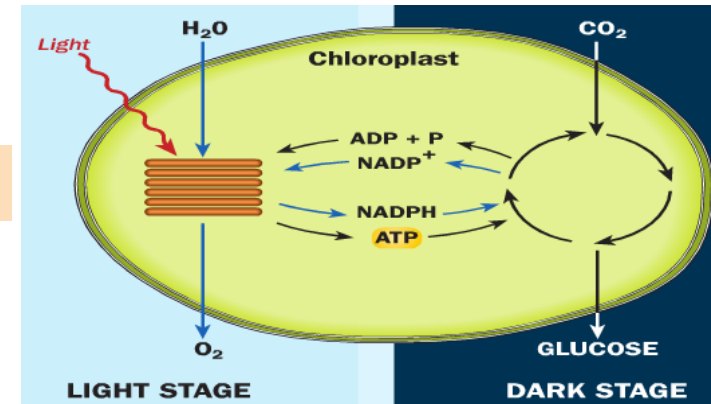


This happens in the **Chloroplast**.
It involves **enzymes** so reactions happen slowly.

The energy carriers (**ATP** and **NADPH**) enter the Dark stage.
They are broken up to release their energy.



This energy drives the **Calvin Cycle**.

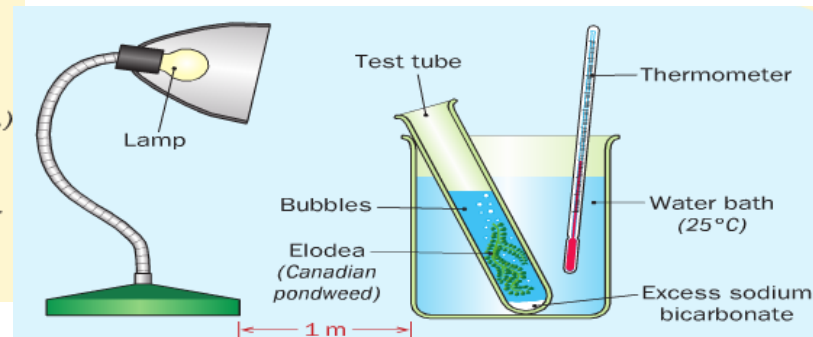


Carbon Dioxide enters the leaf through the pores (stomata).
The Calvin Cycle uses the **CO₂** and mixes it with the **H** from the NADPH.

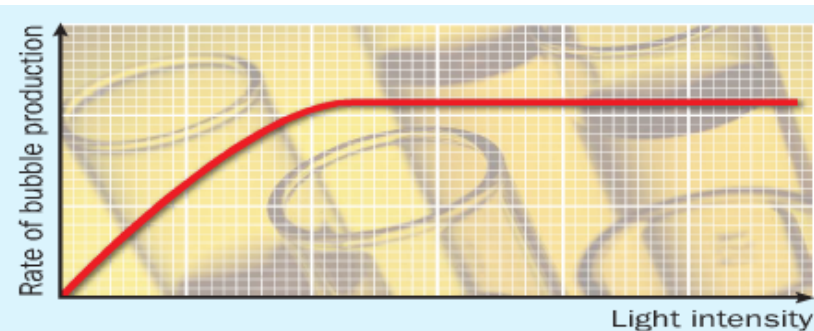
This happens again and again till **C₆H₁₂O₆** (Glucose) is made.
The glucose is then stored as starch for later use in Respiration.

Experiment for Photosynthesis

- 1** Add sodium bicarbonate (also called sodium hydrogen carbonate) to some water in a test tube until it will no longer dissolve. This means that excess bicarbonate has been added and the water is saturated with carbon dioxide. *(As a result there will be a constant concentration of carbon dioxide during the experiment.)*
- 2** Cut a section of *Elodea* and place it (cut end upwards) in the test tube. Set up the apparatus as shown in Figure 11.4 in a darkened room. *(The water bath ensures that the temperature stays constant.)* The lamp should be 1 metre from the apparatus.
- 3** Allow the *Elodea* to stabilise for 5 minutes.
- 4** Count the number of bubbles of oxygen coming from the cut end of the stem per minute. *(This gives an indication of the rate of photosynthesis.)*
- 5** Repeat step 4 twice more.
- 6** Calculate the average number of bubbles per minute. *(This is a measure of the rate of photosynthesis.)*
- 7** Increase the light intensity by moving the lamp closer to the apparatus.
- 8** Repeat steps 3, 4, 5 and 6 each time the lamp is moved (i.e. at 80 cm, 60 cm, 40 cm and 20 cm).
- 9** Record your results as shown in the following table.
- 10** You will see that as the lamp is moved closer to the apparatus the rate of bubble production increases. However, at some point, the rate of bubble production ceases to increase. The plant is then said to be saturated with light.
- 11** Draw a graph of the rate of bubble production vs. light intensity (putting light intensity on the horizontal axis). The graph should appear as:

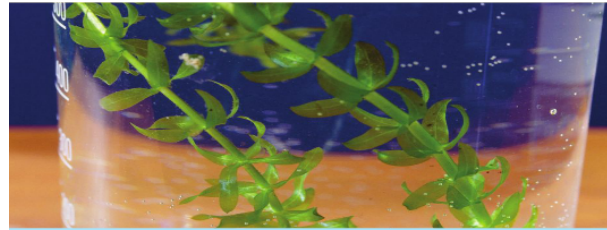


11.4 Apparatus to show the effect of light intensity on rate of photosynthesis



Timer

Experiment for Photosynthesis



Typical questions:

1. Why do we use a water based plant?
2. Why do we add Sodium Bicarbonate?
3. What do we do after moving the lamp?
4. What gas is released by the plant?
5. What temperature is the plant kept at?
6. How did you measure the rate of photosynthesis?
7. Why does the amount of bubbles change?

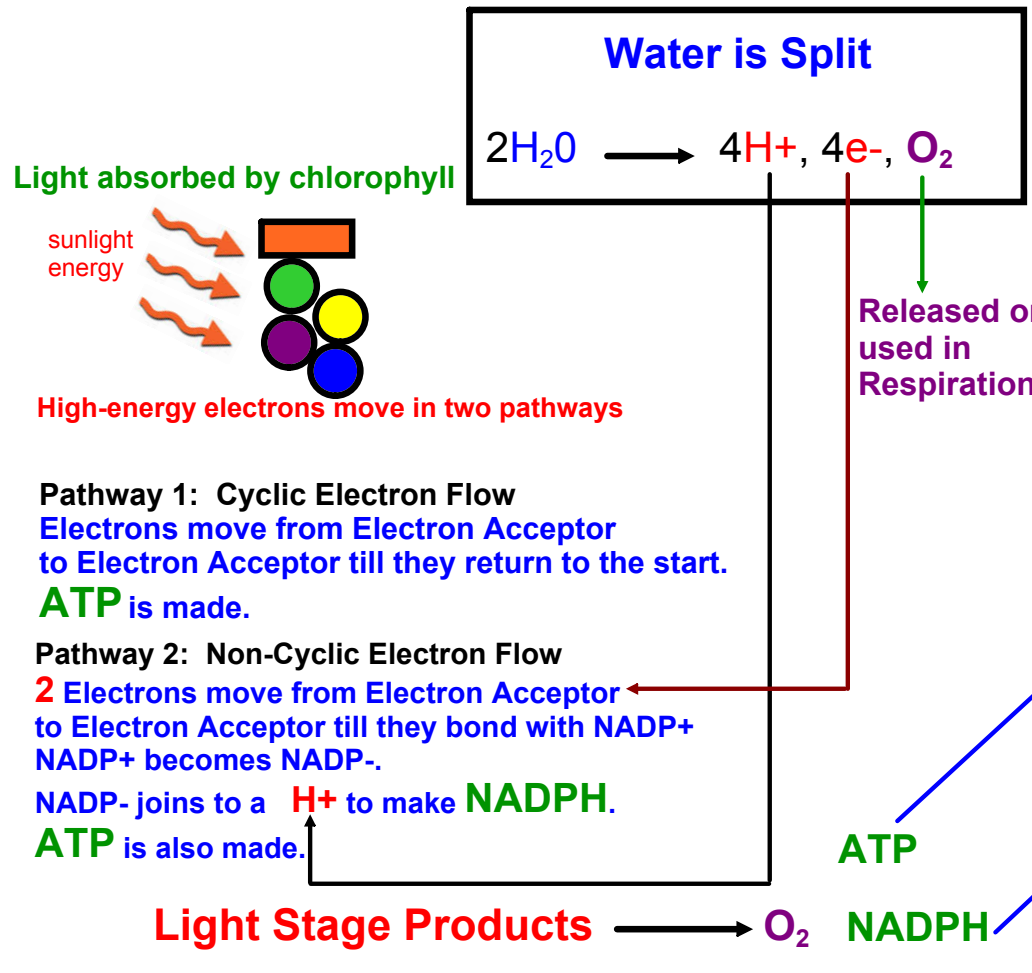
Results

What we should see is that the closer the lamp, the more photosynthesis. A higher photosynthesis rate means more O₂ bubbles per minute. The rate can only go to a certain level though as the plant has limits.

Example Results...

Distance	X-axis			Y-axis	
	$\frac{10,000 \text{ cm}^3}{d^2}$ light intensity	Reading 1	Reading 2	Reading 3	Average Bubbles per min
20	25	20	18	17	18.3
40	6.25	15	14	14	14.3
60	2.8	10	9	9	9.3
80	1.6	5	4	3	4
100	1	2	1	0	1

Light Stage (Happens Quickly with Electrons)



Dark Stage

(Happens Slower with Enzymes)

