Carnivorous plants

In addition to being a subject in the occasional Hollywood horror movie, carnivorous plants are possibly the most fantastic members of the plant world. Over time, they have developed unique morphological characteristics in order to survive, paying homage to Darwin’s theory of natural selection. How carnivorous plants evolved is still somewhat unknown to botanists, this, in addition to their morphology, adds to the mystery surrounding them.

In examining the evolution of carnivorous plants, it’s important to take into consideration the various hypotheses used to explain evolution, their unique morphology, functionality and efficiency, and habitat. These grisly flora are the mysterious strangers of the plant world, disregarding the traditional order in the food chain and carrying with them a fascinating history. Carnivorous plants are plants that trap and consume animals, usually insects, in order to obtain some of their nutrients. There are five basic trapping mechanisms: pitfall traps, flypaper traps, snap traps, lobster pot traps, and bladder traps.

These traps are all unique morphological adaptations that allow these plants to make up for soil lacking nutrients in the form of nitrogen and calcium. They often reside in areas like bogs, living in waterlogged soil that has a low, acidic pH. Other necessary elements, such as consistent sunshine exposure and moisture, are present in these habitats as well as a relatively low level of competition. In addition to allowing growth and reproduction, carnivory allows these plants to make up for what they can’t get in the soil they reside in, that being nitrogen and phosphorous (Thoren, Karlsson).

Carnivorous plants have evolved to thrive against adverse environmental conditions. The question that remains to be fully explained is how exactly these plants have evolved. The difficulty in explaining the evolution of carnivorous plants stems from the scarcity of fossils. The vast majority of the few fossils that have been found are usually seeds or pollen. Even if the plants were fossilized, the traps probably wouldn't be preserved. It is known that carnivorous plants have evolved independently at least six times in five angiosperm orders (Ellison, Gotelli). Despite this, they maintain a high level of morphological convergence.

This means that they have independent origins yet similar development. For example, it was long thought that pitcher plants in North America and Asia were cousins due to their methods of trapping insects. Both have leaves forming a pitcher shape rimmed with nectar glands that attract insects, only for them to fall into the pitchers and be broken down by digestive juices in the tubes. Although the American and Asian appear to be closely related, it's recently been discovered that they're very distant relatives, having descended from completely different blood lines (Angier).

New data shows that in comparison to those with simple sticky traps, carnivorous plant genera with morphologically complex traps have higher relative rates of gene substitutions (Ellison, Gotelli). With this knowledge, botanists have developed two hypotheses regarding the evolution of these plants. The energetics hypothesis states that rapid morphological evolution from a few changes in regulatory genes is responsible for meeting high energy demands of traps. The predictable prey capture hypothesis states that carnivorous plants developed complex traps because they yield more predictable and frequent captures (Ellison, Gotelli).

Botanists believe that traps developed from modifications of the same basic structure, the hairy leaf (Slack, Gate 18). The hairy leaf catches water, which causes insects to land on it, become trapped by the water's surface tension, and suffocate. The water promotes bacteria growth on the leaf, so bacteria breaks down the organism and the leaf absorbs its nutrients. Cupping the leaf allows rainwater to be maintained, represented by pitfall traps, and the production of mucilage causes the leaf to be stickier, represented by flypaper traps (Slack, Gate 18).

With this in mind, it is ideal to believe that carnivorous plants developed traps because the costs equaled or were surpassed by the benefits; evolving from a normal leaf to a pitcher shaped leaf proved to be more beneficial to the plant than costly. They also had to compensate for what their habitats were missing. The information on the hairy leaf exemplifies why the energetics hypothesis is more widely accepted by botanists: because it is more consistent with ecological cost-benefit models and accounts for data suggesting that carnivorous plants have leaf construction costs different from non-carnivorous plants (Ellison).

It is believed that carnivorous plants discovered insect consumption on their own. This claim is supported by the fact that carnivorous plants developed independently yet maintain convergent morphological traits. Because botanists believe carnivorous plants discovered insect consumption on their own, they wonder if other plants could do the same and henceforth develop similar morphological adaptations to carnivorous plants. A study reveals that the closest relatives to carnivorous plants, which include tobacco, tomato, rhubarb, and buckwheat, have the rudimentary equipment that could transform these plants into insectivores (Angier).

These plants have tiny, sticky hairs that act as a defense mechanism and trap small insect pests; scientists believe that the ability to catch insects is the first step towards utilizing their nutrients (Angier). It remains to be seen whether or not these plants will “ realize” the existence of their unutilized food. Carnivorous plants differ from normal plants in their efficiency. Based on ecological cost-benefit models, it’s apparent that carnivorous plants are actually more efficient.

At first glance, the elaborate structures that these plants sport and utilize as necessary appendages to maintain homeostasis seem costly for the plant to make in terms of energy. However, a study published in the American Journal of Botany examining Asian pitcher plants, Venus fly traps, and sundews presents evidence refuting this claim. Harvard University’s Aaron Ellison and Jim Karagatzides measured the costs of constructing the insect-trapping structures on 15 different carnivorous plants and compared them with their rates of photosynthesis (Discovery).

This allowed Ellison and Karagatzides to calculate how long it took the plant to use photosynthesis to “ pay back” the costs of constructing elaborate traps. When comparing the construction costs with the amount of resources it took other plants to make conventional leaves, they discovered that the traps were cheaper and easier to make (Discovery). Despite the fact that carnivorous plants take a longer time to pay for the construction of traps due to low rates of photosynthesis, they are still more efficient than most normal plants that construct leaves.

Cost-benefit models suggest that carnivory improves quality and increases the rate of photosynthesis in pitcher plants (Pavlovic, Singerova, Demko, Hudak). Despite having many advantages, carnivorous plants still remain rare in the world and in areas with their particular habitat. This begs the question: why aren’t there more? Scientists are perplexed by this and the only conclusion they can offer is that there are other ways to solve the problem of how to get nutrients in these habitats, which explains the existence of regular plants in them.

For example, other bog plants like blueberries, huckleberries, and cranberries absorb nitrogen by interacting with fungi in their roots (Discovery). The explanation for the increased efficiency is simple. The low cost of constructing traps is exceeded by the benefit, but the benefit remains relatively low, as insects are only so nutritious. It’s not like these plants are bringing in large amounts of nutrients on a regular basis. Carnivorous plants have evolved having basically no competitors, adapting to thrive in their own niche, but only to a certain extent.

Perhaps the most fascinating part about carnivorous plants is how the various types of traps work. The adapted morphological traits are complex and represent evolutionary genius; it’s as if these plants knew how to change their growth patterns in order to thrive in their environments. Pitfall traps, known better as pitchers, are generally characterized by tube-like leaves filled with water, into which insects fall and are soon digested. Flypaper traps are based on the functionality of sticky mucilage utilized to trap prey.

The leaves are covered in mucilage secreting glands, either short or long. When an insect is trapped, the leaves bend around it and as it decomposes the plant absorbs the nutrients (Brittnacher). Snap traps, like the commonly known Venus fly trap, operate like a mouse trap would. They snap shut in less than a second, an animalistic response, when an insect is between their leaves. As the insect struggles, the increased thigmotropism causes the plant to squeeze even tighter until it dies. The insect is digested inside the leaves (Brittnacher).

Bladder traps are characterized by water that creates a partial vacuum in the bladder, which has a small opening. In aquatic species, when insects touch small hairs emitting from the plant, the bladder opens and the vacuum sucks the insect in, where it is digested (Brittnacher). Lobster traps are relatively easy for prey to enter but difficult to escape from, as inward pointing bristles often obstruct the exit. The prey is forced to travel along a path leading to the plant’s stomach, where it is then digested (Brittnacher).

This is only a basic explanation of how each of the five general types of traps work and yet it exemplifies the fact that there is great variability between the types of carnivorous plant traps. When examined into greater depth, the five general types of traps have a great deal of variation not only from each other, but amongst themselves. Carnivorous plants are some of the most peculiar, thought provoking members of the plant world. Nobody knows exactly how they evolved, although the energetics hypothesis and cost-benefit models provide credible theories.

Carnivorous plants have developed morphological adaptations in the form of complex traps because they do not cost the plant much energy and they occurred as response to small changes in regulatory genes that meet the high energy demands of the traps. They discovered carnivory for themselves and continue to thrive and adapt to their environments, developing independently yet maintaining convergent adaptations. These amazing plants will remain shrouded in mystery and continue to inspire botanists. Luckily for humanity, carnivorous plants haven’t developed a taste for human flesh or the mechanisms to obtain it…yet.