Plant Growth Processes

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Leaves are the primary energy factories for our orchids, harnessing the energy of the sun to produce food for growth and reproduction. Orchid leaves have a waxy cuticle surface that limits water loss through evaporation and a low density of stomata on their undersides. These adjustable pores facilitate the entry of carbon dioxide gas into the leaf for photosynthesis as well as allow water vapor to exit the leaf in the transpiration process. There is a tradeoff between the energy gain from photosynthesis vs. the water loss from transpiration. Many orchids have adapted to this photosynthesis/transpiration compromise by modifying their growth processes.

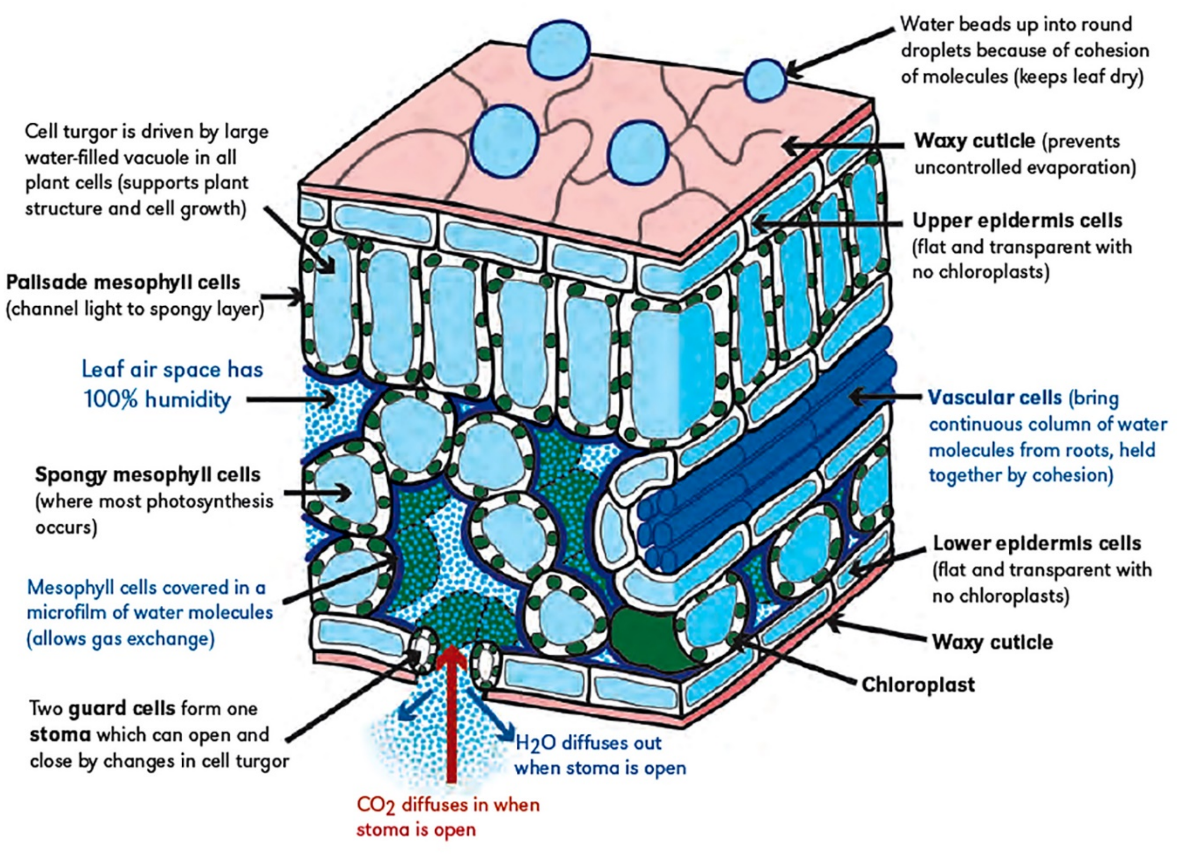

Figure 1. Cells are the fundamental unit of all living things. All plant cells contain the same basic makeup of a nucleus, cytoplasm, organelles, cell membrane, and a cell wall. Many water relationships exist within plant leaves.

Source: Plant Growth Processes: Transpiration, Photosynthesis, and Respiration, University of Nebraska Extension EC1268.

Transpiration. Plants do not have a heart to pump fluid in their vascular system. Instead, water movement is passively driven by pressure and chemical potential gradients. The bulk of water absorbed and transported through plants is moved by negative pressure generated when water evaporates from the leaves, known as transpiration. Water enters the roots, moves up the plant through the xylem and exits through stomata, defying gravity. Transpiration controls essential growth processes.

Evaporative Cooling. Plants transpiring are able to cool their leaves through evaporative cooling as long as the stomata are open. This transformation from the liquid to gas phase has a cooling effect that helps prevent leaf tissues from overheating when growing in direct sunlight.

Carbon Dioxide Absorption. As long as the stomata are open, carbon dioxide is absorbed from the atmosphere for use in the photosynthesis process. Plants can close their stomata to limit water loss during periods of drought or high temperature, but this limits photosynthetic output.

Plant Turgor. The majority of plant tissues are comprised of water and they require a certain cellular water pressure to function properly. The water lost through open stomata must be continually replaced to maintain cell turgor.

Nutrient Uptake. Much of the mineral nutrients are absorbed by the roots and distributed throughout the plant via the transpiration process. Calcium uptake in particularly is dependent on a strong transpiration rate.

Environmental Conditions Affecting the Transpiration Rate		
Environmental Change	Change in Transpiration Rate	Rationale
Increase in Light	Increase	Light Causes Most Stomata to Open
Increase in Temperature	Increase	Water Evaporates More Rapidly and Warm Air Holds More Moisture
Decrease in Root Zone Moisture	Decrease	Less Water Available to Enter Plant Roots
Increase in Wind	Increase	Reduces Humid Boundary Layer Around Leaf
Increase in Humidity	Decrease	Air Moisture Gradient is Not as Steep
Based on Information in Plant Growth Processes: Transpiration, Photosynthesis, and Respiration, University of Nebraska Extension EC1268.		

Photosynthesis is the process by which carbon dioxide absorbed from the atmosphere is transformed into carbohydrates and sugars using light as the energy source. Photosynthesis occurs in the chlorophyll-containing chloroplasts during daylight hours. Depending on the photosynthetic pathway, the stomata are open during the day in some orchids while others are open at night.

C3 Pathway. Thin leaved orchids like many of the oncidiniiae tend to photosynthesize using the C3 pathway (the first stable metabolite is a three carbon sugar). The stomata are open during the day so carbon dioxide can be absorbed during daylight hours while photosynthesis is underway and water vapor is expelled in the transpiration process. In some plants, in excess of 90% of the water absorbed by the roots is transpired through the leaves. If more water is transpired than can be absorbed by the roots, the plants can decrease the stomatal opening to limit evaporation although this will likewise decrease the amount of carbon dioxide that can enter the leaf, reducing potential photosynthetic output.

CAM Pathway. Thick leaved orchids like many in the cattleya alliance and phalaenopsis grow in trees and on rocks with exposed roots subject to dessication during dry periods. These succulent orchids convert light energy to chemical energy using the CAM (an acronym for crassulacean acid metabolism) pathway. They have adapted to their dry xerophytic environment by keeping their stomata closed during the day to prevent water loss, opening at night when the temperatures are lower and humidity higher. Because carbon dioxide can only be absorbed at night, it must be stored chemically in the thick leaf for subsequent use during the day light hours when photosynthesis occurs. CAM orchids tend to have a thicker cuticle and lower density of stomata than C3 orchids.

The CAM adaptation, also used by succulents, benefits the plant by reducing water loss from transpiration but it is a much less efficient process so CAM plants tend to grow more slowly. Interestingly, some orchids can photosynthesize using the C3 pathway under favorable conditions and switch to CAM photosynthesis when challenged by environmental constraints (C3-CAM or facultative CAM plants) while others can only photosynthesize via the CAM pathway even under optimal environmental conditions (obligate or constitutive CAM plants). The degree of succulence is a good indicator of metabolic pathway, with the more succulent orchids more likely to be strong CAM plants. With closed stomata during the daytime, water and nutrients are not drawn into the root system by the transpiration process so water uptake is driven only by differential osmotic pressure at a lesser rate than when transpiring. C3 plants require much more water to produce a certain amount of biomass than CAM plants and they also have a higher maximum rate of net photosynthesis than CAM plants. (Hew and Yong).

Most orchid growers probably have both C3 and CAM plants in their collections. Thin-leaved C3 plants start transpiring at sunrise, absorbing carbon dioxide and photosynthesizing, with the stomata open to cool the leaves while absorbing the water and fertilizer we apply in the morning. Strong CAM plants, though, close their stomata during the day so they cannot cool themselves or move as much water and nutrients up through the xylem during the heat of the day. It is important to make sure these plants do not overheat by providing adequate air movement and shading. In extreme heat, you can help keep your plants cool by wetting the surfaces under benches and on the outside of clay pots.

Early morning watering is the consensus recommendation, but during periods of low humidity, transpiration rates are high and water may evaporate so rapidly it is difficult to keep plants hydrated. During these periods, you might consider Courtney's suggestion to water in the late afternoon so the orchid roots stay wet and absorb moisture overnight, particularly those CAM plants that transpire during these hours. In the early morning, you can apply fertilizer (do not apply fertilizer in the evening to avoid fungal issues). Our experience has been that as long as nighttime temperatures are above 60F, the dew point is below 60F and air movement is good, evening watering works in the St. Augustine area.

Respiration is the process by which carbohydrates and sugars are oxidized releasing chemical energy to maintain plant function, fuel plant growth and produce flowers and seeds. This process is the reverse or photosynthesis, requires oxygen and is temperature dependent, occurring more quickly as temperatures increase. The imbalance between carbohydrate production and consumption is most pronounced at night when there is no photosynthesis. If all the photosynthates made by the plant during the day are consumed in cellular respiration (the so-called compensation point), there is just enough energy to maintain the plant, with no extra reserves for new growth, much less for blooming. Lower nighttime temperatures slow down the rate at which reserves are respired, allowing them to be conserved for growth and ultimately flowering.

Orchids have been evolving for millions of years and have adapted to a broad spectrum of environmental conditions. The more we understand how they grow, the better orchid growers we can be. Some simple guidelines: make sure your plants remain adequately hydrated while maintaining an airy environment around the roots. Make sure they get enough of the right kind of light to manufacture carbohydrate reserves. Provide sufficient air movement and shade to prevent overheating during daylight hours. Expose them to cooler nighttime temperatures so there is enough stored energy for blooming. When you see two or more new growths where last year you had only one, you know your orchids are growing well and your floral reward is soon to appear.

Citations and Additional Reading:

Cushman, John C. (2001). Crassulacean Acid Metabolism. A Plastic Photosynthetic Adaptation to Arid Environments. *Plant Physiology* December 1, 2001 vol. 127 no. 4 1439-1448 doi: http://dx.doi.org/10.1104/pp. 010818

Hew, C.S, and Yong, J.W.H., *The Physiology of Tropical Orchids in Relation to the Industry,* World Scientific Publishing, Singapore. 1997. *Chapter 3, Photosynthesis.*

Holding, David R. and Anne M. Streich. (2013). Plant Growth Processes: Transpiration, Photosynthesis, and Respiration. University of Nebraska Extension. EC1268
Accessed 5/13/17: http://go.unl.edu/plantgrowth

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Kerbauy, Gilberto Barbante, Cassia Ayumi Takahashi, Alejandra Matiz Lopez, Aline Tiemi Matsumura, Leonardo Hamachi, Lucas Macedo Félix, Paula Natália Pereira, Luciano Freschi and Helenice Mercier (2012). Crassulacean Acid Metabolism in Epiphytic Orchids: Current Knowledge, Future Perspectives, *Applied Photosynthesis*, Dr Mohammad Najafpour (Ed.), InTech, DOI: 10.5772/29144. Available from: https://www.intechopen.com/books/applied-photosynthesis/crassulacean-acid-metabolism-in-epiphytic-orchids-current-knowledge-future-perspectives

Lindsten, Clarence S. (1973). The Four Basic Steps to Plant Growth. *American Orchid Society Bulletin* 42 (9) 780-781.

Rodrigues. Maria Aurineide, Alejandra Matiz, Aline Bertinatto Cruz, Aline Tiemi Matsumura, Cassia Ayumi Takahashi, Leonardo Hamachi, Lucas Macedo Félix, Paula Natália Pereira, Sabrina Ribeiro Latansio-Aidar, Marcos Pereira Marinho Aidar, Diego Demarco, Luciano Freschi, Helenice Mercier, Gilberto Barbante Kerbauy. (2013). Spatial patterns of photosynthesis in thin- and thick-leaved epiphytic orchids: unravelling C_3–CAM plasticity in an organ-compartmented way. *Ann Bot* 2013; 112 (1): 17-29. doi: 10.1093/aob/mct090

Silvera, Katia, Louis S. Santiago, John C. Cushman, Klaus Winter. (2009). Crassulacean Acid Metabolism and Epiphytism Linked to Adaptive Radiations in the Orchidaceae. *Plant Physiol.* April 2009 149: 1838-1847. First Published on January 30, 2009; doi:10.1104/pp.108.132555

Withner, Carl L. (1964). The Importance of Light for Orchid Growth: The Intensity of Light. *American Orchid Society Bulletin* 33 (3) 218-220.