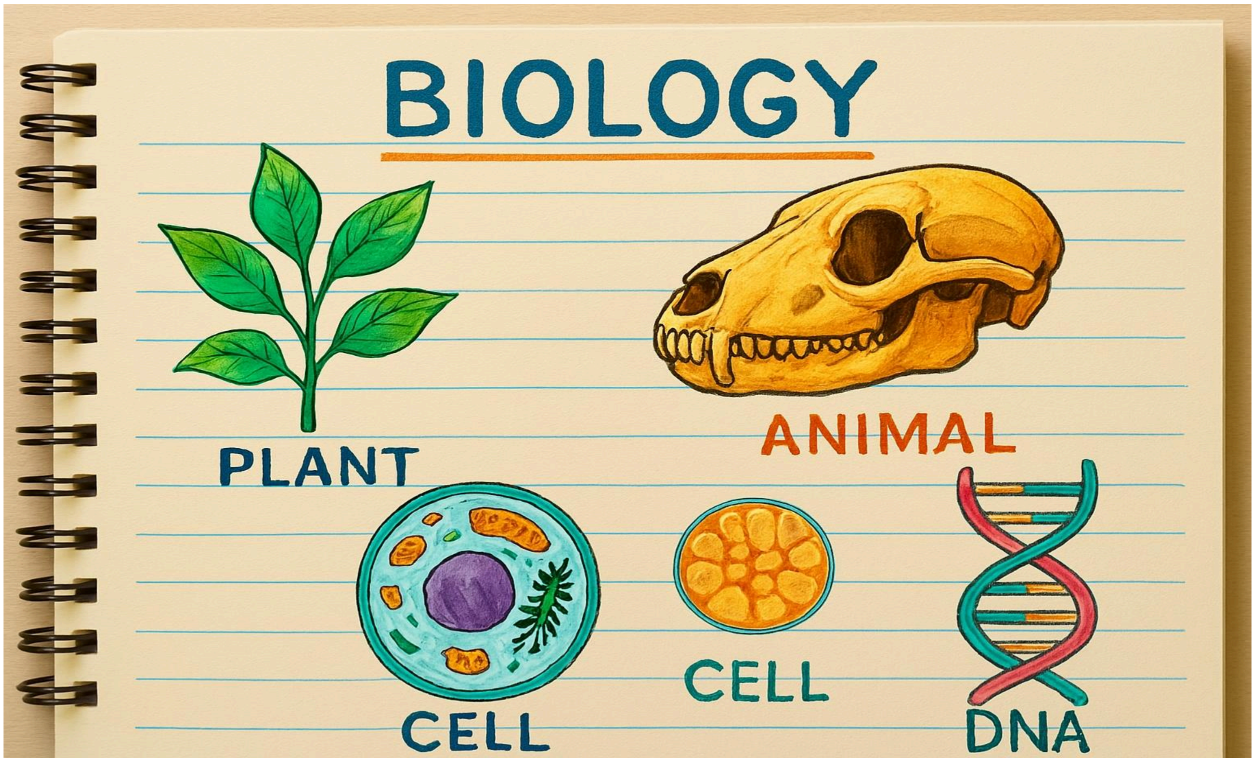


Class: 11th

Subject: Biology

Chapter 6: BIOENERGETICS

❖ Important Mcqs:

1. What is the main role of ATP in cells?

(a) To store genetic information

(b) To act as an energy currency ✅

(c) To transport oxygen

(d) To form cell membranes

2. Which of the following components is NOT part of an ATP molecule?

(a) Adenine

(b) Ribose

(c) Fatty acid ✅

(d) Phosphate groups

3. How much energy is released when one high-energy phosphate bond of ATP is broken?

(a) 3.5 kcal/mole

(b) 7.3 kcal/mole ✅

(c) 10 kcal/mole

(d) 15 kcal/mole

4. During the breakdown of ATP to ADP, what is released?

(a) Oxygen

(b) Inorganic phosphate (Pi) and energy ✅

(c) Carbon dioxide

(d) Water

5. ADP can further break down into which molecule to release energy?

(a) AMP ✅

(b) ATP

(c) Glucose

(d) NADH

6. Bioenergetics primarily studies:

(a) The flow of energy through living systems ✅

(b) The structure of DNA

(c) The transport of proteins

(d) The synthesis of lipids

7. Photosynthesis and respiration are important in bioenergetics because:

(a) Photosynthesis releases energy, respiration captures energy

(b) Both release energy

(c) Photosynthesis captures energy, respiration releases energy ✅

(d) Neither captures nor releases energy

8. Which type of bond in ATP contains high-energy?

(a) Adenine-ribose bond

(b) Ribose-phosphate bond

(c) Phosphate-phosphate bond ✅

(d) Hydrogen bond

9. How do cells obtain energy to make ATP?

(a) By absorbing sunlight directly

(b) By oxidizing food molecules ✅

(c) By breaking down DNA

(d) By diffusion of water

10. ATP transfers energy between metabolic reactions by:

(a) Breaking down DNA

(b) Forming covalent bonds with proteins

(c) Being made during energy-releasing processes and broken during energy-consuming processes ✅

(d) Transporting oxygen in the cell

11. What are the main products of photosynthesis?

(a) Carbon dioxide and water

(b) Glucose and oxygen ✅

(c) ATP and NADPH

(d) Hydrogen and carbon

12. Which of the following are reactants in photosynthesis?

(a) Glucose and oxygen

(b) Carbon dioxide, water, and light ✅

(c) ATP and NADPH

(d) Chlorophyll and starch

13. Why does water appear on both sides of the photosynthesis equation?

(a) Because water is only a product

(b) Because water is only a reactant

(c) Because water is used in some reactions and released in others ✅

(d) Because water is not involved in photosynthesis

14. What is the role of light in photosynthesis?

(a) To provide water

(b) To provide energy required to drive chemical reactions ✅

(c) To act as a carbon source

(d) To absorb carbon dioxide

15. Which pigment primarily absorbs light energy for photosynthesis?

(a) Carotene

(b) Chlorophyll ✅

(c) Xanthophyll

(d) Anthocyanin

16. What is an action spectrum?

(a) A graph showing absorption of light by pigments only

(b) A graph showing rate of photosynthesis at different wavelengths of light ✅

(c) A graph showing CO_2 uptake

(d) A graph showing water usage

17. Who created the first action spectrum of photosynthesis?

(a) Gregor Mendel

(b) T. W. Engelmann ✅

(c) Julius von Sachs

(d) Robert Hooke

18. Which wavelengths of light are most effective for photosynthesis?

(a) Green and yellow

(b) Blue and red ✅

(c) Orange and yellow

(d) Violet and green

19. What is the role of carbon dioxide in photosynthesis?

(a) To act as a source of oxygen

(b) To act as a source of carbon for making sugars ✅

(c) To absorb light energy

(d) To release energy

20. How does carbon dioxide enter the leaves?

(a) Through chloroplasts

(b) Through stomata ✅

(c) Through xylem

(d) Through phloem

21. What is the main source of hydrogen for the reduction of CO_2 in photosynthesis?

(a) Carbon dioxide

(b) Water ✅

(c) Glucose

(d) Oxygen

22. From which molecule is the oxygen released during photosynthesis derived?

(a) Carbon dioxide

(b) Water ✅

(c) Glucose

(d) NADPH

23. Why is water important for aerobic organisms?

(a) Because it releases glucose

(b) Because it provides atmospheric oxygen ✅

(c) Because it absorbs light energy

(d) Because it forms ATP

24. Who hypothesized that plants split water to obtain hydrogen, releasing oxygen as a by-product?

(a) T. W. Engelmann

(b) Van Niel ✅

(c) Gregor Mendel

(d) Julius von Sachs

25. How was Van Niel's hypothesis about the source of oxygen confirmed?

(a) By measuring CO_2 uptake

(b) Using isotopic tracer experiments with heavy oxygen ✅

(c) By testing chlorophyll absorption

(d) By measuring sugar formation

26. In the isotopic tracer experiment, what did plants given $H_2{}^{18}O$ and normal CO_2 produce?

(a) Normal oxygen (O_2)

(b) Oxygen containing ^{18}O ✅

(c) Carbon dioxide

(d) NADPH

27. In the isotopic tracer experiment, what did plants given $C^{18}O_2$ and normal $H_2{}^{16}O$ produce?

(a) Oxygen containing ^{18}O

(b) Normal oxygen (O_2) ✅

(c) Glucose

(d) NADPH

28. What is the role of hydrogen released from water in photosynthesis?

(a) To produce ATP

(b) To reduce $NADP^+$ to NADPH ✅

(c) To release oxygen

(d) To absorb light energy

29. NADPH produced during photosynthesis serves as:

(a) An energy storage molecule

(b) Reducing power for CO_2 reduction ✅

(c) A pigment to absorb light

(d) A source of oxygen

30.Which of the following best summarizes the role of water in photosynthesis?

(a) Provides hydrogen and oxygen for sugar synthesis and atmosphere ✅

(b) Only provides oxygen for respiration

(c) Only provides hydrogen for chlorophyll

(d) Splits glucose to release energy

31. In which decade did Van Niel propose his hypothesis?

(a) 1920s

(b) 1930s ✅

(c) 1940s

(d) 1950s

32. When was Van Niel's hypothesis about water splitting later confirmed experimentally?

(a) 1920s

(b) 1930s

(c) 1940s ✅

(d) 1950s

33. What is the source of hydrogen used to reduce CO_2 into sugar during photosynthesis?

(a) Carbon dioxide

(b) NADPH

(c) Water ✅

(d) Glucose

34. Where are photosynthetic pigments mainly located?

(a) Cytoplasm

(b) Thylakoid membranes ✅

(c) Mitochondria

(d) Nucleus

35. Which of the following is NOT a photosynthetic pigment?

(a) Chlorophyll a

(b) Xanthophylls

(c) Carotenes

(d) Hemoglobin ✅

36. What happens when a pigment molecule absorbs a photon?

(a) It loses energy

(b) Its electrons move to higher energy level ✅

(c) It releases CO_2

(d) It forms glucose

37. Which type of photons have higher energy?

(a) Red light photons

(b) Blue light photons ✅

(c) Green light photons

(d) Yellow light photons

38. What are the two main parts of a chlorophyll molecule?

(a) Porphyrin ring and carbohydrate chain

(b) Hydrophilic head and hydrophobic tail ✅

(c) Pyrrole ring and phosphate group

(d) Protein tail and magnesium head

39. Which atom is present at the center of chlorophyll's porphyrin ring?

(a) Calcium

(b) Magnesium ✅

(c) Iron

(d) Zinc

40. Which wavelengths are mainly absorbed by chlorophylls?

(a) Green and yellow

(b) Violet-blue and orange-red ✅

(c) Red and green

(d) Yellow and orange

41. Which pigment passes energy to chlorophyll a during photosynthesis?

(a) Chlorophyll b and carotenoids ✅

(b) Chlorophyll a only

(c) Water

(d) NADPH

42. What does the absorption spectrum of chlorophyll indicate?

(a) Maximum absorption occurs at green light

(b) Maximum absorption occurs at blue (430 nm) and red (670 nm) light ✅

(c) Maximum absorption occurs at yellow light

(d) Maximum absorption occurs at infrared light

43. What are photosynthetic pigments organized into for efficient light absorption?

(a) Chloroplasts

(b) Photosystems ✅

(c) Grana

(d) Stroma

44. What are the two main components of a photosystem?

(a) Antenna complex and reaction centre ✅

(b) Stroma and thylakoid

(c) Chlorophyll a and NADP

(d) Light and water

45. What is present in the reaction centre of a photosystem?

(a) Chlorophyll b

(b) Chlorophyll a ✅

(c) Carotenoids

(d) Xanthophyll

46. How many photosystems are there in chloroplasts?

(a) One

(b) Two ✅

(c) Three

(d) Four

47. What is the reaction centre chlorophyll of PS-I called?

(a) P680

(b) P700 ✅

(c) P6800

(d) P720

48. Which photosystem absorbs light maximally at 680 nm?

(a) PS-I

(b) PS-II ✅

(c) Both PS-I and PS-II

(d) Neither

49. What happens to water molecules during light-dependent reactions?

(a) They are reduced to form CO_2

(b) They are oxidized to release electrons and oxygen ✅

(c) They are converted into glucose

(d) They are converted into ATP

50. What is the process called when water is split in PS-II?

(a) Photophosphorylation

(b) Photolysis ✅

(c) Chemiosmosis

(d) Cyclic electron flow

51. What is the primary product of non-cyclic photophosphorylation?

(a) ATP only

(b) NADPH only

(c) ATP and NADPH ✅

(d) Oxygen only

52. Which electron transport chain carries electrons from PS-II to PS-I?

(a) Cyclic electron flow

(b) Ferredoxin

(c) PQ ⟶ Cytochrome ⟶ PC ✅

(d) NADP reductase

53. What is the role of ferredoxin in photosynthesis?

(a) To absorb light

(b) To transfer electrons from PS-I to NADP+ ✅

(c) To split water

(d) To release oxygen

54. What is formed when NADP+ gains two electrons and an H+ ion?

(a) ATP

(b) NADPH ✅

(c) ADP

(d) Oxygen

55. What happens during cyclic photophosphorylation?

(a) Both ATP and NADPH are produced

(b) Only ATP is produced ✅

(c) Only NADPH is produced

(d) Oxygen is released

56. Which photosystem is used in cyclic photophosphorylation?

(a) PS-II only

(b) PS-I only ✅

(c) Both PS-I and PS-II

(d) Neither

57. Why does cyclic photophosphorylation occur?

(a) To produce NADPH

(b) When Calvin cycle slows down and NADPH accumulates ✅

(c) To release oxygen

(d) To reduce CO_2

58. What is the zigzag path of electrons through photosystems and electron transport chains called?

(a) Calvin cycle

(b) Z-scheme ✅

(c) Cyclic flow

(d) Photolysis

59. Where do light-dependent reactions take place?

(a) Stroma

(b) Thylakoid membranes of grana ✅

(c) Cytoplasm

(d) Mitochondria

60. Where do light-independent reactions (Calvin cycle) take place?

(a) Thylakoid membranes

(b) Stroma ✅

(c) Cytoplasm

(d) Nucleus

61. What is the most important step of light-dependent reactions?

(a) CO_2 fixation

(b) Formation of ATP ✅

(c) Splitting of CO_2

(d) Absorption of water

62. In non-cyclic photophosphorylation, which photosystems participate?

(a) PS-I only

(b) PS-II only

(c) Both PS-I and PS-II ✅

(d) Neither

63. What is chemiosmosis?

(a) The splitting of water

(b) The mechanism where thylakoid membranes couple redox reactions with ATP synthesis ✅

(c) The fixation of carbon dioxide

(d) The absorption of light

64. How is the energy released from electrons used in chemiosmosis?

(a) To produce glucose

(b) To transport H^+ ions into the thylakoid lumen ✅

(c) To reduce CO_2

(d) To absorb light

65. What is created in the thylakoid lumen during chemiosmosis?

(a) ATP molecules

(b) H^+ ion gradient ✅

(c) NADPH

(d) Oxygen

66. Through which protein do H^+ ions pass back to the stroma to make ATP?

(a) Rubisco

(b) ATP synthase ✅

(c) Ferredoxin

(d) NADP reductase

67. What is the main product of chemiosmosis?

(a) NADPH

(b) ATP ✅

(c) Oxygen

(d) Glucose

68. Where do light-independent reactions occur?

(a) Thylakoid membranes

(b) Stroma of chloroplast ✅

(c) Cytoplasm

(d) Mitochondria

69. What are light-independent reactions also called?

(a) Photophosphorylation

(b) Calvin cycle ✅

(c) Photolysis

(d) Electron transport chain

70. Who discovered the details of light-independent reactions?

(a) Van Niel

(b) Melvin Calvin ✅

(c) T. W. Engelmann

(d) Julius von Sachs

71. During carbon fixation, which enzyme combines CO_2 with RuBP?

(a) ATP synthase

(b) Rubisco ✅

(c) NADP reductase

(d) Ferredoxin

72. How many molecules of 3-PGA are formed when three molecules of CO_2 are fixed?

(a) Three

(b) Six ✅

(c) One

(d) Five

73. What happens during the reduction phase of Calvin cycle?

(a) CO_2 is absorbed

(b) 3-PGA is converted to G3P using ATP and NADPH ✅

(c) RuBP is regenerated

(d) Water is split

74. Which molecule provides hydrogen for the reduction of 1,3-bisphosphoglyceric acid to G3P?

(a) ATP

(b) NADPH ✅

(c) CO_2

(d) ADP

75. How many G3P molecules leave the Calvin cycle to form glucose?

(a) One ✅

(b) Two

(c) Three

(d) Five

76. How are RuBP molecules regenerated in the Calvin cycle?

(a) Five G3P molecules are converted to three RuP and then phosphorylated with three ATP ✅

(b) By splitting water

(c) By absorbing light energy

(d) By reduction with NADPH

77. Light-independent reactions require which molecules from light-dependent reactions?

(a) CO_2 and water

(b) ATP and NADPH ✅

(c) Oxygen and glucose

(d) H_2O only

78. What is the main purpose of cellular respiration?

(a) To produce glucose

(b) To break down carbon compounds and release usable energy ✅

(c) To absorb light energy

(d) To fix carbon dioxide

79. Which compound is known as the respiratory fuel?

(a) Oxygen

(b) Glucose ✅

(c) ATP

(d) Carbon dioxide

80. Which type of respiration occurs in the absence of oxygen?

(a) Aerobic

(b) Anaerobic ✅

(c) Krebs cycle

(d) Glycolysis

81. Which type of respiration occurs in the presence of oxygen?

(a) Anaerobic

(b) Aerobic ✅

(c) Alcoholic fermentation

(d) Lactic acid fermentation

82. What is the first step in both aerobic and anaerobic respiration?

(a) Krebs cycle

(b) Glycolysis ✅

(c) Pyruvic acid oxidation

(d) Electron transport chain

83. How many ATP molecules are produced per glucose in anaerobic respiration?

(a) 2 ✅

(b) 4

(c) 36

(d) 38

84. In alcoholic fermentation, pyruvic acid is converted into:

(a) Lactic acid

(b) Alcohol (C2H5OH) and CO_2 ✅

(c) Glucose

(d) Acetyl-CoA

85. Where does glycolysis occur?

(a) Mitochondria

(b) Cytosol ✅

(c) Chloroplast

(d) Nucleus

86. Which coenzyme accepts hydrogen during glycolysis?

(a) FAD

(b) NAD+ ✅

(c) CoA

(d) ATP

87. What is the product of glycolysis from one glucose molecule?

(a) Two molecules of pyruvic acid ✅

(b) One molecule of acetyl-CoA

(c) Two molecules of citric acid

(d) One molecule of glucose

88. What is formed when pyruvic acid is oxidized before entering Krebs cycle?

(a) Acetyl-CoA ✅

(b) Citric acid

(c) Succinyl-CoA

(d) Malic acid

89. Which molecule combines with acetyl-CoA to form citric acid in Krebs cycle?

(a) Oxaloacetic acid ✅

(b) Pyruvic acid

(c) Succinic acid

(d) Fumaric acid

90. Which reaction releases CO_2 during Krebs cycle?

(a) Oxidative decarboxylation ✅

(b) Phosphorylation

(c) Reduction

(d) Hydration

91. What is the high-energy electron carrier reduced by succinic acid?

(a) NAD+

(b) FAD ✅

(c) ADP

(d) ATP

92. Which molecule is regenerated at the end of Krebs cycle to start a new cycle?

(a) Citric acid

(b) Oxaloacetic acid ✅

(c) Succinyl-CoA

(d) Pyruvic acid

93. How is ATP formed in the Krebs cycle from succinyl-CoA?

(a) Through electron transport

(b) From the high-energy bond between succinyl-CoA and succinic acid ✅

(c) From NADH directly

(d) From FADH2

94. Where do pyruvic acid oxidation, Krebs cycle, and electron transport occur?

(a) Cytosol

(b) Mitochondria ✅

(c) Nucleus

(d) Chloroplast

95. What is the end product when malic acid is oxidized in Krebs cycle?

(a) Succinyl-CoA

(b) Oxaloacetic acid ✅

(c) Citric acid

(d) Pyruvic acid

96. How many carbons does citric acid have in Krebs cycle?

(a) 4

(b) 5

(c) 6 ✅

(d) 3

97. Which coenzyme is reduced during the oxidation of alpha-ketoglutaric acid?

(a) NAD+ ✅

(b) FAD

(c) ADP

(d) ATP

98. Where does the electron transport chain of cellular respiration occur?

(a) Cytoplasm

(b) Inner membrane of mitochondrion ✅

(c) Stroma of chloroplast

(d) Outer membrane of mitochondrion

99. Which coenzyme receives electrons first in the electron transport chain?

(a) NAD+

(b) Coenzyme Q ✅

(c) FAD

(d) Cytochrome c

100. What is the final electron acceptor in the electron transport chain?

(a) NAD+

(b) Oxygen ✅

(c) FAD

(d) Water

101. How many ATP molecules are produced from oxidation of one NADH?

(a) 1

(b) 2

(c) 3 ✅

(d) 4

102. How many ATP molecules are produced from oxidation of one FADH2?

(a) 1

(b) 2 ✅

(c) 3

(d) 4

103. What mechanism couples redox reactions with ATP synthesis in mitochondria?

(a) Substrate-level phosphorylation

(b) Chemiosmosis ✅

(c) Glycolysis

(d) Krebs cycle

104. What creates the H^+ ion gradient in the electron transport chain?

(a) Diffusion of NADH

(b) Active transport of H^+ ions into the inter-membrane space ✅

(c) Substrate-level phosphorylation

(d) Oxidation of pyruvic acid

105. Through which protein do H^+ ions pass back to the mitochondrial matrix to make ATP?

(a) ATP synthase ✅

(b) Rubisco

(c) Cytochrome c

(d) FAD

106. What is formed when oxygen accepts electrons and H^+ ions at the end of the electron transport chain?

(a) CO_2

(b) Water ✅

(c) Glucose

(d) Pyruvic acid

107. What is substrate-level phosphorylation?

(a) ATP synthesis using chemiosmosis

(b) ATP synthesis by transferring phosphate from an organic molecule to ADP ✅

(c) Electron transport

(d) Oxidation of NADH

108. During glycolysis, which molecule undergoes substrate-level phosphorylation to form ATP?

(a) G3P

(b) Phosphoenol pyruvate (PEP) ✅

(c) Fructose 1,6-bisphosphate

(d) Pyruvic acid

109. How many ATP molecules are produced from glycolysis NADH after mitochondrial transport cost?

(a) 1

(b) 2 ✅

(c) 3

(d) 4

110. What is the net ATP yield of aerobic oxidation of one glucose molecule?

(a) 2

(b) 18

(c) 36 ✅

(d) 38

111. Aerobic oxidation of glucose is how many times more efficient than anaerobic glycolysis?

(a) 2 times

(b) 10 times

(c) 18 times ✅

(d) 36 times

112. How are fatty acids used as fuel in cellular respiration?

(a) Converted to pyruvic acid

(b) Converted to acetyl-CoA ✅

(c) Converted to glucose

(d) Converted to G3P

113. What is photorespiration?

(a) Photosynthesis in the dark

(b) Release of CO_2 in light without ATP production ✅

(c) Aerobic respiration in roots

(d) Formation of glucose without CO_2

114. Which enzyme catalyzes the addition of CO_2 or O_2 to RuBP?

(a) ATP synthase

(b) Rubisco ✅

(c) NADP reductase

(d) Phosphofructokinase

115. During photorespiration, RuBP reacts with which molecule instead of CO_2?

(a) H_2O

(b) O_2 ✅

(c) Glucose

(d) NADPH

116. Photorespiration produces which toxic compound in peroxisomes?

(a) CO_2

(b) H_2O_2 ✅

(c) NADH

(d) O_2

117. In photorespiration, glycine is converted into which amino acid in mitochondria?

(a) Serine ✅

(b) Alanine

(c) Glutamate

(d) Aspartate

118. How much fixed carbon can C-3 plants lose due to photorespiration?

(a) 5–10%

(b) 15–20%

(c) 25–50% ✅

(d) 60–75%

119. Photorespiration rate increases under which condition?

(a) Low temperature

(b) High CO_2 concentration

(c) High temperature ✅

(d) High water availability

120. Which plants evolved the C-4 pathway to minimize photorespiration?

(a) Cacti

(b) Corn and sugarcane ✅

(c) Wheat

(d) Mosses

121. In C-4 photosynthesis, CO_2 is first attached to which molecule in mesophyll cells?

(a) Ribulose biphosphate

(b) Phosphoenol pyruvic acid (PEP) ✅

(c) Oxaloacetic acid

(d) Glucose

122. What is the first product of C-4 photosynthesis after CO_2 fixation?

(a) Malic acid

(b) Oxaloacetic acid ✅

(c) Pyruvic acid

(d) Phosphoglycerate

123. Where does the Calvin cycle occur in C-4 plants?

(a) Mesophyll cells

(b) Bundle-sheath cells ✅

(c) Epidermal cells

(d) Guard cells

124. How is CO_2 concentration increased in bundle-sheath cells of C-4 plants?

(a) By opening stomata during the day

(b) By transporting malic acid from mesophyll cells ✅

(c) By direct CO_2 absorption from air

(d) By photorespiration

125. What happens to pyruvic acid produced in bundle-sheath cells?

(a) Converted to glucose

(b) Returns to mesophyll cells to regenerate PEP ✅

(c) Oxidized to CO_2 directly

(d) Stored as starch

126. CAM metabolism is adapted in which type of plants?

(a) Tropical trees

(b) Succulents like cactus and pineapple ✅

(c) Cereal crops

(d) Aquatic plants

127. In CAM plants, stomata open at what time to prevent water loss?

(a) During the day

(b) During the night ✅

(c) Both day and night

(d) Only in winter

128. Why do CAM plants have reduced photorespiration?

(a) High oxygen concentration

(b) High CO_2 concentration in daytime due to nocturnal fixation ✅

(c) Low ATP availability

(d) High water loss

129. CAM plants use which pathways for sugar production?

(a) Only C-3 pathway

(b) Only C-4 pathway

(c) Both C-4 and C-3 pathways ✅

(d) Neither

130. C-4 photosynthesis reduces photorespiration by:

(a) Closing stomata at night

(b) Concentrating CO_2 in bundle-sheath cells ✅

(c) Producing more oxygen

(d) Increasing RuBP concentration

131. Photorespiration mainly occurs in which type of plants?

(a) C-3 plants ✅

(b) C-4 plants

(c) CAM plants

(d) Aquatic plants

132. The main disadvantage of photorespiration is:

(a) Water loss

(b) ATP production

(c) Loss of fixed carbon and reduced yield ✅

(d) Oxygen production

📘 EXERCISE

SECTION 1: MULTIPLE CHOICE QUESTIONS

1. What main process occurs during the dark reaction of photosynthesis?

(a) Release of oxygen

(b) Energy absorption by chlorophyll

(c) Adding of hydrogen to CO_2 ✅

(d) Formation of ATP

2. What is TRUE about glycolysis?

(a) It produces no ATP

(b) It takes place only in aerobic respiration

(c) It takes place in the mitochondrion

(d) It reduces 2 molecules of NAD^+ for every glucose molecule processed ✅

3. Which of the following are produced by the reactions that occur in the thylakoid and consumed by the reactions that occur in the stroma?

(a) CO_2 and H_2O

(b) Glucose and O_2

(c) $NADP^+$ and ADP

(d) ATP and NADPH ✅

4. When deprived of oxygen, yeast cells obtain energy by fermentation, producing CO_2, ATP and:

(a) Acetyl CoA

(b) Ethyl alcohol ✅

(c) Lactic acid

(d) Pyruvic acid

5. Conversion of Glucose-6-phosphate into Fructose-6-phosphate is:

(a) Isomerization ✅

(b) Polymerization

(c) Condensation

(d) Phosphorylation

6. In which of the following conversions, ATP is produced?

(a) Alpha ketoglutaric acid ⟶ Succinyl CoA

(b) Succinyl CoA ⟶ Succinic acid ✅

(c) Succinic acid ⟶ Fumaric acid

(d) Fumaric acid ⟶ Malic acid

7. In electron transport chain, $FADH_2$ produces how many ATPs?

(a) One

(b) Two ✅

(c) Three

(d) Four

8. Which of these is CO_2 acceptor during photosynthesis?

(a) Malic acid

(b) Ribulose biphosphate (RuBP) ✅

(c) Oxaloacetic acid

(d) Phosphoglyceric acid

9. Which of the following takes the electrons lost by Photosystem I on absorption of light energy?

(a) Ferredoxin ✅

(b) Cytochrome

(c) Cytochrome a-3

(d) Plastocyanin

10. Photosystem-II makes up the electrons lost due to light excitation by taking up the electrons released from:

(a) Ferredoxin

(b) $NADPH + H^+$

(c) Plastocyanin

(d) Photolysis of water ✅

SECTION 2: SHORT QUESTIONS

1. Differentiate between action spectrum and absorption spectrum.

Answer:

The **absorption** spectrum shows the wavelengths of light that are absorbed by photosynthetic pigments such as chlorophyll a and chlorophyll b.

The action **spectrum** shows the effectiveness of different wavelengths of light in driving the process of photosynthesis. It indicates the rate of photosynthesis at different wavelengths.

2. How is photosynthesis a redox reaction?

Answer:

Photosynthesis is a redox (oxidation-reduction) reaction because both oxidation and reduction occur together.

During photosynthesis, water molecules are oxidized when they lose electrons and hydrogen ions and release oxygen. At the same time, carbon dioxide is reduced when it gains electrons and hydrogen ions to form sugar.

3. Which molecule contributes oxygen in glucose: water or carbon dioxide?

Answer:

Carbon dioxide contributes the oxygen present in glucose.

During photosynthesis, carbon dioxide is reduced and its atoms become part of the glucose molecule, while oxygen released into the atmosphere comes from water.

4. State the role of CO_2 in photosynthesis.

Answer:

Carbon dioxide provides the carbon required for the synthesis of glucose during photosynthesis. In the Calvin cycle, CO_2 is fixed into organic molecules and eventually forms carbohydrates such as glucose.

5. Define electron transport chain.

Answer:

The electron transport chain is a series of electron carriers present in the thylakoid membrane of chloroplasts. These carriers transfer electrons from one molecule to another, releasing energy that is used for the formation of ATP during photosynthesis.

6. What do you mean by glycolysis?

Answer:

Glycolysis is the breakdown of glucose into two molecules of pyruvic acid. It occurs in the cytosol of the cell and does not require oxygen. During glycolysis, a small amount of energy is released and ATP and NADH are produced.

7. What is the main structural difference between chlorophyll-a and chlorophyll-b?

Answer:

The main structural difference between chlorophyll-a and chlorophyll-b is the functional group present on the second pyrrole ring of the porphyrin ring.

In chlorophyll-a, the second pyrrole ring has a methyl group (CH_3), while in chlorophyll-b, it has an aldehyde group (CHO) at the same position.

8. How can a cell synthesize ATP through substrate-level phosphorylation?

Answer:

In substrate-level phosphorylation, an enzyme transfers a phosphate group from an organic substrate directly to ADP. As a result, ADP is converted into ATP without using an electron transport chain or membrane system.

For example, during the last step of glycolysis, a phosphate group is transferred from phosphoenol pyruvic acid (PEP) to ADP, producing ATP and pyruvic acid.

9. Can pyruvic acid enter Krebs cycle as such? If not, what changes are made to it before Krebs cycle?

Answer:

No, pyruvic acid cannot enter the Krebs cycle directly.

Before entering the Krebs cycle, pyruvic acid undergoes the following changes:

A molecule of carbon dioxide (CO_2) is removed, forming acetaldehyde.

Acetaldehyde is oxidized to form an acetyl group, and NAD^+ is reduced to NADH.

The acetyl group combines with coenzyme-A (CoA) to form acetyl-CoA, which then enters the Krebs cycle.

10. Differentiate between C-3 and C-4 photosynthesis.

Answer:

C-3 Photosynthesis:

C-3 photosynthesis occurs in most plants. In this process, CO_2 is directly fixed in the Calvin cycle to form a three-carbon compound called 3-phosphoglyceric acid (3-PGA). These plants are called C-3 plants and photorespiration occurs frequently in them.

C-4 Photosynthesis:

C-4 photosynthesis occurs in plants such as corn, sugarcane, and sorghum. In this process, CO_2 first combines with a three-carbon compound phosphoenol pyruvic acid (PEP) to form a four-carbon compound oxaloacetic acid. This mechanism helps reduce photorespiration and increases photosynthetic efficiency in warm climates.

SECTION 3: LONG QUESTIONS

🌟 Q1: What are Photosynthetic Pigments and what role do they play in the absorption and conversion of light energy?

❖ Introduction:

Photosynthetic pigments are special light-absorbing molecules present in the thylakoid membranes of chloroplasts. These pigments absorb sunlight and help convert light energy into chemical energy during photosynthesis.

Plants contain different types of pigments so that they can absorb maximum light energy from different wavelengths of light.

The main photosynthetic pigments are:

- Chlorophyll-a (primary pigment)
- Chlorophyll-b
- Carotenoids (carotenes and xanthophylls)

Among these, chlorophyll-a is the most important pigment because it directly participates in the conversion of light energy into chemical energy.

Structure of Chlorophyll

A chlorophyll molecule has two main parts.

1. Porphyrin Ring (Head)

This part contains four pyrrole rings with a magnesium (Mg) atom in the center. Its function is to absorb light energy.

2. Hydrocarbon Tail

This long hydrophobic tail anchors the chlorophyll molecule in the thylakoid membrane of the chloroplast.

Absorption of Light Energy

Photosynthetic pigments absorb photons of light. When a pigment absorbs light:

1. Its electrons gain energy.
2. The electrons move to a higher energy level.
3. The pigment becomes excited.

Chlorophyll mainly absorbs:

- Blue light (around 430 nm)
- Red light (around 670 nm)

Green light is mostly reflected, which is why plants appear green.

Organization of Pigments in Photosystems

Photosynthetic pigments are arranged in clusters called photosystems in the thylakoid membrane.

Each photosystem consists of two main parts.

Antenna Complex

The antenna complex contains many pigment molecules.

These pigments capture light energy and transfer it to the reaction centre.

Reaction Centre

The reaction centre contains chlorophyll-a molecules.

These molecules release high-energy electrons to a primary electron acceptor, which starts the electron transport chain.

There are two types of photosystems in chloroplasts:

- Photosystem II (PS-II) with P680 chlorophyll
- Photosystem I (PS-I) with P700 chlorophyll

Conversion of Light Energy into Chemical Energy

When chlorophyll absorbs light:

1. Electrons become excited.
2. These electrons move through the electron transport chain.
3. Their energy is used to produce ATP.
4. Electrons and hydrogen ions reduce $NADP^+$ to NADPH.

ATP and NADPH store chemical energy, which is later used in the Calvin cycle to produce glucose from carbon dioxide.

Thus, photosynthetic pigments convert solar energy into chemical energy stored in food molecules.

✦ **Summary:**

Photosynthetic pigments are light-absorbing molecules found in the thylakoid membranes of chloroplasts. The main pigments include chlorophyll-a, chlorophyll-b, and carotenoids. These pigments capture light energy and transfer it to the reaction centre of photosystems. The absorbed energy excites electrons which move through an electron transport chain and help produce ATP and NADPH. These energy-rich molecules are later used in the Calvin cycle to synthesize glucose. Therefore, photosynthetic pigments play a crucial role in capturing sunlight and converting it into chemical energy during photosynthesis.

🌟 **Q2: How are the absorption spectra of chlorophyll 'a' and chlorophyll 'b' different?**

❖ **Introduction:**

The absorption spectrum is a graph that shows the amount of light absorbed by a pigment at different wavelengths. Chlorophyll a and chlorophyll b are the main photosynthetic pigments in plants, but they absorb light at slightly different wavelengths. This difference helps plants absorb a wider range of sunlight for photosynthesis.

Absorption Spectrum of Chlorophyll-a

Chlorophyll-a is the primary photosynthetic pigment and directly participates in converting light energy into chemical energy.

Main characteristics:

- It absorbs blue-violet light strongly around 430 nm.
- It also absorbs red light strongly around 670 nm.

- It reflects green light, which is why plants appear green.

Thus, chlorophyll-a mainly absorbs blue and red wavelengths of light.

Absorption Spectrum of Chlorophyll-b

Chlorophyll-b is an accessory pigment. It does not directly participate in the primary reactions but helps chlorophyll-a by capturing additional light energy.

Main characteristics:

- It absorbs blue light around 453 nm.
- It absorbs red light around 642 nm.
- It transfers the absorbed energy to chlorophyll-a.

Because its absorption peaks are slightly different, chlorophyll-b allows plants to use more wavelengths of light.

Key Differences Between Chlorophyll-a and Chlorophyll-b

Absorption Peaks

- Chlorophyll-a absorbs light mainly at 430 nm (blue) and 670 nm (red).
- Chlorophyll-b absorbs light mainly at 453 nm (blue) and 642 nm (red).

Function

- Chlorophyll-a is the primary pigment in photosynthesis.
- Chlorophyll-b acts as an accessory pigment and transfers energy to chlorophyll-a.

Light Utilization

- Chlorophyll-a absorbs specific wavelengths.
- Chlorophyll-b helps plants absorb additional wavelengths of light, increasing photosynthesis efficiency.

Diagram:

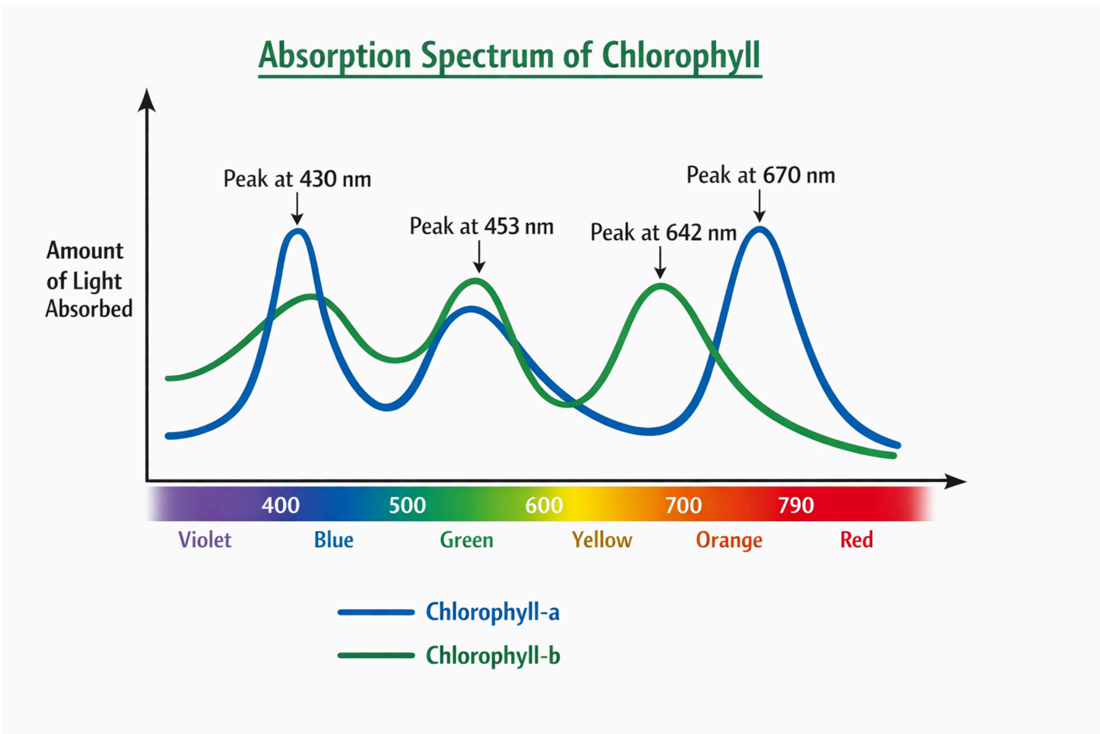


Diagram Description:

X-Axis: Wavelength of light (nm)

Y-Axis: Amount of light absorbed

Two curves appear in the graph:

- **Chlorophyll-a curve:** peaks at 430 nm and 670 nm
- **Chlorophyll-b curve:** peaks at 453 nm and 642 nm

✦ **Summary:**

Chlorophyll-a and chlorophyll-b have different absorption spectra because they absorb light at different wavelengths. Chlorophyll-a absorbs light mainly at 430 nm and 670 nm, while chlorophyll-b absorbs light at 453 nm and 642 nm. Chlorophyll-a is the primary pigment involved in photosynthesis, whereas chlorophyll-b acts as an accessory pigment that captures additional light energy and transfers it to chlorophyll-a. This difference allows plants to utilize a wider range of sunlight for efficient photosynthesis.

🌟 **Q3: Describe and illustrate how photosynthetic pigments are organized in thylakoid membrane?**

❖ **Introduction:**

Photosynthetic pigments such as chlorophyll-a, chlorophyll-b and carotenoids are not scattered randomly inside the chloroplast. Instead, they are organized into special clusters called photosystems. These photosystems are located in the thylakoid membranes of chloroplasts and help plants absorb and convert light energy efficiently during photosynthesis.

✦ Organization of Photosynthetic Pigments

Photosynthetic pigments are arranged in groups known as photosystems. Each photosystem contains hundreds of pigment molecules working together to capture light energy.

A photosystem has two main parts:

1. Antenna Complex (Light-Harvesting Complex)

The antenna complex contains many pigment molecules such as:

- Chlorophyll-a
- Chlorophyll-b
- Carotenoids

These pigments absorb light energy from the sun. The absorbed energy is then passed from one pigment molecule to another until it reaches the reaction centre.

This process increases the efficiency of light absorption because many pigments collect light simultaneously.

2. Reaction Centre

The reaction centre is the central part of the photosystem. It contains a special molecule of chlorophyll-a.

When the light energy reaches the reaction centre:

1. The chlorophyll molecule becomes excited.
2. It releases high-energy electrons.
3. These electrons are transferred to a primary electron acceptor.
4. The electrons then move through the electron transport chain, leading to the production of ATP and NADPH.

Types of Photosystems

There are two types of photosystems present in the thylakoid membrane.

Photosystem II (PS-II)

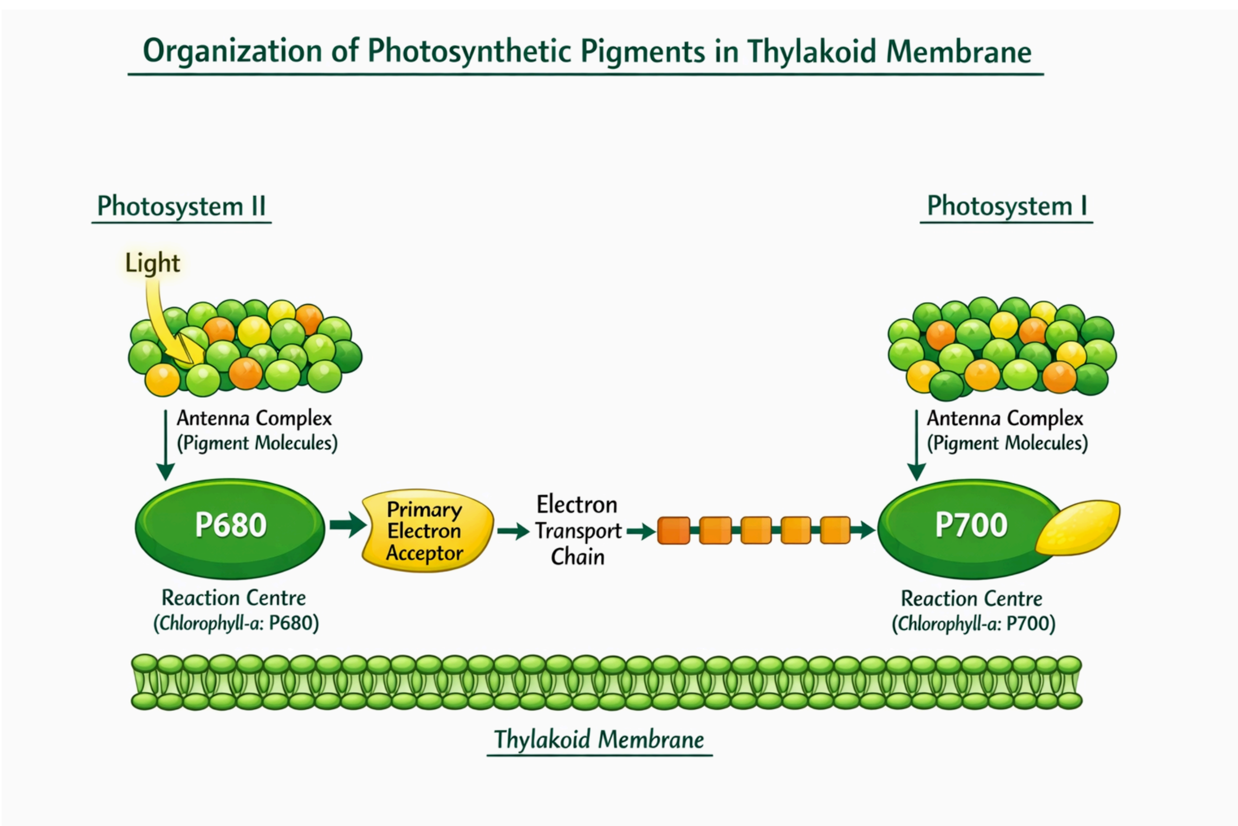
- Reaction centre contains P680 chlorophyll-a.
- Absorbs light best at 680 nm.
- It starts the electron transport chain.
- It is also responsible for photolysis of water, releasing oxygen.

Photosystem I (PS-I)

- Reaction centre contains P700 chlorophyll-a.
- Absorbs light best at 700 nm.
- It helps in the formation of NADPH.

Both photosystems work together in the light-dependent reactions of photosynthesis.

Diagram:



✦ Summary:

Photosynthetic pigments are organized into clusters called photosystems in the thylakoid membranes of chloroplasts. Each photosystem consists of an antenna complex that captures light energy and a reaction centre containing chlorophyll-a that releases high-energy electrons. There are two types of photosystems, PS-II and PS-I, which work together in the light-dependent reactions of photosynthesis to produce ATP and NADPH.

🌟 Q4: Describe how the role of water in photosynthesis can be explained through experiment

❖ Introduction:

Water plays a critical role in photosynthesis. It provides hydrogen ions required for reducing carbon dioxide to sugar and is also the source of oxygen released during photosynthesis. The experimental proof of water's role was established in the 1930s–1940s through studies using isotopic tracers.

Role of Water in Photosynthesis

1. Source of Hydrogen:

- Hydrogen from water is used to reduce CO_2 into glucose during the Calvin cycle.

2. Source of Oxygen:

- Oxygen released during photosynthesis comes from the splitting of water ($H_2O \longrightarrow 2H^+ + \frac{1}{2}O_2 + 2e^-$), not from carbon dioxide.

Experiment to Prove Water as the Oxygen Source

The experiment was designed to trace the source of oxygen in photosynthesis using heavy oxygen isotope (^{18}O).

Step 1: Experimental Groups

- **Group 1:** Plants supplied with water containing heavy oxygen ($H_2{}^{18}O$) and normal CO_2.
- **Group 2:** Plants supplied with normal water ($H_2{}^{16}O$) and heavy oxygen CO_2 ($C^{18}O_2$).

Step 2: Photosynthesis

- Both groups of plants were exposed to light to allow photosynthesis.

Step 3: Collection and Analysis

- Oxygen released during photosynthesis was collected from both groups and tested for isotopes.

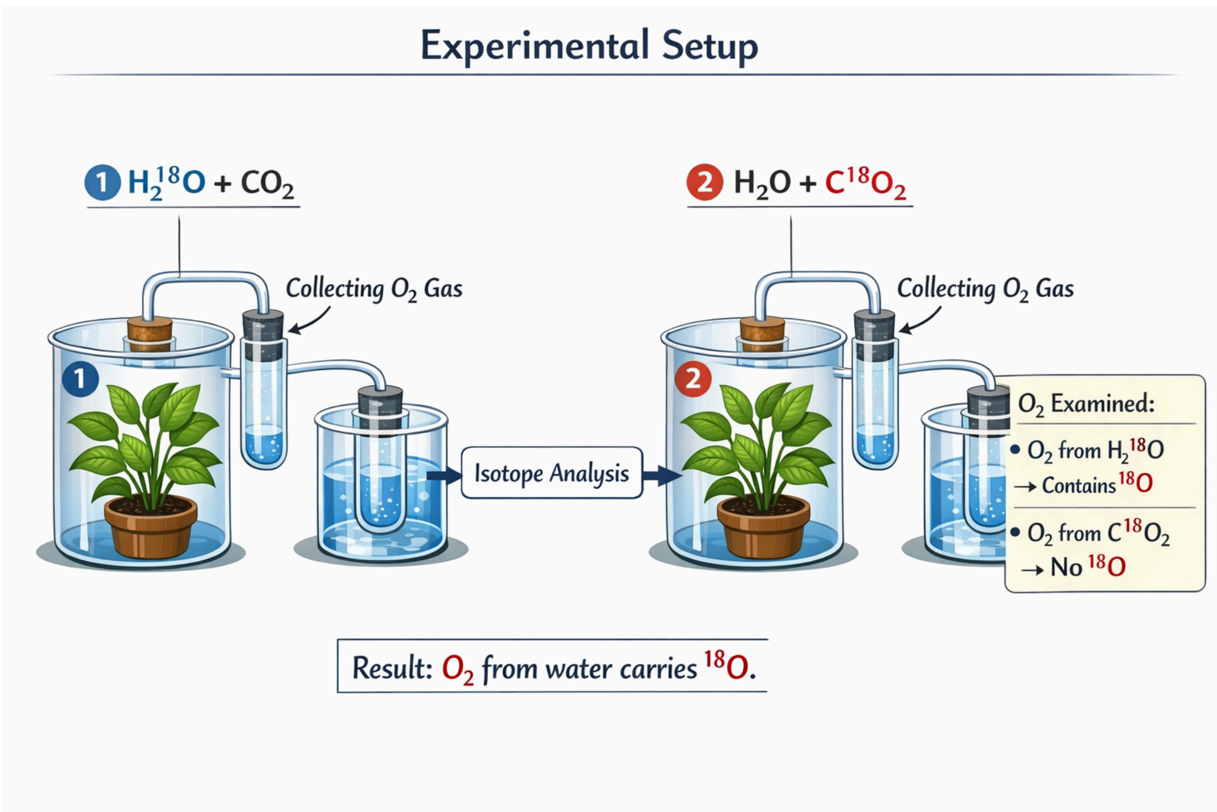
Step 4: Observations

- **Group 1 ($H_2{}^{18}O$ + normal CO_2):** Oxygen released contained ^{18}O, proving oxygen comes from water.
- **Group 2 (normal H_2O + $C^{18}O_2$):** Oxygen released was normal ^{16}O, showing CO_2 is not the source of released O_2.

✦ **Conclusion:**

- Water is split during photosynthesis to provide electrons and hydrogen ions for reducing CO_2 and oxygen is released as a by-product.
- This was experimentally confirmed using isotopic tracing with ^{18}O.

Diagram:



✦ **Summary:**

Water is essential in photosynthesis as the donor of electrons and hydrogen ions for the reduction of CO_2, and as the source of oxygen released. Isotopic tracer experiments using $H_2^{18}O$ demonstrated that the oxygen evolved during photosynthesis comes from water, not from carbon dioxide.

🌟 **Q5: What are the events that capture light and convert it into chemical energy during light-dependent reactions?**

❖ **Answer:**

The light-dependent reactions of photosynthesis occur in the thylakoid membranes of chloroplasts. These reactions convert light energy into chemical energy in the form of ATP and NADPH. The main events are as follows:

1. Absorption of light by Photosystem II (PS-II):

Light energy is absorbed by chlorophyll and accessory pigments in PS-II. This energy excites electrons to a higher energy level.

2. Photolysis of water:

The excited electrons from PS-II leave the chlorophyll molecule, creating an "electron hole." These electrons are replaced by electrons obtained from water molecules. Water is split (photolysis) into hydrogen ions, electrons, and oxygen:

Equation:

$2\ H2O \longrightarrow 4\ H^{+} + 4\ e^{-} + O2$

The oxygen is released as a by-product, and the hydrogen ions contribute to the proton gradient in the thylakoid lumen.

3. Electron transport chain (ETC):

Excited electrons pass from PS-II to PS-I through an electron transport chain composed of plastoquinone (PQ), cytochrome complex, and plastocyanin (PC). During this transport, energy from electrons is used to pump H^+ ions into the thylakoid lumen, creating a proton gradient.

4. Absorption of light by Photosystem I (PS-I):

PS-I absorbs light energy, which excites its electrons. These electrons replace those lost by PS-I, which were replaced by electrons from PS-II via the electron transport chain.

5. Formation of NADPH:

Excited electrons from PS-I are transferred to the primary electron acceptor and then to ferredoxin (Fd). The enzyme $NADP^+$ reductase transfers these electrons to $NADP^+$ along with a hydrogen ion, forming NADPH:

Equation:

$NADP^+ + H^+ + 2\,e^- \longrightarrow NADPH$

6. Synthesis of ATP (Photophosphorylation):

The H^+ ions accumulated in the thylakoid lumen flow back into the stroma through ATP synthase. The flow of H^+ ions provides energy to convert ADP and inorganic phosphate (Pi) into ATP:

Equation:

$ADP + Pi \longrightarrow ATP$

✦ **Summary:**

- Light energy is absorbed by PS-II and PS-I.
- Water is split, providing electrons, H^+ ions, and O_2.
- Electron transport chain pumps H^+ into thylakoid lumen.
- ATP is produced via photophosphorylation.
- NADPH is formed by reduction of $NADP^+$.
- Chemical energy (ATP and NADPH) is used in the light-independent reactions (Calvin cycle).

🌟 **Q6: Illustrate the cyclic photophosphorylation**

❖ **Answer:**

Cyclic photophosphorylation is a type of light-dependent reaction in which electrons follow a circular path and only ATP is produced, without the formation of NADPH or the release of oxygen. It occurs in the thylakoid membrane and involves Photosystem I (PS-I) only.

✦ **Steps of Cyclic Photophosphorylation:**

1. Absorption of light by PS-I:

Light energy excites electrons in the chlorophyll-a molecule (P700) of PS-I to a higher energy level.

2. Electron transfer:

The excited electrons are passed to the primary electron acceptor of PS-I.

3. Electron transport chain (ETC):

Electrons then move through a series of carriers in a cyclic manner, including ferredoxin (Fd), plastoquinone (PQ), and cytochrome complex.

4. Proton gradient formation:

As electrons pass through the electron transport chain, energy is used to pump H^+ ions from the stroma into the thylakoid lumen, creating a proton gradient.

5. ATP synthesis:

H^+ ions flow back into the stroma through ATP synthase, which drives the conversion of ADP and Pi into ATP.

Equation:

$ADP + Pi \longrightarrow ATP$

6. Electron returns to PS-I:

The electrons complete the cycle by returning to P700 chlorophyll, ready to be re-excited by light.

Key Features:

- Only ATP is produced.
- No NADPH is generated.
- No oxygen is released.
- Provides additional ATP needed for the Calvin cycle.

✦ **Summary:**

- Cyclic photophosphorylation is a cyclic flow of electrons in PS-I.
- It generates ATP but not NADPH or O_2.
- Helps maintain the ATP/NADPH balance for the Calvin cycle.

🌟 Q7: Describe light-independent reactions of photosynthesis and illustrate Calvin cycle

❖ **Answer:**

Light-independent reactions, also called dark reactions or the Calvin cycle, occur in the stroma of chloroplasts. These reactions do not require light directly but depend on the ATP and NADPH produced during light-dependent reactions. The main purpose of the Calvin cycle is to fix carbon dioxide (CO_2) into energy-rich organic molecules like glucose.

The cycle is divided into three main phases:

1. Carbon Fixation:

CO_2 molecules enter the chloroplast and are attached to a five-carbon sugar called ribulose-1,5-bisphosphate (RuBP) by the enzyme Rubisco. This produces an unstable six-carbon compound, which immediately splits into two molecules of 3-phosphoglyceric acid (3-PGA).

2. Reduction:

Each 3-PGA molecule is phosphorylated using ATP and reduced using NADPH to form glyceraldehyde-3-phosphate (G3P), a three-carbon sugar. Out of the six G3P molecules produced, one molecule leaves the cycle to contribute to the formation of glucose and other carbohydrates.

3. Regeneration of RuBP:

The remaining five G3P molecules are rearranged using ATP to regenerate three molecules of RuBP, allowing the cycle to continue.

Key points:

- ATP provides energy, while NADPH provides reducing power.
- The Calvin cycle is the primary carbon-fixing process in plants.
- Glucose formation requires two turns of the cycle to combine two G3P molecules.

✦ Summary:

- Light-independent reactions convert CO_2 into glucose using energy from ATP and electrons from NADPH.
- The cycle consists of carbon fixation, reduction, and RuBP regeneration.
- Calvin cycle maintains a continuous supply of RuBP for ongoing CO_2 fixation.

🌟 Q8: What happens with glucose in anaerobic respiration and how different organisms modify the end products?

❖ Answer:

Anaerobic respiration is the process by which cells break down glucose in the absence of oxygen to release energy. Unlike aerobic respiration, which fully oxidizes glucose into CO_2 and H_2O, anaerobic respiration only partially oxidizes glucose, yielding a small amount of energy (about 2 ATP molecules per glucose).

The first step in anaerobic respiration is glycolysis, which occurs in the cytoplasm. During glycolysis, one glucose molecule ($C_6H_{12}O_6$) is split into two molecules of pyruvic acid ($C_3H_4O_3$). In the absence of oxygen, pyruvic acid cannot enter the Krebs cycle and is instead converted into other end products depending on the type of organism:

1. Lactic Acid Fermentation:

- Occurs in muscle cells of animals and some bacteria.
- Pyruvic acid is reduced by NADH to form lactic acid ($C_3H_6O_3$).
- This process regenerates NAD^+, allowing glycolysis to continue.
- Example: Human muscles during intense exercise.

2. Alcoholic Fermentation:

- Occurs in yeast and some plant cells.
- Pyruvic acid is first converted to acetaldehyde, which is then reduced by NADH to produce ethanol (C_2H_5OH) and carbon dioxide (CO_2).
- NAD^+ is regenerated for glycolysis to continue.
- Example: Yeast in brewing and baking industries.

Key Points:

- Anaerobic respiration yields very low energy compared to aerobic respiration (2 ATP vs 36–38 ATP).
- The end product varies depending on the organism: lactic acid in animals, ethanol and CO_2 in yeast and some plants.
- It allows cells to survive temporarily when oxygen is not available.

✦ **Summary:**

Glucose ⟶ Glycolysis ⟶ Pyruvic acid

Without oxygen:

- Animals ⟶ Lactic acid
- Yeast/Plants ⟶ Ethanol + CO_2

Energy yield: Low (2 ATP per glucose)

Purpose: Regenerates NAD^+ to keep glycolysis running.

🌟 **Q9: How is glucose broken down to pyruvic acid in glycolysis?**

❖ **Answer:**

Glycolysis is the first step of cellular respiration and occurs in the cytoplasm of all living cells. It does not require oxygen, so it is an anaerobic process. Its main function is to break down one glucose molecule ($C_6H_{12}O_6$) into two molecules of pyruvic acid ($C_3H_4O_3$), releasing energy in the form of ATP and NADH.

1. Preparatory Phase (Energy Investment Phase)

Purpose: Activate glucose so it can be split into two molecules.

Key Events:

- Glucose ⟶ Glucose-6-phosphate (G6P): A phosphate from ATP is added to glucose. This makes glucose more reactive.
- G6P ⟶ Fructose-6-phosphate (F6P): Rearrangement of G6P into its isomer.

- F6P ⟶ Fructose-1,6-bisphosphate (F1,6BP): Another phosphate from ATP is added.
- F1,6BP ⟶ G3P + Dihydroxyacetone phosphate (DAP): The 6-carbon sugar is split into two 3-carbon molecules. DAP is converted to Glyceraldehyde-3-phosphate (G3P).

Energy Used: 2 ATP molecules per glucose are consumed.

2. Oxidative Phase (Energy Payoff Phase)

Purpose: Extract energy from G3P in the form of ATP and NADH.

Key Events:

- G3P ⟶ 1,3-Bisphosphoglycerate (1,3-BPGA): Hydrogen atoms are removed from G3P and transferred to NAD^+ ⟶ NADH.
- 1,3-BPGA ⟶ 3-Phosphoglycerate (3-PGA): One phosphate group is transferred to ADP → ATP (substrate-level phosphorylation).
- 3-PGA ⟶ 2-Phosphoglycerate (2-PGA): Rearrangement occurs.
- 2-PGA ⟶ Phosphoenolpyruvate (PEP): Water is removed to form high-energy PEP.
- PEP ⟶ Pyruvic Acid: Another phosphate is transferred to ADP ⟶ ATP (substrate-level phosphorylation).

Energy Produced: 4 ATP molecules and 2 NADH molecules.

Net Gain: 2 ATP (4 formed – 2 used) and 2 NADH.

Overall Glycolysis Reaction

Glucose + 2 NAD^+ + 2 ADP + 2 Pi ⟶ 2 Pyruvic acid + 2 NADH + 2 ATP + 2 H_2O

Key Points to Remember:

1. Glycolysis occurs in cytoplasm, not mitochondria.
2. Oxygen is not required, so it occurs in anaerobic conditions.
3. Glucose (6C) is split into 2 pyruvate molecules (3C each).
4. Produces ATP by substrate-level phosphorylation.
5. Produces NADH for further energy extraction in aerobic respiration.
6. Prepares pyruvate for either Krebs cycle (aerobic) or fermentation (anaerobic).

🌟 **Q 10: Describe how Krebs cycle is the completion of the oxidation of glycolytic products.**

❖ **Answer:**

The Krebs cycle (also called citric acid cycle) is the central metabolic pathway in aerobic respiration that completes the oxidation of pyruvic acid (the product of glycolysis) to CO_2 and captures the released energy in the form of ATP, NADH, and $FADH_2$. It occurs in the mitochondrial matrix.

✦ **Explanation:**

1. Preparation of Pyruvic Acid

- Pyruvic acid (3C) from glycolysis cannot enter the Krebs cycle directly.
- First, it is converted into acetyl-CoA (2C):
  - **Decarboxylation:** One CO_2 is removed from pyruvic acid ⟶ 2-carbon acetyl group.

- **Oxidation:** Hydrogen is removed and transferred to $NAD^+ \longrightarrow$ NADH.
- **Attachment to Coenzyme A:** Forms acetyl-CoA, ready to enter Krebs cycle.

2. Entry of Acetyl-CoA into Krebs Cycle

- Acetyl-CoA (2C) combines with oxaloacetate (4C) to form citric acid (6C).
- This marks the beginning of a cyclic process where the 6C compound is gradually oxidized.

3. Oxidation and Energy Capture

The Krebs cycle involves a series of enzyme-catalyzed reactions, resulting in:

1. **Decarboxylation:** Two CO_2 molecules are released per acetyl-CoA.
2. **Oxidation:** Hydrogens are removed and transferred to $NAD^+ \longrightarrow$ NADH and FAD $\longrightarrow$ $FADH_2$.
3. **ATP formation:** One molecule of ATP (or GTP) is produced by substrate-level phosphorylation.

The oxidation of acetyl-CoA releases all the energy stored in the C-H bonds of the original glucose molecule.

Products per acetyl-CoA: 3 NADH, 1 $FADH_2$, 1 ATP, 2 CO_2.

4. Regeneration of Oxaloacetate

- The 4C compound (oxaloacetate) is regenerated at the end of the cycle.
- This allows the cycle to accept another acetyl-CoA and continue.

5. Significance of Krebs Cycle in Completing Glycolysis Oxidation

- Glycolysis produces 2 pyruvate molecules per glucose, each converted to acetyl-CoA.
- Therefore, the Krebs cycle fully oxidizes the carbons of glycolytic products into CO_2.
- Most of the energy released is captured in high-energy electrons of NADH and $FADH_2$, which are later used in electron transport chain to produce a large amount of ATP.
- **Together with glycolysis,** the Krebs cycle ensures complete energy extraction from glucose in aerobic respiration.

✦ **Summary:**

1. Krebs cycle completes the oxidation of glucose-derived pyruvate.
2. Produces CO_2, NADH, $FADH_2$, and ATP.
3. Occurs in mitochondrial matrix.
4. Regenerates oxaloacetate for continuous cycle.
5. Captures energy for electron transport chain, where most ATP is synthesized.

🌟 **Q11: Explain the passage of electrons through the electron transport chain (ETC).**

❖ **Answer:**

The electron transport chain (ETC) is the final stage of aerobic respiration, located in the inner mitochondrial membrane. Its primary role is to transfer high-energy electrons from NADH and $FADH_2$ to molecular oxygen (O_2) while generating ATP through chemiosmosis.

✦ Explanation of Electron Flow:

1. Entry of Electrons

- Electrons from NADH (produced in glycolysis, pyruvate oxidation, and Krebs cycle) are donated to Coenzyme Q (CoQ).
- Electrons from $FADH_2$ (produced in Krebs cycle) also enter CoQ, but they bypass the first complex and yield less ATP compared to NADH.

2. Electron Transport Through Complexes

- CoQ (Ubiquinone) transports electrons to Cytochrome b-c1 complex.
- Electrons are then passed to Cytochrome c, a small mobile carrier protein.
- Cytochrome c transfers electrons to Cytochrome a-a3 complex (also called cytochrome oxidase complex).

3. Reduction of Oxygen

At the end of the chain, electrons combine with oxygen (O_2) and protons (H^+) from the mitochondrial matrix to form water (H_2O):

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

4. Chemiosmosis and ATP Synthesis

- As electrons flow through the ETC, energy is released.
- This energy actively pumps H^+ ions from the matrix into the intermembrane space, creating a proton gradient (electrochemical gradient).

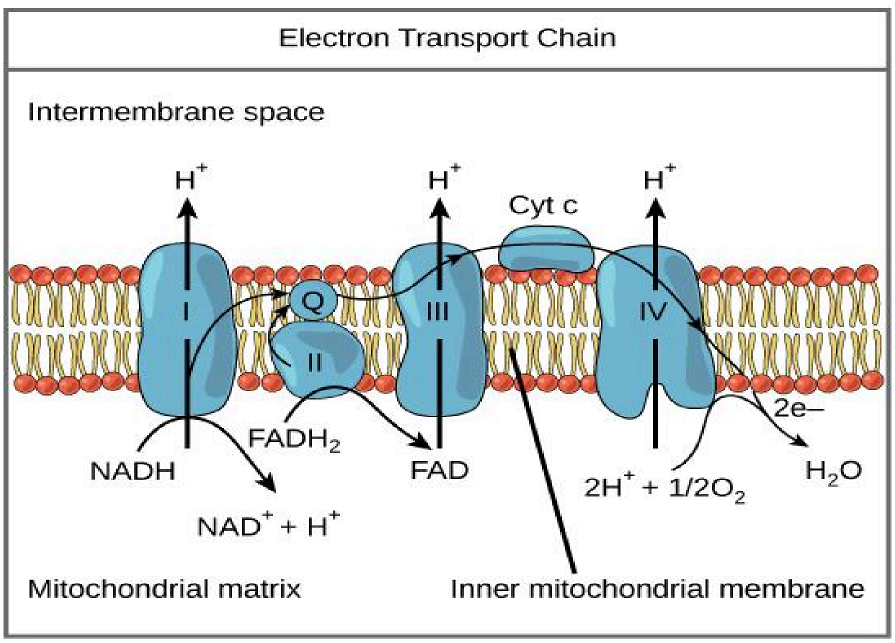
- H^+ ions then diffuse back into the matrix through ATP synthase, driving the synthesis of ATP from ADP and Pi.
- This process is called oxidative phosphorylation.

5. ATP Yield

- Oxidation of 1 NADH ⟶ 3 ATP (approximately).
- Oxidation of 1 $FADH_2$ ⟶ 2 ATP (less energy because it enters ETC at a lower energy point).

Overall, ETC coupled with chemiosmosis produces the majority of ATP in aerobic respiration.

Diagram:



✦ **Summary:**

- ETC transfers electrons from NADH and $FADH_2$ to O_2 via CoQ and cytochromes.
- Energy released during electron flow pumps H^+ ions across the inner membrane.
- Proton gradient drives ATP synthesis via ATP synthase (chemiosmosis).

- Oxygen is the final electron acceptor, forming water.
- ETC is critical for efficient ATP production in aerobic respiration.

🌟 12. Define Chemiosmosis. How is it related to Electron Transport Chain (ETC)?

❖ Definition of Chemiosmosis:

Chemiosmosis is the process by which energy from the transfer of electrons through the electron transport chain (ETC) is used to pump hydrogen ions (H^+) across a membrane, creating a proton gradient. This potential energy is then used by ATP synthase to combine ADP and inorganic phosphate (Pi) to form ATP, the main energy currency of the cell.

✦ Relationship with Electron Transport Chain:

1. Electron Transfer:

- Electrons are released from NADH and FADH2 (produced during glycolysis, pyruvate oxidation, and Krebs cycle).
- These electrons pass through a series of electron carriers in the inner mitochondrial membrane (Coenzyme Q, cytochromes b, c, a).

2. Energy Release and H^+ Pumping:

- As electrons move from one carrier to the next, energy is released.
- This energy is used to actively pump H^+ ions from the mitochondrial matrix into the intermembrane space, creating a high concentration of H^+ ions (proton gradient).

3. Formation of ATP:

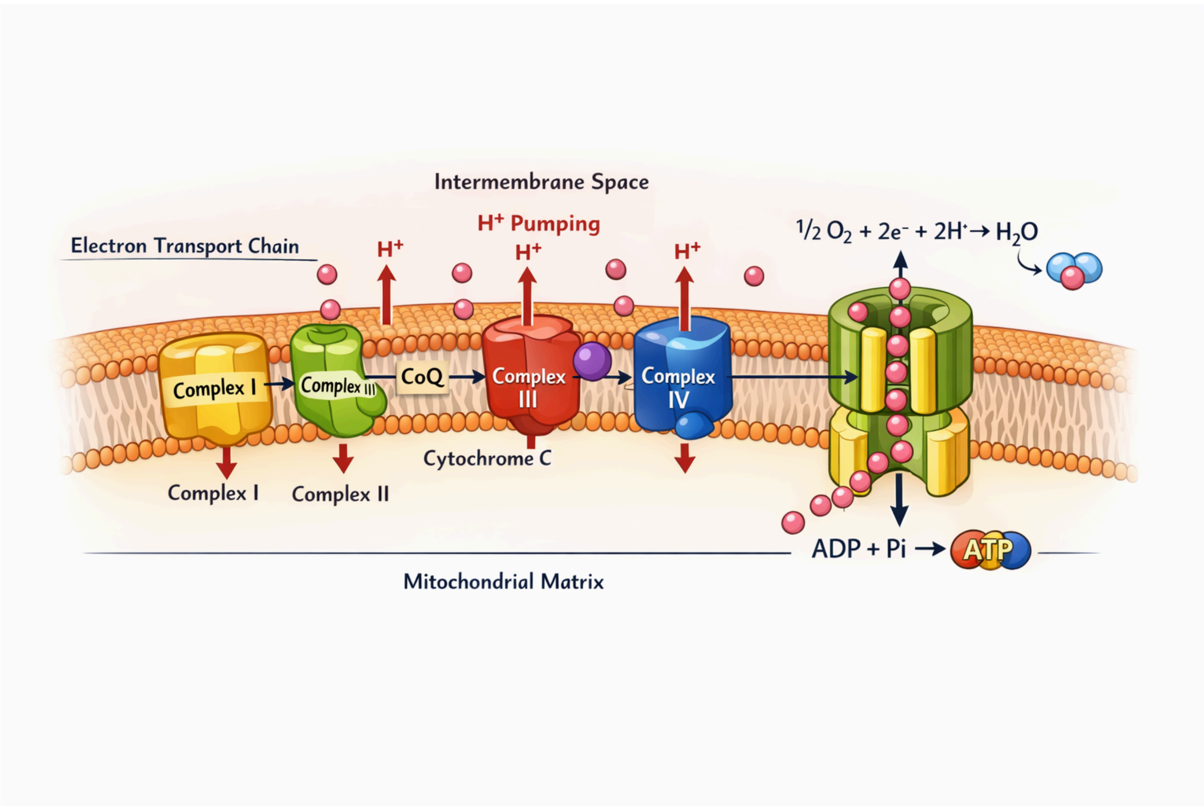
- H^+ ions flow back into the matrix through ATP synthase (a protein channel).
- The flow of H^+ ions provides the energy needed to convert:
- ADP + Pi + energy (from H^+ gradient) ⟶ ATP

4. Final Electron Acceptor:

Oxygen at the end of the ETC accepts electrons and combines with H^+ ions to form water:

O2 + $4e^-$ + $4H^+$ ⟶ 2H2O

Diagram:



Key Points:

- Chemiosmosis links the electron transport chain to ATP production.
- The proton gradient (H^+ ions) acts as a store of potential energy, which drives ATP synthesis.
- ATP produced by chemiosmosis is the main energy output of cellular respiration.

🌟 **Q13: Through which ways proteins and fats enter cellular respiration?**

❖ **Answer:**

Proteins as Energy Source

Proteins are not primarily used as energy sources, but under conditions when glucose is limited, they can enter cellular respiration. Proteins are first digested into amino acids. These amino acids undergo deamination, a process in which the amino group ($-NH_2$) is removed. The remaining carbon skeleton is then converted into molecules compatible with cellular respiration. Some amino acids are converted into pyruvic acid, which enters glycolysis, while others are converted into acetyl-CoA or intermediates of the Krebs cycle, depending on their structure. Once converted, these intermediates follow the normal respiration pathway, producing ATP through the Krebs cycle and electron transport chain.

Fats as Energy Source

Fats provide a rich source of energy because they contain many carbon-hydrogen (C-H) bonds. Fats are first broken down into glycerol and fatty acids. Glycerol is converted into glyceraldehyde-3-phosphate (G3P), which enters glycolysis, eventually forming pyruvic acid and acetyl-CoA, and then enters the Krebs cycle. Fatty acids undergo β-oxidation, which splits them into two-carbon acetyl groups. These acetyl groups combine with Coenzyme-A to form acetyl-CoA, which directly enters the Krebs cycle. The complete oxidation of fats generates significantly more ATP than glucose due to their high energy content.

Integration into Cellular Respiration

Both proteins and fats are thus converted into intermediates that seamlessly enter glycolysis or the Krebs cycle, ensuring that energy stored in their chemical bonds is captured. Once in the Krebs cycle, the electrons released from these molecules are transferred to NAD^+ and FAD, producing NADH and $FADH_2$, which ultimately drive ATP synthesis in the electron transport chain.

🌟 Q14: Define Photorespiration and Explain How It Proves "Photosynthesis is Not Perfect"

❖ **Answer:**

Definition of Photorespiration

Photorespiration is a respiratory process that occurs in green plants in the presence of light, where oxygen is consumed, and carbon dioxide is released. Unlike normal photosynthesis, ATP is not produced during this process. It is also called light-dependent respiration, and it occurs when the enzyme RuBP carboxylase/oxygenase (rubisco) uses O_2 instead of CO_2 as a substrate.

✦ Mechanism of Photorespiration

1. In normal photosynthesis, rubisco adds CO_2 to ribulose bisphosphate (RuBP) to form two molecules of 3-phosphoglycerate (3-PGA), which are then used to produce glucose.

2. During photorespiration, when O_2 concentration is higher and CO_2 is lower in the leaf cells, rubisco binds O_2 to RuBP instead of CO_2.

3. This leads to the formation of one molecule of 3-PGA (usable in Calvin cycle) and one molecule of phosphoglycolate (a 2-carbon compound).

4. Phosphoglycolate is metabolized through peroxisomes and mitochondria to form glycolate, glycine, serine, and eventually glycerate, which re-enters the Calvin cycle.

5. During these reactions, CO_2 is released, hydrogen peroxide (H_2O_2) is formed, and no ATP is generated, making the process wasteful for the plant.

Why Photorespiration Shows That Photosynthesis is Not Perfect

- **Loss of fixed carbon:** Plants that use the Calvin cycle (C-3 plants) can lose 25–50% of their fixed carbon due to photorespiration.

- **Energy wastage:** The process consumes energy without producing ATP or sugars, reducing the efficiency of photosynthesis.
- **Temperature sensitivity:** At higher temperatures, the oxygenation activity of rubisco increases, making photorespiration more frequent, especially in tropical climates.
- **Evolutionary consequence:** When photosynthesis first evolved, there was very little oxygen in the atmosphere, so photorespiration was negligible. Today, oxygen levels are high, leading to competition between O_2 and CO_2 at rubisco's active site.

Thus, photorespiration proves that photosynthesis is not a perfect process, as it reduces carbon fixation efficiency and wastes energy.

🌟 **Q15: What are the effects of temperature on the oxidative activity of Rubisco?**

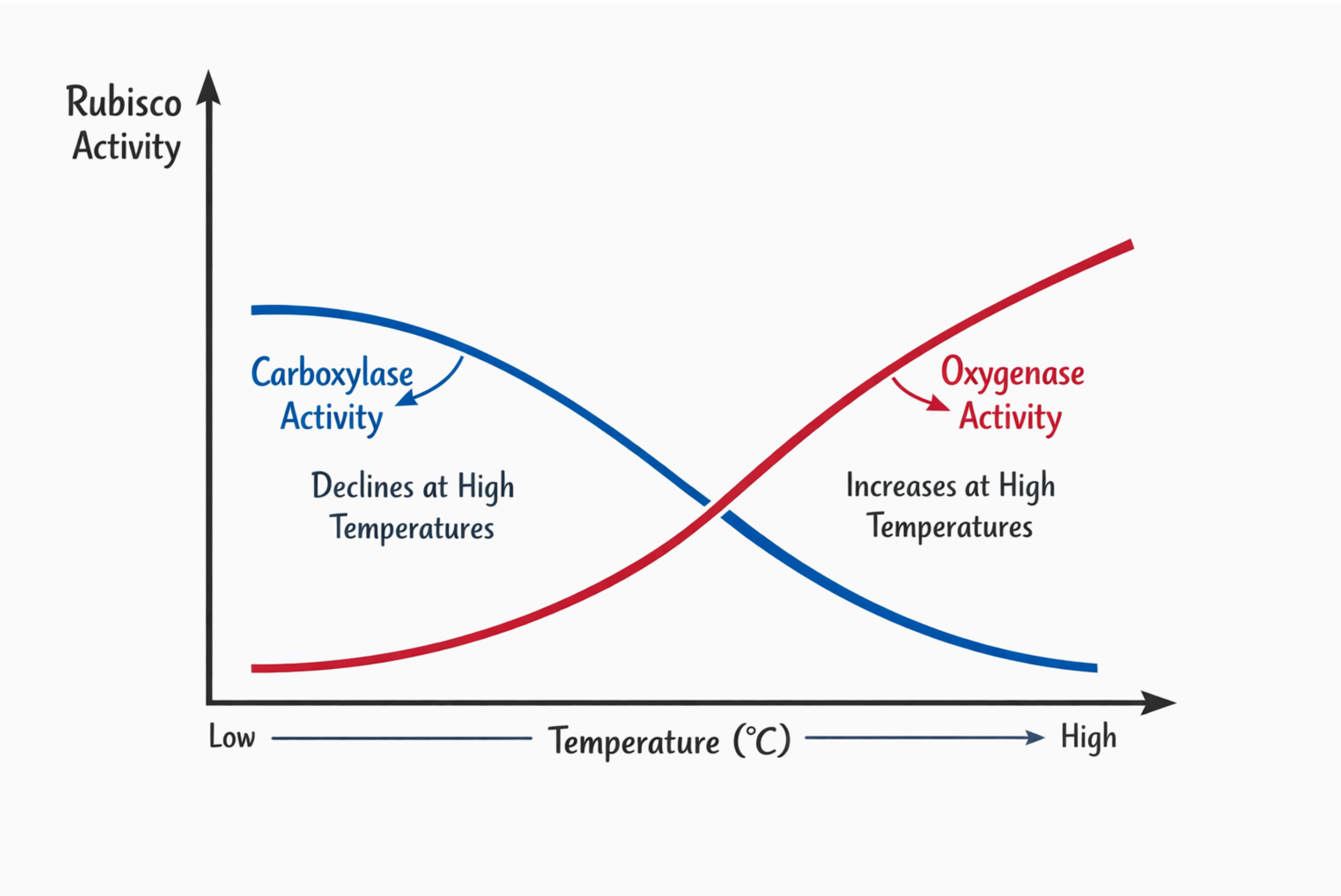
❖ **Answer:**

Rubisco is the enzyme responsible for fixing CO_2 in the Calvin cycle, but it also has an oxygenase activity that causes photorespiration.

- **Low temperature (<25 °C):** Rubisco mainly acts as a carboxylase. CO_2 fixation is efficient, and photorespiration is minimal.
- **Moderate temperature (25–30 °C):** Carboxylase activity is still dominant, but oxygenase activity slightly increases, causing minor photorespiration.
- **High temperature (>30 °C):** Oxygenase activity of Rubisco increases. More O_2 competes with CO_2, increasing photorespiration. This reduces sugar production, wastes ATP, and lowers photosynthetic efficiency.

Conclusion: High temperatures increase the oxidative activity of Rubisco, making photosynthesis less efficient, especially in C-3 plants.

Diagram:



🌟 **Q16: How is the process of C4 photosynthesis an adaptation to deal with the problem of photorespiration?**

❖ **Answer:**

C4 photosynthesis is a special pathway used by certain plants (like corn, sugarcane, and sorghum) to reduce the losses caused by photorespiration, especially in hot climates.

✦ **Mechanism and Adaptation:**

1. CO_2 Capture in Mesophyll Cells:

- In C4 plants, CO_2 is first captured by a 3-carbon molecule called phosphoenol pyruvate (PEP) in the mesophyll cells.
- This forms a 4-carbon compound called oxaloacetic acid, which is then converted to malic acid using NADPH.

2. Transport to Bundle-Sheath Cells:

- Malic acid is transported to bundle-sheath cells, which have fewer air spaces and are less permeable to O_2.
- Here, malic acid is broken down to release CO_2, increasing its concentration around Rubisco.

3. Calvin Cycle Operation:

- High CO_2 concentration in bundle-sheath cells ensures Rubisco acts mainly as a carboxylase, not as an oxygenase.
- This minimizes photorespiration, allowing efficient sugar production even at high temperatures.

4. Regeneration of PEP:

- The remaining 3-carbon compound (pyruvic acid) returns to mesophyll cells.
- ATP is used to convert it back into PEP, completing the C4 cycle.

Importance of Adaptation:

- By concentrating CO_2 near Rubisco, C4 plants avoid losses due to photorespiration, which can waste 25–50% of fixed carbon in C3 plants.
- This adaptation is especially important in tropical climates with high temperature and light intensity.

INQUISITIVE QUESTIONS

🌟 **Q1: Why does cellular respiration release energy more efficiently than fermentation?**

❖ **Answer:**

Cellular respiration releases energy more efficiently than fermentation due to the complete oxidation of glucose in the presence of oxygen, compared to the partial breakdown of glucose during fermentation.

✦ **Explanation:**

1. Complete vs Partial Oxidation:

- In cellular respiration, glucose is completely broken down into CO_2 and H_2O.
- In fermentation, glucose is only partially oxidized to products like lactic acid or ethanol + CO_2.

2. Energy Yield (ATP Production):

- Aerobic respiration produces 36–38 ATP molecules per glucose, extracting almost all the energy stored in the C-H bonds.
- Fermentation produces only 2 ATP per glucose, which is less than 5% of the total energy in glucose.

3. Use of Electron Transport Chain (ETC) and Chemiosmosis:

- In cellular respiration, electrons from NADH and $FADH_2$ are passed through the electron transport chain, creating a proton gradient that drives ATP synthesis via chemiosmosis.

- Fermentation does not involve ETC, so most energy remains in the partially oxidized end products.

4. Efficiency of Energy Conversion:

- Cellular respiration is therefore 18–19 times more efficient than fermentation in extracting usable chemical energy from glucose.

✦ **Summary:**

- Cellular respiration = complete oxidation ⟶ high ATP yield ⟶ efficient energy use.
- Fermentation = partial oxidation ⟶ low ATP yield ⟶ energy mostly remains in end products.

🌟 **Q2: Why is the conversion of glucose into ATP during cellular respiration considered a more efficient use of energy than burning glucose directly?**

❖ **Answer:**

The conversion of glucose into ATP during cellular respiration is more efficient than burning glucose directly because cells extract energy gradually and in a controlled manner rather than losing most of it as heat.

✦ **Explanation:**

1. Stepwise Energy Release:

- In cellular respiration, glucose is broken down in multiple steps: glycolysis ⟶ pyruvate oxidation ⟶ Krebs cycle ⟶ electron transport chain & chemiosmosis.

- Each step releases small amounts of energy, which can be captured in ATP molecules.
- If glucose were burned directly, most energy would be released suddenly as heat, which cannot be used by cells for work.

2. ATP as an Energy Currency:

- The energy captured in ATP is stored in high-energy phosphate bonds.
- Cells can transfer this energy to specific reactions like muscle contraction, active transport, or biosynthesis.
- This controlled transfer makes energy use much more efficient and versatile than heat from burning.

3. Efficiency of Cellular Respiration:

- About 36–38 ATP molecules per glucose are produced, which is highly efficient compared to direct combustion.
- Gradual oxidation ensures minimal energy loss and maximum usable chemical energy is stored.

4. Avoiding Damage:

- Direct burning of glucose in cells would generate excessive heat and damage cellular structures.
- Controlled ATP production prevents overheating and ensures cellular safety.

✦ Summary:

- Cellular respiration = controlled, stepwise energy release ⟶ ATP formation ⟶ efficient use of energy for cellular work.

- Direct burning = rapid energy release → mostly lost as heat → inefficient and harmful for cells.

🌟 Q3: Why might a disruption in either photosynthesis or respiration processes affect global carbon and oxygen cycles?

❖ **Answer:**

The processes of photosynthesis and cellular respiration are crucial for maintaining the balance of carbon dioxide (CO_2) and oxygen (O_2) in the atmosphere. Any disruption in these processes can disturb global carbon and oxygen cycles.

✦ **Explanation:**

1. Role of Photosynthesis:

- Plants, algae, and cyanobacteria absorb CO_2 from the atmosphere during photosynthesis and release O_2.
- If photosynthesis is reduced due to environmental stress (e.g., deforestation, pollution, or climate change):
    - Less CO_2 is removed from the atmosphere → increased greenhouse effect.
    - Less O_2 is released → atmospheric oxygen decreases, affecting animals and humans.

2. Role of Cellular Respiration:

- All living organisms consume O_2 and release CO_2 through respiration.
- If respiration is disrupted (e.g., mass death of organisms, microbial imbalance):

   - CO_2 levels in the atmosphere can drop or increase unevenly.
   - Energy production in ecosystems would be affected, impacting food chains.

3. Interdependence of Photosynthesis and Respiration:

- Photosynthesis produces O_2 and glucose, which are required for respiration.
- Respiration releases CO_2, which is required for photosynthesis.
- Any imbalance in one process disrupts the cycling of carbon and oxygen, affecting climate, plant growth, and life sustainability.

✦ Summary:

- Photosynthesis and respiration maintain carbon and oxygen balance.
- Disruption → CO_2 accumulation or O_2 depletion, impacting climate, ecosystems, and life.

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

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Purpose: To contribute to education by offering insightful and valuable content that enhances learning and understanding.

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