

Letter from the Desk of David Challinor  
March 2006

In my January 2006 letter I used carnivorous plants as an interesting example of plant/insect interactions. Investigation continues into the evolutionary path of these plants that grow in impoverished soils and supplement essential nutrients by digesting insects. More fascinating for me are the insects that have evolved strategies to “beat the system,” by exploiting the nutrient-rich broth that carnivorous pitcher plants maintain to feed themselves. This month’s letter will look at four arthropods: a mosquito, a spider, a fly and a moth; they have managed to avoid entrapment in the pitcher plant’s slippery cavernous maw and to exploit this dangerous niche for their protection and nourishment.

The mosquito *Wyeomyia smithii* is not a glamorous insect, but is valuable for research as it does not need a blood meal to reproduce, as do most other mosquitos. Most of its life cycle takes place within a single purple pitcher plant (*Sarracenia purpurea*), a plant common in bogs and marshes from Canada to the Gulf Coast. The pitcher-shaped pale green leaves grow directly out of the ground and thus partially fill with rain water. Unlike other carnivorous plants, the pitcher plant does not release enzymes to digest its insect prey but instead relies on bacteria to do so, thereby furnishing nutrients to the host plant as well as to the mosquito larvae. They share this watery broth with protozoa, rotifers, mites and other micro-organisms, most of which must pass all or a major part of their life cycles within the plant.

Each spring *Wyeomyia* females deposit one egg at a time in different pitcher plants. When the eggs hatch, the aquatic mosquito larvae are resistant to the resident bacteria and metamorphose into adults. Under ideal mild conditions, a single plant can serve as host for up to four or five mosquito cycles each summer, but two or three cycles are more normal. Adult mosquitos die in the fall when it becomes cold but their larvae survive the winter by going into “suspended animation” or diapause—the scientific term. The larvae of this mosquito are especially interesting because they are sensitive to photoperiod, i.e. when day length shortens to a critical period they stop molting and growing and resume growth only when spring day length reaches the same critical time.

The photoperiod of plants and animals is genetically controlled. Through an elegant experiment two scientists, William Bradshaw and Christina Holzapfel, discovered that *Wyeomyia* living at different latitudes in eastern North America began diapause at different times. In Canada, for example, they stopped growing in late July while in Florida not until well into September. From long-term collecting and careful recording they found that larvae from a swamp in North Carolina in 1972 began diapause when the critical day length was 14 hours and 21 minutes. In 1996 larvae from the same swamp changed their critical photoperiod to 13 hours and 53 minutes. This trend was found in populations of *Wyeomyia* elsewhere in North America with the change most pronounced in the northern latitudes, which are becoming warmer—more like southern ones. This

shift clearly demonstrates how global warming impacts natural selection to alter a key trait. For a detailed explanation of this phenomenon see Bradshaw and Holzapfel – Proceedings of the National Academy of Sciences – December 2001.

The small red crab spider (*Misumenops nepenthicola*) has also developed a life cycle to exploit carnivorous pitcher plants. These spiders live in Southeast Asia in several species of nepenthes pitcher plants—similar to our eastern North American one. As do many spiders, it ambushes its prey by waiting just below the inside edge of the plant's nectar-secreting leaf rim. The spider catches various small insects attracted by the nectar before they fall into the water below. This spider is so adapted to its host plant that when an insect does fall into the water, it will climb down to the water's edge to retrieve the drowning insect, but instead of saving it in the best lifeguard tradition, it eats it.

The female red crab spider is so at home in the plant that she fastens her egg sacs near the waterline so that when danger threatens, newly hatched spiderlings can fall into the water below with complete protection from any predator. Both adults and young can remain under water for up to half an hour. This behavior baffled arachnologist Simon Pollard of the Canterbury Museum in Christchurch, New Zealand. He reasonably thought they should succumb to the watery trap of the pitcher plant in the same way as its other victims.

Pollard determined that the water in the Southeast Asian pitcher plants lacked secreted digesting enzymes as did their North American relatives. Prey was, therefore, digested both by the bacteria in the water as well as the enzymes released by the victim's own body. Furthermore, the plant secreted a wetting agent similar to a detergent which, by destroying surface tension, prevented the insects from moving on the water surface. Mosquito larvae in these pitcher plants generally have a long snorkel tube to let them breathe below the surface. It took time for Pollard to discover how crab spiders could stay under water for so long. By bringing a pitcher plant into his laboratory and watching the spiderlings with a binocular microscope, he saw that before a spider dove, it trapped an air bubble in a small abdominal pit adjacent to its lungs. The bubble furnished air for underwater breathing, similar to the large fisher spider's (*Dolomedes spp.*) ability to trap enough air around its whole fuzzy body to allow submergence for hours. Fisher spiders, however, are vulnerable to surfactants (detergents, *et al.*) and when immersed in water so treated they fail to trap enough air to stay submerged. The question then arose as to how the small crab spider (1/10 the size of a fisher spider) could keep its bubble intact in the surfactant-laced water of the pitcher plant. Careful examination of the adult crab spider's abdominal pit showed it to be lined with long water-repellent hairs that hold the air bubble intact against the pit wall.

The final mystery to be solved was how the spiders were able to move around so agilely within the notoriously smooth and slippery inner leaf surfaces of the pitcher plant. The plant, after all, evolved to foil the escape of its prey, yet crab spiders were able to “beat the system.” The answer was in a network of webs that criss-crossed the pitcher's interior; the web strands were so fine as to be almost invisible to the naked eye.

A sarcophagid (eater of dead things) fly (*Fletcherimyia fletcheri*) has perhaps an even closer relation with pitcher plants than other arthropods in that its larvae, like those of *Wyeomyia*, live within the pitcher plant and feast on trapped prey as well as the microorganisms and mosquito larvae in the water. In late summer, however, the larvae crawl out and pass the winter as pupae in the surrounding sphagnum moss. Adult flies are important pollinators of pitcher plant flowers. To reduce the risk of these pollinators succumbing to its watery trap, pitcher plant flowers are on stalks high above and to the side of the pitcher's opening.

The mosquito, spider and fly do no harm to their host plant, and the pollinating fly is also crucial to its long-term survival. The bad guy, however, is a host-specific moth (*Exyra fax*) whose larvae feed on the inner surface of pitcher plant leaves; when ready to pupate and become a moth, they fasten their cocoon to the slippery surface of the leaf's interior. As obligate feeders on these leaves, the moth larvae cannot afford to kill all its hosts, but occasionally they will kill a plant or at least restrict its growth by damaging foliage. More lethal are the larvae of another moth with the glamorous name *Papaipema appassionata*. These larvae are borers and eat the plant's roots, thereby killing it by blocking nutrients to the leaves. Fortunately, these moths are relatively rare and their threat to these fascinating plants is fairly restricted.

As I have mentioned before, the enjoyment in writing these letters each month comes from the exhilarating reward of learning something new. In this pursuit I have been blest with full access to the library resources of the Smithsonian, which has let me tap the exciting discoveries of curious scientists the world over. As my eldest daughter, whose field is pediatric oncology, once said when struggling to persuade schools to accept terminal cancer children as students, "You are most alive when you are learning." This adage applies to us all.

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1) Information on *Wyeomyia* is from Elizabeth Kolbert's "Butterfly lessons" in *The New Yorker*, 9 Jan. 2006 pp.32-39;  
2) On crab spiders from Stephanie Pain's "Who Dares Spins," *New Scientist*, 24/31 Dec. 2005, pp.60-61;  
3) On pitcher plants from Aaron M. Ellison's "Turning the Tables: Plants Bite Back," WINGS, the Xerces Society, Fall 2005 pp.25-29.