Photosynthesis

1. What is photosynthesis? Describe the mechanism of dark reaction of C_3 plant. (8 marks) (2080)

- Defⁿ: The process of the manufacture of ~~simple~~ glucose carbohydrate in the ~~green~~ chlorophyll parts of the plant from carbondioxide and water in the presence of sunlight.

Dark Reaction:

- Second phase of photosynthesis for which light is not required.
- Takes place in stroma/matrix part of the chloroplast.
- This phase utilizes ATP and

$NADPH_2$ molecules produced during light reaction.
- CO_2 absorbed by the plants from the atmosphere combines with certain compounds to form intermediate compound and ultimately leads to the formation of glucose/starch.
- Calvin-Benson cycle OR C_3 cycle studied under 3 steps.
i. Carboxylation.
ii. Glycolytic reversal.
iii. Regeneration of RuBP.

i. Carboxylation:
- Atmospheric CO_2 is accepted by Ribulose 1,5 biphosphate (RuBP) in the presence of

Ribulose biphosphate carboxylase (RuBISCO) and first stable product 3-Phosphoglyceric Acid (PGA) is formed.
- PGA is the first stable product of C3 cycle.

Ribulose 1,5 biphosphate (RuBP) $+CO_2+H_2O$ $\xrightarrow{\text{Rubisco}}$ 3-phosphoglyceric acid (PGA)

ii. Glycolytic Reversal:
- 3-PGA is converted into Glucose by following steps.
- 3-PGA is converted into 1,3-diphosphoglyceric acid in the presence of Triosephosphate kinase.

- 1,3-diphosphoglyceric acid is converted into 3-phospho-glyceraldehyde (PAGAL)
- 3-phosphoglyceraldehyde is converted into Dihydroxy acetone phosphate (DAP) in the presence of Triose phosphate isomerase.
- DAP is converted into Fructose 1,6-diphosphate in the presence of enzyme Aldolase.
- Fructose 1,6-diphosphate is converted into fructose-6-phosphate in the presence of phosphatase.
- Fructose-6-phosphate is finally converted into Glucose (starch) as food materials for plants.

iii. Regeneration of RuBP:

- Some molecules of Phosphoglyceraldehyde (PGAL) are diverted to regenerate RuBP in the cycle.
- (Sometimes) - Fructose 6-phosphate is converted into Erythrose 4-phosphate in the presence of Transkitolase.
- Erythrose 4-phosphate is converted into Sedoheptulose 1,7-diphosphate in the presence of Transaldolase.
- Sedoheptulase 1,7-diphosphate is converted into Sedoheptulase 7-phosphate in the presence of Phosphate.
- Sedoheptulase-7-phosphate is

converted into Xylose-5-phosphate and Ribose-5-phosphate in the presence of Phosphoketo epimerase.
- Both Xylose-5-phosphate and Ribose-5-phosphate are converted into Ribulose 5-phosphate.
- Finally, Ribulose-5-phosphate is converted into Ribulose-1,5-biphosphate (RuBP) in the presence of Phosphopentokinase.
- During this process, 6 ATP is converted into 6 ADP.
- This way, complex mechanism of C_3 cycle completes in plants.

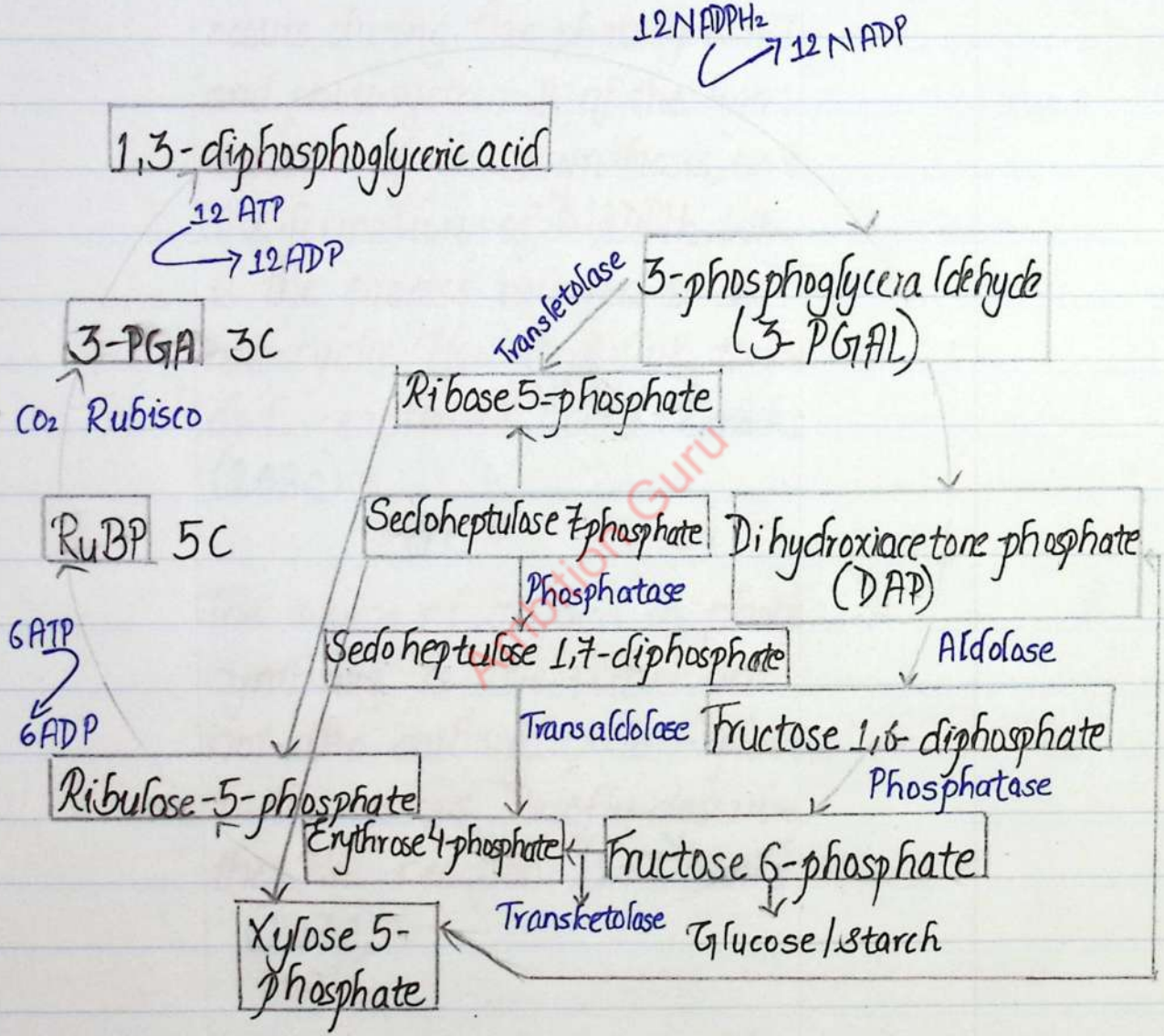

12 NADPH2
12 NADP
1,3-diphosphoglyceric acid
12 ATP
12 ADP
3-phosphoglyceraldehyde (3-PGAL)
Transketolase
3-PGA 3C
Ribose 5-phosphate
CO2 Rubisco
RuBP 5C
Sedoheptulose 7-phosphate
Dihydroxiacetone phosphate (DAP)
Phosphatase
6ATP
6ADP
Sedoheptulose 1,7-diphosphate
Aldolase
Transaldolase
Fructose 1,6-diphosphate
Ribulose-5-phosphate
Phosphatase
Erythrose 4-phosphate
Fructose 6-phosphate
Transketolase
Xylose 5-phosphate
Glucose/starch

Fig: C_3 cycle.

2. Describe the process which occurs during the photosystem-I and photosystem-II of the light reaction of photosynthesis, up to the formation of $NADPH_2$. Why is the process referred to as non-cyclic. How is it link to the dark reactions? (5+1+2) marks (2080)

OR

The source of oxygen in photosynthesis is the water but not the carbondioxide. Explain with reasons. Briefly describe the Hill reaction. (2+6) marks (2079)

• Light reaction:

- First step of photosynthesis in which the light energy is converted into chemical form of energy which is stored in the form of ATP and NADPH + H^+.
- Mechanism of Light reaction occurs in following steps.

i. Photoexcitation of chlorophyll-a:

- Accessory photosynthetic pigments (chl-b) absorbs light and then transfers to reaction center (P_{700} and P_{680}) of chl-a.

Note:

- Photosynthetic pigments except chl-a are called accessory photosynthetic pigments.

- Each chloroplast has two different specific group of pigments co-operate in photosynthesis called photosystem I (P_{700}) and photosystem II (P_{680}).
- Chl-a absorb the light energy from sunlight and releases electron.

ii. Photolysis of water:
- Break down of water in the presence of light energy and liberation of O_2 is called photosynthesis of water.

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

- One electron is produced per water molecule.

- Electron is accepted by PS-II and hydrogen ions are accepted by $NADP^+$ to form $NADPH_2$ during photo-phosphorylation.

iii. Photo phosphorylation:

- Process of formation of high energy phosphates (ATP) in the presence of light.
- Expelled electrons pass through a series of carriers and return to reaction center (P_{700} and P_{680})
- While passing electrons in different electrons carriers, it looses sufficient energy to form ATP.
- Hydrogen ion released during photolysis of water is

utilized by NADP to form $NADPH_2$.
- Both ATP and $NADPH_2$ are utilized during production of sugar in dark reaction.

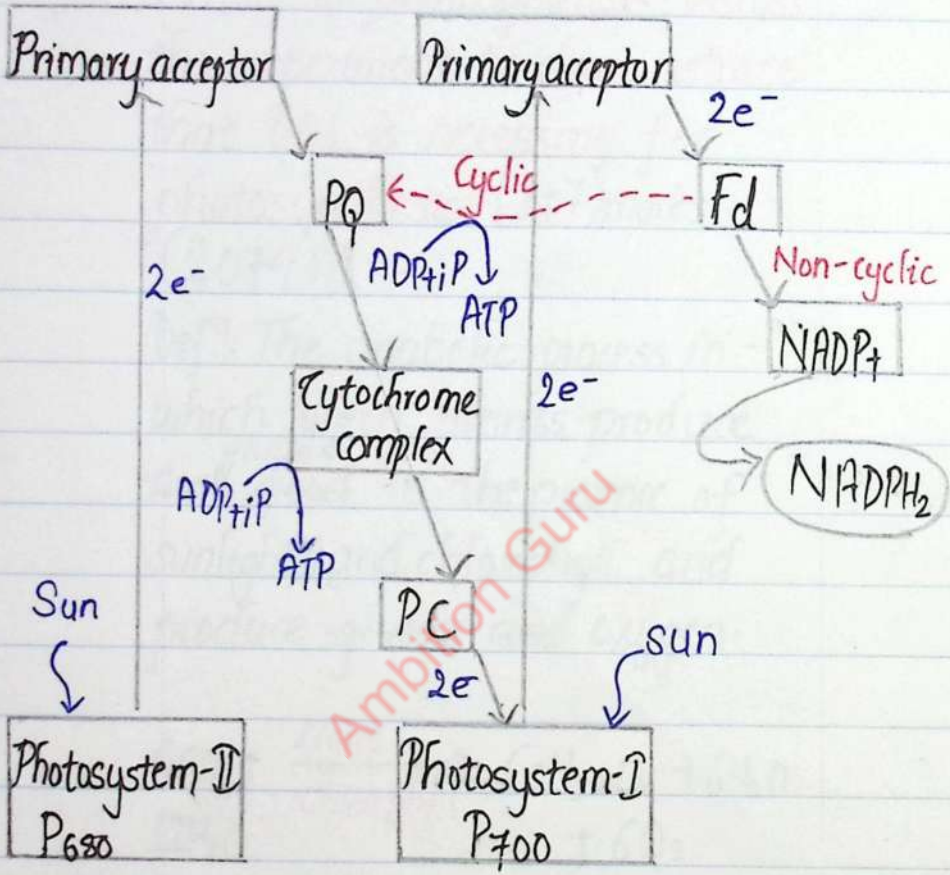
Photo-phosphorylation (Light reaction) is of 2 types:

1. Non-cyclic photophosphorylation:
- Electrons released by P_{680} (PSII) don't go back to P_{680} and hence it is called non-cyclic photophosphorylation.
- Electrons pass through the primary acceptor, Plastoquinone (PQ), Cytochrome complex, Plastocyanin (PC) and finally to P_{700} (PSI)

- Electrons given out by P_{700} are taken up by the primary acceptor and ultimately passed into the NADP.
- Electrons combine with hydrogen ions are reduced from NADP to $NADPH_2$. Hydrogen ions are available by spliting of water.
- Non-cyclic photophorylation needs regular supply of water.
- Net result of non-cyclic photophosphorylation is the formation of oxygen, $NADPH_2$ and ATP.
- Oxygen is produced as waste product of photosynthesis.

ii. Cyclic photophosphorylation:

- Electrons released by P_{700} (PS I) are taken up by the primary acceptor and then passed into Ferrodoxin (Fd), PQ, Cyt. Complex, PC and finally back to P_{700}.
So, called as cyclic photo-phosphorylation.
- Also produces ATP.



$$H_2O \longrightarrow 2H^+ + \frac{1}{2}O_2 + 2e^-$$

Fig: Diagrammatic representation of Light reaction.

3. What is photosynthesis? Discuss the experiment to demonstrate that CO_2 is necessary for photosynthesis. (1+7) marks (2074)

Def^n: The anabolic process in which green plants produce their ~~food~~ glucose in the presence of sunlight, CO_2 and chlorophyll and produce ~~glucose and~~ oxygen.

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

To demonstrate that CO_2 is necessary for photosynthesis by Moll's half leaf experiment:

Requirements:

Apparatus: A wide mouthed bottle, split cork, petridish, beaker, test tube, sprit lamp.

Material: Destarch plant with healthy leaf.

Chemicals: Water, alcohol, iodine solution, vaseline, KOH.

Theory:

- Green part of the plant contains chlorophyll.
- Chlorophyll absorbs light energy from sunlight and initiates the process.
- Therefore, without chlorophyll, there is no possibility of photosynthesis.

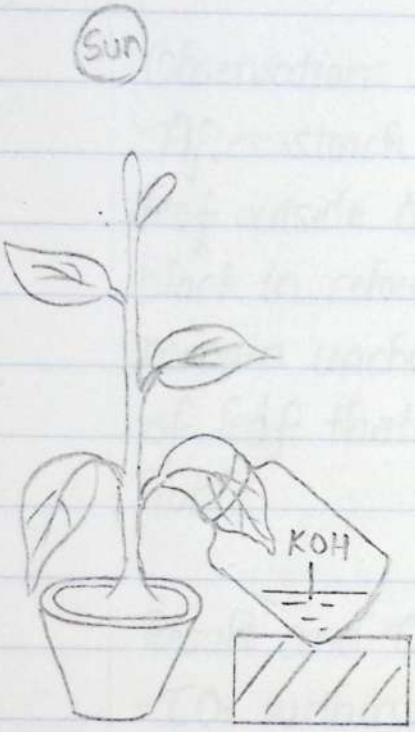
Procedure:

- Select a healthy, green potted plant having elongated leaves.
- Destarch this plant by keeping it in dark room for 2-3 days.
- Take a wide mouth bottle and fill it with KOH solution.
- Select an elongated leaf of the destarched plant and keep it in between the two halves of a split cork.
- Insert the split cork in the mouth of bottle in such a way that half of the leaf is inside the bottle and other half outside the bottle.
- Make the connections air-tight by applying vaseline.

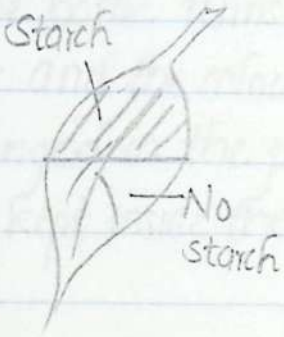
- Expose the experimental apparatus to sunlight for few hours.
- After few hours of exposure, detach the experimental leaf for starch test.

Test for starch:

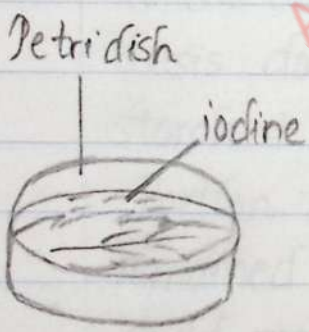
- Boil the experimental leaf in a test tube containing alcohol for 5 minutes to decolorize the leaf by making water bath.
- Wash the leaf with water to remove alcohol.
- Place the leaf on a petridish containing iodine solution.



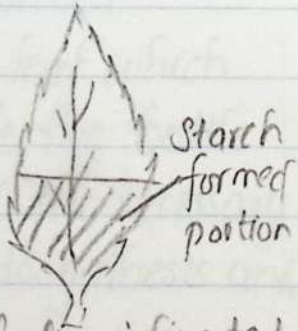
Moll's experiment



Decolorised leaf



Leaf in iodine.



Leaf after iodine test

Fig: Experiment showing necessity of CO_2 for photosynthesis by Moll's half leaf experiment.

Observation:

- After starch test, the portion of leaf outside the bottle turns blue black in colour and the colour remain unchanged in the portion of leaf that kept inside the bottle.

Result and Conclusion:

- CO_2 within the bottle is absorbed by KOH solution and in the absence of CO_2, photosynthesis does not take place and starch is not formed.
- Portion of the leaf which remained outside the bottle could receive all the necessary factors for photosynthesis and

the photosynthesis did take place in this portion forming starch.
- This portion of leaf gives positive starch test and becomes blue-black in contact of iodine solution.
- This way experiment proves that CO_2 is necessary for the process of photosynthesis.

Precautions:
i) Leaf should be destarched.
ii) Mouth of the bottle should be sealed completely.
iii) Portion of leaf inside the bottle shouldn't touch KOH solution.
iv) Setup should be placed in a light.

4. Describe the various factors that influences the photosynthesis in plants. (8 marks) (2076)

- Factors affecting photosynthesis:

- Process of photosynthesis is influenced by number of external and internal factors.

A. External factors:

i. Light:

- Rate of photosynthesis increases with increase in light.
- Occurs only in the visible part of spectrum (i.e. 380-760nm) wavelength.

ii. Temperature:

- Rate of photosynthesis increases with increase in temperature.
- Temperature between 6-37°c shows maximum photosynthesis.

iii. Concentration of CO_2: (Limiting factor)

- Air contains 0.03% of CO_2 by volume.
- High concentration is toxic and inhibit the rate of photosynthesis.

iv. Water:

- Water as raw material for photosynthesis.

- Water deficiency will delay, rate of photosynthesis.

v. Mineral Elements:
- Minerals such as Magnesium, Iron, Copper, etc are essential for photosynthesis.

B. Internal Factors
i. Chlorophyll content:
- Rate of photosynthesis is directly related with the amount of chlorophyll because it is the main pigment which absorb light.

ii. Age of plant:

- Rate of photosynthesis decreases in old leaves, photosynthesis decreases with increase in age of plants.

iii. Anatomy of leaves:

- Presence of thick cuticle, number of stomata affect the rate of photosynthesis.