Science Observer

A Tangled Tale of Plant Evolution

Lignin, the tough stuff so vital to the migration of plants from water to land, gets around

A new discovery in a red alga is challenging some conventional wisdom about plant evolution.

As ancestors of land plants abandoned their aquatic nurseries for life on shore, they needed the means to seal in water and hold themselves up to thrive. Lignin, a strengthening and stiffening polymer common in woody plant cells, contributes to both extremely well.

Lignin production for those tasks was considered a key adaptive achievement of vascular plants, which descend from green algae. Now a University of British Columbia botanist and some highly specialized chemists have strong evidence for lignin in a red alga called *Calliarthron cheilosporioides.*

The finding suggests that a biological building block fundamental to the success of land plants has roots that stretch back far deeper—and maybe wider—through evolutionary time than was known. "This pathway is involved in the production of other secondary metabolites like pigments in plants. A lot of that is likely to be conserved pretty far back in the evolutionary history of algae," says Patrick T. Martone, the botanist who led the study, published in January in *Current Biology.*

Martone, now an assistant professor, didn't set out to locate lignin in algae while a graduate and postdoctoral student at Stanford University. The biomechanist simply wanted to better understand the toughness of *C. cheilosporioides*, which dwells in the harsh habitat of intertidal zones along rocky shores.

During high tides, waves pummel the alga with water velocities exceeding 20 meters per second and with forces that exceed those generated by hurricane winds. The calcified, or rigid-bodied, seaweed has multiple noncalcified joints that make it flexible yet strong enough to handle that setting.

When collaborator Jose Estevez at the Carnegie Institution for Science examined the joints for Martone with a transmission electron microscope, he saw secondary cell walls, features commonly found in land plants. That prompted Martone and Estevez to seek out experts in lignin, a molecule of great research interest right now because its toughness impedes the use of some plants as sources of biofuel and animal feed.

John Ralph and colleagues at the University of Wisconsin-Madison's Great Lakes Bioenergy Research Center detected lignin in *C. cheilosporioides*. They found the same telltale components derived from radical coupling reactions of hydroxycinnamyl alcohols used to describe lignins in terrestrial plants.

At the Centre de Recherches sur les Macromolécules Végétales in France, Katia Ruel applied antibodies designed to locate lignin within land plants to

Kathy Ann Miller

The rigid-bodied red algae *Calliarthron cheilosporioides* thrives in tough intertidal marine environments. Attached to rocks, it rides out daily tide changes that generate huge forces. New research detected lignin, a tough polymer associated with land plants, in the alga.

samples of *C. cheilosporioides*. Her tests detected lignin in the seaweed too.

The amounts are much smaller than what is found in land plants. But lignin is most abundant in the parts of the seaweed that are most mechanically stressed, which suggests to Martone that there could be some environmental stimulation that increases production of the polymer in the organism. The puzzling thing is that it's also present in calcified portions of the algae. "We don't know what it's doing there," Martone says.

Martone's working hypothesis is that the molecular pathways producing lignin emerged long before land plants evolved from green algae, back to some ancestor shared with red algae more than a billion years ago. Molecular evidence and comparisons of the biological gear the algae use to harvest light convince him that both red and green algae descend from one endosymbiotic event, when a eukaryote cell engulfed a photosynthesizing cyanobacterium and gained the ability to make its own food.

Karl J. Niklas, a Cornell University botanist and former editor of the *American Journal of Botany*, considers Martone's evidence for lignin in *C. cheilosporioides* exceptionally strong. But he thinks that red and green algae evolved from separate endosymbiotic events. Still, the progenitors of the two algae may both have carried genes similar to those participating in the lignin production pathways seen today, he says. But they could have used them for different purposes, possibly to produce indigestible substances that protected against microbial attacks.

"This is a stunning example of convergent evolution," Niklas says, comparable to birds, insects and bats developing winged flight independently.

Intrigued by all the mystery, Martone has stepped up his lignin studies.

He has sent a batch of different varieties of seaweeds, including kelps, to Ralph's laboratory to see whether lignins reside there too. Martone's lab is looking for genes in *C. cheilosporioides* that are homologous to genes linked to lignin production in land plants.

"People thought they knew what was going on," says Martone. "But all that is changing."—*Catherine Clabby*