Chapter 12: Photosynthesis

EXERCISE [PAGES 149 - 150]

Exercise | Q 1. (A) | Page 149

Choose the correct option.

A cell that lacks chloroplast does not ______.

1. evolve carbon dioxide
2. **liberate oxygen**
3. require water
4. utilize carbohydrates

SOLUTION

A cell that lacks chloroplast does not **liberate oxygen.**

Exercise | Q 1. (B) | Page 149

Choose the correct option.

Energy is transferred from the light reaction step to the dark reaction step by ______.

1. chlorophyll
2. ADP
3. **ATP**
4. RuBP

SOLUTION

Energy is transferred from the light reaction step to the dark reaction step by **ATP.**

Exercise | Q 1. (C) | Page 149

Choose the correct option.

Which one is wrong in photorespiration.

1. It occurs in chloroplasts
2. It occurs in day time only
3. **It is characteristic of C_4 -plants**
4. It is characteristic of C_3 -plants

SOLUTION

It is characteristic of C_4 -plants

Exercise | Q 1. (D) | Page 149

Choose the correct option.

Non-cyclic photophorylation differs from cyclic photophosphorylation in that former.

1. Involves only PS I
2. Include evolution of O_2
3. Involves formation of assimilatory power
4. **both include evolution of O_2 and involves formation of assimilatory power**

SOLUTION

both include evolution of O_2 and involves formation of assimilatory power.

Exercise | Q 1. (E) | Page 149

Choose the correct option.

For fixation of 6 molecules of CO_2 and formation of one molecule of glucose in Calvin cycle, requires

1. 3 ATP and 2 $NADPH_2$
2. **18 ATP and 12 $NADPH_2$**
3. 30 ATP and 18 $NADPH_2$
4. 6 ATP and 6 $NADPH_2$

SOLUTION

18 ATP and 12 $NADPH_2$

Exercise | Q 1. (F) | Page 149

Choose the correct option.

In maize and wheat, the first stable products formed in bundle sheath cells respectively are ________.

1. OAA and PEPA
2. OAA and OAA
3. **OAA and 3PGA**
4. 3PGA and OAA

SOLUTION

In maize and wheat, the first stable products formed in bundle sheath cells respectively are **OAA and 3PGA.**

Exercise | Q 1. (G) | Page 149

Choose the correct option.

C_4 pathway is also called as dicarboxylation pathway because ______.

1. RuBP + CO_2 in bundle sheath cells
2. **PEPA + CO_2 in mesophyll cells**
3. both RuBP + CO_2 in bundle sheath cells and PEPA + CO_2 in mesophyll cells
4. It occurs in presence of intensive light H. The head and tail of chlorophyll are

SOLUTION

C_4 pathway is also called as dicarboxylation pathway because **PEPA + CO_2 in mesophyll cells.**

Exercise | Q 1. (H) | Page 149

Choose the correct option.

The head and tail of chlorophyll are made up of ______.

1. porphyrin and phytin respectively
2. pyrrole and tetrapyrrole respectively
3. **porphyrin and phytol respectively**

4. tetrapyrole and pyrrole respectively

SOLUTION

The head and tail of chlorophyll are made up of **porphyrin and phytol respectively**.

Exercise | Q 1. (I) | Page 149
Choose the correct option.
The net result of photo-oxidation of water is release of ______.

1. electron and proton
2. proton and oxygen
3. **proton, electron and oxygen**
4. electron and oxygen

SOLUTION

The net result of photo-oxidation of water is release of **proton, electron and oxygen.**

Exercise | Q 1. (J) | Page 149
Choose the correct option.
For fixing one molecule of CO_2 in Calvin cycle _______ are required.

1. 3ATP + 1$NADPH_2$
2. **3ATP + 2$NADPH_2$**
3. 2ATP + 3$NADPH_2$
4. 3ATP + 3$NADPH_2$

SOLUTION

For fixing one molecule of CO_2 in Calvin cycle **3ATP + 2$NADPH_2$** are required.

Exercise | Q 1. (K) | Page 149
Choose the correct option.
In presence of high concentration of oxygen, RuBP carboxylase converts RuBP to ______.

1. Malic acid and PEP
2. PGA and PEP
3. PGA and malic acid
4. **PGA and phosphoglycolate**

SOLUTION

In presence of high concentration of oxygen, RuBP carboxylase converts RuBP to **PGA and phosphoglycolate.**

Exercise | Q 1. (K) | Page 149
Choose the correct option.
In presence of high concentration of oxygen, RuBP carboxylase converts RuBP to ______.

1. Malic acid and PEP

2. PGA and PEP
3. PGA and malic acid
4. **PGA and phosphoglycolate**

SOLUTION

In presence of high concentration of oxygen, RuBP carboxylase converts RuBP to **PGA and phosphoglycolate.**

Exercise | Q 1. (L) | Page 149

Choose the correct option.

The sequential order in electron transport from PSII to PSI of photosynthesis is ______.

1. FeS, PQ, PC and Cytochrome
2. FeS, PQ, Cytochrome and PC
3. **PQ, Cytochrome, PC and FeS**
4. PC, Cytochrome, FeS, PQ

SOLUTION

The sequential order in electron transport from PSII to PSI of photosynthesis is **PQ, Cytochrome, PC and FeS.**

Exercise | Q 2. (A) | Page 150

Answer the following question.

Describe the light-dependent steps of photosynthesis. How are they linked to the dark reactions?

SOLUTION

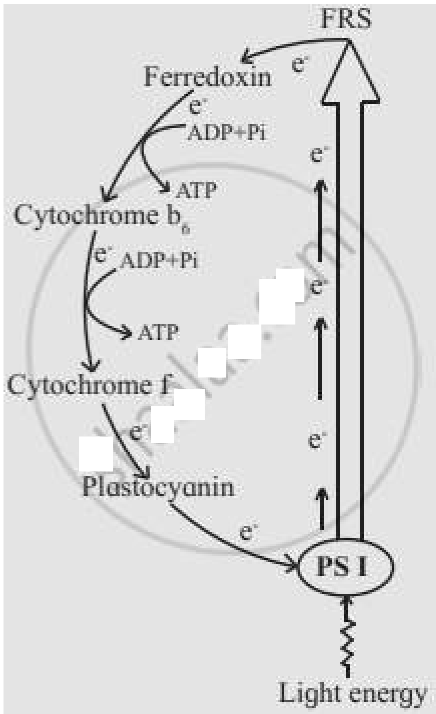
The light-dependent steps of photosynthesis include cyclic and non-cyclic photophosphorylation.

- **Cyclic photophosphorylation:**

1. Illumination of photosystem-I causes electrons to move continuously out of the reaction center of photosystem-I and back to it.

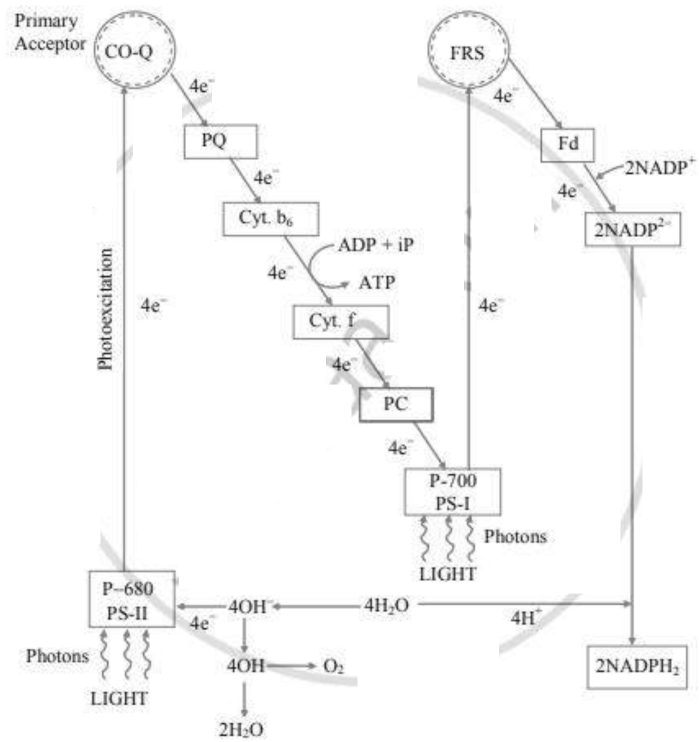
2. The cyclic electron-flow is accompanied by the photophosphorylation of ADP to yield ATP. This is termed as Cyclic photophosphorylation.

3. Since this process involves only pigment system I, photolysis of water and consequent evolution of oxygen does not take place.



- **Non-cyclic photophosphorylation:**

1. It involves both photosystems- PS-I and PS-II.
2. In this case, electron transport chain starts with the release of electrons from PS-II.
3. In this chain high energy electrons released from PS-II do not return to PS-II but, after passing through an electron transport chain, reach PS-I, which in turn donates it to reduce $NADP^+$ to NADPH.
4. The reduced $NADP^+$ (NADPH) is utilized for the reduction of CO_2 in the dark reaction.
5. Electron-deficient PS-II brings about oxidation of water-molecule. Due to this, protons, electrons and oxygen atom are released.
6. Electrons are taken up by PS-II itself to return to reduced state, protons are accepted by $NADP^+$ whereas oxygen is released.
7. As in this process, high energy electrons released from PS-II do not return to PS-II and it is accompanied with ATP formation, this is called Non-cyclic photophosphorylation.



where CO-Q: Co-enzyme quinone
FRS: Ferredoxin Reducing Substance
PC: Plastocyanin
PQ: Plastoquinone
Cyt: Cytochrome
Fd: Ferredoxin.

- **Link between light-dependent and dark reactions:**
  Link between light-dependent and dark reactions: The light reaction gives rise to two important products, a reducing agent $NADPH_2$ and an energy-rich compound ATP. Both these are utilized in the dark phase of photosynthesis.

  ATP and $NADPH_2$ molecules function as vehicles for the transfer of energy of sunlight into dark reaction leaving to carbon fixation. In this reaction, CO_2 is reduced to carbohydrates.

  During dark reaction, ATP and $NADPH_2$ are transformed into ADP, iP and NADP which are transferred to the grana in which light reaction takes place.

Exercise | Q 2. (B) (a) | Page 150

Distinguish between Respiration and Photorespiration.

SOLUTION

	Respiration	**Photorespiration**

1.	Occurs in all aerobic and anaerobic organisms.	Occurs in C_3 plants under high temperature, bright light, high oxygen and low CO_2 concentration.
2.	A light-independent process occurs in both the presence and absence of light.	A light-dependent process occurs in presence of light.
3.	Produce energy-rich molecules like ATP, GTP, $FADH_2$, $NADH_2$.	Do not produce energy-rich molecules such as ATP.
4.	Respiration is an energy-producing process.	Photorespiration is an energy wastage process.

Exercise | Q 2. (B) (b) | Page 150

Distinguish between action spectrum and absorption spectrum.

SOLUTION

	Action Spectrum	**Absorption Spectrum**
1.	The curve that shows the rate of photosynthesis at different wavelengths is called action spectrum.	The curve which shows the amount of light absorbed by pigments at each wavelength is termed as absorption spectrum
2.	It explains the relationship between photosynthetic activity in relation to different wavelengths of light.	It explains the relationship between quality of light and absorbing capacity of the pigments.
3.	In action spectrum, the rate of photosynthesis is measured as amount of CO_2 fixation, oxygen production, $NADP^+$ reduction.	In absorption spectrum, absorption of different wavelengths of light pigments can be measured by spectrophotometer.

Exercise | Q 2. (B) (c) | Page 150

Distinguish between Cyclic photophosphorylation and Non-cyclic photophosphorylation.

SOLUTION

	Cyclic photophosphorylation	**Non – cyclic photophosphorylation**
1.	Electrons emitted by chlorophyll return back to the same chlorophyll.	The electrons emitted by chlorophyll do not return back to the same chlorophyll.
2.	First electron acceptor is FRS.	First electron acceptor is CO - Q
3.	It forms the only ATP.	$NADPH_2$ and ATP are formed.

4.	Does not involve photolysis of H_2O.	Involves photolysis of H_2O.
5.	No evolution of O_2.	There is evolution of O_2.
6.	Only Photosystem-I (P700) is involved in this cycle.	Both Photosystem PS-I (P700) as well as PS-II (P680) are involved.

Exercise | Q 2. (C) | Page 150

Answer the following question.
What are the steps that are common to C_3 and C_4 photosynthesis?

SOLUTION

Steps that are common to C_3 and C_4 photosynthesis are Carboxylation, Reduction, Glucose synthesis, Regeneration.

Exercise | Q 2. (D) | Page 150

Answer the following question.
Are the enzymes that catalyze the dark reactions of carbon fixation located inside the thylakoids or outside the thylakoids?

SOLUTION

Carbon fixation occurs in the stroma by series of enzyme catalyzed steps. The enzymes that catalyze the dark reactions of carbon fixation are located outside the thylakoids.

Exercise | Q 2. (E) | Page 150

Answer the following question.
Calvin cycle consists of three phases, what are they?

SOLUTION

The entire process of dark reaction was traced by Dr. Melvin Calvin along with his co-worker, Dr. Benson. Hence, the process is called as Calvin cycle or Calvin- Benson cycle. Since the first stable product formed is a 3-carbon compound, it is also called as C_3 pathway and the plants are called C_3 plants. Calvin carried out experiments on unicellular green algae (Chlorella), using a radioactive isotope of carbon, C_{14} as a tracer.

It is also called the synthesis phase or second phase of photosynthesis.

The cycle is divided into the following phases:

- **Carboxylation phase:**

1. Carbon dioxide reduction starts with a five-carbon sugar ribulose-1,5-bisphosphate (RuBP). It is a 5- carbon sugar with two phosphate groups attached to it.
2. RuBP reacts with CO_2 to produce an unstable 6 carbon intermediate in the presence of Rubisco.

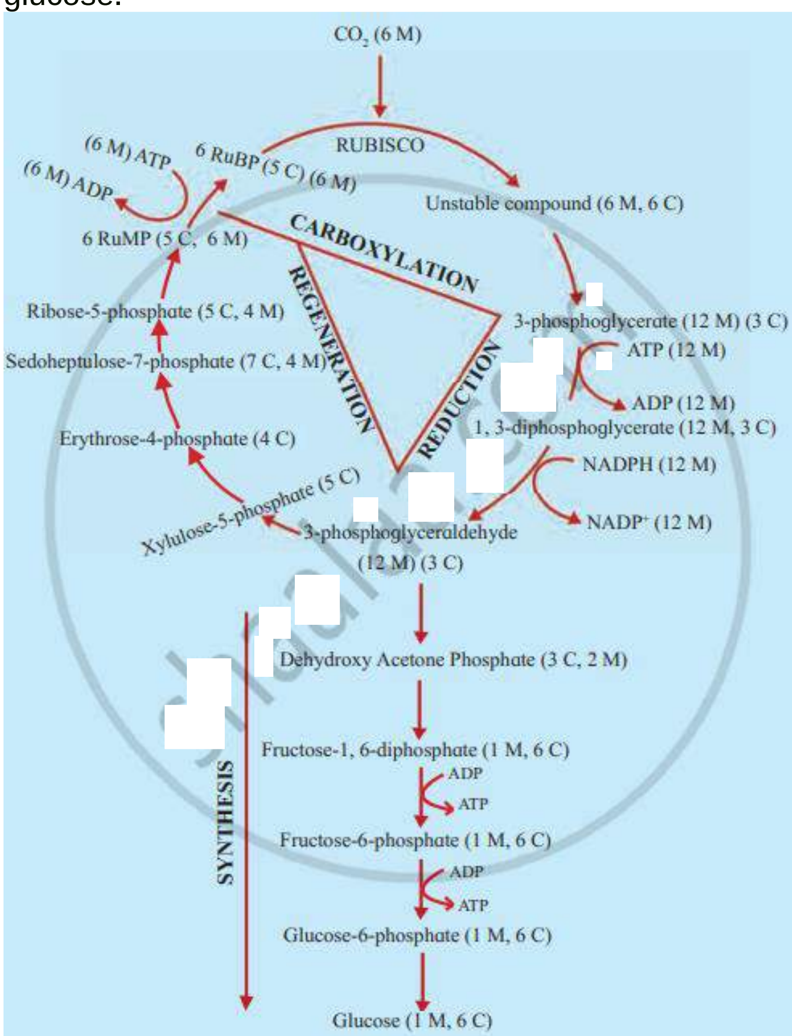
3. It immediately splits into 3 carbon compounds called 3-phosphoglyceric acid.
4. RuBisCO is a large protein molecule and comprises 16% of the chloroplast proteins.

- **Glycolytic reversal:**

1. 3-phosphoglyceric acid form 1,3-diphosphoglyceric acid by utilizing ATP molecule.
2. These are then reduced to glyceraldehyde-3-phosphate (3-PGA) by NADPH supplied by the light reactions of photosynthesis.
3. In order to keep Calvin cycle continuously running there must be a sufficient number of RuBP and a regular supply of ATP and NADPH.
4. Out of 12 molecules of 3-phosphoglyceraldehyde, two molecules are used for the synthesis of one glucose molecule.

- **Regeneration of RuBP:**

1. 10 molecules of 3-phosphoglyceraldehyde are used for the regeneration of 6 molecules of RuBP at the cost of 6 ATP.
2. Therefore, six turns of the Calvin cycle are needed to get one molecule of glucose.



Calvin cycle and regeneration of RuBP

Exercise | Q 2. (F) | Page 150

Answer the following question.
Why are plants that consume more than the usual 18 ATP to produce 1 molecule of glucose favoured in tropical regions?

SOLUTION

1. C_4 plants are favoured in tropical regions as they require 30 ATP to produce 1 molecule of glucose.
2. The high temperature in tropical regions leads to closure of stomata to reduce the rate of transpiration. Due to this availability of CO_2 decreases.
3. PEP carboxylase present in mesophyll cells can fix CO_2 even at low concentration. This helps the plant inefficient assimilation of atmospheric carbon dioxide.
4. C_4 plants contain special leaf anatomy called Kranz anatomy which minimizes the losses due to photorespiration.
5. It helps C_4 plants to survive in conditions of high daytime temperatures, intense sunlight and low moisture.

Exercise | Q 2. (G) | Page 150

Answer the following question.
What is the advantage of having more than one pigment molecule in a photocenter?

SOLUTION

Advantages of having more pigment molecules in a photo center are as follows:

1. Having more than one pigment molecule in photocenter means more sunlight being captured and thus facilitating more effective light reaction.
2. It will provide protection to chlorophyll molecule against photo-oxidation.
3. More pigments will capture more energy to start the initial reactions, which is not possible by a single pigment.

Exercise | Q 2. (H) | Page 150

Answer the following question.
Why does chlorophyll appear green in reflected light and red transmitted light? Explain the significance of these phenomena in terms of photosynthesis.

SOLUTION

1. Chlorophyll is a light-absorbing pigment. It absorbs light in red and blue regions of the visible light spectrum. The absorption spectrum of chlorophyll for red light is maximum so chlorophyll appears red in transmitted light. Greenlight is not absorbed but reflected so chlorophyll appears green in reflected light.
2. Chlorophyll predominantly absorbs red and violet-blue light and it allows plants to use this light as a form of energy for the photosynthesis process.

3. It is the most effective wavelength of light in photosynthesis as it has the exactly the right amount of energy to excite electrons of chlorophyll and boost them out of their orbits to higher energy levels.

Exercise | Q 2. (I) | Page 150

Answer the following question.
Explain why photosynthesis is considered the most important process in the biosphere.

SOLUTION

Photosynthesis is considered to be the most important process in the biosphere due to the following reasons:

1. Photosynthesis is the biochemical process through which all plants (primary producers) produce food.
2. It is responsible for the release of oxygen into the atmosphere.
3. Heterotrophs are directly or indirectly dependent on autotrophs for energy and other related resources.
   Therefore, photosynthesis is considered the most important process in the biosphere.

Exercise | Q 2. (J) | Page 150

Answer the following question.
Why is photolysis of water accompanied with non-cyclic photophosphorylation?

SOLUTION

1. Photolysis of water provides new electrons to Photosystem – II.
2. The water molecule is lysed into three components:
   a. Protons (H^+) which are used as part of reactions that make NADPH.
   b. The Second component formed is electrons which replaces the electrons lost by PS-II.
   c. The third component is oxygen (O_2) which is released into the atmosphere.
3. Photosystem I sends electrons to reduce $NADP^+$.
4. Then, Photosystem II sends replacement electrons to Photosystem I.
5. Finally, the photolysis of water replaces the electrons lost by Photosystem II.
6. Water is the ultimate source of electrons for photosynthesis.
   Therefore, the photolysis of water is accompanied by non – cyclic photophosphorylation.

Exercise | Q 2. (K) | Page 150

Answer the following question.
In C-4 plants, why is C-3 pathway operated in bundle sheath cells only?

SOLUTION

1. Decarboxylation of malic acid occurs in bundle sheath cells of C_4 plants. Due to which concentration of CO_2 increases in bundle sheath cells.
2. The enzymes required for the Calvin cycle i.e. RuBisCO are present in bundle sheath cells.
3. In presence of a high concentration of CO_2, RuBisCO acts as a carboxylase and brings about carboxylation of RuBP. Hence, in C-4 plants, C-3 pathway is operated in bundle sheath cells only.

Exercise | Q 2. (L) | Page 150

Answer the following question.
What would have happed if C-4 plants did not have Kranz anatomy?

SOLUTION

Photorespiration would occur if C_4 plants did not have Kranz anatomy.

Exercise | Q 2. (M) | Page 150

Answer the following question.
Why does RuBisCO carry out preferentially carboxylation than oxygenation in C_4 plants?

SOLUTION

1. In C_4 plants, CO_2 taken from the atmosphere is accepted by a 3-carbon compound, phosphoenolpyruvic acid in the chloroplasts of mesophyll cells.
2. This leads to the formation of 4-carbon compound oxaloacetic acid with the help of enzyme phosphoenolpyruvate carboxylase.
3. It is converted to another 4-carbon compound called malate.
4. Malate is transported to chloroplasts of bundle sheath cells where malate is converted to pyruvate and releases CO_2 in the cytoplasm thus increasing the concentration of CO_2 in the bundle sheath cells.
5. Chloroplasts of bundle sheath cells contain enzymes of the Calvin cycle. Thus, due to the high concentration of CO_2, RuBisCO participates in carboxylation and not in oxygenation.

Exercise | Q 2. (N) | Page 150

Answer the following question.
What would have happened if plants did not have accessory pigments?

SOLUTION

1. Accessory pigments are light-absorbing molecules which are found in photosynthetic organisms.
2. They transfer the absorbed light to chlorophyll-a and thus increasing the photosynthetic rate.
3. In absence of accessory pigments, less amount of light will be absorbed and also there would be no protection provided to chlorophyll molecule from photo-oxidation.

Exercise | Q 2. (O) | Page 150

Answer the following question.
How can you identify whether the plant is C_3 or C_4? Explain / Justify.

SOLUTION

1. By observing the cross-section of a leaf we can identify whether the plant is a C_3 plant or a C_4 plant.
2. C_4 plants possess special anatomy of leaves called Kranz anatomy. In Kranz anatomy, two types of chloroplasts are present, agranal in bundle sheath cells and granal in mesophyll cells.
3. In C_3 plants Kranz anatomy is absent.

Exercise | Q 2. (P) | Page 150

Answer the following question.
In C_4 plants, bundle sheath cells carrying out the Calvin cycle are very few in number. Then also, C_4 plants are highly productive. Explain.

SOLUTION

1. C_4 plants have a special type of leaf anatomy called Kranz anatomy.
2. In C_4 plants, CO_2 fixation occurs twice.
3. In these plants, chloroplasts of mesophyll cells contain the enzyme PEP carboxylase which fixes atmospheric CO_2. Thus, first CO_2 fixation occurs in mesophyll cells.
4. Decarboxylation of malic acid in bundle sheath cells results in an increase in CO_2 concentration.
5. Thus, RuBisCO acts as carboxylase and brings about carboxylation of RuBP.
6. Due to this oxygenation of RuBP and photorespiration is prevented.
   Thus, despite of having less number of bundle sheath cells carrying out Calvin cycle, C_4 plants are highly productive.

Exercise | Q 2. (Q) | Page 150

Answer the following question.
What is the functional significance of Kranz anatomy?

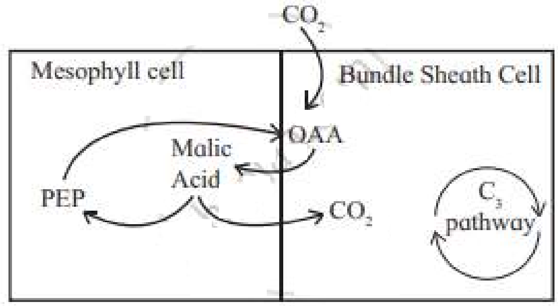
SOLUTION

1. Leaves of C_4 plants show some structural peculiarities called Kranz anatomy.
2. The chloroplast of mesophyll cells contains the enzyme PEP Carboxylase, which can fix CO_2 at low concentration.
3. Thus, light reaction and evolution of O_2 occur in mesophyll cells.
4. Decarboxylation of malate occurs in bundle sheath cells, which results in release of CO_2, due to which concentration of CO_2 in bundle sheath cells increases.

5. Enzyme RuBisCO present in bundle sheath cells acts as carboxylase in presence of high CO_2 concentration and catalyzes the carboxylation of RuBP.
6. Thus, the possibility of oxygenation of RuBP is avoided and photorespiration does not take place.

Exercise | Q 3 | Page 150

Correct the pathway and name it.



SOLUTION

The pathway shown is C_4 pathway.

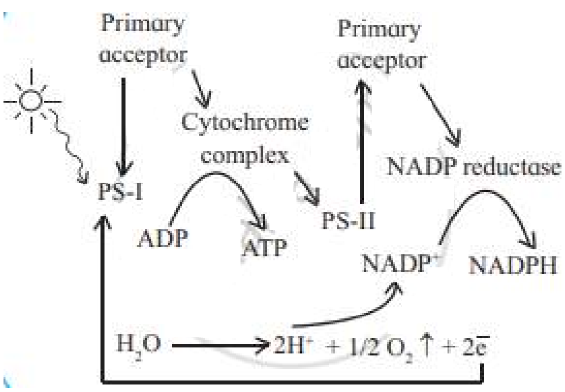
M. D. Hatch and C. R. Slack while working on sugarcane found four-carbon compounds (dicarboxylic acid) as the first stable product of photosynthesis.
It occurs in tropical and sub-tropical grasses and some dicotyledons.
The first product of this cycle is a 4-carbon compound oxaloacetic acid. Hence it is also called as C_4 pathway and plants are called C_4 plants. Mechanism:

1. CO_2 taken from the atmosphere is accepted by a 3-carbon compound, phosphoenolpyruvic acid in the chloroplasts of mesophyll cells, leading to the formation of 4-C compound, oxaloacetic acid with the help of enzyme phosphoenolpyruvate carboxylase.
2. It is converted to another 4-C compound, malic acid.
3. It is transported to the chloroplasts of bundle sheath cells.
4. Malic acid (4-C) is converted to pyruvic acid (3-C) with the release of CO_2 in the cytoplasm.
5. Thus, the concentration of CO_2 increases in the bundle sheath cells.
6. Chloroplasts of these cells contain enzymes of the Calvin cycle.
7. Because of the high concentration of CO_2, RuBP carboxylase participates in the Calvin cycle and not photorespiration.

8. Sugar formed in the Calvin cycle is transported into the phloem.
9. Pyruvic acid generated in the bundle sheath cells re-enter mesophyll cells and regenerates phosphoenolpyruvic acid by consuming one ATP.
10. Since this conversion results in the formation of AMP (not ADP), two ATP are required to regenerate ATP from AMP.
11. Thus, C_4 pathway needs 12 additional ATP.
12. The C_3 pathway requires 18 ATP for the synthesis of one glucose molecule, whereas C_4 pathway requires 30 ATP. Thus, C_4 plants are better photosynthesizers as compared to C_3 plants as there is no photorespiration in these plants.

Exercise | Q 4 | Page 150

Is there something wrong with following the schematic presentation? If yes, correct it so that photosynthesis will be operated.



SOLUTION

1. It involves both photosystems- PS-I and PS-II.
2. In this case, the electron transport chain starts with the release of electrons from PS-II.
3. In this chain high energy electrons released from PS-II do not return to PS-II but, after passing through an electron transport chain, reach PS-I, which in turn donates it to reduce $NADP^+$ to NADPH.
4. The reduced $NADP^+$ (NADPH) is utilized for the reduction of CO_2 in the dark reaction.
5. Electron-deficient PS-II brings about oxidation of water-molecule. Due to this, protons, electrons, and an oxygen atom are released.
6. Electrons are taken up by PS-II itself to return to a reduced state, protons are accepted by $NADP^+$ whereas oxygen is released.

7. As in this process, high energy electrons released from PS-II do not return to PS-II and it is accompanied with ATP formation, this is called Non-cyclic photophosphorylation.