PHOTOSYNTHESIS IN PLANTS

- The process of photosynthesis involves the conversion of light energy from the sun to chemical energy stored in starch.
- This is the route by which virtually all energy enters the biosphere.
- In photosynthesis green plants use light energy, water and carbon dioxide to synthesize carbohydrates (starch) and release oxygen.
- Although plant cell contains a variety of organic molecules: proteins, lipids, nucleic acids, vitamins and carbohydrates, photosynthesis however produce only carbohydrates.
- All the other organic molecules in plant cell are produced by metabolic rearrangement of carbohydrates.
- In photosynthesis, solar energy is converted to chemical energy. The overall chemical equation for this process is:

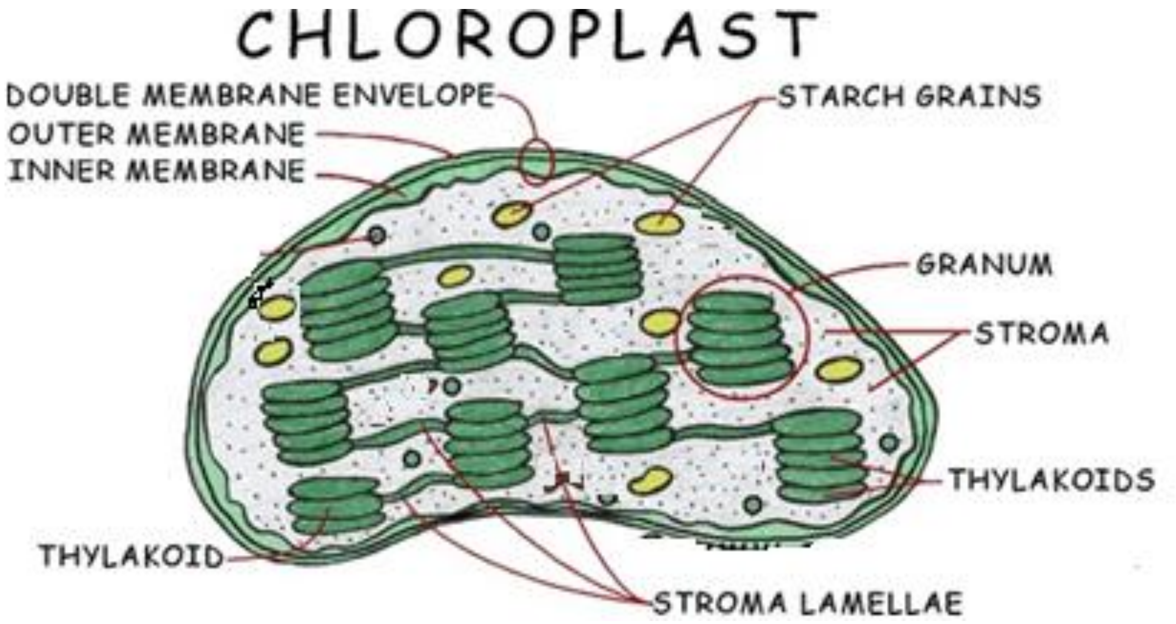
$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{light}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

- 6 molecules of carbon dioxide ($6CO_2$) and 12 molecules of water ($12H_2O$) are consumed in the process, while one molecule of glucose ($C_6H_{12}O_6$), six molecules of oxygen ($6O_2$), and six molecules of water ($6H_2O$) are produced at the end of the process.

Chloroplast

- In plants, photosynthesis occurs in the chloroplast mainly in leaves.
- In some plants, the stem and other plant parts contains chlorophyll and are capable of carrying out photosynthesis e.g. herbaceous plants with green stems, green calyx of flowers.
- Since photosynthesis requires sunlight, carbon dioxide and water, all of these must be available to the leaves.
- Carbon dioxide is obtained from the atmosphere through tiny pores in leaves called stomata.
- Water obtained by the roots is transported to the leaves through vascular tissues.
- Sunlight is absorbed by chlorophyll, a green pigment located in the chloroplasts.

STRUCTURE OF CHLOROPLAST



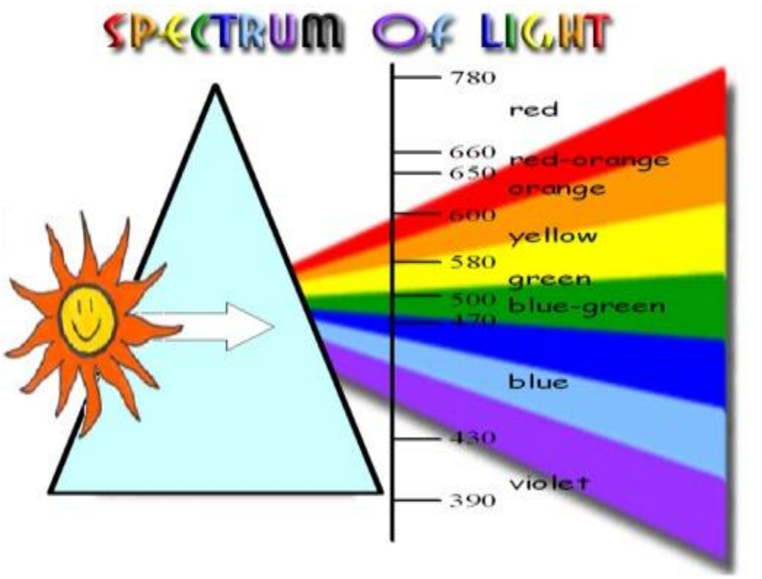
Outer and inner membranes: protective coverings that keep chloroplast structures enclosed**.**

Stroma: dense fluid within the chloroplast. Site of conversion of carbon dioxide to sugar.

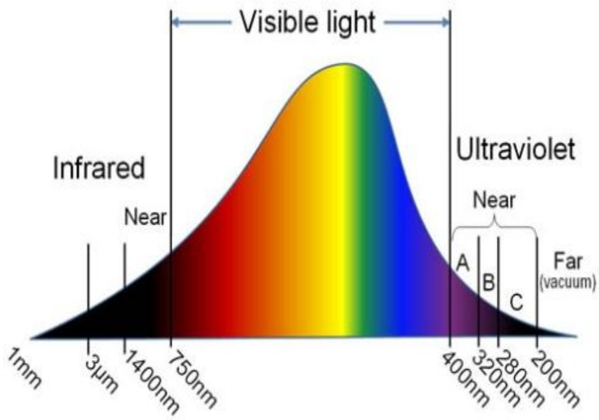
Thylakoid: are the extensive membrane system in chloroplast made up of grana (stacks of thylakoid sacs) and stroma lamellae (un-stacked membranes connecting grana). Site of conversion of light energy to chemical energy.

- Chloroplasts are surrounded by an inner and an outer membrane which encloses a fluid-filled region called the stroma.
- The stroma contains enzymes for the dark reactions of photosynthesis.
- Infolding of the inner membrane forms interconnected stacks of disk-like sacs called thylakoids, often arranged in stacks called grana.
- The thylakoid contain fluid-filled interior space (lumen) with chlorophyll and other photosynthetic pigments as well as electron transport chains.
- The light-dependent reactions of photosynthesis occur in the thylakoids.
- The chlorophyll and accessory pigments along with the electron acceptors and enzymes of the light reactions are located in the internal membrane system i.e. grana and their interconnecting membranes.

ELECTROMAGNETIC VISIBLE SPECTRUM



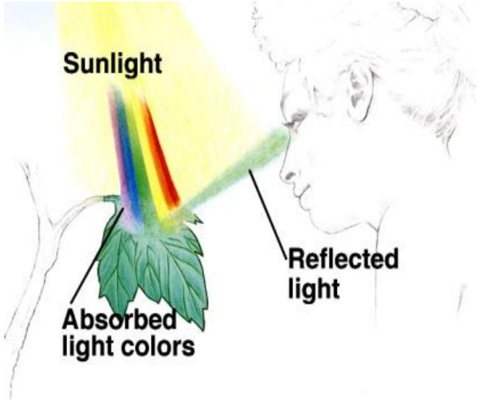
- Light behaves as if it were composed of "units" or "packets" of energy that travel in waves. These packets are known photons.
- White light from the sun consists of different colours or wavelengths. These are referred to as an electromagnetic spectrum.
- This visible part of the electromagnetic spectrum consists of the colors that we see in a rainbow – VIBGYOR (violet, indigo, blue, green, yellow, orange and red) between 400 – 700 nm.

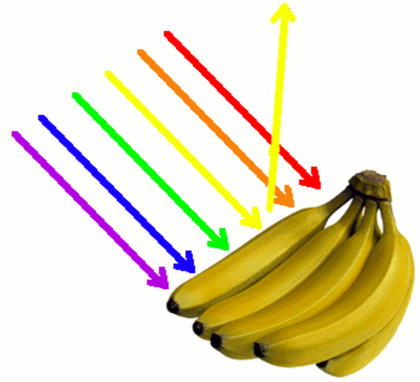


- Each of these colors actually corresponds to a different wavelength of light measured in nanometers (nm).
- For example, the wavelength of red is about 700 nm and the wavelength of blue light is about 470 nm.
- The longer wavelengths occur in the red region while the shorter wavelengths occur in the violet region.
- Wavelengths longer than red are referred to as infrared, while those shorter than violet are ultraviolet (ultraviolet radiation (UV) is dangerous to cells because it breaks chemical bonds, for this reason UV light is used for sterilization).

- Light striking an object is either reflected, transmitted or absorbed.
- The color of things come from the wavelengths of light reflected (in other words, those not-absorbed).

- Leaves appear green because chlorophyll molecules in leaf cells reflect green and





yellow wavelengths of light, and absorb the other wavelengths.

- If it absorbs all the regions of the visible light there would be no color for reflection left and would then look black instead of green.

- Any object that looks black absorbs all the visible light and hence we see it as BLACK.

- **Plants use electromagnetic spectrum wavelengths in the range of 400 to 700 nanometers for photosynthesis and growth.**

- These light wavelengths are collectively known as photosynthetically active radiations (PAR) which are absorbed by various plant pigments present in chloroplast.

PROCESS OF PHOTOSYNTHESIS

The process of photosynthesis is divided into two parts:

- the energy-fixing reaction (also called the light reaction) and

- the carbon-fixing reaction (also called the dark reaction or the light-independent reaction).

Light reaction

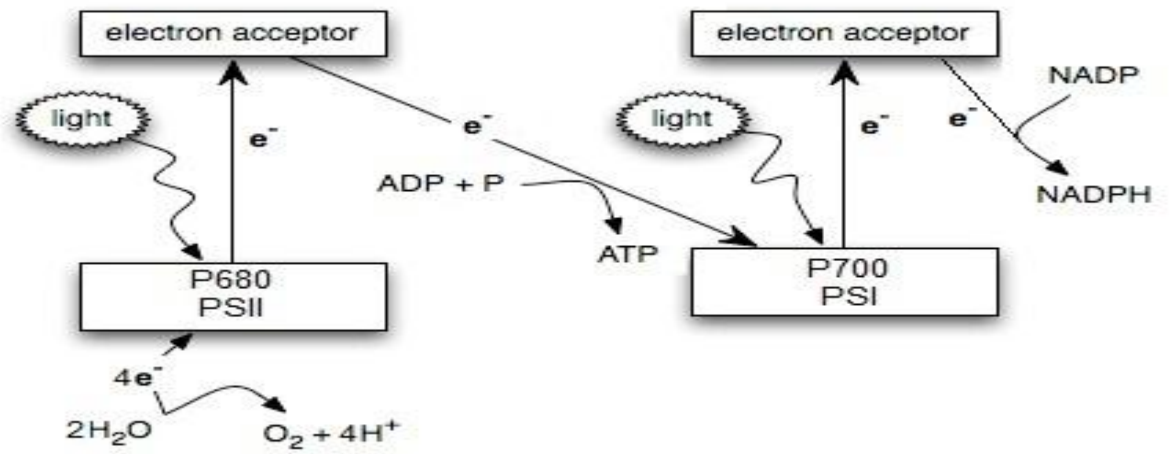
- The light reactions take place in the grana of the chloroplast. In the grana sunlight is converted to chemical energy in the form of ATP and NADPH which are later used in the dark reaction as energy sources for the production of carbohydrates.

- Light energy for photosynthesis is absorbed by various pigments – chlorophyll a, chlorophyll b and carotenoids. The main pigment involved in photosynthesis is chlorophyll a. Chlorophyll b and carotenoids are known as accessory pigments. They absorb light energy and pass it on to chlorophyll a. Chlorophyll a molecules take up these energies and start a chain of reactions that results in the production of ATP, NADPH, and oxygen.

There are two sites for the light reactions –

- Photo system I – PSI (P700)
- Photo system II – PSII (P680)

PSI and PSII are chlorophyll a molecules absorb light energy of specific wavelengths – PSI from 700nm and PSII from 680 nm, directly from the sun. They also receive the energy from the accessory pigments. When sunlight falls on the leaves, these two pigments absorb light simultaneously and initiate the light reactions.



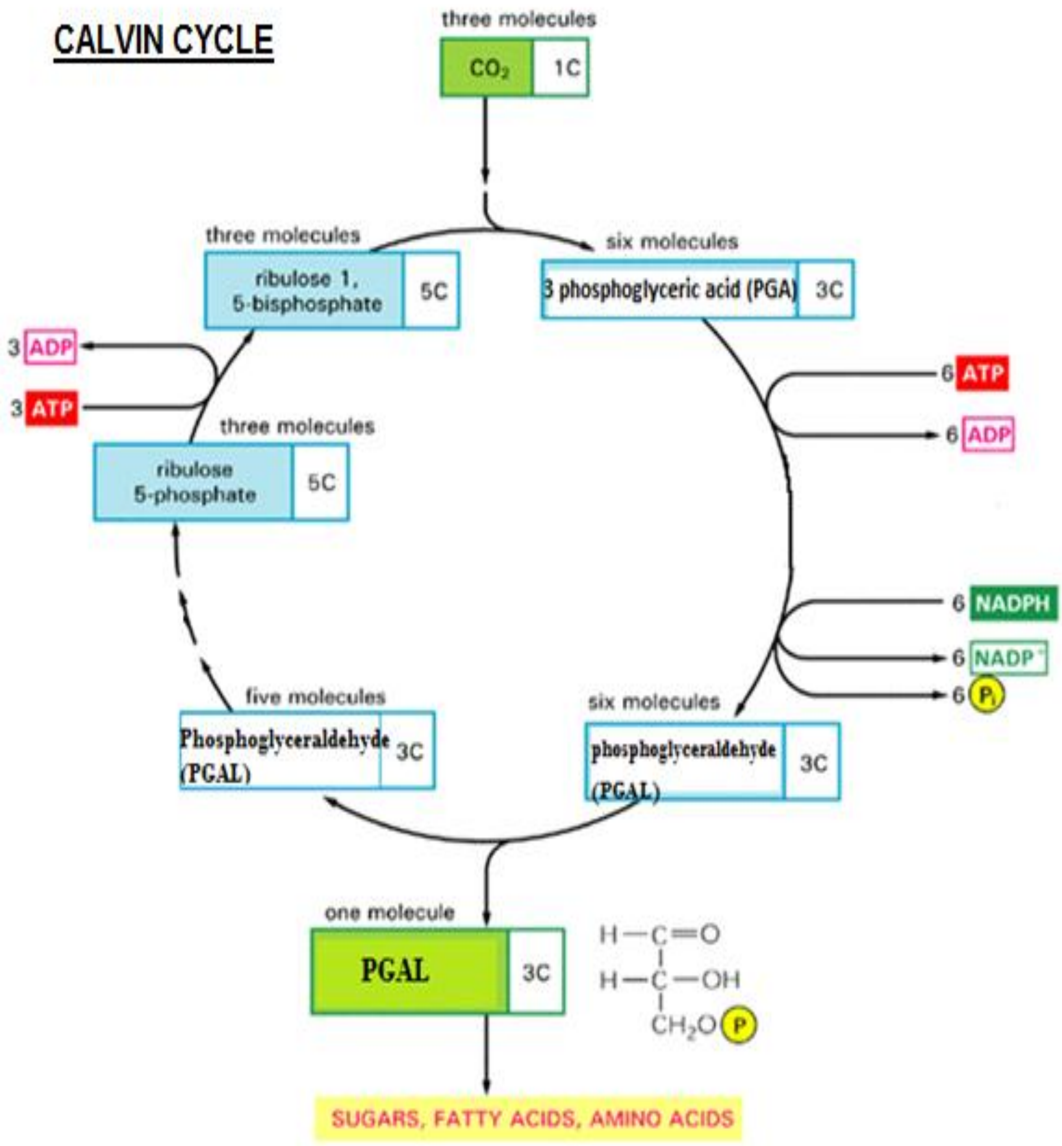
- After absorbing the light energy, PSII releases electrons which pass through an electron transport chain to PSI.
- During this movement of electrons in the electron chain, ATP is produced. The release of electrons by PSII causes it to enter into an excited state which is unstable.
- So to get back to stable state and continue to absorb light energy, it has to receive electrons that it has released.
- Subsequently these electrons are supplied to PSII through the splitting of water.
- The splitting of water results in release of oxygen (O_2), protons (H^+) and electrons (e^-). Therefore at the end of light reaction in PSII, oxygen and protons are released.

PSI releases electrons that are transported by a different electron transport chain to reduce NADP to NADPH. Thus the light reaction produces ATP, NADPH and oxygen as a by-product

<u>THIS IS WHY PLANTS ARE VERY IMPORTANT FOR LIVING ORGANISMS (USING OXYGEN FOR RESPIRATION) SINCE THEY REPLENISH THE OXYGEN IN THE ATMOSPHERE……………….</u>

B. DARK REACTION (Carbon-fixing reaction, C3 CYCLE OR CALVIN CYCLE)

- The dark reaction is a light independent process which usually follows the light reaction and is referred to as the carbon fixing reaction, C3 cycle and Calvin cycle (after the scientist who elucidated it).
- These reactions of photosynthesis occur in the stroma of the chloroplast and utilize the ATP and NADPH generated during the light reaction for the production of glucose and other carbohydrates (end products of photosynthesis).



- The initial step of the dark reaction involves a five-carbon sugar molecule present in the stroma called ribulose bisphosphate, or RuBP.
- Three molecules of RuBP accept and bind to 3 molecules of atmospheric CO2 (that enters the chloroplast) to form 3 molecules of an unstable 6 carbon intermediate compound that has not been isolated yet. The enzyme catalyzing this reaction is ribulose 1,5 – bisphosphate carboxylase/oxygenase (RUBISCO).

- Each unstable 6 carbon compound immediately splits to give 2 molecules of the 3 carbon compound - 3-phosphoglycerate (3PG), also called phosphoglyceric acid (PGA). Thus 6 molecules of PGA are synthesized.

- The 6 PGAs are initially activated by 6 ATPs and then reduced (addition of a hydrogen ion) to 6 phosphoglyceraldehyde (PGAL). Six molecules of NADPH (product of light reaction) acts as hydrogen donors.

- One molecule of PGAL is used to synthesis glucose which is converted to sucrose and other carbohydrates. These are the end products of dark reactions.

- The other 5 molecules of PGAL are used to regenerate RuBP to continue the cycle. This reaction is necessary because the initial RuBP in the stroma is used up during the synthesis of glucose and needs to be replaced. Three ATP molecules are used in this regeneration process.

The glucose is converted into

- Sucrose – which is transported throughout the plant
- Starch – which is stored in the chloroplast

Eg. C3 plants - rice, wheat, soya beans, barley, potatoes