

Study sheds light on how carnivorous plants acquired a taste for meat

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Cephalotus follicularis, the Australian pitcher plant. Photographed here in its native range in Western Australia, this carnivorous plant evolved to digest insects through a strikingly similar evolutionary pathway as other plants that developed the same capability independently, a new study finds. Credit: Mitsuyasu Hasebe

To the average plant-eating human, the thought of a plant turning the

tables to feast on an animal might seem like a lurid novelty.

Now, science is showing just how remarkable these macabre traits really are.

A new study probes the origins of carnivory in several distantly related plants—including the Australian, Asian and American pitcher plants, which appear strikingly similar to the human (or insect) eye. Although each species developed carnivory independently, the research concludes that the biological machinery required for digesting insects evolved in a strikingly similar fashion in all three.

The findings hint that for a plant, the evolutionary routes to carnivory may be few and far between.

"It suggests that there are only limited pathways for becoming a carnivorous plant," says University at Buffalo biologist Victor A. Albert. "These plants have a genetic tool kit, and they're trying to come up with an answer to the problem of how to become carnivorous. And in the end, they all come up with the same solution."

The research, "Genome of the pitcher plant *Cephalotus* reveals genetic changes associated with carnivory," which will be published on Feb. 6, 2017 in *Nature Ecology and Evolution*. It was conducted by an international team led by Mitsuyasu Hasebe, PhD, of the National Institute for Basic Biology in Japan and SOKENDAI (The Graduate University for Advanced Studies) in Japan; Kenji Fukushima, PhD, of the same institutions and the University of Colorado School of Medicine; Shuaicheng Li, PhD, of BGI-Shenzhen in China; and Albert, PhD, a professor of biological sciences in UB's College of Arts and Sciences.



A close-up of the pitchers of *Cephalotus follicularis*, the Australian pitcher plant. A soup of digestive fluids sits at the bottom of these waxy pitchers, breaking down the flesh and exoskeletons of insects that fall in. The plant is photographed here in Western Australia, the only place in the world where the species is known to naturally occur. Credit: Mitsuyasu Hasebe

How to become a pitcher plant: a narrow evolutionary road

Pitcher plants capture insects by luring them into a pitfall trap—a cupped leaf with a waxy, slippery interior that makes it difficult to climb out. A soup of digestive fluids sits at the bottom of this chamber and breaks down the flesh and exoskeletons of prey.

Australian, Asian and American pitcher plants possess these features despite having evolved independently to become carnivores, as Albert and colleagues discovered in a 1992 study published in the journal *Science*.

The new paper builds on this older work, conducting a deeper investigation into how unrelated pitcher plants came to share so much in common.

As it turns out, the path to carnivory was remarkably similar for the three species examined—*Cephalotus follicularis* (the Australian pitcher plant, related to starfruit), *Nepenthes alata* (an Asian pitcher plant related to buckwheat) and *Sarracenia purpurea* (an American pitcher plant related to kiwifruit). A genetic analysis, which included sequencing the entire genome of *Cephalotus*, found strong evidence that during their evolution into carnivores, each of these plants co-opted many of the same ancient proteins to create enzymes for digesting prey.

Over time, in all three species, plant protein families that originally assisted in self-defense against disease and other stresses developed into the digestive enzymes we see today, genetic clues suggest. These enzymes include basic chitinase, which breaks down chitin—the major component of insects' hard, exterior exoskeletons—and purple acid phosphatase, which enables plants to obtain phosphorus, a critical nutrient, from victims' body parts.

Enzymes in a fourth carnivorous species, the sundew *Drosera adela*, a relative of *Nepenthes* that is not a pitcher plant, also appeared to share this evolutionary road.

'Constraints on the available routes' to carnivory

The findings represent an example of convergent evolution, in which

unrelated species evolve independently to acquire similar traits, say co-authors Hasebe and Fukushima.

"Such parallel development often points to a particularly valuable adaptation," Hasebe says.

As Fukushima explains, "Carnivorous plants often live in nutrient-poor environments, so the ability to trap and digest animals can be indispensable given the dearth of other sources of nourishment."

It's striking that the plants studied took such a similar route to becoming predators, the co-authors say. Convergent evolution often works this way: For example, Albert and colleagues showed in a previous study that while coffee and chocolate plants developed caffeine independently, they co-opted closely related proteins to produce caffeine.

The new study's results "imply constraints on the available routes to evolve plant carnivory," the authors write in *Nature Ecology and Evolution*. This prospect is underscored by unusual commonalities between digestive enzymes in *Cephalotus* and *Nepenthes* plants.

During the course of evolution, building blocks of enzymes called amino acids are often swapped out and replaced by other amino acids. In *C. follicularis* and *N. alata*, basic chitinases and purple acid phosphatases share numerous identical or highly similar amino acid substitutions that don't occur in non-carnivorous species, suggesting that these alterations may help these enzymes function in special, carnivorous ways.

Similarly, the enzyme RNase T2, which breaks down a material called RNA in insect cells to produce food for plants, had multiple evolutionarily convergent amino acid substitutions in *C. follicularis* and a common ancestor of *N. alata* and *D. adela*.

More information: Kenji Fukushima et al, Genome of the pitcher plant *Cephalotus* reveals genetic changes associated with carnivory, *Nature Ecology & Evolution* (2017). [DOI: 10.1038/s41559-016-0059](https://doi.org/10.1038/s41559-016-0059)

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