The New York Times https://www.nytimes.com/2025/08/27/science/biology-trees-microbiomes.html

Scientists have found that a single tree can be home to a trillion microbial cells — an invisible ecosystem that is only beginning to be understood.

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By Alexa Robles-Gil

Aug. 27, 2025

A forest is a complex, dynamic ecosystem in which a rich array of living things, from old-growth trees to microscopic fungi, interact and depend on one another for survival.

So is the inside of a tree, it turns out.

Earlier this month, a team of scientists published the most comprehensive study of the microbiomes living inside tree trunks. Their findings suggest that the woody tissues of trees contain a trillion microbial cells above and beyond actual tree cells: communities of bacteria and single-celled organisms called archaea that have specialized to different parts of the tree and even to individual tree species.

The study's results, published in the journal Nature, reveal a vast and largely unexplored reservoir of microbial diversity. "A tree individual is sort of a complex ecosystem in and of itself," said Jonathan Gewirtzman, an ecosystem ecologist at Yale University and an author of the study.

He noted that while the research is still in its early stages, it was "sort of impossible" that some of these microbes weren't crucial to a tree's health, growth and immunological resilience.

The team sampled more than 150 trees across 16 species in the Northeastern United States. They extracted wood cores, all thinner than a pen, from red maples, black birches, white ash trees and more. Then, the team tried out a variety of

methods — grinding, blending, beating the wood samples — to extract the DNA and estimate the microbial population in the tree trunks.

Jonathan Gewirtzman, an ecologist at Yale University, attaches a chamber of a portable gas analyzer to a tree to measure greenhouse gas emissions in the Yale-Myers Forest, July 2021. Judith Rosentreter

Fungus growing on a birch tree at the Yale-Myers Forest in 2021. Jonathan Gewirtzman

Microbes can live in two different parts of the tree trunk: the outer wood, known as sapwood, and the inner wood, known as heartwood. The new study found that each region has its own community of microbes. Sapwood is dominated by microbes that require oxygen, whereas heartwood is dominated by microbes that don't. Much of the methane produced by a tree originates from the heartwood, the study found.

“That’s really exciting, because it shows that the internal woody tissues are quite dynamic environments,” said James McDonald, a microbial ecologist at the University of Birmingham who was not involved in the research. “It’s a fantastic study.”

Dr. McDonald studies how a deadly oak disease known as acute oak decline changes the microbiome of oak trees. A better understanding of the microbiome of specific tree species could help scientists predict how the trees will respond to various diseases, he said.

The study found that tree microbiomes differed from species to species. Sugar maples, known for producing maple syrup, had more sugar-eating bacteria, whereas others, like the oak trees used for wine barrels, harbored a microbial group known to aid fermentation. Such examples demonstrate how tree microbes affect “our everyday lives in sort of unexpected ways,” said Wyatt Arnold, a microbial ecologist and an author on the study.

The study also underscored that trees are not single units but “sort of like all these different layers and compartments,” he said.

A cross-section of the black oak tree felled for the study; dried and sanded in the lab at Yale University. Jonathan Gewirtzman

Wyatt Arnold, a co-author of the study and a microbial ecologist at Yale at the time of the study, adding liquid nitrogen to a cryo-grinder to process tree cores and extract microbial DNA in 2022. Jonathan Gewirtzman

It may well be that tree microbiomes display evolutionary signatures, with closely related tree species sharing similar microbial communities. “That suggests that there is really a tight coupling between these microbiomes and their hosts in a way that’s not just incidental,” Dr. Arnold said.

How do microbes get inside the tree’s woody tissues? Some might be inherited through seeds and retained into a tree’s adulthood, while others might enter through wounds or natural openings. Still others might arrive through routes that scientists haven’t yet discovered.

The new study was modeled on past research on the human microbiome: Start not with a deep dive on a particular species but a broader survey of tree microbiomes generally. “This is sort of, hopefully, giving people a little bit of a map to dive into deeper questions,” Dr. Arnold said.

For Fréderique Reverchon, a microbial ecologist at the Institute of Ecology in Mexico who was not involved in the study, one of those deeper questions is tied to microbiomes in tropical trees. “This catches my attention,” she said. “What happens in those ecosystems in southern Mexico or Brazil?” This study was a great starting point, she said. “It’s opening up research opportunities for many people, so that’s cool,” she said.

Mr. Gewirtzman noted that the complexity of a tree’s ecosystem highlighted the diversity of the forest around it, not to mention the complex individuality of the tree itself. “What looks like one thing is a trillion-in-one organisms living together,” he said.

Alexa Robles-Gil is a science reporter and a member of the 2025-26 Times Fellowship class, a program for journalists early in their careers.

A version of this article appears in print on , Section D, Page 5 of the New York edition with the headline: Inside Looks At Many Small Lives In the Woods