Algal genome provides insights into first land plants

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Penium margaritaceum. Credit: Cornell University

Cornell researchers have sequenced and analyzed the genome of a single-celled alga that belongs to the closest lineage to terrestrial plants and provides many clues to how aquatic plants first colonized land.

The report, "The Penium margaritaceum Genome: Hallmarks of the Origins of Land Plants," was published May 21 in the journal *Cell*.

Penium margaritaceum belongs to a group of freshwater algae called charophytes, and specifically to a subgroup called the Zygnematophyceae, which had a common ancestor with the first land plants some 600 million years ago. In order to shift from water to land—a transition that still puzzles scientists—plants had to protect themselves from drying out and from ultraviolet (UV) radiation, and they had to develop structures to support themselves without the buoyancy provided by water.

The researchers found footprints of all these adaptations in the Penium genome, providing insight into the mechanisms and genetics that early terrestrial plants required.

"We knew almost nothing about the genomes of the immediate ancestors of land plants," said senior author Jocelyn Rose, professor of plant biology in the College of Agriculture and Life Sciences.

"We now have exciting insights into the last common ancestor of algae and land plants," Rose said, "and that allows plant biologists to infer the origins of land plant molecular pathways, developmental systems and biological processes, and to place them in the context of land colonization in ways that have not previously been possible."

Though some algae of the charophyte group are branched and look like early land plants, molecular data reveals that the common ancestor had a simpler filament-like shape.

"We are very interested in why it is that the simple body plan might have been evolutionarily advantageous," Rose said. "Penium lives in the margins of fresh water and land, in habitats that expose it to periods of drying and rehydration and this was likely a key factor."

The Penium genome contains a great deal of repetitive and "junk" (non-coding) DNA, which created challenges for the researchers. They ended up extracting a clean set of DNA from purified nuclei and integrating many kinds of DNA sequencing techniques and assembly programs to cover the entire genome. They also conducted cutting-edge transcriptome (RNA) sequencing to complement the genome sequencing and to understand which genes were turned on and off by different stresses.

"We found out that the genome is huge," said Zhangjun Fei, professor of bioinformatics at Boyce Thompson Institute and an adjunct associate professor in the Plant Pathology and Plant-Microbe Biology Section. Fei is a co-leading author of the study and handled the computational and sequencing work.

The genome of this tiny single-celled alga is even larger than the notoriously large maize genome and the human genome.

"One big result is that we found flavonoids, chemicals that can protect from UV light radiation," Fei said.

"Previously it was thought that these compounds only existed in land plants," Rose said. "We detected not only the flavonoids themselves, but also parts of the pathway for their biosynthesis."

The researchers also identified genes involved in regulatory systems and hormone signaling that have previously only been found in land plants, as well as mechanisms that keep plants from drying out, including the production of mucilage.

They also found a large number of genes that contribute to cell wall biosynthesis and reorganization, which are necessary for structural support.

"Again, it's a single cell, but it has enormous families of cell wall modifying proteins," Rose said. "This suggests highly complex control of wall structure, dynamics and biomechanical properties that may be every bit as elaborate as in multicellular lands."

The researchers believe the Penium genome will open up investigations into many areas of plant biology, including possible applications for modern crops. The team plans to investigate the genomes of other species of charophytes.

More information: Chen Jiao et al. The Penium margaritaceum Genome: Hallmarks of the Origins of Land Plants, *Cell* (2020). DOI: 10.1016/j.cell.2020.04.019

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