

MENU

First Land Plants and Fungi Changed Earth's Climate, Paving the Way for Explosive Evolution of Land Animals, New Gene Study Suggests



Lichen

Lichens and moss covering rocks in Pennsylvania. Did Precambrian land look like this? Photo Credit: David Geiser, Penn State

The largest genetic study ever performed to learn when land plants and fungi first appeared on the Earth has revealed a plausible biological cause for two major climate events: the Snowball Earth eras, when ice periodically covered the globe, and the era called the Cambrian Explosion, which produced the first fossils of almost all major categories of animals living today.

According to the authors of the study, which will be published in the 10 August 2001 issue of the journal *Science*, plants paved the way for the evolution of land animals by simultaneously increasing the percentage of oxygen in the Earth's atmosphere and decreasing the percentage of carbon dioxide, a powerful greenhouse gas.

"Our research shows that land plants and fungi evolved much earlier than previously thought — before the Snowball Earth and Cambrian Explosion events — suggesting their presence could have

had a profound effect on the climate and the evolution of life on Earth," says **Blair Hedges**, an evolutionary biologist and leader of the Penn State research team that performed the study.

The researchers found that land plants had evolved on Earth by about 700 million years ago and land fungi by about 1,300 million years ago — much earlier than previous estimates of around 480 million years ago, which were based on the earliest fossils of those organisms. Prior to this study, it was believed that Earth's landscape at that time was covered with barren rocks harboring nothing more than some bacteria and possibly some algae. No undisputed fossils of the earliest land plants and fungi have been found in rocks formed during the Precambrian period, says Hedges, possibly because their primitive bodies were too soft to turn into fossils.

The early appearance on the land of fungi and plants suggests their plausible role in both the mysterious lowering of the Earth's surface temperature during the series of Snowball Earth events roughly 750 million to 580 million years ago and the sudden appearance of many new species of fossil animals during the Cambrian Explosion era roughly 530 million years ago. "Both the lowering of the Earth's surface temperature and the evolution of many new types of animals could result from a decrease in atmospheric carbon dioxide and a rise in oxygen caused by the presence on land of lichen fungi and plants at this time, which our research suggests," Hedges says.

"An increase in land plant abundance may have occurred at the time just before the period known as the Cambrian Explosion, when the next Snowball Earth period failed to occur because temperatures did not get quite cold enough," Hedges says. "The plants conceivably boosted oxygen levels in the atmosphere high enough for animals to develop skeletons, grow larger, and diversify."

Lichens are believed to have been the first fungi to team up with photosynthesizing organisms like cyanobacteria and green algae. Lichens can live without rain for months, providing protection for photosynthesizing organisms, which produce oxygen and release it into the atmosphere. The researchers suggest that the pioneer lichen fungi, which produce acids strong enough to dissolve rocks, also could have helped to reduce carbon dioxide. When washed away by rainwater, the calcium released from the lichen-encrusted rocks eventually forms calcium carbonate limestone in the ocean, preventing the carbon atoms from forming the greenhouse gas, carbon dioxide, in the atmosphere.

Land plants also can lower levels of carbon dioxide in the atmosphere. They have molecules called lignins, which contain carbon but do not readily decompose. After the plant dies, some of its carbon remains locked up in the lignins and can become buried in the Earth through geologic processes, preventing those carbon atoms from returning to the atmosphere and effectively lowering atmospheric carbon dioxide.



LichenMoss

Lichens and moss covering rocks in Pennsylvania. Photo Credit: David Geiser, Penn State

"The Earth cools when you take away carbon dioxide," Hedges says. "Other factors such as the location of the continents may have had some effect in cooling the atmosphere and creating periods of Snowball Earth, but I suspect the biggest cooling effect came from the reduction of carbon dioxide in the atmosphere by fungi and plants, which we have shown were living on the land at that time."

Fossil fuels like coal and oil are made from plant material, containing carbon that was taken out of the atmosphere and buried in swamps millions of years ago. Releasing those same carbon atoms back into the atmosphere by burning fossil fuels appears to be causing the Earth to get warmer again, according to many studies.

Hedges and his research team made their surprising discoveries about the early appearance on Earth of the first land plants and fungi by studying as many of the genes as possible of their descendants — the species of plants and fungi living today. They began by sifting through their molecular fingerprints — the unique sequences of amino-acid building blocks — in many thousands of genes from hundreds of species archived in the public gene-sequence databases.

Eventually, they found 119 genes common to living species of fungi, plants, and animals that met the researchers' stringent criteria for use as "molecular clocks." Previous studies had used a single gene. By detailed comparisons of the amino-acid sequences of individual genes among numbers of species, the scientists identified those genes that had accumulated mutations at a fairly constant rate relative to one another during their evolution. "Because mutations start occurring at regular intervals in these genes as soon as a new species evolves — like the ticking of a clock — we can use them to trace the evolutionary history of a species back to its time of origin," Hedges explains.

The scientists calibrated each of their gene clocks with evolutionary events well established by fossil studies, primarily those in the history of animals. Using these known dates as secure calibration points, and the mutation rate for each of the constant-rate genes as a timing device, the researchers were able to determine how long ago each of the species originated.

Hedges says his research might help in the search for life on other planets by providing a link between the different stages of life's evolution on Earth and the timing of events in the chemical evolution of Earth's atmosphere, such as the rise in oxygen. "Possibly the early history of life on Earth can give us clues for predicting the kinds of lifeforms that are likely to exist on planets in other solar systems from the chemical content of their atmospheres," Hedges says.

In addition to Hedges, the Penn State research team includes **Daniel S. Heckman**, an undergraduate student whose senior honors thesis formed part of this research; **David M. Geiser**, assistant professor of plant pathology; and undergraduate students **Brooke R. Eidell**; **Rebecca L. Stauffer**; and **Natalie L. Kardos**. This research was supported, in part, by the National Aeronautics and Space Administration through the Penn State Astrobiology Research Center.

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CONTACT:

Blair Hedges, 814-865-9991, sbh1@psu.edu
Barbara K. Kennedy, 814-863-4682, science@psu.edu

IMAGES:

Additional high-quality color images of lichen are available directly from **Stephen Sharnoff**, a professional photographer and colleague of the researchers, via e-mail at lichen@idiom.com, telephone at 510-548-9189, or postal service at 2406 Roosevelt Ave., Berkeley, CA 94703.