

reproducing them. I found that even the more delicate *Droseras* tend to grow well outdoors in spite of the summer heat as long as sufficient water is provided at all times. While partial shading appears to be beneficial to some species, most appear to thrive without any protection from the sun, even in a location where the sun is intense and clouds are few. Despite what many earlier authors on the subject of carnivorous plant cultivation may contend the need to provide artificially high humidity for many common species seems to have been overemphasized. If the other requirements of light, water, soil, and dormancy cycles are observed, the humidity question seems to fade away, at least in the hot, semiarid environment of inland Southern California.

Are Genlisea traps active? A Crude Calculation

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I find the structure of the *Genlisea* trap very interesting, although they are not well understood in the botanical literature. Many questions remain unanswered. Are prey attracted or do they just wander into the traps? How is the prey retained in the utricle (the trap's digestive chamber) and how is it digested? How are the digested nutrients retained and then assimilated? With more time and research, these questions will be answered.

The form of *Genlisea* traps is well known, and I described some of its features in the previous article. In this article I concentrate on a single aspect of the *Genlisea* trap, an aspect that would seem to be a flaw in the trap's construction. An observation has been made by Juniper, Robins, and Joel in the book, *The Carnivorous Plants* (hereafter JRJ), which may point to the plant's solution to this flaw—namely that the trap is actually active. To complete my conjectures, I present an approximate calculation exploring whether this is plausible.

It seems CP are fairly efficient digestion mechanisms. *Dionaea* traps allow prey to escape if the prey are too small to be worth digesting. JRJ report that *Drosera erythrorhiza* absorb a full 76% of the available nitrogen in insect prey. Yet consider the fate of a rotifer (to choose a likely nutrient source) swimming along the interior of a *Genlisea* trap. Because of strategically located trap hairs it can only swim towards the utricle where it dies and is broken down for absorption. But what of the chemicals released by the dissolving rotifer, before they are absorbed by the plant? There are no one-way valves at the entrance of the utricle (as there are in *Utricularia* bladders), and inward pointing hairs have no effect on individual molecules. So what prevents a significant portion of the valuable nutrients from diffusing through the utricle entrance, out of the trap, and away from the plant?

How does *Genlisea* prevent a wasteful loss of nutrients from the trap? Or does it simply operate inefficiently? JRJ make an observation which may be important (pg. 126). They note that utricles contain not only the digested carcasses of prey, but also particles of dirt. The traps of *Genlisea* hang downward, so it is difficult to explain how sinking or drifting dirt particles could find their ways into the utricle. After settling into the spiral trap entrance, the particles would need to inexplicably rise into the trap mouth, through the trap tube, and into the utricle. Instead of that unlikely scenario, is it possible these bits of detritus have been sucked into the trap by the plant's effort? Perhaps the plant is expelling water from the trap through the utricle walls. New water from outside the trap would flow up the trap tube to replace the water removed from the utricle. The expulsion would be comparable to the phase in which water is removed from the interior of a sprung *Utricularia* bladder and is excreted into its surroundings. This is not too implausible since the two genera are closely related and the traps of both genera contain similar internal and external glands. The purpose of this expulsion might be to suck valuable nutrients into the cell walls, and thus prevent their escape from the trap. *Genlisea* traps may be active and not passive.

I decided to make a few simple calculations to see if it is even wildly possible that a *Genlisea* trap could function as a pump. Could it remove water from its utricle at a

rate sufficient to overcome the molecular speed of nutrients diffusing down the trap tube to the trap bifurcation, and then into open water? Being a scientist, I know that approximate calculations provide insight to basic phenomena. You can get a rough idea of what is going on, or if a mechanism is possible—then let the next group of researchers worry about the details! To treat this problem I needed to calculate two velocities. First, what is the velocity of liquid being sucked through the trap tube to the utricle? Second, what is a typical velocity at which nutrient molecules diffuse out of the trap? If the velocity of fluid up the tube (V_f) is greater than a molecule's diffusion speed (V_d) then the plant could overcome diffusion and thus maximize its efficiency. If you find math uninteresting or paralyzing, skip the next three paragraphs and read the one starting with "I don't expect you...." for the results.

First I estimated the flow velocity through the tube. JRJ note work by various researchers who measured that *Utricularia* bladders expel about 40% of their fluid volume in approximately 20 minutes. Assuming a spherical bladder 1 mm in diameter, this corresponds to $1.74 \times 10^{-7} \text{ cm}^3/\text{sec}$ of water pumped through its surface area. Some research suggests the glands scattered over the entire exterior surface of the bladders are responsible for removing the internal bladder fluid. Since similar glands are found on the exterior of the *Genlisea* utricle, it is plausible they remove water from the trap in the same way. Modeling a typical large African *Genlisea* utricle as a sphere 4 mm in diameter, it would have sixteen times the surface area of the *Utricularia* bladder and could pump water sixteen times faster. As this water is sucked through the narrow trap tube, which has an inner diameter of about 0.05 cm, it would produce a flow velocity of $V_f = 0.0014 \text{ cm/s}$.

And what is the diffusion speed of nutrient molecules through water? This is a little more complicated. A molecule of mass m and at temperature T (in Kelvins) will have a molecular velocity W approximately given by $\frac{1}{2} mW^2 = kT$, where k is Boltzmann's constant. For a typical nutrient like the phosphate ion (PO_4^{3-}) at $T=25^\circ\text{C}$, $W=2.3 \times 10^4 \text{ cm/s}$. As this ion races among the water molecules, it will travel only a short distance L before colliding with one. This distance is called the mean free path. (The mean free path can be estimated using $L^3 = m/p$, where m and p are the molecular mass and density of H_2O .) The time for a particle to traverse a mean free path is given by $t=L/W$. Because of all these molecular collisions, the ion will not travel in a straight line. Instead it will randomly wander around. It can be shown that after n molecular collisions, the ion will have wandered a distance X from its starting point, where $X=n^{1/2}L$. For it to wander about 1.5 cm (the length of the trap tube for a large *Genlisea*) the ion will suffer 2.3×10^{15} collisions! To wander this distance will take the phosphate ion a total amount of time equal to nt , so I can write the effective diffusion velocity as $V_d = (n^{1/2}L)/(nt) = L/(n^{1/2}t) = W/n^{1/2}$. For our nutrient ion, this gives a diffusion velocity of $V_d = 0.00048 \text{ cm/s}$.

My velocity calculations were admittedly crude and did not consider a wealth of interesting details. But unless I made a fatal blunder and neglected an important effect, the details that would make these calculations many times more difficult are unlikely to change the results too much. I note for example that I did not treat the effects of intermolecular forces at all. But these forces would only conspire to decrease diffusion velocities, and therefore make the trap even more effective. I think the strongest criticism against my argument is that the methods of water excretion in both *Utricularia* and *Genlisea* traps are not understood. In spite of its greater size a *Genlisea* trap might pump fluid only at the same rate as a *Utricularia* trap. But still the flow and diffusion velocities would be roughly comparable and the pumping mechanism would be useful for the plant. After all, diffusion is a random process and the diffusion velocity I calculated is only a typical value for a molecule—there will always be faster and slower particles. So the precise value of V_d is not important. For this reason, I am not too concerned with my choice of a phosphate ion as the test particle— V_d is modified only by the square root of the nutrient's molecular mass. I would be very surprised if all my approximations would combine to change the ratio

of velocities I calculated by as much as 100.

I don't expect you necessarily followed that calculation. But the point is the following: simple estimates show that a *Genlisea* trap may be fully capable of generating a current into its stomach with a speed three times faster than the speed at which nutrient molecules could escape. This tactic would allow *Genlisea* to extract a greater percent of nutrients from its prey. Perhaps the water-sucking phase of a *Genlisea* trap only occurs when the trap is signaled by some mechanical or chemical means, analogous to the 20 minutes of water expulsion *Utricularia* bladders experience after they have been sprung. In fact, a *Genlisea* would have to draw fluid through its utricle for 18 minutes to completely change the fluid in its tube. It is striking that this is about the same time period as for a *Utricularia* bladder's water suction phase. Maybe *Genlisea* swallows!

Finally, while these calculations are interesting and even evocative, they do not prove anything. It might just be that despite any calculations *Genlisea* is a passive carnivore. Proof must await the laboratory and not the calculator. But an experimental investigation to prove or disprove the hypothesis that *Genlisea* is active would be relatively easy to perform. Place a chemically killed but structurally intact *Genlisea* trap next to a live and functioning one. Observations of how quickly dyes migrate through the tubes of each trap should reveal if the live trap is drawing dye into its utricle faster than the dead trap. Unfortunately I have neither the facilities nor the familiarity with biological lab methods to do this experiment to my own satisfaction, so I will leave that job to someone else. Clearly, this is a field of study that is in need of solid experiments for information and insights into the mechanism of this fascinating plant.

CP Paradise in the Bush

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When we first bought our 5 acre block here in Queensland, it was during a severe drought but I could see the remains of dead *Drosera spatulata* here and there. When we moved here, it was after a very wet summer and fall so the CPs were again growing, but this was short lived as the next summer was long and hot with virtually no rain, so the CPs departed again.

This summer had good rain in the latter half, and the fall has also been quite wet, so that the CPs have returned again. The species that has been quickest to recolonise parts of the block has been *Drosera burmanii*, which has established colonies and scattered plants in various areas.

D. spatulata is also becoming obvious again, however, it is a little slower in colonising areas, probably due to the fact that it is a slower grower than *D. burmanii*. *D. pygmaea* is also present, but much harder to find due to its smaller size.

I have also found my first plant of *Byblis liniflora* for this year, as I had not seen it here for about two years due to the drought. It seems to only grow during very wet periods. The same can be said for *Utricularia lateriflora*, which can only be found after the ground becomes really waterlogged.

I am able to find scattered clumps of *U. lateriflora* in various areas, and most are rather small plants with small off-white flowers. However, I recently found a large form of this species that has purple flowers around the same colour as *U. dichotoma*. At first I thought it was this latter species, until I took a closer look.

The flowers are approximately twice as big as the smaller form, on scapes four times as long. The leaves appear to be around 1 1/2 times the size of the smaller form.

I've also again found what appears to be a tiny annual species of *Utricularia*, with a minute purple flower about .5 mm on a scape only a few millimeters long. It is extremely difficult to find, and you have to be in the right place, and specifically looking for it, in order to find it.

Most of our block is left as natural bushland, with only areas near the house and



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