BIOLOGY

PHOTOSYNTHESIS IN HIGHER PLANTS

Photosynthesis

Photosynthesis is an enzyme regulated anabolic process of manufacture of organic compounds inside the chlorophyll containing cells from carbon dioxide and water with the help of sunlight as a source of energy.

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

Historical Perspective

Josheph Priestley (1770): Showed that plants have the ability to take up CO_2 from atmosphere and release O_2. (Candle with bell jar and mouse expt.)

Jan Ingenhousz (1779): Release of O_2 by plants was possible only in sunlight and only by the green parts of plants. (Expt. with aquatic plant in light & dark)

Theodore de Saussure (1804): Water is an essential requirement for photosynthesis to occur.

Julius Von Sachs (1854): Green parts in plant produce glucose which is stored as starch.

T.W. Engelmann (1888): The effect of different wavelength of light on photosynthesis and plotted the first action spectrum of photosynthesis.

C.B. Van Niel (1931): Photosynthesis is essentially a light dependent reaction in which hydrogen from an oxidizable compound reduces CO_2 to form sugar. He gave a simplified chemical equation of photosynthesis.

$$2H_2A + CO_2 \xrightarrow{\text{Sun Light}} 2A + CH_2O + H_2O$$

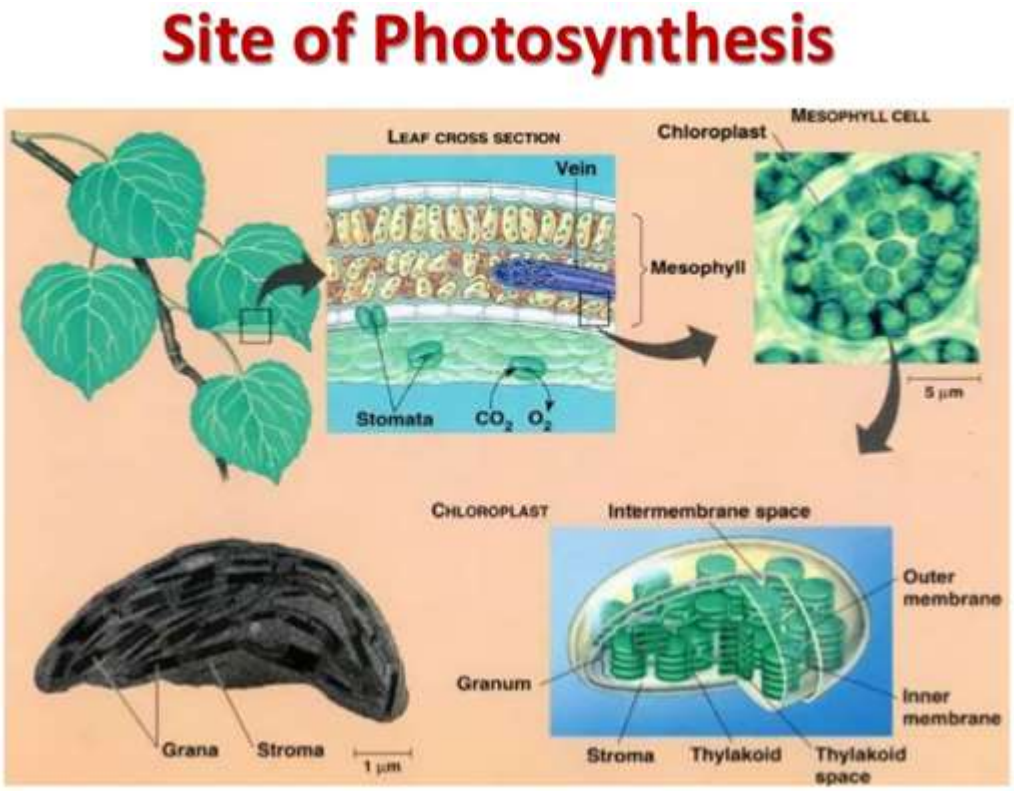
Hill (1937): Evolution of oxygen occurs in light reaction.

Calvin (1954-55): Traced the pathway of carbon fixation.

Site for photosynthesis

Photosynthesis takes place only in green parts of the plant, mostly in leaves. Within a leaf, photosynthesis occurs in mesophyll cells which contain the chloroplasts. Chloroplasts are the actual sites for photosynthesis. The thylakoids in chloroplast contain most of pigments required for capturing solar.

Energy to initiate photosynthesis: The membrane system (grana) is responsible for trapping the light energy and for the synthesis of ATP and NADPH. Biosynthetic phase (dark reaction) is carried in stroma.



Importance of Photosynthesis

- Synthesis of organic compounds.
- Change of radiant energy into chemical energy.
- Useful products are obtained from plants gums, oils timber fire wood, resins rubber, fibers and drugs, etc.
- Balance the percentage of O_2 and CO_2 in atmosphere.
- Fossil fuels like coal, natural gas and petroleum have been formed inside the earth indirectly as a product of photosynthesis.

Pigments involved in photosynthesis

Chlorophyll a: (Bright or blue green in chromatograph). Major pigment, act as reaction center, involved in trapping and converting light into chemical energy. It is called universal photo-synthetic pigment.

Chlorophyll b: (Yellow green)

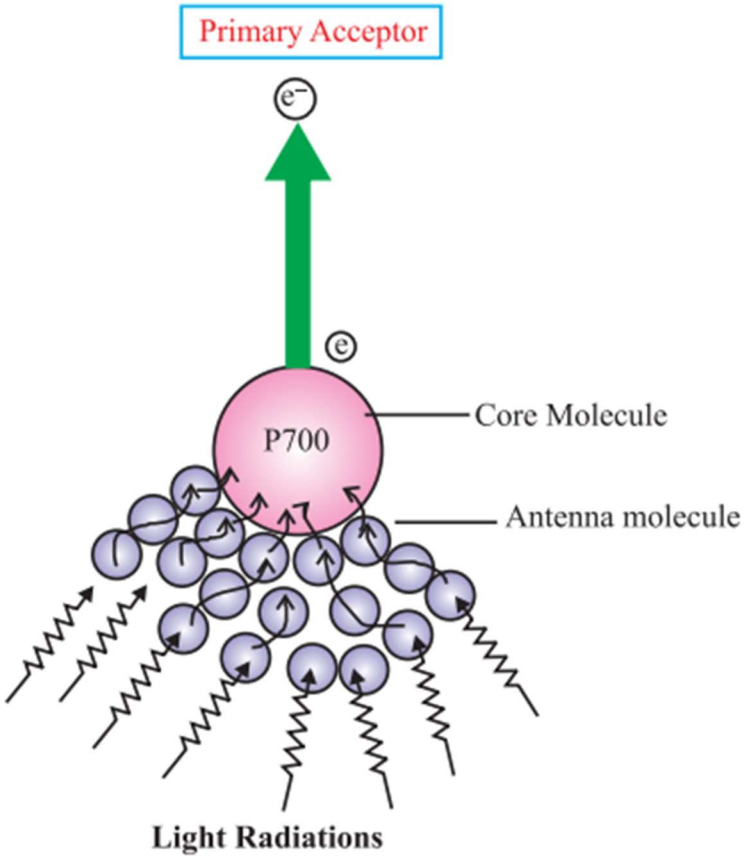
Xanthophyll's: (Yellow)

Carotenoids: (Yellow to yellow-orange)

In the blue and red regions of spectrum shows higher rate of photosynthesis.

Light Harvesting Complexes (LHC)

The light harvesting complexes are made up of hundreds of pigment molecules bound to protein within the photosystem I (PS-I) and photosystem II (PS-II). Each photosystem has all the pigments except one molecule of chlorophyll 'a' forming a light harvesting system (antennae). The reaction center (chlorophyll a) is different in both the photosystems.



Light Harvesting Complex

Photosystem I (PS-I): Chlorophyll 'a' has an absorption peak at 700 nm (P700).

Photosystem II (PS-II): Chlorophyll 'a' has absorption peak at 680 nm (P680),

Process of photosynthesis

It includes two phases-Photochemical phase and biosynthetic phase. (Formerly known as Light reaction and dark reaction)

Photochemical phase (Light reaction): This phase includes-light absorption, splitting of water, oxygen release and formation of ATP and NADPH. It occurs in grana region of chloroplast.

Biosynthetic phase (Dark reaction): It is light independent phase, synthesis of food material

(sugars). (Calvin cycle). It occurs in stroma region of chloroplast.

Photophosphorylation

The process of formation of high-energy chemicals (ATP and NADPH) in presence of light.

Non-Cyclic photophosphorylation

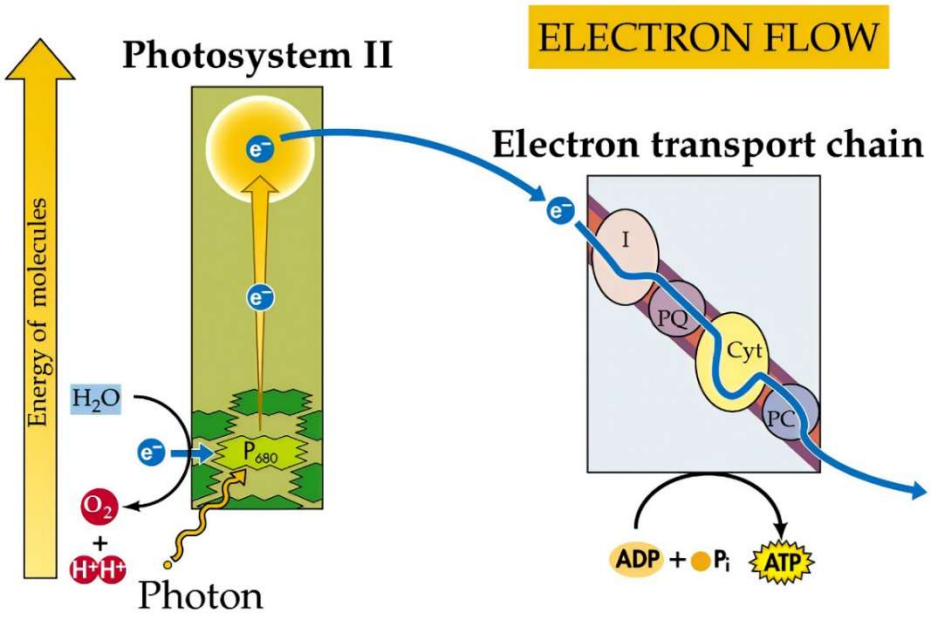
Two photosystems work in series First PSII and then PSI. These two photosystems are connected through an electron transport chain (Z. Scheme). Both ATP and NADPH + H+ are synthesized by this process. PSI and PSII are found in lamellae of grana, hence this process is carried here.

Cyclic photophosphorylation

Only PS-I works, the electron circulates within the photosystem. It happens in the stroma lamellae (possible location) because in this region PSII and NADP reductase enzyme are absent. Hence only ATP molecules are synthesized. It occurs when only light of wavelengths beyond 680 nm are available for excitation.

The Electron Transport System

1. Reaction center of photosystem II absorbs light of 680 nm in red region and causing electron to become excited. These electrons are picked by an electron acceptor which passes to electron transport system consisting of cytochromes.
2. Electrons are passed down the electron transport chain and then to the pigment of PS I.
3. Electron in the PSI also get excited due to light of wavelength 700nm and are transferred to another accepter molecule having a greater redox potential.
4. When electron passes in downhill direction, energy is released. This is used to reduce the ADP to ATP and NADP+ to NADPH. The whole scheme of transfer of electron is called Z-scheme due to its shape.
5. Photolysis of water release electrons that provide electron to PS II. Oxygen is also released during this process.

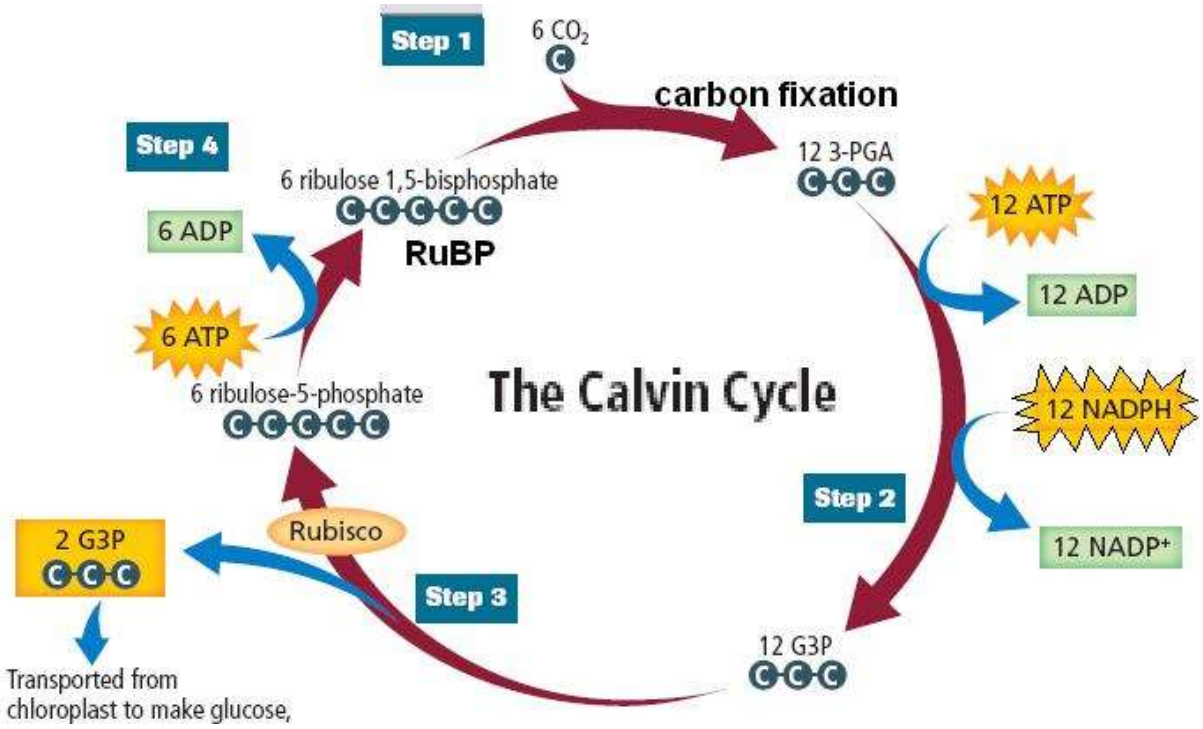


Calvin Cycle/ C_3 cycle/ Reductive Pentose Sugar Phosphate Pathway

Malvin Calvin, Benson and their colleagues used radioactive 14C and Chlorella and Scenedesmus algae to discover that first CO_2 fixation product is 3-carbon organic compound (3-phosphoglyceric acid) or PGA. Later on a new compound was discovered which contain 4-carbon called Oxaloacetic Acid (AAO). On the basis of number of carbon atoms in first stable product they are named C_3 and C_4 pathway.

Calvin cycle can be described under three stages: carboxylation, reduction and regeneration.

1. Carboxylation is the fixation of into 3-phosphoglyceric acid (3-PGA). Carboxylation of RuBP occurs in presence of enzyme RuBP carboxylase (RuBisCO) which results in the formation of two molecules of 3-PGA.
2. Reduction is series of reaction that leads to formation of glucose. Two molecules of ATP and two molecules of NADPH are required for reduction of one molecule of. Six turns of this cycle are required for removal of one molecule of Glucose molecules from pathway.
3. Regeneration is the generation of RuBP molecules for the continuation of cycle. This process requires one molecules of ATP.
4. For every molecule of entering the Calvin Cycle, 3 molecules of ATP and 2 molecules of NADPH is required. To make one molecules of glucose 6 turns of cycle is completed so total energy molecule required is.



In	Out
Six CO_2	One glucose
18 ATP	18 ADP
12 NADPH	12 NADP

C_4 pathway/ Hatch Slack Pathway

- This pathway was worked out by Hatch and Slack (1965, 1967), mainly operational in plants growing in dry tropical region like Maize, Sugarcane, Sorghum etc.
- In this pathway first stable product is a 4-carbon compound Oxaloacetic acid (AAO) so called as C_4 pathway. C_4 plants have Kranz Anatomy (vascular bundles are surrounded by bundle sheath cells arranged in wreath like manner), characterized by large no of chloroplast, thick wall impervious to gases and absence of intercellular spaces.
- The primary CO_2 acceptor is a 3-carbon molecule Phosphoenol Pyruvate present in mesophyll cells and enzyme involved is PEP carboxylase.
- OAA formed in mesophyll cell forms 4-carbon compound like malic acid or aspartic acid which is transported to bundle sheath cells.
- In bundle sheath cell, it is broken into CO_2 and a 3-carbon molecule. The 3-carbon molecule is returned back to mesophyll cells to form PEP.
- The CO_2 molecules released in bundle sheath cells enters the Calvin cycle, where enzyme RuBisCO is present that forms sugar.

Photorespiration

- It is a the light dependent process of oxygenation of RuBP and release of carbon dioxide by photosynthetic organs of plants.
- Photorespiration decreases the rate of photosynthesis when oxygen concentration is increased from 2-3% to 21%.
- Presence of light and higher concentration of Oxygen results in the binding of RuBisCO enzyme with O_2 to form.
- RuBisCO + O_2 PGA + phosphoglycolate
- This pathway involves Chloroplast, Peroxisome and Mitochondria. Photorespiration do not occurs in C_4 plants.

Difference between C_3 Plants and C_4 Plants

C_3 plants	C_4 plants
The leaves do not have Kranz anatomy.	The leaves show Kranz anatomy in leaves.
Photorespiration occurs.	Photorespiration does not occur.
RuBisCO is the first acceptor of CO_2.	PEP is the first acceptor of CO_2.
PGA is the first stable product.	OAA is the first stable product.
Plants are adapted to all climates.	Plants are adapted to tropical climate.
Mesophyll cells perform complete photosynthesis.	Mesophyll cells perform only initial fixation.

Factors affecting photosynthesis

- **Light:** As light intensity increases, the rate of photosynthesis also increases until light saturation point.
- **Carbon dioxide concentration:** With increase in concentration of CO_2 rate of photosynthesis increase till the compensation point.
- **Temperature:** It does not influence the rate of photosynthesis directly but at higher temperature enzyme activity is inhibited due to denaturation of enzymes which affect the dark reaction.
- **Water:** due to increase in amount of water, rate of photosynthesis does not increase proportionally as after saturation no more water is required during photosynthesis.

Blackman's Law of Limiting Factors states

If a chemical process is affected by more than one factor, then its rate will be determined by the factor which is nearest to its minimal value it is the factor which directly affects the process if its quantity is changed.

CHAPTER : 13 PHOTOSYNTHESIS IN HIGHER PLANTS

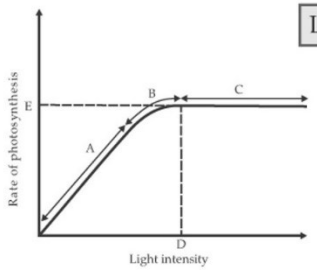
Photosynthesis in Higher Plants

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

Photosynthesis an enzyme regulated anabolic process of manufacture of organic compounds inside the chlorophyll containing cells, from carbon oxide and water with the help of sunlight as source of energy.

Photosynthesis as a Means of Autotrophic Nutrition

Factors Affecting Photosynthesis

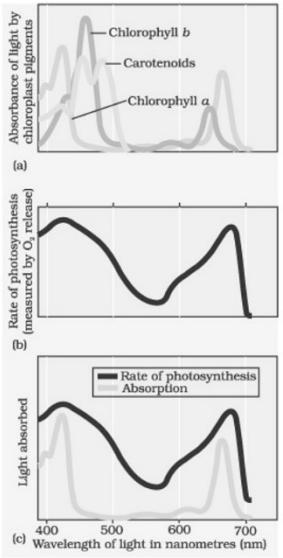


- Light
- Carbon dioxide
- Temperature
- Water

Site of photosynthesis

Chloroplast in leaves

- Grana → light Reaction
- Stroma → Dark Reaction

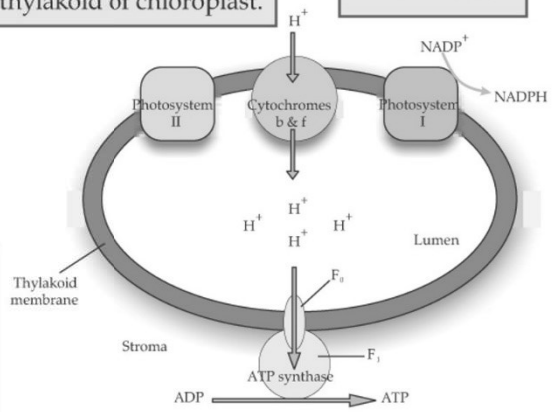


Pigments Involved in Photosynthesis

- Chl a
- Chl b
- Xanthophyll
- Carotenoids

Chemiosmotic hypothesis

Explains the mechanism of ATP synthesis in thylakoid of chloroplast.



Photorespiration

- It is the light induced respiration in green plants.
- It is a process in which there is no formation of ATP or NADPH, but there is utilization of ATP with release of CO_2.

Light Reaction

Photophosphorylation

- Cyclic
  - Involves only photosystem I.
  - Only ATP is formed.
  - Electrons move in a closed circle.
- Non-cyclic
  - Involves both photosystem I and II.
  - Both ATP and NADPH are produced.
  - Electrons do not move in a closed circle.

Biosynthetic Phase Or Dark reaction

- C4 or Hatch and Slack pathway
  - Occurs in mesophyll and bundle sheath cells.
  - Enzyme RuBisCo is absent from the mesophyll cells
- C3 or Calvin cycle
  - Carboxylation
  - Reduction
  - Regeneration
  - For every CO_2 molecules, 3 molecules of ATP and 2 molecules of NADPH are required.

Important Questions

➢ Multiple Choice Questions:

Question 1. Kranz anatomy is found in or is typical of

(a) C_3 plants

(b) C_4 plants

(c) C_2 plants

(d) Succulents (CAM Plants)

Question 2. A cell that lacks chloroplast does not

(a) Utlize carbohydrates

(b) Evolve carbon dioxide

(c) Require water

(d) Liberate oxygen

Question 3. Energy is transformed from the light reaction step to the dark reaction step by

(a) ATP

(b) RUBP

(c) ADP

(d) Chlorophyll

Question 4. Translocation of carbohydrates or sugars (photosynthetic products) in flowering plants occurs in the form of

(a) Glucose

(b) Starch

(c) Maltose

(d) Sucrose

Question 5. Photo-respiration is induced by

(a) High oxygen content

(b) High temperature

(c) High light intensity

(d) High CO_2 content

Question 6. AH vegetation is only due to

(a) Oxygen

(b) CO_2

(c) Water

(d) Hydrogen

Question 7. Site of dark reaction is

(a) Granum

(b) Unit membrane

(c) Lamella

(d) Stroma

Question 8. All vegetation is only due to water was proved experimentally by

(a) Aristotle

(b) Van Helmont

(c) Joseph

(d) Stephen Hales

Question 9. Vegetation always purifies the air was proved experimentally first by

(a) Liebig

(b) Warburg

(c) Stephen Hales

(d) Joseph Priestly

Question 10. Reduction of NADP+ to NADPH occurs during

(a) PSI

(b) Calvin Cycle

(c) Cyclic photophosphorylation

(d) Non cyclic photophosphorylaction

Question 11. Wastage of energy is associated with

(a) Krebs cycle

(b) Photorespiration

(c) Photosynthesis

(d) Glycolysis

Question 12. Green plants convert solar energy into chemical energy of organic matter was proved by

(a) Joseph Priestly

(b) Van Mayer

(c) Semebier

(d) Lavoisier

Question 13. When the rate of translocation is slow, the rate of photosyntheis shall

(a) Increase

(b) Decrease

(c) Remain Unaffected

(d) Become Zero

Question 14. The first visible product of photosynthesis is

(a) Starch

(b) Glycogen

(c) Sugar

(d) Fatty acids

Question 15. The enzyme ribulose biphosphate carboxylase oxygenase is located in

(a) Mitochondria

(b) Chloroplasts

(c) Golgi bodies

(d) peroxisomes

➢ Fill In the Blanks:

1. All animals including human beings depend on ……. for their food.
2. Green plants carry out …….. process by which they use light energy to derive the synthesis of organic compounds.
3. Photosynthesis is important for life due to two reasons: It is the ……. by which all food gets synthesised on earth and is also responsible for the release of …… into the atmosphere by plants.
4. A first ……., …… of photosynthesis was thus described.
5. A milestone contribution to the understanding of ……. was that made by a microbiologist, …….. (1897-1985), who based on his studies of …….. and green ……
6. The membrane system is responsible for trapping the light energy and synthesising of ……. and ……..

➢ True or False:

1. Water stress causes the stomata to close hence reducing the CO_2 availability.
2. Tropical plants have a higher temperature optimum than that of the plants adapted to temperate climates.
3. The C_4 plants show saturation at about 450 µ. L-1 while C_3 responds to increased CO_2 concentration and saturation is seen only beyond 360µ. L-1
4. Green plants carry out 'photosynthesis', a physico-chemical process by which they use light energy to drive the synthesis of organic compounds.
5. Julius Von Sachs in 1770's performed a series of experiment that revealed the essential role of air in growth of green plants.
6. Joseph Priestlay showed that sunlight is essential to the plant process that somehow purifies the air fouled by burning candles or breathing animals.

➢ Very Short Question:

1. What is the full form of NADP?
2. What are the complete photosynthetic units of plants?
3. Give one difference between chlorophyll 'a' and chlorophyll 'b'.
4. How many ATP molecules are required for the synthesis of one molecule of glucose in the C_3 pathway?
5. In which part of the leaves chlorophyll is found?
6. What is the primary acceptor of CO_2 in the C_3 plant?
7. In which part of chloroplast light reaction takes place?
8. What is the relation between photosynthetic units and reaction centers?
9. What is the compensation point?
10. What is Kranz's anatomy?

➢ Short Questions:

1. Expand the abbreviation RuBP. What is its role in photosynthesis?
2. What is the porphyrin system?
3. What are the two main functions of pigments other than chlorophyll in green leaves?
4. What is the significance of chlorophyll-a in photosynthesis carried out by higher plants?
5. What are the steps that are common to C_3 and C_4 photosynthesis?
6. What is the coupling factor in photosynthesis?
7. What is 3 – PGA?
8. What is the Emerson effect or photosynthetic enhancement?

➢ Long Questions:

1. What is photorespiration? Describe the process in detail and link it with the Calvin cycle.
2. Describe carbon reactions of the C_3 pathway. Does this pathway operate also in C_4 plants?
3. Describe briefly the experiment conducted by the scientist, T.W. Englemann.
4. What is a photosystem? Which is the pigment that acts as a reaction center? Describe the interaction of photosystem 1 and photosystem II.

Assertion Reason Question-

1. In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

   (a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.

   (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

   (c) If Assertion is true but Reason is false.

   (d) If both Assertion and Reason are false.

   Assertion: Chloroplasts mostly occur in mesophyll cells along their walls inside the leaves.

   Reason: The membrane system of chloroplast is responsible for trapping the light energy and also for the synthesis of ATP and NADPH.

2. In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

   (a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.

   (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

   (c) If Assertion is true but Reason is false.

   (d) If both Assertion and Reason are false.

   Assertion: Rhoeo leaves contain anthocyanin pigments in epidermal cells.

   Reason: Anthocyanins are accessory photosynthetic pigments. [AIIMS 2002]

✓ Answer Key-

➢ Multiple Choice Answers:

1. (b) C_4 plants
2. (d) Liberate oxygen
3. (a) ATP
4. (d) Sucrose
5. (a) High oxygen content

6. (c) Water
7. (d) Stroma
8. (b) Van Helmont
9. (d) Joseph Priestly
10. (d) Non cyclic photophosphorylaction
11. (b) Photorespiration
12. (b) Van Mayer
13. (b) Decrease
14. (b) Starch
15. (b) Chloroplasts

➢ Fill In the Blanks:

1. plants
2. Answer: photosynthesis a physico chemical
3. Answer: mechanism, oxygen
4. Answer: action, spectrum
5. Answer: photosynthesis, Cornelius van Niel, purple, bacteria
6. ATP, NADPH

➢ True or False:

1. True
2. True
3. True
4. True
5. False
6. Falae

➢ Very Short Answers:

1. Answer: Nicotinamide Adenine Dinucleotide phosphate.
2. Answer: Chloroplasts.
3. Answer: Chlorophyll (a) has a methyl group (CH_3) whereas chlorophyll (b) has an aldehyde group (CHO).
4. Answer: 18 ATP molecules are required for the synthesis of one molecule of glucose.

5. Answer: In the thylakoid membrane of the chloroplast.
6. Answer: RiBulose 1.5 biphosphate (RuBP).
7. Answer: Grana.
8. Answer: A photosynthetic unit consists of P6g0 and P700 reaction centers of photosystems.
9. Answer: The point at which the rate of photosynthesis is equal to the rate of respiration.
10. Answer: It is a type of leaf structure in which the vascular bundle is surrounded by bundle sheath and mesophyll cells.

➢ Short Answer:

1. Answer: The full form of RuBP is ribulose 1,5 biphosphate; RuBP is the first acceptor of atmospheric CO_2 during the dark reaction of photosynthesis. The reaction is called carboxylation.

$$6\ RuBP + 6\ CO_2 + 6\ H_2O \longrightarrow \text{Unstable 6C compond} \longrightarrow 3\ PGA.$$

   RuBP is regenerated during the final formation of sugar molecules.

2. Answer: The porphyrin system consists of

   i. A complex ring structure of alternating single and double bonds called a porphyrin ring having four pyrrole rings containing a magnesium atom in the center.

   ii. A lengthy hydrocarbon tail attached to the porphyrin group called phytol.

3. Answer: The functions of pigments other than chlorophyll are:

   i. to absorb light energy and transfer it to chlorophyll for photosynthesis.

   ii. to protect the chlorophyll molecule from photooxidation.

4. Answer: In higher plants, all the pigments carotenes, xanthophylls, and chlorophyll-b transfer the absorbed solar energy to chlorophyll-a. It is the chlorophyll-a molecule, which initiates the process of photosynthesis.

5. Answer: The following steps are common in both C_3 and C_4 photosynthesis.

   i. Photolysis of H_2O and photophosphorylation in the light reaction.

   ii. The dark reaction occurs in the stroma in both cases.

   iii. Carboxylation-but in C_3 plants CO_2 acceptor is RuBP whereas in C_4 it is phosphoenolpyruvic acid.

   iv. The Calvin cycle resulting in the formation of starch occurs in both C_3 and C_4 photosynthesis.

6. Answer: These are similar to the F_0 - F_1 complex of mitochondria present in appressed and non-appressed regions, granular and stromal thylakoids. These participate in the

photophosphorylation process.

7. Answer: It is a protein molecule located on the outer surface of the thylakoid membrane. It is the first stable intermediate product of photosynthesis. It comprises 16% of the chloroplast protein, which is the most abundant protein of the biological world on earth.
8. Answer: Emerson in 1957 showed that the rate of photosynthesis can be increased if monochromatic beams of two different wavelengths i.e. long and short are used simultaneously around a trap center in a photosynthetic unit. This phenomenon is known as the Emerson effect or photosynthetic enhancement.

➢ Long Answer:

1. Answer: Enzyme Rubisco catalyzes the carboxylation reaction where CO_2 combines with RuBP. This enzyme catalyzes the combination of O_2 with RuBP called oxygenation. Respiration that is initiated in chloroplasts and occurs in light only is called photorespiration.

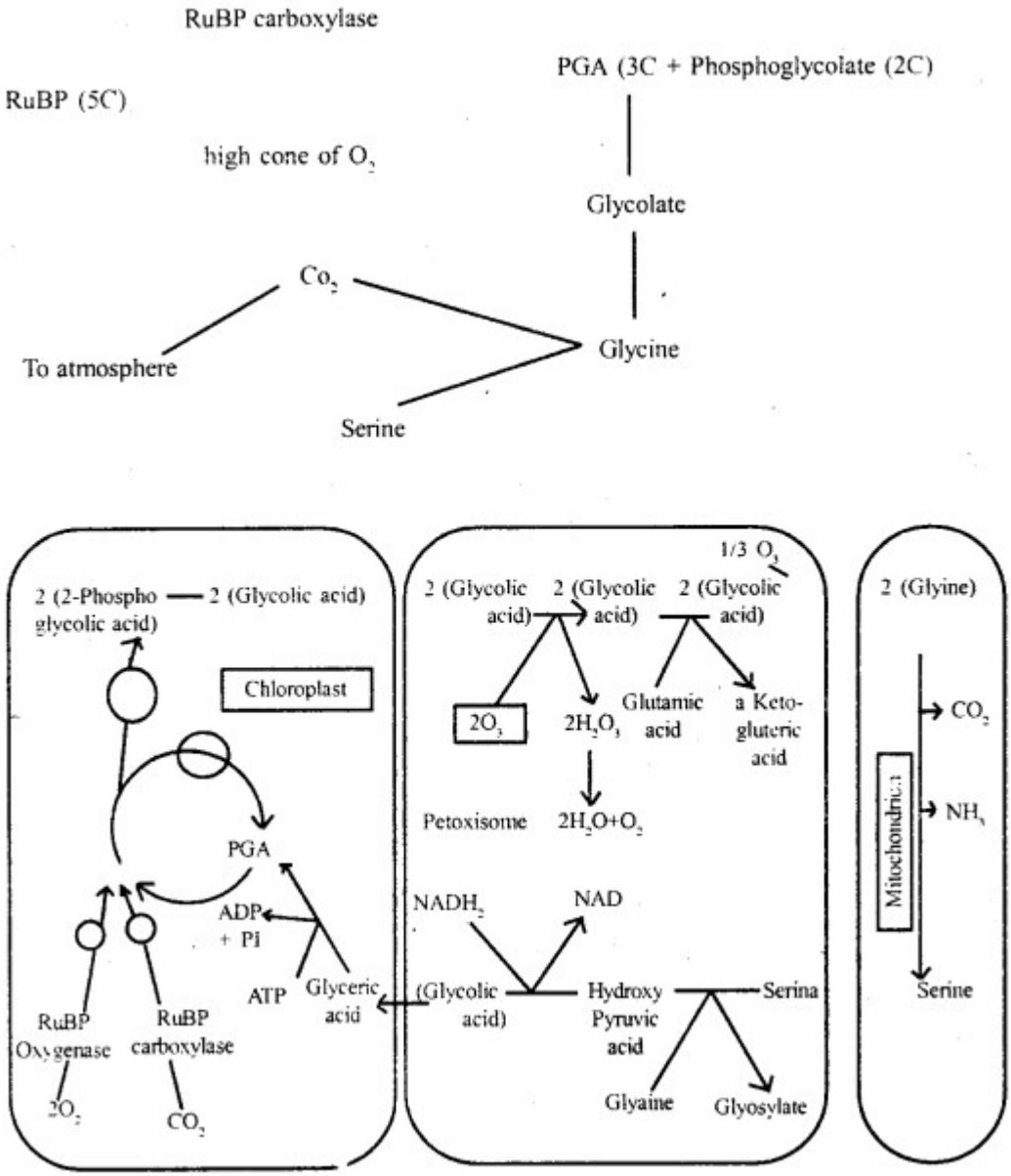
   The oxygenation of RuBP in presence of O_2 is the first of photorespiration, which leads to the formation of one molecule of phosphoglycolate, a two-carbon compound, and one molecule of PGA. While PGA is used up in the Calvin cycle, the phosphoglycolate is dephosphorylated to form glycolate in the chloroplast and in turn diffused to peroxide, where it is oxidized to glyoxylate.

   In the peroxide, the glyoxylate is used to form amino acid and glycine-calycine enters mitochondria where two glycine molecules (4 carbon) give rise to one molecule of serine (3 carbon) and one CO_2 (one carbon). The serine is taken up by peroxisome and converted into glycerate. The glycerate enters the chloroplast where it is phosphorylated to form PGA. PGA molecules enter the Calvin cycle to make carbohydrates releasing one molecule of CO_2 In mitochondria photorespiration is also called the photosynthetic carbon oxidation cycle

   Increased O_2 level increases photorespiration whereas increased CO_2 level increases photorespiration (and increases C_2 photosynthesis).

   In C_3 plants photosynthesis occurs only in one cell type i.e. mesophyll cells. Both light reactions and carbon reactions occur in mesophyll cells in C_3 plants. In C_4 plant photosynthesis requires the presence of two types of photosynthesis cells that is mesophyll cells and bundle sheath cells. The C_4 plants contain dimorphic chloroplasts, which means chloroplasts in mesophyll cells are granular. Therefore C_2 pathway does not operate in the C_4 pathway.

   All the important changes can be summarised as



2. Answer: The reactions catalyzing the assimilation of CO_2 to carbohydrates take place in the stroma where all the necessary enzymes are localized. These reactions are referred to as 'carbon reactions' (also called dark reactions) leading to the photosynthetic reduction of carbon to carbohydrates.

   In the first phase of carbon reaction, CO_2 enters the leaf through the stroma. This CO_2 is accepted by a 5-carbon molecule, ribulose-1-5 bisphosphate (RuBP) already present in the leaf. It forms two molecules of 3-carbon, compound, 3- phosphoglycerate (PGA). This 3-carbon molecule is the first stable product of this pathway and hence it is called C, PATHWAY.

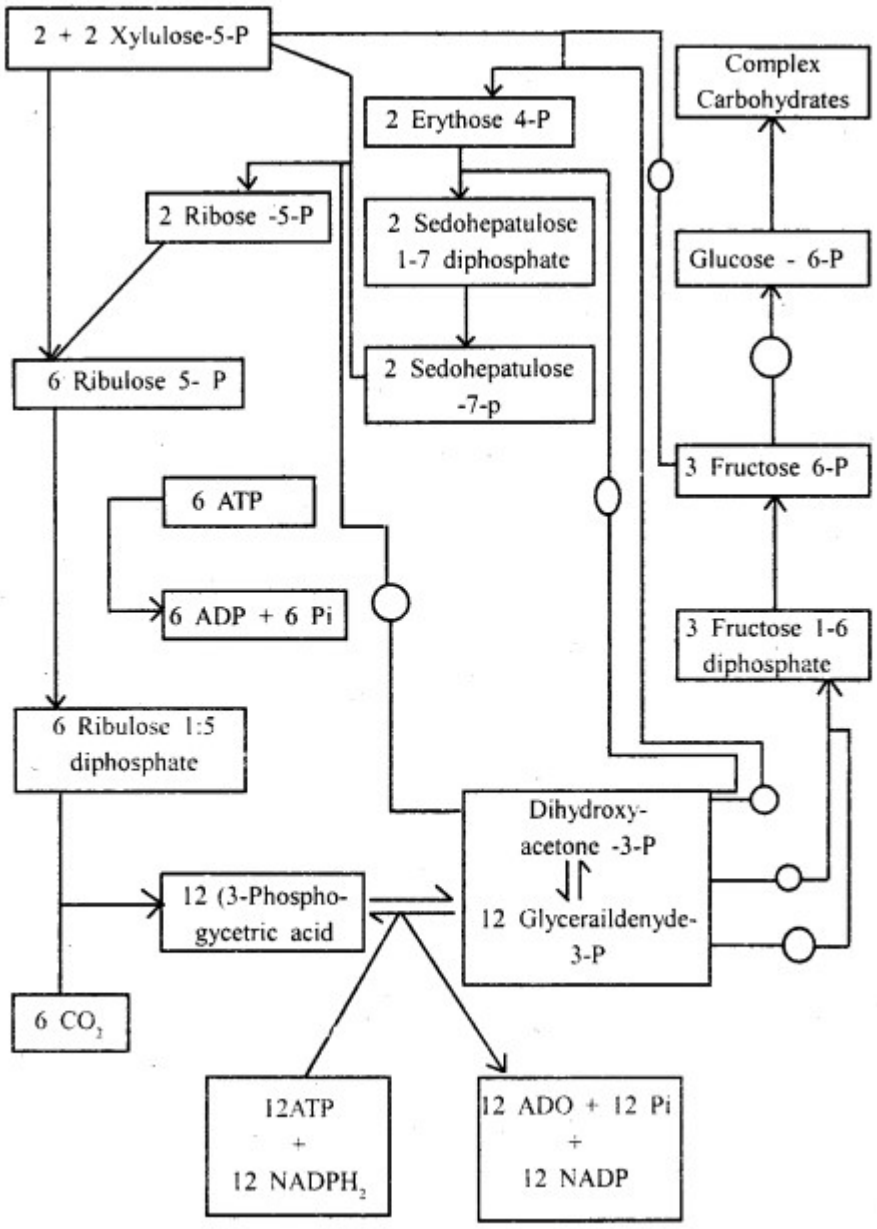
   The formation of (PGA) with CO_2 combining with RuBP is called carboxylation. This reaction is catalyzed by an enzyme called ribulose bisphosphate carboxylase (Rubisco). This enzyme also possesses oxygenase activity and hence abbreviated as Rubisco. This activity allows O, to compete with CO_2 for combining with RuBP.

   After the carboxylation reduction of PGA occurs and ATP and NADPH, formed during

photochemical reactions with the reduction of PGA, glyceraldehyde-3 phosphate-a carbohydrate is formed. These 3-carbon molecules, also called triose phosphates act as precursors for the synthesis of sucrose and starch. To complete the cycle, and to continue it, regeneration of the 5-carbon acceptor molecule, that is RuBP takes place.

The C_3 type of carbon reaction occurs in the stroma of the chloroplast. This pathway is called the Calvin cycle.

The CO_2 concentrating mechanism is called the C_4 pathway. Operation of the C_4 pathway requires the cooperation of both cell-type mesophyll and bundle sheath cells. The objective of the C. pathway is to build up a high concentration of CO_2 which suppresses photorespiration. This C. pathway is more efficient than the C_3 pathway. Hence C? pathway does not operate C4 plants. (See the table)

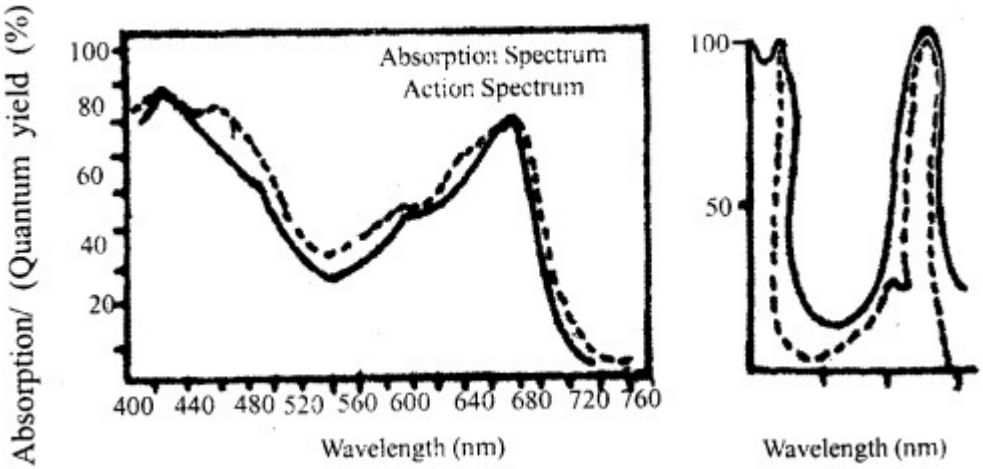


Schematic representation of C_3 pathway Calvin cycle.

3. Answer: T.W. Englemann plotted the action spectrum of photosynthesis.

   Photosynthesis can occur in visible light of wavelength varying between 390 to 763 nm. The rate of photosynthesis is not uniform in light of all wavelengths.

   It varies depending upon their relative absorption by chlorophyll pigments. The graph showing the relative yield or rate of photosynthesis in plants exposed to monochromic light of different wavelengths is termed as ACTION SPECTRUM. The rate of photosynthesis, as shown in the action spectrum is maximum in the blue region of light.

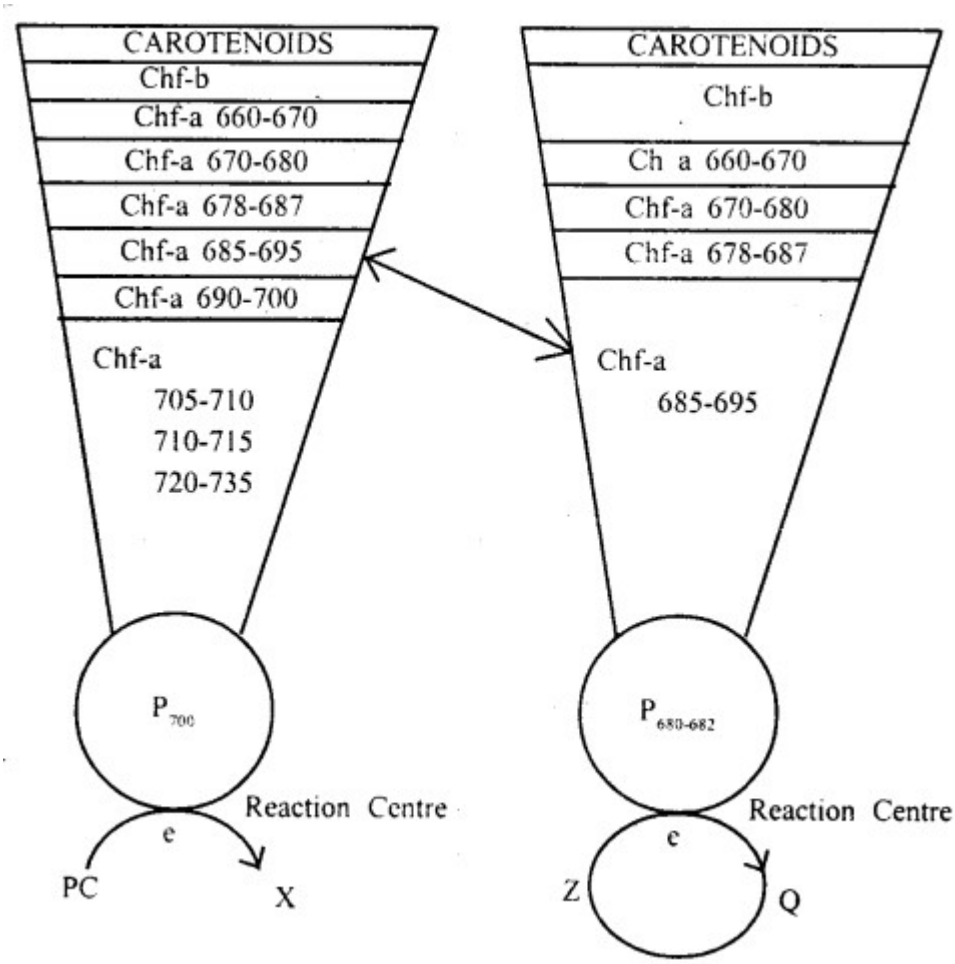


   Curves showing a comparison of absorption and action spectra of chlorophyll pigments during photosynthesis

4. Answer: The light is entrapped by a group of chlorophyll molecules which together constitute a photosystem. Each pigment system has a trap or reaction center, which is either P700 or P680 ao. In this 'P' stands for pigment and figures 680 and 700 for the wavelength of light. Chlorophyll molecule acts as a trap center with the transfer of high energy electron to electron transport system (ETS).

   The high-energy electrons return rapidly to their normal low energy orbitals in the absence of light and the excited chlorophyll molecule reverts to its original stable condition. These two photosystems: photosystem-I and photosystem-11 exist with different forms of chlorophyll 'a' as the reaction center. The PS-II is located in the appressed regions of grana thylakoids and the PS-I in the stroma thylakoids and non-appressed regions of grana.

   The function of two photosystems that interact with each other is to trap light energy and convert it to chemical energy (ATP). This chemical energy stored in the form of ATP is used by living cells.



Distribution of pigment in photosystem I and Photosystem II.

Assertion Reason Answer-

1. (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

   Explanation: Chloroplasts function as the site of photosynthesis in eukaryotic photoautotrophs. Inside the leaves, the chloroplasts occur mostly in the mesophyll cells along their walls for easy diffusion of gases and receiving optimum quantity of incident light. Within the chloroplast there is the membranous system consisting of grana, the stroma lamellae, and the fluid stroma. The membrane system is responsible for trapping the light energy and also for the synthesis of ATP and NADPH.

2. (c) If Assertion is true but Reason is false.

   Explanation: Anthocyanin pigments only give colouration since the epidermal cells mainly have potential colouring pigments. It is responsible for blue, red, pink and purple colours, observed in different parts of plants such as petals, stamens and fruits etc.

   Anthocyanins are also important for attracting insects for pollination and seed dispersal. Hence, anthocyanin pigments are not accessory photosynthetic pigments.