PHOTOSYNTHESIS IN HIGHER PLANTS
WHERE ARE THE ATP AND NADPH USED

DARK REACTION :

The products of light reaction are ATP, NADPH and O_2. Of these O_2 diffuses out of the chloroplast while ATP and NADPH are used to drive the process leading to synthesis of food, (more accurately sugars). This is biosynthetic phase of photosynthesis. This process does not directly depend on the presence of light but is dependent on the product of the light reaction
i.e. ATP and NADPH, besides CO_2 and H_2O.

Q. Does the term dark reaction for biosynthetic phase of photosynthesis, is a misnomer?

Ans. Yes, dark reaction term is a misnomer because this reaction not occurs in dark. Instead this reaction is dependent on the product of the light reaction i.e, ATP and NADPH, so dark reaction process also occurs in presence of light.

Dark reaction occurs at fluid of stroma and also called Blackman's reaction or Biosynthetic phase. It is a reductive step (CO_2 reduced) of photosynthesis. Dark reaction operates in different photosynthetic organisms through three different ways :

(A) C_3 pathway (B) C_4 pathway (C) CAM pathway

C_3 pathway consists of only C_3 cycle or Calvin cycle while C_4 pathway and CAM pathway consists of both C_3 cycle and C_4 cycle. Therefore, Calvin cycle occurs in all photosynthetic plants ; it does not matter wheather they have C_3 or C_4 (or any other) pathways.

(A) The Calvin cycle :

The use of radioisotope ^{14}C by Calvin in alga (Chiarella) photosynthesis studies led to the discovery that the first CO_2 fixation product is a 3 carbon organic acid called 3 phosphoglyceric acid or in short 3 PGA. It has a 3 carbons thus cycle named C_3 cycle.

Melvin Calvin and his co-workers then worked out the whole pathway and showed that the pathway operated in cyclic manner ; the RUBP was regenerated.

Calvin cycle can be described under three stages :

(1) Carboxylation **(2) Reduction** **(3) Regeneration**

(1) CARBOXYLATION:

It is the most crucial step (because RuBisCO has dual nature and this step will determines wheather Calvin cycle run or photorespiration). In this step CO_2 is utilised for the carboxylation of RUBP. This reaction is catalysed. by the enzyme RuBisCO which results in the formation of two molecules of 3-PGA.

RuBisCO

- Its full name is Ribulose 1,5-bisphosphate carboxylase oxygenase enzyme, Its former name, was carboxydismutase.
- RuBisCO is considered as a most abundant protein on the earth.
- It has dual nature, thus capable to bind with CO_2 (carboxylase) as well as O_2 (oxygenase). Although the enzyme has more affinity with CO_2.
- Binding of CO_2 or O_2 is competitive with active site. It is the relative concentration of O_2 and CO_2 in the stroma of chloroplast that determines which of the two will bind to the enzymes.
- Mg and Red light are necessary for activation of enzyme RuBisCO.

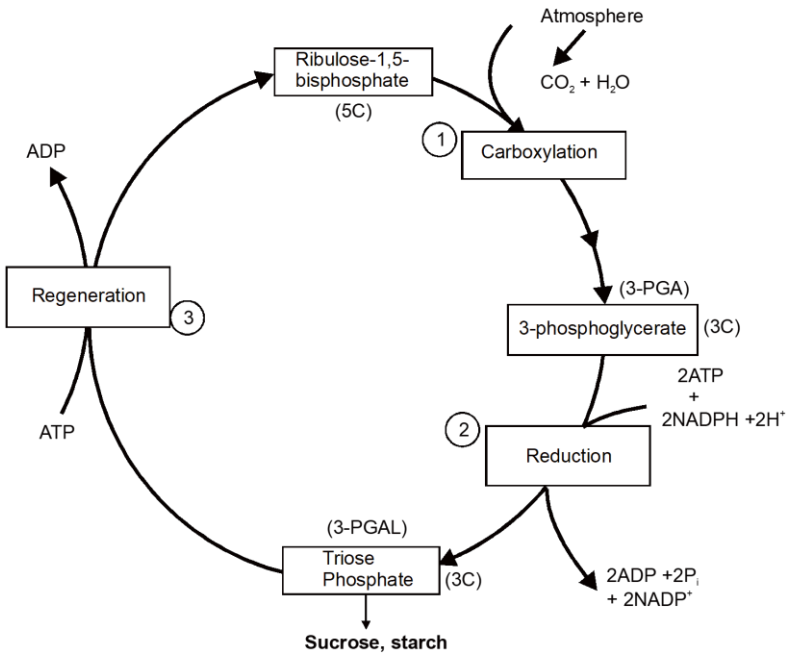

Fig : The Calvin cycle proceeds in three stages:

(1) carboxylation, during which CO_2 combines with ribulose-1,5-bisphosphate;

(2) reduction during which carbohydrate is formed at the expense of the photochemically made ATP and NADPH; and

(3) regeneration during which the CO_2 acceptor ribulose- 1,5-bisphosphate is formed again so that the cycle continues

(2) REDUCTION :

These are a series of reactions that lead to the formation of glucose. (glycolytic reversal) The fixation of six molecules of CO_2 and for this fixation 6 turns of the Calvin cycle are required for removal of one molecule of glucose from the pathway.

(3) REGENERATION :

Regeneration of the CO_2 acceptor molecule RUBP is crucial if the cycle is to continue uninterrupted.

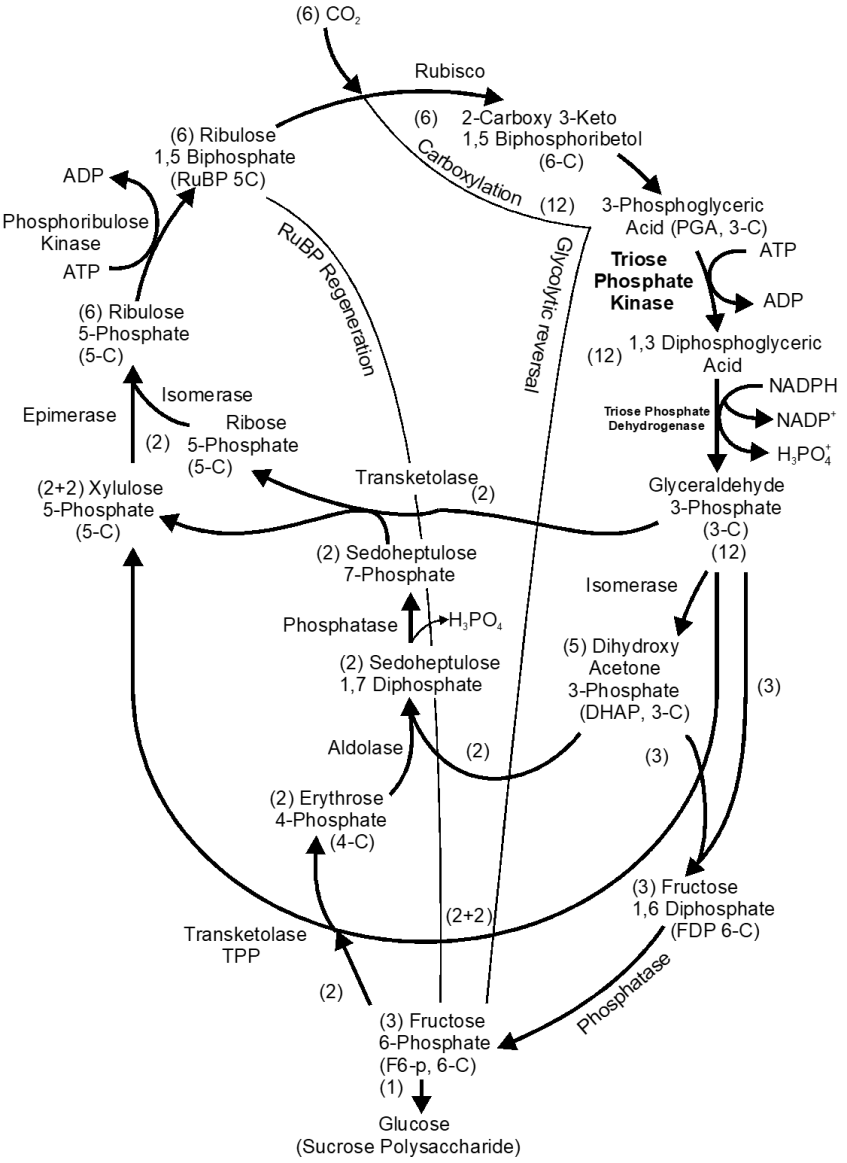

Fig. : Calvin cycle

Steps of calvin cycle	Number of ATP and NADPH required per CO_2
Carboxylation	Zero ATP and Zero NADPH + H^+
Reduction	Two ATP and two NADPH + H^+
Regeneration	One ATP and Zero NADPH + H^+

Hence for every CO_2 molecule entering the Calvin cycle, 3 molecules of ATP and 2 of NADPH are required.

Input	Output
6 CO_2	$C_6H_{12}O_6$
18 ATP	18 ADP
12 NADPH	12 $NADP^+$