What Does CAM Mean to Your Cacti?

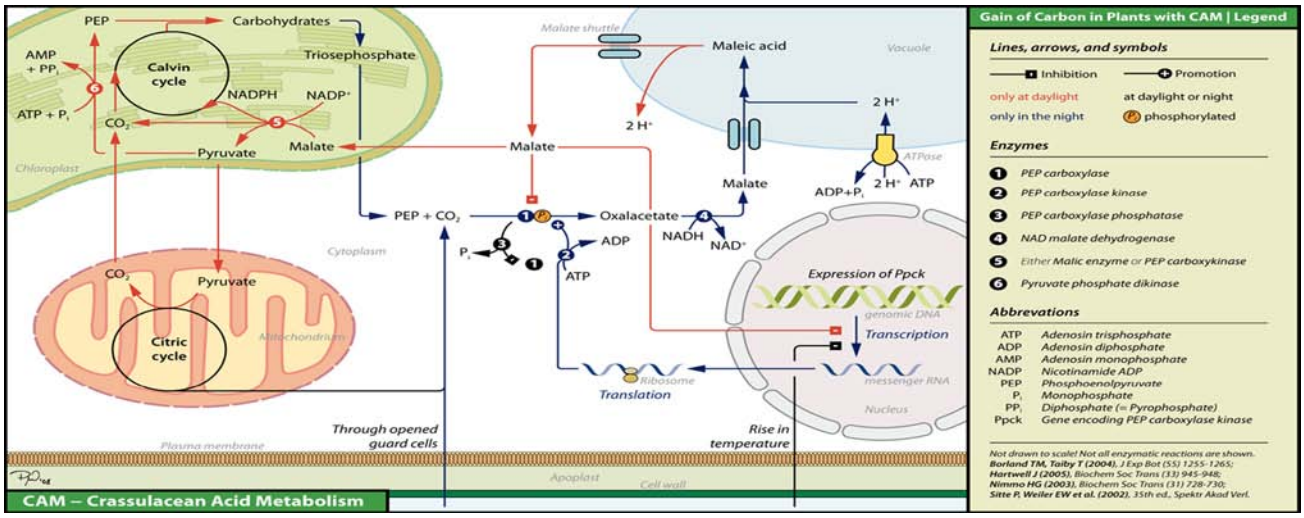
by: Patsy M. Miller, Ph.D.

MY CACTUS GROWS VERY WELL, THANKS TO CAM

CAM is the way cacti "make their living." Crassulacean acid metabolism (CAM) is the process cacti use to convert carbon dioxide gas into sugars and starches. CAM is one of the three methods plants use in photosynthesis. The other two methods, C3 and C4 , perhaps will be a topic for another Desert Awareness Committee column.[1]

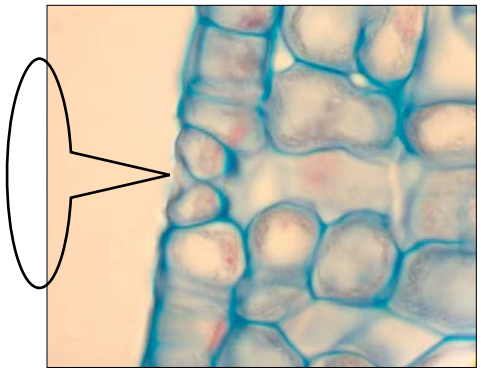
CAM[2] occurs in over 20 families of land plants including cacti native to the Upper Sonoran Desert. The discovery of this type of photosynthesis was based on observations made by Benjamin Heyne in 1815 who reported that the leaves of a succulent *Kalanchoe calycina*, a type of stonecrop (common name for these little plants), accumulated acid at night. He tasted leaves of his succulent plants and found that they tasted very acid in the early morning, became less acid tasting during the day, but regained their acidity by the next morning. Not until about 150 years later was the underlying mechanism and importance of this observation understood.

The Biochemistry of CAM



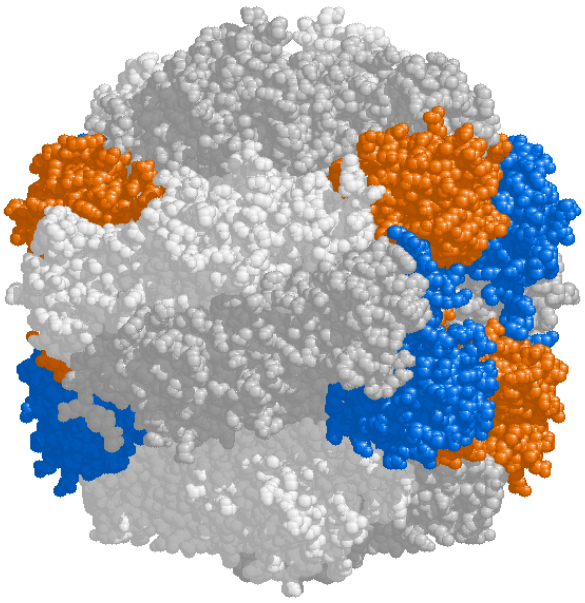
("How does your cactus grow? – perhaps more than you care to know) [Wikipedia]

To conserve water, a cactus open its stomates, which are small pore-like openings in the outer skin (epidermis), at night and closes them during the day. During the night carbon dioxide (CO_2) diffuses through the stomates along a concentration gradient from the air into the interior of a cactus. This is a rather tortuous trip. First the CO_2 must dissolve in water because all the biochemistry inside the plant takes place in aqueous solutions. Then it crosses a membrane, through the magic of biochemistry is "transformed" into malic acid in the liquid cytosol, crosses another membrane, and is stored as malate in the vacuole (the large storage compartment in the center of a living plant cell). After spending the night in the vacuole, malate is transported back to the cytosol where, using energy from the sun and catalyzed by RuBisCo (the most common enzyme on Earth), it is turned into sugars and starches which the cactus uses to maintain itself and to grow.



A stoma in cross-section
(note the two guard cells)

Ribulose-bisphosphate carboxylase



Space filling view of RuBisCO showing the arrangement of the large chain dimers (white/grey) and the small chains (blue and orange).

This daytime biochemistry is the same process (C3 and C4) used by all other plants to produce sugars and starch. The difference is that in cacti all of this biochemistry takes place while the stomates are closed. By keeping their stomates closed during the day, cacti conserve water. In the Upper Sonoran Desert, air and plant tissue temperatures are often considerably lower at night than during the day. Since the vapor content of the air (relative humidity) is strongly dependent on air temperature, relative humidity is higher at night than during the day. Higher relative humidity reduces the amount of water

that is lost from the inner surfaces of the stomates when the stomates are open during cooler nighttime hours. The amount of water lost (transpired) by a cactus can be seven times less at night than would be lost if the stomates were open during the day.

When soil water is severely limited, as it is during the current drought, the stomates of cacti may not even open at night. No water is lost through transpiration, but no additional CO_2 can be taken up. Cacti still have to support internal metabolic processes; they do this through a process called CAM "idling," which was first described by Dr. I. P. Ting of University of California-Riverside. Malate moving in and out of the vacuoles releases enough CO_2 to support the "basic metabolism" of cacti. During these periods of water deprivation cacti cannot grow, but they can survive until the next rain event allows them to open their stomates at night and again take up CO_2.

Although the highest CO_2 uptake rates measured for cacti are only about one-fourth of those measured for corn, they are similar to maximum rates for ferns and many trees. When *Opuntia ficus-indica* (Indian fig cactus) is grown in an area with adequate rainfall and is fertilized, it can produce as much dry weight per meter square of ground area as rice or corn.

photo: Dave Mills

Indian Fig
Opuntia ficus-indica

So if someone asks you, "How does your cactus grow?" you can answer, "Very well, thanks to CAM."

This article is based on information in *The Cactus Primer* by A. C. Gibson and P. S. Nobel, and *Environmental Biology of Agaves and Cacti* by P. S. Nobel.

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[1] This article first published July 2002.

[2] See related article in Wikipedia.