CHAPTER 13

Photosynthesis in Higher Plants

13.2 Early Experiments

1. One scientist cultured *Cladophora* in a suspension of *Azotobacter* and illuminated the culture by splitting light through a prism. He observed that bacteria accumulated mainly in the region of
(a) violet and green light
(b) indigo and green light
(c) orange and yellow light
(d) blue and red light. *(Odisha NEET 2019)*

2. Oxygen is not produced during photosynthesis by
(a) Green sulphur bacteria
(b) *Nostoc*
(c) *Cycas*
(d) *Chara*. *(NEET 2018)*

3. Anoxygenic photosynthesis is characteristic of
(a) *Rhodospirillum* (b) *Spirogyra*
(c) *Chlamydomonas* (d) *Ulva*. *(2014)*

4. Oxygenic photosynthesis occurs in
(a) *Oscillatoria* (b) *Rhodospirillum*
(c) *Chlorobium* (d) *Chromatium*. *(2009)*

13.3 Where does Photosynthesis Take Place?

5. Stroma in the chloroplasts of higher plant contains
(a) light-dependent reaction enzymes
(b) ribosomes (c) chlorophyll
(d) light-independent reaction enzymes. *(2009)*

13.4 How Many Types of Pigments are Involved in Photosynthesis?

6. Emerson's enhancement effect and Red drop have been instrumental in the discovery of
(a) photophosphorylation and cyclic electron transport
(b) oxidative phosphorylation
(c) photophosphorylation and non-cyclic electron transport
(d) two photosystems operating simultaneously. *(NEET-I 2016)*

7. Chromatophores take part in
(a) movement (b) respiration
(c) photosynthesis (d) growth. *(2015)*

8. Which fractions of the visible spectrum of solar radiations are primarily absorbed by carotenoids of the higher plants?
(a) Blue and green (b) Green and red
(c) Red and violet (d) Violet and blue *(2003)*

9. Which element is located at the centre of the porphyrin ring in chlorophyll?
(a) Calcium (b) Magnesium
(c) Potassium (d) Manganese *(2003)*

10. Chlorophyll *a* molecule at its carbon atom 3 of the pyrrole ring II has one of the following
(a) carboxylic group (b) magnesium
(c) aldehyde group (d) methyl group. *(1997)*

11. The core metal of chlorophyll is
(a) Ni (b) Cu
(c) Fe (d) Mg. *(1997)*

12. Chlorophyll *a* occurs in
(a) all photosynthetic autotrophs
(b) in all higher plants
(c) all oxygen liberating autotrophs
(d) all plants except fungi. (1992)

13. Photosynthetic pigments found in the chloroplasts occur in
(a) thylakoid membranes
(b) plastoglobules
(c) matrix
(d) chloroplast envelope. *(1991)*

14. The size of chlorophyll molecule is
(a) head 15 × 15 Å, tail 25 Å
(b) head 20 × 20 Å, tail 25 Å
(c) head 15 × 15 Å, tail 20 Å
(d) head 10 × 12 Å, tail 25 Å. *(1989)*

13.5 What is Light Reaction?

15. Which of the following is not a product of light reaction of photosynthesis?
(a) ATP (b) NADH
(c) NADPH (d) Oxygen *(NEET 2018)*

16. Which of the following absorb light energy for photosynthesis?
(a) Chlorophyll (b) Water molecule
(c) O_2 (d) RuBP *(2002)*

17. The first step for initiation of photosynthesis will be
(a) photolysis of water
(b) excitement of chlorophyll molecules due to absorption of light
(c) ATP formation
(d) glucose formation. *(2000)*

18. $NADPH_2$ is generated through
(a) photosystem II (b) anaerobic respiration
(c) glycolysis (d) photosystem I. *(1997)*

19. Which of the following pigments acts as a reaction-centre during photosynthesis?
(a) Carotene (b) Phytochrome
(c) P_{700} (d) Cytochrome *(1994)*

20. Ferredoxin is a constituent of
(a) PS I (b) PS II
(c) Hill reaction (d) P_{680}. *(1991)*

13.6 The Electron Transport

21. In light reaction, plastoquinone facilitates the transfer of electrons from
(a) PS-II to Cytb_6f complex
(b) Cytb_6f complex to PS-I
(c) PS-I to $NADP^+$
(d) PS-I to ATP synthase. *(NEET 2020)*

22. In a chloroplast the highest number of protons are found in
(a) intermembrane space
(b) antennae complex
(c) stroma
(d) lumen of thylakoids. *(NEET-I 2016)*

23. Read the following four statements (A – D).
(A) Both photophosphorylation and oxidative phosphorylation involve uphill transport of protons across the membrane.
(B) In dicot stems, a new cambium originates from cells of pericycle at the time of secondary growth.
(C) Stamens in flowers of *Gloriosa* and *Petunia* are polyandrous.
(D) Symbiotic nitrogen fixers occur in free-living state also in soil.
How many of the above statements are right?
(a) Two (b) Three
(c) Four (d) One *(Mains 2012)*

24. Which one of the following is essential for photolysis of water?
(a) Manganese (b) Zinc
(c) Copper (d) Boron *(Mains 2011)*

25. Read the following four statements, (i), (ii), (iii) and (iv) and select the right option having both correct statements.
Statements :
(i) Z scheme of light reaction takes place in presence of PSI only.
(ii) Only PSI is functional in cyclic photophosphorylation.
(iii) Cyclic photophosphorylation results into synthesis of ATP and $NADPH_2$.
(iv) Stroma lamellae lack PSII as well as NADP.
(a) (ii) and (iv) (b) (i) and (ii)
(c) (ii) and (iii) (d) (iii) and (iv)
(Mains 2010)

26. Cyclic photophosphorylation results in the formation of
(a) ATP and NADPH (b) ATP, NADPH and O_2
(c) ATP (d) NADPH. *(2009)*

27. Electrons from excited chlorophyll molecule of photosystem II are accepted first by
(a) quinone (b) ferredoxin
(c) cytochrome-*b* (d) cytochrome-*f*. *(2008)*

28. The first acceptor of electrons from an excited chlorophyll molecule of photosystem II is
(a) iron-sulphur protein (b) ferredoxin
(c) quinone (d) cytochrome. *(2007)*

29. In photosystem I, the first electron acceptor is
(a) an iron-sulphur protein
(b) ferredoxin
(c) cytochrome
(d) plastocyanin. *(2006)*

30. Which one of the following concerns photophosphorylation?
(a) $ADP + AMP \xrightarrow{\text{Light energy}} ATP$
(b) $ADP + \text{Inorganic } PO_4 \xrightarrow{\text{Light energy}} ATP$
(c) $ADP + \text{Inorganic } PO_4 \longrightarrow ATP$
(d) $AMP + \text{Inorganic } PO_4 \xrightarrow{\text{Light energy}} ATP$ *(2003)*

31. In photosynthesis energy from light reaction to dark reaction is transferred in the form of
(a) ADP (b) ATP
(c) RuDP (d) chlorophyll. *(2002)*

32. Which pigment system is inactivated in red drop?
(a) PS-I and PS-II (b) PS-I
(c) PS-II (d) None of these *(2001)*

33. During light reaction of photosynthesis, which of the following phenomenon is observed during cyclic phosphorylation as well as non-cyclic phosphorylation?
(a) Release of O_2
(b) Formation of ATP
(c) Formation of NADPH
(d) Involvement of PS I and PS II pigment systems *(1994)*

34. A photosynthesising plant is releasing ^{18}O more than the normal. The plant must have been supplied with
(a) O_3 (b) H_2O with ^{18}O
(c) CO_2 with ^{18}O (d) $C_6H_{12}O_6$ with ^{18}O. *(1993)*

35. Photosystem II occurs in
(a) stroma (b) cytochrome
(c) grana
(d) mitochondrial surface. *(1992)*

36. $NADP^+$ is reduced to NADPH in
(a) PS I (b) PS II
(c) Calvin cycle
(d) noncyclic photophosphorylation. *(1988)*

13.7 Where are the ATP and NADPH Used?

37. In photosynthesis, the light-independent reactions take place at
(a) photosystem II (b) stromal matrix
(c) thylakoid lumen (d) photosystem I. *(2015)*

38. Which one of the following organisms is correctly matched with its three characteristics?
(a) Pea: C_3 pathway, endospermic seed, vexillary aestivation
(b) Tomato: twisted aestivation, axile placentation, berry
(c) Onion: bulb, imbricate aestivation, axile placentation
(d) Maize: C_3 pathway, closed vascular bundles, scutellum *(Mains 2012)*

39. PGA as the first CO_2 fixation product was discovered in photosynthesis of
(a) bryophyte (b) gymnosperm
(c) angiosperm (d) alga. *(2010)*

40. The chemiosmotic coupling hypothesis of oxidative phosphorylation proposes that adenosine triphosphate (ATP) is formed because
(a) a proton gradient forms across the inner membrane
(b) there is a change in the permeability of the inner mitochondrial membrane toward adenosine diphosphate (ADP)
(c) high energy bonds are formed in mitochondrial proteins
(d) ADP is pumped out of the matrix into the intermembrane space. *(2008)*

41. Chemiosmotic theory of ATP synthesis in the chloroplasts and mitochondria is based on
(a) membrane potential
(b) accumulation of Na^+ ions
(c) accumulation of K^+ ions
(d) proton gradient. *(2005)*

42. In C_3 plants, the first stable product of photosynthesis during the dark reaction is
(a) malic acid
(b) oxaloacetic acid
(c) 3-phosphoglyceric acid
(d) phosphoglyceraldehyde. *(2004)*

43. For assimilation of one CO_2 molecule, the energy required in form of ATP and $NADPH_2$ are
(a) 2 ATP and 2 $NADPH_2$
(b) 5 ATP and 3 $NADPH_2$
(c) 3 ATP and 2$NADPH_2$
(d) 18 ATP and 12 $NADPH_2$. *(2000)*

44. For the synthesis of one glucose molecule the Calvin cycle operates for
(a) 2 times (b) 4 times
(c) 6 times (d) 8 times. *(2000)*

45. Carbon dioxide acceptor in C_3-plants is
(a) PGA (b) PEP
(c) RuDP (d) none of these. *(1999)*

46. The mechanism of ATP formation both in chloroplast and mitochondria is explained by
(a) chemiosmotic theory
(b) Munch's hypothesis (mass flow model)
(c) relay pump theory of Godlewski
(d) Cholodny-Wont's model. *(1997)*

47. What will be the number of Calvin cycles to generate one molecule of hexose?
(a) 8 (b) 9
(c) 4 (d) 6 *(1996)*

48. The primary acceptor, during CO_2 fixation in C_3 plants, is
(a) phosphoenolpyruvate (PEP)
(b) ribulose 1, 5-diphosphate (RuDP)
(c) phosphoglyceric acid (PGA)
(d) ribulose monophosphate (RMP). *(1995)*

49. The carbon dioxide acceptor in Calvin cycle/ C_3-plants is
(a) phosphoenol pyruvate (PEP)
(b) ribulose 1, 5-diphosphate (RuDP)
(c) phosphoglyceric acid (PGA)
(d) ribulose monophosphate (RMP). *(1993)*

50. Which technique has helped in investigation of Calvin cycle?
(a) X-ray crystallography
(b) X-ray technique
(c) Radioactive isotope technique
(d) Intermittent light *(1991)*

51. Dark reactions of photosynthesis occur in
(a) granal thylakoid membranes
(b) stromal lamella membranes
(c) stroma outside photosynthetic lamellae
(d) periplastidial space. *(1991)*

52. Carbon dioxide joins the photosynthetic pathway in
(a) PS I (b) PS II
(c) light reaction (d) dark reaction. *(1988)*

13.8 The C_4 Pathway

53. Phosphoenol pyruvate (PEP) is the primary CO_2 acceptor in
(a) C_4 plants (b) C_2 plants
(c) C_3 and C_4 plants (d) C_3 plants.
(NEET 2017)

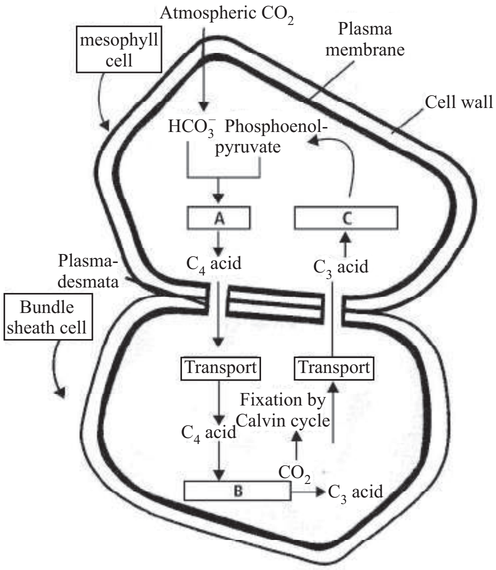
54. A plant in your garden avoids photorespiratory losses, has improved water use efficiency, shows high rates of photosynthesis at high temperatures and has improved efficiency of nitrogen utilisation. In which of the following physiological groups would you assign this plant?
(a) CAM (b) Nitrogen fixer
(c) C_3 (d) C_4 *(NEET-I 2016)*

55. Bundle sheath cells
(a) are rich in PEP carboxylase
(b) lack RuBisCO
(c) lack both RuBisCO and PEP carboxylase
(d) are rich in RuBisCO. *(Karnataka NEET 2013)*

56. CAM helps the plants in
(a) conserving water (b) secondary growth
(c) disease resistance (d) reproduction. *(2011)*

57. In kranz anatomy, the bundle sheath cells have
(a) thin walls, many intercellular spaces and no chloroplasts
(b) thick walls, no intercellular spaces and large number of chloroplasts
(c) thin walls, no intercellular spaces and several chloroplasts
(d) thick walls, many intercellular spaces and few chloroplasts. *(Mains 2011)*

58. Study the pathway given below.



In which of the following options correct words for all the three blanks A, B and C are indicated?

	A	B	C
(a)	Decarboxylation	Reduction	Regeneration
(b)	Fixation	Transamination	Regeneration
(c)	Fixation	Decarboxylation	Regeneration
(d)	Carboxylation	Decarboxylation	Reduction

(Mains 2010)

59. Kranz anatomy is one of the characteristics of the leaves of
(a) potato (b) wheat
(c) sugarcane (d) mustard. *(Mains 2010)*

60. The C_4 plants are photosynthetically more efficient than C_3 plants because
(a) the CO_2 efflux is not prevented
(b) they have more chloroplasts
(c) the CO_2 compensation point is more
(d) CO_2 generated during photorespiration is trapped and recycled through PEP carboxylase.
(2008)

61. In leaves of C_4 plants, malic acid synthesis during CO_2 fixation occurs in
(a) bundle sheath (b) guard cells
(c) epidermal cells (d) mesophyll cells. *(2008)*

62. In the leaves of C_4 plants, malic acid formation during CO_2 fixation occurs in the cells of
(a) bundle sheath (b) phloem
(c) epidermis (d) mesophyll. *(2007)*

63. As compared to a C_3-plant, how many additional molecules of ATP are needed for net production of one molecule of hexose sugar by C_4-plants?
(a) Two (b) Six
(c) Twelve (d) Zero *(2005)*

64. Photosynthesis in C_4 plants is relatively less limited by atmospheric CO_2 levels because
(a) effective pumping of CO_2 into bundle sheath cells
(b) RuBisCO in C_4 plants has higher affinity for CO_2
(c) four carbon acids are the primary initial CO_2 fixation products
(d) the primary fixation of CO_2 is mediated *via* PEP carboxylase. *(2005)*

65. In sugarcane plant $^{14}CO_2$ is fixed to malic acid, in which the enzyme that fixes CO_2 is
(a) ribulose biphosphate carboxylase
(b) phosphoenol pyruvic acid carboxylase
(c) ribulose phosphate kinase
(d) fructose phosphatase. *(2003)*

66. Stomata of CAM plants
(a) are always open
(b) open during the day and close at night
(c) open during the night and close during the day
(d) never open. *(2003)*

67. Which pair is wrong?
(a) C_3-maize (b) C_4-kranz anatomy
(c) Calvin cycle-PGA
(d) Hatch and Slack cycle - OAA *(2001)*

68. Which is the first CO_2 acceptor enzyme in C_4 plants?
(a) RuDP carboxylase (b) Phosphoric acid
(c) RuBisCO (d) PEP- carboxylase
(2000)

69. In C_4 plants, CO_2 combines with
(a) phosphoenol pyruvate
(b) phosphoglyceraldehyde
(c) phosphoglyceric acid
(d) ribulose diphosphate. *(1996)*

70. In C_4 plants, CO_2 fixation is done by
(a) sclerenchyma
(b) chlorenchyma and hypodermis
(c) mesophyll cells
(d) guard cells. *(1996)*

71. The CO_2 fixation during C_4 pathway occurs in the chloroplast of
(a) guard cells
(b) bundle sheath cells
(c) mesophyll cells
(d) spongy parenchyma. *(1995)*

72. Which one is a C_4-plant?
(a) Papaya (b) Pea
(c) Potato (d) Maize/corn *(1993)*

73. The enzyme that catalyses carbon dioxide fixation in C_4 plants is
(a) RuBP carboxylase (b) PEP carboxylase
(c) carbonic anhydrase (d) carboxydismutase.
(1992)

74. The first carbon dioxide acceptor in C_4-plants is
(a) phosphoenol-pyruvate
(b) ribulose 1, 5-diphosphate
(c) oxaloacetic acid
(d) phosphoglyceric acid. *(1992, 1990)*

75. Kranz anatomy is typical of
(a) C_4 plants (b) C_3 plants
(c) C_2 plants (d) CAM plants. *(1990)*

76. In C_4 plants, Calvin cycle operates in
(a) stroma of bundle sheath chloroplasts
(b) grana of bundle sheath chloroplasts
(c) grana of mesophyll chloroplasts
(d) stroma of mesophyll chloroplasts. *(1989)*

13.9 Photorespiration

77. The oxygenation activity of RuBisCO enzyme in photorespiration leads to the formation of
(a) 2 molecules of 3-C compound
(b) 1 molecule of 3-C compound
(c) 1 molecule of 6-C compound
(d) 1 molecule of 4-C compound and 1 molecule of 2-C compound *(NEET 2020)*

78. The process which makes major difference between C_3 and C_4 plants is
(a) glycolysis (b) Calvin cycle
(c) photorespiration (d) respiration.
(NEET-II 2016)

79. A process that makes important difference between C_3 and C_4 plants is
(a) transpiration (b) glycolysis
(c) photosynthesis (d) photorespiration.
(2012)

80. The correct sequence of cell organelles during photorespiration is
(a) chloroplast, Golgi-bodies, mitochondria
(b) chloroplast, rough endoplasmic reticulum, dictyosomes
(c) chloroplast, mitochondria, peroxisome
(d) chloroplast, vacuole, peroxisome. *(2012)*

81. C_4 plants are more efficient in photosynthesis than C_3 plants due to
(a) higher leaf area

(b) presence of larger number of chloroplasts in the leaf cells
(c) presence of thin cuticle
(d) lower rate of photorespiration. *(2010)*

82. During photorespiration, the oxygen consuming reaction(s) occur in
(a) stroma of chloroplasts
(b) stroma of chloroplasts and mitochondria
(c) stroma of chloroplasts and peroxisomes
(d) grana of chloroplasts and peroxisomes. *(2006)*

83. Which one of the following is wrong in relation to photorespiration?
(a) It occurs in chloroplast.
(b) It occurs in day time only.
(c) It is a characteristic of C_4 plants.
(d) It is a characteristic of C_3 plants. *(2003)*

84. Photorespiration is favoured by
(a) high temperature and low O_2
(b) high humidity and temperature
(c) high O_2 and low CO_2
(d) high CO_2 and low O_2. *(1996)*

85. The substrate for photorespiration is
(a) phosphoglyceric acid
(b) glycolate
(c) serine
(d) glycine. *(1989)*

13.10 Factors Affecting Photosynthesis

86. With reference to factors affecting the rate of photosynthesis, which of the following statements is not correct?
(a) Increasing atmospheric CO_2 concentration up to 0.05% can enhance CO_2 fixation rate.
(b) C_3 plants respond to higher temperature with enhanced photosynthesis while C_4 plants have much lower temperature optimum.
(c) Tomato is a greenhouse crop which can be grown in CO_2-enriched atmosphere for higher yield.
(d) Light saturation for CO_2 fixation occurs at 10% of full sunlight.
(NEET 2017)

87. Plants adapted to low light intensity have
(a) larger photosynthetic unit size than the sun plants
(b) higher rate of CO_2 fixation than the sun plants
(c) more extended root system
(d) leaves modified to spines. *(2004)*

88. The rate of photosynthesis is higher in
(a) very high light (b) continuous light
(c) red light (d) green light.
(1999)

89. 'The law of limiting factors' was proposed by
(a) Leibig (b) Hatch and Slack
(c) Blackman (d) Arnon. *(1996)*

90. At a temperature above 35°C
(a) rate of photosynthesis will decline earlier than that of respiration
(b) rate of respiration will decline earlier than that of photosynthesis
(c) there is no fixed pattern
(d) both decline simultaneously. *(1992)*

91. During monsoon, the rice crop of eastern states of India shows lesser yield due to limiting factor of
(a) CO_2 (b) light
(c) temperature (d) water. *(1991)*

ANSWER KEY

1.	(d)	**2.**	(a)	**3.**	(a)	**4.**	(a)	**5.**	(d)	**6.**	(d)	**7.**	(c)	**8.**	(d)	**9.**	(b)	**10.**	(d)
11.	(d)	**12.**	(c)	**13.**	(a)	**14.**	(c)	**15.**	(b)	**16.**	(a)	**17.**	(b)	**18.**	(d)	**19.**	(c)	**20.**	(a)
21.	(a)	**22.**	(d)	**23.**	(a)	**24.**	(a)	**25.**	(a)	**26.**	(c)	**27.**	(a)	**28.**	(c)	**29.**	(a)	**30.**	(b)
31.	(b)	**32.**	(c)	**33.**	(b)	**34.**	(b)	**35.**	(c)	**36.**	(d)	**37.**	(b)	**38.**	(c)	**39.**	(d)	**40.**	(a)
41.	(d)	**42.**	(c)	**43.**	(c)	**44.**	(c)	**45.**	(c)	**46.**	(a)	**47.**	(d)	**48.**	(b)	**49.**	(b)	**50.**	(c)
51.	(c)	**52.**	(d)	**53.**	(a)	**54.**	(d)	**55.**	(d)	**56.**	(a)	**57.**	(b)	**58.**	(c)	**59.**	(c)	**60.**	(b)
61.	(d)	**62.**	(d)	**63.**	(c)	**64.**	(d)	**65.**	(b)	**66.**	(c)	**67.**	(a)	**68.**	(d)	**69.**	(a)	**70.**	(c)
71.	(c)	**72.**	(d)	**73.**	(b)	**74.**	(a)	**75.**	(a)	**76.**	(a)	**77.**	(b)	**78.**	(c)	**79.**	(d)	**80.**	(c)
81.	(d)	**82.**	(c)	**83.**	(c)	**84.**	(c)	**85.**	(b)	**86.**	(b)	**87.**	(a)	**88.**	(c)	**89.**	(c)	**90.**	(a)
91.	(b)																		

Hints & Explanations

1. (d)

2. (a) : Green sulphur bacteria do not have the ability to use water as an electron donor (or cannot oxidise water), instead they perform photosynthesis using sulfide. Therefore, they do not evolve oxygen during photosynthesis.

3. (a) : In *Rhodospirillum,* electron donor is organic compound instead of water hence no oxygen is released, *i.e.,* anoxygenic photosynthesis occurs. In other plants water is used as electron donor and H^+ and O_2 are produced during photolysis of water.

4. (a) : *Oscillatoria* is a filamentous cyanobacteria which performs oxygenic photosynthesis because of the presence of chlorophyll-*a* like eukaryotic algae and higher plants.

5. (d) : The dark reactions of photosynthesis are purely enzymatic and slower than the primary photochemical reaction. They take place in stroma portion of the chloroplast and are independent of light, *i.e.*, they can occur either in presence or in absence of light provided that assimilatory power is available.

6. (d) : Emerson *et al.* (1957) found that if light of shorter wavelengths was provided at the same time as the longer red wavelengths, photosynthesis was even faster than the sum of the two rates with either colour alone. This synergism or enhancement became known as the Emerson enhancement effect. The two separate groups of pigments or photosystems cooperate in photosynthesis-long red wavelengths are absorbed only by one photosystem, called photosystem I (PS I) and the second photosystem, photosystem II (PS II), absorbs wavelengths shorter than 690 nm, and for maximum photosynthesis wavelengths absorbed by both systems must function together. The two photosystems normally cooperate to cause photosynthesis at all wavelengths shorter than 690 nm, because both photosystems absorb those wavelengths. The importance of Emerson's work is that it suggested the presence of two distinct photosystems.

7. (c) : Chromatophores are the internal membrane systems of photosynthetic forms which possess photosynthetic pigments. They occur in photoautotrophic bacteria, *e.g.*, purple bacteria and green bacteria.

8. (d) : Carotenoids of higher plants are fat soluble compounds that include carotenes and xanthophylls. Most of them absorb light of violet and blue range. Green light is absorbed in less amount.

9. (b) : Chlorophyll is the green pigment present in plants and some photosynthetic bacteria. The empirical formula of chlorophyll-*a* molecule is $C_{55}H_{72}O_5N_4Mg$. It consist of a porphyrin head and a phytol tail. Porphyrin is a cyclic tetrapyrrole structure, having a magnesium atom in the centre. Tail consists of phytol alcohol and it is attached with one of the pyrrole rings.

10. (d) : The empirical formula of chlorophyll *a* molecule is $C_{55}H_{72}O_5N_4Mg$. It has tadpole like configuration. It consists of a porphyrin head and a phytol tail. Porphyrin is a cyclic tetrapyrol structure, having a magnesium atom in the centre. In chlorophyll *a*, a methyl group (CH_3) is attached to the third carbon in the porphyrin head.

11. (d) : *Refer to answer 9.*

12. (c) : Chlorophyll-*a* occurs in all photosynthesizing plants except bacteria. Chlorophyll-*a* is common to all organisms that possess chlorophyll (the only one in blue green algae) and is believed to be specifically required. In a few photosynthetic bacteria other kinds of chlorophyll, bacteriochlorophylls occur.

13. (a) : Photosynthetic pigments are found in the thylakoid membrane of chloroplasts. The grana lamellae are paired to form sac like structures and form thylakoids. Chlorophylls and other photosynthetic pigments are confined to grana.

14. (c) : Chlorophyll are the magnesium porphyrin (head, 15 × 15 Å) compounds. The porphyrin ring consists of four pyrrole rings joined together by CH bridges. A long chain of C atoms called as phytol (tail; 20 Å) chain is attached to porphyrin ring.

15. (b) : In light reaction of photosynthesis, ATP, NADPH and oxygen are produced. NADPH participates in anabolic reactions (*e.g.*, photosynthesis) that consume energy in order to build up larger molecules. NADH participates in catabolic reactions (*e.g.*, respiration) that break down molecules to release energy.

16. (a) : Photosynthesis occurs in chloroplasts that contain photosynthetic pigments - chlorophylls, carotenoids, etc. The light energy required for photosynthesis comes from sunlight. The sunlight travels in the form of small particles called photons. Each photon has a quantum of energy. This quantum of energy is absorbed by a single antenna chlorophyll and then migrates from one molecule to the other till it reaches the reaction center of photosystems. The reaction center is also P_{700} chlorophyll molecule that releases electron as a result of transferred energy. This electron is transferred between various acceptors and generates ATP and $NADPH_2$ in the light reaction of photosynthesis.

17. (b) : The process of photosynthesis involves two steps–

(i) Light dependent phase or photochemical reaction.

(ii) Light independent phase or dark reaction.

Light reaction occurs in grana fraction of chloroplast and in this reaction are included those activities, which are dependent on light.

The grana of chloroplasts contains many collaborating molecules of pigment. A quantum of light is absorbed by a single antenna chlorophyll, then it migrates from one molecule to the other till it reaches the reaction center. This quantum of light is used for generating ATP and NADPH, which is later consumed in dark reactions produce sugars by fixing CO_2 molecules.

18. (d)

19. (c) : During photosynthesis a portion of light energy absorbed by chlorophyll and carotenoids is eventually stored as chemical energy *via* the formation of chemical bonds. This conversion of energy from one form to another is a complex process that depends on cooperation between many pigment molecules and a group of electron transfer proteins. The majority of pigments serve as an antenna complex, collecting light and transfusing energy to the reaction center complex.

There are two photochemical complexes, known as photosystem I and II. PSII absorbs far red light of wavelengths greater than 680 nm and PSI absorbs red light of wavelengths greater than 700 nm. Both these complexes are involved in light reactions of photosynthesis.

20. (a) : In photosystem-I, the ejected electron is trapped by iron-sulphur protein complex which is an unknown oxidation - reduction system. The electron is now transferred to a non-heme iron protein called ferredoxin (Fd) from which electron is transferred to $NADP^+$ intermediate protein electron carrier ferrodoxin-NADP reductase. So that $NADP^+$ is reduced to $NADPH + H^+$.

21. (a) : After excitement, e^- is passed from PS-II(P_{680}) to primary electron acceptor (Pheophytin). From primary e^- acceptor, e^- is passed to plastoquinone. Plastoquinone (PQ) in turn transfer its e^- to Cyt b_6f complex. Therefore plastoquinone facilitiates the transfer of electrons from PS-II to Cyt b_6f complex.

22. (d)

23. (a) : Polyandrous condition (having large and indefinite number of stamens) is present in *Gloriosa* (Family Liliaceae) and *Petunia* (Family Solanaceae).

Nitrogen fixation is the conversion of inert atmospheric nitrogen into utilisable compounds of nitrogen like nitrate, ammonia, amino acids, etc. Biological nitrogen fixation is performed by free living and symbiotic bacteria and cyanobacteria. Symbiotic nitrogen fixers occur in association with roots of higher plants. For example *Rhizobium* is nitrogen fixing bacterial symbiont of papilionaceous roots and *Frankia* is symbiont in root nodules of several non-leguminous plants like *Casuarina*. Both *Rhizobium* and *Frankia* live free as aerobes in the soil and develop the ability to fix nitrogen only as symbionts when they become anaerobic.

24. (a) : Manganese (Mn^{2+}) is used for photolysis of water to produce oxygen and electrons during light reaction of photosynthesis. It is the phenomenon of breaking up of water into hydrogen and oxygen in the illuminated chloroplast.

25. (a) : Z scheme involves both PSI and PSII to transfer electron excited by light starting from PSII uphill to the acceptor, down to the electron transport chain to PSI, which further comprise of excitation of electrons, transfer to another acceptor and finally down hill to $NADP^+$ causing reduction of it to $NADPH + H^+$. Cyclic photophosphorylation results only in synthesis of ATP not of $NADPH + H^+$. Stroma lamella contains PSI only.

26. (c) : *Refer to answer 25.*

27. (a) : The electrons released during photolysis of water are picked up by P_{680} photocentre of photosystem II. The electron extruded by the photocentre of photosystem II picked up by the quencher phaeophytin. From here the electron passes over a series of carriers in a downhill journey losing its energy at every step. The major carriers are plastoquinone (PQ), cytochrome $b - f$ complex and plastocyanin (PC). While passing over cytochrome complex, the electron loses sufficient energy for the creation of proton gradient and synthesis of ATP from ADP and inorganic phosphate. The process is called photophosphorylation (noncyclic).

28. (c) : *Refer to answer 27.*

29. (a) : *Refer to answer 20.*

30. (b) : The light dependent production of ATP from ADP + P*i* in the chloroplasts is called photophosphorylation. Photophosphorylation is of 2 types – Cyclic photophosphorylation – It involves only PS-I, water is not utilised and so no oxygen is evolved. Here two ATP molecules are produced. Non-cyclic photophosphorylation – It involves both PS-I and PS-II, water is utilised and so oxygen is evolved. Here one ATP molecule and one $NADPH_2$ molecule are produced.

31. (b) : Photosynthesis consists of light dependent phase and light independent phase or dark reaction. Light dependent phase occurs in grana fraction of chloroplast. It involves cyclic and non-cyclic photophosphorylation where assimilatory powers (ATP and $NADPH_2$) are produced. In dark reaction, which occurs in stroma fraction of chloroplast, actual reduction of CO_2 to carbohydrates takes place using the assimilatory powers (ATP and $NADPH_2$) produced in the light dependent phase. It needs 18 ATP and 12 $NADPH_2$ molecules to produce one molecule of glucose.

32. (c) : Emerson and Lewis worked on *Chlorella* and calculated the quantum yield for different wavelengths. Emerson observed that rate of photosynthesis declines in the red region of the spectrum. This decline in photosynthesis is called "Red drop". It was observed that the quantum yield falls when the light of wavelengths more than 680 or 690 nm are supplied. As the PS-II P_{680} is driven by red light, so it remains inactive during red drop.

33. (b) : *Refer to answer 30.*

34. (b) : Water molecule breaks up into hydrogen and oxygen in the illuminated chloroplasts. This is called photolysis of water. If a photosynthesising plant is releasing ^{18}O more than the normal, the plant must have been supplied with H_2O with ^{18}O.

35. (c) : Photosystem II has almost equal number of chlorophyll *a* and chlorophyll *b* molecules. It is dark green in colour and located mostly in the appressed parts of grana thylakoids towards the inner surface of membranes.

36. (d) : Non-cyclic photophosphorylation involves both PS-I and PS-II. Here electrons are not cycled back and are used in the reduction of NADP to $NADPH_2$. The electrons generated by PSII are passed over a series of electron carriers in a downhill journey and handed over to reaction centre of PSI. PSI again passes the electrons to $NADP^+$ which combines with H^+ ions to form NADPH.

37. (b) : The light-independent reactions (dark or Blackman's reactions) of photosynthesis take place in stroma or matrix of chloroplasts. These reactions are enzymatic reactions which catalyse assimilation of CO_2 into carbohydrates.

38. (c)

39. (d) : Calvin, Benson and their colleagues in California, U.S.A. fed *Chlorella* and *Scenedesmus* with radioactive ^{14}C in carbon dioxide. Radioactive carbon, ^{14}C has a half life of 5568 years. Therefore, the path of CO_2 fixation can be easily traced with its help. Algal suspension, illuminated and carrying out photosynthesis with normal carbon dioxide, was supplied $^{14}CO_2$. The alga was killed at intervals in near boiling methanol. It immediately stopped photosynthesis activity due to denaturation of enzymes. Alcohol was evaporated and after crushing the alga, the product was made into paste. The paste was placed on paper chromatogram and the different compounds were separated by two dimensional chromatography. The radioactive compounds were identified by comparing their position on the chromatogram with standard chemicals. Calvin and co-workers found that after three seconds, radioactivity appeared in phosphoglyceric acid or PGA. Phosphoglyceric acid is, therefore, the first stable product of photosynthesis.

40. (a) : The chemiosmotic coupling hypothesis of oxidative phosphorylation proposed by Mitchell, explains the process of ATP formation and states that it is linked to development of a proton gradient across a membrane. ATP synthase, required for ATP synthesis is located in F_1 particles present in the inner mitochondrial membrane and becomes active only when there is high concentration of proton on F_0 side as compared to F_1 side. The flow of proton through F_0 channel induces F_1 particle to function as ATP synthase and the energy of proton gradient produces ATP by attaching a phosphate radical to ADP.

41. (d) : Chemiosmotic coupling hypothesis is the most widely accepted explanation for oxidative phosphorylation in mitochondria and photophosphorylation in thylakoid membranes. Mitchell proposed the idea of chemiosmotic coupling. He suggested that a concentration gradient of protons is established across the mitochondrial membrane because there is an accumulation of hydrogen ions on one side of the mitochondrial membrane. The proton accumulation is necessary for energy transfer to the endergonic ADP phosphorylation process.

42. (c) : The Calvin cycle is also known as C_3 cycle because CO_2 reduction is cyclic process and first stable product in this cycle is a 3-C compound (*i.e.*, 3-phosphoglyceric acid or 3-PGA). In this cycle, CO_2 acceptor molecule is RuBP or RuDP (*i.e.*, Ribulose 1, 5-biphosphate or Ribulose 1, 5-diphosphate). There occurs covalent bonding of CO_2 to RuBP and the enzyme catalyzing this reaction is RuBP-carboxylase/oxygenase (RuBisCO).

43. (c) : Photosynthesis is actually oxidation reduction process in which water is oxidised and CO_2 is reduced to carbohydrates. The reduction of CO_2 to carbohydrates needs assimilatory powers, *i.e.*, ATP and $NADPH_2$. The process of photosynthesis involves two steps–

(i) Light dependent phase or photochemical reaction.

(ii) Light independent phase or dark reaction.

In Calvin cycle, CO_2 acceptor molecule is RuBP or RuDP. The enzyme catalyzing this reaction is RuBP-carboxylase/ oxygenase (RuBisCO). As Calvin cycle takes in only one carbon (as CO_2) at a time, so it takes six turns of the cycle to produce a net gain of six carbons (*i.e.*, hexose or glucose). In this cycle, for formation of one mole of hexose sugar (Glucose), 18 ATP and 12 $NADPH_2$ are used. For 6 molecules of CO_2 it needs 18 ATP and 12 $NADPH_2$ molecules so for assimilation of one molecule of CO_2 it needs 3 ATP and 2 $NADPH_2$ molecules.

44. (c) : *Refer to answer 43.*

45. (c) : The Calvin cycle is also known as C_3 cycle because CO_2 reduction is cyclic process and first stable product in this cycle is a 3-C compound (*i.e.*, 3-phosphoglyceric acid or 3-PGA). In this cycle, CO_2 acceptor molecule is RuBP or RuDP (*i.e.*, Ribulose 1, 5-biphosphate or Ribulose 1, 5-diphosphate). There occurs covalent bonding of CO_2 to RuBP and the enzyme catalyzing this reaction is RuBP-carboxylase/oxygenase (RuBisCO).

46. (a) : *Refer to answer 41.*

47. (d) : *Refer to answer 43.*

48. (b) : *Refer to answer 45.*

49. (b) : *Refer to answer 45.*

50. (c) : By employing ^{14}C labelled carbon dioxide $^{14}CO_2$ in photosynthesis and observing the appearance of characteristic radiations in different reaction intermediates and product in different experiments, Calvin and his co-workers were able to formulate the complete metabolic path of carbon assimilation in the form of cycle which is called Calvin cycle.

51. (c) : The dark reactions of photosynthesis are purely enzymatic and slower than the primary photochemical reaction. They take place in stroma portion of the chloroplast and independent of light, *i.e.*, they can occur either in presence or in absence of light provided that assimilatory power is available.

52. (d) : The dark reactions or Blackman's reactions or biosynthetic phase involves three steps: (i) Fixation of CO_2, (ii) Reduction of CO_2 and (iii) Synthesis of other compound from glucose. It is independent of light. Pigment System I is relatively very weakly fluorescent while pigment system II is strongly fluorescent. Light energy absorbed by pigment in the two systems is ultimately trapped by the P_{700} and P_{680}. Light reaction is associated with the grana of the chloroplasts. It takes place in the presence of light only.

53. (a) **54. (d)**

55. (d) : C_4 plants show kranz type of anatomy. In kranz anatomy, the mesophyll is undifferentiated and its cells occur in concentric layers around vascular bundles. The vascular bundles are surrounded by large sized bundle sheath cells which are arranged in wreath like manner in one to several layers. In C_4 plants there are two carboxylation reactions, first in mesophyll chloroplast and second in bundle sheath chloroplast. RuBP is present in bundle sheath chloroplasts where C_3 cycle takes place.

56. (a) : Crassulacean acid metabolism (CAM) is photosynthesis by the C_4 pathway in which carbon-dioxide is taken up during the night, when the plant's stomata are open and fixed into malic acid. During the day, when the stomata are closed, carbon dioxide is released from malic acid for use in the Calvin cycle. This is important for plants that live in arid conditions as it enables them to keep their stomata closed during the day to reduce water loss from evaporation. Crassulacean acid metabolism is common in succulent plants of desert regions, including cacti and in certain ferns.

57. (b) : The C_4 plants are adapted to dry tropical regions and have greater productivity of biomass. They have special type of leaf anatomy known as kranz anatomy. In this type of anatomy the bundle sheath cells form several layers around the vascular bundles; they are characterised by having a large number of chloroplasts, thick walls impervious to gaseous exchange and no intercellular spaces.

58. (c)

59. (c) : In kranz anatomy, the mesophyll is undifferentiated and its cells occur in concentric layers around vascular bundles. Vascular bundles are surrounded by large sized bundle sheath cells which are arranged in a wreath-like manner in one to several layers. C_4 plants, both monocots and dicots, such as sugarcane, maize, sorghum have kranz anatomy in leaf.

60. (b) : C_4 plants are photosynthetically more efficient than C_3 plants because C_4 plants contain two types of chloroplast, *i.e.*, bundle sheath chloroplast and mesophyll chloroplast. So such plants operate a dicarboxylic acid cycle in addition to Calvin cycle. CO_2 acceptor molecule (PEP) is present in large bundle sheath cell which has higher efficiency in picking up CO_2. Thus, photosynthesis continues even at low CO_2 concentration and the rate of photorespiration is also negligible.

61. (d) : C_4 plants show kranz anatomy, *i.e.,* the mesophyll is undifferentiated and its cells occur in concentric layers around vascular bundle, which is surrounded by large sized bundle sheath cells, in a wreath like manner. In this type of plants, the initial fixation of CO_2 occur in mesophyll cell. The primary acceptor (phosphoenol pyruvate) combines with CO_2 to form oxaloacetic acid which later reduces to malic acid. Malic acid is then translocated to bundle sheath cell for further decarboxylation.

62. (d) : *Refer to answer 61.*

63. (c) : In C_4 plants, 12 ATP molecules are required for producing one hexose sugar. In the bundle sheath cells, C_3 cycle operates which requires 18ATP and $12NADPH_2$ molecules. So total 30 ATP and 12 $NADPH_2$ molecules are required in C_4 cycle. Whereas in C_3 cycle 18 ATP and $12NADPH_2$ molecules are required.

64. (d)

65. (b) : C_4 pathway was first reported in members of Family Gramineae (grasses) like sugarcane, maize, sorghum, etc. In C_4 plants, PEP case (PEP carboxylase) is the key enzyme used to fix CO_2 in C_4 plants. Oxaloacetic acid is a 4-C compound and is the first stable product so this pathway is known as C_4 cycle.

Phosphoenol pyruvic acid + Carbon dioxide $\xrightarrow{\text{PEP-carboxylase}}$ Oxaloacetic acid

66. (c) : Stomata of most plants open at sunrise and close in darkness to allow the entry of CO_2 needed for photosynthesis during the daytime. Certain succulents that are native to hot, dry conditions (*e.g.,* cacti, *Kalanchoe*, and *Bryophyllum*) act in an opposite manner. They open their stomata at night, fix carbon dioxide into organic acids in the dark, and close their stomata during the day. This is an appropriate way to absorb CO_2 through open stomata at night, when transpiration stress is low, and conserve water during the heat of the day. These plants show Crassulacean Acid Metabolism (CAM).

67. (a) : C_4 pathway was first reported in members of Family Gramineae (grasses) like sugarcane, maize, sorghum, etc.

68. (d) : In C_4 plants, PEP case (PEP carboxylase) is the key enzyme used to fix CO_2 in C_4 plants.Oxaloacetic acid is a 4-C compound and is the first stable product so this pathway is known as C_4 cycle.

Phosphoenol pyruvic acid + Carbon dioxide $\xrightarrow{\text{PEP-carboxylase}}$ Oxaloacetic acid

69. (a) : *Refer to answer 65.*

70. (c) : The C_4 plants have a characteristic leaf anatomy called kranz anatomy. Here two types of chloroplasts are present - bundle sheath chloroplasts and mesophyll chloroplasts. In C_4 plants, there are two carboxylation reactions which occur first in mesophyll chloroplasts and then in bundle sheath chloroplasts. CO_2 acceptor molecule in mesophyll chloroplasts is PEP (Phosphoenol pyruvate) and not Ribulose 1, 5-biphosphate. Further it has enzyme PEP-carboxylase for initial CO_2 fixation. RuBP-carboxylase is absent in mesophyll chloroplasts but is present in bundle sheath chloroplasts. The first product formed is oxaloacetic acid and hence it is known as C_4 cycle. Bundle sheath cells fix CO_2 through C_3 cycle.

71. (c) : *Refer to answer 70.*

72. (d)

73. (b) : *Refer to answer 65.*

74. (a) : In C_4 cycle, CO_2 combines with phosphoenol pyruvic acid to form oxaloacetic acid with the help of enzyme phosphoenol pyruvate carboxylase (PEPcase). The oxaloacetic acid breaks up into pyruvic acid and CO_2 combines with RuBP to form PGA as in Calvin cycle.

75. (a)

76. (a) : *Refer to answer 70.*

77. (b) : During photorespiration in C_3 plants, some O_2 does bind to RuBisCO and RuBP instead of being converted to 2 molecules of PGA binds with O_2 to form one molecule of phosphoglycerate (3 Carbon) and phosphoglycolate (2 Carbon).

78. (c) : Photorespiration is the light dependent process of oxygenation of ribulose biphosphate (RuBP) and release of carbon dioxide by the photosynthetic organs of a plant. It leads to oxidation of considerable amount of photosynthetic products to CO_2 and H_2O without the production of useful energy. Photorespiration occurs only in C_3 plants because at high temperature and high oxygen concentration RuBP carboxylase changes to RuBP oxygenase. Photorespiration is absent in C_4 plants. Peroxisome and mitochondria are required for completing the process.

79. (d) : *Refer to answer 78.*

80. (c)

81. (d) : Rate of net photosynthesis in C_3 plants is 15-35 mg $CO_2/dm^2/hr$ while in C_4 plants is 40-80 mg $CO_2/dm^2/hr$. This variation in rate is due to photorespiration. Photorespiration is an inhibitory process which decreases the rate of photosynthesis. In excess of oxygen RuBP carboxylase converts to RuBP oxygenase. As a result glycolate synthesis is enhanced and leads to begin photorespiration. Photorespiration is negligible or absent in C_4 plants and present only in C_3 plants. So C_4 plants are photosynthetically more efficient.

82. (c)

83. (c) : Photorespiration is the light dependent process of oxygenation of ribulose biphosphate (RuBP) and release of carbon dioxide by the photosynthetic organs of a plant. It leads to oxidation of considerable amount of photosynthetic products to CO_2 and H_2O without the production of useful energy. Photorespiration occurs only in C_3 plants because at high temperature and high oxygen concentration RuBP carboxylase changes to RuBP oxygenase. Photorespiration is absent in C_4 plants. Peroxisome and mitochondria are required for completing the process.

84. (c) : *Refer to answer 83.*

85. (b)

86. (b) : C_4 plants respond to higher temperature with enhanced photosynthesis while C_3 plants have lower temperature optimum.

87. (a) : To absorb more sunlight (quantitatively), the plants growing in low light conditions have larger photosynthetic unit size. It means that they have more number of chlorophyll molecules per reaction center. to trap more light energy available to them.

88. (c) : Plants can use a small portion of light which falls upon them. Chlorophyll-*a* and chlorophyll-*b* absorb too much light in the blue and red region. Carotenoids absorb light mostly in the blue region of spectrum of light. In monochromatic lights, maximum photosynthesis occurs in red light, followed by blue light and poor photosynthesis in green light. Under very high light intensity solarisation phenomenon occurs. It involves photooxidation of different cellular components including chlorophyll.

89. (c) : Blackman (1905) gave the law of limiting factors which states that when a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest process. It is the factor which is present in minimum amount.

90. (a) : The plants can perform photosynthesis on a range of temperature, while some cryophytes can do photosynthesis at 35°C. Usually the plants can perform photosynthesis between 10°C - 40°C. The optimum temperature ranges between 25°C - 30°C. At high temperature the enzymes are denatured and hence the photosynthetic rate declines.

91. (b) : Rate of yield is dependent of light as photosynthesis is dependent on light. Maximum rate of photosynthesis occur when light is brightest (high light intensity). But during monsoon, the light is dim (low light intensity) and so this reduces rate of photosynthesis and hence yield.

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