Chapter 13. Photosynthesis in Higher Plants

1. 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)*

2. 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)

3. 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)

4. Water vapour comes out from the plant leaf through the stomatal opening. Through the same stomatal opening carbon dioxide diffuses into the plant during photosynthesis. Reason out the above statements using one of following options.
(a) The above processes happen only during night time.
(b) One process occurs during day time and the other at night.
(c) Both processes cannot happen simultaneously.
(d) Both processes can happen together because the diffusion coefficient of water and CO_2 is different. *(NEET-I 2016)*

5. 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)*

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. 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)*

8. Water soluble pigments found in plant cell vacuoles are
(a) carotenoids (b) anthocyanins
(c) xanthophylls (d) chlorophylls.
(NEET-I 2016)

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

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

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

12. 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)*

13. 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)

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

15. 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)*

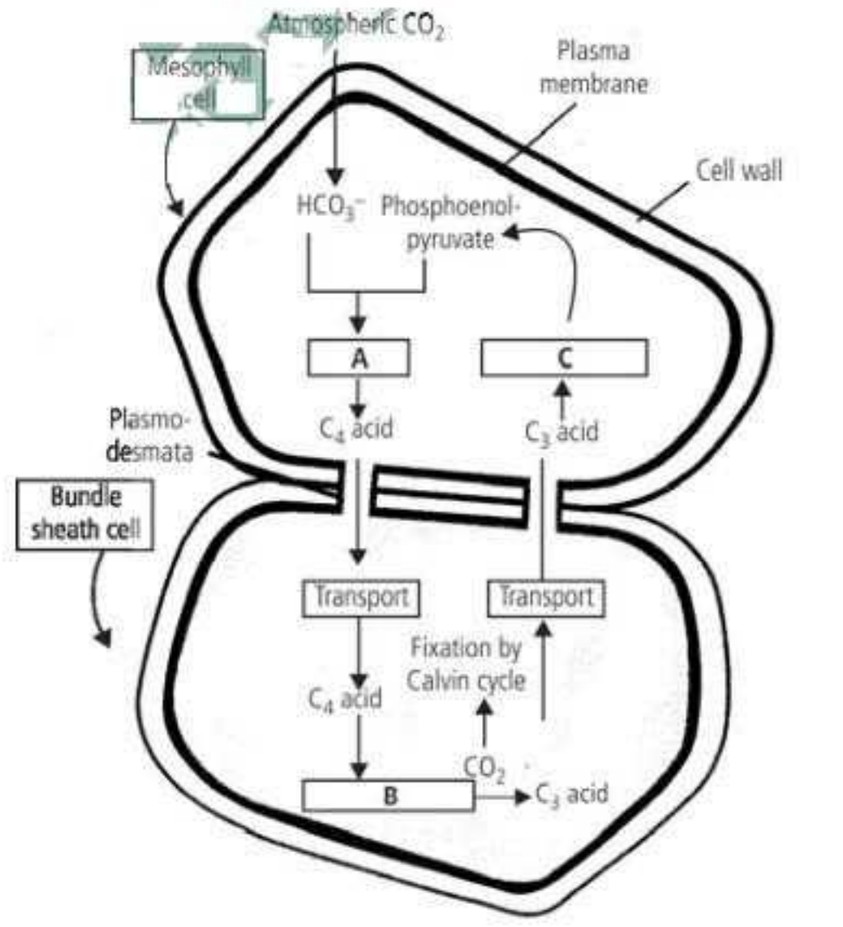
16. Which one of the following is essential for photolysis of water?
(a) Manganese (b) Zinc
(c) Copper (d) Boron
(Mains 2011)

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

18. 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)*

19. 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)

20. 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)

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

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

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

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

25. 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)*

26. 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)*

27. 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)*

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. 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)*

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

31. 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)*

32. Photosynthetic Active Radiation (PAR) has the following range of wavelengths.
(a) 340-450 nm (b) 400-700 nm
(c) 500-600 nm (d) 450-950 nm *(2005)*

33. 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)*

34. 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)*

35. 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)*

36. 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)*

37. 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)*

38. 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)*

39. 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)*

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

41. 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)

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

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

44. Which pigment absorbs the red and far-red light?
(a) Cytochrome (b) Phytochrome
(c) Carotenoids (d) Chlorophyll
(2002)

45. What is true for photolithotrophs?
(a) Obtain energy from radiations and hydrogen from organic compounds
(b) Obtain energy from radiations and hydrogen from inorganic compounds
(c) Obtain energy from organic compounds
(d) Obtain energy from inorganic compounds
(2001)

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

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

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

49. 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)*

50. 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)*

51. 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)*

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

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

54. 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)

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

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

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

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

59. 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)*

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

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

62. 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)*

63. 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)*

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

65. 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)*

66. 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)*

67. Maximum solar energy is trapped by
(a) planting trees
(b) cultivating crops
(c) growing algae in tanks
(d) growing grasses. *(1993)*

68. 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)*

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

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

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

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

73. 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)*

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

75. 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)*

76. 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)*

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

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

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

80. A very efficient converter of solar energy with net productivity of 204 kg/m^2 or more is the crop
(a) wheat (b) sugarcane
(c) rice (d) bajra. *(1989)*

81. 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)*

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

83. 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)*

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

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

Answer Key

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

EXPLANATIONS

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

2. (a)

3. (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.

4. (d) **5. (d)**

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 and that such long red wavelengths are absorbed only by one photosystem, called photosystem I (PS I). 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. (d)

8. (b) : Anthocyanins are water soluble pigments, which commonly occur in membrane enclosed vacuoles. They are responsible for colour of fruits and flower petals.

9. (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.

10. (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.

11. (d) : *Refer to answer 3.*

12. (c) : *Refer to answer 3.*

13. (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 *e.g., 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.

14. (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 spurges and in certain ferns.

15. (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.

16. (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. It acts as an essential cofactor.

17. (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.

18. (d) : Rate of net photosynthesis in C_3 plants is 15-35 mg $CO_2/dm^2/hr$ while in C_4 plants it 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.

19. (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 $NADPH + H^+$. Stroma lamella contains PSI only.

20. (c) : A – Fixation of CO_2 by PEP carboxylase
B – Decarboxylation
C – Regeneration

21. (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.

22. (c) : In cyclic photophosphorylation, 2 molecules of ATP are synthesised which are used in dark reaction. Cyclic photophosphorylation is not concerned with photolysis of water. So O_2 is not evolved and NADPH is also not produced.

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

24. (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).

25. (b) : C_4 plants are photosynthetically more efficient than C_3 plants because C_4 plant 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.

26. (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.

27. (d)

28. (c) : Type I photosystems use ferredoxin like iron-sulphur cluster proteins as terminal electron acceptors, while type II photosystems ultimately shuttle electrons to a quinone terminal electron acceptor. One has to note that both reaction centres

types are present in chloroplasts of plants and cyanobacteria, working together to form an unique photosynthetic chain able to extract electrons from water, evolving oxygen as a byproduct.

29. (c)

30. (a) : In light reaction of photosynthesis two types of photosystems are involved. PS-I consists of plenty of chlorophyll-*a* and very less quantity of chlorophyll-*b*. These pigments absorb light energy and transfer it to the reaction centre - P_{700}. After absorbing adequate amount of light energy electron gets excited from P_{700} molecule and moves to iron-sulphur protein complex, designated as A (Fe-S). It gets reduced after accepting electrons. It later gives these electron to ferredoxin and gets oxidized again.

31. (c) : In C_4 plants the cost of concentrating CO_2 within the bundle sheath cell is 2ATP per CO_2.

Energetics of the C_4 photosynthetic carbon cycle–

$PEP + H_2O + NADPH + CO_2 \rightarrow Malate + NADP^+ + iP$
$Malate + NADP^+ \rightarrow Pyruvate + NADPH + CO_2$
$Pyruvate + iP + ATP \rightarrow PEP + AMP + iPP$
$iPP + H_2O \rightarrow 2iP$
$AMP + ATP \rightarrow 2ADP$
Net: CO_2 (mesophyll) $\rightarrow$ CO_2 (bundlesheath) + $2ADP + 2iP$ $+ ATP + 2H_2O$

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.

32. (b) : Wavelengths between 400 and 700 nm, which comprise the visible range of electromagnetic spectrum are capable of causing photosynthesis. These are called photosynthetically active radiations. Chlorophyll *a* and *b* absorb too much light in the blue and red region of spectrum of light. Carotenoids mostly absorb is the blue region of the spectrum.

33. (d)

34. (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).

35. (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.

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

37. (c) : *Refer to answer 3.*

38. (b) : C_4 pathway was first reported in members of family Gramineae (grasses) like sugarcane, maize, sorghum, etc.

In C_4 plants PEPCo (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

39. (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).

40. (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.

41. (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 utilized 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 utilized and so oxygen is evolved. Here one ATP molecule and one $NADPH_2$ molecule are produced.

42. (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.

43. (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.

44. (b) : Phytochrome has a light absorbing or light detecting portion (the chromophore) attached to small protein of about 1,24,000 daltons. Phytochrome occurs in 2 forms, *i.e.*, P_R and P_{FR} (*i.e.*, red light and far red light absorbing forms) and these 2 forms are interconvertible.

Cytochromes are electron transferring proteins. They contain iron porphyrin or copper porphyrin as prosthetic groups. Chlorophyll is the fundamental green pigment of photosynthesis. It is localized in the chloroplasts. Carotenoids are lipid compounds and they are yellow, orange, purple etc. in colour. These are found in higher plants red algae, green algae, fungi and photosynthetic bacteria.

45. (b) : Photolithotrophs are those plants that obtain energy from radiation and hydrogen from inorganic compounds.

46. (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.

47. (a) : *Refer to answer 38.*

48. (d) : *Refer to answer 38.*

49. (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 RuBP. 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.

50. (c) : *Refer to answer 49.*

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

(i) Light dependent phase or photochemical reaction.

(ii) Light independent these 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.

52. (c) : An enzyme ribulose biphosphate carboxylase catalyses the dark reaction, pertaining to the addition of CO_2 to Ribulose-1-5-diphosphate. It is found in abundance in leaves and it is believed that

it is the single most abundant protein on earth. It is clear that the first acceptor of CO_2 is Ribulose 1-5 diphosphate and the first product formed after fixation of CO_2 is 3-phosphoglyceric acid.

53. (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 solarization phenomenon occurs. It involves photooxidation of different cellular components including chlorophyll.

54. (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.

55. (d) : *Refer to answer 54.*

56. (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.

57. (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.

58. (d) : *Refer to answer 49.*

59. (c) : *Refer to answer 3.*

60. (a) : *Refer to answer 38.*

61. (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 (Phospho-enol 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.

62. (b) : *Refer to answer 34.*

63. (c) : *Refer to answer 61.*

64. (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.

65. (b) : *Refer to answer 41.*

66. (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.

67. (c) : Maximum solar energy is trapped by growing algae in tanks. The light spectrum of red and blue light are most effective in performing photosynthesis for growing algae.

68. (b) : In Calvin cycle, CO_2 is accepted by Ribulose - 1, 5 - diphosphate (RuDP) already present in the cells and a 6-carbon addition compound is formed which is unstable. It soon gets converted into 2 molecules of 3-phosphoglyceric acid due to hydrolysis and dismutation. Phosphoenol pyruvate (PEP) and Phosphoglyceric acid (PGA) are formed in glycolysis.

69. (d)

70. (c) : Chlorophyll-*a* occur in all photo-synthesizing plants except bacteria. Chlorophyll-*a* is the only one 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.

71. (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.

72. (b) : *Refer to answer 38.*

73. (a) : The primary acceptor of CO_2 is a 3 carbon compound phosphoenol pyruvic acid. Addition of CO_2 to any compound is called carboxylation. In C_4 cycle, CO_2 combines with phosphoenol pyruvic acid to form oxaloacetic acid, with the help of enzyme phosphoenol pyruvate carboxylase (PEPCo). The oxaloacetic acid breaks up into pyruvic acid and CO_2 which combines with RuBP to form PGA as in Calvin cycle.

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

75. (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.

76. (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 as Calvin cycle.

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

78. (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.

79. (a) : *Refer to answer 61.*

80. (b) : A very efficient converter of solar energy with net productivity of 2-4 kg/m^2 or more is sugarcane, maize which are C_4 plants. Others are C_3 plants.

81. (a) : *Refet to answer 61.*

82. (b)

83. (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.

84. (d) : *Refer to answer 56.*

85. (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.