ECOLOGY

Plant Wannabes

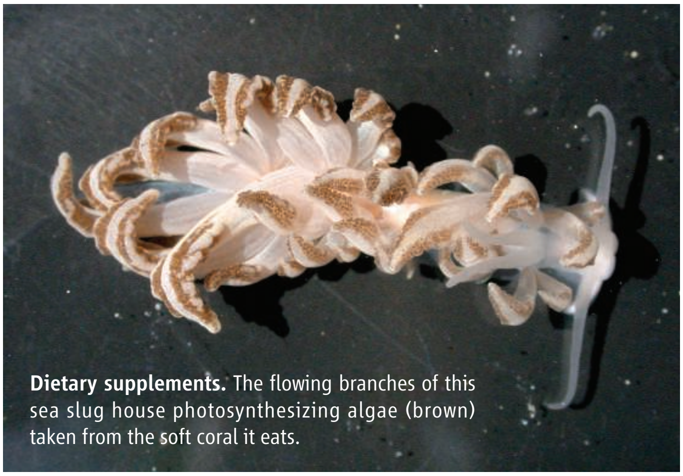
Sea slugs that take in chloroplasts or algae make the photosynthesizers feel right at home

VIENNA, AUSTRIA—Some sea slugs have figured out how to act like plants or at least like coral. Several species of these shell-less mollusks carry algae or chloroplasts in cells of their digestive glands. The slugs acquire the algae or the organelles from their diet and harvest the carbohydrates or lipids the chloroplasts produce by photosynthesis.

Researchers have known for decades about these partnerships, but only through histological studies. Now, they are watching them in action. In presentations here last month at the International Symbiosis Society Congress, two research teams described how they have brought sea slugs into the lab and begun to use the latest molecular techniques to reveal the secrets of the symbiotic relationships.

They reported that algae and even naked chloroplasts can function for months inside a slug and that one sea slug species has acquired algal genes to help such a partnership thrive. The discoveries are "nice examples of coevolution," says Jörg Ott, a marine biologist at the University of Vienna.

Ingo Burghardt, a zoologist at Ruhr University in Bochum, Germany, has focused on *Phyllodesmium*, a sea slug genus with species that salvage algae from the soft corals they eat. Working with Heike Wägele of the University of Bonn, Burghardt has demonstrated that slugs hosting microscopic algae called zooanthellae can last without food for up to 260 days, thanks to contributions from the algae. The longevity of the zooanthellae—and the sea slug's ability to withstand starvation—seems tied in part to the slug's evolution of a complex midgut that houses the algae, Burghardt reported.

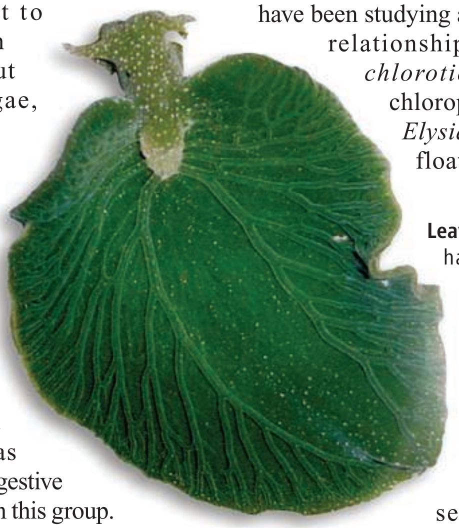


Dietary supplements. The flowing branches of this sea slug house photosynthesizing algae (brown) taken from the soft coral it eats.

To understand how sea slug–zooanthellae partnerships arose, Burghardt has been working out the *Phyllodesmium* family tree by comparing each species' ribosomal DNA. At the same time, he has been examining the digestive systems of slugs within this group. He uses a fluorometer, which measures energy released in the form of fluorescence during photosynthetic reactions, to monitor the efficiency of photosynthetic activity when the slugs are given no access to food.

So far, he's found that various sea slug species differ in the complexity of their digestive gland, the size of dorsal appendages that contain these branches, and their ability to keep zooanthellae. When such features are overlaid onto the slug family tree, "you can see that species that have similar digestive-gland structures group together," he said. Moreover, there is a correlation between a species' success at keeping zooanthellae—and itself—alive and the degree of branching in its digestive gland. "Species with highly branched glands hold on to their zooanthellae a longer time," he reported.

The algae turn *Phyllodesmium* slugs the same color as the soft corals they eat, and Burghardt suspects that this camouflaging originally prompted the evolution of a relationship between the two. Only later, he surmises, did the slugs evolve the ability to use the zooanthellae's photosynthesizing as a food source. And as it did, it made more room by adding on to its digestive glands. "What we see," says Ott, "is an interplay between dependence on symbiosis and the development of special organs."



Leaves of the sea. This sea slug harvests chloroplasts from its seaweed meals and depends on them for some of its energy needs.

Mary Rumpho, a biochemist at the University of Maine, Orono, and her colleagues have been studying an even more intriguing relationship: the sea slug *Elysia chlorotica*'s dependence on chloroplasts. They found that *Elysia* eggs hatch into free-floating larvae that harbor no chloroplasts, but when University of Maine colleague Mary Tyler filmed juvenile sea slugs munching on their favorite seaweed, *Vaucheria litorea*, "we could literally watch the sea slug suck the chloroplasts out of the alga," says Rumpho. The ability to harness chloroplasts is critical: If the juveniles don't have access to this organelle, "they don't make it," Rumpho reported. Moreover, despite being removed from its normal algal home, the chloroplasts can continue to photosynthesize within the sea slug for most of the animal's 10-month life. "That's pretty spectacular," says Margaret McFall-Ngai of the University of Wisconsin, Madison.

It's perhaps not too surprising that sea slugs can house zooanthellae: These algae can survive on their own if they have to. But chloroplasts are dependent on proteins that are typically provided by the plant's nuclear genome. *Elysia*, it turns out, has what it takes to make the slug-chloroplast partnership work. At the meeting, Rumpho's graduate student Jared Worful described his discovery of large parts of two plant genes in the sea slug's DNA. "When [the sea slug] takes in the chloroplast, it has the machinery to keep the chloroplast active and happy," says David Richardson, a lichenologist at Saint Mary's University in Halifax, Canada.

Because these genes are not normally found in animals, Rumpho is convinced they originally came from ingested algae. "We're seeing the evolution of photosynthesis in an animal," says Rumpho.

–ELIZABETH PENNISI

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