

## Chapter 12: Photosynthesis

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### 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<sub>4</sub> -plants**
4. It is characteristic of C<sub>3</sub> -plants

### SOLUTION

It is characteristic of C<sub>4</sub> -plants

#### Exercise | Q 1. (D) | Page 149

Choose the correct option.

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

1. Involves only PS I
2. Include evolution of O<sub>2</sub>
3. Involves formation of assimilatory power
4. **both include evolution of O<sub>2</sub> 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. tetrapyrrole 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  $\text{CO}_2$  in Calvin cycle \_\_\_\_\_ are required.

1.  $3\text{ATP} + 1\text{NADPH}_2$
2.  **$3\text{ATP} + 2\text{NADPH}_2$**
3.  $2\text{ATP} + 3\text{NADPH}_2$
4.  $3\text{ATP} + 3\text{NADPH}_2$

#### **SOLUTION**

For fixing one molecule of  $\text{CO}_2$  in Calvin cycle  $3\text{ATP} + 2\text{NADPH}_2$  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.**

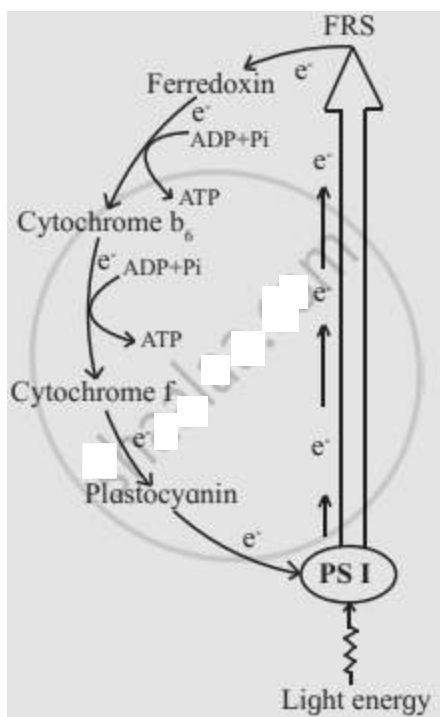
Describe the light-dependent steps of photosynthesis. How are they linked to the dark reactions?

#### **SOLUTION**

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

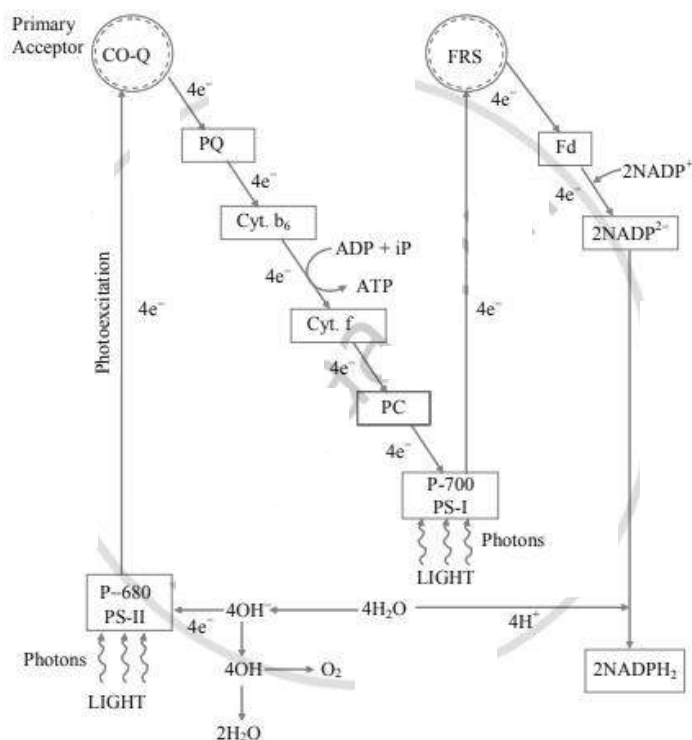
- **Cyclic photophosphorylation:**

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  $\text{NADP}^+$  to NADPH.
4. The reduced  $\text{NADP}^+$  (NADPH) is utilized for the reduction of  $\text{CO}_2$  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  $\text{NADP}^+$  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<sub>2</sub> and an energy-rich compound ATP. Both these are utilized in the dark phase of photosynthesis.

ATP and NADPH<sub>2</sub> molecules function as vehicles for the transfer of energy of sunlight into dark reaction leaving to carbon fixation. In this reaction, CO<sub>2</sub> is reduced to carbohydrates.

During dark reaction, ATP and NADPH<sub>2</sub> 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
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1.	Occurs in all aerobic and anaerobic organisms.	Occurs in C <sub>3</sub> plants under high temperature, bright light, high oxygen and low CO <sub>2</sub> 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 <sub>2</sub> , NADH <sub>2</sub> .	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**

	<b>Action Spectrum</b>	<b>Absorption Spectrum</b>
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 <sub>2</sub> fixation, oxygen production, NADP <sup>+</sup> 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**

	<b>Cyclic photophosphorylation</b>	<b>Non – cyclic photophosphorylation</b>
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 <sub>2</sub> 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.

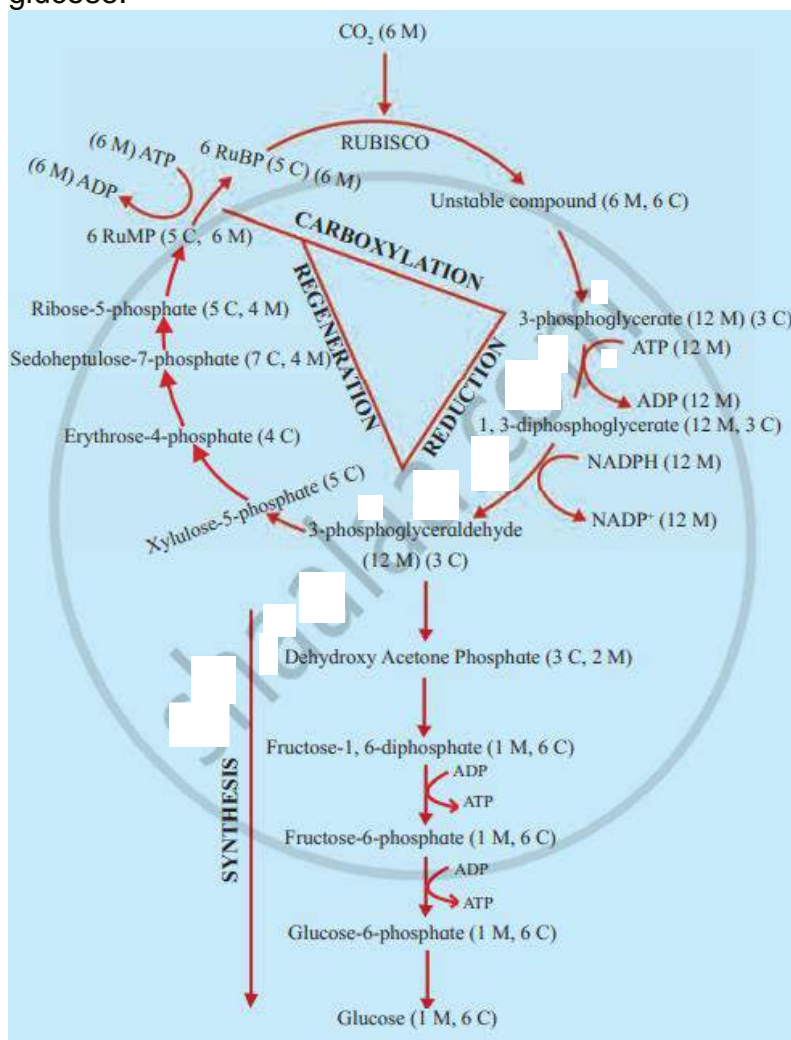
**The cycle is divided into the following phases:**

- **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<sub>4</sub> 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<sub>2</sub> decreases.
3. PEP carboxylase present in mesophyll cells can fix CO<sub>2</sub> even at low concentration. This helps the plant in efficient assimilation of atmospheric carbon dioxide.
4. C<sub>4</sub> plants contain special leaf anatomy called Kranz anatomy which minimizes the losses due to photorespiration.
5. It helps C<sub>4</sub> 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. Green light 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 happened 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**

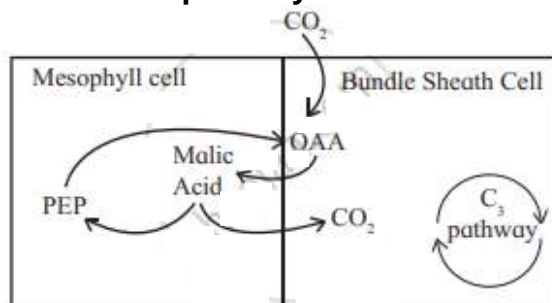
1. Leaves of  $C_4$  plants show some structural peculiarities called Kranz anatomy.
2. The chloroplast of mesophyll cells contains the enzyme PEP Carboxylase, which can fix  $CO_2$  at low concentration.
3. Thus, light reaction and evolution of  $O_2$  occur in mesophyll cells.
4. Decarboxylation of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



- Enzyme RuBisCO present in bundle sheath cells acts as carboxylase in presence of high  $\text{CO}_2$  concentration and catalyzes the carboxylation of RuBP.
- 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<sub>4</sub> 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<sub>4</sub> pathway and plants are called C<sub>4</sub> plants. Mechanism:

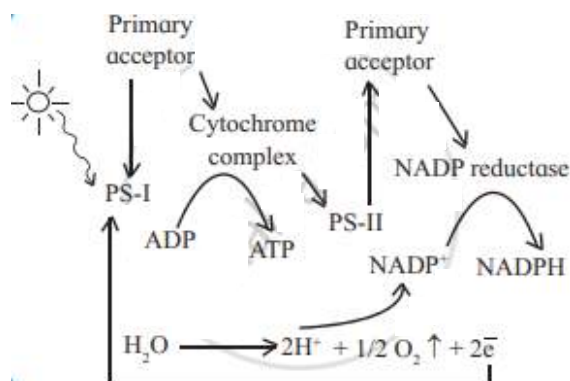
- $\text{CO}_2$  taken from the atmosphere is accepted by a 3-carbon compound, phosphoenolpyruvic acid in the chloroplasts of mesophyll cells, leading to the formation of 4-C compound, oxaloacetic acid with the help of enzyme phosphoenolpyruvate carboxylase.
- It is converted to another 4-C compound, malic acid.
- It is transported to the chloroplasts of bundle sheath cells.
- Malic acid (4-C) is converted to pyruvic acid (3-C) with the release of  $\text{CO}_2$  in the cytoplasm.
- Thus, the concentration of  $\text{CO}_2$  increases in the bundle sheath cells.
- Chloroplasts of these cells contain enzymes of the Calvin cycle.
- Because of the high concentration of  $\text{CO}_2$ , 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<sub>4</sub> pathway needs 12 additional ATP.
12. The C<sub>3</sub> pathway requires 18 ATP for the synthesis of one glucose molecule, whereas C<sub>4</sub> pathway requires 30 ATP. Thus, C<sub>4</sub> plants are better photosynthesizers as compared to C<sub>3</sub> 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<sup>+</sup> to NADPH.
4. The reduced NADP<sup>+</sup> (NADPH) is utilized for the reduction of CO<sub>2</sub> 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<sup>+</sup> 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.