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As mushrooms evolve to live symbiotically with trees, they give up parts of their DNA: study

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Harvard researchers are unlocking the evolutionary secrets of one of the world's most recognizable groups of mushrooms, and to do it, they're using one of the most comprehensive fungal "family trees" ever created.

As reported in paper published July 18 in PLoS ONE, Associate Professor of Organismic and Evolutionary Biology Anne Pringle and Ben Wolfe, a Post-Doctoral Fellow in FAS Center for Systems Biology, studied the genetics of more 100 species of Amanita mushrooms – about one-sixth of the genus' total diversity – to create an elaborate phylogeny showing how each species is related to one another.

Arguably the most widely-recognized group of mushrooms in the world, Amanita mushrooms have appeared in popular culture ranging from Fantasia to the Super Mario Brothers video games. Though it includes a number of edible species, such as the Amanita caesarea, the group is probably best known for its many toxic species, including the death-cap mushroom.

Armed with their family tree, Pringle and Wolfe were able to determine that Amanita evolution has largely been away from species that help decompose organic material and toward those that live symbiotically on trees and their roots. More interestingly, they found that the transition came at a steep price – the loss of the genes associated with breaking down cellulose.

"There had been earlier suggestions that this type of gene loss might be taking place, but our study is the first precise test of that hypothesis," Pringle said. "The idea makes sense – if you're going to actively form a cooperative relationship with a tree, you probably shouldn't simultaneously be trying to break it apart and eat it. But it's a very tricky dance to form these kinds of tight, cooperative interactions, and I think this work shows there is a cost associated with that. You have to change, you have to commit, and it can become a sort of gilded cage – these mushrooms are very successful, but they're stuck where they are."

In addition to many species which are housed in the Farlow Herbarium, located at the Harvard University Herbaria, Wolfe spent months tracking rare species in far-flung locations like London and Hawaii.

After extracting DNA from the samples, Wolfe used the genetic codes of four different genes to determine how the various species are related to one another. He then used a process called ancestral state reconstruction to show that the mushrooms have switched from being decomposers to being symbiotic with trees only once in their evolutionary history. Once the mushrooms switched to this new symbiotic lifestyle, they didn't go back to their free-living past.

Ultimately, Pringle said, the paper highlights one reason she finds such symbiotic partnerships "intrinsically interesting" – for all their apparent benefits, the cost can be high.

"I think the really interesting thing is this idea that once you become symbiotic, some of your machinery is lost," she said. "It seems like a dead end in some ways – you have to make this change to enter this niche, but once you're there, you can't go back – you've lost the capacity to be free-living."

Provided by Harvard University