

Chapter 13 Photosynthesis in higher plants

13.1-Photosynthesis – It is an anabolic process taking place in green plants, where in carbon dioxide and water combine together to produce glucose, in the presence of sunlight.

Sunlight



Chloroplast

During photosynthesis chlorophyll absorbs light energy (solar electromagnetic radiations) and this energy is used for combining the raw materials water and carbon dioxide, producing glucose. Oxygen is the by product and it is released to the atmosphere.

13.2- Mechanism of photosynthesis

Studies have shown that photosynthesis takes place in two steps- they are **light reaction** (Hill reaction) and **dark reaction** (Calvin-Benson cycle)

Light reaction is the first step of photosynthesis, where in the photosynthetic pigments absorb solar radiation energy and convert it into chemical energy which is stored in ATP and NADPH molecules. (Fig. 13.1 and 13.2) The important events that take place during light reaction under the influence of light are,

1. Excitation of electrons of chlorophyll molecule (Photo excitation)



2. Splitting of water molecule (Photo oxidation/photolysis of water) $2\text{H}_2\text{O} \xrightarrow{\hspace{1em}} 4\text{H}^+ + \text{O}_2 \uparrow + 4\text{e}^-$.

(Splitting of water molecule into proton, electron and oxygen under the influence of light during the light reaction is called photolysis or photo oxidation of water)

3. Synthesis of ATP (Photo phosphorylation) $\text{ADP} + \text{P}_i \xrightarrow{\hspace{1em}} \text{ATP}$

(Synthesis of ATP by the addition of P_i to ADP under the influence of light during the light reaction is called 'photophosphorylation;')

4. Reduction of NADP to NADPH_2 (photo reduction) $\text{NADP} + 2\text{H}^+ + 2\text{e}^- \xrightarrow{\hspace{1em}} \text{NADPH}_2$

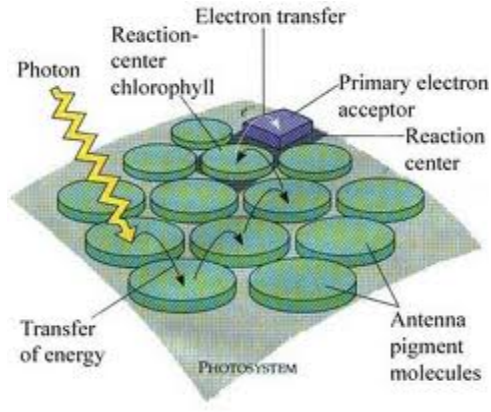
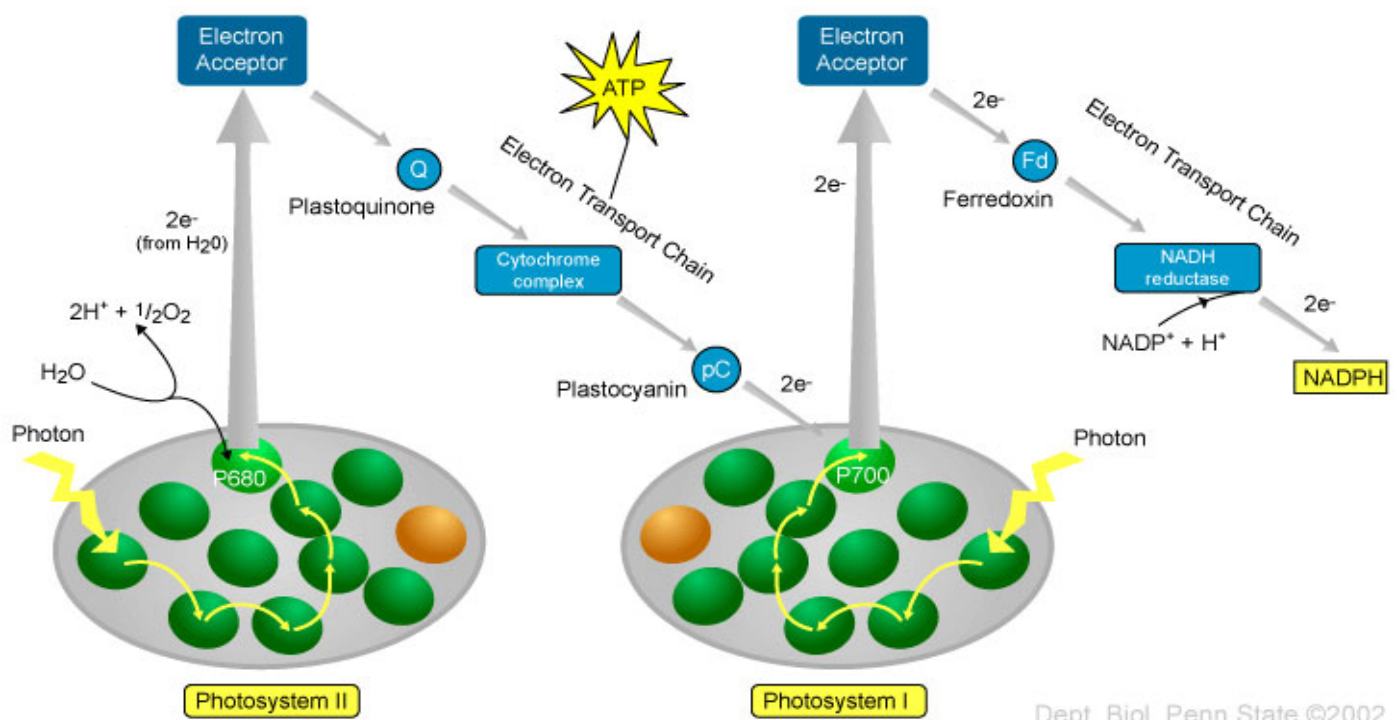


FIG13.1- Light reaction Showing photoexcitation of chlorophyll electrons



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Fig 13.2 -Light reaction- showing photolysis of water, Photophosphorylation and photoreduction

Dark reaction (Calvin cycle) is the second step of photosynthesis where in carbon dioxide is fixed or reduced using ATP and NADPH produced during light reaction, synthesising glucose, as shown below. (Fig.13.3). Initially in this reaction, a five carbon

compound called Ribulose bi phosphate (RuBP) accepts CO_2 forming a six carbon stable compound called Phosphoglyceric acid (PGA). The intermediate compounds of this light independent process were studied by Melvin Calvin, Benson and Bassham. Hence this cycle is also called '**Calvin cycle**'. Six Calvin cycles have to operate to synthesise one molecule of glucose.

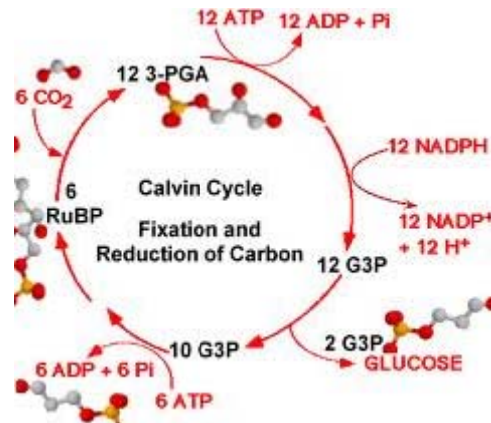


Figure 13.3– Dark reaction – Phases of Calvin cycle

(RuBP- Ribulose bi phosphate, 3 PGA- 3 Phosphoglyceric acid, G3P- 3 phosphoglyceraldehyde)

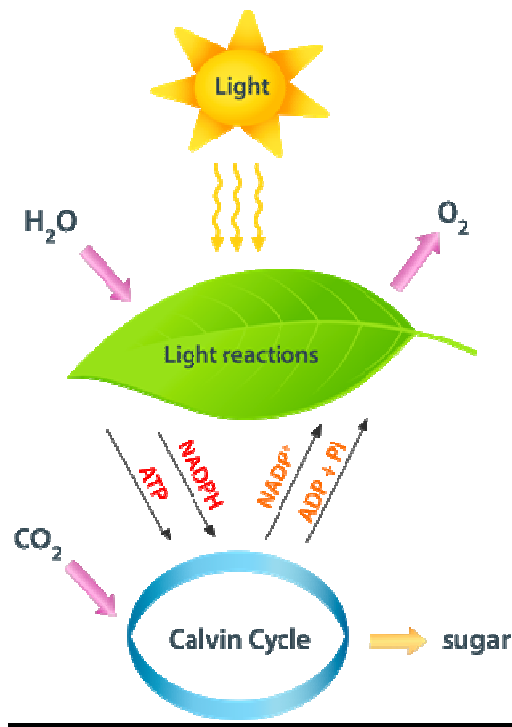


Fig 13.4. Summary of photosynthesis showing light and dark reactions.

Comparison of light and dark reactions

Light reaction	Dark reaction
1. Light dependent process. 2. Takes place on the thylakoid membrane of the chloroplast. 3. water is used 4. Products are ATP, NADPH and Oxygen.	1. Light independent process 2. Takes place in the matrix of chloroplast 3. Carbon dioxide is used. 4. Product is Glucose.

13.3 -C₃ and C₄ plants- Based on the first stable compound formed during dark reaction, plants have been classified into **C₃ and C₄ plants**. Plants in which the first stable compound during carbon dioxide fixation is a 3C phosphoglyceric acid (PGA), are called **C₃ plants** and those in which the first stable compound is a 4C oxaloacetic acid (OAA), are called **C₄ plants**. C₄ pathway is also called 'Hatch-Slack' pathway. Sugarcane and Maize are C₄ plants. They show a different type of leaf anatomy called 'Krantz' anatomy.

13.4-Photorespiration- It is a phenomenon seen in almost all C₃ plants where an increase in the concentration of carbon dioxide brings about a decrease in the rate of photosynthesis.

SUMMARY

- Photosynthesis is an anabolic process seen in plants where carbon dioxide and water are combined to synthesise complex organic substance (food) in the presence of sunlight and chlorophyll.
- Photosynthesis has 2 steps- light reaction and dark reaction.
- In light dependent light reaction water undergoes oxidation, ATP is synthesized and NADP is reduced to NADPH. Chlorophyll is needed for this process.
- In dark reaction (Calvin cycle) ATP and NADPH produced during light reaction are used for the fixation or reduction of carbon dioxide into glucose. For the synthesis of one molecule of glucose six Calvin cycles have to operate.
- The plants have been classified into C₃ and C₄ plants depending upon the first stable compound formed during dark reaction.
- Photorespiration is decrease in the rate of photosynthesis in the presence of more amount of carbon dioxide.

Exercise

1. Define photosynthesis.
2. Name the major step of photosynthesis.
3. Differentiate between light reaction and dark reaction.
4. List the major events that take place during light reaction.
5. Draw a neat labelled diagram of chloroplast.
6. Name the photosynthetic pigments.
7. Distinguish between C3 and C4 plants.
8. Name any two C4 plants.
9. Define photorespiration.

Exercise- question and answers

1. Define photosynthesis.

It is an anabolic process taking place in green plants, where in carbon dioxide and water combine together to produce glucose, in the presence of sunlight.

2. Name the major steps of photosynthesis.

Light reaction/ Hill reaction and dark reaction/ calvin cycle.

3. Differentiate between light reaction and dark reaction.

Light reaction	Dark reaction
1. Light dependent process. 2. Takes place on the thylakoid membrane of the chloroplast. 3. water is used 4. Products are ATP, NADPH and Oxygen.	1. Light independent process 2. Takes place in the matrix of chloroplast 3. Carbon dioxide is used. 4. Product is Glucose.

4. List the major events that take place during light reaction.

The four major events of light reaction are,

1. Excitation of electrons of chlorophyll molecule (Photo excitation)

2. Splitting of water molecule (Photo oxidation/photolysis of water) $2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + \text{O}_2 + 4\text{e}^-$

3. Synthesis of ATP (Photo phosphorylation) $\text{ADP} + \text{Pi} \rightarrow \text{ATP}$

4. Reduction of NADP to NADPH₂ (photo reduction) $\text{NADP} + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{NADPH}_2$

5. Name the photosynthetic pigments.

Chlorophyll-a and Chlorophyll b.

6. Distinguish between C₃ and C₄ plants.

Plants in which the first stable compound during carbon dioxide fixation is a 3C phosphoglyceric acid (PGA), are called **C₃ plants** and those in which the first stable compound is a 4C oxaloacetic acid (OAA), are called **C₄ plants**.

7. Name any two C₄ plants.-Sugar cane and maize

8. Define photorespiration.

It is a phenomenon seen in almost all C₃ plants where an increase in the concentration of carbon dioxide brings about a decrease in the rate of photosynthesis.