Hatch and Slack Pathway

In some plants, particularly growing in tropical areas, the predominant compounds formed after very short period of photosynthesis are four carbon compounds such as Malate and Aspartate. It was firstly demonstrated experimentally by Kortschak, Hartt and Barr in 1965. They showed that rapidly photosynthesising sugar cane plants fix CO_2 into aspartic and malic acids. It was confirmed by Hatch and Slack in 1967. Hatch and Slack, while working on sugarcane found four carbon compound ~~[illegible]~~ as the first stable product of photosynthesis. Because the products are four carbon compounds, the plants showing this pathway are referred as C_4 plants. This pathway is also called as Hatch and Slack pathway or co-operative photosynthesis.

It takes place even at 30-45°c and also found in maize, various grasses, some dicots and in most of the plants growing in tropical climatic regions.

Anatomy of C_4 plants

The anatomy of the leaves of C_4 plants is different from that of C_3 plants. The leaves of C_4 plants are characterised by a sheath of parenchyma cells present around each vascular bundle. Loosely arranged spongy mesophyll cells are also present around the bundle sheath cells. This closed vascular bundle sheath arrangement is known as 'Kranz anatomy'. This is the characteristic feature of C_4 plants.

The chloroplasts of bundle sheath cells are large and do not have grana. Starch grains are ~~also absent~~ present. The chloroplasts of mesophyll cells are smaller in size and have well developed grana. Starch grains are absent here. The mesophyll cells of C_4 plants shows high activity of phosphoenol pyruvate carboxylase, which catalyses the fixation of CO_2 with Phosphoenol pyruvate (PEP) to form oxaloacetate. Calvsn cycle enzymes are absent in mesophyll chloroplast. This cycle occurs only in the chloroplast of sheath cells. The bundle sheath cells show high

RuDP carboxylase, and other enzymes of calvin cycle.

It is now evident that the leaves of C_4 plants are compartmentalised and exhibit a division of labour with respect to the fixation of CO_2 into C_4 compounds in mesophyll chloroplast and the subsequent formation of sugar and starch in bundle sheath chloroplast. one product of fixation is transported from the mesophyll cells to the bundle sheath chloroplasts, where decarboxylation takes place. Plasmodesmata have been observed to connect adjacent cells of the bundle sheath and mesophyll cells. It acts as channel for transport of metabolites.

C_4-cycle

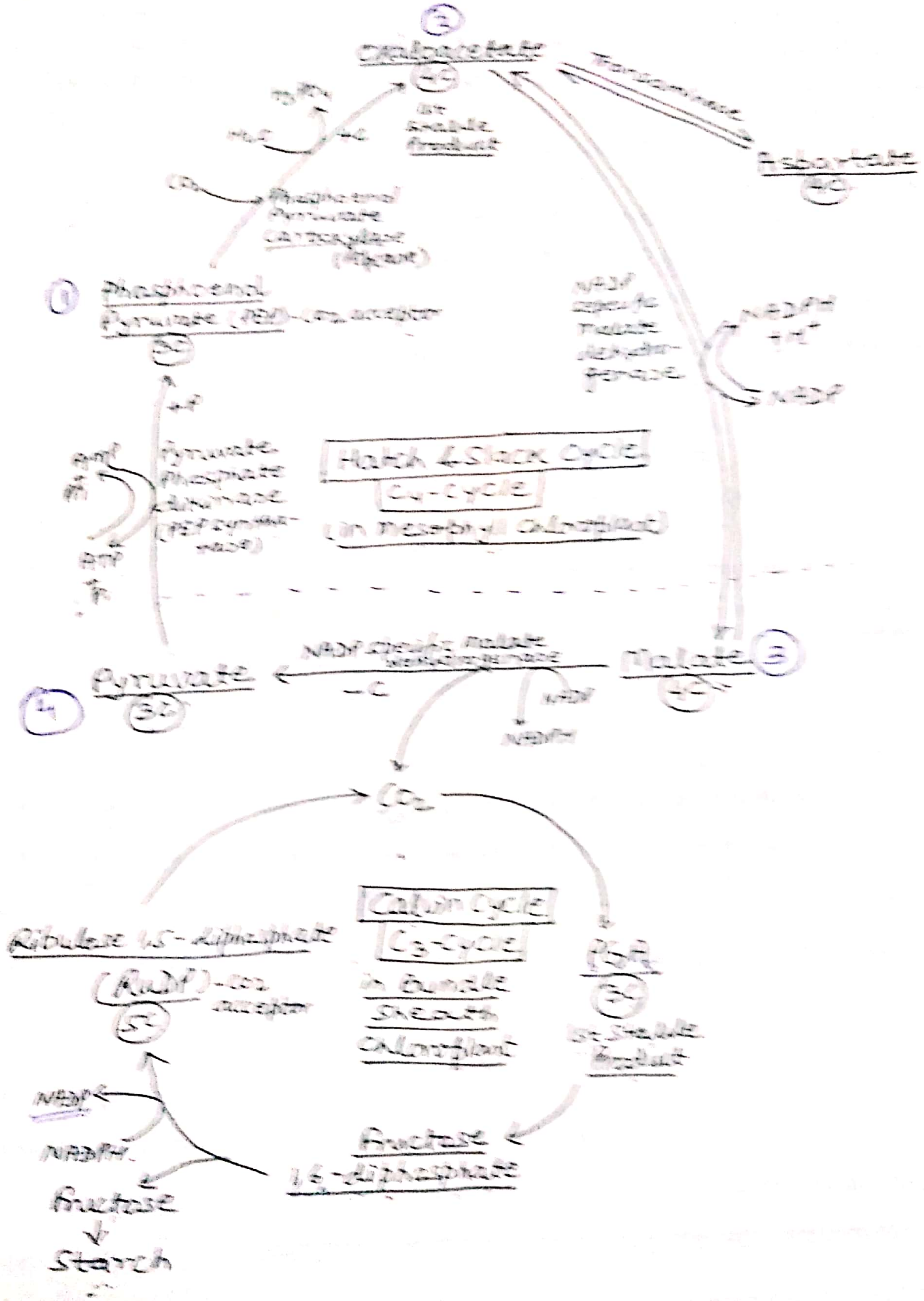
C_4 plants have two carboxylation reaction, the Hatch and Slack pathway and Calvin cycle both. So, it is also called as dicarboxylation cycle. ~~also~~

In the first step of Hatch and slack pathway, in the mesophyll cells, CO_2 is introduced by the carboxylation of phosphoenol pyruvate (PEP). The formation of PEP from pyruvate and ATP is initiated by the enzyme Pyruvate phosphate dikinase in mesophyll cells. Then PEP forms oxaloacetate after carboxylation. This step requires a molecule of water and releases a molecule of phosphoric acid as by product. Enzyme phosphoenol pyruvate carboxylase is needed in this reaction.

The oxaloacetate is rapidly converted into malate or Aspartate, depending upon species. Malate is derived from oxaloacetate by reduction with NADPH in the presence of enzyme malate dehydrogenase.

In the second phase, the malate is transported to the chloroplasts of bundle sheath cells, where it is decarboxylated by NADP specific malate dehydrogenase enzyme. Thus malate is converted into pyruvate and carbon dioxide.

The Pyruvate is then transported back to the chloroplast of mesophyll cells where, it is reconverted into the phosphoenol pyruvate by utilising energy of ATP.


Oxaloacetate
4C
1st stable Product
Transaminase
Aspartate
4C
Phosphoenol Pyruvate Carboxylase (PEPcase)
Phosphoenol Pyruvate (PEP)-CO2 acceptor
3C
NADP specific malate dehydrogenase
NADPH + H+
NADP
Pyruvate Phosphate dikinase
AMP
ATP
Hatch & Slack Cycle
C4-cycle
(in mesophyll chloroplast)
NADP specific malate dehydrogenase
Malate
4C
Pyruvate
3C
-C
NADP
NADPH
CO2
Calvin cycle
C3-cycle
in Bundle Sheath Chloroplast
Ribulose 1,5-diphosphate
(RuDP)-CO2 acceptor
5C
PGA
3C
1st Stable Product
Fructose 1,5-diphosphate
NADP
NADPH
Fructose
Starch

The liberated CO_2 from the decarboxylation reaction is incorporated into the calvin cycle. CO_2 is refixed by the RUDP carboxylase catalysed carboxylation of ribulose 1,5-diphosphate to produce PGA (Phospho-glyceric acid), the first product of the calvin cycle of photosynthesis. It follows the further steps of calvin cycle to produce sucrose and starch.

Here, it is interesting to note that there are two carboxylation reactions in C_4 plants.

<u>Biological Significance of C_4-cycle</u>

The net photosynthetic rate is higher in C_4 plants due to the lack of photorespiration. It is believed that C_4 plants are well adapted to grow at low water content and higher temperature and light intensities, at which photosynthesis in C_3 plants would have stopped.

A plant can photosynthesise even in presence of very low concentration of CO_2 (10 ppm). The partial closure of stomata due to xeric conditions would not disturbs the rate of C_4 cycle. The photosynthetic rate remain higher also ~~due to~~ because it does not reach at saturation point even in full sunlight.

Therefore, the C_4 plants can adapt to grow in low water content and higher light intensities. In this way, C_4 cycle is specially suited to such plants which grow in dry climates of tropics and subtropics.

—x—