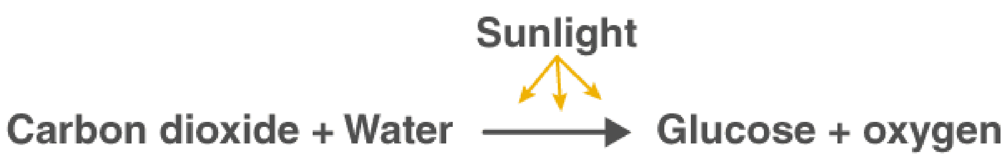
QUICK REVISION NOTES
For NEET
BIOLOGY CLASS 11

PHOTOSYNTHESIS

What is Photosynthesis?

Photosynthesis is a process by which phototrophs convert light energy into chemical energy, which is later used to fuel cellular activities. The chemical energy is stored in the form of sugars, which are created from water and carbon dioxide.



A visual representation of the photosynthesis reaction

Where Does This Process Occur?

Chloroplasts are the sites of photosynthesis in plants and blue-green algae. All green parts of a plant, including the green stems, green leaves, and sepals – floral parts comprise of chloroplasts – green colour plastids. These cell organelles are present only in plant cells and are located within the mesophyll cells of leaves.

Photosynthesis Equation

Photosynthesis reaction involves two reactants, carbon dioxide and water. These two reactants yield two products, namely, oxygen and glucose. Hence, the photosynthesis reaction is considered to be an endothermic reaction. Following is the photosynthesis formula:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Unlike plants, certain bacteria that perform photosynthesis do not produce oxygen as the by-product of photosynthesis. Such bacteria are called anoxygenic photosynthetic bacteria. The bacteria that do produce oxygen as a by-product of photosynthesis are called oxygenic photosynthetic bacteria.

Factors Affecting Photosynthesis

Photosynthesis process requires several factors such as:

Light Intensity: Increased light intensity results in a higher rate of photosynthesis. On the other hand, low light intensity results in a lower rate of photosynthesis.

The concentration of CO_2: Higher concentration of carbon dioxide helps in increasing the rate of photosynthesis. Usually, carbon dioxide in the range of 300 – 400 PPM is adequate for photosynthesis.

Temperature: For efficient execution of photosynthesis, it is important to have a temperature range between 25° to 35° C.

Water: As water is an important factor in photosynthesis, its deficiency can lead to problems in the intake of carbon dioxide. The scarcity of water leads to the refusal of stomatal opening to retain the amount of water they have stored inside.

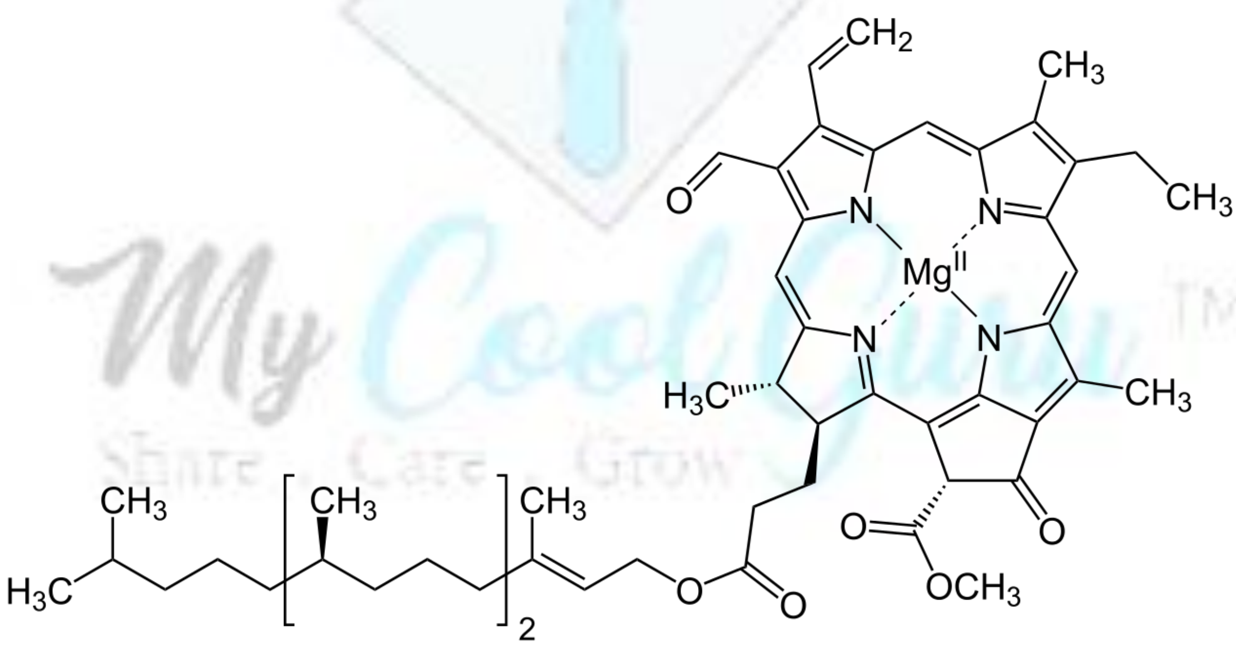
Pollution: Industrial pollutants and other particulates may settle on the leaf surface. This can block the pores of stomata which makes it difficult to take in carbon dioxide.

Photosynthetic Pigments:

There are four different types of pigments present in leaves:

I. Chlorophyll a
II. Chlorophyll b
III. Xanthophylls
IV. Carotenoids

Structure of Chlorophyll



The structure of Chlorophyll consists of 4 nitrogen atoms that surround a magnesium atom. A hydrocarbon tail is also present. Pictured above is chlorophyll-*f*, which is more effective in nearinfrared light than chlorophyll-*a*

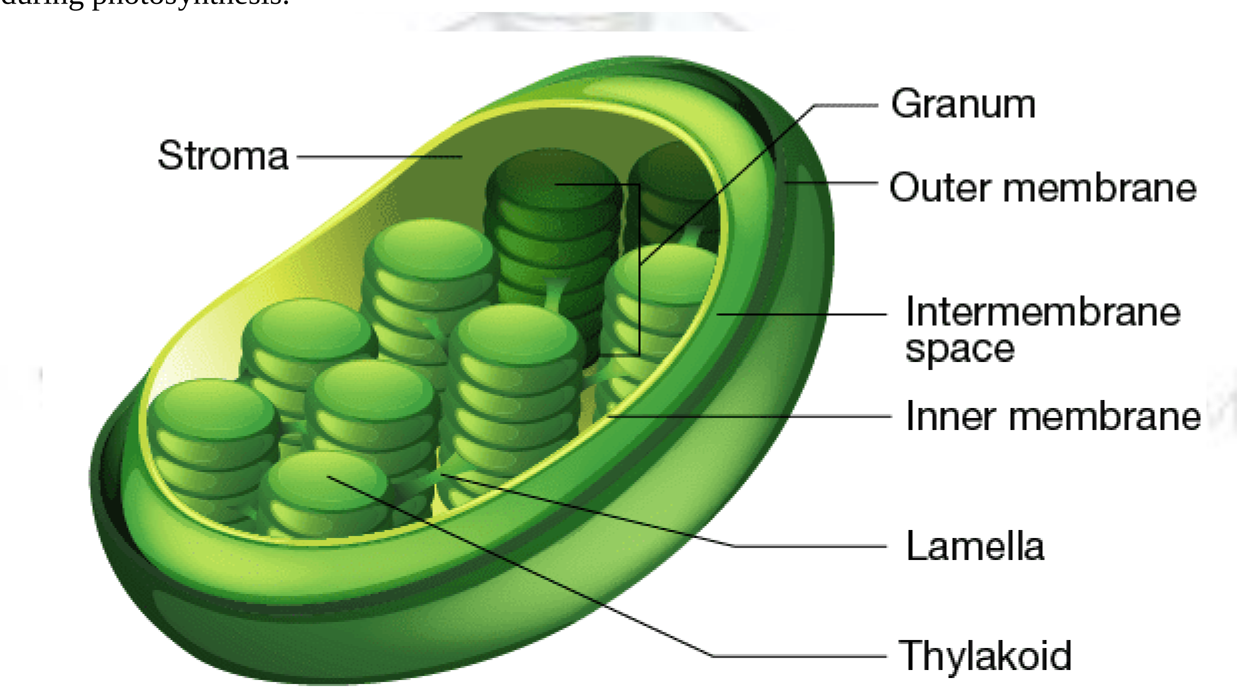
Chlorophyll is a green pigment found in the chloroplasts of the **plant cell** and in the mesosomes of cyanobacteria. This green colour pigment plays a vital role in the process of photosynthesis by permitting plants to absorb energy from sunlight. Chlorophyll is a mixture of chlorophyll-*a* and chlorophyll-*b*.

Besides green plants, other organisms that perform photosynthesis contain various other forms of chlorophyll such as chlorophyll-*c1*, chlorophyll-*c2*, chlorophyll-*d* and chlorophyll-*f*.

Process Of Photosynthesis

At the cellular level, the photosynthesis process takes place in cell organelles called chloroplasts. These organelles contain a green-coloured pigment called chlorophyll, which is responsible for the characteristic green colouration of the leaves.

As already stated, photosynthesis occurs in the leaves and the specialized cell organelles responsible for this process is called the chloroplast. Structurally, a leaf comprises a petiole, epidermis and a lamina. The lamina is used for absorption of sunlight and carbon dioxide during photosynthesis.



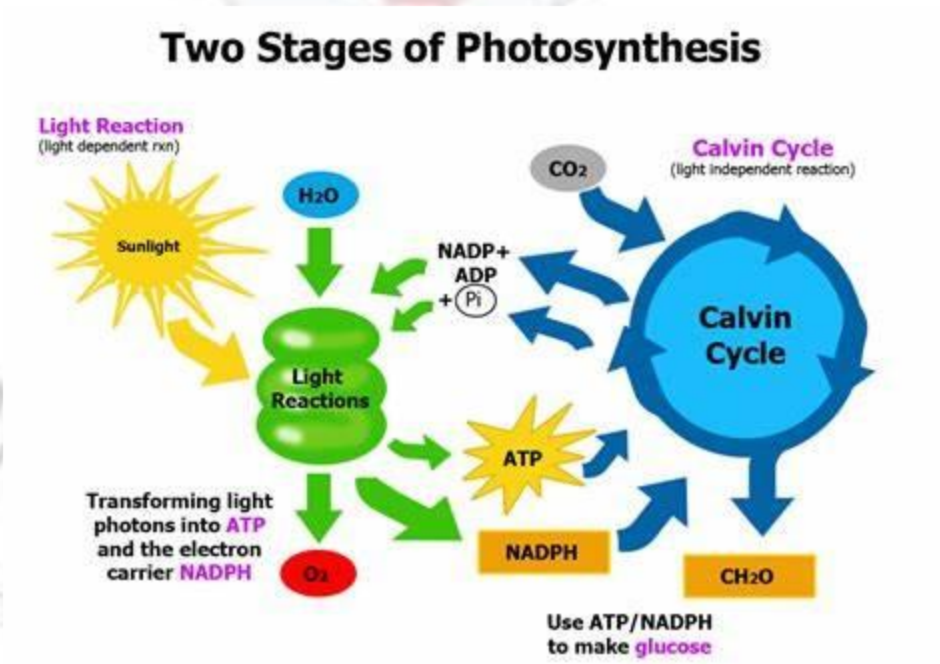
Structure of Chloroplast.

"Photosynthesis Steps:"

- During the process of photosynthesis, carbon dioxide enters through the stomata, water is absorbed by the root hairs from the soil and is carried to the leaves through the xylem vessels. Chlorophyll absorbs the light energy from the sun to split water molecules into hydrogen and oxygen.
- The hydrogen from water molecules and carbon dioxide absorbed from the air are used in the production of glucose. Furthermore, oxygen is liberated out into the atmosphere through the leaves as a waste product.
- Glucose is a source of food for plants that provide energy for **growth and development**, while the rest is stored in the roots, leaves and fruits, for their later use.
- Pigments are other fundamental cellular components of photosynthesis. They are the molecules that impart colour and they absorb light at some specific wavelength and reflect back the unabsorbed light. All green plants mainly contain chlorophyll a, chlorophyll b and carotenoids which are present in the thylakoids of chloroplasts. It is primarily used to capture light energy. Chlorophyll-a is the main pigment.

The **process of photosynthesis** occurs in two stages:

- Light-dependent reaction or light reaction
- Light independent reaction or dark reaction



Stages of Photosynthesis in Plants depicting the two phases – Light reaction and Dark reaction

Light Reaction of Photosynthesis (or) Light-dependent Reaction

- Photosynthesis begins with the light reaction which is carried out only during the day in the presence of sunlight. In plants, the light-dependent reaction takes place in the thylakoid membranes of chloroplasts.
- The Grana, membrane-bound sacs like structures present inside the thylakoid functions by gathering light and is called photosystems.
- These photosystems have large complexes of pigment and proteins molecules present within the plant cells, which play the primary role during the process of light reactions of photosynthesis.
- There are two types of photosystems: photosystem I and photosystem II.
- Under the light-dependent reactions, the light energy is converted to ATP and NADPH, which are used in the second phase of photosynthesis.
- During the light reactions, ATP and NADPH are generated by two electron-transport chains, water is used and oxygen is produced.

The chemical equation in the light reaction of photosynthesis can be reduced to:

$$\mathbf{2H_2O + 2NADP^+ + 3ADP + 3Pi \rightarrow O_2 + 2NADPH + 3ATP}$$

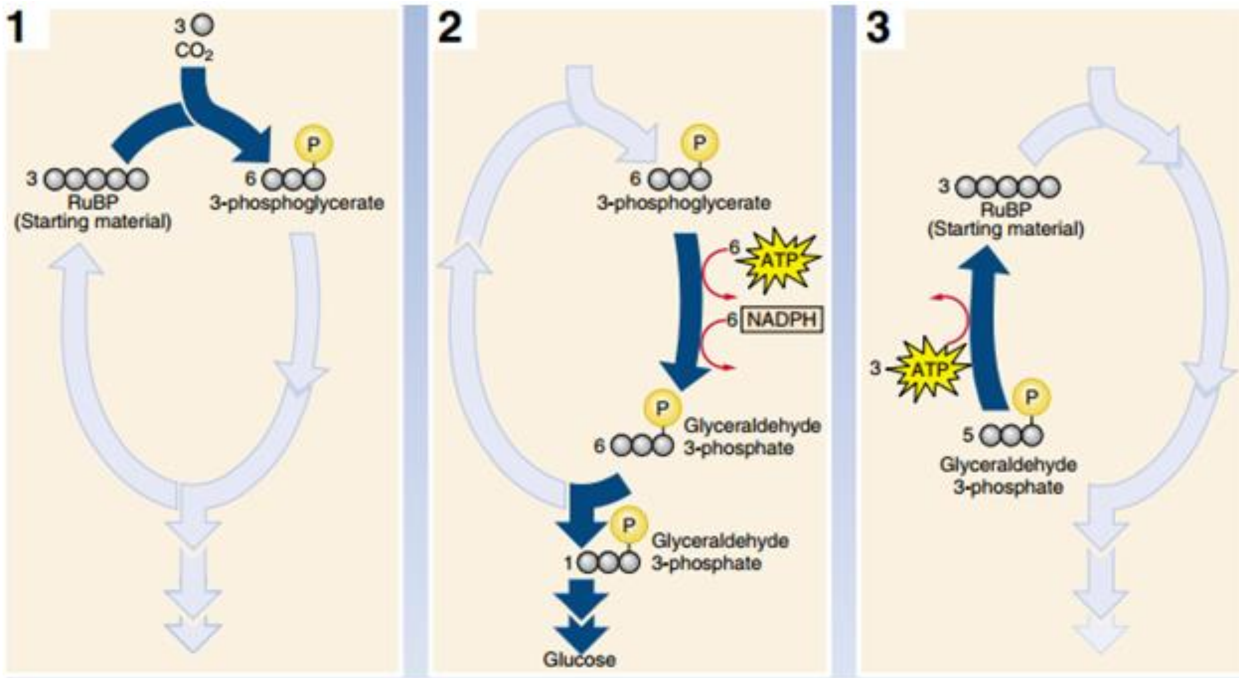
Dark Reaction of Photosynthesis (or) Light-independent Reaction

- Dark reaction is also called carbon-fixing reaction.
- It is a light-independent process in which sugar molecules are formed from the water and carbon dioxide molecules.
- The dark reaction occurs in the stroma of the chloroplast where they utilize the NADPH and ATP products of the light reaction.
- Plants capture the carbon dioxide from the atmosphere through stomata and proceed to the Calvin photosynthesis cycle.
- In the **Calvin cycle**, the ATP and NADPH formed during light reaction drive the reaction and convert 6 molecules of carbon dioxide into one sugar molecule or glucose.

The chemical equation for the dark reaction can be reduced to:

$$3CO_2 + 6\ NADPH + 5H_2O + 9ATP \rightarrow G3P + 2H^+ + 6\ NADP^+ + 9\ ADP + 8\ Pi$$

* G3P – glyceraldehyde-3-phosphate



Calvin photosynthesis Cycle (Dark Reaction)

Importance of Photosynthesis

- Photosynthesis is essential for the existence of all life on earth. It serves a crucial role in the food chain – the plants create their food using this process, thereby, forming the primary producers.
- Photosynthesis is also responsible for the production of oxygen – which is needed by most organisms for their survival.

Cyclic & Non cyclic photophosphorylation

We all are well aware of the complete process of photosynthesis. Yes, it is the biological process of converting light energy into chemical energy. In this process, light energy is captured and used for converting carbon dioxide and water into glucose and oxygen gas. The complete process of photosynthesis is carried out into two processes:

Light reaction

The light reaction takes place in the grana of the chloroplast. Here, light energy gets converted to chemical energy as ATP and NADPH. In this very light reaction, the addition of phosphate in the presence of light or the synthesizing of ATP by cells is known as photophosphorylation.

Dark reaction

While in the dark reaction, the energy produced previously in the light reaction is utilized to fix carbon dioxide into carbohydrates. The location where this happens is the stroma of the chloroplasts.

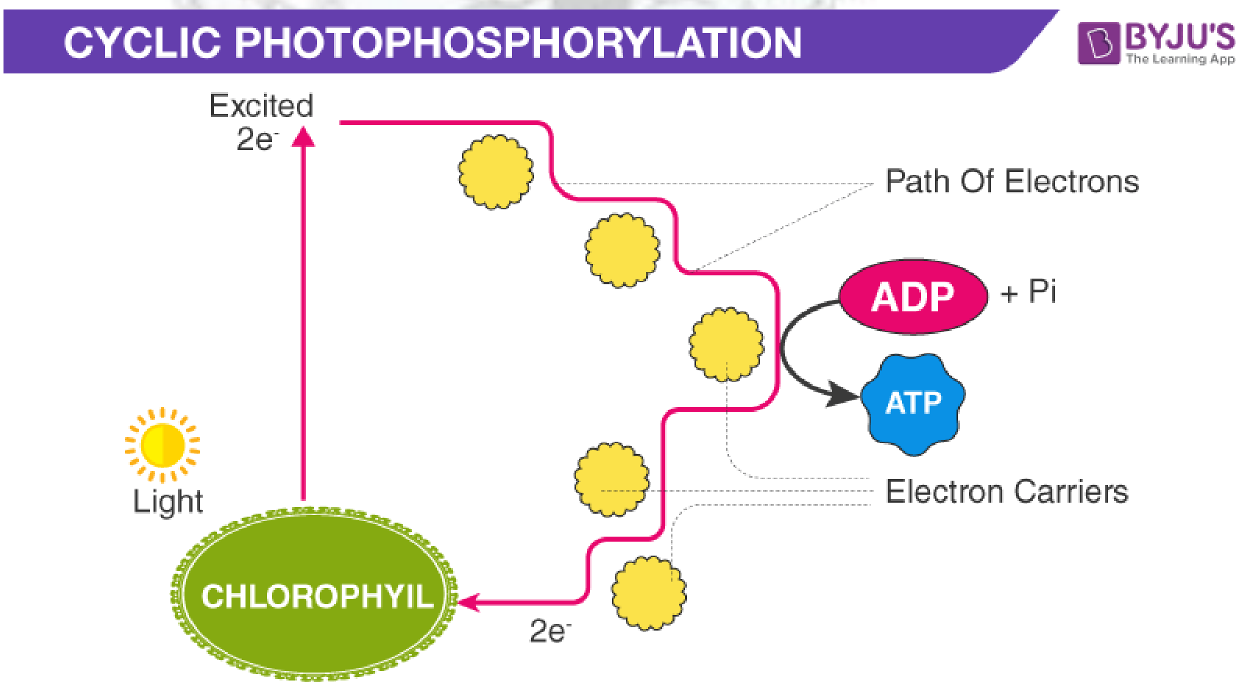
Photophosphorylation

Photophosphorylation is the process of utilizing light energy from photosynthesis to convert ADP to ATP. It is the process of synthesizing energy-rich ATP molecules by transferring the phosphate group into ADP molecule in the presence of light.

Photophosphorylation is of two types:

- Cyclic Photophosphorylation
- Non-cyclic Photophosphorylation

Cyclic Photophosphorylation



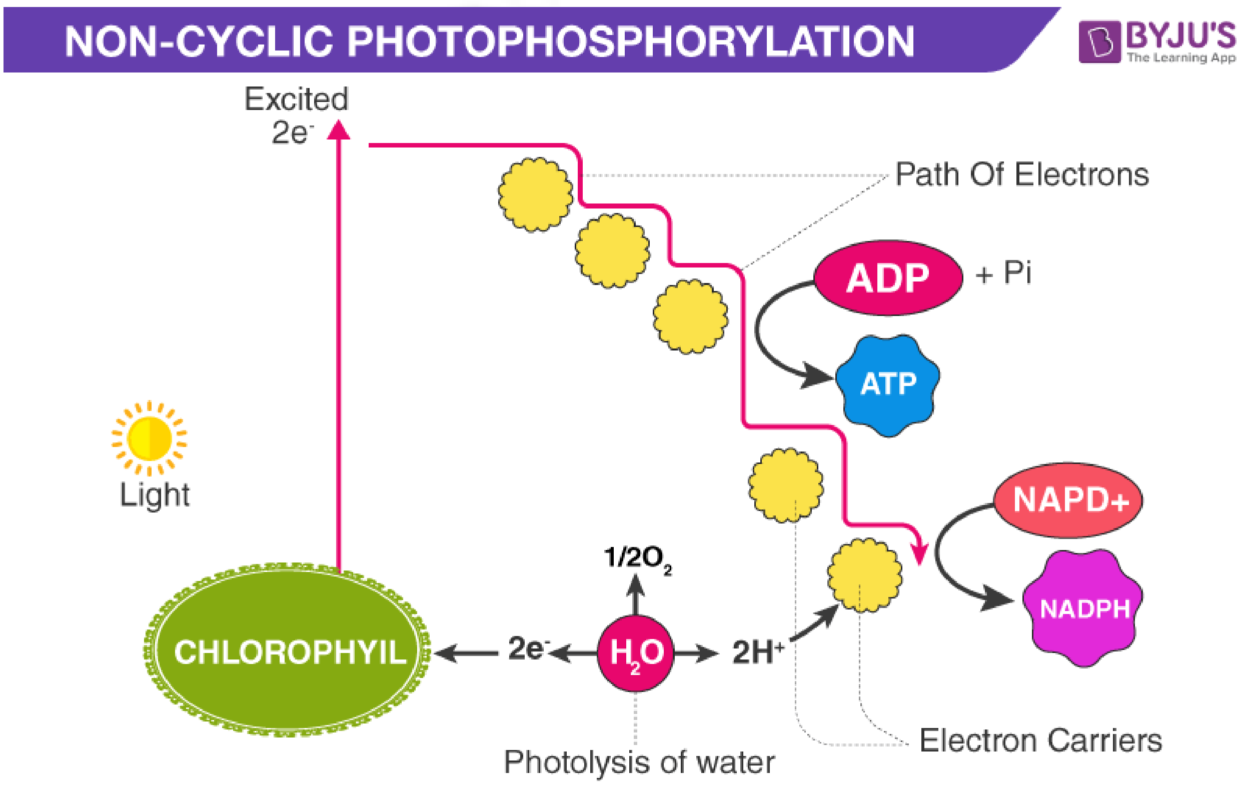
Cyclic Photophosphorylation

The photophosphorylation process which results in the movement of the electrons in a cyclic manner for synthesizing ATP molecules is called cyclic photophosphorylation.

In this process, plant cells just accomplish the ADP to ATP for immediate energy for the cells. This process usually takes place in the thylakoid membrane and uses Photosystem I and the chlorophyll P700.

During cyclic photophosphorylation, the electrons are transferred back to P700 instead of moving into the NADP from the electron acceptor. This downward movement of electrons from an acceptor to P700 results in the formation of ATP molecules.

Non-Cyclic Photophosphorylation



Non-cyclic Photophosphorylation

The photophosphorylation process which results in the movement of the electrons in a non-cyclic manner for synthesizing ATP molecules using the energy from excited electrons provided by photosystem II is called non-cyclic photophosphorylation.

This process is referred to as non- cyclic photophosphorylation because the lost electrons by P680 of Photosystem II are occupied by P700 of Photosystem I and are not reverted to P680. Here the complete movement of the electrons is in a unidirectional or in a non- cyclic manner.

During non-cyclic photophosphorylation, the electrons released by P700 are carried by primary acceptor and are finally passed on to NADP. Here, the electrons combine with the protons – H+ which is produced by splitting up of the water molecule and reduces NADP to NADPH2.

Difference between Cyclic and Non-Cyclic Photophosphorylation

Following are the important difference between cyclic and non-cyclic photophosphorylation:

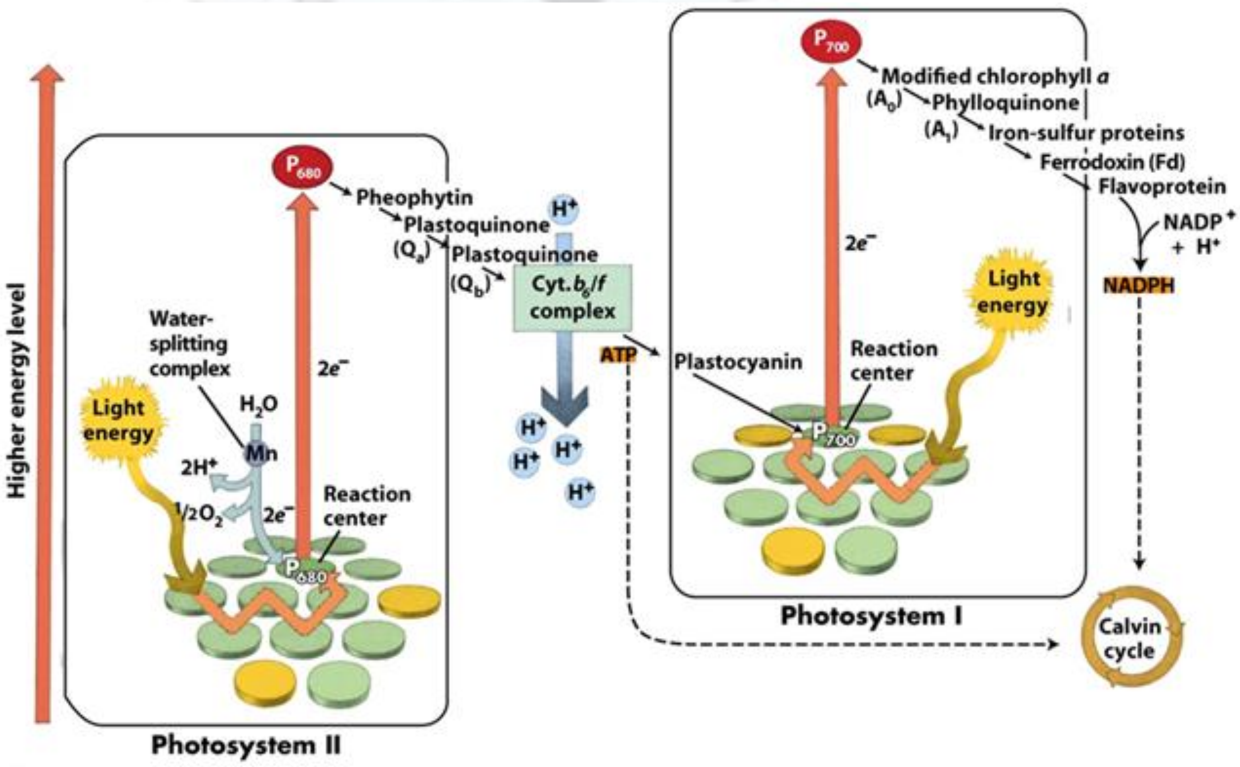
Cyclic Photophosphorylation	**Non-Cyclic Photophosphorylation**
Only Photosystem I is involved.	Both Photosystem I and II are involved.
P700 is the active reaction centre.	P680 is the active reaction centre.
Electrons travel in a cyclic manner.	Electrons travel in a non – cyclic manner.
Electrons revert to Photosystem I	Electrons from Photosystem I are accepted by NADP.
ATP molecules are produced.	Both NADPH and ATP molecules are produced.
Water is not required.	Photolysis of water is present.
NADPH is not synthesized.	NADPH is synthesized.
Oxygen is not evolved as the by-product	Oxygen is evolved as a by-product.
This process is predominant only in bacteria.	This process is predominant in all green plants.

Comparison Chart

BASIS FOR COMPARISON	PHOTOSYSTEM I (PS I)	PHOTOSYSTEM II (PS II)
Meaning	Photosystem I or PS I uses light energy to convert NADP+ to NADPH2. It involves the P700, chlorophyll and other pigments.	Photosystem II or PS II is the protein complex that absorbs light energy, involving P680, chlorophyll and accessory pigments and transfer electrons from water to plastoquinone and thus works in dissociation of water molecules and produces protons (H+) and O2.

BASIS FOR COMPARISON	PHOTOSYSTEM I (PS I)	PHOTOSYSTEM II (PS II)
Location	It is located on the outer surface of the thylakoid membrane.	It is located on the inner surface of the thylakoid membrane.
Photocenter or reaction centre	P700 is the photo center.	P680 is the photo center.
Absorbing wavelength	The pigments in the photosystem 1 absorb longer wavelengths of light which is 700 nm (P700).	The pigments in the photosystem2 absorb shorter wavelengths of light which is 680 nm (P680).
Photophosphorylation	This system is involved in both cyclic as well as non-cyclic photophosphorylation.	This system is involved in both cyclic photophosphorylation.
Photolysis	No photolysis occur.	Photolysis occurs in this system.
Pigments	Photosystem I or PS 1 contains chlorophyll A-670, chlorophyll A-680, chlorophyll A-695, chlorophyll A-700, chlorophyll B, and carotenoids.	Photosystem II or PS 2 contains chlorophyll A-660, chlorophyll A-670, chlorophyll A-680, chlorophyll A-695, chlorophyll A-700, chlorophyll B, xanthophylls and phycobilins.
The ratio of the chlorophyll carotenoid pigments	20-30 :1.	3-7 :1.

BASIS FOR COMPARISON	PHOTOSYSTEM I (PS I)	PHOTOSYSTEM II (PS II)
Function	The primary function of the photosystem I is in NADPH synthesis, where it receives the electrons from PS II.	The primary function of the photosystem II is in the hydrolysis of water and ATP synthesis.
Core Composition	The PSI is made up of two subunits which are psaA and psaB.	The PS II is made up of two subunits made up of D1 and D2.



Red Drop

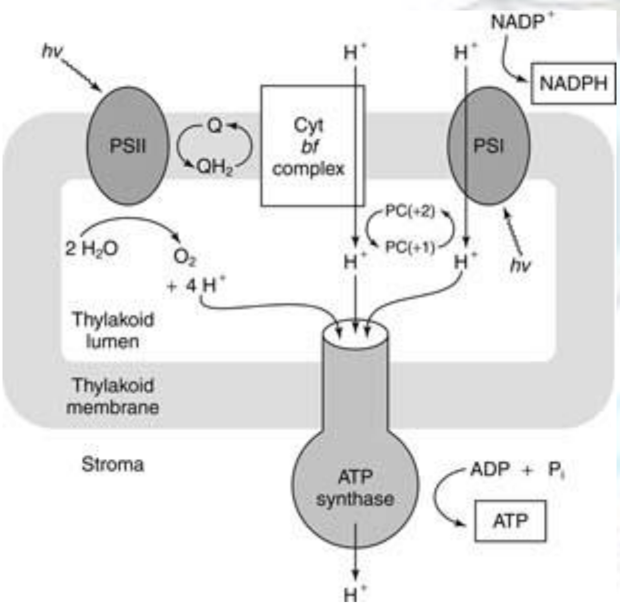
The lowering in the rate of photosynthesis when a plant is illuminated with light of wavelength more than 680nm, then this lowering is called red drop.

Hill Reaction

The **Hill reaction** is the light-driven transfer of electrons from water to Hill reagents (non-physiological oxidants) in a direction against the chemical potential gradient as part of photosynthesis. Robin Hill discovered the reaction in 1937. He demonstrated that the process by which plants produce oxygen is separate from the process that converts carbon dioxide to sugars.

Z-Scheme of Photosynthesis

The "Z-scheme" describes the oxidation/reduction changes during the light reactions of photosynthesis. The vertical axis in the figure represents the reduction potential of a particular species—the higher the position of a molecular species, the more negative its reduction potential, and the *more easily it donates electrons*. See Figure 1 .



In the Z-scheme, electrons are removed from water (to the left) and then donated to the lower (non-excited) oxidized form of P680. Absorption of a photon excites P680 to P680*, which "jumps" to a more actively reducing species. P680* donates its electron to the quinone-cytochrome bf chain, with proton pumping. The electron from cytochrome bf is donated to PSI, converting P700 to P700*. This electron, along with others, is transferred to NADP, forming NADPH. Alternatively, this electron can go back to cytochrome bf in cyclic electron flow.

Calvin Cycle

“Calvin cycle or C3 cycle is defined as a set of chemical reactions performed by the plants to reduce carbon dioxide and other compounds into glucose.”

What is Calvin Cycle?

Calvin cycle is also known as the C3 cycle or light-independent or dark reaction of photosynthesis. However, it is most active during the day when NADPH and ATP are abundant. To build organic molecules, the plant cells use raw materials provided by the light reactions:

1. Energy: ATP provided by cyclic and noncyclic photophosphorylation, which drives the endergonic reactions.

2. Reducing power: NADPH provided by photosystem I is the source of hydrogen and the energetic electrons required to bind them to carbon atoms. Much of the light energy captured during photosynthesis ends up in the energy-rich C—H bonds of sugars.

Plants store light energy in the form of carbohydrates, primarily starch and sucrose. The carbon and oxygen required for this process are obtained from CO2, and the energy for carbon fixation is derived from the ATP and NADPH produced during the photosynthesis process.

The conversion of CO2 to carbohydrate is called Calvin Cycle or C3 cycle and is named after Melvin Calvin who discovered it. The plants that undergo Calvin cycle for carbon fixation are known as C3 plants.

Calvin Cycle requires the enzyme ribulose-1,5-bisphosphate carboxylase/oxygenase commonly called RuBisCO. It generates the triose phosphates, 3-phosphoglycerate (3-PGA), glyceraldehyde-3P (GAP) and dihydroxyacetone phosphate (DHAP), all of which are used to synthesize the hexose phosphates fructose-1,6-bisphosphate and fructose 6-phosphate.

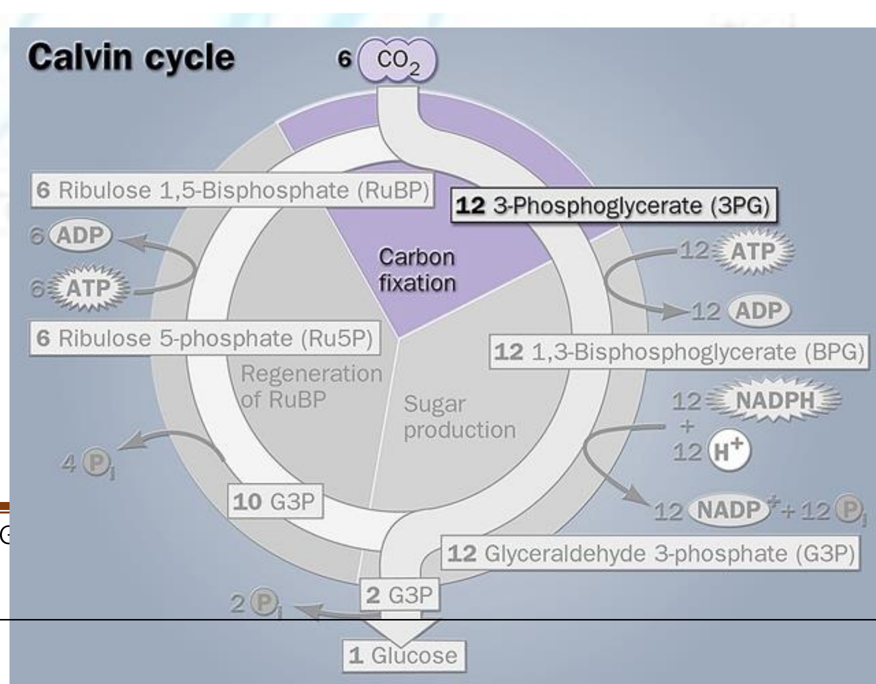
Stages of C3 Cycle

Calvin cycle or C3 cycle can be divided into three main stages:

Carbon fixation

The key step in the Calvin cycle is the event that reduces CO2.

CO2 binds to RuBP in the key process called carbon fixation, forming two-three carbon molecules of phosphoglycerate. The enzyme that carries out this reaction is ribulose bisphosphate carboxylase/oxygenase,



which is very large with a four-subunit and present in the chloroplast stroma. This enzyme works very sluggishly, processing only about three molecules of RuBP per second (a typical enzyme process about 1000 substrate molecules per second). In a typical leaf, over 50% of all the protein is RuBisCO. It is thought to be the most abundant protein on the earth.

Reduction

It is the second stage of Calvin cycle. The 3-PGA molecules created through carbon fixation are converted into molecules of simple sugar – glucose.

This stage obtains energy from ATP and NADPH formed during the light-dependent reactions of photosynthesis. In this way, Calvin cycle becomes a pathway in which plants convert sunlight energy into long-term storage molecules, such as sugars. The energy from the ATP and NADPH is transferred to the sugars.

This step is known as reduction since electrons are transferred to 3-PGA molecules to form glyceraldehyde-3 phosphate.

Regeneration

It is the third stage of the Calvin cycle and is a complex process which requires ATP. In this stage, some of the G3P molecules are used to produce glucose, while others are recycled to regenerate the RuBP acceptor.

Also read: Light reaction And Dark reaction

Products of C3 Cycle

- One molecule of carbon is fixed in each turn of the Calvin cycle.
- One molecule of glyceraldehyde-3 phosphate is created in three turns of the Calvin cycle.
- Two molecules of glyceraldehyde-3 phosphate combine together to form one glucose molecule.
- 3 ATP and 2 NADPH molecules are used during the reduction of 3-phosphoglyceric acid to glyceraldehyde-3 phosphate and in the regeneration of RuBP.
- 18 ATP and 12 NADPH are consumed in the production of 1 glucose molecule.

Key Points on C3 Cycle

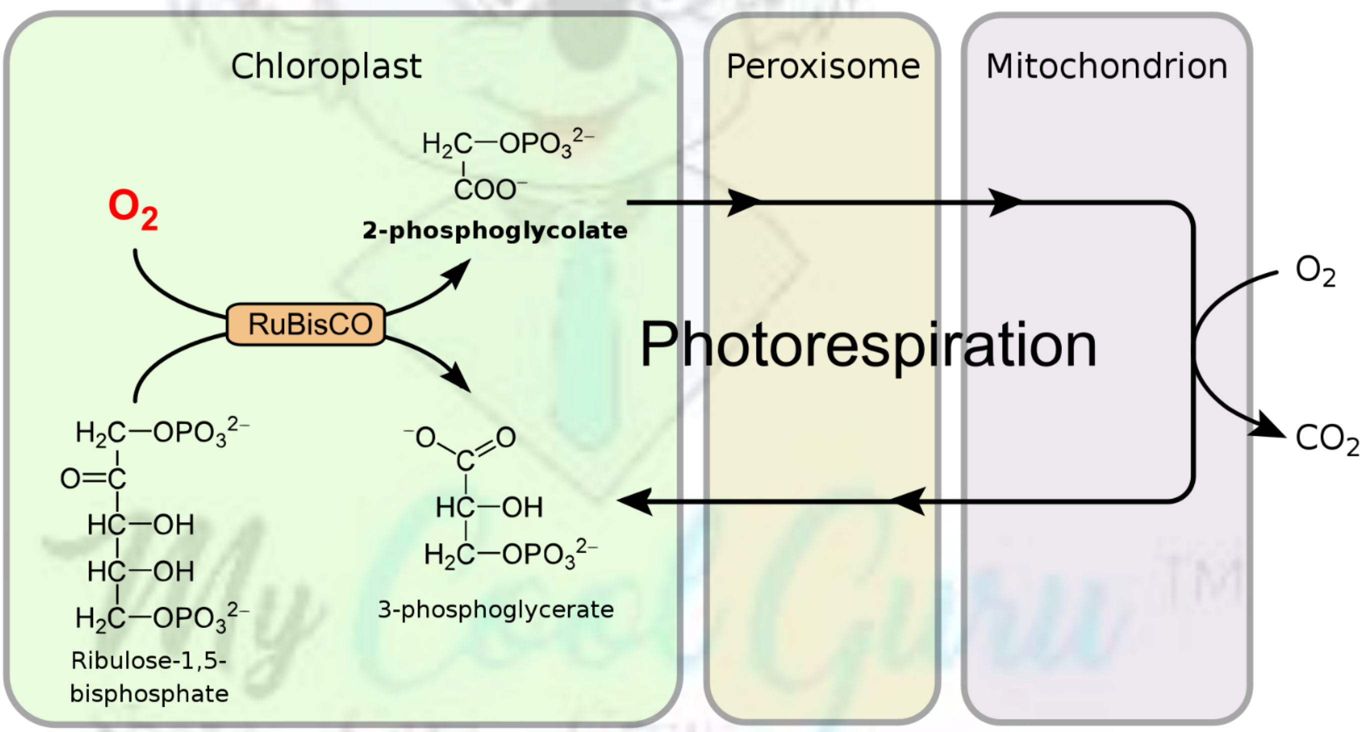
- C3 cycle refers to the dark reaction of photosynthesis.
- It is indirectly dependent on light and the essential energy carriers are products of light-dependent reactions.
- In the first stage of Calvin cycle, the light-independent reactions are initiated and carbon dioxide is fixed.
- In the second stage of C3 cycle, ATP and NADPH reduce 3PGA to G3P. ATP and NADPH are then converted into ATP and NADP+.
- In the last stage, RuBP is regenerated. This helps in more carbon dioxide fixation.

Photorespiration

When the carbon dioxide concentration inside a leaf drops, photorespiration take place. This takes place mostly on warm arid days when plants are compelled to shut their stomata to avert surplus water loss. The oxygen proportions of the leaf will automatically surge if the plants keep trying to fix carbon dioxide when their stomata's are shut, all the carbon dioxide stored will be consumed and the oxygen proportions will surge when compared to carbon dioxide levels.

Explain Photorespiration

Photorespiration is the chemical processes that occur within a living organism of phosphoglycolate that is produced during oxygenation catalyzed by the enzyme RubisCO and inhibits photosynthesis by interfering with CO2 fixation by RubisCO.



Photorespiration is influenced by high temperature as well as light intensity and accelerating the formation of glycolate and the flow through the photorespiratory pathway.

Photorespiration causes a light-reliant acceptance of O2 and discharge of CO2 and is related to the creation and **metabolism** of a minute particle named glycolate.

Photosynthesis and photorespiration are two biological processes (in flourishing plants) that can function simultaneously beside each other as photosynthesis gives off oxygen as its byproduct and photorespiration gives off carbon dioxide as its byproduct, and the said gases are the raw material for the said processes.

When the carbon dioxide levels inside the leaf dip to about 50 ppm, RuBisCO begins combining Oxygen with RuBP as an alternative of Carbon dioxide.

The final result of this is that as an alternative to manufacturing 2 molecules of 3C- PGA units, merely one unit of PGA is fashioned with a noxious 2C molecule termed as phosphoglycolate.

To purge themselves of the phosphoglycolate the plant takes some steps**.** Primarily, it instantly purges itself from the phosphate cluster, transforming those units into glycolic acid. After that, this glycolic acid is transferred to the peroxisome and then transformed into glycine. The conversion of glycine into serine takes place in the mitochondria of the **plant cell**. The serine produced after that is used to create other organic units. This causes loss of carbon dioxide from the flora as these reactions charge plants energy.

C4 Pathway (Hatch and Slack Pathway)

Every photosynthetic plant follows Calvin cycle but in some plants, there is a primary stage to the Calvin Cycle known as C4 pathway. Plants in tropical desert regions commonly follow the C4 pathway. Here, a 4-carbon compound called oxaloacetic acid (OAA) is the first product by carbon fixation. Such plants are special and have certain adaptations as well.

The C4 pathway initiates with a molecule called phosphoenolpyruvate (PEP) which is a 3-carbon molecule. This is the primary CO2 acceptor and the carboxylation takes place with the help of an enzyme called PEP carboxylase. They yield a 4-C molecule called oxaloacetic acid (OAA).

Eventually, it is converted into another 4-carbon compound known as malic acid. Later, they are transferred from mesophyll cells to bundle sheath cells. Here, OAA is broken down to yield carbon dioxide and a 3-C molecule.

The CO2 thus formed is utilized in the Calvin cycle whereas 3-C molecule is transferred back to mesophyll cells for regeneration of PEP.

Corn, sugarcane and some shrubs are examples of plants that follow the C4 pathway. Calvin pathway is a common pathway in both C3 plants and C4 plants but it takes place only in the mesophyll cells of the C3 Plants but not in the C4 Plants.

CAM – Crassulacean Acid Metabolism

CAM plants are the plants, which fix carbon dioxide by CAM pathway or Crassulacean acid metabolism. It was first discovered in the plants of the Crassulaceae family. They are present in dry and arid environments. The CAM pathway is adapted to minimise water loss and photorespiration. Examples of CAM plants include cactus, pineapple, etc.

CAM Photosynthesis

CAM pathway is adapted in plants to perform photosynthesis under stress. The CAM pathway reduces photorespiration.

In CAM plants stomata are open at night and they absorb carbon dioxide at night to reduce water loss during the daytime. The process has the following steps:

1. The first step in carbon dioxide fixation is the combination of CO_2 with PEP (phosphoenolpyruvate) to form 4 carbon oxaloacetate (same as C_4 plants) in the chloroplast of mesophyll cells. The reaction is catalysed by PEPcarboxylase. This occurs at night.
2. Oxaloacetate is converted to malate and other C_4 acids. Malate is stored in vacuoles at night.
3. During the daytime, stomata remain closed, so there is no gas exchange. Malate is transported out of the vacuole and CO_2 is released by the process of decarboxylation.
4. This CO_2 finally enters the Calvin cycle and carbon dioxide fixation completes. The CO_2 which gets accumulated around RuBisCO increases the efficiency of the photosynthesis process and minimizes photorespiration.

CAM Plants Examples

CAM plants are mostly xerophytic. CAM pathway is also present in some aquatic plants such as *Hydrilla*, *Vallisneria*, etc. In aquatic plants, the CAM pathway occurs due to scarcity of CO_2. Carbon dioxide supply is limited due to slower diffusion in water. Aquatic CAM plants absorb CO_2 at night when there is less competition from other photosynthetic plants.

Some of the common examples of CAM plants

Orchids, *Cacti, Aloe,* Pineapple, *Agave*, *Moringa*, Some species of *Euphorbia* and Bromelioideae, etc.

WHAT IS ANOXYGENIC PHOTOSYNTHESIS?

It is called photosynthesis to the process by which some organisms use the energy of solar radiation to synthesize organic molecules that can later be used as fuel for their cellular metabolism.

In this way, thanks to photosynthesis, these organisms are able to manufacture their own food with the help of light, so they are classified as photoautotrophic organisms .

There are two main types of photosynthesis: oxygenic photosynthesis and anoxygenic photosynthesis.

All plants , together with most algae and cyanobacteria , perform oxygenic photosynthesis . This type of photosynthesis uses light energy to combine water (H 2 O) and carbon dioxide (CO 2) and form glucose.

In this reaction , water acts as an electron donor (reducing agent) and molecular oxygen (O 2) is produced as a waste product , which is why it is called oxygenic photosynthesis.

The global reaction of oxygenic photosynthesis responds to the following equation:

6CO 2 + 12H 2 O + Light ? C 6 H 12 O 6 + 6O 2+ 6H 2 O

The anoxygenic photosynthesis is another type of photosynthesis in which oxygen is not clear and that perform only certain groups of bacteria . Instead of water, another inorganic molecule acts as an electron donor , for example hydrogen sulfide (H_2S):

$CO_2 + 2H_2S$ + Light ? $[CH_2O] + 2S + H_2O$

Anoxygenic photosynthetic bacteria

Among eukaryotic organisms, only plants and algae are capable of photosynthesis, and in both cases they perform oxygenic photosynthesis.

In the case of prokaryotic organisms, we find bacteria that perform oxygenic photosynthesis (the cyanobacteria) and bacteria that produce anoxygenic photosynthesis.

Among the photosynthetic anoxygenic bacteria there is a great variety, both in their phylogenetic and in the composition of the photosynthetic apparatus, while the organisms that carry out oxygenic photosynthesis (plants, algae and cyanobacteria) share a common mechanism

In fact, the chloroplasts of plants and algaeare believed to come from ancient cyanobacteria that entered into symbiosis with primitive plants and algae, which is why they would share the same common mechanism of photosynthesis.

None of the photosynthetic anoxygenic bacteria is capable of using water as an electron donor, in other words, they are not capable of oxidizing water . Instead they use sulfur compounds, hydrogen or organic substrates that donate electrons to reduce CO_2 molecules and transform it into organic carbon.

The most studied anoxigenic photosynthetic bacteria are the purple sulfur bacteria , which could be related to our mitochondria, but there are other groups:

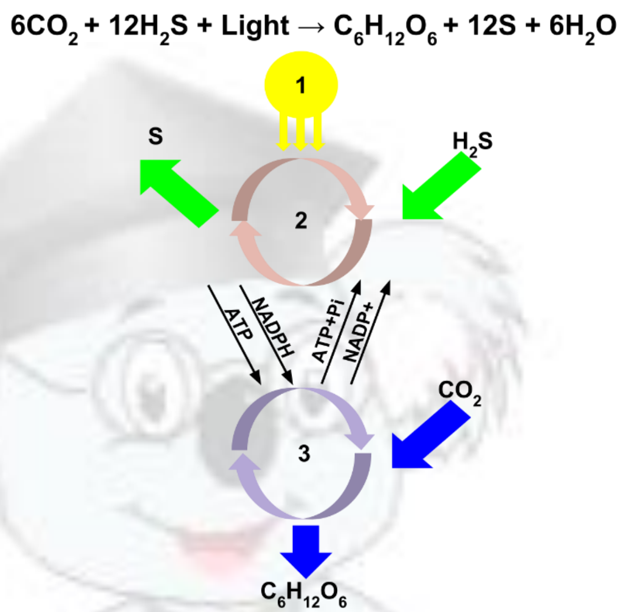
Purple sulfur bacteria : family Chromatiaceae , family Ectothiorhodospiraceae . They are anaerobic or microaerophilic. They use hydrogen sulfide (H_2S, in solution called hydrogen sulfide) and produce sulfur gas (S_2). They do not tolerate the presence of oxygen, which is why they usually live in stagnant waters or sulphurous hydrothermal vents.

Green sulfur bacteria : family Chlorobiaceae . They use hydrogen sulfide (H_2S) or sulfur (S) as an electron donor.

Acidobacteria : as an electron donor can use various compounds. For example, iron bacteria use ferrous oxide, which when oxidized electrons oxidizes and forms insoluble ferric oxide that gives the brown color typical of the waters where these bacteria live.

Heliobacteria : the photosynthetic pigment bacteriochlorophyll g is unique to this type of bacteria. Exclusively anaerobic They are considered photoheterotrophs, since they obtain the energy of light or chemical products, but do not use CO2 as a carbon source (their carbon source are exclusively organic compounds).

Anoxygenic filamentous bacteria : formerly known as green and purple bacteria, not sulfur, but later it was discovered that some use sulfur compounds. They can be photoautotrophs, chemoorganotrophs or photoheterotrophs.



Difference Between C3, C4 and CAM pathway

BASIS FOR COMPARISON	C3 PATHWAY	C4 PATHWAY	CAM
Definition	Such plants whose first product after the carbon assimilation from sunlight is 3-carbon molecule or 3-phosphoglyceric acid for the production of energy is called C3 plants, and the pathway is called as the C3 pathway. It is most commonly used by plants.	Plants in the tropical area, convert the sunlight energy into C4 carbon molecule or oxaloacetice acid, which takes place before the C3 cycle and then it further convert into the energy, is called C4 plants and pathway is called as the C4 pathway. This is more efficient than the C3 pathway.	The plants which store the energy from the sun and then convert it into energy during night follows the CAM or crassulacean acid metabolism.

BASIS FOR COMPARISON	C3 PATHWAY	C4 PATHWAY	CAM
Cells involved	Mesophyll cells.	Mesophyll cell, bundle sheath cells.	Both C3 and C4 in same mesophyll cells.
Example	Sunflower, Spinach, Beans, Rice, Cotton.	Sugarcane, Sorghum and Maize.	Cacti, orchids.
Can be seen in	All photosynthetic plants.	In tropical plants	Semi-arid condition.
Types of plants using this cycle	Mesophytic, hydrophytic, xerophytic.	Mesophytic.	Xerophytic.
Photorespiration	Present in high rate.	Not easily detectable.	Detectable in the afternoon.
For the production of glucose	12 NADPH and 18 ATPs are required.	12 NADPH and 30 ATPs are required.	12 NADPH and 39 ATPs are required.
First stable product	3-phosphoglycerate (3-PGA).	Oxaloacetate (OAA).	Oxaloacetate (OAA) at night, 3 PGA at daytime.
Calvin cycle operative	Alone.	Along with the Hatch and Slack cycle.	C3 and Hatch and Slack cycle.
Optimum temperature for photosynthesis	15-25 °C	30-40 °C	> 40 degrees °C
Carboxylating Enzyme	RuBP carboxylase.	In mesophyll: PEP carboxylase. In bundle sheath: RuBP	In the dark: PEP carboxylase. In light: RUBP

BASIS FOR COMPARISON	C3 PATHWAY	C4 PATHWAY	CAM
		carboxylase.	carboxylase.
CO_2: ATP: $NADPH_2$ ratio	1:3:2	1:5:2	1:6.5:2
Initial CO_2 acceptor	Ribulose-1,5-biphophate(RuBP).	Phosphoenolpyruvate (PEP).	Phosphoenolpyruvate (PEP).
Kranz Anatomy	Absent.	Present.	Absent.
CO_2 compensation point (ppm)	30-70.	6-10.	0-5 in dark.