in the ocean, say researchers. As Scripps oceanographer and ATOC project manager Andrew Forbes puts it, “A single measurement is very tantalizing, but inconclusive.”

Forbes and his colleagues have some tantalizing results of their own. Even though the full-scale ATOC experiment is on hold, the Scripps group managed to get permission for a short “engineering test” of a single sound source last November. Intended mainly as a dry run for their instruments, the test clocked acoustic travel times from California to New Zealand that were noticeably shorter than models based on scattered historical measurements had predicted. The results, say the Scripps researchers, point to up to 0.05 degrees of warming along the sound path.

Physical oceanographer Peter Worcester, also of Scripps, emphasizes that the apparent warming is a “quick-look result,” not to be heavily interpreted. The sparse past measurements don't provide a solid baseline for the warming estimate, he says, and even if the warming is real, sporadic ocean events like El Niño, rather than a global greenhouse warming, could be to blame. But the engineering test has left Worcester “very encouraged” with the quality of the sound signal. He says he's optimistic that acoustics will eventually become the “weather service” of the ocean, providing oceanographers with the continuous data flow they crave.

–Antonio Regalado

MYCOLOGY

# Origins of Lichen Fungi Explored

A hiker encountering a scaly gray growth on a rock is likely to recognize it as a lichen. She may also remember from a long-ago biology class that every lichen consists of a fungus and an alga living in a symbiotic union. But despite being the poster child of symbiosis, lichens have a low profile among the biologists who study fungi. “A lot of the known fungi are lichens, maybe 20%,” says mycologist John Taylor of the University of California, Berkeley. “But mycologists often don't think of lichens when they think of fungi. People who teach classes about fungi, myself included, certainly don't give 20% of the time to lichens; we give much less.”

Now lichens may be moving into the mycology mainstream. On page 1492, Andrea Gargas and Paula DePriest of the Smithsonian Institution in Washington, D.C., and their colleagues report the results of a DNA analysis that dispels the widely held notion that lichen-forming fungi are a closely knit fringe group in the fungus world. Instead, the Smithsonian team shows that lichens are scattered throughout the fungus family tree, a finding that indicates the lichen lifestyle has apparently arisen multiple times during fungus evolution. “What is really exciting and interesting about this paper,” says Duke University lichenologist William Culberson, “is that this is the first molecular information about the evolutionary origin of major lifestyle differences” in the fungi.

Researchers who work on lichens have recognized that the union—in which algae provide organic nutrients to fungi, while the fungi may provide algae with less tangible benefits such as protection from harsh conditions—must have arisen multiple times during the course of evolution. But until now they have had little direct proof. Pinpointing species' origins requires a good family tree, and such a tree has been hard to come by for the fungi. The problem is that the organisms don't have many physical characteristics that can be compared among all the species and used to determine their relationships.

The Smithsonian team got around that obstacle by using something every fungus does have: DNA. They compared DNA sequences from 75 different fungus species, including 10 that form lichens, and used a computer program to generate the most likely family tree for those 75 species. The lichen-forming fungi fell into five separate groups, each of which was more closely related to groups of non–lichen-forming fungi than to each other. This suggests that each group of lichen-forming fungi evolved from a different initial liaison with an alga, DePriest says: “The fungi are opportunists. Throughout their evolutionary history they have taken up occupations as they are available.”

Mitchell Sogin, an evolutionary biologist at the Woods Hole Marine Biological Laboratory in Massachusetts who has used DNA trees to show relationships between micro-organisms, fungi, and animals, says the Smithsonian group's tree makes a solid argument for multiple origins of the lichen lifestyle. “I see four independent events at a minimum,” he says. “What the upper limit is nobody can say.” Berkeley's Taylor agrees. “There are a lot more lichens out there,” says Taylor. “It is likely that as you look at those, you will see further evidence of multiple origins.”

SYLVIA DURAN SHARNOFF

**Partners.** This fungus belongs to one of several lichen-forming groups that apparently evolved independently.

Not only did lichens apparently evolve multiple times, but the new tree suggests that they arose “from fungi that are doing different things for their living,” says DePriest. The closest relatives to the different lichen-forming groups span the spectrum of fungal lifestyles, from free-living saprobes that live off dead organic matter, to mycorrhizae that live symbiotically in the roots of plants, to pathogens that cause diseases in plants and animals.

Because those close relatives are the best indicator of the ancestors that gave rise to the different lichen-forming fungi, that means they apparently evolved from fungi whose lifestyles range from benevolent to virulent. Moreover, the authors point out, lichen-forming fungi apparently have given rise to fungi that act as harmful parasites on lichens. Together, that evidence puts one more nail in the coffin of a notion that has been around for years—and falling out of favor recently—that symbiotic relationships evolve in an orderly progression from those that are parasitic and damaging to one partner to those, like the lichens', that are more benign. Instead, says DePriest, it appears “that lichenization can take different evolutionary pathways,” and that, from the fungus's perspective, at least, a benign relationship is not necessarily the evolutionary stopping point.

But the details of the Smithsonian team's work are certainly not carved in lichen-covered stone. Phylogenetic trees are based on probabilities, and some of the relationships are certain to change as more data are added. Indeed, a competing group led by Joseph Spatafora at Oregon State University and including Culberson and others at Duke has unpublished results that suggest there may be fewer independent origins for one lichen group than the Smithsonian team has proposed. Nevertheless, the new work has boosted some researchers toward what may be a long-overdue recognition that lichens are mainstream fungi. “I think instead of teaching lichenized fungi as a separate unit,” says Berkeley's Taylor, “I should teach them when they come up. That way the students would know they are diverse and that [lichen formation] is a common thing” among fungi.

–Marcia Barinaga