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SET 02

PHOTOSYNTHESIS IN HIGHER PLANTS

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MASTERING NCERT

SET 02 PHOTOSYNTHESIS IN HIGHER PLANTS

NEET KEY NOTES

- All animals including human beings depend on plants for their requirement of food. Green plants can synthesise the food they need, but all other organisms depend on them for their needs.
- Green plants carry out photosynthesis. It is a physio-chemical process by which they use the light energy to manufacture organic compounds.
- Photosynthesis is an important phenomenon due to the following two reasons
  - It is the primary source of all food on the earth.
  - It is also responsible for the release of oxygen into the atmosphere by green plants.
- Photosynthesis in plants requires chlorophyll, light and CO_2.
- The basic reaction of photosynthesis appears extremely simple. Water and carbon dioxide combine to form carbohydrates and molecular oxygen and this reaction is driven by light energy.

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light energy}} C_6H_{12}O_6 + 6O_2$$

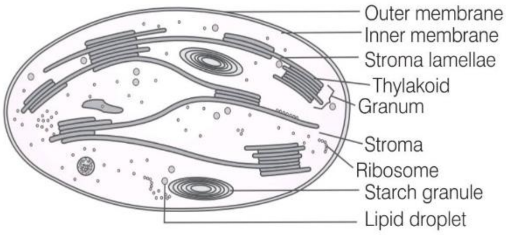
Early Experiments

The early experiments related to photosynthesis are as follows

- **Joseph Priestley** (1733-1804) in 1770, performed experiments to find out the role of oxygen in growth of green plants.
- **Jan Ingenhousz** (1730-1799) showed that sunlight is essential to the plants.
- **TW Engelman** (1843-1909) used a prism to split light into its spectral components and illuminated a green alga, *Cladophora* placed in a suspension of aerobic bacteria. The bacteria were used to detect the sites of oxygen evolution. He observed that the bacteria accumulated in the region of blue and red light of the split spectrum. The first action spectrum was thus described.
- **Julius von Sachs** (1854) showed that the chlorophyll is located in chloroplasts in plants cells.
- **Cornelius van Niel** (1897-1985) demonstrated that photosynthesis is essentially a light dependent reaction.

Where does Photosynthesis take Place ?

- Photosynthesis occurs in green parts of the plant, e.g. leaves. The actual site of photosynthesis is **chloroplast**.
- Chloroplasts are aligned along the walls of the mesophyll cell to get the optimum quality of the incident light.
- Within the chloroplast there is membranous system containing grana, the stroma lamellae and the matrix stroma.
- The membranous system is responsible for trapping the light energy and also for the synthesis of ATP and NADH.
- The stroma is the site of **dark reaction** (carbon reactions). The lamellar system within the stroma forms flattened sac like lamellae called **thylakoids**. Thylakoids are stacked to form granum.
- The major functions of thylakoid is to perform photosynthetic **light reaction** (photochemical reaction).



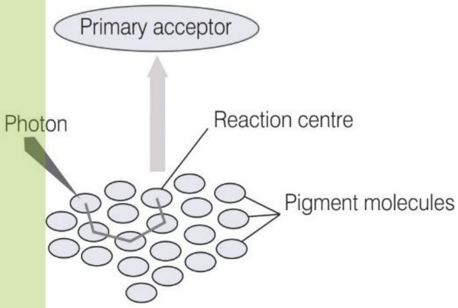
Diagrammatic representation of an electron micrograph of a section of chloroplast

Pigments Involved in Photosynthesis

- Photosynthetic pigments are substances that have an ability to absorb light, at specific wavelengths.
- The chromatographic separation of the leaf pigments shows that the colour of the leaf is due to four pigments.
- They are **chlorophyll-*a***, (bright or blue-green in the chromatograph), **chlorophyll-*b*** (yellow-green), **xanthophylls** (yellow) and **carotenoids**.
- The wavelengths at which there is maximum absorption by chlorophyll-*a*, i.e. in the blue and red regions, also shows higher rate of photosynthesis. This shows that chlorophyll-*a* is the chief pigment associated with photosynthesis.
- The other thylakoid pigments (called accessory pigments) like chlorophyll-*b*, xanthophylls and carotenoids also absorb light and transfer the energy to chlorophyll-*a* and also protect it from photo-oxidation.
- **Absorption spectrum** It is the curve that shows spectrum of different wavelength of lights absorbed by a different photosynthetic pigments.
- **Action spectrum** It is the curve that depicts the relative rates of photosynthesis at different wavelength of light.

What is Light Reaction?

- Photosynthesis begins with the absorption of light energy by chlorophyll. The process of photosynthesis takes place in the following two steps
  - Light reaction or Photochemical phase
  - Dark reaction or Biosynthetic phase
- Light reaction takes place in the presence of light. During this phase there is light absorption, water splitting, oxygen release and the formation of high energy chemical intermediates, ATP and NADPH. Several protein complexes are involved in the process.
- The pigments absorbing light are organised into two discrete photochemical **Light Harvesting Complex** (LHC) within the **Photosystem-I** (PS-I) and **Photosystem-II** (PS-II).
- The LHC are made up of hundreds of pigment molecules bound to proteins.

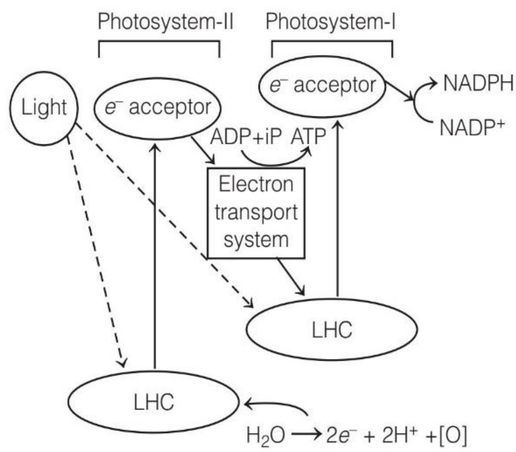


The light harvesting complex

- **Photosystem** Each photosystem has all the pigments (except one molecule of chlorophyll-*a*) forming a light harvesting system also called **antennae**. The single chlorophyll-*a* molecule forms the **reaction centre**.
- In PS-I, reaction centre chlorophyll-*a* has an absorption peak at 700 nm, hence called **P 700**, while in PS-II it has absorption maxima at 680 nm and is called **P680**.

The Electron Transport

- In PS-II, the chlorophyll-*a* absorbs 680 nm wavelength of red light causing electrons to become excited and jump into an orbit.
- These electrons are picked up by an electron acceptor, which passes them to an **electrons transport system consisting of cytochromes**.
- These electrons are not used up, but are passed on to the pigments of PS-I.
- The electrons in the reaction centre PS-I are also excited when they receive red light of wavelength 700 nm and are transferred to another acceptor molecule.
- These electrons move down hill to a molecule of energy rich $NADP^+$. The addition of these electrons reduces $NADP^+$ to $NADPH + H^+$.
- This whole scheme of transfer of electrons, starting from PS-II, uphill to the acceptor and finally down hill to $NADP^+$ causing it to reduced to $NADPH + H^+$ is called **Z-scheme**, due to its characteristic shape.



Z-scheme of Light Reaction

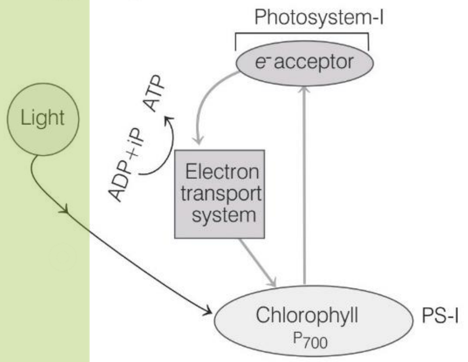
Splitting of Water

- PS-II supplies electrons continuously by splitting of water. Water is split into $2H^+$, [O] and electrons in the presence of light (i.e. photolysis). This creates oxygen, one of the net products of photosynthesis.

$$2H_2O \longrightarrow 4H^+ + O_2 + 4e^-$$

Cyclic and Non-Cyclic Photophosphorylation

- Photophosphorylation is the process through which ATP is synthesised from ADP and inorganic phosphate (Pi) by the cell organelles (like mitochondria and chloroplasts) with the help of energy form solar radiation.
- The process of photophosphorylation is of two types
  - **Non-Cyclic Photophosphorylation** It is a type of photophosphorylation in which both the photosystems (PS-I and PS-II) cooperate in light driven synthesis of ATP.
  - **Cyclic Photophosphorylation** It is the type of photophosphorylation in which only PS-I is taking part and the electron released from the reaction centre P700 returns to it after passing through a series of carrier, i.e. circulation takes place within the photosystem and the phosphorylation occurs due to cyclic flow of electrons. A possible location where this could be happening is in stroma lamellae.



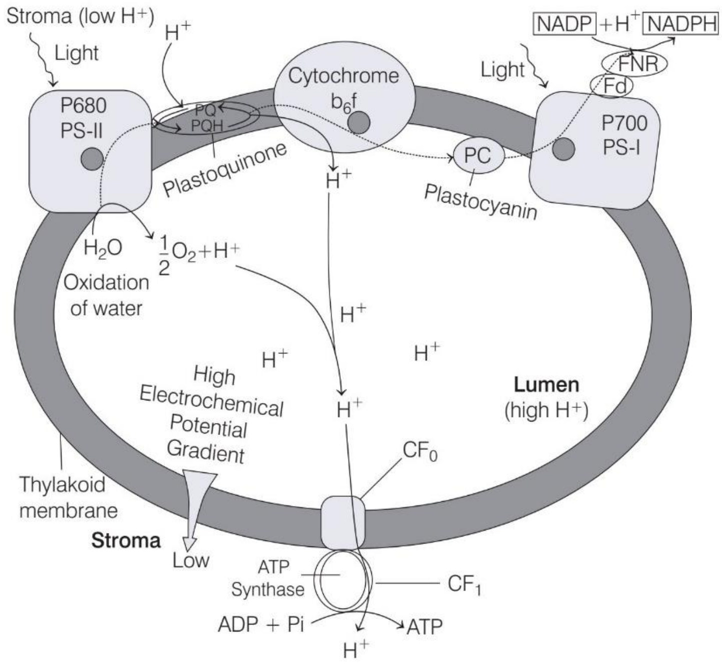
Cyclic photophosphorylation

Chemiosmotic Hypothesis

- It explains the mechanism of ATP synthesis in chloroplast. ATP synthesis is related to development of a proton gradient across a membrane. The steps that cause a proton gradient to develop are
  - The proton or hydrogen ions that are produced by splitting of water, accumulate within the lumen of thylakoids.
  - As electrons move through the photosystems, protons are transported across the membrane. This is because the primary acceptor of electron, which is located towards the outer side of membrane transfers its electrons not to an electron carrier, but to H carrier. Hence, this molecule removes a proton from the stroma, while transporting an electron.

The proton is then released into the inner side of the membrane.

- The NADP reductase enzyme is located on the stroma side of membrane. The protons are necessary for the reduction of $NADP^+$ to NADPH + H^+. These protons are also removed from the stroma.



ATP synthesis through chemiosmosis

- Hence, within the chloroplast, protons in the stroma decrease in number, while in the lumen there is accumulation of protons. This creates a proton gradient across the thylakoid membrane.
- The breakdown of gradient provides enough energy to cause a change in F_1 particle of the ATPase, which makes the enzyme synthesise several molecules of energy packed ATP. ATPase enzyme catalyses the formation of ATP.
- The ATP is used immediately in biosynthetic reaction taking place in stroma, responsible for fixing CO_2 and synthesis of sugar.

Where are the ATP and NADPH used ?

- We learnt that the products of light reaction are ATP, NADPH and O_2 of these O_2 diffuses out of the chloroplast while ATP and NADPH are used to drive the processes leading to the synthesis of food, more accurately, i.e. sugars. This is the **biosynthetic phase** of photosynthesis.
- It involves the fixation and reduction of CO_2 resulting in the formation of carbohydrates. Dark reaction is also called as **Blackman reaction**. It occurs in the stroma of the chloroplasts.
- Dark reaction does not directly depend on the presence of light, but is dependent on the products of light reaction, i.e. ATP and

NADPH, besides CO_2 and H_2O. CO_2 assimilation during photosynthesis follows two routes

- C_3-**pathway** in which first product of CO_2-fixation is a C_3 acid (**3PGA-3 phosphoglyceric acid**). It occurs in all plants.
- C_4-**pathway**, in which the first product of CO_2-fixation is a C_4 acid (**Oxaloacetic Acid or OAA**). It occurs in plants adapted to live in dry tropical regions.

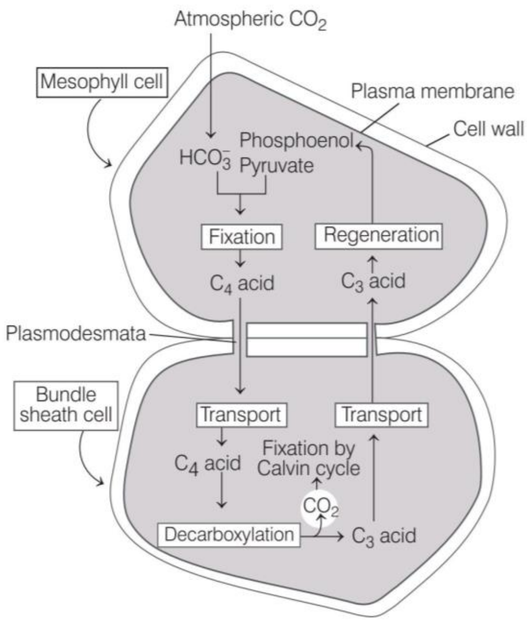
The Calvin Cycle

- This cycle was discovered by **Melvin Calvin** (1951) to explain the process of CO_2 fixation in green plants.
- In this pathway, the assimilatory power NADP(H) and ATP produced in light phase are used to reduce CO_2 into carbohydrate $(C_6H_{12}O_6)_n$.
- Calvin pathway occurs in all **photosynthetic plants**. It does not matter whether they have C_3 or C_4 (or any other) pathways.
- C_3-pathway involves three major steps are as follows
  - **Carboxylation** is the step in which CO_2 is utilised for the carboxylation of RuBP (Ribulose bisphosphate). RuBP is a acceptor molecule of CO_2, a 5-carbon ketose sugar. Carboxylation is catalysed by RuBP carboxylase oxygenase (**RuBisCO**), which results in the formation of 3 PGA.
  - **Reduction** involves two molecules of ATP for phosphorylation and two of NADPH for reduction per CO_2 molecule fixed.
  - **Regeneration** of CO_2 acceptor molecule RuBP require one ATP for phosphorylation to form RuBP.
- It might help you to understand all of this if we look at what goes in and what comes out of the Calvin cycle.

In	Out
6 CO_2	One glucose
18 ATP	18 ADP
12 NADPH	12 NADP

The C_4-Pathway

- C_4-pathway is present is plants that are adapted to live in dry tropical regions.
- These plants (C_4-plants) have the C_4 oxaloacetic acid as the first CO_2 fixation product, they use the C_3-pathway or the Calvin cycle as the main biosynthetic pathway.
- Characteristics of C_4-plants
  - They have a special type of leaf anatomy.
  - They can tolerate high temperatures.
  - They show a highlight intensities.
  - They lack a process called photorespiration and have greater productivity of biomass.
- C_4-plants have **bundle sheath cells** in their leaves called as **'Kranz anatomy'**.
- In Kranz anatomy, bundle sheath cells form several layers around the vascular bundles, having a large number of chloroplasts, thick walls impervious to gas exchange and no intercellular spaces.
- C_4-plants follow Hatch and Slack pathway. In this, the primary acceptor is a 3 carbon molecule **Phosphoenol Pyruvate** (PEP) and is present in mesophyll cells. The enzyme used is **PEP carboxylase**.
- The mesophyll cells lack RuBisCO enzyme. The C_4-acid OAA is formed in the mesophyll cells.
- OAA then forms other 4-carbon compounds like malic acid or aspartic acid in the mesophyll cells itself.
- The 3-carbon molecule released is transported back to mesophyll cells where it is converted to PEP again, thus completing the cycle.
- The CO_2 released in bundle sheath cells now enters the C_3 or the Calvin pathway (common to all plants). Calvin cycle does not take place in mesophyll cells in C_4-plants, but occurs only in bundle sheath cells.



Diagrammatic representation of the Hatch and Slack Pathway

Photorespiration

- Photorespiration is a process, which creates an important difference between C_3 and C_4-plants.
- It is a process which occurs in C_3-plants only.
  - In this, O_2 bind to the RuBisCO and decreases CO_2 fixation.
  - Then, RuBP binds with O_2 instead of forming PGA and to form one molecule of phosphoglycerate and phosphoglycolate. This pathway is called **photorespiration**.

NEET KEY NOTES

- In this pathway, there is neither synthesis of sugars nor of ATP. Rather, it results in release of CO_2 with the utilisation of ATP. So, photorespiration is a wasteful process here.
- In C_4-plants, photorespiration does not occur, this is because they have the mechanism that increases the concentration of CO_2 at the enzyme site.
  - This takes place C_4-acid from mesophyll cells is broken down in the bundle sheath cells to release CO_2, this results in increasing the intracellular concentration of CO_2.
  - In turn, this ensures that the RuBisCO functions as a carboxylase minimising the oxygenase activity.
  - The C_4-plants lack photorespiration, that is why the productivity and fields are better in these plants.

Factors Affecting Photosynthesis

- The rate of photosynthesis gets affected by many internal and external or environmental factors.

1. Internal Factors

These factors include number, size, age and orientation of leaves, mesophyll cells and chloroplasts, internal concentration of CO_2 and chlorophyll content.

2. External Factors

Some of the external factors which affect photosynthesis are listed below

- **Light** For this, two conditions are observed
  - At **low light intensities**, the linear relationship between incident light and rate of CO_2-fixation occurs.
  - While at **higher light intensities**, the rate fails to show further increase as the other factors becomes limiting (saturation point).
- CO_2 **concentration** with increase in CO_2 concentration, the rate of photosynthesis also increase but up to a limit.
- **Water** In water deficit condition the rate of photosynthesis is indirectly affected.
- **Temperature** The C_4-plants respond to higher temperatures and show higher rate of photosynthesis while C_3-plants have a much lower temperature optimum.
- **Blackman's** (1905) **law of limiting factors** states that if a chemical process is attached by more than one factor, then its rate will be determined by the factor, which is nearest to its minimal value. It is the factor, which directly affects the process, if its quantity is changed. Photosynthesis is mainly affected by light, CO_2 concentration, temperature and water.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Photosynthesis : Introduction and Early Experiments*

1 Photosynthesis is an important process for life on earth because
(a) it is the primary source of all food on earth
(b) it is responsible for the release of oxygen
(c) it is the only natural process responsible for the utilisation of sunlight
(d) All of the above

2 The process carried out by green plants by which they synthesise organic compounds is photosynthesis. It is a
(a) physical process (b) chemical process
(c) physicochemical process (d) photochemical process

3 The main purpose of photosynthesis is to
(a) consume CO_2
(b) produce ATP
(c) convert light energy into chemical energy
(d) produce starch

4 Which one of the following organisms does not evolve oxygen during photosynthesis? ***AIIMS 2018***
(a) Blue-green algae
(b) Red algae
(c) Chemosynthetic bacteria
(d) C_4-plants

5 In an experiment, a leaf was partially covered with black paper, and was exposed to light. On testing these leaves for starch, it was seen that uncovered part turned blue-black. This concludes that photosynthesis had occurred in
(a) green parts of leaves
(b) black paper covered part of leaves
(c) black part of leaves
(d) Both (a) and (b)

6 In half leaf experiment, a part of a leaf is enclosed in a test tube containing KOH soaked cotton, while the other half is exposed to air and then setup is placed in light for some time. It was later found that part of leaf, which was exposed to air tested positive for starch. This indicates that
(a) light is essential for photosynthesis
(b) oxygen is liberated in photosynthesis
(c) water is essential for photosynthesis because in KOH soaked leaf, starch synthesis does not occur as water reacts with KOH and it become unavailable for photosynthesis
(d) carbon dioxide is essential for photosynthesis because in KOH soaked leaf, starch synthesis does not occur as CO_2 is absorbed by KOH and not available for photosynthesis

7 Joseph Priestley observed that when mouse alone was placed in a closed bell jar with burning candle, it was suffocated and burning candle extinguished, but when mouse was placed with a mint plant in the same bell jar, that mouse stayed alive and candle continued to burn. What he concluded from this experiment?
(a) Burning candle removed the air
(b) Mint plant restores the air
(c) CO_2 is required for burning of candle
(d) Both (a) and (b)

8 The scientist, who discovered oxygen is
(a) Priestley (b) Ingenhousz
(c) Engelmann (d) van Niel

9 Jan Ingenhousz did an experiment with an aquatic plant and concluded that
(a) plants release O_2
(b) only green parts of plant release O_2
(c) plants release CO_2
(d) only green parts of plant release CO_2

10 Sunlight is essential for plant was concluded by
(a) Joseph Priestley (b) Jan Ingenhousz
(c) van Niel (d) None of these

11 Who provided evidence that in green parts of plant glucose is produced and stored as starch ?
(a) Sachs (b) Arnon
(c) Arnold (d) Englemann

12 The first action spectrum of photosynthesis was observed by
(a) Julius von Sachs (b) Priestley
(c) TW Engelmann (d) Cornelius van Niel

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

14 Who demonstrated that O_2 comes from water instead from CO_2 during photosynthesis by using purple and green bacteria in their experiment?
(a) van Niel (b) Engelmann
(c) Blackman (d) Warburg

15 Which one is the correct equation of photosynthesis?
(a) $6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} 6O_2 + C_6H_{12}O_6$
(b) $6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6O_2 + 6H_2O$
(c) $C_6H_{12}O_6 + 6O_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} 6CO_2 + 12H_2O + \text{Energy}$
(d) $C_6H_{12}O_6 + 6O_2 \xrightarrow[\text{Chlorophyll}]{\text{Light}} 6CO_2 + 6\,H_2O + \text{Energy}$

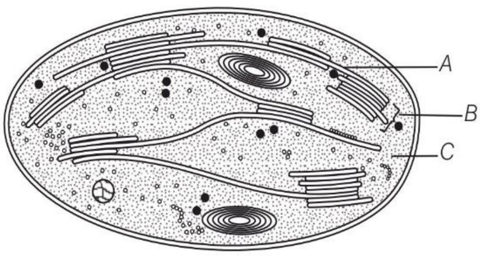
16 Which equation is correct to prove that O_2 comes from water during photosynthesis?
(a) $6CO_2^{18} + 12H_2O \longrightarrow 6O_2^{18} + C_6H_{12}O_6 + 6H_2O$
(b) $6CO_2 + 12H_2O^{18} \longrightarrow 6O_2 + C_6H_{12}O_6 + 6H_2O^{18}$
(c) $6CO_2^{18} + 12H_2O \longrightarrow 6CO_2^{18} + C_6H_{12}O_6$
(d) $6CO_2 + 12H_2O^{18} \longrightarrow 6O_2^{18} + C_6H_{12}O_6 + 6H_2O$

TOPIC 2 ~ *Sites and Pigment of Photosynthesis*

17 Large number of chloroplast are present in which of the following cells ?
(a) Parenchymatous cell
(b) Mesophyll cell
(c) Peroxisomal cell
(d) Cell wall

18 When intensity of light is low, chloroplasts align themselves in the mesophyll cell in such a way that their flat surfaces are
(a) antiparallel to the cell wall
(b) perpendicular to the cell wall
(c) parallel to the cell wall
(d) middle in the cell

19 Identify *A*, *B* and *C* in given figure.



(a) A–Stroma wall, B–Granum, C–Stroma
(b) A–Stroma lamella, B–Granum, C–Stroma
(c) A–Stroma lamella, B–Stroma, C–Granum
(d) A–Stroma wall, B–Stroma, C–Granum

20 Which is incorrect with reference to chloroplast ? ***JIPMER 2018***

(a) Presence in algae and plants
(b) Releases O_2
(c) Occurs only in cell with aerobic respiration
(d) None of the above

21 The function(s) of chloroplast's membrane system is/are

(a) trapping of light energy
(b) synthesis of ATP
(c) synthesis of NADPH
(d) All of the above

22 Dark reaction ***JIPMER 2019***

(a) occurs in light
(b) occurs in dark
(c) requires product of light reaction
(d) All of the above

23 Water soluble pigments found in plant cell vacuoles are ***NEET 2016***

(a) chlorophylls (b) carotenoids
(c) anthocyanins (d) xanthophylls

24 Molecular formula of chlorophyll-*b* is ***JIPMER 2018***

(a) $C_{55}H_{70}O_6N_4Mg$ (b) $C_{55}H_{72}O_5N_4Mg$
(c) $C_{55}H_{70}O_5N_4Mg$ (d) $C_{54}H_{70}O_6N_4Mg$

25 A chromatography paper is shown to you and it is asked that which of the following pigments is represented by the yellow colour band on the paper?

(a) Chlorophyll-*a* (b) Chlorophyll-*b*
(c) Xanthophylls (d) Porphyrin

26 The cheif photosynthetic pigment in the plants is

(a) chlorophyll-*a* (b) chlorophyll-*b*
(c) xanthophylls (d) carotenoids

27 A graph that plots the effect of different wavelenghts of light on the rate of photosynthesis is called

(a) an absorption spectrum (b) an adsorption spectrum
(c) pigment kinetics (d) an action spectrum

28 Absorption spectrum of chlorophyll-*a* and the action spectrum of photosynthesis is identical because chlorophyll-*a*

(a) absorbs the maximum light
(b) absorbs the minimum light
(c) absorbs the red and blue light
(d) is found most abundantly

29 What is the wavelength of radiations in visible spectrum?

(a) 400-700 nm (b) 400-800 nm
(c) 390-760 nm (d) 760-390 nm

30 Correct sequence of rate of photosynthesis in different light is

(a) Red > Blue > Green (b) Blue > Red > Green
(c) Green > Blue > Red (d) Green > Red > Blue

31 Which of the following options is/are correct for accessory photosynthetic pigments ?

(a) They include chlorophyll-*b*, xanthophylls and carotenoids
(b) They absorb light and transfer to chlorophyll-*a*
(c) They enable absorption of wider range of wavelength of incoming light for photosynthesis
(d) All of the above

TOPIC 3 ~ *Light Reaction*

32 Light reaction or photochemical phase includes

(a) light absorption
(b) water splitting and oxygen release
(c) ATP and NADPH formation
(d) All of the above

33 Light Harvesting Complexes (LHCs) are

(a) present within PS-I and PS-II
(b) very few molecule of chlorophyll-*a*
(c) hundreds of pigment molecules bound to proteins
(d) Both (a) and (c)

34 Photosystems (PS) are made up of which of the following?

(a) Reaction centre (b) Antennae
(c) Reaction centre and H_2O (d) Both (a) and (b)

35 PS-I is located on the

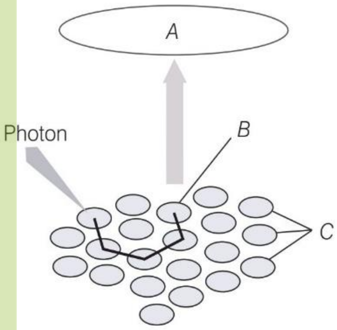
(a) non-appressed part of grana thylakoids
(b) stroma thylakoids
(c) appressed part of grana thylakoids
(d) Both (a) and (b)

36 PS-I has absorption peak at …*A*…. and PS-II has absorption peak at…*B*.

Choose the correct option and fill the blank.

(a) A–700 nm; B–800 nm
(b) A–680 nm; B–700 nm
(c) A–700 nm; B–680 nm
(d) A–800 nm; B–700 nm

37 Given figure depicts the Light Harvesting Complex (LHC) of Photosystem-I (PS-I) and select the correct option.



	A	B	C
(a)	Core molecules	Plastocyanin	Primary acceptor
(b)	Primary acceptor	Reaction centre	Pigment molecules
(c)	Reaction centre	Pigment molecules	Primary acceptor
(d)	Pigment molecules	Primary acceptor	Reaction centre

38 Emerson's enhancement effect and red drop have been instrumental in the discovery of ***NEET 2016***

(a) two photosystems operating simultaneously

(b) photophosphorylation and cyclic electron transport

(c) photophosphorylation

(d) photophosphorylation and non-cyclic electron transport

TOPIC 4 ~ *The Electron Transport*

39 Photophosphorylation is the

(a) formation of ADP in the presence of light

(b) formation of ATP in the presence of chemicals

(c) formation of ATP in the presence of light

(d) formation of ATP in the presence of reducing agents

40 When the chloroplast pigments absorb light

(a) they become reduced and move down hill in the ETS

(b) they lose their potential energy

(c) their electrons become excited and move uphill in the ETS

(d) None of the above

41 The electrons in the reaction centre of PS-I are

(a) excited simultaneously with PS-II

(b) excited simultaneously with P680

(c) excited simultaneously with P700

(d) Both (a) and (b)

42 The movement of electrons in Electron Transport System (ETS) in light reaction is

(a) uphill in terms of redox potential scale

(b) down hill in terms of redox potential scale

(c) uphill in terms of oxidation

(d) Both (a) and (b)

43 In Z-scheme of light reaction, the participating pigment systems is/are

(a) PS-I and PS-II

(b) PS-III

(c) carotenoid and xanthophyll

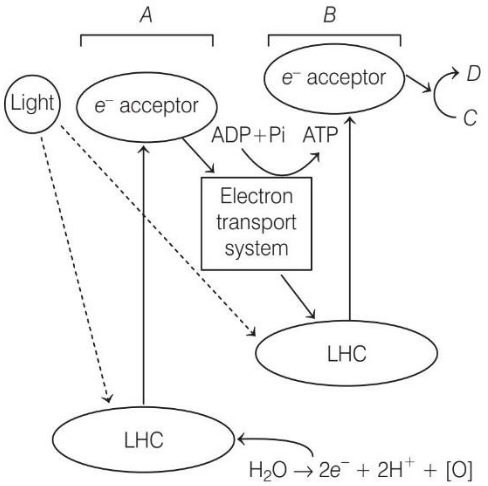
(d) PS-II

44 Electrons are transferred by splitting of H_2O through ETC during light reaction and reduce

(a) NAD to NADH + H^+ (b) NADPH to H^+

(c) $NADP^+$ to NADPH + H^+ (d) NAD to NADPH + H^+

45 Given below is the diagrammatic representation of the Z-scheme of light reaction of photosynthesis. Identify *A, B, C* and *D* select the correct option accordingly.



	A	B	C	D
(a)	Photosystem -I	Photosystem -II	$NADP^+$	NADPH
(b)	Photosystem-II	Photosystem-I	$NADP^+$	NADPH
(c)	Photosystem-I	Photosystem-II	NADPH	$NADP^+$
(d)	Photosystem-II	Photosystem-I	NADPH	$NADP^+$

46 Which chemical compound/molecule supplies electrons continuously to PS-II?

(a) CO_2 (b) O_2 (c) H_2O (d) NADPH

47 During the light reaction, the water splits into

(a) H^+, O_2 and electrons

(b) H_2, O_2 and electrons

(c) $2H^+$, [O] and 2 electrons

(d) $\frac{1}{2}H_2, \frac{1}{2}O_2$ electrons

48 If green plants are incubated with O^{18} labelled water, which molecule (photosynthesis product) will become radioactive from the given options?
(a) O_2 (b) electrons
(c) CO_2 (d) $C_6H_{12}O_6$

49 How many H^+ ions are formed from 12 water molecules during non-cyclic photophosphorylation?
(a) 12 (b) 24
(c) 36 (d) 48

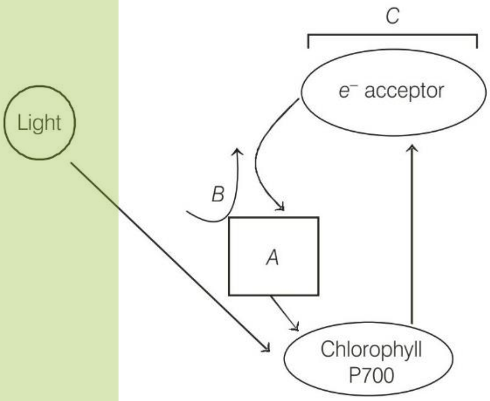
50 The oxygen evolved during photosynthesis comes from water molecules. Which of the following pairs of elements is involved in this reaction? ***CBSE-AIPMT 2015***
(a) Manganese and potassium
(b) Magnesium and molybdenum
(c) Magnesium and chlorine
(d) Manganese and chlorine

51 Conditions required for cyclic photophosphorylation are
(a) aerobic condition, low light intensity
(b) aerobic condition, optimum light intensity
(c) anaerobic condition, low light intensity
(d) anaerobic condition, optimum light intensity

52 Which photosystem is involved only in cyclic photophosphorylation? ***JIPMER 2018***
(a) PS-II (b) PS-I
(c) Xanthophyll and PS-II (d) Xanthophyll and PS-I

53 Cyclic photophosphorylation
(a) results in the formation of ATP only
(b) occurs at wavelength beyond 680 nm
(c) occurs in stroma lamellae
(d) All of the above

54 Identify *A*, *B* and *C* in the given figure of cyclic phosphorylation and choose the correct option accordingly.



(a) A–ETS, B–ADP + Pi $\rightarrow$ ATP, C–PS-II
(b) A–ETS, B–ADP + Pi $\rightarrow$ ATP, C–PS-I
(c) A–$NADH_2$, B–ADP + Pi $\rightarrow$ ATP, C–PS-I
(d) A–$NADH_2$, B–ADP + Pi $\rightarrow$ ATP, C–PS-II

55 Photophosphorylation in chloroplast is most similar to the
(a) mitochondrial substrate level phosphorylation
(b) mitochondrial oxidative phosphorylation
(c) mitochondrial hydrolysis of H_2O
(d) All of the above

56 Along with the electrons that come from the electron acceptor of ……, protons are necessary for the reduction of $NADP^+$.
(a) PS-II (b) PS-I (c) ATP (d) NADPH

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

58 During light reaction of photosynthesis,
(a) ADP is phosphorylated and NADPH is oxidised
(b) ADP is phosphorylated and NADP is reduced
(c) ADP is phosphorylated and NADPH is reduced
(d) ATP is phosphorylated and NADPH is reduced

59 Select the correct pathway for electron transport during photosynthesis.
(a) $CO_2 \rightarrow$ RuBP $\rightarrow$ Glucose - ATP
(b) $H_2O \rightarrow$ PS-I $\rightarrow$ PS-II $\rightarrow$ NADPH + H^+
(c) $H_2O \rightarrow$ PS-II $\rightarrow$ PS-I $\rightarrow$ NADPH + H^+
(d) $H_2O \rightarrow$ PS-II $\rightarrow$ PS-I $\rightarrow$ ATP

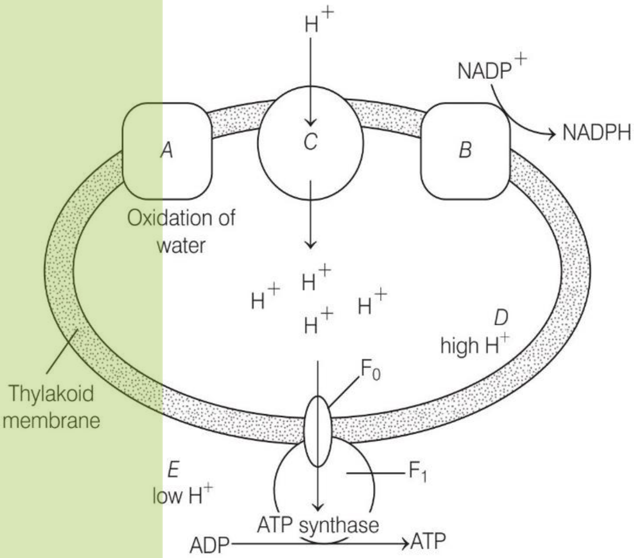
60 The membranous system or grana is responsible for
(a) trapping light energy, but not for ATP and $NADPH_2$ formation
(b) trapping light energy and also for fixation of CO_2
(c) ATP and $NADPH_2$ formation, but not for light trapping
(d) light capturing and also for $NADPH_2$ and ATP formation

61 Which hypothesis best explains the synthesis of ATP in chloroplast?
(a) Chemosynthetic hypothesis
(b) Chemiosmotic hypothesis
(c) Potential gradient hypothesis
(d) Redox gradient hypothesis

62 Photosynthesis and respiration have which of the following in common?
(a) In eukaryotes, both processes occur in specialised organelles
(b) ATP synthesis in both processes relies on chemiosmotic mechanism
(c) Both use electron transport
(d) All of the above

63 Proton gradient is very important across the membrane because
(a) building up of proton gradient releases energy
(b) building up of proton gradient increases the pH towards lumen side of thylakoid membrane
(c) breakdown of proton gradient releases CO_2
(d) breakdown of proton gradient releases energy

64 Identify *A*, *B*, *C*, *D* and *E* from the given figure and choose the correct option accordingly.



(a) A–PS-I, B–PS-II, C–Cytochrome-*b* and *c*, D–Lumen stroma, E–Stroma
(b) A–PS-I, B–PS-II, C–Cytochrome-*b* and *c*, D–Stroma, E–Lumen
(c) A–PS-II, B–PS-I, C–Cytochrome-*b* and *c*, D–Stroma, E–Lumen
(d) A–PS-II, B–PS-I, C–Cytochrome-b_6 and *f*, D–Lumen, E–Stroma

65 During photosynthesis the protons are transported across the thylakoid membrane into the lumen because
(a) electrons are transferred to hydrogen carrier which is present on inner membrane
(b) electrons are transferred to electron carrier
(c) electrons are transferred to intermembrane space
(d) electrons are transferred to hydrogen carrier, which is present outerside of membrane

66 NADP reductase enzyme is present on the
(a) lumen side of membrane
(b) lamellae side of membrane
(c) stroma side of membrane
(d) cell membrane of chloroplast membrane

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

68 Proton gradient is broken down due to
(a) movement of electrons across the membrane to stroma
(b) movement of electrons across the membrane to lumen
(c) movement of proton across the membrane to lumen
(d) movement of proton across the membrane to stroma

69 The ATP synthase of chloroplast consists of
(a) CF_0 and CF_1 (b) CF_1 and CF_2
(c) CF_0 and CF_2 (d) All of these

70 ATPase has
(a) channel that allows H^+ diffusion
(b) channel that allows electron diffusion
(c) channel that allows O_2 molecule diffusion
(d) channel that allows CO_2 molecule diffusion

TOPIC 5~ *Where are the ATP and NADPH Used?*

71 ATP and NADPH produced in light reaction by the movement of electrons in ETC are used immediately for
(a) oxidation of carbohydrate
(b) synthesis of sugar in biosynthetic phase
(c) reduction of carbon dioxide
(d) Both (b) and (c)

72 If the light becomes unavailable during photosynthesis then
(a) immediately biosynthetic process stops
(b) biosynthetic phase does not stop
(c) biosynthetic phase stops forever
(d) biosynthetic phase continues for some time and then stops

73 In terms of the spatial organisation of photosynthesis within the chloroplast, what is the advantage of light reactions producing ATP and $NADPH_2$ on the stromal side of the thylakoid membrane?
(a) Water is more in thylakoid
(b) Light reaction occurs in stroma
(c) Dark reaction/Calvin cycle occurs in grana and needs ATP + $NADPH_2$
(d) The Calvin cycle, which consumes ATP and $NADPH_2$ occurs in stroma

74 Plants are divided into two groups based on the pathways they use for CO_2 assimilation during biosynthetic phase of photosynthesis. These are
(a) C_3 plants forming PGA and C_4 plants forming OAA, respectively as first products of CO_2 fixation
(b) C_3 plants forming OAA and C_4 plants forming PGA, respectively as first product of CO_2 fixation
(c) C_3 plants forming PEP and C_4 plants forming OAA, respectively as first product of CO_2 fixation
(d) None of the above

75 During the dark reaction, the acceptor of CO_2 is
(a) $NADPH_2$ (b) RuBP
(c) H_2O (d) CO_2

TOPIC 6~ The Calvin Cycle (C_3) and C_4-pathway

76 Why Calvin cycle is called C_3-cycle?
(a) Primary CO_2 acceptor is C_3 compound
(b) Many intermediate compounds are C_3 compound
(c) 1st stable product is 3 PGA which is a C_3 compound
(d) None of the above

77 In stroma,
(a) enzymatic reactions incorporate CO_2 into the plant leading to ATP and $NADH_2$ formation
(b) enzymatic reactions incorporate CO_2 into plant leading to the synthesis of sugar, which in turn, forms starch
(c) light energy is captured to form glucose
(d) ATP and $NADPH_2$ are splitted and H_2O and O_2 comes out

78 Carboxylation (C_3 cycle) is catalysed by
(a) carboxylase
(b) RuBP carboxylase
(c) RuBP oxygenase
(d) Both (b) and (c)

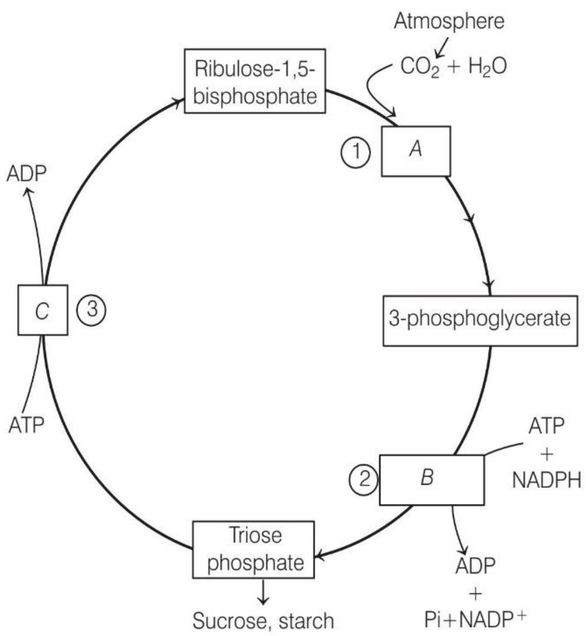
79 Every CO_2 molecule entering the Calvin cycle needs
(a) 2 molecules of NADPH and 3 molecules of ATP for its fixation
(b) 2 molecules of NADPH and 2 molecules of ATP for its fixation
(c) variable amount of ATP
(d) Only NADPH

80 In dark reaction, regeneration of RuBP needs
(a) 2 molecules of ATP
(b) 1 molecule of ATP
(c) 3 molecules of ATP
(d) 4 molecules of ATP

81 How many turns of Calvin cycle produces one molecule of glucose?
(a) Eight
(b) Six
(c) Three
(d) One

82 In dark cycle, one molecule of glucose formation needs
(a) 12 ATP and 12 NADPH
(b) 14 ATP and 12 NADPH
(c) 16 ATP and 12 NADPH
(d) 18 ATP and 12 NADPH

83 Identify *A*, *B* and *C* in the given figure and choose the correct option from the set (*A*-*C*) given below.



(a) A–Reduction, B–Carboxylation, C–Regeneration
(b) A–Reduction, B–Regeneration, C–Carboxylation
(c) A–Carboxylation, B–Reduction, C–Regeneration
(d) A–Carboxylation, B–Regeneration, C–Reduction

84 In Calvin cycle, if one molecule of RuBP is carboxylated than how many PGA molecule will be formed?
(a) 2 (b) 3 (c) 4 (d) 5

85 Which of the following begins the Calvin cycle and is the commitment step that results the entire pathway being carried out?
(a) $3PGA \xrightarrow[ATP,\ NADPH_2]{} 3PGAld$
(b) The regeneration of RuBP
(c) $CO_2 + RuBP \longrightarrow 3PGA$
(d) It can start from anywhere

86 With reference to three Calvin cycles, which of the given options is correct for the following questions?
I. How many gross PGAL molecules are produced?
II. Total, how many ATP molecules are required for synthesis of PGAL molecules?
III. Total how many $NADPH_2$ molecules are required for the synthesis of obtained PGAL molecules?
(a) I–3PGAL, II–3ATP, III–3$NADPH_2$
(b) I–6PGAL, II–6ATP, III–6 $NADPH_2$
(c) I–18PGAL, II–18ATP, III–18$NADPH_2$
(d) I–9 PGAL, II–9ATP, III–9$NADPH_2$

87 Bundle sheath cells of C_4-plants are rich in which enzyme?
(a) PEP carboxylase (b) Malate dehydrogenase
(c) Phosphofructokinase (d) RuBisCO

88 Kranz anatomy is found in **JIPMER 2019**
(a) C_3-plants (b) Only in monocots
(c) Both C_4 and C_3-plants (d) C_4-plants

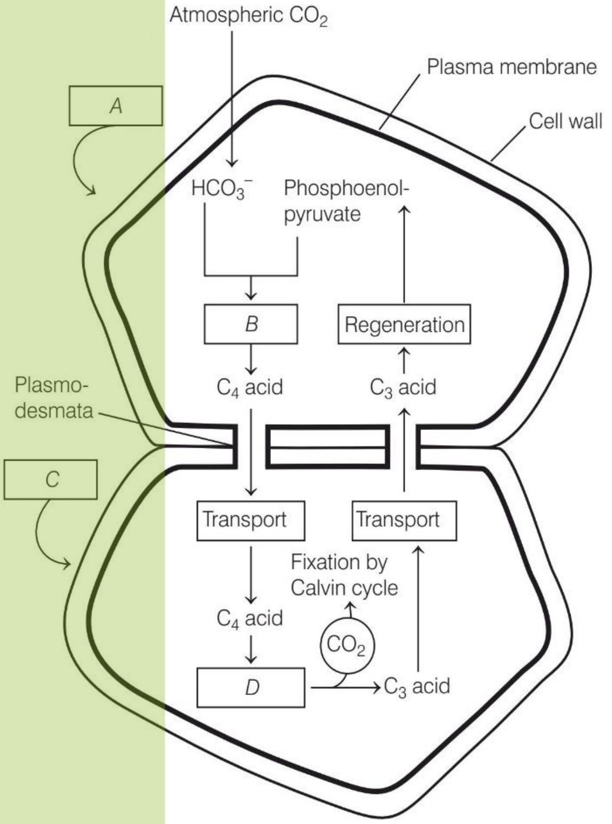
89 In Hatch and Slack pathway, the primary CO_2 acceptor is **NEET (Odisha) 2019**
(a) Oxaloacetic acid (b) Phosphoglyceric acid
(c) Phosphoenol pyruvate (d) RuBisCO

90 $PEP + CO_2 + H_2O \xrightarrow{X}$ Oxaloacetic acid $+ H_3PO_4$.
Identify X.
(a) Ligase (b) Oxidoreductase
(c) PEP carboxylase (d) Lyase

91 Malic acid or aspartic acid and oxaloacetic acid both are found in
(a) mesophyll cell (b) meristematic cell
(c) bundle sheath cell (d) epidermal cell

92 Which of these is incorrect for C_4 plants? **JIPMER 2018**
(a) Kranz anatomy (b) CO_2 acceptor is PEP
(c) PEPCase in mesophyll (d) RuBisCO in mesophyll

93 Identify A, B, C and D in the given figure and choose the correct option accordingly.



(a) A–Mesophyll cell, B–Fixation, C–Bundle sheath cell, D–Decarboxylation
(b) A–Mesophyll cell, B–Decarboxylation, C–Bundle sheath cell, D–Fixation
(c) A–Chloroplast, B–Decarboxylation, C–Bundle sheath cell, D–Fixation
(d) A–Chloroplast, B–Fixation, C–Bundle sheath cell, D–Fixation

94 Fixation of one molecule of CO_2 requires how much (in C_4 plants) ATP and NADPH, respectively?
(a) 5/2 (b) 2/5
(c) 2/3 (d) 3/2

95 Which plant performs photosynthesis even after the closing of stomata?
(a) C_2 (b) C_3
(c) C_4 (d) C_5

96 PEPCase has an advantage over RuBisCO. The advantage is
(a) RuBisCO combines with O_2, but PEPCase does not
(b) RuBisCO combines with NO_2, but PEPCase does not
(c) RuBisCO conserves energy, but PEPCase does not
(d) PEPCase is present in both mesophyll cells and bundle sheath cells, but RuBisCO is not

97 Chloroplasts without grana are known to occur in
(a) bundle sheath cells of C_3 plant
(b) bundle sheath cells of C_4 plant
(c) mesophyll cells of C_4 plant
(d) mesophyll cells of C_3 plant

98 What is the site of C_3 cycle in C_3 and C_4 plants? **AIIMS 2019**
(a) In C_3 plants–Mesophyll cell and in C_4 plants–Bundle sheath cell
(b) In C_3 plants–Bundle sheath cell and in C_4 plants–Mesophyll cell
(c) In C_4 plants–Bundle sheath cell and in C_3 plants–Bundle sheath cell
(d) In C_3 plants–Mesophyll cell and in C_4 plants–Mesophyll cell

99 C_4-pathway is advantageous over C_3-pathway in plants, because it **AIIMS 2019**
(a) occurs in relatively low CO_2 concentration
(b) uses more amount of water
(c) occurs in relatively low O_2 concentration
(d) is less efficient in energy utilisation

100 Which of the following materials are not recycled between dark and light reactions?
(a) NADPH + H
(b) ADP
(c) ATP
(d) O_2 and CO_2

TOPIC 7 ~ Photorespiration

101 Photorespiration is the light dependent reaction in which utilisation of
(a) oxygen and release of H_2O takes place
(b) oxygen and release of H^+ takes place
(c) oxygen and release of CO_2 takes place
(d) oxygen and release of ATP takes place

102 The process, which makes major difference between C_3 and C_4 plants is *NEET 2016, CBSE-AIPMT 2012*
(a) glycolysis (b) Calvin cycle
(c) photorespiration (d) respiration

103 The most abundant enzyme in the world is
(a) ligase (b) RuBisCO
(c) PEPCase (d) Carboxylase

104 In C_3 plant, when O_2 concentration is more, the O_2 binds to RuBisCO and RuBP gets changed to
(a) 2 molecules of PGA
(b) 2 molecules of phosphoglycerate
(c) 2 molecules of phosphoglycolate
(d) one molecule each of phosphoglycerate and phosphoglycolate

105 The correct sequence of cell organelles during photorespiration is *CBSE-AIPMT 2012*
(a) Chloroplast–Golgi bodies–Mitochondria
(b) Chloroplast–Rough endoplasmic reticulum–Dictyosomes
(c) Chloroplast–Mitochondria–Peroxisome
(d) Chloroplast–Peroxisome–Mitochondria

106 C_4 plant minimises the photorespiration because C_4 plants
(a) use PEPCase to initiate CO_2-fixation
(b) do not carry out the Calvin cycle in low CO_2 level
(c) exclude Calvin cycle
(d) show photorespiration

107 Which crop utilises solar energy most efficiently?
(a) Potato (b) Sugarcane (c) Wheat (d) Rice

108 RuBisCO performs oxygenase activity at
(a) low CO_2 concentration
(b) high CO_2 concentration
(c) high H_2O concentration
(d) low H_2O concentration

109 Peroxisomes in photorespiration
(a) help in the oxidation of glycolate
(b) help in the oxygenation of vacuole
(c) help in the synthesis of PGA
(d) help in the reduction of glyoxylate

110 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? *NEET 2016*
(a) C_4
(b) CAM
(c) Nitrogen-fixer
(d) C_3

TOPIC 8~ Factors Affecting Photosynthesis

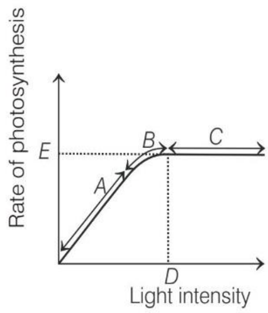
111 Plant factors affecting photosynthesis include
(a) number, age, size and orientation of leaves, mesophyll cells and chloroplast, internal CO_2 concentration and the amount of chlorophyll
(b) nature of leaves, size of mesophyll cell and light
(c) mesophyll cells distribution and temperature
(d) quantity of chlorophyll, size of leaves and CO_2

112 The internal factors that affect photosynthesis of plant depend on the
(a) morphological predisposition
(b) genetic predisposition
(c) temperature
(d) environmental predisposition

113 Law of limiting factor in relation to photosynthesis is proposed by
(a) Blackman (b) Wiseman
(c) Calvin (d) Emerson

114 Light compensation point is the point where
(a) gaseous exchange occurs in photosynthesis
(b) gaseous exchange does not occur in photosynthesis
(c) gaseous exchange reduces in photosynthesis
(d) light intensity become appropriate for photosynthesis

115 Study the following graph showing the effect of light intensity on the rate of photosynthesis. Which of the following option regarding this is correct ?



(a) Light is a limiting factor in the region-A
(b) Region C represents that rate of photosynthesis is not increased further by increasing light intensity bacause some other factor becomes limiting
(c) Point D represents the intensity of light at which some other factor becomes limiting
(d) All of the above

116 Light is rarely a limiting factor in nature except in
(a) maize
(b) sugarcane
(c) *Sorghum*
(d) plants in shade or in dense forests

117 Under normal condition, which one of the following is a major limiting factor?
(a) Light (b) CO_2
(c) Temperature (d) Chlorophyll

118 C_3 plants show optimum photosynthesis at
(a) high O_2 concentration (b) high CO_2 concentration
(c) low O_2 concentration (d) high temperature 45°C

119 The plants that respond to higher temperatures and show higher rate of photosynthesis are
(a) C_4
(b) C_3
(c) CAM
(d) Both (a) and (b)

120 I. Tropical plants have a ...*A*... than plants adapted to temperate climates.
II. Water has a/an ...*B*... effect on the rate of photosynthesis.
III. The optimum temperature for photosynthesis of different plants depends on ...*C*....
Identify *A* and *B* and choose the correct option.

	A	B	C
(a)	higher temperature optimum	direct	habitat
(b)	lower temperature optimum	indirect	water
(c)	lower temperature optimum	direct	light
(d)	higher temperature optimum	indirect	habitat

121 I. Temperature
II. CO_2 concentration
III. Chlorophyll arrangement
IV. Water
Among the given factors, identify the external factors that affect the rate of photosynthesis and choose the correct option accordingly.
(a) I, II and IV
(b) I, II and III
(c) II, III and IV
(d) I, III and IV

NEET

SPECIAL TYPES QUESTIONS

I. Assertion and Reason

■ **Direction** (Q. No. 122-139) *In each of the following questions, a statement of Assertion (A) is given followed by corresponding statement of Reason (R).*
Of the statements, mark the correct answer as
(a) If both A and R are true and R is the correct explanation of A
(b) If both A and R are true, but R is not the correct explanation of A
(c) If A is true, but R is false
(d) If A is false, but R is true

122 **Assertion** (A) Photosynthesis is a physicochemical process.
Reason (R) During photosynthesis, conversion of light energy is a physical process, while synthesis of glucose is a chemical process.

123 **Assertion** (A) During photosynthesis, glucose is formed, but it is stored in the form of starch.
Reason (R) Glucose is osmotically active, while starch is inactive.

124 **Assertion** (A) The absorption spectrum of chlorophyll-*a* shows close correlation with its action spectrum.
Reason (R) Both PS-I and PS-II contain chlorophyll-*a*.

125 **Assertion** (A) The presence of accessory pigments increases the rate of photosynthesis.
Reason (R) These pigments absorb the light of different wavelengths and transfer it to reaction centre.

126 **Assertion** (A) PS-I and PS-II names are given on the basis of activity in the photosynthesis.
Reason (R) During non-cyclic photophosphorylation, PS-II works first and then PS-I.

127 Assertion (A) Both PS-I and PS-II are present on the different surfaces of thylakoid membranes.

Reason (R) Photolysis of water occurs inside the lumen, while $NADP^+$ is used in stroma for the reduction of CO_2.

128 Assertion (A) Dark reaction always takes place in dark only.

Reason (R) Enzymes of dark reaction are temperature sensitive.

129 Assertion (A) 6 cycles of Calvin cycle are required for synthesis of one glucose molecule.

Reason (R) In each Calvin cycle, only one molecule of CO_2 is fixed. Hence, 6 molecules of CO_2 are required for one molecule of glucose.

130 Assertion (A) C_4 plants can survive in high temperature.

Reason (R) PEPCase enzyme works at high temperature only.

131 Assertion (A) In C_3-cycle, the first stable compound is 3C compound. ***AIIMS 2019***

Reason (R) In C_4 plants, Calvin cycle is absent.

132 Assertion (A) C_3-pathway is more efficient than C_4-pathway.

Reason (R) Photorespiration does not occur in C_4 plants.

133 Assertion (A) C_4 plants can perform photosynthesis at very low level of CO_2 too.

Reason (R) In C_4 plants, CO_2 is utilised efficiently in bundle sheath cells.

134 Assertion (A) Calvin pathway of sugar synthesis is same in C_3 and C_4 plants.

Reason (R) C_3 is the only pathway for synthesis of sugar from CO_2.

135 Assertion (A) Photorespiration is a waste process.

Reason (R) During photorespiration, neither ATP nor NADPH is formed.

136 Assertion (A) The light reaction is temperature sensitive.

Reason (R) Change in temperature affects light reaction more than dark reaction.

137 Assertion (A) Water is rarely limiting factor in photosynthesis.

Reason (R) Plants use less than 1% of the absorbed water for photosynthesis.

138 Assertion (A) Lack of water indirectly decreases the rate of photosynthesis.

Reason (R) Lack of water causes wilting of leaves, which reduces their surface area.

139 Assertion (A) Twelve molecules of water are used in the equation of photosynthesis.

Reason (R) The equation of photosynthesis is

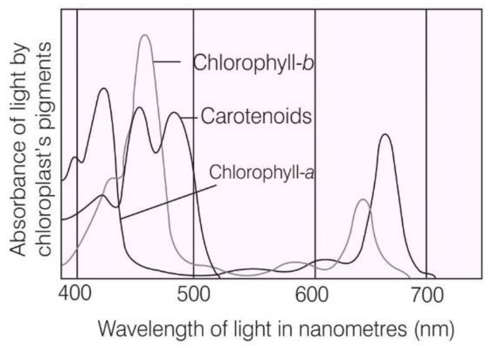
$$6CO_2 + 12H_2O \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

II. Statement Based Questions

140 Which one of the following statements is incorrect about chloroplast ?

(a) Usually chloroplast align themselves along the walls of mesophyll cells, so that they get optimum quantity of incident light
(b) Within chloroplast there is a membranous system consisting of grana, stroma lamellae and stroma
(c) There is division of labour
(d) In grana CO_2 is fixed

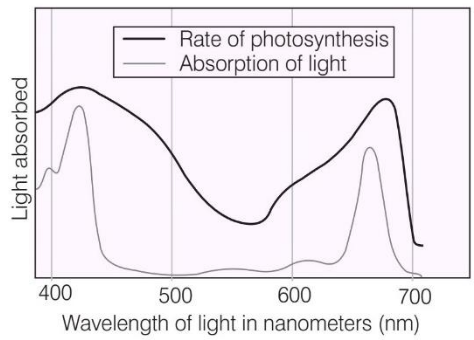
141 Study the graph below showing the absorption specturm of chlorophyll-*a*, *b* and the carotenoids.



Select the correct statement regarding the graph.

(a) The curve showing the amount of absorption of different wavelengths of light by a photosynthetic pigment is called as absorption spectrum
(b) Chlorophyll-*a* and chlorophyll-*b* absorb maximum light in blue and red wavelength of light
(c) Rate of photosynthesis is maximum in blue light and red light
(d) All of the above

142 Consider the graph below and select the statement which explains the graph correctly.



(a) The action spectrum shows a graphic representation of amount of light of different wavelengths absorbed by a pigment
(b) Absorption spectrum depicts the relative rates of photosyntesis of different wavelengths of light
(c) Action spectrum corresponds closely to absorption spectrum of chlorophyll-*a*
(d) None of the above

143 Which of the following statements concerning the light reaction of photosynthesis is true ?
(a) PS-I can operate independent of PS- II
(b) PS-I and II are activated by different wavelengths of light
(c) PS-I and II transfer electrons and create proton gradients across the thylakoid membrane
(d) All of the above

144 Which one of the following statements is false in case of C_4 plants ?
(a) CO_2 acceptor is RuBisCO in mesophyll cell
(b) Carboxylation occurs in mesophyll cells
(c) Leaves have two cell types
(d) Mesophyll cells lack RuBisCO

145 Which one of the following statements is false?
(a) H_2S, not H_2O, is involved in photosynthesis of purple sulphur bacteria
(b) Light and dark reactions are stopped in the absence of light
(c) Calvin cycle occurs in the grana of chloroplast
(d) ATP is produced during light reaction *via* chemiosmosis

146 Which of the following statements regarding photorespiration are true?
(a) Photorespiration is a metabolically expensive pathway
(b) Photorespiration is avoided when CO_2 is abundant
(c) Photorespiration results in a loss of usable carbon dioxide
(d) All of the above

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

148 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 the following options. ***NEET 2016***
(a) Both processes can happen together because the diffusion coefficient of water and CO_2 is different
(b) The above processes happen only during night time
(c) One process occurs during daytime and the other at night
(d) Both processes cannot happen simultaneously

149 I. Cyclic photophosphorylation needs PS-I and PS-II.
II. Cyclic photophosphorylation produces $NADPH + H^+$ and ATP.
III. Cyclic photophosphorylation involves H_2O.
IV. Electrons are recycled in cyclic photophosphorylation.
Identify the correct and incorrect statements and select the option accordingly.
(a) I, II and III are incorrect, IV is correct
(b) I, II and IV are incorrect, III is correct
(c) I, II and III are incorrect, II is correct
(d) IV, III and II are incorrect, I is correct

150 Consider the following statements.
I. In biosynthetic phase (C_3 cycle), enzymes are present in the matrix of Golgi body.
II. C_3 and C_4 cycle are two parts of biosynthetic phase of photosynthesis in C_3 plants.
(a) Both I and II are true
(b) Both I and II are false
(c) I is true, II is false
(d) I is false, II is true

151 The following (I-VI) are the main steps of chemosynthetic ATP synthesis in the light reaction. Arrange them in correct order.
I. H^+ concentration gradient established.
II. H^+ diffuses through ATP synthetase.
III. Carriers use energy from electrons to move H^+ across the membrane.
IV. Electrons from PS-II pass along electron transport chain.
V. Light excites electrons in PS-II.
VI. Energy of H^+ flow is used by ATP synthetase to make ATP.
(a) I, II, III, IV, V, VI (b) II, IV, V, III, II, VI
(c) V, IV, III, I, II, VI (d) V, VI, III, IV, II, I

152 Calvin cycle can be described under three stages. These stages are
I. Carboxylation of CO_2 into stable organic intermediate.
II. Ligation reactions leading to the formation of RuBisCO.
III. Reduction reactions leading to the formation of glucose.
IV. Regeneration of CO_2 acceptor molecule.
Choose the correct option.
(a) II, III and IV (b) I, III and IV
(c) I, II and IV (d) I, II and III

153 Consider the following statement regarding C_4 plants.

I. Sunflower exhibits Kranz anatomy.

II. In mesophyll cells of C_4 plants, both RuBisCO and PEPCase enzyme occurs.

III. Oxaloacetate is formed by carboxylation of phosphoenol pyruvate in mesophyll cells of C_4 plants.

Choose the option containing correct statements.

(a) I and II (b) II and III
(c) I and III (d) I, II and III

154 Study the following statements regarding chlorophyll-*a*.

I. Chlorophyll-*a* appears blue-green in colour.

II. It is the primary photosynthetic pigment.

III. It is soluble in water as well as petroleum ether.

Choose the option containing incorrect statements.

(a) Only I (b) Only II
(c) Only III (d) II and III

155 Consider the following statements.

I. During chemiosmotic synthesis of ATP, one ATP molecule is formed when $2H^+$ pass through ATPase.

II. Light reactions of photosynthesis involve photochemical reactions.

III. Dark reactions of photosynthesis involve carbon reactions.

IV. Splitting of water takes place on the inner surface of the thylakoid membrane.

Choose the option containing correct statements.

(a) II, III and IV (b) I, III and IV
(c) I, II, III and IV (d) I, II and III

III. Matching Type Questions

156 Match the following with respect to early experiments of photosynthesis.

Scientists		Experiments	
A.	Joseph Priestley	1.	Showed that plants release O_2
B.	Jan Ingenhousz	2.	Showed that sunlight is essential for photosynthesis
C.	Julius von Sachs	3.	Proved that plants produce glucose when they grow
D.	Cornelius van Neil	4.	Showed that hydrogen reduces CO_2 to carbohydrates

Codes

	A	B	C	D
(a)	1	2	3	4
(b)	2	3	4	1
(c)	4	3	2	1
(d)	1	2	4	3

157 Match the following columns.

Column I (Photosynthetic reaction)		Column I (Features)	
A.	Light reaction	1.	Occurs in stroma
B.	Dark reaction	2.	NADPH and ATP produced
		3.	Starch
		4.	Occurs in grana

Codes

	A	B		A	B
(a)	4, 2	1, 3	(b)	3, 4	1, 2
(c)	1, 3	2, 4	(d)	2, 1	3, 4

158 Match the following columns.

Column I (Pigments)		Column I (Colour produced on chromatograph)	
A.	Chlorophyll-*a*	1.	Blue-green
B.	Chlorophyll-*b*	2.	Yellow-green
C.	Xanthophyll	3.	Yellow
D.	Carotenoid	4.	Yellow to yellow-orange

Codes

	A	B	C	D		A	B	C	D
(a)	1	2	3	4	(b)	1	3	2	4
(c)	4	3	1	2	(d)	4	3	2	1

159 Match the following columns.

Column I		Column I	
A.	Red colour of tomato and chilly	1.	Chlorophyll-*a*
B.	Reaction centre	2.	Phycobilin
C.	Phycoerythrin and phycocyanin	3.	Lycopene

Codes

	A	B	C		A	B	C
(a)	3	2	1	(b)	1	2	3
(c)	2	1	3	(d)	3	1	2

160 Match the following columns.

Column I (Saturation point)		Column II (Plant types)	
A.	10% of full sunlight	1.	Plant in shade or in dense forest
B.	50-70% of full sunlight	2.	Most photosynthetic plants
C.	200% of full sunlight	3.	Plant in dry tropical region

Codes

	A	B	C		A	B	C
(a)	3	2	1	(b)	3	1	2
(c)	1	3	2	(d)	1	2	3

NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

161 Which metal ion is a constituent of chlorophyll?
(a) Iron (b) Copper
(c) Magnesium (d) Zinc

162 Which pigment acts directly to convert light energy to chemical energy?
(a) Chlorophyll-*a*
(b) Chlorophyll-*b*
(c) Xanthophyll
(d) Carotenoid

163 Which range of wavelength (in nm) is called Photosynthetically Active Radiation (PAR)?
(a) 100-390 (b) 390-430
(c) 400-700 (d) 760-10000

164 Which light range is most effective in photosynthesis?
(a) Blue (b) Green
(c) Red (d) Violet

165 Chemosynthetic bacteria obtain energy from
(a) sun
(b) infrared rays
(c) organic substances
(d) inorganic chemicals

166 Energy required for ATP synthesis in PS-II comes from
(a) proton gradient
(b) electron gradient
(c) reduction of glucose
(d) oxidation of glucose

167 During light reaction in photosynthesis, which of the following are formed
(a) ATP and sugar
(b) Hydrogen, O_2 and sugar
(c) ATP, hydrogen donor and O_2
(d) ATP, hydrogen and O_2 donor

168 Splitting of water is associated with
(a) photosystem-I
(b) lumen of thylakoid
(c) Both photosystem-I and II
(d) inner surface of thylakoid membrane

169 The correct sequence of flow of electrons in the light reaction is
(a) PS-II, plastoquinone, cytochromes, PS-I, ferredoxin
(b) PS-I, plastoquinone, cytochromes, PS-II, ferredoxin
(c) PS-I, ferredoxin, PS-II
(d) PS-I, plastoquinone, cytochromes, ferredoxin, PS-II

170 Dark reaction in photosynthesis is called so because
(a) it can occur in dark also
(b) it does not depend on light energy
(c) it cannot occur during daylight
(d) it occurs more rapidly at night

171 PEP is primary CO_2 acceptor in ***NEET 2017***
(a) C_4 plants (b) C_3 plants
(c) C_2 plants (d) Both (a) and (b)

172 The enzyme that is not found in a C_3 plant is
(a) RuBP carboxylase (b) PEP carboxylase
(c) NADP reductase (d) ATP synthase

173 The reaction that is responsible for the primary fixation of CO_2 is catalysed by
(a) RuBP carboxylase (b) PEP carboxylase
(c) PGA synthase (d) Both (a) and (b)

174 When CO_2 is added to PEP, the first stable product synthesised is
(a) pyruvate
(b) glyceraldehyde-3-phosphate
(c) phosphoglycerate
(d) oxaloacetate

Answers

Mastering NCERT with MCQs

1 (d)	2 (c)	3 (c)	4 (c)	5 (a)	6 (d)	7 (d)	8 (a)	9 (b)	10 (b)
11 (a)	12 (c)	13 (d)	14 (a)	15 (b)	16 (d)	17 (b)	18 (c)	19 (b)	20 (c)
21 (d)	22 (d)	23 (c)	24 (a)	25 (c)	26 (a)	27 (d)	28 (c)	29 (c)	30 (a)
31 (d)	32 (d)	33 (d)	34 (d)	35 (d)	36 (c)	37 (b)	38 (a)	39 (c)	40 (c)
41 (d)	42 (b)	43 (a)	44 (c)	45 (b)	46 (c)	47 (c)	48 (a)	49 (b)	50 (d)
51 (b)	52 (b)	53 (d)	54 (b)	55 (b)	56 (b)	57 (b)	58 (b)	59 (c)	60 (d)
61 (b)	62 (d)	63 (d)	64 (d)	65 (a)	66 (c)	67 (a)	68 (d)	69 (a)	70 (a)
71 (d)	72 (d)	73 (d)	74 (a)	75 (b)	76 (c)	77 (b)	78 (d)	79 (b)	80 (b)
81 (b)	82 (d)	83 (c)	84 (a)	85 (c)	86 (a)	87 (d)	88 (d)	89 (c)	90 (c)
91 (a)	92 (d)	93 (a)	94 (a)	95 (c)	96 (a)	97 (c)	98 (a)	99 (a)	100 (d)
101 (c)	102 (c)	103 (b)	104 (d)	105 (d)	106 (a)	107 (b)	108 (a)	109 (a)	110 (a)
111 (a)	112 (b)	113 (a)	114 (b)	115 (d)	116 (d)	117 (b)	118 (b)	119 (a)	120 (d)
121 (a)									

NEET Special Types Questions

122 (a)	123 (a)	124 (b)	125 (a)	126 (d)	127 (a)	128 (d)	129 (a)	130 (a)	131 (c)
132 (d)	133 (a)	134 (a)	135 (a)	136 (c)	137 (a)	138 (a)	139 (b)	140 (d)	141 (d)
142 (c)	143 (d)	144 (a)	145 (c)	146 (d)	147 (c)	148 (a)	149 (a)	150 (b)	151 (c)
152 (b)	153 (b)	154 (c)	155 (c)	156 (a)	157 (a)	158 (a)	159 (d)	160 (d)	

NCERT Exemplar Questions

161 (c)	162 (a)	163 (c)	164 (c)	165 (d)	166 (a)	167 (c)	168 (d)	169 (a)	170 (b)
171 (a)	172 (b)	173 (d)	174 (d)						

Answers & Explanations

2 (*c*) Green plants carry out photosynthesis, a physico-chemical process by which they use light energy to drive the synthesis of organic compounds.

4 (*c*) Chemosynthetic bacteria do not evolve oxygen during photosynthesis. While, blue-green algae, red algae and C_4- plants take in CO_2 from the environment and release O_2 into the environment during photosynthesis.

$$CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2\uparrow$$

5 (*a*) Green parts of leaves perform photosynthesis. In the experiment, we see that uncovered part was able to absorb light and starch was synthesised here as the product of photosynthesis. Thus, turned blue-black on dipping in iodine (as iodine react with starch to give this colour).

6 (*d*) Half leaf experiment demonstrates that CO_2 is essential for photosynthesis. In this experiment, a part of a leaf is enclosed in a test tube containing some KOH soaked cotton (which absorbs CO_2) and the other half part is exposed to air. The setup is then placed in light for some time.

On testing for starch later in the two halves of the leaf, the exposed part of the leaf tested positive for starch, while the portion that was in the tube, tested negative. This showed that CO_2 is required for photosynthesis.

7 (*d*) Both options (a) and (b) are correct.

Priestley hypothesised that plants restore to the air whatever breathing animal and burning candle removes.

9 (*b*) Jan Ingenhousz did an experiment with aquatic plant, where he showed that in bright sunlight, small bubbles are seen around green parts. These bubbles were later identified as oxygen. Hence, Jan Ingenhousz concluded that only green parts of plant release oxygen.

13 (*d*) Opton (d) is correct and can be explained as

TW Engelmann (1843-1909) performed an interesting experiment using a prism. He splits light into its spectral components and then illuminated a green alga, *Cladophora*, placed in a suspension of aerobic bacteria (*Azotobater*).

The bacteria were used to detect the sites of O_2 evolution. He observed that the bacteria accumulated mainly in the region of blue and red light of the split spectrum. The first action spectrum of photsynthesis was thus described.

14 (*a*) van Niel demonstrated that O_2 comes from water instead from CO_2. He saw in green plants, H_2O is the hydrogen donor and is oxidised to O_2 during photosynthesis. Some organisms do not release O_2 during photosynthesis.

When H_2S, instead of H_2O is the hydrogen donor for purple and green sulphur bacteria, the oxidation product is sulphur or sulphate depending on the organism and not O_2. Hence, he inferred that O_2 evolved by green plant comes from H_2O, not from carbon dioxide. This was later proved by using radioisotopes technique.

16 (*d*) Ruben and Kamen (1941) and Ruben, *et al.* (1941) suspended *Chlorella* in water having non-radioactive heavy isotope of oxygen O^{18}, instead of natural oxygen (O^{16}).

The suspension was then illuminated. Oxygen evolved was tested by means of mass spectrometer. It was found to be having isotope, O^{18}. This can be possible only if oxygen evolved during photosynthesis comes from splitting of water.

$$6CO_2 + 12H_2O^{18} \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6H_2O + 6O_2^{18}$$

17 (*b*) Chloroplasts are found in the mesophyll cells of the leaves. Leaves have maximum number of chloroplasts.

18 (*c*) When intensity of light is low, chloroplasts align themselves in the mesophyll cell in such a way that their flat surfaces are parallel to the cell wall of mesophyll cells. This allows the chloroplasts to get the optimum quantity of the incident light.

19 (*b*) The correct option is (b). The labelled parts are as follows

A–Stroma lamella–It is the region of the stroma that interconnects the thylakoids stalks. It does not contain chlorophyll.

B–Granum (plural grana)–It is stacks of discs formed by aggregated thylakoids. It contains light harvesting system composed of chlorophyll.

C–Stroma–It refers to the fluid-filled inner space of chloroplasts surrounding thylakoids and grana. Dark reaction occurs here to form starch.

20 (*c*) Option (c) is incorrect about chloroplasts. It can be corrected as
They arc not associated with any type of respiration, i.e. aerobic and anaerobic and can be found in any type of cell. They are spherical, ovoid or disc-shaped cell organelles. These are found in plants and algae. They are involved in photosynthesis due to the presence of chlorophyll in them. During photosynthesis, O_2 is released here.

21 (*d*) The chloroplast's membrane system is responsible for trapping the light energy. The light energy is used in synthesis of ATP and NADPH.

22 (*d*) In dark reaction, the products formed from light reaction are required. The dark reaction occurs outside of the thylakoids during day in CAM plants and during night in C_3-plants. In this reaction, the energy from ATP and NADPH are used to fix carbon dioxide.

Thus, all the options are correct.

23 (*c*) Anthocyanins are water soluble pigments found in plant cell vacuoles. They may appear red, purple or blue depending on pH. They are impermeable to cell membranes of plants and can leak out only when membranes are damaged or dead.

24 (*a*) The molecular formula of chlorophyll-*b* is $C_{55}H_{70}O_6N_4Mg$. It helps in photosynthesis by absorbing light energy. It is more soluble in polar solvents than chlorophyll-*a* because of its carbonyl group. It is of yellow colour and primarily absorbs blue light.

26 (*a*) Chlorophyll-*a* is the chief photosynthetic pigment in the plants. It is the main pigment which allows maximum absorption of light thereby doing maximum photosynthesis.

28 (*c*) Absorption spectrum is the curve obtained by plotting the amount of absorbed light of different wavelengths by a particular pigment. Action spectrum is the curve depicting the relative rate of photosynthesis at different wavelength of light. It shows that the maximum photosynthesis occurs at the blue and red region. Thus, absorption spectrum of chlorophyll-*a* and action spectrum of photosynthesis is identical as chlorophyll-*a* absorbs red and blue light.

29 (*c*) Visible light consists of radiation having a wavelength between 390-760 nm (or 3900-7600 A). It can be resolved into light of different colours. Namely, violet (390-430 nm), blue (430-470 nm), blue-green (470-500 nm), green (500-580 nm), yellow (580-600 nm), orange (600-650 nm), red (650-760 nm).

Red light above 760 nm is called infrared and the light radiation shorter than the violet is called ultraviolet light.

30 (*a*) Maximum photosynthesis rate has been observed in the full spectrum. Regarding the effect of different wavelengths, maximum photosynthesis occurs in red light (660 nm), second maximum in blue light (440 nm) and minimum in green light.

31 (*d*) Option (d) is correct as
Chlorophyll-*b*, xanthophylls and carotenoids are called accessory pigments of photosynthesis. These pigments absorb light and transfer the energy to chlorophyll-*a*. They enable a wider range of wavelength of incoming light to be utilised for photosynthesis but also protect chlorophyll-*a* from photooxidation.

32 (*d*) Light reaction starts when solar radiation or light falls on the PS-II. Light reaction is also called photochemical phase, which includes light absorption, water splitting, oxygen release and the formation of high energy chemical intermediates like ATP and NADPH.

33 (*d*) Both options (a) and (c) are correct. Light Harvesting complexes (LHCs) are present within the photosystem-I (PS-I) and photosystem-II (PS-II). The LHCs are made up of hundreds of pigment molecules bound to proteins.

34 (*d*) Photosystems (PS) are made up of reaction centre and antennae.

Each photosystem has all the pigments (except one molecule of chlorophyll-*a*) forming antennae (a light harvesting system). These pigments help to make photosynthesis more efficient by absorbing different wavelength of light. The single chlorophyll-*a* molecule forms the reaction centre.

38 (*a*) Emerson performed photosynthetic experiment on *Chlorella*. He provided monochromatic light of more than 680 nm and observed decrease in rate of photosynthesis known as red drop.

Later, he provided synchronised light of 680 nm and 700 nm and observed increase in rate of photosynthesis, known as enhancement effect. This experiment led to discovery of two photosystems, i.e.

70 (*a*) ATPase has two parts, i.e. F_0 and F_1. F_0 part has channels through which the diffusion of protons takes place.

71 (*d*) Both options (b) and (c) are correct. Along with the NADPH produced by the movement of electrons, the ATP will be used immediately in the biosynthetic reaction taking place in the stroma, responsible for fixing CO_2 (reduction) and synthesis of sugars.

72 (*d*) Option (d) is correct.
As synthesis of sugars or carbohydrates takes place in the biosynthetic phase of photosynthesis. This process does not directly depends on the presence of light, but is dependent on the products of the light reaction, i.e. ATP and NADPH, besides CO_2 and H_2O. Therefore if light becomes unavailable during photosynthesis then biosynthetic phase continues for some time and then stops, due to unavailability of products.

74 (*a*) CO_2 assimilation during biosynthetic phase of photosynthesis was said to be of two main types, i.e. C_3-plants in which first stable product of CO_2-fixation is PGA (C_3 acid) and C_4-plants in which first stable product of CO_2-fixation is OAA (C_4 acid).

75 (*b*) During the dark reaction, the acceptor of CO_2 is RuBP (Ribulose-1, 5, Bisphosphate). After accepting, CO_2, RuBP forms the intermediate six carbon compound, which breaks down into 3 carbon stable compound. It is called 3-Phosphoglyceric Acid (PGA).

76 (*c*) In Calvin cycle, the first product identified was 3-phosphoglyceric acid or PGA. Thus, this cycle is known as C_3 cycle. Melvin Calvin used radioactive ^{14}C in algal photosynthesis, which led to the discovery that the first CO_2-fixation product as 3 carbon organic acid. He also contributed to working out the complete biosynthetic pathway; hence it was called Calvin cycle after him.

82 (*d*) Glucose molecule contains 6 carbons. For fixing one carbon (CO_2), Calvin cycle needs 2 ATP and 2 NADPH and 1 ATP for RuBP regeneration.
Then for fixing six carbon ($C_6H_{12}O_6$), Calvin cycle needs 18 ATP and 12 NADPH.
The net reaction of C_3 dark fixation of CO_2 is
$6\,RuBP + 6\,CO_2 + 18\,ATP + 12\,NADPH$
$\rightarrow 6RuBP + C_6H_{12}O_6 + 18\,ADP + 18O_2 + 12NADP^+$

84 (*a*) Carboxylation of one molecule of RuBP leads to the formation of 2 molecules of 3-PGA.

$$RuBP + CO_2 \xrightarrow[\text{carboxylase}]{\text{RuBP}} \text{2-carboxyl 3-keto 1-5, bisphosphoribotol}$$

$$\text{2-carboxyl 3-keto 1-5-bisphosphoribotol} + H_2O \longrightarrow 2(3PGA)$$

86 (*a*) In Calvin cycle, ribulose 1-5 bisphosphate ultimately produces 3 molecules of PGAL, i.e. total 6 molecules by three Calvin cycles.
In the same process, one ATP and one $NADPH_2$ are required for each 3 PGAL molecules to be phosphorylated. Thus, for three Calvin cycles, 3 molecules each of ATP and $NADPH_2$ will be required.

87 (*d*) In bundle sheath cells, the RuBisCO is present in highest concentration and PEP carboxylase is absent. In mesophyll cells, the PEP carboxylase is present and RuBisCO is absent.

88 (*d*) Kranz anatomy is found in C_4-plants. These are plants that are adapted to dry tropical conditions
Kranz anatomy refers to the presence of two types of chloroplasts agranal in bundle sheath cells and granal in mesophyll cells ,e.g. sugarcane, maize, etc.
In these plants, the first stable product after the fixation of CO_2 is 4C dicarboxylic acid called Oxaloacetic Acid (OAA). But they still use the C_3 pathway or the Calvin cycle as the main biosynthetic pathway.

89 (*c*) In Hatch and Slack pathway, the primary CO_2 acceptor is phosphoenol pyruvate. This occurs in C_4-plants. Phosphoenol pyruvate, a 3-carbon compound, acceptor of CO_2 and forms oxaloacetic acid which is a 4-carbon compound.

92 (*d*) Among the given options, option (d) is incorrect about C_4-plants. The mesophyll cells of C_4-plants do not possess RuBisCO enzyme. C_4-plants show Kranz anatomy. In these plants, the initial fixation of CO_2 occurs in mesophyll cells. The primary acceptor of CO_2 is Phosphoenol Pyruvate or PEP. It combines with CO_2 in the presence of PEP carboxylase or PEPCase to form oxaloacetic acid or oxaloacetate.

94 (*a*) Fixing of one molecule of CO_2 or carbon needs 5 ATP and 2 NADPH in C_4-plants. C_4-plants take 2 more ATP than C_3-plants. But the photorespiration is absent in C_4-plants, thus C_4-plants are more economical than C_3-plants.

95 (*c*) Even after the closing of the stomata, C_4-plants perform photosynthesis because they can produce their own CO_2 by decarboxylation of malic acid. This CO_2 is used in Calvin cycle like in C_3-plants.

96 (*a*) PEPCase has an advantage over the RuBisCO because PEPCase does not bind to the oxygen. But RuBisCO binds with oxygen and does the photorespiration, which is a harmful and wastage process and leads to decrease in photosynthetic yield.

98 (*a*) In C_3-plants, all the reactions of C_3 or Calvin cycle occur in mesophyll cells of leaves, while C_4-plants show a distinct type of anatomy called as Kranz anatomy, where two different regions mesophyll cells and bundle sheath, are involved in this process.

101 (*c*) Photorespiration is the light dependent reaction in which utilisation of oxygen and release of carbon dioxide takes place by photosynthetic organs of plant. Normally, photosynthetic organs do the reverse in the light, i.e. uptake of CO_2 and release of O_2.

102 (*c*) Photorespiration naturally occurs in C_3-plants, but not in C_4-plants. C_4-plants have evolved C_4 cycle to compensate photorespiratory loss.

103 (*b*) RuBisCO is the most abundant enzyme in the world. It is characterised by the fact that active sites can bind to both CO_2 and O_2.
This binding is competitive. It is the relative concentration of O_2 and CO_2 that determines, which of two (CO_2 and O_2) will bind to enzyme.

104 (*d*) In C_3 plants, the site for photorespiration is chloroplast. RuBP carboxylase functions as oxygenase and instead of fixing carbon dioxide, it converts oxidase Ribulose-1, 5-Bisphosphate (RuBP) to produce one molecule each of phosphoglycerate and phosphoglycolate.

$$\text{RuBP} + O_2 \xrightarrow[\text{Oxygenase}]{\text{RuBP}} \text{PGA} + \text{Phosphoglycolate}$$

105 (*d*) Photorespiration requires three cell organelles in sequence of chloroplast, peroxisome and mitochondria.

106 (*a*) C_4-plants have very little photorespiration because its initial carbon dioxide-fixation is done by PEP carboxylase not by RuBisCO. Beside this, C_4 plants generate their own CO_2 by decarboxylation of C_4 acids in bundle sheath. Due to these reasons, the C_4 plants minimise photorespiration.

107 (*b*) C_4 plants utilise solar energy more efficiently because rate of photosynthesis is very high in them, e.g. sugarcane, maize, etc.

108 (*a*) At the low CO_2 and high O_2 concentration, RuBisCO oxygenase activity increases. Binding of RuBP with oxygen leads to the formation of 2-phosphoglycolate and 3-phosphoglycerate.

109 (*a*) In photorespiration, glycolate is formed in chloroplast, it passes to the peroxisomes and gets oxidised to glyoxylate. Glyoxylate is aminated and gives rise to amino acid glycine, which enters into the mitochondria.

113 (*a*) Law of limiting factor was proposed by FF Blackman (1905). It stated that, when a process is condition to its number of separate factors, the rate of the process is limited by the pace of the slowest factor (i.e. the factor present in minimum amount).

114 (*b*) There is a point in the light intensity, where there is no gaseous exchange in photosynthesis. It is called light compensation point.

115 (*d*) All options are correct. In the given graph, rate of photosynthesis initially increases with an increase in light intensity (region A) but soon it is levelled off. Thus, initially light intensity was limiting the rate of photosynthesis.
However, when light intensity was present in sufficient amounts (region C), rate of photosynthesis did not increases further. This is due to the fact that in region C, some other factor (e.g. CO_2 concentration) becomes the limiting factor.
At this region, the rate of photosynthesis could be further enhanced only by the increase in availability of other limiting factor (e.g. CO_2). Point D represents the intensity of light at which some other becomes limiting.

116 (*d*) In nature, light is rarely a limiting factor except for plants in shade or in dense forests.
This because a limiting factor is the one which is least quantity in the plant and we know that sunlight is always in abundance to plants except for plants in shade or in dense forest.

117 (*b*) Carbon dioxide is usually a limiting factor in photosynthesis under normal conditions particularly, in clear summer days under adequate water supply.

121 (*a*) The external factors would include the availability of sunlight, temperature, CO_2 concentration and water. As a plant photosynthesises, all these factors will simultaneously affect its rate.

122 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.
Photosynthesis is a physicochemical process. This is because photosynthesis involves the conversion of light energy, which is a physical process and leads to the formation of glucose which is a chemical process.

123 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.
During photosynthesis, glucose is formed, but it is stored in the form of starch. This is because glucose being osmotically active can lead to water imbalance whereas starch being osmotically inactive will not pull water and will not cause water imbalance in the plant.

124 (*b*) Both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
The absorption spectrum of chlorophyll-*a* shows close correlation with its action spectrum. This is because chlorophyll-*a* is the chief pigment associated with photosynthesis and most of the photosynthesis takes place in the blue and red regions of the spectrum, chlorophyll-*a* is found in PS-I and PS-II.

125 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.
The accessory pigments, i.e. chlorophyll-*b*, xanthophylls and carotenoids also absorb light and transfer the energy to chlorophyll-*a*. Hence, they increase the rate of photosynthesis. These pigments enable a wider range of wavelength of incoming light to be utilised for photosynthesis.

126 (*d*) Assertion is false, but Reason is true. Assertion can be corrected as
The photosystem-I and photosystem-II are named in the sequence of their discovery and not in the sequence in which they function during the light reaction. During non-cyclic photophosphorylation PS-II works first and then PS-I.

127 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.
PS-II causes photolysis of water inside the lumen, while PS-I causes the reduction of CO_2 in the stroma by using $NADP^+$. Thus, PS-I and PS-II are present on the different surfaces of thylakoid membranes.

128 (*d*) Assertion is false, but Reason is true. Assertion can be corrected as

Dark reaction is independent of light. It can take place in the day or night time different plants. Dark reaction or Biosynthetic phase of photosynthesis used the product of light reaction. Enzymes of dark reaction are temperature sensitive not light sensitive.

130 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

PEP carboxylase is the primary CO_2 acceptor in C_4- plants and this enzyme works at high temperature only. Thus, C_4-plants can survive in high temperature.

131 (*c*) Assertion is true, but Reason is false.

In C_3 cycle, the first stable compound is 3C compound — the phosphoglycerate.

The Reason can be corrected as

In C_4-plants, the first CO_2-fixation product is a 4C-oxaloacetic acid, but they use C_3-pathway or Calvin cycle as the main biosynthetic pathway for carbon-fixation (carboxylation), which occurs in the bundle sheath cells of leaves.

132 (*d*) Reason is true, but Assertion is false. Assertion can be corrected as

C_3 pathway produces CO_2 and utilises ATP. C_4 pathway is more evolved than C_3 pathway and involved a superior CO_2-fixing mechanism. Thus, C_4-pathway is more efficient than C_3-pathway.

133 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

C_4-plants can perform photosynthesis at very low level of CO_2 too. This is due to the occurrence of Calvin cycle in the bundle sheath cells of the leaves of C_4-plants. This pathway ensures efficient utilisation of CO_2.

134 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

Calvin cycle is the only pathway which enables sugar synthesis from CO_2. Thus, Calvin cycle occurs both in C_3 and C_4-plants.

135 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

In photorespiratory pathway neither ATP, nor NADPH is produced. It produces CO_2 and utilises ATP. Thus, photorespiration decreases photosynthetic output.

136 (*c*) Assertion is true, but Reason is false. The light reaction and dark reacitons are both temperature sensitive.

Reason can be corrected as

The dark reaction is enzymatic thus affected by change in temperatrue much more than light reaction.

137 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

Water is rarely a limiting factor in photosynthesis as plants use less than 1% of the water absorbed. The effect of water as a factor is more through its effect on the plant, rather than directly on photosynthesis.

138 (*a*) Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

Lack of water indirectly decreases the rate of photosynthesis as lack of water causes wilting of leaves. This leads to a decrease in the surface area of leaves which subsequently leads to the reduced availability of surface area for exchange of gases to carry out photosynthesis.

139 (*b*) Both Assertion and Reason are true, but Reason is not the correct explanation of Assertion.

The net reaction of photosynthesis is

$$6CO_2 + 12H_2O \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

From this reaction it is clear that to form one molecule of glucose, six molecules of CO_2 are required.

This is because the product of light reaction required in dark reactions to form one molecule of glucose are 12 molecules of NADPH and 18 molecules of ATP.

For forming 2 molecules of NADPH from NADP +, 2 molecules of water are required, so that demand of 4 electrons and protons can be satisfied. Two molecules of water split to form 1 molecules of oxygen and the respective number of electrons and hydrogen ions are also formed. Now for producing 12 molecules of NADPH, total 12 molecules of water are required.

140 (*d*) Statement in option (d) is incorrect and can be corrected as

CO_2 is fixed during Calvin cycle in the stroma of chloroplast.

141 (*d*) All statements are correct.

The graph that shows the amount of absorption of different wavelength of light absorbed by a pigment which is called absorption spectrum. The absorption spectra of chlorophyll-*a* and *b* shows that they absorb maximum light in the blue-violet and red wavelengths. The pigments are often known after the wavelength which is absorbed to the maximum, e.g. Chl-a_{673}, Chl-a_{683} (P_{680}), Chl, a_{703} (P_{700}). Rate of photosynthesis is maximum in blue and red light.

142 (*c*) Statement in option (c) explains the graph correctly. The graph shows action spectrum of photosynthesis superimposed on absorption spectrum of chorophyll-*a*. Rest statements are incorrect and corrected as

- The absorption spectrum shows a graphic representation of amount of light of different wavelengths absorbed by a pigment.
- Action spectrum depicts the relative rates of photosynthesis of different wavelengths of light.

144 (*a*) The statements in option (a) is false in case of C_4-plants. The statement is corrected as follows

In case of C_4- plants, the primary CO_2 acceptor is a 3 carbon molecule, i.e. phosphoenol pyruvate and is present in the mesophyll cells.

145 (*c*) The statement in option (c) is incorrect and can be corrected as

Calvin cycle occurs in the stroma of chloroplast.

Rest of the statements are correct.

147 (*c*) Statement in option (c) is not correct with reference to factors affecting the rate of photosynthesis. The statement can be corrected as

C_3- plants respond to higher temperature with decreased photosynthesis, while C_4-plants have much lower temperature optimum.

Rest of the statements are correct.

148 (*a*) The reason given in option (a) is correct.

During photosynthesis, water vapour comes out through a stomatal opening of the leaf of a plant. And through the same opening CO_2 diffuses into the leaf. This simultaneous entry and exit of CO_2 and water vapour, respectively, occurs due to a difference in the diffusion coefficient of CO_2 and water vapour.

149 (*a*) Statements I, II and III are incorrect, IV is correct. Incorrect statements can be corrected as

- Cyclic photophosphorylation operates only by PS-I.
- During cyclic photophosphorylation, only ATP formation takes place and recyclation of electrons also occurs.
- Unlike, the non-cyclic phosphorylation, splitting of H_2O does not take place in the cyclic phosphorylation.

150 (*b*) Both I and II statements are false. These statements can be corrected as

- C_3 and C_4 cycle are the two parts of biosynthetic phase or dark reaction of photosynthesis in C_4-plant, but in C_3-plant, only C_3 cycle occurs.
- The enzyme in these two cycles are present in chloroplast not in Golgi bodies.

151 (*c*) The correct order of steps in chemosynthetic ATP synthesis is as follows

V. Light excites electrons in PS-II.

IV. Electrons from PS-II pass along electron to move H^+ across the membranes.

III. Carriers use energy from electrons to move H^+ across the membrane.

I. H^+ concentration gradient is established.

II. H^+ diffuses through ATP synthsase.

VI. Energy of H^+ flow is used by ATP synthesis to make ATP.

152 (*b*) Statements I, III and IV are correct about Calvin cycle. This cycle can be described under three stages. These stages are

- Carboxylation is the fixation of CO_2 into stable organic intermediate.
- Reduction is a series of reactions that lead to the formation of glucose.
- Regeneration of CO_2 acceptor molecule, RuBP is main part of this stage.

153 (*b*) The statements II and III are correct. Statement I is incorrect and can be corrected as

Sunflower does not exhibit Kranz anatomy as it is a C_3-plant.

154 (*c*) Statement III is incorrect and can be corrected as

Chlorophyll-*a* is not soluble in water as well as petroleum ether.

Rest of the statements are correct.

161 (*c*) Magnesium (Mg) is present in the centre of porphyrin ring of the chlorophyll molecule.

162 (*a*) Chlorophyll-*a* is the primary photosynthetic pigment. It forms the reaction centre where the conversion of light energy into chemical energy occurs. In photosynthesis, sunlight energises electrons in chlorophyll, moving them to a higher energy state. In turn chlorophyll molecules become oxidised and these electrons are used in the next steps of photosynthesis.

163 (*c*) Photosynthetically Active Radiation (PAR) ranges from 400-700 nm. This is the visible range of light energy.

164 (*c*) Red Light (620nm-750nm) is the most effective in photosynthesis because it has exactly the right amount of energy to energise, or excite, chlorophyll electrons and boost them out of their orbits to a higher energy level.

165 (*d*) Chemosynthetic bacteria were the first organism on earth who synthesised their own food by obtaining energy from inorganic chemicals like H_2S, NO_2, etc. Photosynthetic bacteria have taken their origin from chemosynthetic bacteria.

166 (*a*) The energy for ATP synthesis comes from proton gradient, which develops along the inner membrane, e.g. in case of mitochondria in electron transport chain and in chloroplast in the PS-II.

167 (*c*) Light dependent reaction of photosynthesis uses solar power to generate ATP, $NADPH_2$, Hydrogen donor and O_2.

168 (*d*) Splitting of water is associated with PS-II, which occurs in the presence of Mn^{2+} and Cl^- ions on the inner surface of thylakoid membrane.

170 (*b*) Dark reaction is called so because, it does not depend on light energy. It depends on the products of light reaction (i.e. ATP and NADPH). It is also called as light independent reaction.

171 (*a*) C_4-plants have evolved PEP as primary acceptor of CO_2 to avoid the sensitivity of RuBP carboxylase-oxygenase to high concentration of oxygen, so that they can avoid photorespiratory loss of CO_2.

172 (*b*) PEP carboxylase enzyme is found in C_4-plants not C_3-plants to carry out initial fixation of CO_2.

173 (*d*) In C_3 cycle, RuBP carboxylase is used to fix atmospheric CO_2 whereas, in C_4-plants PEP carboxylase is involved in primary CO_2-fixation. So, both are used in CO_2-fixation, but in different cycles.

174 (*d*) In C_4 cycle, the primary CO_2 acceptor is PEP, present in the mesophyll cells. The addition of CO_2 to PEP forms the first stable product, i.e. a C_4 acid oxaloacetate (a four carbon compound) in the mesophyll cells.