Ferns borrowed genes to flourish in low light

April 14 2014

A gene that became critical to the survival of many ferns (pictured) came from an unexpected source: hornworts, a group related to mosses. Credit: Fay-Wei Li

During the age of the dinosaurs, the arrival of flowering plants as competitors could have spelled doom for the ancient fern lineage. Instead, ferns diversified and flourished under the new canopy—using a mysterious gene that helped them adapt to low-light environments.

A team led by Duke University scientists has pinpointed the curious origins of this gene and determined that it was transferred to ferns from a group of unassuming moss-like plants called hornworts. The findings were announced today, April 14, in the *Proceedings of the National Academy of Sciences*.

For years, researchers have suspected that a gene called neochrome played a role in the evolution of ferns. Neochrome is a hybrid of two other plant genes which code for photoreceptor proteins that sense blue and red light.

"Neochrome is a 'chimeric' gene," said Fay-Wei Li, lead author and Ph.D. student in Duke's biology department. It produces a photoreceptor that senses both blue and red light, affording ferns a unique advantage in forests shaded by flowering plants. "Most plants sense and grow toward blue light, but under the canopy, the filtered light spectrum has more red light than blue."

"Neochrome helped ferns to 'see' better," Li said. What hasn't been crystal clear is the gene's origin. Li set out to investigate its evolution by systematically combing through plant genomes from the Duke Herbarium and 1000 Plants Initiative.

Neochrome turned up in a surprising place: the genomes of hornworts, a damp-loving plant group related to mosses.

Three scenarios could have explained how the gene came to be shared by ferns and hornworts: 1) a common ancestor that had the gene; 2) independent evolution of the gene in both groups; or 3) a process called horizontal gene transfer, which ferried neochrome from one group to the other.

To sort out these theories, the team looked not only at the evolutionary relationships of land plants and algae, but also at how all of their light-sensitive genes were related.

Ferns and hornworts diverged in evolution 400 million years ago. If neochrome came from a common ancestor, it would have been passed on to many other plant families, too. But then it had to have been lost in all but the ferns, since no seed plants still have it. The analysis also didn't support the idea that an unusual gene like neochrome evolved independently in both hornworts and ferns.

What the scientists found instead was strong evidence that the fern version of neochrome descended from the hornwort version. By looking at sequence changes in the gene's various spellings, they constructed a family tree of light-sensitive genes, in which fern neochrome "nested" neatly within the hornwort lineage. The analysis also showed that the gene versions separated about 179 million years ago.

Only one mechanism could explain how the gene hopped from hornworts to ferns so long after the lineages themselves diverged: horizontal gene transfer. But researchers have only just begun to explore how this occurs in plants.

"We're actually seeing more and more incidence of horizontal gene transfer in plants, but there's no definite answer as to what mediates it," Li said.

In the microbial world, bacteria, fungi and viruses have been shown to mediate horizontal gene transfer wherever bits of genetic material get mixed up in different organisms. It's a messy affair, but it can have powerful evolutionary consequences—gene transfer is how many bacteria learn antibiotic resistance, for example.

"You have to have cell contact," Li said. Ferns have a unique life cycle that might lend itself to horizontal gene transfer, he added. Gametophytes, the fern form that produces sex cells, are promiscuous little plants.

"They have no protective layer on top, no cuticle," said Kathleen Pryer, an authority on ferns and professor of biology at Duke. "A gametophyte is also a really compact structure, and the sex organs are right there, with lots of contact with other plants that are all competing for light and space."

Easy access to a fern's sperm and eggs could mean foreign genetic material—like the gene neochrome—might easily be passed on to the subsequent generation. However neochrome was transferred, it seems to have occurred at just the right moment in ferns' evolutionary history.

"The acquisition of hornwort neochrome appears responsible for the expansion of the fern lineage in the shade of angiosperms (flowering plants)," said J. Clark Lagarias, professor of biochemistry at the University of California, Davis, who was not involved with this research.

Fay-Wei Li will continue to unravel the history of neochrome for his dissertation.

More information: "Horizontal transfer of an adaptive chimeric photoreceptor from bryophytes to ferns," Fay-Wei Li, Juan Carlos Villarreal, Steven Kelly, et al. *Proceedings of the National Academy of Sciences*, April 14, 2014. DOI: dx.doi.org/10.5061/dryad.fn2rg

Provided by Duke University

Citation: Ferns borrowed genes to flourish in low light (2014, April 14) retrieved 28 April 2024 from https://phys.org/news/2014-04-ferns-genes-flourish.html

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