13

Photosynthesis in Higher Plants

Multiple Choice Questions (MCQs)

Q. 1 Which metal ion is a constituent of chlorophyll?

(a) Iron (b) Copper (c) Magnesium (d) Zinc

Thinking Process

Chloroplast is a type of plastid (a cell organelle) which is green in colour. It absorbs light energy and convert it to a chemical energy with the help of the chlorophyll pigments.

Ans. *(c)* Magnesium (Mg) is present in the centre of porphyrin ring of the chlorophyll molecule. Other ions, *i.e.,* iron, copper and zinc participate in other metabolic processes which are

Fe is an important part of **cytochrome** and **ferridoxin**.

Cu plays an important role in enzyme catalysing redox reactions.

Zn is associated with auxin (a phytohormone) synthesis.

Q. 2 Which pigment acts directly to convert light energy to chemical energy?

(a) Chlorophyll-*a* (b) Chlorophyll-*b*

(c) Xanthophyll (d) Carotenoid

Ans. *(a)* **Chlorophyll-*a*** acts directly to convert light energy to chemical energy.

The other pigments chlorophyll-*b*, xanthophyll and carotenoids are accessory pigments associated with the main pigment, *i.e.,* chlorophyll-*a* to harvest the light energy.

Q. 3 Which range of wavelength (in nm) is called Photosynthetically Active Radiation (PAR)?

(a) 100-390 (b) 390-430 (c) 400-700 (d) 760-100,00

Ans. *(c)* **Photosynthetically Active Radiation** (PAR) ranges from 400-700 nm. This is the visible range of light energy.

The range of other wavelength are associatic with

100-300 nm : Ultraviolet (UV) range

390-430 nm : Infrared (NIR) range

760-100,00 nm : Mid Infrared (MIR) range

Q. 4 Which light range is most effective in photosynthesis?

(a) Blue (b) Green (c) Red (d) Violet

Thinking Process

The visible spectrum wavelength ranges from 400 - 700 nm of which red light has 700 nm.

Ans. *(c)* **Red** light is most effective in photosynthesis.

In other lights namely blue and violet the photosynthesis takes place but the rate is slow, whereas in green light the photosynthesis is least because plants do not absorb this range of light reflect back thus, they appear green.

Q. 5 Chemosynthetic bacteria obtain energy from

(a) sun (b) infrared rays

(c) organic substances (d) inorganic chemicals

Ans. *(d)* **In Inorganic Chemicals** Chemosynthetic bacteria were the first organism on earth synthesise their own food by obtaining energy from chemicals like H_2S, NO_2, etc. Photosynthetic bacteria have taken their origin from chemosynthetic bacteria.

Sun, infrared rays and organic substances are not used as the sources of energy for chemosynthetic bacteria.

Q. 6 Energy required for ATP synthesis in PS II comes from

(a) proton gradient (b) electron gradient

(c) reduction of glucose (d) oxidation of glucose

Ans. *(a)* The synthesis of ATP is directly linked to the development of proton gradient across the thylakoid membranes of a chloroplast. It results when the water molecule splits inside the inner membrane and form H^+ and OH^- ions.

The energy for ATP synthesis comes from proton gradient which develops along the inner membrane, *e.g.,* in case of mitochondria in electron transport chain and in chloroplast in the PS II.

The other options (b), (c) and (d) are not involved in the synthesis of ATP molecule.

Q. 7 During light reaction in photosynthesis the following are formed

(a) ATP and sugar (b) hydrogen, O_2 and sugar

(c) ATP, hydrogen donor and O_2 (d) ATP, hydrogen and O_2 donor

Ans. *(c)* Light dependent reaction uses solar power to generate ATP and $NADPH_2$ which provide chemical and reducing power respectively to sugar synthesising reaction of the Calvin cycle, while the O_2 in released as a by product of light dependent reaction.

Other options are incorrect because

(a) ATP is produced in light reaction but sugar is produced in dark reaction.

(b) H_2 is produced by splitting of water $\left(H_2O \rightarrow 2H^+ + \frac{1}{2}O_2\right) H^+$ are released. The $2H^+$ is accepted by NADP to form NADPH and oxygen (O_2) is of course produced but sugar is not.

(c) O_2 donor and ATP is produced in light reaction but not the hydrogen.

Q. 8 Dark reaction in photosynthesis is called so because

(a) it can occur in dark also
(b) it does not depend on light energy
(c) it cannot occur during day light
(d) it occurs more rapidly at night

Thinking Process

C_3 cycle is involved in all kinds of plants carrying out photosynthesis which produces glucose as the first product of photosynthesis. There are certain adaptations and modifications in dark reactions of photosynthesis in certain plants called C_4 plants.

Ans. ***(b)*** Dark reaction is called so because it does not depend on light. It is also called as light independent reaction.

Q. 9 PEP is primary CO_2 acceptor in

(a) C_4 plants
(b) C_3 plants
(c) C_2 plants
(d) both C_3 and C_4 plants

Ans. ***(a)*** C_4 plants have evolved PEP as primary acceptor of CO_2 to avoid the sensitivity of RuBP carboxylase-oxygenase to high concentration of oxygen, so that they can avoid photorespiratory loss of CO_2 occuring in them.

Other options (b), (c) and (*d*) are incorrect. PEP is not primary acceptor in them.

Q. 10 Splitting of water is associated with

(a) photosystem I
(b) lumen of thylakoid
(c) both photosystem I and II
(d) inner surface of thylakoid membrane

Ans. ***(d)*** The thylakoid is a photosynthetic unit in the chloroplast. It is a membrane bound structure. The membrane has photosystems I and II embedded in it, in the form of chemicals and molecules. Splitting of water is associated with PS-II, which occurs in presence of Mn^{2+} and Cl^- ions on the inner surface of thylakoid membrane.

$$2H_2O \xrightarrow[Cl^-]{Mn^+} 4H^+ + O_2 + 4e^-$$

Photosystem I and II are associated with light reactions.

Q. 11 The correct sequence of flow of electrons in the light reaction is

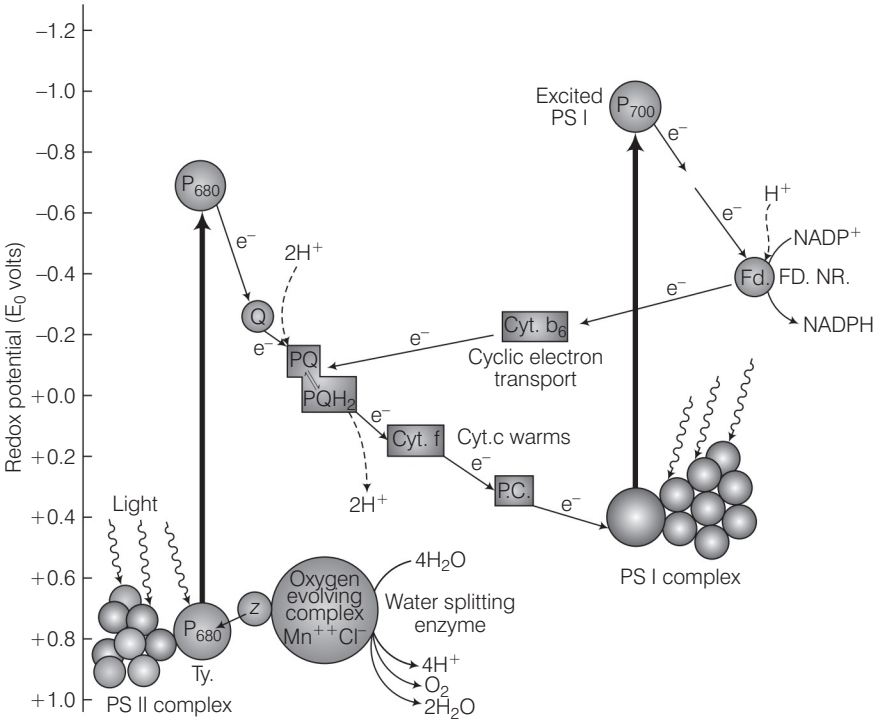
(a) PS II, plastoquinone, cytochromes, PS I, ferredoxin
(b) PS I, plastoquinone, cytochromes, PS II, ferredoxin
(c) PS I, ferredoxin, PS II
(d) PS I, plastoquinone, cytochromes, PS II, ferredoxin

Thinking Process

The light reaction of photosynthesis is mainly involved in trapping of solar radiation and converting it to ATP and produce $NADPH_2$ also. The excited electron move through chains of pigments and their energy is used in ATP formation.

Ans. ***(a)*** Option (a) is the correct sequence of movement of electrons.

The options (b), (c) and (d) do not give this correct sequence of events.



Q. 12 The enzyme that is not found in a C_3 plant is

(a) RuBP carboxylase
(b) PEP carboxylase
(c) NADP reductase
(d) ATP synthase

Thinking Process

C_3 plants are those plants which have calvin cycle to produce glucose molecules in dark reaction. C_3 cycle is found in all photosynthesising plants. Some plants have problem in fixing atmospheric CO_2 because of deviation to property of RuBP carboxylase oxygenase enzyme. So they have evolved C_4 mechanism.

Ans. ***(b)*** PEP carboxylase enzyme is found in C_4 plants to carry out initial fixation of CO_2.

The functions of other enzymes in options (a), (c) *and* (d) *are as follows*

(a) RuBP carboxylase operates in C_3 plants.
(c) NADP reductase is involved in electron transport chain.
(d) ATP synthase is used in ATP synthesis.

Q. 13 The reaction that is responsible for the primary fixation of CO_2 is catalysed by

(a) RuBP carboxylase
(b) PEP carboxylase
(c) RuBP carboxylase and PEP carboxylase
(d) PGA synthase

Ans. *(c)* In C_3 cycle **RuBP carboxylase** is used to fix atmospheric CO_2 whereas, in C_4 plants **PEP carboxylase** is involved in primary CO_2 fixation. So, both are used in CO_2 fixation but in different cycles.

Other options are incorrect because in (a) and (b) option is giving incomplete information and option (d) PGA synthase is not at all involved in CO_2 fixation.

Q. 14 When CO_2 is added to PEP, the first stable product synthesised is

(a) pyruvate
(b) glyceraldehyde-3-phosphate
(c) phosphoglycerate
(d) oxaloacetate

Thinking Process

C_4 plants use PEP (phosphoenol pyruvate) to fix atmospheric CO_2. In a normal photosynthetic cycle RuBP carboxylase is used to trap CO_2 in C_3 plants.

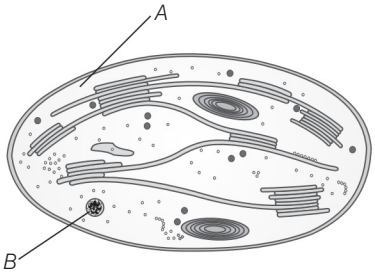
Ans. *(d)* **Oxaloacetate** is a four carbon compound formed in C_4 cycle and is a first stable product, that is why such plants are called C_4 plants.

Rest of the options are incorrect as because

(a) Pyruvate is formed in glycolysis.
(b) Glyceraldehyde-3-phosphate is also an intermediate compound of glycolysis.
(c) Phosphoglycerate is also an intermediate compound of glycolysis.

Very Short Answer Type Questions

Q. 1 Examine the figure



(a) Is this struture present in animal cell or plant cell?
(b) Can these be passed on to the progeny? How?
(c) Name the metabolic processes taking place in the places marked (*A*) and (*B*).

Ans. **(a)** The above figure show the chloroplast which is green in colour and performs photosynthesis in plants thus, The structure is present in plant cell.

(b) *Yes*, chloroplast has the power of self replication because of presence of extranuclear DNA.

(c) The metabolic that occurs in the marked places are as follows.

A–It is the stroma of chloroplast where dark reaction of photosynthesis takes place.

B–It is the structure of extra nuclear DNA and is responsible for replication of chloroplast, when it is required in the photosynthesising cells.

Q. 2 $2H_2O \rightarrow 4H^+ + O_2 + 4e^-$

Based on the above equation, answer the following questions

(a) Where does this reaction take place in plants?

(b) What is the significance of this reaction?

Thinking Process

Water is a universal solvent, every living cell contains 70% water with protoplasm. It plays an important role in the process of photosynthesis.

Ans. (a) The reaction takes place in reaction centre PS II, located on the inner surface of thylakoid membrane. It is known as water splitting centre where electrons are extracted from water. The Mn^+ and Cl^- ions catalyse this reaction.

(b) *Splitting of water is an important event in photosynthesis as*

(i) It releases molecular oxygen as byproduct of photosynthesis and is the significant source of oxygen in air, or is essential for all living beings on earth.

(ii) Hydrogen ions produced, are utilised in reducing NADP to NADPH, a strong reducing agent.

(iii) The electrons released are transferred from PS II to PS I through a series of electron carriers thus, creating a gradient for the synthesis of ATP.

Q. 3 Cyanobacteria and some other photosynthetic bacteria don't have chloroplasts. How do they conduct photosynthesis?

Thinking Process

Cyanobacteria are simple, one cell prokaryotic organisms belonging to Monera. The process of photosynthesis have evolved in the organisms of this group.

Ans. The cyanobacteria and photosynthetic bacteria are prokaryotes. They do not have well defined membrane bound cell organelles, but these organisms have photosynthetic pigments in a membranous form, which are primitive in nature but can trap and use solar energy. So, they can carry out photosynthesis.

Q. 4 (a) NADP reductase enzyme is located on ..... .

(b) Breakdown of proton gradient leads to release of ..... .

Ans. (a) NADP reductase enzyme is located on the outer side of **thylakoid membrane**. It is bounded to the thylakoid membrance in light and becomes free in stroma during dark.

(b) ATP Molecules The movement of H^+ ions across the membrane is coupled with the formation of ATP synthesis in presence of enzyme ATP synthase.

Q. 5 Can girdling experiments be done in monocots? If yes, How? If no, why not?

Thinking Process

Xylem and phloem are conducting tissues in angiosperms. Xylem transports water and minerals and phloem transport food. It has been proved by many experiments.

Ans. The girdling experiment cannot be done in monocots. The monocot stem has vascular bundles scattered all over the width of stem so, we cannot reach that specific band of the phloem tissues as we get in dicots.

Q. 6 $3CO_2$ + 9ATP + 6NADPH + water $\longrightarrow$ Glyceraldehyde 3–phosphate + 9ADP + 6$NADP^+$ + 8Pi.

Analyse the above reaction and answer the following questions

(a) How many molecules of ATP and NADPH are required to fix one molecule of CO_2?

(b) Where in the chloroplast does this process occur?

Ans. **(a)** 2 molecules of ATP for phosphorylation and two molecules of NADPH for reduction are required per CO_2 molecule fixed.

(b) The calvin cycle occurs in the stroma of the chloroplast.

Q. 7 Does moonlight support photosynthesis? Find out.

Thinking Process

Solar radiation is the main source of energy for the survival of plant and animal life on the planet earth.

Ans. Plants cannot carry out photosynthesis in moonlight because it does not carry enough energy to excite chlorophyll molecule, *i.e.,* reaction centres PS I and PS II, so light dependent reactions does not get initiate. Thus, no photosynthesis occurs in presence of moonlight.

Q. 8 Some of these terms/chemicals are associated with the C_4 cycle. Explain.

(a) Hatch Slack pathway (b) Calvin cycle

(c) PEP carboxylase (d) Bundle sheath cells

Ans. *The terms associated with* C_4 *cycle are*

Hatch Slack Pathway The process of synthesis of glucose in C_4 plants is different from C_3 plants which was discovered by two scientists **MD Hatch** and **CR Slack** (1977). Hence, named Hatch Slack pathway.

PEP Carboxylase It is an enzyme present in mesophyll cells of C_4 plants. It fixes CO_2 to form 4-carbon compound, *i.e.,* oxaloacetate (OAA).

Bundle Sheath Cells These are specialised sclerenchymatous cells present arround the vascular bundle, in the veins of monocot leaves. These have agranal chloroplast. C_3 cycle occurs in these cells to manufacture glucose in C_4 plants.

Calvin Cycle This cycle operates in bundle sheath cells and fixes CO_2 to form glucose molecules.

Q. 9 Where is NADP reductase enzyme located in the chloroplast? What is the role of this enzyme in proton gradient development?

Ans. NADP reductase enzyme is located on the outer side of lamella or thylakoid of the chloroplast. This enzyme causes breakdown of proton gradient to release energy, *i.e.,* NADPH.

Q. 10 ATPase enzyme consists of two parts. What are those parts? How are they arranged in the thylakoid membrane? Conformational change occur in which part of the enzyme?

Thinking Process

Thylakoid is a photosynthetic unit present in the grana of chloroplast, the cell organelle. It is the site for many important photosynthetic reactions.

Ans. *ATP synthase enzyme has two parts*

(a) F_1-head piece is a peripheral membrane protein complex and contain the site for synthesis of ATP from ADP + pi (inorganic phosphate).

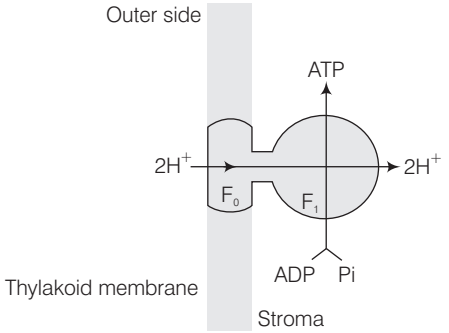
(b) F_0-integral membrane protein complex that forms the channel through which proton cross the inner membrane.

The arrangment of F_1 and F_0 *in thylakoid membrane is as follaws*

F_0-portion is present within the thylakoid membrane.

F_1-portion of ATP synthase enzyme is present in the stroma if chloroplast.

The conformational change occurs in F_1 portion of ATP synthase thus, facilitaling the ATP synthesis.



Diagramatic presentation of ATP synthesis in chloroplast

Q. 11 Which products formed during the light reaction of photosynthesis are used to drive the dark reaction?

Ans. ATP and NADPH formed during light reaction of photosynthesis are used in dark reaction for fixing CO_2 and to form glucose molecule.

Q. 12 What is the basis for designating C_3 and C_4 pathways of photosynthesis?

Ans. *The basis for designating* C_3 *and* C_4 *pathways* of photosynthesis is as follows

C_3 Pathway	C_4 Pathway
In Calvin cycle or C_3 cycle (dark reaction), carbon dioxide is fixed into first stable compound called 3-PGA, (3-phorphoglyceric acid) which is a 3 carbon compund.	In C_4 plants, the Calvin cycle C_3 cycle occurs in bundle sheath cells. Prior to reaching there, the CO_2 is trapped by mesophyll cells and fixed into a 4-carbon stable product called oxalo acetic acid.

Short Answer Type Questions

Q. 1 Succulents are known to keep their stomata closed during the day to check transpiration. How do they meet their photosynthetic CO_2 requirements?

Thinking Process

Succulents plants have water conserving tissue as they have adaptations to conserve water because they grow in xeric conditions. They have other mechanisms too, to conserve water/ to prevent loss of water.

Ans. Succulent plants grow in dry and xeric conditions so, they have to shut down the stomata during day time, to prevent water loss through transpiration. So and the gaseous exchange does not take place.

Thus plants have developed the mechanism to fix CO_2 during night in the form of malic acid, which is a 4 carbon compound and store CO_2, release it during day, inside the photosynthetic cells.

Q. 2 Chlorophyll-'*a*' is the primary pigment for the light reaction. What are accessory pigments? What is their role in photosynthesis?

Ans. Accessory pigments are also photosynthetic pigments. These are chlorophyll-*b*, xanthophyll and carotenoids. These are not directly involved in emission of excited electrons, but they help in harvesting solar radiation and pass it on to chlorophyll-*a*.

This pigment itself absorbs maximum radiation at blue and red region. So, Chlorophylla is the chief pigment of photosynthesis and others (*i.e.,* chlorophyll-*b*, xanthophyll and carotinoion) are accessory pegment.

Q. 3 Do reactions of photosynthesis called, as 'Dark Reaction' need light? Explain

Ans. Dark reactions are actually light independent reactions. CO_2 is reduced through various biochemical reactions to produce $C_6H_{12}O_6$ (glucose) which does not need light. But they depend on the products formed during light reactions, *i.e.,* $NADPH_2$ and ATP.

Q. 4 How are photosynthesis and respiration related to each other?

Thinking Process

Photosynthesis and respiration both are important in plant metabolism. One is anabolic process (synthesising) other is catabolic (breakdown) reactions.

Ans. **Photosynthesis and respiration** are related, as in both mechanisms, the plants gain energy.

In photosynthesis, plants gain energy from solar radiations whereas, in respiration, they break down glucose molecule to get energy in the form of ATP molecules.

They are releted also because they are dependent on each other. The product of photosynthesis *i.e.,* glucose (food) is utilised in respiration to yield energy (ATP). Which doing so, it releases many other simple molecules ($CO_2 + H_2O$) whcih are utilised in photosynthesis to produce more sugers.

Q. 5 If a green plant is kept in dark with proper ventilation, can this plant carry out photosynthesis? Can anything be given as supplement to maintain its growth or survival?

Ans. The plant in given conditions can not carry out photosynthesis. Light is must for any green plant to make its own food.

The plant should be watered properly for its survival.

Q. 6 Photosynthetic organisms occur at different depths in the ocean. Do they receive qualitatively and quantitatively the same light? How do they adapt to carry out photosynthesis under these conditions.

Thinking Process

The major part of photosynthesis occuring on earth is performed under water by plants specially algae present in ocean.

Ans. Plant present at various depth in ocean are mostly algae. These show great variations in its photosynthetic pigments. These can absorb different wave lengths of light and performs photosynthesis.

Green algae–chlorophyll-*a*, (absorbs red) and b(absorbs blue violet).

Brown algae–chlorophyll-*a*, *c* and fucoxanthin (absorbrs yollow).

Rhodophyceae–chlorophyll-*a*, *d* and phycoerythrin.

Q. 7 In tropical rain forests, the canopy is thick and shorter plants growing below it, receive filtered light. How are they able to carry out photosynthesis?

Ans. The plants carry out photosynthesis in presence of light. The quality and intensity of light affect only the rate of photosynthesis. So, plants growing in different canopy will carry out photosynthesis, but rate could be different depending upon the intensity and quantity of light recevied.

Q. 8 What conditions enable RuBisCO to function as an oxygenase? Explain the ensuing process.

Thinking Process

RuBisCo is the largest occurring enzme which is involved in photosynthesis.

Ans. RuBisCo is an enzyme which has dual nature. It acts as carboxylase, when CO_2 concentration is good enough in atmosphere. But if O_2 concentration increases, its nature changes and it binds with O_2 and acts as oxygenase enzyme, which forces CO_2 to enter C_2 cycle thus leading to photorespiration and loss of CO_2.

Q. 9 Why does the rate of photosynthesis decrease at higher temperatures?

Ans. Photosynthesis is an enzyme specific process. All enzymes act at an otptimum temperature (*i.e.,* 25-35°C). If temperature increases, enzyme get denature, thus leading to fall in the rate of photosynthesis.

Q. 10 Explain how during light reaction of photosynthesis, ATP synthesis is a chemiosmotic phenomenon.

Thinking Process

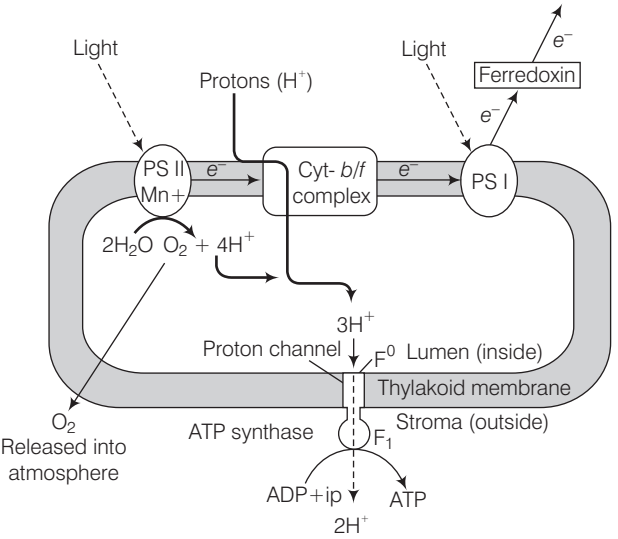
Chemiosmosis refers to the movement of protons (H^+) from the region of higher concentration to lower concentration. Their movement is coupled with ATP synthesis in thylalkoid membrane.

Ans. In light reaction plants trap solar radiation by photosynthetic pigments which convert light energy into chemical energy. Main event of light reaction is photophosphorylation, *i.e.*, formation of ATP from ADP + Pi by using energy of excited electron movement through electron transport chain, present in thylakoid membrane.

Chemiosmosis is the movement of ions across a selectively permeable membrane, down the electrochemical/ proton gradient.

Chemiosmosis hypothesis of ATP formation was first proposed by Mitchell (1961) according to which the enzyme ATP synthase generales ATP *via* a membrane, proton pump and proton gradient. ATP synthase allows ions O_2 protons to pass through membrane and proton pump.

This creales a high cocentration of protons (H^+) in the lumen and hence diffuses across the membrane to activale ATPase, releasing ATP molecules. One molecule of ATP is released for every two (H^+) ions passing Through ATPase.



Proton (H^+) gradient and ATP formation

Q. 11 Find out how Melvin Calvin worked out the complete biosynthetic pathway for synthesis of sugar.

Thinking Process

Melvin Calvin was awarded Nobel Prize in 1961 for developing the technique to trace the path of carbon in glucose synthesis in dark reaction of photosynthesis.

Ans. Melvin Calvin used *Chlorella* as an experimental material and discovered the first stable compound of photosynthesis, *i.e.,* 3 phosphoglyceric acid so as to trace the path of carbon by using a radioactive isotope of carbon (C^{14}) and autoradiography technique.

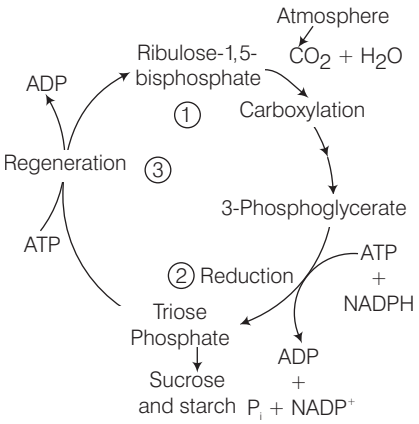
He then, compared the radioactive compounds on the chromatogram as a result of which he found and concluded that the PGA (phosphoglyceric acid), as the first stable product of photosynthesis and gradually the other sugars including hexoses, tetroses and pentoses etc.

Thus, he derived the pathway of CO_2 fixation from these radioactive products (sugars) formed.

Q. 12 Six turns of Calvin cycle are required to generate one mole of glucose. Explain.

Ans. Ribulose 5 phosphate is a five carbon compound which accepts atmospheric CO_2 in presence of RuBisCo and form 2 molecules of 3PGA, a ^{3c} carbon compound. It uses 3 ATP and 2 NADPH to fix one molecule of CO_2 per cycle of Calvin.

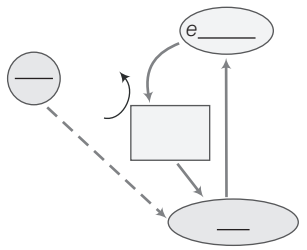
So, to fix 6 CO_2 molecules to form 6 carbon compound glucose 6 cycles are required as mentioned below.



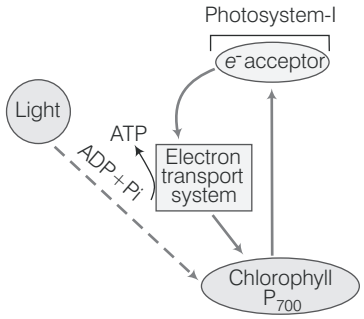
Calvin cycle

In	Out
Six CO_2	One glucose molecule ($C_6H_{12}O_6$)
18 ATP	18 ADP
12 NADPH	12 NADP

Q. 13 Complete the flow chart for cyclic photophosphorylation of the photosystem-I.



Ans. *The following flow chart show cyclic photophosphorylation and the missing part of this flow chart are*



Cyclic photophosphorylation

Q. 14 In what kind of plants do you come across 'Kranz anatomy'? To which conditions are those plants better adapted? How are these plants better adapted than the plants, which lack this anatomy?

Ans. Kranz anatomy refers to the dimorphism in the chloroplast structure. It is found in C_4 plants. The cells of leaves have two types of chloroplast in them.

Granal Chloroplast It is found in the mesophyll cells of leaves. Chloroplast have well developed grana in them. These chloroplast effectively fix CO_2 even if it is present in lower concentrations. PEP carboxylase is present which fix CO_2 and to form oxaloacetic acid (4 carbon compound).

Agranal Chloroplast Present in bundle sheath cells of the leaves. C_3 cycle occurs in these cells with the presence of RuBisCo enzyme.

The C_4 plants are well adapted to high O_2 concentrations and high temperature.

C_4 plants can absorb CO_2 even when CO_2 concentration in much low thus C_4 plants can perform high rate of photosynthesis even the stomata are closed or there is the shortage of water thus, they can conserve water.

Since, PEP-carboxylase is insensitive to O_2 thus excess O_2 has us inhibitory effect in C_4 pathway and there is no photosynthesis in C_4 plant.

Thus, C_4 plants are better adapted to tropical and desert (hot acid habitats) areas than the plants, that lack this anatomy.

Q. 15 A process is occurring throughout the day, in 'X' organism. Cells are participating in this process. During this process ATP, CO_2 and water are evolved. It is not a light dependent process.

(a) Name the process.

(b) Is it a catabolic or an anabolic process?

(c) What could be the raw material of this process?

Ans. (a) The name of the process is cellular respiration.

(b) It is a catabolic process which involves break down of glucose molecule.

$$\underset{\text{Carbohydrate + oxygen}}{C_6H_{12}O_6 + 6O_2} \longrightarrow \underset{\text{carbon dioxide + water + (ATP)}}{6CO_2 + 6H_2O} + \text{Energy}$$

(c) Raw material for this process is glucose molecule and oxygen, which are products of photosynthesis, occurring in plants.

Q. 16 Tomatoes, carrots and chillies are red in colour due to the presence of one pigment. Name the pigment. Is it a photosynthetic pigment?

Ans. The different colours other than green are present in the plant because of presence of chromoplasts. It is a kind of plastid and develops different coloured pigments which are not photosynthetic. Pigment lycopene present in tomato, carrot and chillies, imparts red colour to them.

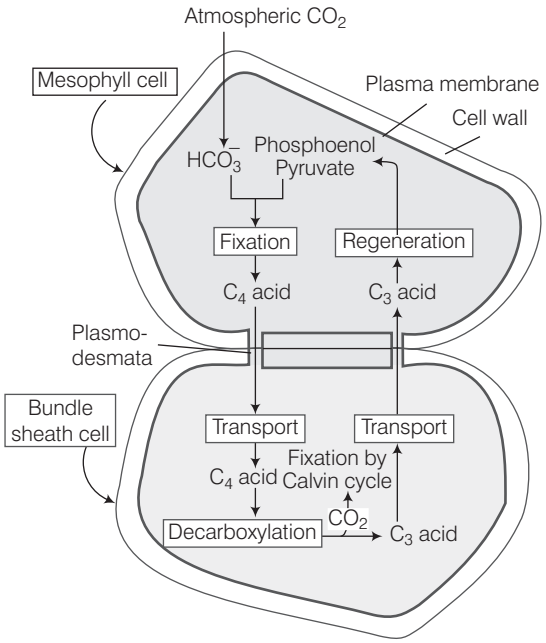
Q. 17 Why do we believe chloroplast and mitochondria to be semi-autonomous organelle?

Thinking Process

The plant cell is a eukaryotic cell. It has number of well developed cell organelles. Few are single membrane bound, few are double membrane bound (chloroplast and mitochondria) structures.

Ans. Both the cell organelles, chloroplast and mitochondria have extra chromosomal DNA and 70S type of ribosomes. The presence of DNA enables then to duplicate, when cell need more mitochondria and the chloroplasts. So they are called as semi-autonomous cell organelles.

Q. 18 Observe the diagram and answer the following.



(a) Which group of plants exibit these two types of cells?

(b) What is the first product of C_4 cycle?

(c) Which enzyme is there in bundle sheath cells and mesophyll cells?

Ans. **(a)** Monocot plants belonging to Graminae/Poaceae family, *e.g.,* sugarcane, maize etc., possess these two types of cells. *i.e.,* bundle sheath and mesophyll cell (in kranz anatomy).

(b) A 4-carbon compound oxaloacetic acid is the first product of C_4 cycle.

(c) Mesophyll cells have PEP carboxylase to fix atmospheric CO_2 to form a 4-carbon compound oxalo acetic acid, whereas bundle sheath cells have RuBP carboxylase which fix CO_2 by this enzyme to form 3-carbon compound 3 PGA (3 phosphoglyceric acid).

Q. 19 A cyclic process is occurring in C_3 plant, which is light dependent and needs O_2. This process doesn't produce energy rather it consumes energy.

(a) Can you name the given process?

(b) Is it essential for survival?

(c) What are the end products of this process?

(d) Where does it occur?

Ans. (a) Photorespiration is the process, which do not produce energy rather consum it.

(b) It is not needed for the survival of C_3 plant.

(c) The end product of this process is H_2O_2.

(d) This process involves three cell organelles of the plant cell.

(i) Chloroplast (ii) Peroxisome

(iii) Mitochondria

Q. 20 Suppose *Euphorbia* and maize are grown in the tropical area.

(a) Which one of them do you think will be able to survive under such conditions?

(b) Which one of them is more efficient in terms of photosynthetic activity?

(c) What difference do you think are there in their leaf anatomy?

Ans. (a) *Euphorbia* is a CAM plant. It fixes CO_2 during night and uses it in day time. It will be able to survive in hot tropical climate.

(b) Maize being a C_4 plant is more efficient in terms of photosynthetic activity as it is able to use CO_2 at lower level as well as high O_2 and temperature.

(c) Maize plants show kranz anatomy in their leaves. They have granal chloroplast in mesophyll cells and agranal in bundle sheath cells. *Euphorbia* does not have C_4 cycle so kranz anatomy is not found in them.

Long Answer Type Questions

Q. 1 Is it correct to say that photosynthesis occurs only in leaves of a plant? Besides leaves, what are the other parts that may be capable of carrying out photosynthesis? Justify.

Thinking Process

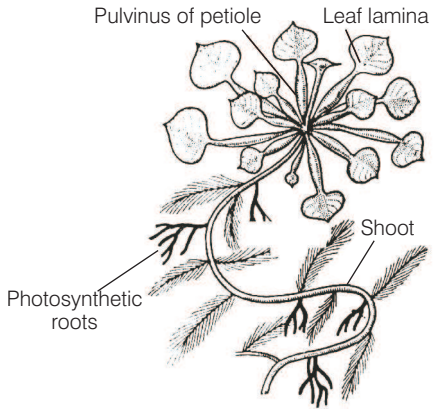
Photosynthesis is a process of manufacturing food by plants. Many plant parts other than leaf also perform this function in some plants.

Ans. Photosynthesis is a process which mainly occurs in leaves of all green plants. The plants have designed their leaf in such a way that it is able to trap solar radiation and effectively convert solar/light energy to chemical energy.

But biology is science of exceptions. Some plants carry out photosynthesis in modified plant parts other then leaves.

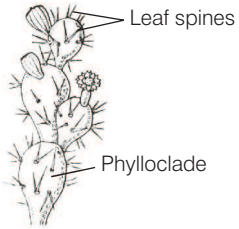
Few examples are as follows

1. **Root as Photosynthetic Organ**



When roots develop chlorophyll and start photosynthesis, they are called assimilitory roots. *Trapa* and *Tinospora* are the examples of assimilatory roots.

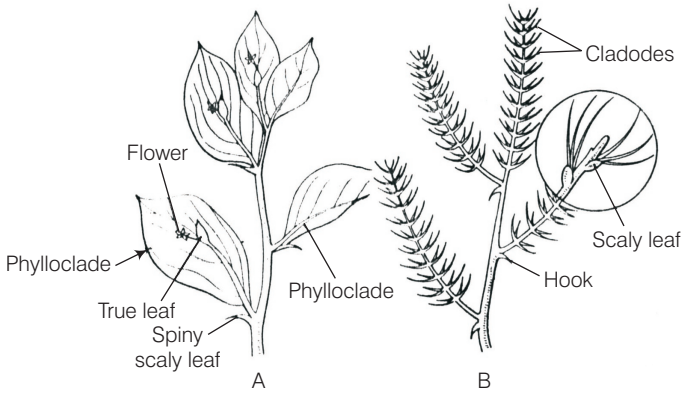
2. **Stem as Photosynthetic Organ**



Phylloclade of *Opuntia*

In *Opuntia*, the stem gets modified to take up the function of leaves. It becomes flattened, thick and succulent and perform photosynthesis. Such structures are called phylloclade.

3. **Petiole as Photosynthetic Organ** In Australian *Acasia* the petiole takes the shape and function of photosynthesis because leaf lamina soon falls off.



A. Phylloclade of *Ruscus*

B. Cladode of *Asparages*

Q. 2 The entire process of photosynthesis consists of a number of reactions. Where in the cell do each of these take place?

(a) Synthesis of ATP and NADPH ..... .

(b) Photolysis of water ..... .

(c) Fixation of CO_2 ..... .

(d) Synthesis of sugar molecule ..... .

(e) Synthesis of starch ..... .

Ans. **(a)** Synthesis of ATP and NADPH takes place in outer side of **thylakoid membrane.**

(b) Photolysis of water occurs in **inner side of thylakoid membrane.**

(c) Fixation of CO_2 occurs in **stroma of chloroplast.**

(d) Synthesis of sugar molecule occurs in **chloroplast.**

(e) Synthesis of starch occurs in **cytoplasm.**

Q. 3 Which property of the pigment is responsible for its ability to initiate the process of photosynthesis? Why is the rate of photosynthesis higher in the red and blue regions of the spectrum of light?

Thinking Process

Plants are green because of the presence of the photosynthetic pigment called chlorophyll. They absorb all colours of light except green.

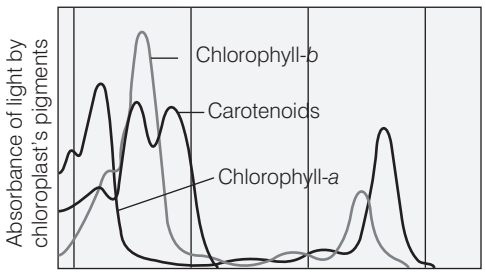
Ans. The chlorophyll pigments are present in the thylakoid membranes. They have the property of excitability and emits e^- in the excited stage, though this e^- is replaced and transferred by the e^- generated from splitting of water molecules.

Red and Blue Light have maximum energy which a chlorophyll pigment absorbs and get excited and initiate the process of photosynthesis. Also, its wavelength are (400-700 nm) *i.e.,* between the Photosynthetic Active Radiation (PAR).

Thus, the rate of photosynthesis is higher in blue and red light.

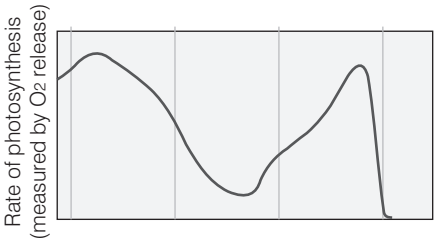
Q. 4 What can we conclude from the statement that the action and absorption spectrum of photosynthesis overlap? At which wavelength do they show peaks?

Ans. **Absorption Spectrum** This depicts the absorption of light of different wavelength by chlorophyll-*a, b*, xanthophyll and carotenoids.



Graph showing the absorption spectrum of chlorophyll-*a, b* and the carotenoids

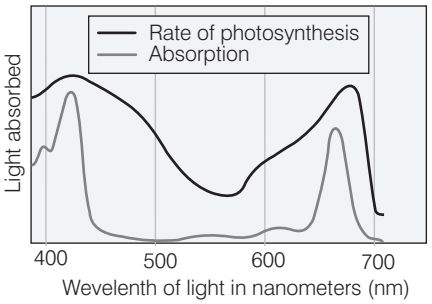
Action Spectrum This shows the rate of photosynthesis in the plant in the light of different wavelengths.



Graph showing action spectrum of photosynthesis

Super Imposed Absorption and Action Spectrum When we superimposed both action and absorption spectrum, it shows that in the region of red and blue light, the chlorophyll-*a* and *b* harness the maximum light energy and are the main photosynthetic pigments.

So, the rate of photosynthesis is high in these two regions. It shows maximum activity peak at wavelength (red light) *i.e.,* 660-670 nm, 430-470 nm (blue) and 390-430 nm (violet).



Graph showing action spectrum of photosynthesis superimposed on absorption spectrum of chlorophyll-*a*

Q. 5 Under what conditions are C_4 plants superior to C_3?

Thinking Process

The different plants show different adaptations in carrying out photosynthesis. This process is important for autotrophs as it synthesises food for survival of plants and animals as well.

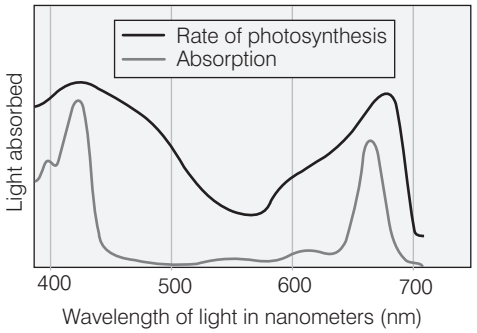
Ans. C_4 *plants are advantageous in following ways*

(i) These plants can carry out photosynthesis even at low concentration of CO_2 in the atmosphere and in the shortage of water.

(ii) These plants can tolerate high O_2 concentration and temperature as enzyme PEP carboxylase in C_4 cycle in insensitive to O_2 and do not show- photorespiration in comparison to the C_3 plants, which start process of photorespiration and lose CO_2 fixation in the form of glucose molecule.

Thus, C_4 plants are superior to C_3 plants.

Q. 6 In the figure given below, the black line (upper) indicates action spectrum for photosynthesis and the lighter line (lower) indicates the absorption spectrum of chlorophyll-*a*, answer the following



(a) What does the action spectrum indicate? How can we plot an action spectrum? Explain with an example.

(b) How can we derive an absorption spectrum for any substance?

(c) If chlorophyll-*a* is responsible for light reaction of photosynthesis, why do the action spectrum and absorption spectrum not overlap?

Ans. (a) The effectiveness of different wavelengths of light on photosynthesis is measured and the rate of photosynthesis is plotted. This is called the action spectrum of photosynthesis.

(b) Absorption of different wavelengths of light by a particular pigment is plotted and the graph is called the absorption spectra of that pigment.

(c) Chlorophyll-*a* is responsible for light reaction of photosynthesis, but the action spectrum and absorption spectrum do not overlap because, though chlorophyll-*a* is the main pigment responsible for absorption of light, other thylakoid pigments like chlorophyll-*b*, xanthophylls, carotenoid, which are accessory pigments, also absorb and transfer the energy to chlorophyll-*a*.

Indeed they not only enable a wider range of wavelength of incoming light to be utilised for photosynthesis but also protect chlorophyll-*a* from photooxidation.

Q. 7 What are the important events and end products of the light reaction?

Ans. *The important events of light reaction are*

(i) Excitation of chlorophyll molecule to emit a pair of electrons and use of their energy in the formation of ATP from ADP + Pi. This process is called photophosphorylation.

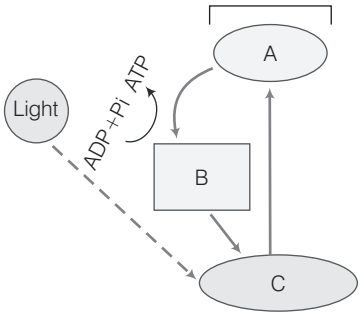
(ii) *Splitting of water molecule*

(a) $2H_2O \longrightarrow 4H^+ + 4e^- + O_2 \uparrow$ (b) $NADP + 2H^+ \longrightarrow NADPH_2$

End products of light reaction are NADPH and ATP.

Reducing power is produced in the light reaction *i.e.,* ATP and $NADPH_2$ molecules which are used up in dark reaction, O_2 is evolved as a by product by the splitting of water.

Q. 8 In the diagram shown below label A, B, C. What type of phosphorylation is possible in this?



Ans. A–Electron acceptor B–Electron transport system

C–Chlorophyll (photosystem I) P_{700}

The cyclic photophosphorylation is shown in the above figure.

Q. 9 Why is the RuBisCo enzyme more appropriately called RUBP carboxylase-oxygenase and what important role does it play in photosynthesis?

Thinking Process

RuBisCo is the largest occurring enzyme on earth.

Ans. RuBP carboxylase and oxygenase has dual nature. It has affinity for both CO_2 and O_2 but has more affinity for CO_2 than O_2. Thus, the concentrations of two determines which of the two will bind to the enzyme.

Consider the following two situations

(i) In a normal condition when CO_2 and O_2 concentrations are normal, it acts as carboxylase and fix CO_2 by combining with ribulose bisphosphate and C_3 cycle operates normally, producing glucose molecule as an first product of photosynthesis.

(ii) If O_2 concentration goes up and CO_2 goes down, it starts acting as an oxygenase enzyme and C_2 cycle (photorespiration) starts where RuBP binds with O_2 to form phosphoglycolate.

(iii) C_4 plants have mechanisms to increase the concentration of CO_2 at enzyme site, and increasing the intracellular concentration of CO_2. Thus, here RuB is Co acts as carboxylase, minimising the affect of oxygenase.

Q. 10 What special anatomical features are displayed by leaves of C_4 plants? How do they provide advantage over the structure of C_3 plants?

Ans. **Kranz Anatomy**, is the feature exhibited by C_4 plant. These possess two types of chloroplast in their leaves. Agranal chloroplast found in bundle sheath cells whereas granal chloroplast is found in the mesophyll cells.

Bundle sheath cell perform C_3 cycle (dark reaction) where as mesophyll cell perform C_4 cycle.

C_4 plants are more efficient even in high O_2 concentration and temperature as compared to C_3 plants. Many important crop plants (monocots) show C_4 cycle like maize, sorghum, sugarcane and millet.

Q. 11 Name the two important enzymes of C_3 and C_4 pathway, respectively. What important role do they play in fixing CO_2?

Ans. **The important enzyme of C_3 cycle is RuBP carboxylase oxygenase** which catalyses reaction of carboxylation of ribulose bis-phosphate, which is 5-carbon compound. to form PGA, the first stable product in C_3 cycle.

In C_4 cycle, the important enzyme is **phosphoenol pyruvate** carboxylase (PEP carboxylase) which help in fixing CO_2 to form oxaloecetate (4-carbon compound), the first stable product of dark reaction is C_4 cycle.

Q. 12 Why is RuBisCo enzyme the most abundant enzyme in the world?

Ans. RuBisCo, now termed as RuBP carboxylase-oxygenase, is widely occurring enzyme because RuBisCo is used in the Calvin cycle to catalyse the first major step of carbon fixation.

RuBisCO is thought to be the most abundant protein in the world since, it is present in every plant that undergoes photosynthesis and molecular synthesis through the Calvin cycle.

It makes about 20-25% of the soluble protein in leaves and is made on the earth at the rate of about 1000 kg/s. It is estimated that every person on earth is supported by about 44 kg of RuBisCo.

Q. 13 Why does not photorespiration take place in C_4 plants?

Ans. Photorespiration is associated with C_3 cycle, where plant lose CO_2 fixation because of the increase in concentrate ion of O_2 and change the nature of activity of RuBP carboxylase-oxygenase.

C_4 plants have evolved a mechanism to avoid loss of CO_2. There is not a direct contact of RuBP carboxylase-oxygenase as C_3 cycle operates in bundle sheath cells (where both temperature and oxygen level low).

CO_2 fixation is done by another enzyme PEP carboxylase in mesophyll cells and oxaloacetate is formed which is converted to malic acid and transported to bundle sheath cells.

There, it gives off CO_2 which is used in Calvin cycle, operating in bundle sheath cells of C_4 plants.