Plant Biochemistry

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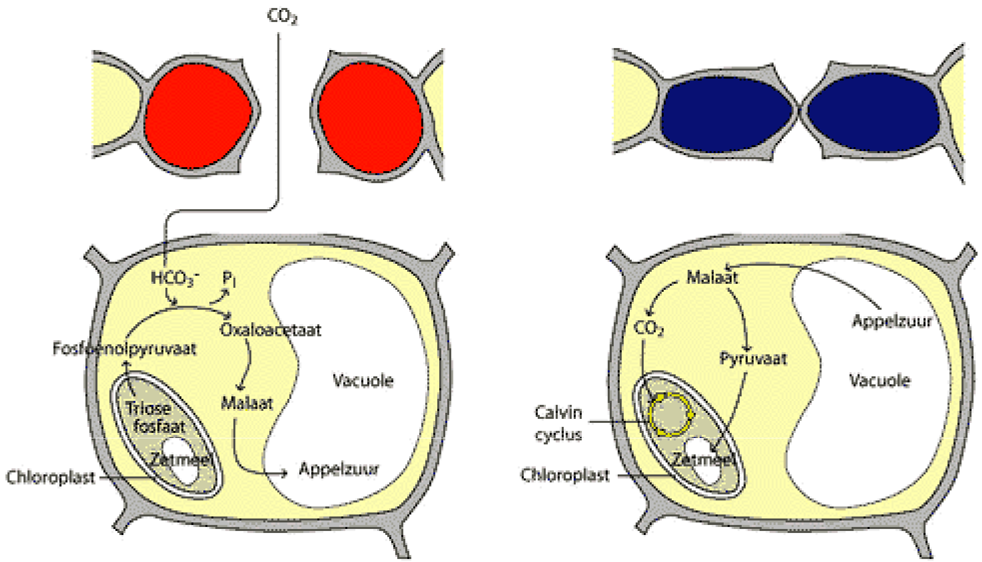
CAM

Crassulacean acid metabolism

Another CO^2 concentrating mechanism that results in even greater water savings

Crassulacean Acid (Zuur) Metabolisme (CAM)



A Nacht: sluitcellen open

B Dag: sluitcellen dicht

CAM

Crassulacean acid metabolism

- To survive in a dry environment with little and irregular rainfall, succulent plant may store water in any of their body parts, i.e. leaves, stems and roots.

- This system is only effective with sufficient isolation and with a large storage capacity.

- Since the absorption of CO_2 is only possible at night, CO2 storage and changes in metabolism are necessary to carry out photosynthesis by day.

- At night CO_2 is stored as malate in the large vacuoles, to be released for photosynthesis by day.

  This mechanism was discovered first in Crassulacean plants, such as Crassula and therefore is called Crassulacean Acid (acid: malate) or CAM Metabolism.

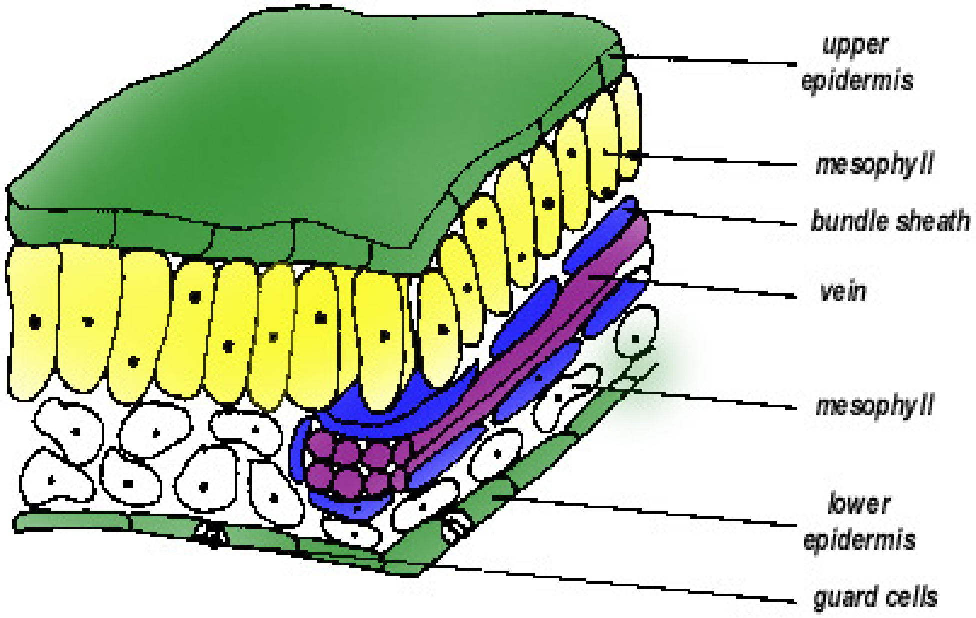
- These plants often show specific adaptations in their metabolism (CAM metabolism).

  To prevent water loss, the stomata of these plants are closed by day,

  to open only at night when temperature decreases and humidity rises.

- This type of metabolism appeared to occur not only dicotyledonous plants Cactaceae, but also in a number of monocotyledonous, among others the crop pineapple and the pot plant Sanseveria

CROSS-SECTION OF A LEAF



During the night

the CAM plant's stomata are open, allowing CO_2 to enter and be fixated as organic acids that are stored in vacuoles.

During the day

the stomata are closed (thus preventing water loss) and the carbon is released to the Calvin Cycle so that photosynthesis may take place

- The carbon dioxide is fixed in the mesophyll cell's cytoplasm by a PEP reaction similar to that of C4 plants.
- But, unlike C4 plants, the resulting organic acids are stored in vacuoles for later use; that is, they are not immediately passed on to the Calvin Cycle.
- Of course, the latter (Calcin cycle) cannot operate during night because the light reactions which provide it with ATP and NADPH cannot take place without light.

The benefits of CAM

- The most important benefit to the plant is the ability to leave most leaf stomata closed during the day.
- CAM plants are most common in desert, where the weather is very dry.
- Being able to keep stomata closed during the hottest and driest part of the day reduces the loss of water through evapotranspiration, allowing CAM plants to grow in environments that would otherwise be far too dry

During the day

- The carbon in the organic acids is freed from the mesophyll cell's vacuoles and enters the chloroplast's stroma and thus into the Calvin Cycle

Comparison with C_4 metabolism

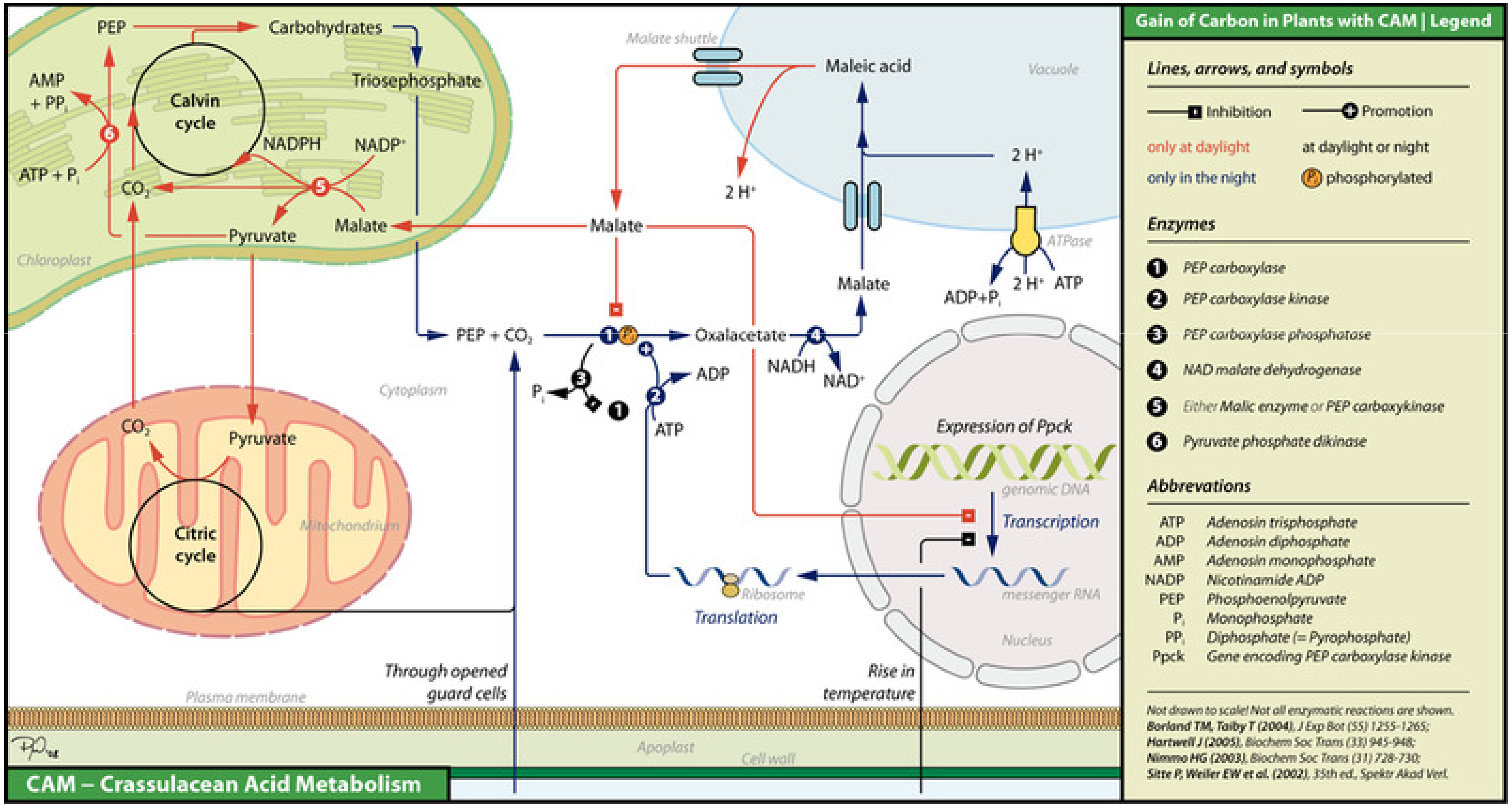
- CAM is named after the family Crassulaceae, to which Jade plant belongs

- The C_4 pathway bears resemblance to CAM; both act to concentrate CO_2 around RuBisCO, thereby increasing usefulness

- CAM concentrates it in time, providing CO_2 during the day, and not at night, when respiration is the dominant reaction.

- C_4 plants, on the contrary, concentrate CO_2 spatially, with a RuBisCO reaction centre in a "bundle sheath cell" being inundated with CO_2.

Biochemistry of Crassulacean Acid Metabolism



- Plants with Crassulacean Acid Metabolism (CAM plants) must control storage of carbon dioxide and its reduction to branched carbohydrates in space and time.

- At low temperatures (frequently at night), when CAM plants open their guard cells, carbon dioxide molecules diffuse into the spongy mesophyll's intracellular spaces and finally get into the cytoplasm.

- Here, they can meet phosphoenolpyruvate (PEP), which is a phosphorylated triose.

- the enzyme PEP carboxylase catalyze the formation of oxalacetate that can be subsequently transformed into malate by NAD malate dehydrogenase.

* $CO_2 + H_2O \longrightarrow H_2CO_3 \longrightarrow H^+ + HCO_3^-$

* $HCO_3 + PEP \xrightarrow{\text{PEP carboxylase}} \text{Oxaloacetate}$

* $\text{Oxaloacetate} + NADH + H^+ \xrightarrow{\text{Malate dehydrogenase}} \text{Malate} + NAD^+$

- Malate is then transported via malate shuttles into the vacuole, where it is converted into the storage form malic acid.

- CAM plants have large vacuoles (about 90% of the cell).

- PEP carboxylase is active during night.
- Rubisco is active at day.

- At daylight, CAM plants close their guard cells and discharged malate that is subsequently transported into chloroplasts.
- There, depending on plant species, it is cleaved into pyruvate and carbon dioxide either by malic enzyme or PEP carboxykinase.
- Carbon dioxide is then introduced into the Calvin cycle,

- The by-product pyruvate can be further degraded in the mitochondrial citric acid cycle and therefore, provides additional carbon dioxide molecules for the calvin cycle.

- Alternatively, pyruvate can be also used to recover PEP via pyruvate phosphate dikinase, a high energy step, which requires ATP and an additional phosphate

- In the following cold night, PEP is finally exported into the cytoplasm, where it is involved in fixing carbon dioxide via malate