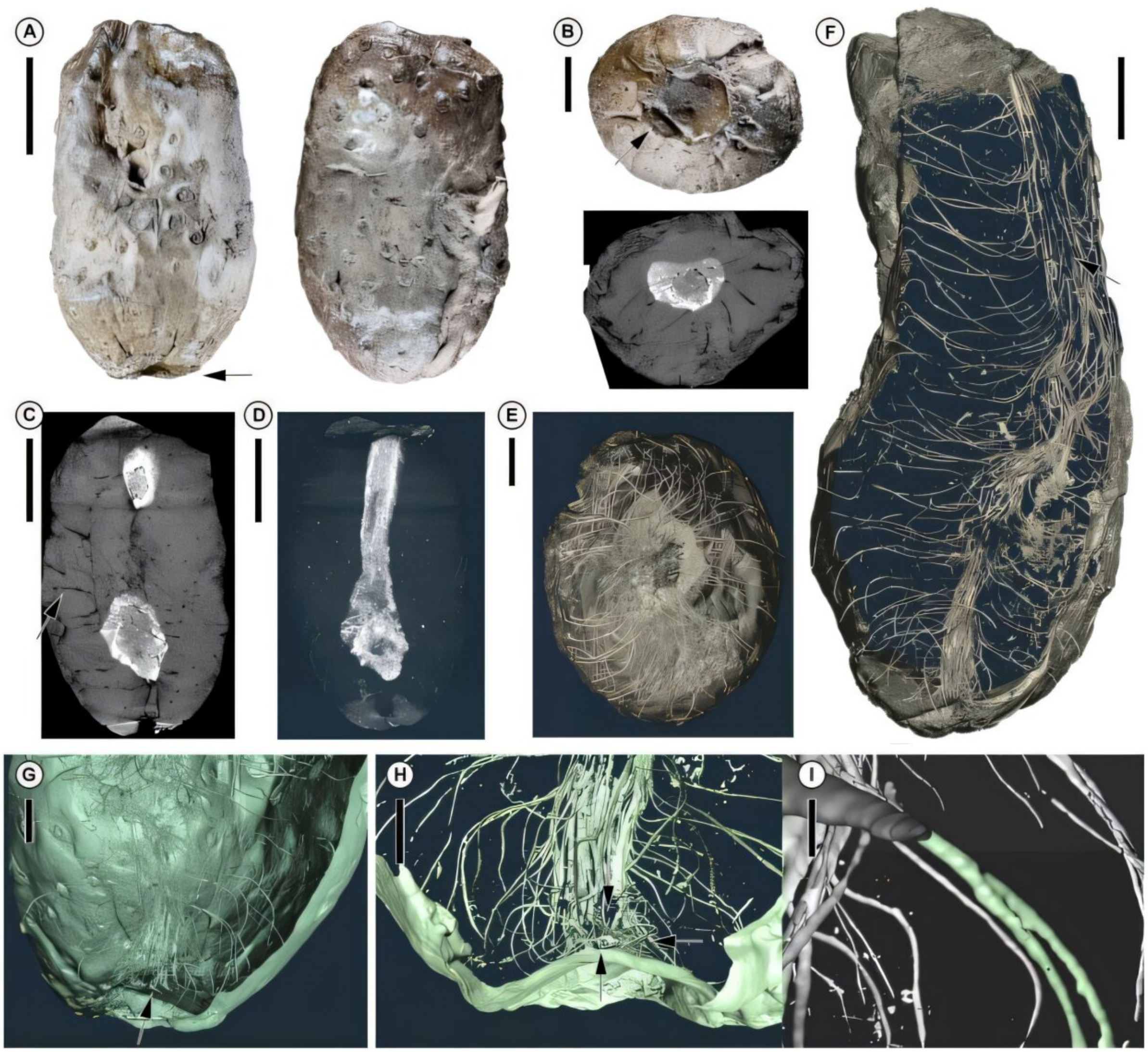
The root of the problem: Ancient trees may have grown their roots backwards

May 5 2026, by Sayan Tribedi



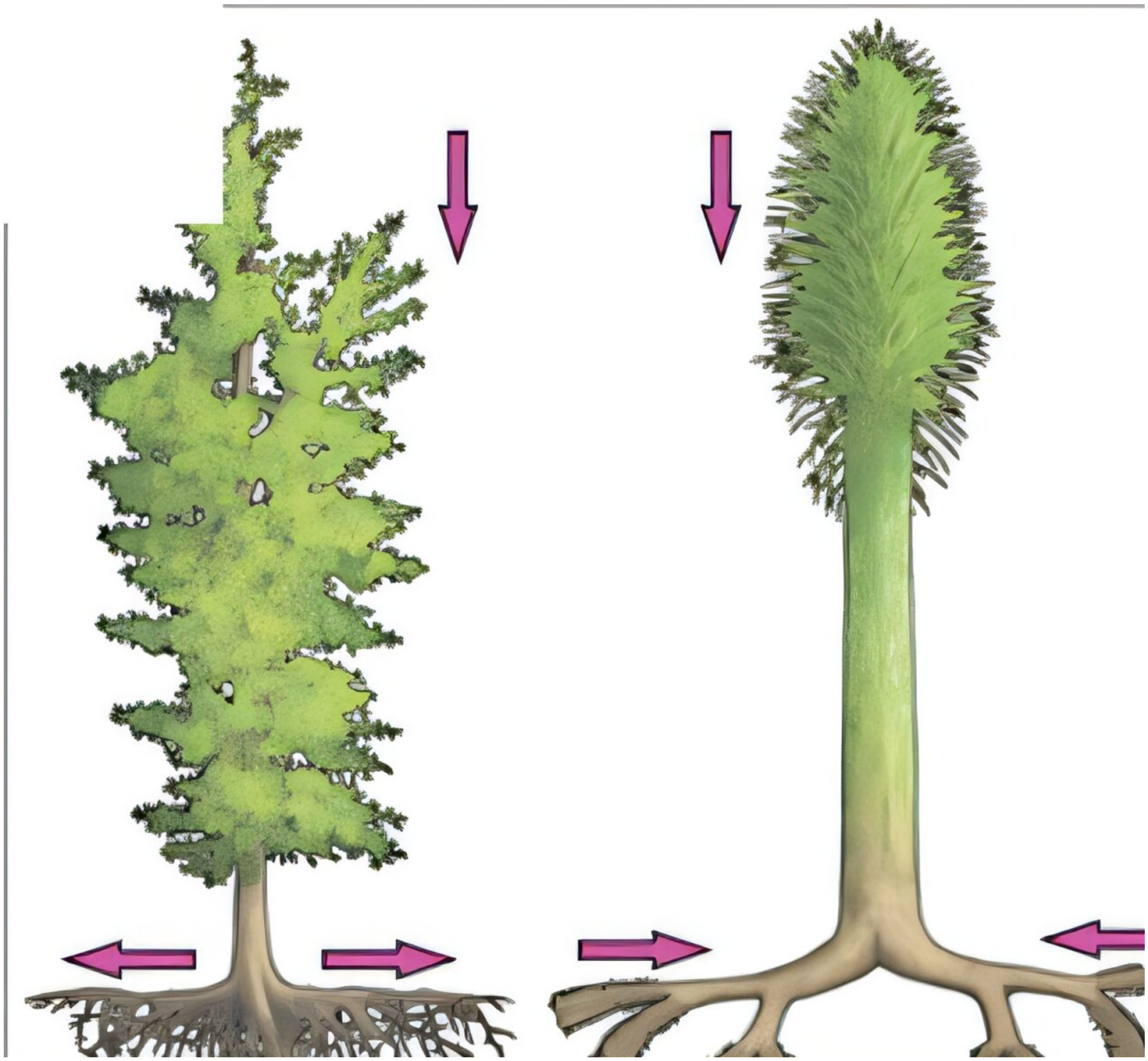
A glimpse into the past: Fossil casts of Stigmaria. Credit: Michael P. D'Antonio

et al, A shoot at the root? Unique development and evolution of the stigmarian apical meristem, *Proceedings of the Royal Society B: Biological Sciences* (2026). DOI: 10.1098/rspb.2025.2863

Secrets about how giant trees grew in reverse can be found in fossil imprints of their roots. Micro-CT scanning shows that the roots were growing tip-to-tail like shoots.

Stigmaria (meaning "little mark" for the pit patterns) are casts of the underground axes of giant Paleozoic lycopsid trees—relatives of living clubmosses and quillworts. These swamp-adapted trees (like Sigillaria and Lepidodendron) towered tens of meters high in the late Carboniferous, and their buried "roots" could run for meters. The casts are recognized by rows of tiny circular or oval depressions on their surface, each marking where a slender rootlet once attached.

By the mid-1800s, discoveries of Stigmaria attached to Sigillaria and Lepidodendron stumps made it clear they were roots. These fossils even helped prove that coal swamps were true in-place forests (the roots show the trees grew on the spot). But how did these roots grow—like those of modern plants, or in a novel way? Researchers debated Stigmaria's nature for decades, but without internal anatomy, the mystery remained unsolved.



A hormonal reversal: PAT in typical tracheophytes such as Ginkgo (left) and arborescent lycopsids (right) . Credit: Michael P. D'Antonio et al, A shoot at the root? Unique development and evolution of the stigmarian apical meristem, *Proceedings of the Royal Society B: Biological Sciences* (2026). DOI: 10.1098/rspb.2025.2863

X-ray vision inside fossils

The solution of this longstanding riddle entailed the use of state-of-the-art technology, specifically, X-ray micro-computed tomography (μCT) scanning technology. The procedure involves the use of scanning technology similar to that used in a medical computed tomographic scanner, but on a much smaller scale, on a microscopic level, to be able to look inside without damaging the priceless fossils.

In a new study published in the journal *Proceedings of the Royal Society B: Biological Sciences*, this novel technology was employed to conduct scans on three perfectly preserved Stigmaria fossils obtained from museums.

In the course of this procedure, the fossils underwent X-rays from various angles. Different substances, specifically denser minerals that have substituted the tissue of the plants themselves and the rock that contained them, absorbed X-rays differently. Then, using a powerful computer, thousands of these images were put together into highly accurate three-dimensional representations of the internal structure of the fossils.

As a result, "virtual fossils" were created, enabling researchers to virtually "peel off" the layers of stone. It was possible to isolate internal channels feeding each individual rootlet within this three-dimensional model to get to know its intricacies better.

When roots act like shoots

The results were startling. Instead of branching downward from the base, the tiny daughter axes (rootlet traces) consistently emerge right near the apex of the Stigmaria axis. In other words, the growing tip of the Stigmaria root sent out new branches in a pattern much like a plant shoot. This is the opposite of normal plant roots, where the growth hormone auxin flows toward the tip to guide downward growth.

"The stigmarian apical meristem has characteristic developmental features typical of vascular plant shoots," the researchers note, observing the familiar shoot-like hormone patterns. In fact, they conclude, "the shoot-like developmental pattern of Stigmaria challenges the foundational assumption that roots develop by auxin transport towards the apex." In plain terms, the Stigmaria root tips behaved more like stems: instead of pumping hormones into the tip, this system pumped them away, just as shoots do.

All evidence points to Stigmaria being a novel type of root organ. Instead of matching the roots of living lycopsids (like the modern quillwort Isoetes), Stigmaria likely evolved as a shoot-derived structure. These Carboniferous giants essentially grew a new "root" out of a modified shoot axis—an idea that had been hypothesized before, now backed by fossil anatomy.

A forest of possibilities

Questions remain for further research. Scanning has been done on only a few fossils so far, and all were from one species of lycopsid. Researchers advise caution, and more data are needed to draw conclusions about other species. Is it true of all the ancient coal tree roots? Every fossil casting holds its story within, which is now being told by CT scans. Using the same methodology on more casts would help understand if the shoot-like root was unique to one species.

These findings also provide insights into ancient ecology. The giant lycopsids formed dense forests, which fueled Carboniferous swamps, whose roots affected their geochemistry and architecture. Knowing how such roots developed aids paleobotanists in understanding the evolution of forests. Stigmaria teaches us that even common fossils may contain surprises, which tell us that the ancient forests have more to reveal.

More information: Michael P. D'Antonio et al, A shoot at the root? Unique development and evolution of the stigmarian apical meristem, *Proceedings of the Royal Society B: Biological Sciences* (2026). DOI: 10.1098/rspb.2025.2863

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