

Yeast emerges as hidden third partner in lichen symbiosis

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Bryoria tortuosa, a lichen species studied by a team of University of Montana researchers, show that some of the world's most common lichen species actually are composed of three partners, not the widely recognized two. Credit: Photo by Tim Wheeler, timwheelerphotography.com, via. University of Montana

For nearly 150 years, lichens have been the model organisms of symbiosis. Now researchers have uncovered an unexpected third partner embedded in the lichen cortex or "skin" - yeast.

Since 1867, scientists have recognized the fundamental partnership that produces lichens: A fungus joins with an alga or cyanobacteria in a relationship that benefits both individuals. In a study led by the University of Montana and co-authored by Purdue mycologist M. Catherine Aime, researchers show that lichens across six continents also contain basidiomycete yeasts, single-celled fungi that likely produce chemicals that help lichens ward off predators and repel microbes.

The finding could explain why many genetically similar lichens present wildly different physical features and why scientists have been unable to synthesize lichens in the laboratory, even when combining species that partner successfully in nature.

"This discovery overturns our longstanding assumptions about the best-studied symbiotic relationship on the planet," said Aime, professor of botany and plant pathology. "These yeasts comprise a whole lineage that no one knew existed, and yet they are in a variety of lichens on every continent as a third symbiotic partner. This is an excellent example of how things can be hidden right under our eyes and why it is crucial that we keep studying the microbial world."

The study was published online by the journal *Science* on Thursday (July 21). It will appear in the print version of *Science* as the cover story on July 29.

Based on his study of lichens, Swiss botanist Simon Schwendener was the first scientist to propose that some organisms are not autonomous individuals but combinations of unrelated species that work together. He observed that lichens are the result of collaboration between a single fungus and a photosynthetic partner - either an alga or cyanobacterium. The alga or cyanobacterium produces food by converting energy from the sun and carbon dioxide into sugars. The fungus, in turn, forms the main structure of the lichen and offers its photosynthesizing partner protection from the environment.

This cross-kingdom combination of strengths and abilities has allowed lichens to thrive on a variety of surfaces and in almost every habitat on the planet, ranging from the Arctic to deserts. They come in myriad shapes, colors and forms and produce a rich variety of secondary metabolites. Lichens were also some of the first land-dwelling organisms, suggesting that a communal effort helped life make the ocean-to-land leap.

The discovery that specific yeasts act as third symbiotic partners in lichens began with an investigation into why two lichen species seemed genetically identical but had distinctive attributes. The lichen *Bryoria tortuosa* is yellow and produces a toxic substance known as vulpinic acid while *B. fremontii* - made up of the same fungus and alga - is dark brown and produces no such acid. An analysis of gene expression of the known fungal partner in the two species showed no differences.

But when the team broadened the data search to include all fungi, they found indications that genes were being expressed differently - unexpectedly, by a fungus that appeared to belong to the Basidiomycota,

a completely different phylum than the known fungal partner. These data suggested the presence of a second fungal partner, an undescribed species of yeast in a poorly studied class of early-evolving basidiomycetes.

Toby Spribille, first author of the study and postdoctoral researcher at Montana, said he was initially skeptical of the results.

"It took a long time to convince myself that I wasn't dealing with a contamination," he said.

But once the researchers began looking for traces of similar yeasts in other lichens, they found related lineages in 52 genera of lichens worldwide and molecular evidence that indicates a long, shared evolutionary history between the symbiotic partners.

"There is a long, venerable history of scientists and natural historians who have peered at [lichens](#) through microscopes since the 1800s," said Spribille, also a postdoctoral researcher at the University of Graz. "The yeasts were always there, and somehow we got to crack it open. It gives me goose bumps."

The high amounts of [yeast](#) in *B. tortuosa* enable the lichen to produce the acid that helps defend it against invasion from other microbes. Aime's work with related yeasts points to similar beneficial roles in plants, but basidiomycete yeasts are still understudied, she said.

"We have barely touched the tip of the iceberg in understanding the importance and ubiquity of microbes in a variety of biological systems," she said.

More information: "Basidiomycete yeasts in the cortex of ascomycete macrolichens," *Science*, [science.sciencemag.org/lookup/ ...](https://www.sciencemag.org/lookup/...)

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Provided by Purdue University

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