PHOTOSYNTHESIS

GR 11 LIFE SCIENCES

Definition:

Photosynthesis is the process where the energy of the sunlight is used by green plants (and some animals) to bond molecules together to form carbohydrates and thus allow the plants to manufacture their own food

EQUATION

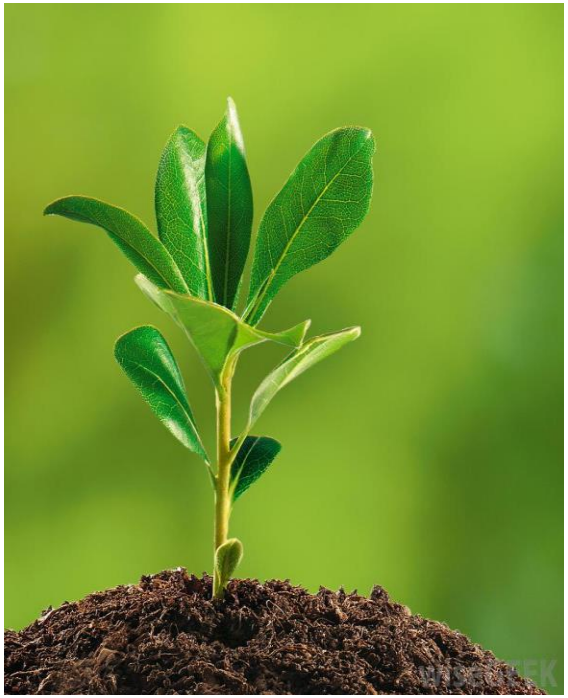
Carbon dioxide + Water + Light $\xrightarrow[\text{Enzymes}]{\text{Chlorophyll}}$ Glucose + oxygen

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

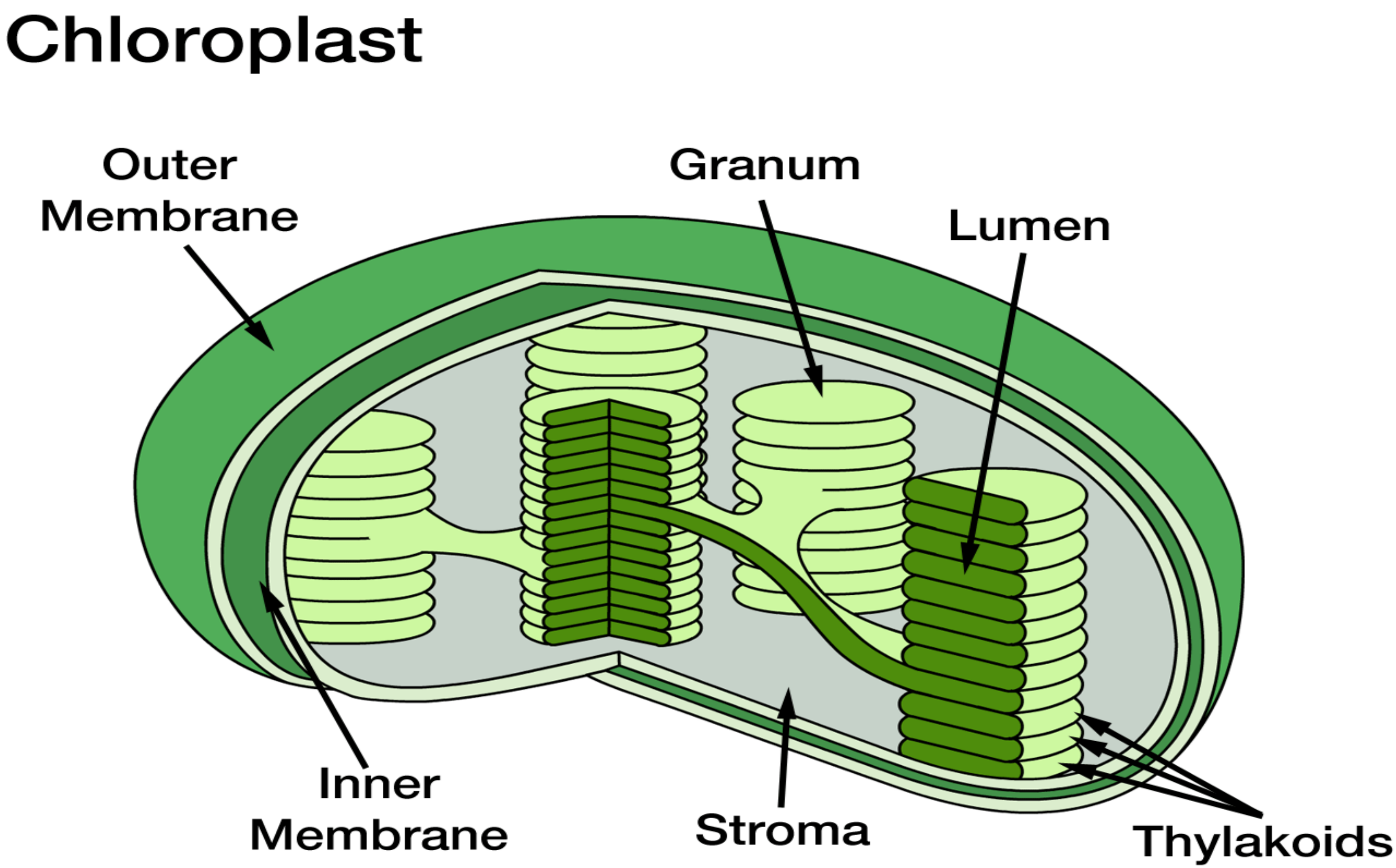
TEST FOR PHOTOSYNTHESIS

Experiments to follow:

- Test for starch
- If light is necessary
- If chlorophyll is necessary
- If CO_2 is necessary
- Which gas is released



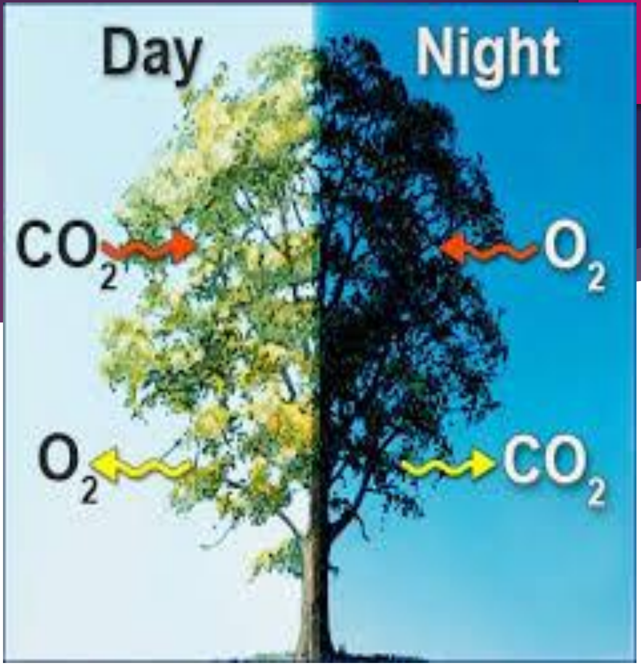
Reminder


Chloroplast
Outer Membrane
Granum
Lumen
Inner Membrane
Stroma
Thylakoids

Functions of each

- **Outer membrane** - It is a semi-porous membrane and is permeable to small molecules and ions, which diffuses easily. The outer membrane is not permeable to larger proteins.
- **Inner membrane** - The inner membrane of the chloroplast forms a border to the stroma. It regulates passage of materials in and out of the chloroplast. In addition of regulation activity, the fatty acids, lipids and carotenoids are synthesized in the inner chloroplast membrane.
- **Stroma:** Stroma is an alkaline, aqueous fluid which is protein rich and is present within the inner membrane of the chloroplast. The space outside the thylakoid space is called the stroma. The chloroplast DNA, chloroplast ribosomes and the thylakoid system, starch granules and many proteins are found floating around the stroma.
- **Thylakoid System**
  The thylakoid system is suspended in the stroma. The thylakoid system is a collection of membranous sacks called thylakoids. The chlorophyll is found in the thylakoids and is the site for the process of light reactions of photosynthesis to happen. The thylakoids are arranged in stacks known as grana.

Raw materials



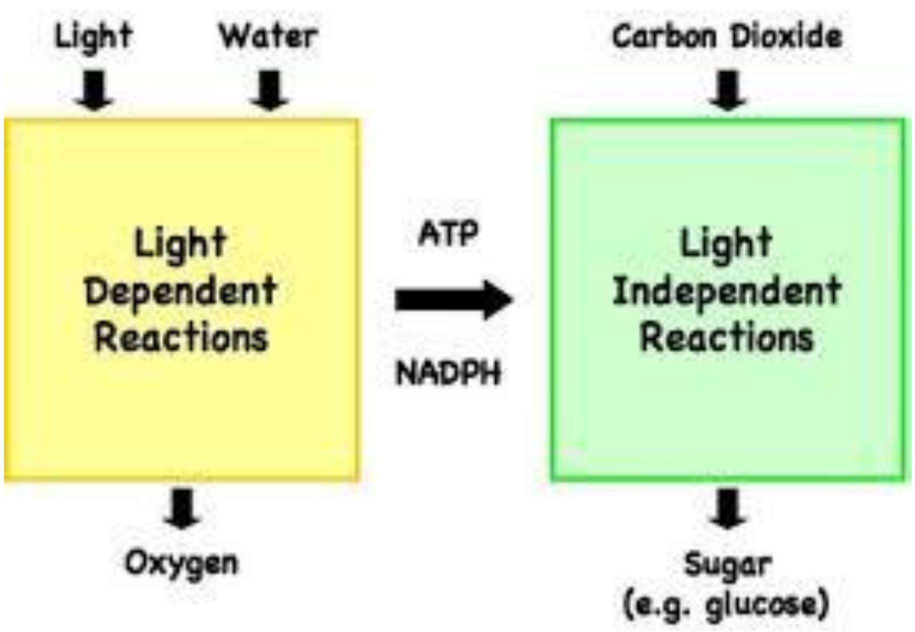
- Carbon dioxide from the atmosphere
- Water from the soil
- Radiant energy from the sun
- Chlorophyll in the chloroplasts of green plants
- Enzymes

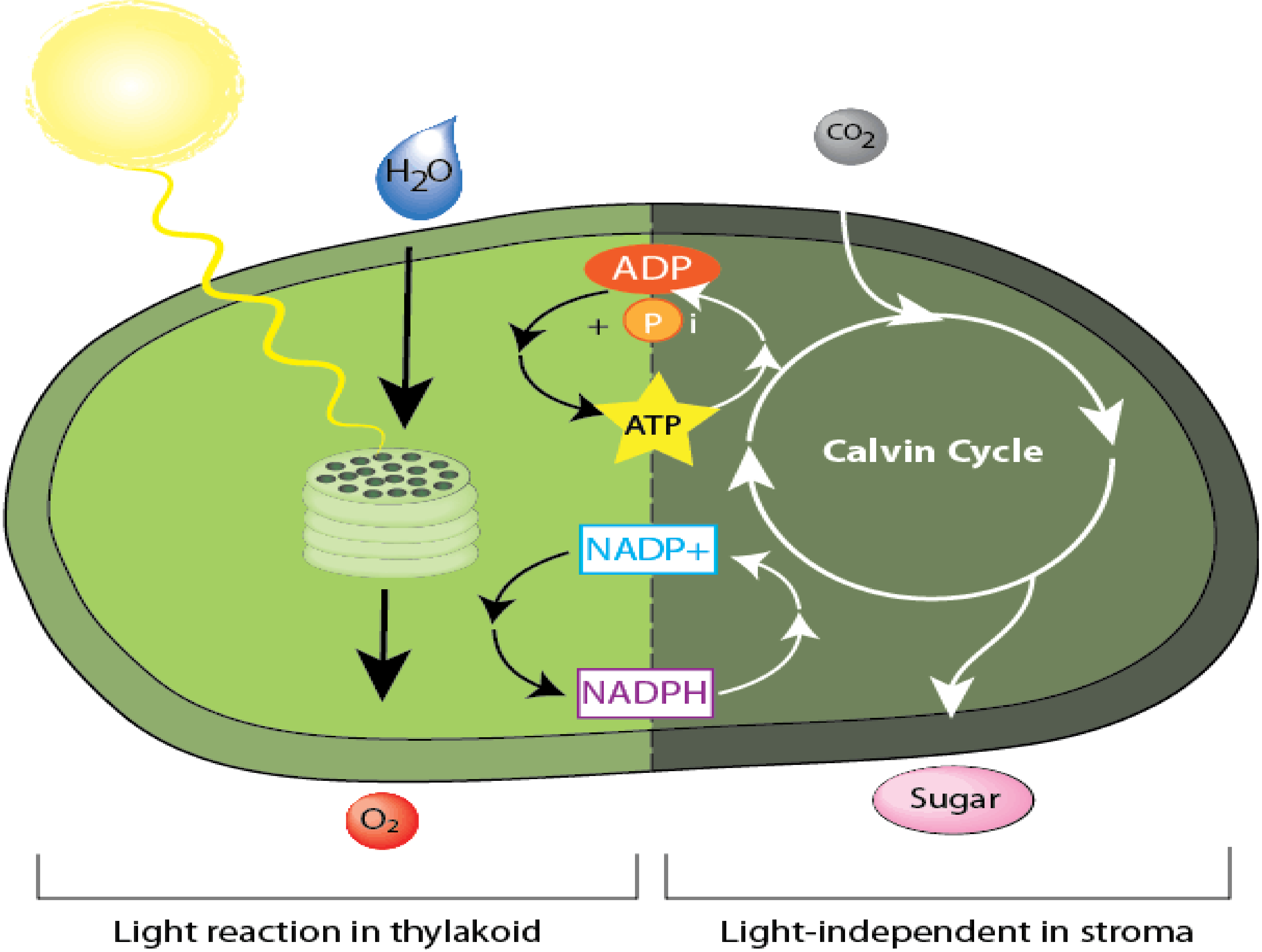
Products

- Glucose, which is stored in the plant as starch
- Oxygen, which is released into the atmosphere.

The process of Photosynthesis

- Occurs as a series of complex biochemical processes
- Two phases: Light Phase (Light Dependent Phase) and dark phase (Light Independent Phase)



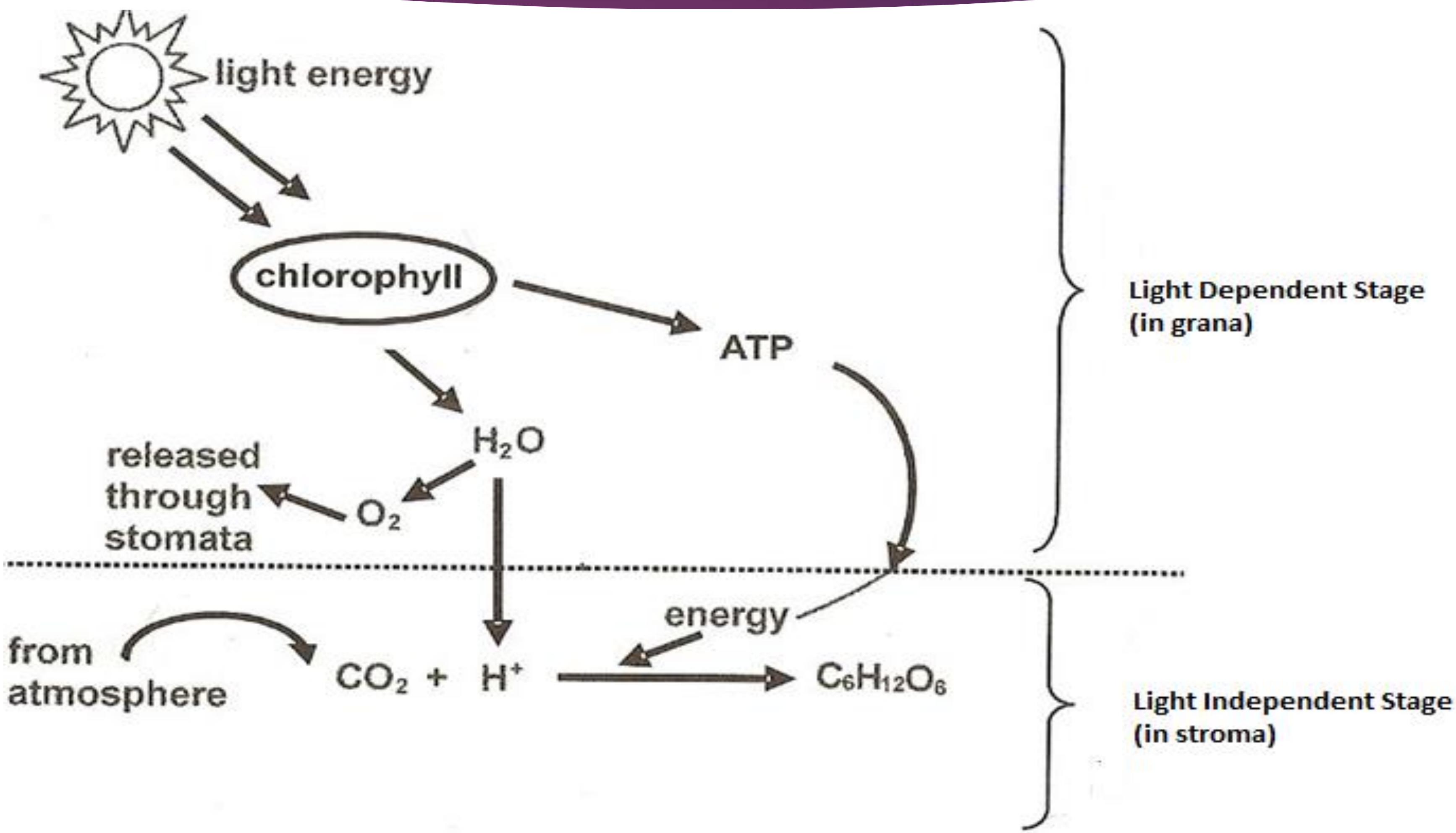


H2O
CO2
ADP
+ P i
ATP
Calvin Cycle
NADP+
NADPH
O2
Sugar
Light reaction in thylakoid
Light-independent in stroma

Light and Calvin cycle

1. In the **light** cycle light falls on the **granum** of a chloroplast.
2. Chlorophyll molecules inside other granum absorb the light energy**(radiant energy)**
3. Some of this energy is used to make **energy rich ATP** and some is used to **split water molecules into oxygen and energy rich hydrogen atoms**
4. In the **dark** phase ,**carbon dioxide**, the **energy rich ATP** and the **energy rich hydrogen** atoms are **used to make glucose molecules**
5. The energy from the energy rich ATP and energy rich hydrogen atoms is **stored in the bonds** holding the atoms of the **glucose molecule** together
6. So light energy is transferred to energy rich ATP and hydrogen atoms. The energy in these molecules is then transferred to the bonds in glucose molecules.

Schematic representation of process

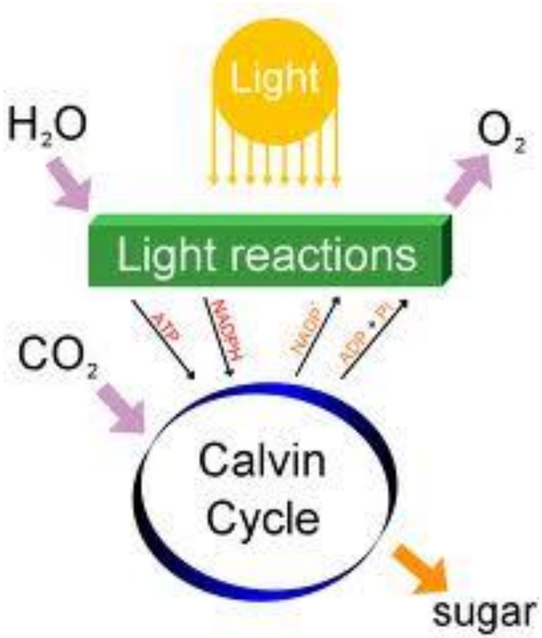


Light Dependent Stage

- The reactions of the light phase take place in the grana of the chloroplast which contain chlorophyll
- The chlorophyll molecules absorb light energy
- ADP + P(phosphate) = ATP
- **This energy is used in two ways:**
  - It is used to form the **energy carrier ATP** (Adenosine Triphosphate)
  - It is used **to split** water molecules **to release** two high- energy hydrogen atoms and oxygen. The **oxygen** is **released** into the atmosphere as a **by product**

Light Independent Stage
Calvin Cycle

- The reactions of the dark phase take place in the stroma of the chloroplast (refers to the colorless fluid surrounding the grana within the **chloroplast)**
- CO_2 provides carbon and oxygen, which combine with the high energy hydrogen atoms from the light phase to form carbohydrates such as glucose and starch (Very Quickly)
- The high energy hydrogen atoms and the ATP from the light phase provide the energy for this process
- All the reactions of the dark phase are controlled by enzymes



Adaptations of chloroplasts for photosynthesis

- The double membrane allows water and CO_2 to enter easily
- The grana contains chlorophyll to trap sunlight
- The grana are flat discs with a large surface area
- The stroma contain enzymes for reactions of the dark phase
- Ribosomes in the stroma synthesize enzymes for photosynthesis
- Starch granules are present to temporarily store the starch that is produced

Adaptations of a leaf

- Leaf has a large surface area
- Leaf is thin
- Epidermis is transparent and has no chloroplasts
- Stomata are found in the epidermis
- Many chloroplasts in the palisade mesophyll cells
- Few chloroplasts in the spongy mesophyll cells – large air spaces
- Veins contain xylem and phloem tubes

Importance of photosynthesis

- Photosynthesis keeps the **oxygen** concentration in the atmosphere and water constant, as oxygen, which is required by organisms for cell respiration is released during photosynthesis
- Keeps the level of **carbon dioxide** in the atmosphere and water constant

Importance of photosynthesis

- Provides food for heterotrophic organisms, as fats and proteins are also made from the glucose and starch that are produce during **photosynthesis**
- Makes chemical energy available for cell functioning as radiant energy is trapped and transformed into chemical energy during photosynthesis so that it can be released during cellular respiration

Factors affecting the rate of photosynthesis

- INTERNAL FACTORS
  - The structure of the leaf
  - The concentration of products of photosynthesis (if the starches made are not transported away quickly they will slow down the rate)
  - Nature of protoplasm (shortage of water – rate will be reduced

Factors affecting the rate of photosynthesis

- EXTERNL FACTORS
  - **The CO_2 concentration in the atmosphere**

A decrease in Carbon dioxide concentration leads to a decrease in the rate of photosynthesis

An increase in CO_2 concentration leads to an increase in the rate of photosynthesis

Factors affecting the rate of photosynthesis

- **The intensity of the light**

An increase in the light intensity results in an increase in the rate of photosynthesis, but only to a maximum level.

If the light intensity becomes too high, the stomata close and carbon dioxide then becomes a limiting factor.

Factors affecting the rate of photosynthesis

- **The temperature**

Plants photosynthesizes optimally at 25◦c

Temperatures that are too high or too low inhibit the rate of photosynthesis.

At low temperatures enzymes become inactive and at high temperatures enzymes denature.

At high environmental temperatures, the stomata close to limit water loss and then carbon dioxide becomes a limiting factor once again

Factors that affect the rate of photosynthesis

- Three important factors namely; light intensity, carbon dioxide concentration and temperature

- As the light intensity (brightness of light) increases so the rate of photosynthesis increases

- As the carbon concentration increases so the rate of photosynthesis increases

- Photosynthesis is controlled by enzymes and enzymes work best at a temperature of 37 degrees Celsius. The temperature should not increase above 37 degree Celsius as enzymes denature at a temperature higher than this.

- Photosynthesis will eventually level off and not increase due to the limiting factors

- Limiting factors are factors that prevent an increase in the rate of a process such as photosynthesis

- In other words even if the light intensity continues increasing there is only so much carbon dioxide available and the temperature is constant.

- The carbon dioxide and temperature are, in this case known as limiting factors as all three factors work collaboratively to increase the rate of photosynthesis

- An optimum rate of photosynthesis is ensured by giving the plant as much light as possible, a high concentration of carbon dioxide as well as a temperature of not higher than 37 degrees Celsius

Improving Crop Fields

- The greater the rate of photosynthesis the greater the productivity of the plant.

- The productivity of a plant is known as how much extra dry mass (excluding its water content) it gains over a period of time

- A greater productivity of a plant crop the larger quantity of food to eat.
- Plants grown in greenhouses or greenhouse tunnels may grow better then those grown outside. This is because:
- The glass roof and walls let lots of light into the greenhouse and trap the heat inside thereby allowing for a high light intensity and a high temperature
- Gas cylinders can be used to pump additional carbon dioxide into the greenhouse where it is trapped

- Watering is much more efficient within a greenhouse

- The plants do not need to be watered as often as those outside as transpiration is decreased due to the increased humidity within the greenhouse.

- Insecticides can be sprayed inside the greenhouse in order to control pests more effectively.

The role of ATP

- ATP (Adenosine Triphosphate) is an energy rich molecule
- It is formed when ADP (Adenosine diphosphate) combines with a third phosphate by means of an energy rich bond
- This is known as phosphorylation. In other words ADP is phosphorylated.
- This reaction is reversible. ATP can be broken down into ADP and a phosphate when an energy rich bond is broken. ATP is dephosphorylated.

- The energy from the energy-rich bond is released during this reaction and used in the cell

- ATP is an energy carrier in the cell. When a cell needs energy the ATP is broken down into ADP.

- The energy released is used for different functions such as:

  - Synthesis of macromolecules such as nucleic acids, proteins and fats

  - The contraction of muscle cells

- The beating of cillia and flagella.
  - Cilla (tiny hair like structures – move things over the surface of the cell such as dust particles)
  - Flagella (longer thread like structures that help cells move through liquid)

- Active transport. To move substances from a low concentration gradient to a high concentration gradient

- Bioluminescence. The ability of living organisms to give off light through a chemical reaction. For example fireflies and jellyfish glow in the dark