The Secret Lives of Thai Fungi Revealed

TURNING ANTS INTO ZOMBIES

An ant's life in Thailand is no picnic. Prey to the specialized fungal parasite *Ophiocordyceps unilateralis,* a hapless carpenter ant (*Camponotus leonardi*) is doomed to suffer a grisly death if infected. The fungus, a skilled behavioral manipulator, allows the ant to live just long enough to climb down from its nest high in the forest canopy and find a leaf where temperatures and humidity are ideal for fungal growth.

"The fungus accurately manipulates the infected ant into dying where the parasite prefers to be, and makes the ant travel a long way during the last hours of its life," says David P. Hughes, of Harvard University, whose recent findings about this "fine-tuned fungal adaptation," which he and his team consider "an extended phenotype," can be found in the September issue of the *American Naturalist.*

Once it has found a leaf about 25 centimeters above the soil on the northern side of a sapling, an infected ant attaches its mandible firmly onto a major vein on the leaf's underside, dies, and is quickly turned into a fungus factory. The host's remains undergo extensive internal restructuring; in two or three days a stalk begins to emerge from the back of the victim's head, and about two weeks later a fruiting body, or perithecium, sprouts and begins raining spores onto the forest floor to infect more ants.

The researchers used the "death grip" of ants infected by a fungus as their model system to test the hypothesis that parasite genes can control host behavior. They systematically examined every low-hanging leaf in 1360 square meters of primary rainforest in the Khao Chong Wildlife Sanctuary in Thailand and discovered high-density aggregations of dead ants, which they termed "graveyards"—a niche very different from that occupied by healthy ants. Hughes and his team rarely encountered live *C. leonardi* or their trails in the understory during months of fieldwork. They did, however, discover an extensive network of aerial highways extending 50 to 100 meters across the canopy. In contrast to carpenter ants in uninfected areas, "at-risk *C. leonardi* seem to avoid the forest floor as a defense mechanism and only descend out of necessity, for example, when aerial trails cannot traverse canopy gaps," he says.

"But the forest floor is where infection must take place," Hughes stresses, "because *O. unilateralis* spores are too heavy to be dispersed over long distances. Instead they create a circumscribed 'killing field' about 1 square meter below the dead host." To compensate for the infective fragility of its hefty spores and the evasive tactics of the ants, the fungus produces spores continuously over an extended period, allowing time for carpenter ants to stray into the spore dispersal zone.

This elaborate yet inefficient reproductive strategy was probably more effective before the ants figured out what was happening and took to the trees. But it does prove Hughes's major hypothesis that parasites can genetically provoke self-destructive behavior in a host for the sole purpose of increasing their own fitness. "It also proves, if further proof is needed," says Hughes, "that ants are smarter than fungi."

PARTNERING WITH ORCHIDS

Although it is well known that orchids in temperate regions form mycorrhizal symbioses with specific fungal partners, a team led by Marc-André Selosse, from the Center for Functional and Evolutionary Ecology in Montpellier, France, recently discovered that three tropical Neottieae orchid species get their carbon from associated fungi. "Because the fungi colonize both orchid and tree roots, nearby trees are the most likely carbon source," Selosse says.

Remarkably, and unlike any other known mycoheterotrophic plants, two of the orchids Selosse and his colleagues studied proved to be fungally promiscuous, partnering with up to nine different clades at a time. A detailed study of the relationships between orchids and fungi collected from 10 different sampling sites in diverse parts of Thailand was published this September in the open-access journal *BMC Biology.*

"All orchids need fungus at germination—the seeds have no reserves," says Selosse, "and at this stage the fungi provide all their nutrients, including carbon." Most species eventually become green and thus autotrophic, but they still need root fungi to gather mineral nutrients. "However, some orchids have adapted to the shaded forest understory by remaining achlorophyllous and are, therefore, totally dependent on fungal partners for carbon for their entire lives."

The researchers focused their investigations on two mycoheterotrophic species from the rare and "enigmatic" genus *Aphyllorchis,* as well as one *Cephalanthera* species. The orchids' associated fungi were identified through DNA barcoding of short ribosomal sequences, using standards found in GenBank. The two *Aphyllorchis* orchids harbored a highly diverse ectomycorrhizal community; *Cephalanthera* was much more specific in its choice of fungal partners.

The orchids' nutrient sources were tracked by measuring their carbon-13 and nitrogen-15 concentrations, and the results strongly suggest that in the Thai rainforest, as in temperate zones, carbon goes from autotrophic to mycoheterotrophic plants by means of their shared mycorrhizal fungus. "The impact of this relationship on the fungus is unknown," says Selosse, "but plants interact with fungi in unexpectedly diverse ways, and these relationships need unraveling."

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