M.Sc. Botany

Semester-II (2018-20)

MBOTCC-7: Physiology & Biochemistry

Unit –II
CALVIN CYCLE

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CALVIN CYCLE

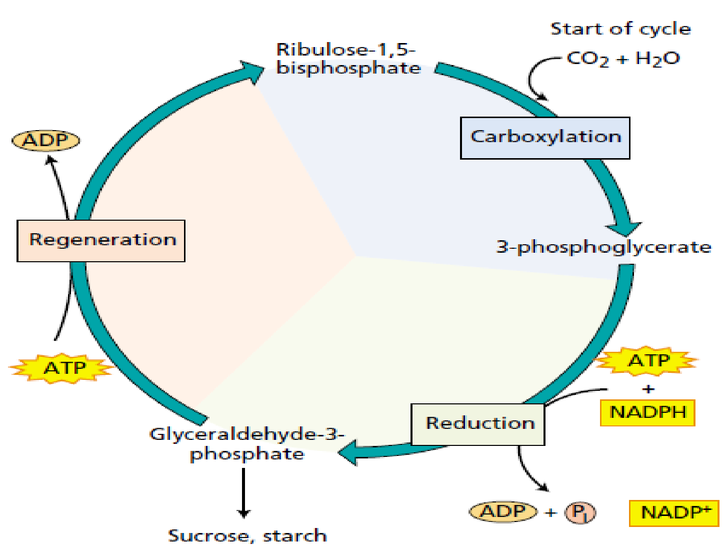
Autotrophic organisms have the ability to convert physical and chemical sources of energy into carbohydrates in the absence of organic substrates. Most of the external energy is consumed in transforming CO_2 to a reduced state that is compatible with the needs of the cell (—CHOH—). The reduction of CO_2 to carbohydrate via the carbon-linked reactions of photosynthesis is coupled to the consumption of NADPH and ATP synthesized by the light reactions of thylakoid membranes..

These stroma reactions were long thought to be independent of light and, as a consequence, were referred to as the dark reactions. However, because these stroma-localized reactions depend on the products of the photochemical processes, and are also directly regulated by light, they are more properly referred to as the carbon reactions of photosynthesis.

All photosynthetic eukaryotes, from the most primitive alga to the most advanced angiosperm, reduce CO_2 to carbohydrate via the same basic mechanism: the photosynthetic carbon reduction cycle originally described for C3 species (the Calvin cycle, or reductive pentose phosphate [RPP] cycle).

Other metabolic pathways associated with the photosynthetic fixation of CO_2, such as the C4 photosynthetic carbon assimilation cycle and the photorespiratory carbon oxidation cycle, are either auxiliary to or dependent on the basic Calvin cycle.

1. The Calvin cycle was elucidated as a result of a series of elegant experiments by Melvin Calvin and his colleagues in the 1950s, for which a Nobel Prize was awarded in 1961.
2. The Calvin Cycle has three Stages: Carboxylation, Reduction, and Regeneration.
   i. Carboxylation of the CO_2 acceptor ribulose-1,5-bisphosphate, forming two molecules of 3-phosphoglycerate, the first stable intermediate of the Calvin cycle
   ii. Reduction of 3-phosphoglycerate, forming gyceraldehyde-3-phosphate, a carbohydrate
   iii. Regeneration of the CO_2 acceptor ribulose-1,5-bisphosphate from glyceraldehyde-3-phosphate



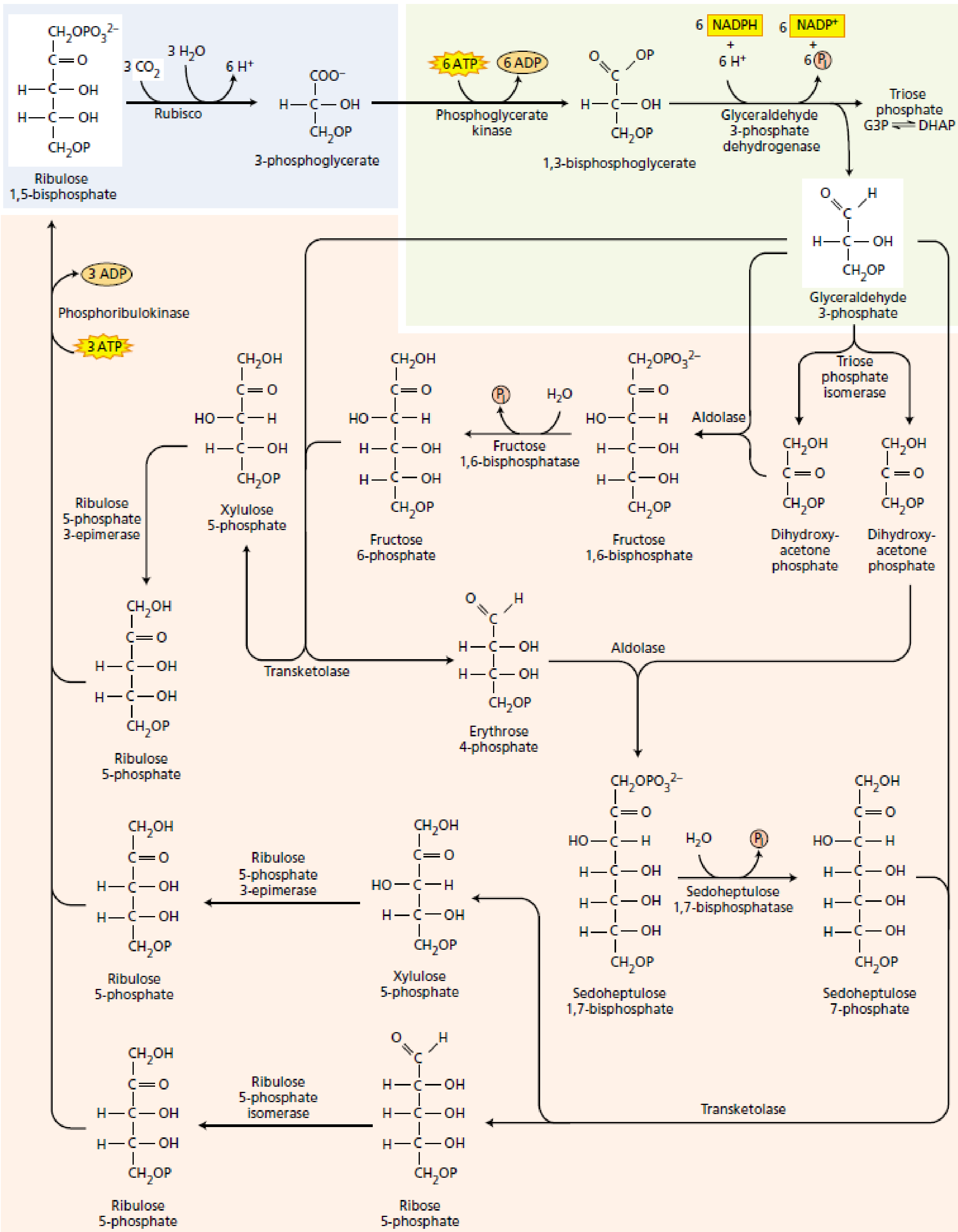


Fig: The Calvin cycle. The carboxylation of three molecules of ribulose-1,5-bisphosphate leads to the net synthesis of one molecule of glyceraldehyde-3-phosphate and the regeneration of the three molecules of starting material. This process starts and ends with three molecules of ribulose-1,5-bisphosphate, reflecting the cyclic nature of the pathway

3. Net reaction of the Calvin Cycle:

$$\text{Net: } 6\,CO_2 + 11\,H_2O + 12\,NADPH + 18\,ATP \rightarrow \text{Fructose-6-phosphate} + 12\,NADP^+ + 6\,H^+ + 18\,ADP + 17\,P_i$$

4. The affinity of rubisco for CO_2 is sufficiently high to ensure rapid carboxylation at the low concentrations of CO_2 found in photosynthetic cells.
5. The Calvin cycle reactions regenerate the biochemical intermediates that are necessary to maintain the operation of the cycle. But more importantly, the rate of operation of the Calvin cycle can be enhanced by increases in the concentration of its intermedi ates; that is, the cycle is autocatalytic.
6. Calvin Cycle Stoichiometry Shows That Only One-Sixth of the Triose Phosphate is used for Sucrose or Starch.
7. Five light-regulated enzymes operate in the Calvin cycle:
   i. Rubisco
   ii. NADP:glyceraldehyde-3-phosphate dehydrogenase
   iii. Fructose-1,6-bisphosphatase
   iv. Sedoheptulose-1,7-bisphosphatase
   iv. Ribulose-5-phosphate kinase

The continued operation of the cycle is ensured by the regeneration of ribulose-1,5-bisphosphate. The Calvin cycle consumes two molecules of NADPH and three molecules of ATP for every CO_2 fixed and, provided its substrates, has a thermodynamic efficiency close to 90%.