Dark reaction

— It takes place in stroma of chloroplast.

— Reduction of CO_2 takes place with the help of NADPH and ATP. Light is not required directly, so it is called dark reaction.

— Reduction of CO_2 into sugar is called C-fixation or C-assimilation. It is accomplished by C_3-cycle. However, there are other pathways also. These are C_4-pathway and CAM. Whether plant shows C_4 pathway or CAM, C_3 cycle would take place also.

C_3-Cycle

C_3-Cycle is also known as Calvin cycle/Calvin Benson cycle/ Photosynthetic Carbon Reduction (PCR) cycle.

— It takes place in stroma of chloroplast.

— The pathway reported by Calvin *et al* by use of ^{14}C in *Chlorella* and *Scenedesmus* with the help of paper chromatography and radioautography.

— Calvin cycle is divisible into carboxylation, reduction, regeneration and production formation

Carboxylation:

Ribulose monophosphate (RuMP) is phosphorylated into ribulose bisphosphate (RuBP). It is accomplished with the help of ATP. The enzyme catalysing the reaction is phosphoribulokinase.

— **RuBP** acts as **CO_2 acceptor in C_3-cycle**. Its carboxylation is catalysed by **rubisco** (ribulose bisphosphate carboxylase). As a result of its catalytic activity two molecules of **PGA (Phosphoylceric acid)** are formed. PGA **is three carbon compound**. It **is initial carbon dioxide fixation product in C_3-cycle.** The cycle has got its name on the basis of PGA, 3C- compound.

Rubisco:

— Rubisco occurs in stroma of chloroplast. It is the most abundant protein on the earth. It represents 50% of total soluble protein of leaves.

— Rubisco is composed of 16 subunits. Eight of them are small subunits and rest of eight are large subunits.

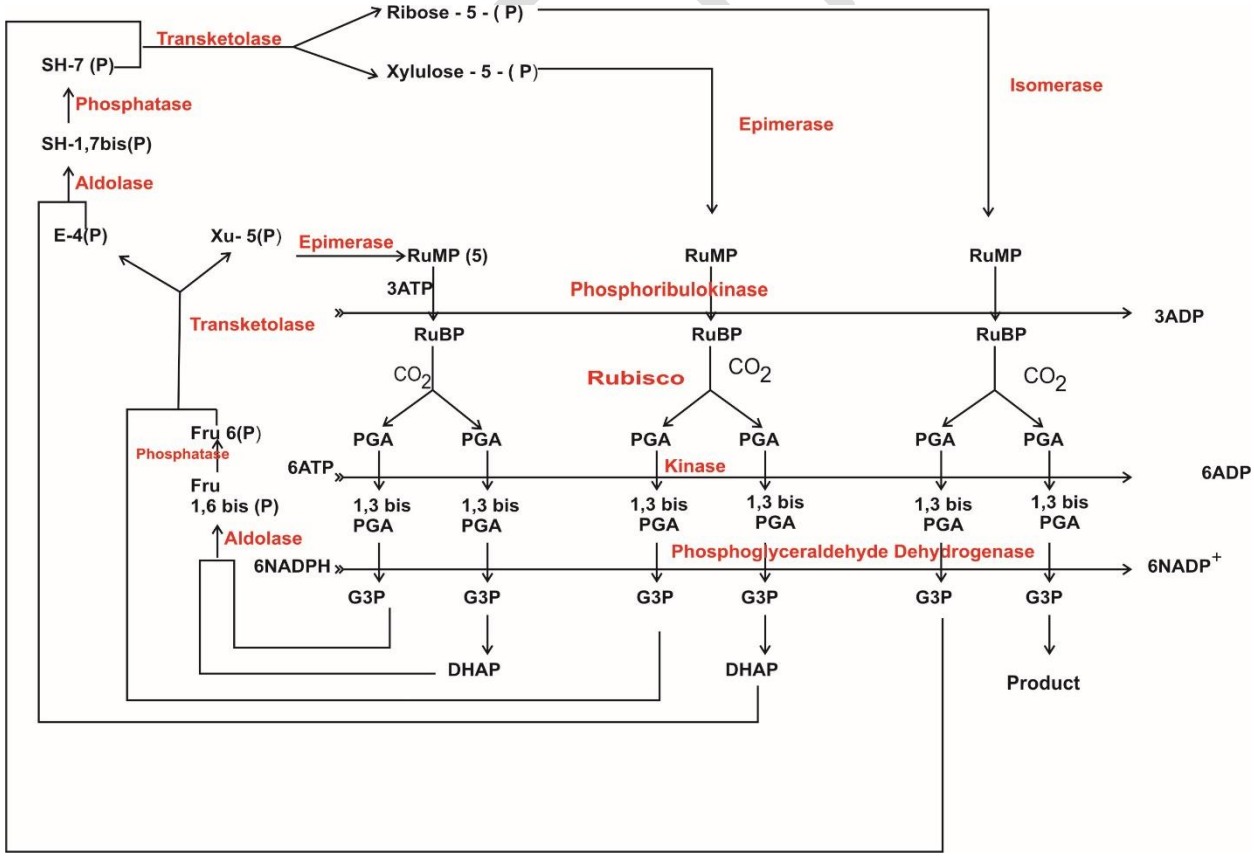
— Small subunits are synthesized in cytoplasm under control of nuclear DNA.

Large subunits are synthesized in chloroplast under control of DNA of chloroplast. After synthesis, small subunits are brought into chloroplast to form rubisco.

Thus, formation of rubisco is result of cooperation between nuclear DNA and DNA of chloroplast.

— Rubisco is not on efficient enzyme. Its Km value is high.

— It shows carboxylase as well as oxygenase activity. When CO_2/O_2, ratio is high it shows carboxylase activity. Its carboxylase activity is observed in C_3-cycle.



— When CO_2/O_2, ratio is low it shows oxygenase activity. Such activity is observed in photorespiration.

Reduction:— PGA is phosphorylated into 1,3 bis PGA (1,3 bisphosphoglyceric acid) with help of ATP. The step is catalysed by PGA kinase.

— 1, 3 bisPGA is reduced into G3P (glyceraldehyde-3-phosphate). The step is catalysed by glyceraldehyde-3-phosphate dehydrogenase. Similar enzyme is active in respiration. But in this reaction oxidation of G3P into 1,3 bis PGA is achieved in presence of NAD.

Regeneration:

— G3P is converted into DHAP (Dihydroxyacetone phosphate). It is catalysed by triose isomerase.

— G3P and DHAP combine to form Fru 1,6 bisP (Fructose 1,6 bisphosphate) under catalytic activity of aldolase.

— Fru 1,6 bis P is dephosphorylated into Fru 6 P (fructose 6-P) under catalytic activity of phosphatase.

— Fru 6 P reacts with G3P in presence of transketolase. It results in formation of xylulose 5-P (Xu5P) and erythrose 4-P (E 4 P).

— Now E4P and DHAP react with each other to form sedoheptulose 1,7 bisP (S1,7 bisP) under catalytic effect of aldolase.

SH1,7 bisP is dephosphorylated into SH-7-P (sedoheptulose 7 phosphate) in presence of phosphatase.

— SH-7-P react with G 3 P to form ribose 5 -P (R5P) and X5P (xylulose 5-P) under catalytic effect of transketolase.

— X5P undergoes epimeric conversion to form ribulose monophosphate (RuMP). The enzyme to epimerase.

— R5P is converted into RuMP in presence of isomerase.

Product formation:

Sucrose and starch are primary products of photosynthesis.

— Sucrose formation takes place in cytoplasm in following manner:

— Triose phosphates (DHAP and G3P) are transported to cytoplasm from chloroplast in exchange of orthophosphate.

— In cytoplasm triose phosphates are utilized to form fructose 1, 6 bis P which is dephosphorylated into Fru 6-P.

— Fru 6-P is converted into Glc-6-P which in turn is changed into Glc-1-P.

— Glc-1-P is converted into UDP-Glc. In plants sucrose formation takes place in following manner:

UDP-Glc + Fru- 6-P⟶ Sucrose-6- P + UDP

Sucrose-6-P ⟶ sucrose + Pi

However, in some plants sucrose formation occurs in following manner:

UDP– Glc + Fru ⟶ sucrose + UDP

— When CO_2 fixation rate in chloroplasts is very vigorous starch synthesis begins in stroma of chloroplast. Triose phosphates are converted into Glc 1-P which then reacts with ATP to form ADP- Glc.

Glc 1-P+ATP ⟶ ADP- Glc + PPi

A small amount of starch represented as Glc_n actually acts as primer to which Glc molecules are added successively, thus increasing the size of the starch molecule by chain elongation.

Factors affecting Photosynthesis

Factors: According to concept of three cardinal point (proposed **by Sachs**) there are minimum, optimum and maximum values of a factor in relation to photosynthesis. *For example*: there is minimum temperature below which no photosynthesis occurs. There is maximum temperature beyond which there is no photosynthesis. At the optimum temperature, rate of photosynthesis in maximum. It was found that there are different optima of a factor in the same species in different condition occurrence of different optima was due to different conditions and there are many factors which effect photosynthesis. Concept of Blackman's limiting factor explained this aspect.

The concept of Blackman's limiting factor is based on law of minimum. Law of minimum was proposed by **Liebig.** Acc. to law of minimum, a process affected by many factors is only as rapid as the slowest factor permits.

According to concept of Blackman limiting factor effect of external factors on photosynthesis can be measured individually within limit. Beyond limit some other factor becomes limiting.

Light :

In photosynthesis it is light energy which is conserved. Light energy is observed by pigments. Maximum absorption of violet blue and orange red is made by chlorophyll. Green light is not observed by chlorophyll.

Despite greater excitation of electron due to absorption of blue light than the absorption of red light, it is red light which is more efficiently utilized. It is due to the fact that excited electron after absorption of blue light comes to on energy level after loss of energy which is lower than the energy level achieved by excited electron after absorption of red light.

— Within limit increase in intensity of light and rate of photosynthesis show direct relationship.

Optimum intensity of light varies in different spp.

Optimum intensity is low in shade plant (sciophytes) but optimum intensity is high in sun loving plant (heliophytes).

↑ in light intensity beyond a limit results in oxidation of chlorophyll is called **solarization**.

— Light intensity in which CO_2 consumed in photosynthesis is equal to CO_2 released in respiration is called light compensation point.

— In bright sunny days it is CO_2 instead of light which becomes limiting factors.

Oxygen :

With ↑ in O_2 level photosynthesis is inhibited. Such inhibition is observed in C_3 plants but not in C_4-plants.

The inhibition of photosynthesis due to ↑ in O_2 level in C_3-plants is result of inhibition of oxygenase activity of rubisco. In C_4 plants photosynthesis is not inhibited because these plants ration high in bundle sheath cell where rubisco occurs.

Inhibition of photosynthesis due to high level of O_2 is called **Warburg effect.**

CO_2. :

It is CO_2 which is reduced in photosynthesis plants get CO_2 from atmosphere stomata. They get CO_2 from water through surface in aquatic medium. CO_2 becomes limiting in bright sunny days.

— CO_2 compensation points.

H_2O

— H_2O serves as source of electron for reduction of CO_2 in photosynthesis. Normally availability of H2O is adequate for photosynthesis. But it becomes limiting after prolonged drought period or in afternoon in hot days. However deficiency of H2O would affect photosynthesis indirectly. In water deficient condition, the stomata get closed which would affect gaseous exchange adversely. This would affect photosynthesis.

Temperature :

— Temperature affects biochemical process of photosynthesis because it is catalyzed by enzymes. It does not effect physicochemical process.

Internal factor :

Various internal factor affects photosynthesis. Some of these factor are as follows :

- pigmentation
- age of leaves
- age of trees
- venation etc