AllGuideSite :
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Maharashtra State Board 11th Biology Solutions Chapter 12 Photosynthesis

1. Choose correct option

Question (A)
A cell that lacks chloroplast does not
(a) evolve carbon dioxide
(b) liberate oxygen
(c) require water
(d) utilize carbohydrates
Answer:
(b) liberate oxygen

Question (B)
Energy is transferred from the light reaction step to the dark reaction step by
(a) chlorophyll
(b) ADP
(c) ATP
(d) RuBP
Answer:
(c) ATP

Question (C)
Which one is wrong in photorespiration?
(a) It occurs in chloroplasts
(b) It occurs in day time only
(c) It is characteristic of C_4-plants
(d) It is characteristic of C_3-plants
Answer:
(c) It is characteristic of C_4-plants

Question (D)
Non-cyclic phosphorylation differs from cyclic photophosphorylation in that former
(a) involves only PS
(b) Include evolution of 02
(c) involves formation of assimilatory power
(d) both (b) and (c)
Answer:
(d) both (b) and (c)

Question (E)
For fixation of 6 molecules of $C0_2$ and formation of one molecule of glucose in Calvin cycle, requires
(a) 3 ATP and 2 MADPPE
(b) 18 ATP and 12 $NADPH_2$
(c) 30 ATP and 18 $NADPH_2$
(d) 6 ATP and 6 $NADPIT_2$
Answer:
(b) 18 ATP and 12 $NADPH_2$

Question (F)
In maize and wheat, the first stable products formed in bundle sheath cells respectively are
(a) OAA and PEPA
(b) OAA and OAA
(c) OAA and 3PGA
(d) 3PGA and OAA
Answer:
(c) OAA and 3PGA

Question (G)
The head and tail of chlorophyll are made up of
(a) porphyrin and phytin respectively
(b) pyrrole and tetrapyrrole respectively
(c) porphyrin and phytol respectively
(d) tetrapyrole and pyrrole respectively

Answer:
(c) porphyrin and phytol respectively

Question (H)
The net result of photo-oxidation of water is release of ....
(a) electron and proton
(b) proton and oxygen
(c) proton, electron and oxygen
(d) electron and oxygen
Answer:
(c) proton, electron and oxygen

Question (I)
For fixing one molecule of $C0_2$ in Calvin cycle are required.
(a) 3ATP + 1NADPFE
(b) 3ATP + $2NADPH_2$
(c) 2ATP + $3NADPH_2$
(d) 3ATP + 3NADPFE
Answer:
(b) 3ATP + $2NADPH_2$

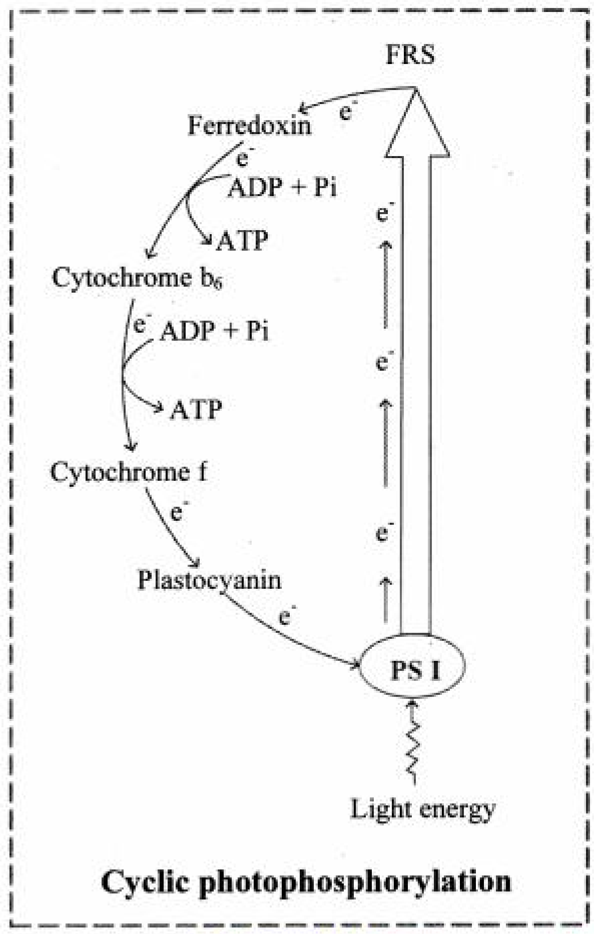
Question (J)
In presence of high concentration of oxygen, RuBP carboxylase converts RuBP to ....
(a) Malic acid and PEP
(b) PGA and PEP
(c) PGA and malic acid
(d) PGA and phosphoglycolate
Answer:
(d) PGA and phosphoglycolate

Question (K)
The sequential order in electron transport from PSII to PSI of photosynthesis is
(a) FeS, PQ, PC and Cytochrome
(b) FeS, PQ, Cytochrome and PC
(c) PQ, Cytochrome, PC and FeS
(d) PC, Cytochrome, FeS, PQ
Answer:
(c) PQ, Cytochrome, PC and FeS

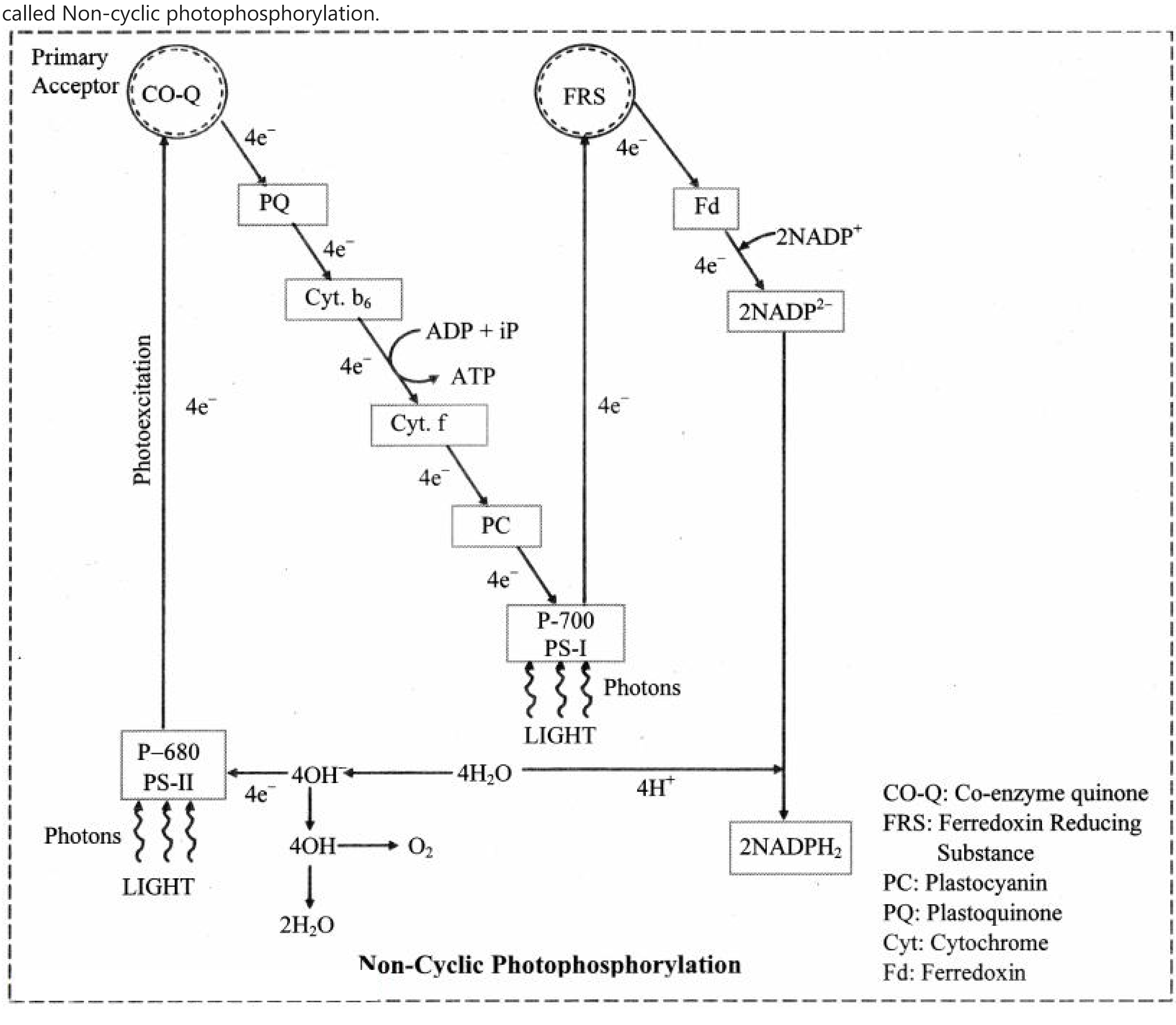
2. Answer the following questions

Question (A)
Describe the light-dependent steps of photosynthesis. How are they linked to dark reactions?
Answer:
The light dependent steps of photosynthesis include cyclic and non-cyclic photophosphorylation,
1. Cyclic photophosphorylation:
a. Illumination of photosystem-I causes electrons to move continuously out of the reaction center of photosystem-I and back to it.
b. The cyclic electron-flow is accompanied by the photophosphorylation of ADP to yield ATP. This is termed as Cyclic photophosphorylation.

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



2. Non-cyclic photophosphorylation:
a. It involves both photosystems- PS-I and PS-II.
b. In this case, electron transport chain starts with the release of electrons from PS-II.
c. 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.
d. The reduced NADP+ (NADPH) is utilized for the reduction of CO_2 in the dark reaction.
e. Electron-deficient PS-II brings about oxidation of water-molecule. Due to this, protons, electrons and oxygen atom are released.
f. Electrons are taken up by PS-II itself to return to reduced state, protons are accepted by NADP+ whereas oxygen is released.
g. 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.



3. Link between light-dependent and dark reactions:

1. 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.
2. ATP and $NADPH_2$ molecules function as vehicles for transfer of energy of sunlight into dark reaction leaving to carbon fixation. In this reaction $C0_2$ is reduced to carbohydrate.
3. 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.

(B)

Question (a)
Distinguish between Respiration and Photorespiration
Answer:

Respiration	Photorespiration
1. Occurs in all aerobic and anaerobic organisms.	Occurs in C_3 plants under high temperature, bright light, high oxygen and low $C0_2$ concentration.
2. A light independent process, occurs in both presence and absence of light.	A light dependent process, occurs in presence of Jight.
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.

Question (b)
Distinguish between Cyclic photophosphorylation and Non-cyclic photophosphorylation
Answer:

Cyclic photophosphorylation	Non – cyclic photophosphorvlution
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 only ATP.	$NADPH_2$ and ATP are formed.
4. Does not involve photolysis of H_20.	Involves photolysis of H_20.
5. No evolution of 0_2.	There is evolution of 0_2.
6. Only Photosystem-I (P700) is involved in this cycle.	Both Photosystem PS-I (P700) as well as PS-II (P680) are involved.

Question (C)
Answer the following questions.
1. What are the steps that are common to C_3 and C_4 photosynthesis?
2. Differentiate between C_3 and C_4 plants.
Answer:
Steps that are common to C_3 and C_4 photosynthesis are Carboxylation, Reduction, Glucose synthesis, Regeneration.
[Note: Students are expected to refer the given Q.R code for detail understanding the common steps between C_1 and C_4 plants.]

Question (D)
Are the enzymes that catalyze the dark reactions of carbon fixation located inside the thylakoids or outside the thylakoids?
Answer:
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.

Question (E)
Calvin cycle consists of three phases, what are they? Explain the significance of each of them.
Answer:
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_{14} plants.
Calvin carried out experiments on unicellular green algae (Chlorella), using radioactive isotope of carbon, C_{14} as a tracer.
It is also called synthesis phase or second phase of photosynthesis.

The cycle is divided into the following phases:
1. Carboxylation phase:
a. Carbon dioxide reduction starts with a five-carbon sugar ribulose-l,5-bisphosphate (RuBP). It is a 5- carbon sugar with two phosphate groups attached to it.
b. RuBP reacts with CO_2 to produce an unstable 6 carbon intermediate in the presence of Rubisco.
c. It immediately splits into 3 carbon compounds called 3-phosphoglyceric acid.
d. RuBisCO is a large protein molecule and comprises 16% of the chloroplast proteins.

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

3. Regeneration of RuBP:
a. 10 molecules of 3-phosphoglyceraldehyde are used for the regeneration of 6 molecules of RuBP at the cost of 6 ATP.
b. Therefore, six turns of Calvin cycle are needed to get one molecule of glucose.
Significance:
1. Carboxylation: RuBisCO is the most abundant enzyme in the world. It is responsible for fixing carbon in the form of $C0_2$ into sugar. As a result of Carboxylation, the first stable product of carbon fixation i.e. 3- PGA is synthesized.
2. Reduction/Glycolytic reversal: NADPH2 donates electrons to 1, 3-Bisphoshoglycerate to form 3- phosphoglyceraldehyde molecules. During this process ADP and NADP are generated which are used in light reaction.
3. Regeneration of RuBP: Some 3-phosphoglyceraldehyde molecules are involved in production of glucose while others are recycled to regenerate the 5-carbon compound RuBP which used to accept new carbon molecules. Thus, regeneration of RuBP is required for Calvin cycle to run continuously.

Question (F)
Why are plants that consume more than the usual 18 ATP to produce 1 molecule of glucose favoured in tropical regions?
Answer:

1. C_4 plants are favoured in tropical regions as they require 30 ATP to produce 1 molecule of glucose.
2. High temperature in tropical regions leads to closure of stomata to reduce rate of transpiration. Due to this availability of $C0_2$ decreases.
3. PEP carboxylase present in mesophyll cells can fix $C0_2$ even at low concentration. This helps the plant in efficient assimilation of atmospheric carbon dioxide.
4. C_4 plants contain a 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.

Question (G)
What is the advantage of having more than one pigment molecule in a photocenter?
Answer:
Advantages of having more pigment molecules in a photocenter 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 single pigment.

Question (H)
Why does chlorophyll appear green in reflected light and red transmitted light? Explain the significance of these phenomena in terms of photosynthesis.
Answer:
1. Chlorophyll is a light absorbing pigment. It absorbs light in red and blue regions of the visible light spectrum. 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 appear 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 photosynthesis process.
3. It is most effective wavelength of light in photosynthesis as it has exactly right amount of energy to excite electrons of chlorophyll and boost them out of their orbits to higher energy level.

Question (I)
Explain why photosynthesis is considered the most important process in the biosphere.
Answer:
Photosynthesis is considered to be the most important process in the biosphere due to following reasons:
1. Photosynthesis is the biochemical process through which all plants (primary producers) produce food.
2. It is responsible for release of oxygen in 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.

Question (J)
Why is photolysis of water accompanied with non-cyclic photophosphorylation?
Answer:
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 makes NADPH.
b. Second component formed is electrons which replaces the electrons lost by PS-II.
c. The third component is oxygen (0_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, photolysis of water replaces the electrons lost by Photosystem II.
6. Water is the ultimate source of electrons for photosynthesis.
Therefore, photolysis of water is accompanied with non – cyclic photophosphorylation.

Question (K)
In C-4 plants, why is C-3 pathway operated in bundle sheath cells only?
Answer:

1. Decarboxylation of malic acid occurs in bundle sheath cells of C_4 plants. Due to which concentration of $C0_2$ increases in bundle sheath cells.
2. The enzymes required for Calvin cycle i.e. RuBisCO is present in bundle sheath cells.
3. In presence of high concentration of $C0_2$, RuBisCO acts as carboxylase and bring about carboxylation of RuBP.
4. Hence, in C-4 plants, C-3 pathway is operated in bundle sheath cells only.

Question (L)
What would have happened if C-4 plants did not have Kranz anatomy?
Answer:
Photorespiration would occur if C_4 plants did not have Kranz anatomy.

Question (M)
Why does RuBisCO carry out preferentially carboxylation than oxygenation in C_4 plants?
Answer:

1. In C_4 plants, $C0_2$ 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 $C0_4$ in the cytoplasm thus increasing the concentration of $C0_2$ in the bundle sheath cells.
5. Chloroplasts of bundle sheath cells contains enzymes of Calvin cycle.
6. Thus, due to high concentration of $C0_2$, RuBisCO participates in carboxylation and not in oxygenation.

Question (N)
What would have happened if plants did not have accessory pigments?
Answer:

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.

Question (O)
How can you identify whether the plant is C_3 or C_4? Explain / Justify.
Answer:

1. By observing the cross section of a leaf we can identify whether the plant is a C_3 plant or a C_3 plant.
2. C_4 plants possess a 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.

Question (P)
In C_4 plants, bundle sheath cells carrying out Calvin cycle are very few in number. Then also, C_4 plants are highly productive. Explain.
Answer:

1. C_4 plants have special type of leaf anatomy called Kranz anatomy.
2. In C_4 plants, $C0_2$ fixation occurs twice.
3. In these plants, chloroplasts of mesophyll cells contain enzyme PEP carboxylase which fixes atmospheric $C0_2$.
4. Thus, first $C0_2$ fixation occurs in mesophyll cells.
5. Decarboxylation of malic acid in bundle sheath cells results in increase in $C0_2$ concentration.
6. Thus, RuBisCO acts as carboxylase and brings about carboxylation of RuBP.

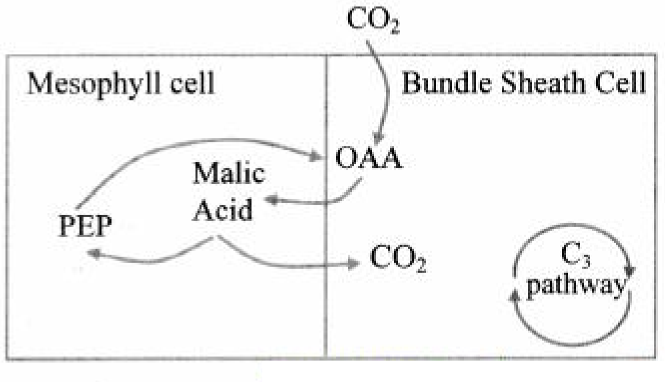
7. Due to this oxygenation of RuBP and photorespiration is prevented.
8. Thus, despite of having less number of bundle sheath cells carrying out Calvin cycle, C_4 plants are highly productive.

Question (Q)
What is functional significance of Kranz anatomy?
Answer:

1. Leaves of C_4 plants show some structural peculiarities called Kranz anatomy.
2. The chloroplast of mesophyll cells contain enzyme PEP Carboxylase, which can fix $C0_2$ at low concentration.
3. Thus, light reaction and evolution of 0_2 occurs in mesophyll cells.
4. Decarboxylation of malate occurs in bundle sheath cells, which results in release of $C0_2$, due to which concentration of $C0_2$ in bundle sheath cells increases.
5. Enzyme RuBisCO present in bundle sheath cells acts as carboxylase in presence of high $C0_2$ concentraion and catalyses carboxylation of RuBP.
6. Thus, possibility of oxygenation of RuBP is avoided and photorespiration does not take place.

3. Correct the pathway and name it.

Question 1.
Correct the pathway and name it.
Answer:



1. The pathway shown is C_4 pathway.
2. M. D. Hatch and C. R. Slack while working on sugarcane found four carbon compounds (dicarboxylic acid) as the first stable product of photosynthesis.
3. It occurs in tropical and sub-tropical grasses and some dicotyledons.
4. 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. $C0_2$ taken from 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 $C0_2$ in the cytoplasm.
5. Thus, concentration of $C0_2$ increases in the bundle sheath cells.
6. Chloroplasts of these cells contain enzymes of Calvin cycle.
7. Because of high concentration of $C0_2$, RuBP carboxylase participates in Calvin cycle and not photorespiration.
8. Sugar formed in 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 C4 pathway requires 30 ATP.
13. Thus, C_4 plants are better photosynthesizers as compared to C_3 plants as there is no photorespiration in these plants.

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

Question 1.
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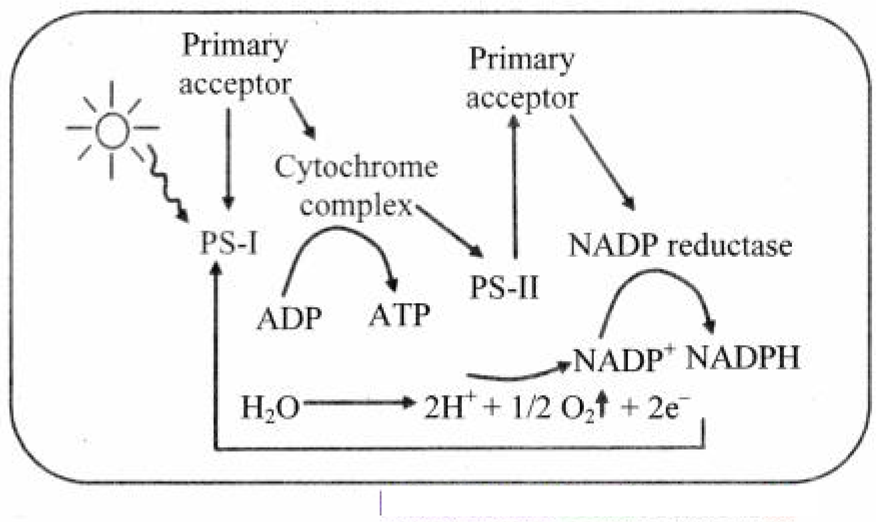
Answer:



Non-cyclic photophosphorylation:
a. It involves both photosystems- PS-I and PS-II.
b. In this case, electron transport chain starts with the release of electrons from PS-II.
c. 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.
d. The reduced $NADP^+$ (NADPH) is utilized for the reduction of CO_2 in the dark reaction.
e. Electron-deficient PS-II brings about oxidation of water-molecule. Due to this, protons, electrons and oxygen atom are released.
f. Electrons are taken up by PS-II itself to return to reduced state, protons are accepted by $NADP^+$ whereas oxygen is released.
g. 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.

Practical/ Project:

Question 1.
Draw schematic presentation of different processes/ cycles/ reactions related to photosynthesis.
Answer:
Cyclic photophosphorylation:
a. Illumination of photosystem-I causes electrons to move continuously out of the reaction center of photosystem-I and back to it.
b. The cyclic electron-flow is accompanied by the photophosphorylation of ADP to yield ATP. This is termed as Cyclic photophosphorylation.
c. Since this process involves only pigment system I, photolysis of water and consequent evolution of oxygen does not take place.

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Interdependence of light and dark reactions:

1. 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.
2. ATP and $NADPH_2$ molecules function as vehicles for transfer of energy of sunlight into dark reaction leaving to carbon fixation. In this reaction $C0_2$ is reduced to carbohydrate.
3. 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.

Calvin cycle: 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_{14} plants.
Calvin carried out experiments on unicellular green algae (Chlorella), using radioactive isotope of carbon, C_{14} as a tracer.
It is also called synthesis phase or second phase of photosynthesis.
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1. Carboxylation phase:
a. Carbon dioxide reduction starts with a five-carbon sugar ribulose-l,5-bisphosphate (RuBP). It is a 5- carbon sugar with two phosphate groups attached to it.
b. RuBP reacts with CO_2 to produce an unstable 6 carbon intermediate in the presence of Rubisco.
c. It immediately splits into 3 carbon compounds called 3-phosphoglyceric acid.
d. RuBisCO is a large protein molecule and comprises 16% of the chloroplast proteins.

2. Glycolytic reversal:
a. 3-phosphoglyceric acid form 1,3-diphosphoglyceric acid by utilizing ATP molecule.
b. These are then reduced to glyceraldehyde-3-phosphate (3-PGA) by NADPH supplied by the light reactions of photosynthesis.

c. In order to keep Calvin cycle continuously running there must be sufficient number of RuBP and regular supply of ATP and NADPH.
d. Out of 12 molecules of 3-phosphoglyceraldehyde, two molecules are used for synthesis of one glucose molecule.

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

Photorespiration: Mechanism:
1. Photorespiration involves three organelles chloroplast, peroxisomes and mitochondria and occurs in a series of cyclic reactions which is also called PCO cycle. (Photosynthetic Carbon Cycle)
2. Enzyme Rubisco acts as oxygenase at higher concentration of O_2 and photorespiration begins.
3. When RuBP reacts with 0_2 rather than $C0_2$ to form a 3-carbon compound (PGA) and 2-carbon compound phosphoglycolate.
4. Phosphoglycolate is then converted to glycolate which is shuttled out of the chloroplast into the peroxisomes.
5. In Peroxisomes, glycolate is converted into glyoxylate by enzyme glycolate oxidase.
6. Glyoxylate is further converted into amino acid glycine by transamination.
7. In mitochondria, two molecules of glycine are converted into serine (amino acid) and $C0_2$ is given out.
8. Thus, it loses 25% of photosynthetically fixed carbon.
9. Serine is transported back to peroxisomes and converted into glycerate.
10. It is shuttled back to chloroplast to undergo phosphorylation and utilized in formation of 3-PGA, which get utilized in C_3 pathway.
Hatch-Slack 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. $C0_2$ taken from 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 $C0_2$ in the cytoplasm.
5. Thus, concentration of $C0_2$ increases in the bundle sheath cells.
6. Chloroplasts of these cells contain enzymes of Calvin cycle.
7. Because of high concentration of $C0_2$, RuBP carboxylase participates in Calvin cycle and not photorespiration.
8. Sugar formed in 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.
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11. xi. Thus, C_4 pathway needs 12 additional ATP.
12. The C_3 pathway requires 18 ATP for the synthesis of one glucose molecule, whereas C4 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.
13. CAM Pathway: In CAM plants, malic acid accumulates during night, which is formed from Oxaloacetic acid in presence of the enzyme malate dehydrogenase.

Question 2.
Check the effects of different factors on photosynthesis under the guidance of teacher.
Answer:
External factors which affect photosynthesis are as follows:
1. Light:
a. It is an essential factor as it supplies the energy necessary for photosynthesis.
b. Quality and intensity of light affects the photosynthesis.
c. Highest rate of photosynthesis takes place in red light followed by blue light.
d. The rate of photosynthesis considerably decreases in plants which are growing under a forest canopy.
e. In most of the plants, photosynthesis is maximum in bright diffused sunlight.
f. Uninterrupted and continuous photosynthesis for a very long period of time may be sustained without any visible damage to the plant.

2. Carbon dioxide:
The main source of $C0_2$ in land plants is the atmosphere, which contains only 0.3% of the gas.
b. Under normal conditions of temperature and light, carbon dioxide acts as a limiting factor in photosynthesis.
c. Increase in concentration of CO_2 increases the photosynthesis.
d. Increase in $C0_2$ to about 1% is advantageous to most of the plants.
e. Higher concentration of the gas has an inhibitory effect on photosynthesis.

3. Temperature:
a. Like all other physiological processes, photosynthesis also needs a suitable temperature.
b. The optimum temperature at which the photosynthesis is maximum is 25-30 °C. Except in plants like Opuntia, photosynthesis takes place at as high as 55 °C.
c. This is the maximum temperature. Minimum temperature is temperature at which photosynthesis process just starts.

d. In the presence of sufficient light and CO_2, photosynthesis increases with the rise of temperature till it becomes maximum. After that there is a decrease or fall in the rate of the process.

4. Water:
a. Water is necessary for photosynthetic process.
b. An increase in water content of the leaf results in the corresponding increase in the rate of photosynthesis.
c. Thus, the limiting effect of water is not direct but indirect.
d. It is mainly due to the fact that it helps in maintaining the turgidity of the assimilatory cells and the proper hydration of their protoplasm.
[Students can refer the given information and perform this activity on their own]

11th Biology Digest Chapter 12 Photosynthesis Intext Questions and Answers

Can you recall? (Textbook Page No. 138)

(i) Why energy is essential in different life processes?
Answer:
a. Energy is the basic requirement of life.
b. Without energy no work can be done.
c. All living organisms need energy for reproduction and survival.
d. Sun is the main source of energy, and that energy should be transformed into the usable forms for living organisms to carry out life processes.
Therefore, energy is essential in different life processes.

(ii) How do we get energy?
Answer:
a. Sun is the main source of energy.
b. Plants utilize sunlight, carbon dioxide and water for the process called photosynthesis to produce sugars.
c. Animals make use of these sugars provided by the plants in their own cellular energy factories called mitochondria. Thus, energy is obtained.

Use your brainpower (Textbook Page No. 138)

Justify: All life on earth is 'bottled solar energy'.
Answer:

1. Life on earth is dependent on solar energy directly or indirectly.
2. Plants by carrying out photosynthesis converts solar energy into chemical energy by producing carbohydrates.
3. Humans and animals depend on plants for food. Basically, life on earth depends totally on photosynthesis for food and energy.
4. Therefore, all life on earth is bottled solar energy.

Can you tell? (Textbook Page No. 140)

Draw well labeled diagram of ultrastructure of chloroplast.
Answer:

1. The chloroplasts are discoid and lens shaped in higher plants. Chloroplast is bounded by a double membrane. System of chlorophyll bearing a double-membrane sac is present inside the stroma.
2. These are stacked one above the other to form grana.
3. Individual sacs in each granum is are known as thylakoid.
4. All the pigments chlorophylls, carotenes and xanthophylls are located in thylakoid membranes.
5. These pigments are fat soluble and are present in lipid part of membrane also they absorb light of specific spectrum in the visible regions.

Use your brainpower (Textbook Page No. 140)

The photosynthetic lamellae taken out from a chloroplast and suspended in a nutrient medium in the presence of $C0_2$ and light. Will they synthesize sugar or not?
Answer:
Photosynthetic ladmellae will not synthesize sugar because sugar synthesis occurs only in stroma, as all the enzymes required for sugar synthesis are present there. In photosynthetic lamellae only light reactions occur. Thus, lamellae cannot synthesize sugar even when $C0_2$, light and other nutrients are provided.

Internet my friend (Textbook Page No. 139)

Collect information: Why does chlorophyll appear red in reflected light and green in transmitted light?
Answer:
Chlorophyll is a light absorbing pigment. It absorbs light in red and blue regions of the visible light spectrum. 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 appear green in reflected light. [Note: Chlorophyll appear red in transmitted light and green in reflected light.[

Activity 1 (Textbook Page No. 139)

Grind the spinach leaves in small quantity of acetone / nail paint remover. Mix the contents properly and filter with filter paper in test tube. Test tube contains green filtrate. Take the test tube in dark-room and put a flash of torch on it. Now, solution appears red. Why does this occur? Which phenomenon is this? Discuss this with your physics, chemistry and biology teachers.
Answer:
Chlorophyll is the green pigment present in chloroplast. It absorbs light in red and blue region of visible spectrum. It does not absorb green light and thus the green light is reflected which is why it appears green. In this experiment, the chlorophyll in test tube appears red when a flash torch is put on it in the dark room.

This is because when the electrons of the chlorophyll molecule are excited in dark in the absence of electron transport chain the electrons release their energy in the form of red light as they return to ground state. This phenomenon observed here is transmission of light.

Activity 2 (Textbook Page No. 139)

To separate the chloroplast pigments by paper chromatography. Concentrate the extracted chlorophyll solution by evaporation. Apply a drop of it at one end, 2cm away from edge of a strip of chromatography paper and allow it to dry thoroughly. Take a mixture of petroleum ether and acetone in the ratio of 9:1 at temperature of 40 to 60°C. Hang the strip in the jar with its loaded end dipping in the solvent. Close the jar tightly and keep it for an hour. The pigments separate into distinct green and yellow bands of chlorophyll and carotenoid respectively.
Answer:
Pigments are the molecules which reflects only certain wavelengths of visible light. Chromatography is the technique used to separate the chloroplast pigments. Carotenes form yellow-orange band, chlorophyll forms blue-green band, chlorophyll b forms yellow-green bands.

Can you tell? (Textbook Page No. 139)

Tomatoes, carrots and chillies are red in colour due to the presence of pigments. Name the pigment. Answer:
Red colour pigment present in tomatoes, carrots and chillies is lycopene.

Think about it (Textbook Page No. 140)

Large number of gas bubbles are evolved during day time in a pond of water.
Answer:
Photosynthesis occurs in the presence of sunlight. During photosynthesis, plants give out oxygen and take in carbon dioxide. The plants present underwater carryout photosynthesis and release oxygen. Hence, large number of gas bubbles are evolved during day time in a pond.

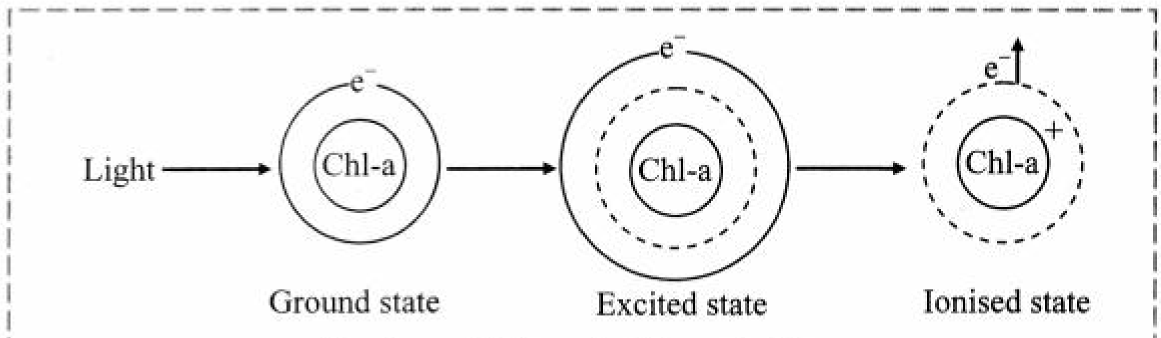
Think about it (Textbook Page No. 141)

Does moonlight support photosynthesis?
Answer:
The reactions of photosynthesis take place in the presence of sunlight. The intensity of moonlight is several thousand times less than that of direct sunlight which is insufficient for the light dependent phase of photosynthesis. As the sun sets, rate of photosynthesis also decreases. Therefore, moonlight does not support photosynthesis.

Can you tell? (Textbook Page No. 145)

How chlorophyll – a is excited? Show it with a diagram.
Answer:

1. Chlorophyll-a is an essential photosynthetic pigment as it converts light energy into chemical energy and acts as a reaction centre.
2. Initially, it lies at ground state or singlet state but when it absorbs or receives photons (solar energy), it gets activated and goes in excited state or excited second singlet state.
3. In the excited state, chlorophyll-a emits an electron. The emitted electron is energy rich, i.e. has extra amount of energy.
4. Due to the loss of electron (e–), chlorophyll-a becomes positively charged. This is the ionized state.
5. Chlorophyll-a molecule cannot remain in the ionized state for more than 10’9 seconds. Hence the photo-chemical reaction or electron transfer occurs very fast.
6. The energy rich electron is then transferred through various electron acceptors and donors (carriers).
7. During the transfer, the electron emits energy which is utilized for the synthesis of ATP. This shows that light energy is converted into chemical energy in the form of ATP.



Photoexcitation of chlorophyll-a

Can you tell? (Textbook Page No. 140)

What made Hill to perform his experiment?
Answer:
Robert Hill proved that the source of oxygen evolved during photosynthesis is water and not carbon dioxide. Hence, it is called Hill's Reaction.

1. In this experiment, Hill cultured isolated chloroplasts in a medium containing $C0_2$ free water, haemoglobin and ferric compound.
2. Ferric salts and haemoglobin were added in the medium as hydrogen and oxygen acceptors respectively.
3. When the suspension was illuminated, he observed that haemoglobin turned into oxyhaemoglobin (red colour).
4. This confirmed that water must have oxidized releasing 0_2, that reacted with haemoglobin. Reduction of ferric compound was also indicated by change in colour.
5. The H_2O molecule oxidized to evolve 0_2 as a by-product. Thus, Hill proved that the source of evolving 0_2 is H_20 and not $C0_2$.
6. This process of splitting up of water molecules under the influence of light in the presence of chlorophyll is called Photolysis of water or Hill Reaction.
7. Hill's reaction can be represented as follows:

$$2H_2O + 2A \xrightarrow[\text{chlorophyll}]{\text{Sunlight}} 2AH_2 + O_2$$

Can you tell? (Textbook Page No. 145)

Draw a flowchart of non-cyclic photophosphorylation.
Answer:
Non-cyclic photophosphorylation:
a. It involves both photosystems- PS-I and PS-II.
b. In this case, electron transport chain starts with the release of electrons from PS-II.
c. 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.
d. The reduced $NADP^+$ (NADPH) is utilized for the reduction of CO_2 in the dark reaction.
e. Electron-deficient PS-II brings about oxidation of water-molecule. Due to this, protons, electrons and oxygen atom are released.
f. Electrons are taken up by PS-II itself to return to reduced state, protons are accepted by $NADP^+$ whereas oxygen is released.
g. 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.

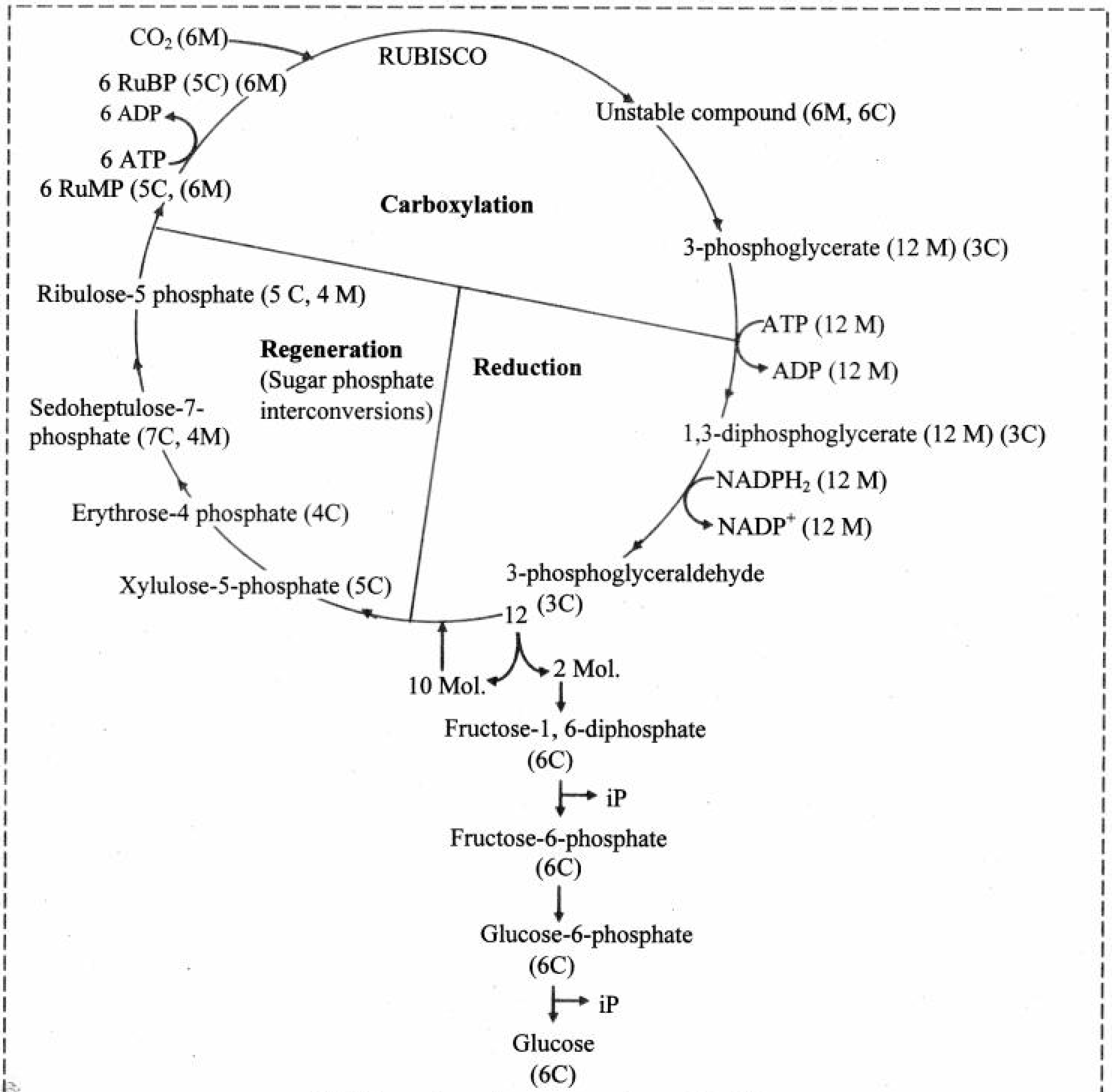
Can you tell? (Textbook Page No. 145)

Describe Calvin's cycle.
Answer:
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_{14} plants.
Calvin carried out experiments on unicellular green algae (Chlorella), using radioactive isotope of carbon, C_{14} as a tracer.
It is also called synthesis phase or second phase of photosynthesis.
The cycle is divided into the following phases:
1. Carboxylation phase:
a. Carbon dioxide reduction starts with a five-carbon sugar ribulose-l,5-bisphosphate (RuBP). It is a 5- carbon sugar with two phosphate groups attached to it.
b. RuBP reacts with CO_2 to produce an unstable 6 carbon intermediate in the presence of Rubisco.
c. It immediately splits into 3 carbon compounds called 3-phosphoglyceric acid.
d. RuBisCO is a large protein molecule and comprises 16% of the chloroplast proteins.

2. Glycolytic reversal:
a. 3-phosphoglyceric acid form 1,3-diphosphoglyceric acid by utilizing ATP molecule.
b. These are then reduced to glyceraldehyde-3-phosphate (3-PGA) by NADPH supplied by the light reactions of photosynthesis.

c. In order to keep Calvin cycle continuously running there must be sufficient number of RuBP and regular supply of ATP and NADPH.
d. Out of 12 molecules of 3-phosphoglyceraldehyde, two molecules are used for synthesis of one glucose molecule.

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



Calvin cycle and regeneration of RuBP

Can you tell? (Textbook Page No. 147)

Summarise the photosynthetic reaction.
Answer:
$6CO_2 + 12H_2O \rightarrow C_2H_{12}O_6 + 6O_2 + 6H_2O$
1. Photosynthesis is a two step process.
The light dependent reactions convert the light energy from the sun into chemical energy.
The light independent reactions convert the chemical energy to synthesize carbohydrates.
2. Light dependent reactions: Light is absorbed by chlorophyll which results in the production of ATP. Photolysis of water produce oxygen and hydrogen. The hydrogen and ATP are used in the light independent reactions and the oxygen is released from stomata.
3. Light independent reactions: ATP and hydrogen are transferred to the site of light independent reactions. The hydrogen is combined with carbon dioxide to form complex organic compounds.
The ATP provides the required energy to power these anabolic reactions and fix the carbon molecules.

Can you tell? (Textbook Page No. 147)

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Can you tell? (Textbook Page No. 147)

C_4 plants are more productive. Why?
Answer:

1. Photorespiration is considered to be a wasteful process in plants. It is an energy consuming process in plants which ultimately leads to reduction in final yield of plants.
2. During C_3 photosynthesis, 25% of the carbon dioxide fixed has to pass through photorespiratory process.
3. This decreases the photosynthetic productivity.
4. In C_4 plants, photorespiration is absent and hence they have better productivity.

Can you tell? (Textbook Page No. 147)

Xerophytic plants survive in high temperature. How?
Answer:

1. Xerophytic plants are those that have adapted to dry environments.
2. They have adapted to arid conditions by storing water in stems.
3. Stomata of these plants remain closed during day time to reduce the rate of transpiration to bare minimum.
4. Leaves are modified into spines or are reduced in size to check the loss of water due to transpiration.
5. The waxy surfaces of xerophytic plants prevent the loss of moisture.
6. Thus, they are able to survive in high temperature.

Can you tell? (Textbook Page No. 147)

Compare C_4 plants and CAM plants.
Answer:

C_4 Plants	CAM Plants
1. These are mostly tropical and subtropical plants.	These are mostly xerophytic plants.
2. Leaves show Kranz anatomy.	Leaves does not show Kranz anatomy.
3. Stomata is open during day time.	Stomata is open during night time.
4. Photorespiration is not easily detectable.	Photorespiration is detectable in afternoon.
5. Carbon fixation takes place in mesophyll cells and Calvin Cycle takes place in bundle sheath cells.	Photosynthesis takes place in the mesophyll cells but carbon fixation takes place at night and Calvin cycle happens during day.
e.g. Sugarcane, maize, jowar, Amaranthus, etc.	e.g. Kalanchoe, Opuntia, Aloe, etc.