M.Sc. Botany

Semester-II (2018-20)

MBOTCC-7: Physiology & Biochemistry

Unit –II

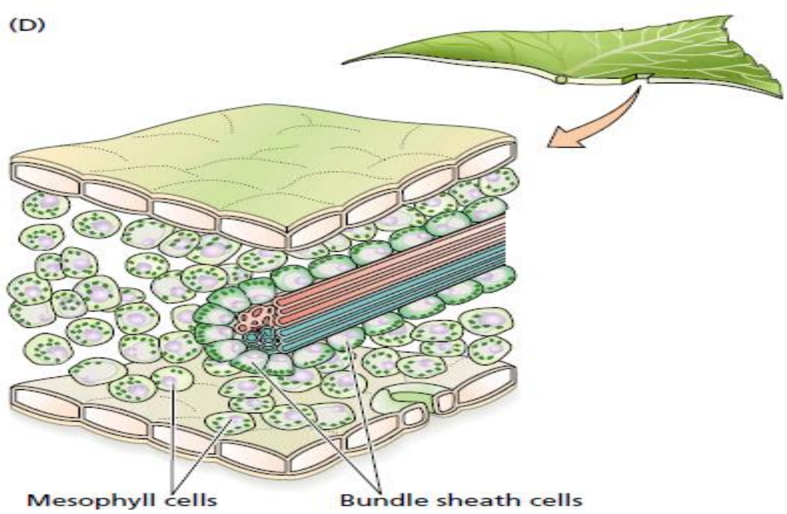
C4 CYCLE

Nitu Bharti
Assistant Professor
Department of Botany

C4 CYCLE

Photosynthetic carbon metabolism in the intact leaf reflects the integrated balance between two mutually opposing and interlocking cycles. The Calvin cycle can operate independently, but the C2 oxidative photosynthetic carbon cycle depends on the Calvin cycle for a supply of ribulose-1,5-bisphosphate. The balance between the two cycles is determined by three factors: the kinetic properties of rubisco, the concentrations of the substrates CO_2 and O_2, and temperature.
The concentration ratio of CO_2 to O_2 decreases as the temperature rises. As a result of this property, photorespiration (oxygenation) increases relative to photosynthesis (carboxylation) as the temperature rises. This effect is enhanced by the kinetic properties of rubisco, which also result in a relative increase in oxygenation at higher temperatures. Overall, then, increasing temperatures progressively tilt the balance away from the Calvin cycle and toward the oxidative photosynthetic carbon cycle.

1. C4 plants do not photorespire at all, these plants have normal rubisco, and their lack of photorespiration is a consequence of mechanisms that concentrate CO_2 in the rubisco environment and thereby suppress the oxygenation reaction.
2. There are differences in leaf anatomy between plants that have a C4 carbon cycle (called C4 plants) and those that photosynthesize solely via the Calvin photosynthetic cycle (C3 plants). A typical C3 leaf has one major chloroplast-containing cell type, the mesophyll. In contrast, a typical C4 leaf has two distinct chloroplast-containing cell types: mesophyll and bundle sheath (or Kranz, German for "wreath") cells.



3. Operation of the C4 cycle requires the cooperative effort of both cell types. No mesophyll cell of a C4 plant is more than two or three cells away from the nearest bundle sheath cell. In addition, an extensive network of plasmodesmata connects mesophyll and bundle sheath cells, thus providing a pathway for the flow of metabolites between the cell types.

4. The C4 pathway was elucidated by M. D. Hatch and C. R. Slack, in Australia, in 1966, also called the Hatch and Slack Pathway.
5. They established that the C4 acids malate and aspartate are the first stable, detectable intermediates of photosynthesis in leaves of sugarcane.
6. The primary carboxylation in these leaves is catalyzed not by rubisco, but by PEP (phosphoenylpyruvate) carboxylase.
7. The participating enzymes occur in one of the two cell types: PEP carboxylase and pyruvate–orthophosphate dikinase are restricted to mesophyll cells; the decarboxylases and the enzymes of the complete Calvin cycle are confined to the bundle sheath cells.
8. The basic C4 cycle consists of four stages:
    i. Fixation of CO_2 by the carboxylation of phosphoenolpyruvate in the mesophyll cells to form a C4 acid (malate and/or aspartate).
    ii. Transport of the C4 acids to the bundle sheath cells.
    iii. Decarboxylation of the C4 acids within the bundle sheath cells and generation of CO_2, which is then reduced to carbohydrate via the Calvin cycle.
    iv. Transport of the C3 acid (pyruvate or alanine) that is formed by the decarboxylation step back to the mesophyll cell and regeneration of the CO_2 acceptor phosphoenolpyruvate (it consumes two "high-energy" phosphate bonds: one in the reaction catalyzed by pyruvate–orthophosphate dikinase and another in the conversion of PPi to 2Pi catalyzed by pyrophosphatase .

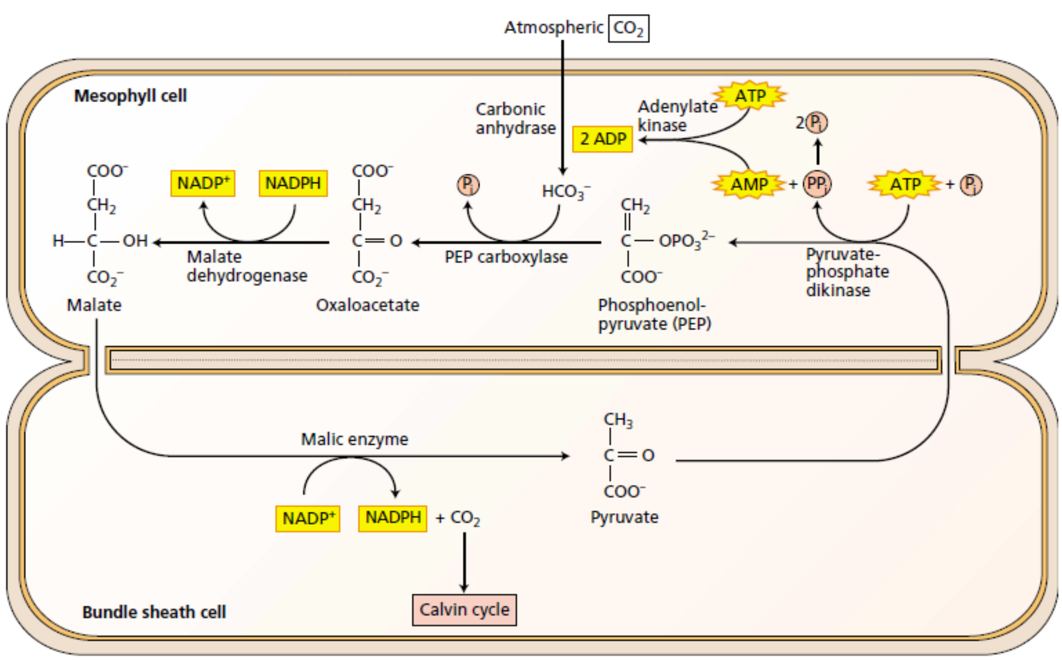


Fig:The C4 photosynthetic pathway

1. The CO_2- concentrating process consumes two ATP equivalents (2 "high-energy" bonds) per CO2 molecule transported. Thus the total energy requirement for fixing CO2 by the combined C4 and Calvin cycles is five ATP plus two NADPH per CO2 fixed.

2. Light is essential for the operation of the C4 cycle because it regulates several specific enzymes. For example, the activities of PEP carboxylase, NADP:malate dehydrogenase, and pyruvate–orthophosphate dikinase are regulated in response to variations in photon flux density.
3. In Hot, Dry Climates, the C4 Cycle Reduces Photorespiration and Water Loss
   i. high activity of PEP carboxylase (oxygen is not a competitor in the reaction) enables C4 plants to reduce the stomatal aperture. and thereby conserve water while fixing CO_2 at rates equal to or greater than those of C3 plants.
   ii. suppression of photorespiration resulting from the concentration of CO_2 in bundle sheath cells.

Discovered in the tropical grasses, sugarcane, and maize, the C4 cycle is now known to occur in 16 families of both monocotyledons and dicotyledons, and it is particularly prominent in Gramineae (corn, millet, sorghum, sugarcane), Chenopodiaceae (Atriplex), and Cyperaceae (sedges). There are three variations of the basic C4 pathway that occur in different species . The variations differ principally in the C4 acid (malate or aspartate) transported into the bundle sheath cells and in the manner of decarboxylation. Depending on their natural environment, some plants show properties intermediate between strictly C3 and C4 species.