Plant light sensors came from ancient algae

July 28 2015

Leaves floating on water waves.

The light-sensing molecules that tell plants whether to germinate, when to flower and which direction to grow were inherited millions of years ago from ancient algae, finds a new study from Duke University.

The findings are some of the strongest evidence yet refuting the prevailing idea that the ancestors of early plants got the red light sensors that helped them move from water to land by engulfing light-sensing bacteria, the researchers say.

The results appear online in *Nature Communications*.

"Much like we see the world through our eyes, plants 'see' the world through light-sensitive proteins in their leaves called photoreceptors," said Duke postdoctoral researcher Fay-Wei Li.

Photoreceptors monitor changes in the direction, intensity, duration and wavelength of light shining on a plant, and send signals that tell plants when to sprout, when to blossom, and how to bend or stretch to avoid being shaded by their neighbors.

"Light is what gives plants the energy they need to survive," Li said. "But light is constantly changing with the time of day and the seasons and the surrounding vegetation. Photoreceptors help plants determine if it's summer or winter, or if they're under the canopy or out in the open."

A group of photoreceptor proteins called phytochromes enable plants to detect and absorb light in the red and far-red regions of the light spectrum, the main wavelengths of light that plants use for photosynthesis.

Just 20 years ago, researchers discovered that plants weren't the only living things with phytochromes. Thanks to DNA sequencing, scientists started uncovering similar genes in cyanobacteria, tiny green bacteria that live in oceans, rivers and streams.

Based on the striking similarities between the phytochrome genes in plants and cyanobacteria, scientists proposed that plants acquired their phytochromes millions of years ago by engulfing cyanobacteria that were living independently.

Instead of digesting them, the theory goes, the plant ancestors supplied a safe home for the cyanobacteria to grow, and the cyanobacteria supplied

their light-harvesting machinery to help capture energy from the sun, until the two grew dependent upon one another and eventually joined together to become permanent partners.

The idea is a widely accepted explanation for the origin of chloroplasts, the organelles in plant cells that convert sunlight to food.

But in more recent years researchers have also discovered phytochrome genes in bacteria, fungi and some algae, which got them thinking again: "Where did plant phytochromes come from?" Li said.

To find out, Li and Kathleen Pryer of Duke and Sarah Matthews of Harvard scoured existing databases and analyzed 300 DNA and RNA sequences from the phytochrome proteins of a wide range of algae and land plants, including ferns, mosses, liverworts, hornworts, green algae, red algae, kelp, diatoms and other green blobs commonly found in ocean plankton.

By calculating the similarities between the sequences, the researchers were able to reconstruct the genetic changes that these red light sensors underwent as they were passed from one lineage to the next.

Plant phytochromes turned out to be more closely related to algae than cyanobacteria, consistent with suspicions that earlier ideas about their bacterial origins may not be right after all.

The researchers also found a surprisingly diverse array of phytochromes in green algae, which could help scientists better understand how plants transitioned from life in the water to life on land.

Plants are generally thought to have colonized land more than 400 million years ago, when pioneering green algae—perhaps living at the edges of freshwater pools—managed to survive when water levels

dropped on shore.

The previously unknown diversity of phytochromes in green algae suggests that the aquatic and semi-aquatic ancestors of early plants could absorb and use wavelengths of light that modern land plants can't "see."

"The first ancestral algae to move onto land would have faced a very different light environment than they experienced in the water—a lot more light, and in different wavelengths," Li said. "Photoreceptors played a key role in helping plants adapt to these changing light conditions."

More information: "Phytochrome Diversity in Green Plants and the Origin of Canonical Plant Phytochromes," Li, F. et al. *Nature Communications*, July 28, 2015. DOI: 10.1038/ncomms8852

Provided by Duke University