PHOTOSYNTHESIS

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CLASS: XI **BIOLOGY**

1. **What is photosynthesis?**

   The process by which carbohydrates are produced from CO_2 and water by chlorophyll in the presence of sunlight, releasing oxygen as a by-product is called photosynthesis.

2. **Write the equation of photosynthesis given by Van Niel.**

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

3. **Name the reaction centres in PS I and PS II.**

   In PS I the reaction centre is chlorophyll-a, has an absorption peak at 700 nm, hence is called **P700,** while in PS II it has absorption maxima at 680 nm, and is called **P680.**

4. **What is light reaction of photosynthesis?**

   The set of reactions of photosynthesis which are directly dependent on light and occur in the thylakoidal membrane is known as light reaction.

5. **What is dark reaction of photosynthesis?**

   The set of reactions of photosynthesis which are independent of light and occur in the stroma is known as dark reaction.

6. **What is photorespiration?**

   The process by which carbon dioxide is liberated from the photosynthetic tissues of C_3 plants under high temperature and high oxygen concentration (low levels of CO_2) is known as photorespiration.

7. **What is C_3 pathway of photosynthesis?**

   The photosynthetic pathway where the first product of carbon fixation is a three carbon compound - 3 Phosphoglyceric acid (3 PGA) is called C_3 pathway.

8. **What is C_4 pathway of photosynthesis?**

   The photosynthetic pathway where the first product of carbon fixation is a four carbon compound - Oxaloacetic acid (OAA) is called C_4 pathway.

9. **What is a pigment?**
   A pigment is a substance that absorbs light of different wavelengths.

10. **Where does the chlorophyll absorb light in the visible spectrum for photosynthesis?**
    Chlorophyll absorbs light in the violet, blue and red regions of the visible spectrum.

11. **What is meant by photosynthetically active radiation (PAR)?**
    The portion of the visible spectrum of light between 400 nm and 700 nm is referred to as photosynthetically active radiation

12. **Why do leaves appear green in colour?**
    As chlorophyll absorbs all other colours and reflect green light, the leaves appear green in colour.

13. **Name the two kinds of chlorophyll present in higher plants.**
    Chlorophyll *a* and chlorophyll *b*.

14. **Mention the main difference between chlorophyll a and Chlorophyll b.**
Chlorophyll a has a methyl group (a blue green pigment) and chlorophyll *b* has an aldehyde group (yellow green pigment) in one of the side chains of porphyrin ring.

15. **Name the accessory pigments of photosynthesis and mention their functions.**
Carotenoids (orange pigment) and Xanthophylls (yellow pigment). They absorb the sunlight at different wavelengths and pass it on to the reaction centre.(Chl-a)

16. **State the law of limiting factors.**

When a physiological pathway is controlled by a number of factors, the rate of the reaction depends on the least factor.

17. **Write the full form of NADP.**
Nicotinamide Adenine dinucleotide phosphate.

18. **Name the metal element present in a chlorophyll molecule.**
Magnesium.

19. **How is the biosynthetic phase of photosynthesis dependent on the photochemical phase?**
Biosynthetic phase of photosynthesis depends on the ATP and $NADPH_2$ produced during the photochemical phase.

20. **What are the end products of photochemical phase (or light reaction) of photosynthesis?**
ATP, $NADPH_2$ and OXYGEN are the end products of light reaction of photosynthesis.

21. **What is photolysis?**
The light-dependent splitting of water into H^+ ions and OH^- ions by chlorophyll is called photolysis.

22. **What is meant by a photosystem?**
The reaction centre and the accessory pigments together form a photosystem.

Short Answer Questions (2 marks)

1. **Why is photosynthesis considered as the most important biological process in the biosphere?**

It is the only process by which oxygen that is necessary for respiration of all living organisms, is liberated.

This process makes the bulk of dry matter of any organism.

The food produced during photosynthesis is used directly or indirectly as food by all living organisms.

2. **Mention the two ways in which oxygen liberated during photosynthesis is useful to living organisms.**

Oxygen is used for oxidation of food materials during respiration to produce energy.

Oxygen forms ozone in the outer layer of atmosphere, which helps in preventing the entry of harmful ultraviolet rays to the earth.

3. **What are light harvesting complexes? How do they help in photosynthesis?**

The light harvesting complexes (LHC) are made up of hundreds of pigment molecules bound to proteins. Each photosystem has all the pigments (except chlorophyll-a, the reaction centre) forming a light harvesting system also called antennae.

These pigments help to make photosynthesis more efficient by absorbing different wavelengths of light. The carotenoids protect the chlorophyll from photo oxidative damage.

4. **'If all green plants are removed from the earth, life cannot be sustained.' Justify the statement.**

If all green plants are removed, there will be no photosynthesis.

In the absence of photosynthesis, there will be,

No oxygen available for the living organisms to respire.

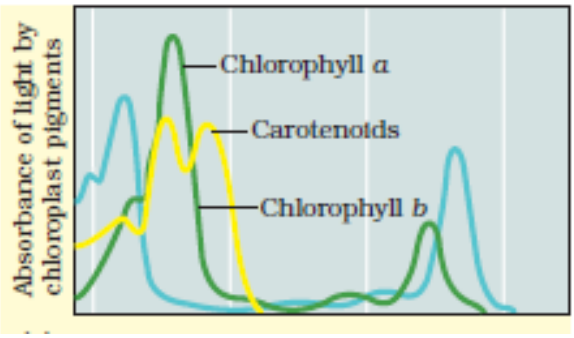
No food produced to sustain life.

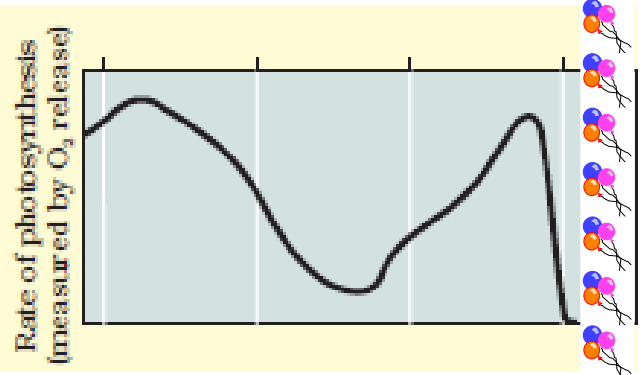
5. **How is photosystem I (PS I) different from photosystem II (PS II)**

PS-I	PS-II
It consists of the reaction centre P_{700} (Chl-a), chlorophyll-b and accessory molecules.	It consists of the reaction centre P_{680} (Chl-a), chlorophyll-b and accessory molecules.
It is involved in both cyclic and non-cyclic photophosphrylation.	It is involved only in non-cyclic Photophosphorylation.
The electrons are not passed on to NADP.	The electrons are passed on to NADP
The electrons emitted from this photosystem come back to PS I	The electrons emitted from this photosystem do not come back to PS II. Electrons from water replace the electrons emitted by PS II.

6. **Differentiate between absorption spectrum and action spectrum.**

Absorption Spectrum	Action spectrum
It is a graph plotted with the amount of light absorbed as a function of wavelength of light.	It is a graph plotted with the rate of photosynthesis in terms of CO_2 fixed or O_2 liberated as a function of wavelength of light.





7. **Bring out the differences between cyclic and non-cyclic Photophosphorylation.**

Cyclic Photophosphorylation	Non-Cyclic Photophosphorylation
It occurs only in photosystem I.	It occurs in photosystems I and II.
It involves only the synthesis of ATP.	It involves the synthesis of ATP and $NADPH_2$.
The electrons emitted by PS I (P_{700}), come back to the same chlorophyll P_{700}	The electrons emitted by PS II (P_{680}) do not come back to the same chlorophyll.
Two molecules of ATP are formed.	Only one molecule of ATP is formed.
Photolysis, oxygen liberation and NADPH formation do not occur during this process.	Photolysis, oxygen liberation and NADPH formation occur during this process.

8. How does temperature influence the biosynthetic phase of photosynthesis?

The optimum temperature for biosynthetic phase is about 25^0 C in C_3 plants and 35^0 - 45^0 C in C_4 plants.

At higher temperatures, the enzymes become denatured and are inactive. Affinity of the enzyme Rubisco decreases at higher temperature.

Low temperature sensitivity in C_4 plants is due to the enzyme phosphopyruvate dikinase.

9. Why do scientists expect a faster growth and more yield by C_3 plants, if atmospheric carbon dioxide increases?

In C_3 plants, the rate of photosynthesis increases with increase in carbon dioxide concentration for two reasons:

a. High availability of substrate for the carboxylation reaction.

b. Reduced rate of photorespiration as more carbon dioxide is available. The higher rate of photosynthesis is expected to result in higher yield and faster growth.

10. Why does the rate of photosynthesis decrease at higher light intensities? Give two reasons.

The other factors necessary for photosynthesis may become limiting.

At high light intensities, in the presence of oxygen, the chlorophyll becomes photooxidatively damaged; hence the rate of photosynthesis decreases.

11. How does the age of leaf influence the rate of photosynthesis?

With increase in leaf age, the following units occur in a leaf that influences the rate of photosynthesis.

With advancing age, the leaf undergoes senescence, i.e., yellowing of leaf due to loss of chlorophyll.

The photosynthetic enzymes get deactivated, resulting in reduced rate of photosynthesis.

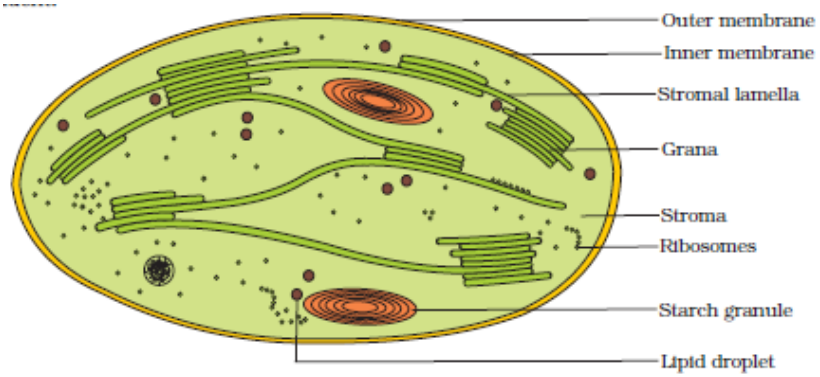
12. Give two reasons as to why the rate of photosynthesis declines under conditions of water stress.

When guard cells lose water and become flaccid under water stress, the stomata remain closed and there is reduced or no entry of carbon dioxide into the plant.

Water stress reduces the leaf expansion by reducing water potential; since there is reduction in the photosynthetic area, the rate of photosynthesis decreases.

Short Answer Questions (3 marks)

1. Draw a neat and well labelled diagram of chloroplast.



2. Answer the following questions.

(a) Where does Calvin cycle occur?

(b) Name the three major steps involved in the cycle.

(c) How many turns of this cycle yield one molecule of glucose?

(a) Calvin cycle occurs in the stroma of chloroplasts in the mesophyll cells in C_3 plants and in the chloroplasts of bundle sheath cells in C_4 plants.

(b) The major steps in the cycle are:

a. Carboxylation b. Reduction and c. Regeneration

(c) Six turns of this cycle yield one molecule of glucose.

3. Differentiate between C_3 plants and C_4 plants

C_3 plants	**C_4 plants**
The plants which employ C_3 pathway of photosynthesis.	The plants which employ C_4-pathway of photosynthesis.
They do not show Kranz anatomy.	They show Kranz anatomy.
They have only one type of chloroplasts, which are found only in the mesophyll.	They have two types of chloroplasts one in the bundle sheath cells and the other in the mesophyll cells.
RuBisCo is present in the mesophyll cells.	RuBisCo is present in the bundle-sheath cells.
Photorespiration occurs.	Photorespiration does not occur.
Eg, Rice, wheat, bean, potato.	Eg, Maize, sugarcane, amaranth.

4. Write any four differences between C_3 photosynthesis and C_4 photosynthesis

C_3 Pathway	**C_4 Pathway**
Ribulose 1,5 bisphosphate is the primary acceptor of CO_2.	Phosphoenol pyruvate is the primary acceptor of CO_2.
The first stable product is 3-phosphoglycerate.	The first stable product is oxaloacetic acid.
It occurs only in the mesophyll cells of leaves.	It occurs in the mesophyll and bundle sheath cells.
18 molecules of ATPs are spent for the synthesis of one molecule of glucose.	30 molecules of ATPs are spent for the synthesis of one molecules of glucose.
The optimum temperature for photosynthesis is about 25^0 C.	The optimum temperature is about 35^0- 45^O C.
It is a slower process of carbon fixation and photo-respiratory losses are high.	It is a faster process of carbon fixation and photo-respiratory losses are low.

5. **Where does cyclic Photophosphorylation occur in leaves? Explain the events in sequence. Why this process is called cyclic Photophosphorylation?**

Cyclic Photophosphorylation occurs in the thylakoids and stroma lamella. It involves PS-I.

When PS-I gets exited, it emits a pair of electrons which are accepted by the primary acceptor and transferred through various electron carriers such as Fd, PQ, Cytochrome, PC and come back to the same molecule.

During the travel of electron, a little amount of energy is released which is used for the formation of ATP.

The electrons released from PS-I come back to the same molecule and ATPs are produced using light. So, this process is known as cyclic Photophosphorylation.

6. **Why does the rate of photosynthesis decrease at higher intensities of light? What plays a protective role in such situations?**

Rate of photosynthesis decreases for two reasons:

Other factors required for photosynthesis become limiting.

Destruction of chlorophyll by photo oxidation.

Carotenoids play a protective role by:

Absorbing the excess light and

Acting as an antioxidant to detoxify the effect of activated oxygen species.

7. **What is the significance of photolysis of water in photosynthesis? What happens to each of the product of this process?**

Photolysis is significant because water is the source of hydrogen for the reduction of carbon dioxide.

During photolysis, water is spilt into $2H^+$, $2e^-$ and oxygen.

Oxygen is liberated as a by-product of photosynthesis comes from water.

The protons (H^+) accumulate inside the thylakoids membranes resulting in a proton gradient.

The protons diffuse across the thylakoids membranes into the stroma following concentration gradient; the energy released by them is used for the formation of ATP.

The protons replace the electrons emitted by P_{680} (PS- II) to bring PS- II to ground level.

8. **Describe the two photosystems involved in photosynthesis.**

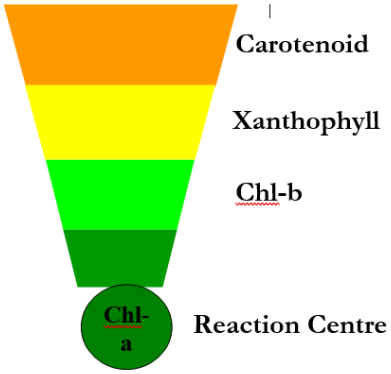
About 250 to 400 pigment molecules constitute a single photosystem.

In photosystem I (PS I), chlorophyll-a, with maximum absorption at 700nm (P_{700}) forms the reaction centre.

In photosystem-II (PS II), chlorophyll-a, with maximum absorption, at 680nm (P_{680}), forms the reaction centre.

PS-II is located in the appressed regions of grana thylakoids, while PS-I is located in the non-appressed regions of grana and the stroma thylakoids.

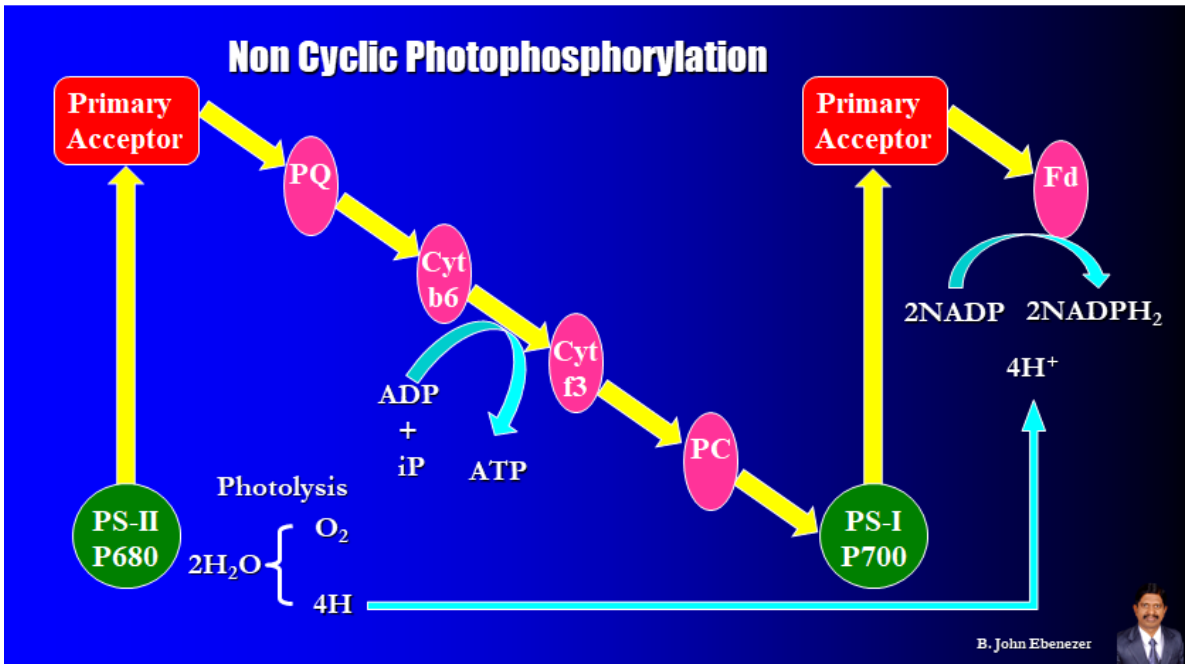
The primary function of the two photosystems, is to trap light energy and convert it into chemical energy.



9. Where does non-cyclic photophosphorylation take place in leaves? Explain the events in sequence. Why this process is called cyclic?

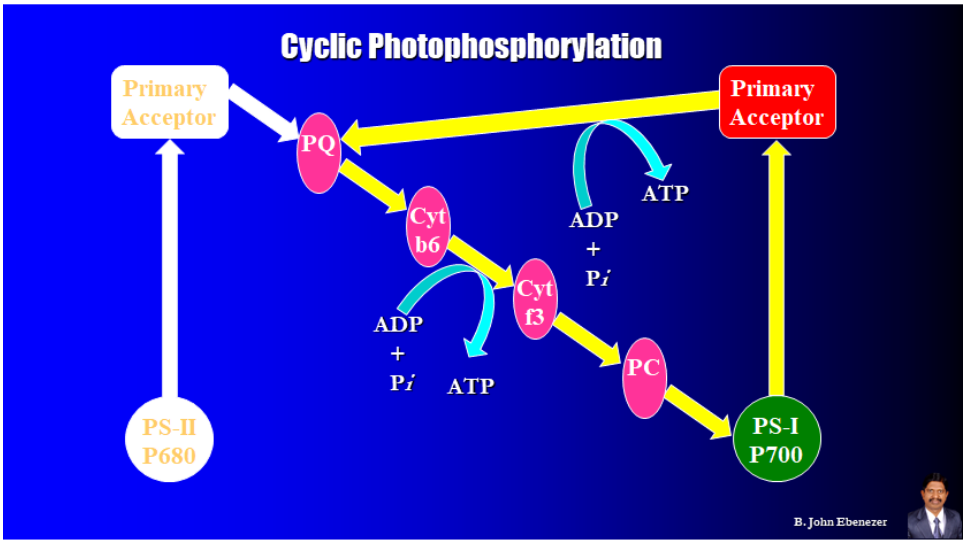
(Non-cyclic Photophosphorylation)

- It occurs in the thylakoidal membranes of chloroplast.
- When P_{680} (PS II) acquires sufficient amount of light energy, it becomes excited and emits electrons.
- These electrons (with high energy) run down an electron transport chain, consisting of a primary acceptor, plastoquinone, Cytochrome complex and plastocyanin to P_{700}, which transfers them to ferredoxin.
- Ferredoxin in turn transfers the electrons to NADP, which is reduced to NADPH with the help of hydrogen ions obtained from PS-II.
- The electrons lost by PS II are replaced by the electrons generated by splitting of water.
- Since the electrons lost by PS II do not come back to it, this process of ATP formation is called non-cyclic Photophosphorylation.
- Thus **ATP, NADPH and O_2** are produced during Non-cyclic Photophosphorylation.



10. Describe the cyclic pathway of photosynthesis. (Cyclic Photophosphorylation)

- When PS I (P_{700}) is activated by light, it is raised to high energy level and emits a pair of electrons.
- These electrons are captured by the primary acceptor, which passes them on to ferredoxin, plastoquinone, cytochrome complex and plastocyanin.
- Finally the de-energized electrons come back to P_{700}.
- Since the electrons come back to P_{700}, this process of ATP formation is known as cyclic photophosphorylation



Long Answer Questions (5 marks)

1. Tabulate the work of various scientists who contributed towards better understanding of the process of photosynthesis.

Scientist	Period	Contribution
Joseph Priestley	1733-1804	Showed that plants have the ability to take up CO_2 from the atmosphere and release O_2
Jan Ingenhousz	1730-1799	Release of O_2 by plants was possible only in sunlight and only by the green parts of the plants.
T.W Engelmann	1843-1909	Discovered the effect of different wave-lengths of light on photosynthesis and plotted the action spectrum.
Blackmann	1905	Proposed the Law of Limiting Factors. He also proposed the occurrence of a dark phase in photosynthesis.
Melvin Calvin	1954	Traced the path of carbon fixation and gave the complete C_3 cycle. He was awarded the Nobel Prize in 1961 for his work.
M.D. Hatch and C. R. Slack	1965	Reported C_4 pathway for carbon dioxide fixation in certain tropical grasses.
Cornelius Van Niel	1897-1985	Proposed that the oxygen evolved during photosynthesis is derived from water.
Julius von Sachs	1854	Provided evidence for production of glucose when plants grow.

2. Describe the events which occur in Calvin cycle or C_3 pathway. (Biosynthetic phase or Dark Reaction of photosynthesis)

The path of carbon in the dark reaction was traced by Melvin Calvin through a technique called autoradiography, using ^{14}C; hence this pathway is termed as Calvin cycle.

Calvin cycle consists of three phase namely:

a. Carboxylation

b. Reduction

c. Regeneration of RuBP.

Carboxylation:

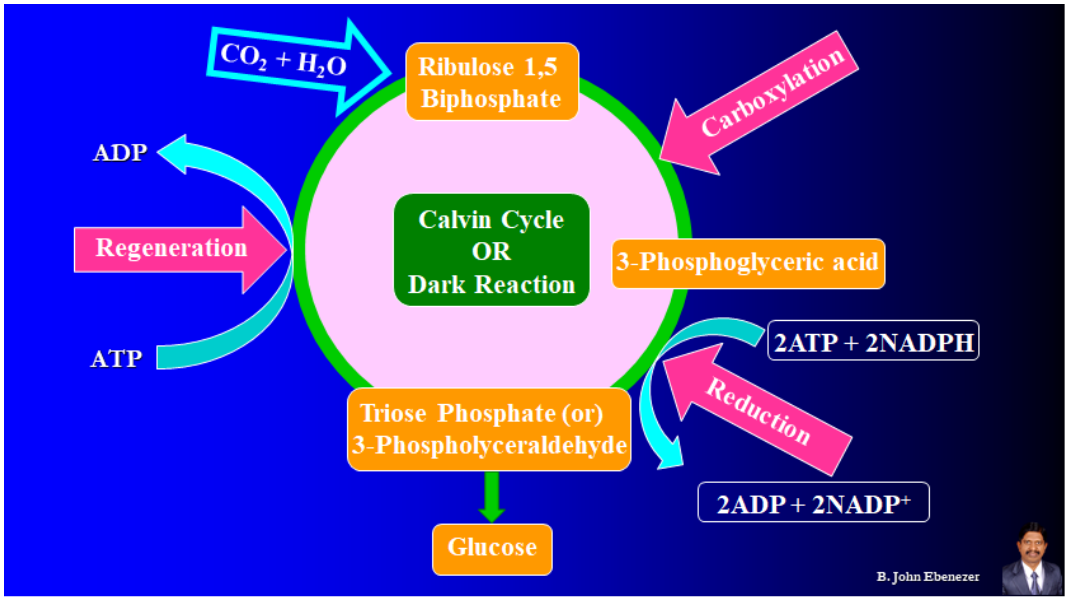
- Six molecules of Ribulose 1, 5 bisphosphate reacts with six molecules of carbon dioxide to form 12 molecules of 3-phosphoglyceric acid (PGA), a 3C-compound.
- This reaction is catalysed by the enzyme RuBP-carboxylase (Rubisco)
- Phosphoglyceric acid (PGA), a 3C-compound is the first stable compound in this pathway. So this pathway is known as C_3 Cycle.

Reduction

- 12 molecules of phosphoglyceric acid are converted into 12 molecules of 1, 3-diphosphoglycerate and then reduced to phosphoglyceraldehyde (PGAL) using ATP and NADPH molecules respectively.
- Two molecules of phosphoglyceraldehyde (PGAL) are diverted for the synthesis of one molecule of glucose.

Regeneration of RuBP

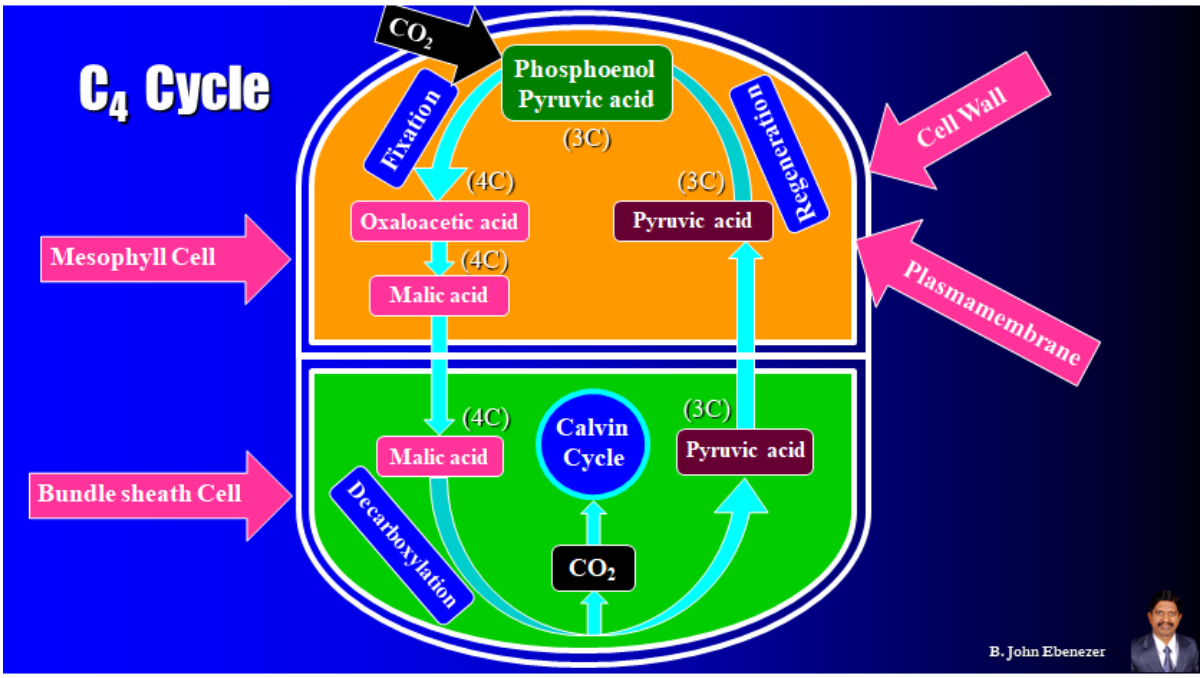
- For the cycle to continue, the primary acceptor of carbon dioxide, i.e., RuBP has to be regenerated.
- 10 molecules of phosphoglyceraldehyde (PGAL), by a series of complex reactions are converted into 6 molecules of 5C- compound, RuBP.
- The formation of 6 molecules of RuBP requires six ATP molecules.



3. Describe with schematic representation the biosynthetic pathway of C_4 plants.

Carboxylation of **Phosphoenol Pyruvate** (PEP) occurs in the stroma of mesophyll chloroplasts, in the presence of enzyme PEP- Carboxylase.

- The first stable product is a 4C-Compound, **Oxaloacetic Acid.** Hence this pathway is called **C_4** pathway
- It is converted into **Malic acid** and then transported to bundle sheath cell.
- In the bundle sheath cells, malic acid is split into **pyruvic acid** and **carbon dioxide.**
- Carbon dioxide is used for carboxylation of RuBP and Calvin cycle continues to form sugars.
- Pyruvic acid is transported back to mesophyll cells, where it is converted into Phosphoenol Pyruvate, each molecule utilising two molecules of ATP.



4. (i) Explain the mechanism of photorespiration.

(ii) Name the organelles involved in the process.

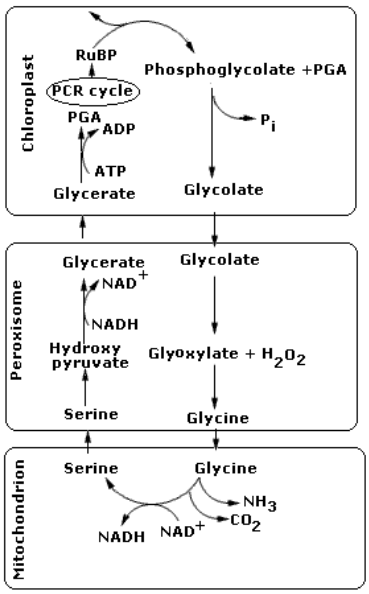
(iii) Why do plants need to overcome photorespiration?

- Photorespiration occurs when the CO_2 levels inside a leaf become low. This happens on hot dry days when a plant is forced to close its stomata to prevent excess water loss.
- If the plant continues to fix CO_2 when its stomata are closed, the CO_2 will get used up and the O_2 ratio in the leaf will increase relative to CO_2 concentrations.
- When the CO_2 levels inside the leaf drop to around 50 ppm, Rubisco starts to combine O_2 with RuBP instead of CO_2.
- The net result of this is that instead of producing two 3C PGA molecules, only one molecule of PGA is produced and a toxic 2C molecule called phosphoglycolate is produced which is converted into molecule of glycolic acid.
- The glycolic acid is then converted to glycine. The glycine is then transported into mitochondria where it is converted into serine. The serine is then used to make other organic molecules. All these conversions cost the plant energy and results in the net lost of CO_2 from the plant.

(ii) Chloroplast, Mitochondria and Peroxisome.

(iii) The process of photorespiration interferes with the normal functioning of the calvin cycle.

It is quite different from the respiration as there is no production of ATP or NADPH molecule. Moreover, this process is harmful to the plants because as much as half of the fixed CO_2 may be lost into the atmosphere during this process. Hence these plants need to overcome photorespiration.



5. Write a brief account on chemiosmotic theory.

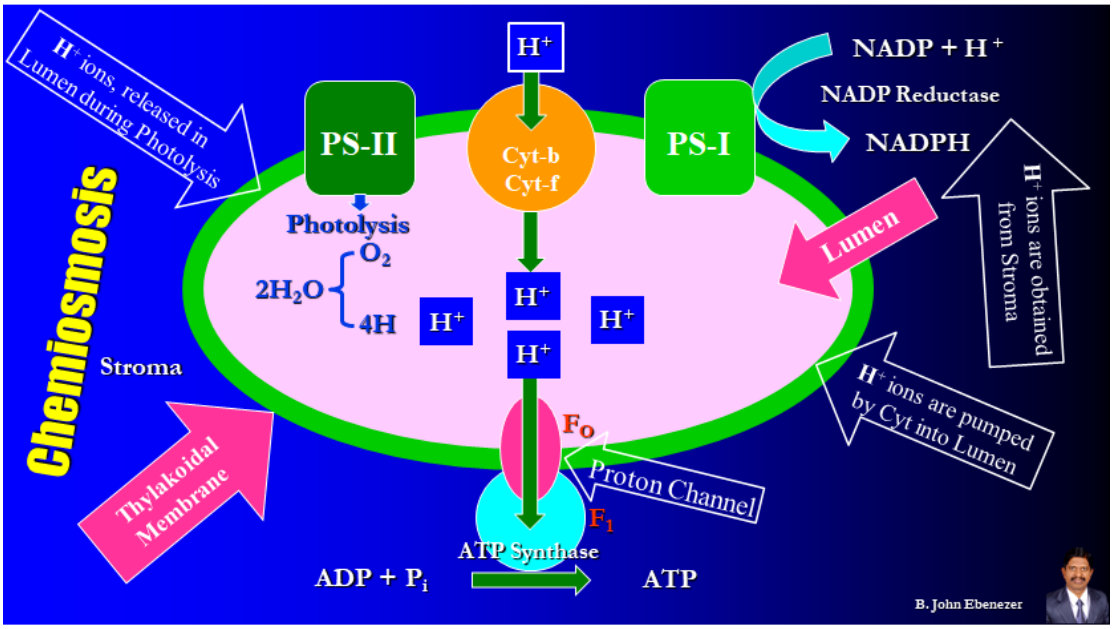
This theory explains the formation of high energy molecules, i.e., ATP. The processes that cause a proton gradient to develop are:

(a) Due to the splitting of the water molecule, the protons or hydrogen ions accumulate within the lumen of the thylakoids.

(b) As electrons move through the photosystems, protons are transported across the membrane and released into the inner side or the lumen side of the membrane.

(c) During the electron transport, the protons which are necessary for the reduction of NADP+ to NADPH+ H+ also removed from the stroma.

- Hence, within the chloroplast, protons in the stroma decrease in number, while in the lumen there is accumulation of protons. This causes a formation of proton gradient. This gradient is important because it is the breakdown of this gradient that leads to release of energy.
- The gradient is broken down due to the movement of protons across the membrane to the stroma through the transmembrane channel of the F_0 of the ATPase.
- ATPase consists of two parts: the F_0 is embedded in the membrane and forms a transmembrane channel that carries out facilitated diffusion of protons across the membrane and the other portion is called F_1 which protrudes on the outer surface of the thylakoid membrane on the side that faces the stroma.
- The breakdown of the gradient provides enough energy to cause a conformational change in the F_1 particle of the ATPase, which makes the synthesis of several molecules of ATP.

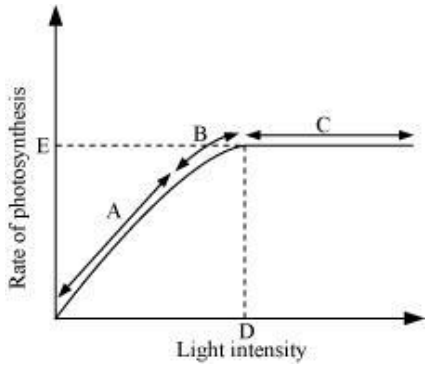


6. The following figure shows the effect of light on the rate of photosynthesis. Based on the graph, answer the following questions:

(a) At which point/s (A, B or C) in the curve is light a limiting factor?

(b) What could be the limiting factor/s in region A?

(c) What do C and D represent on the curve?



(a) Generally, light is not a limiting factor. It becomes a limiting factor for plants growing in shade or under tree canopies.

In the given graph, light is a limiting factor at the point where photosynthesis is the minimum. The least value for photosynthesis is in region **A**. Hence, light is a limiting factor in this region.

(b) Light is a limiting factor in region **A**. Water, temperature, and the concentration of carbon dioxide could also be limiting factors in this region.

(c) Point D represents the optimum point and gives the light intensity at which the maximum photosynthesis is recorded. The rate of photosynthesis remains constant after this point, even though the intensity of light increases in region **C**.

7. **Explain the factors affecting photosynthesis.**

Several factors such as light, temperature, CO_2 and water affect the rate of photosynthesis.

Law of Limiting Factor (Stated by Blackmann): When a physiological process is controlled by a number of factors, the rate of reaction depends on the least factor, so the factor which is the least or limiting will determine the rate of Photosynthesis.

Light:

Light quality and light intensity influence photosynthesis. As the intensity of light increases, the rate of photosynthesis increases. But at higher light intensity the rate of photosynthesis decreases because higher intensity of light destructs chlorophyll. Wavelength of light between 400 nm 700 nm is effective for photosynthesis and is called photosynthetically active radiation (PAR).

Temperature:

The rate of photosynthesis is maximum at an optimum temperature, which differs in different plants. High temperature denatures enzymes of biosynthetic phase and low temperature inactivates.

Carbon dioxide:

It is the major limiting factor. Concentration of CO_2 up to 0.5 % increases the rate of photosynthesis. However, beyond this value, it is harmful.

Water:

Water is the main reactant in the process of photosynthesis and its scarcity leads to water stress, which causes closure of stomata, hence supply of less carbon dioxide. Water stress also reduces leaf expansion and less photosynthetic surface area.

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