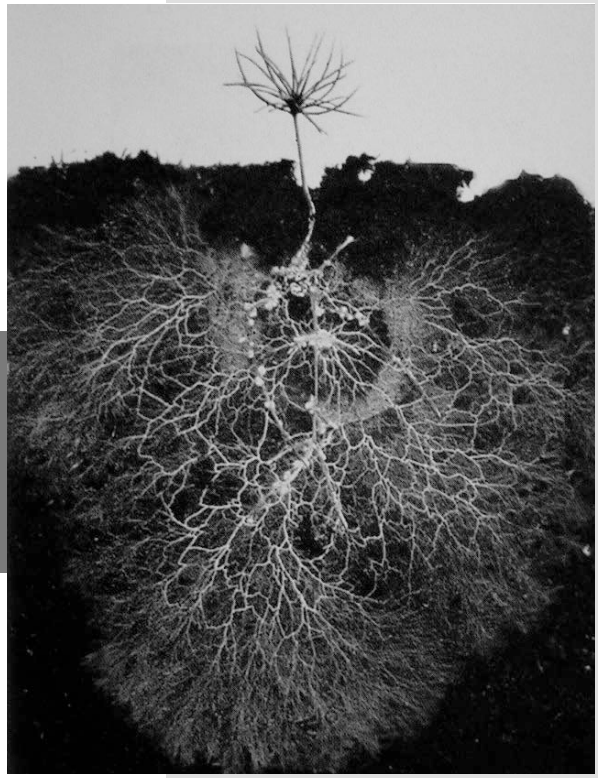
EarthDate

The Secret Life of Soil



A small pine tree grown in a glass box reveals the level of white, finely branched mycorrhizal threads or "mycelium" that attach to roots and feed the plant.

Credit: Professor Emeritus David Read, University of Sheffield, UK

Leonardo da Vinci once said: "We know more about the movement of celestial bodies than about the soil underfoot."

He was right 500 years ago, and he's still right today.

That's partly because the study of space is mysterious and cool, and there really wasn't much interest in studying dirt. Until recently...

We now know that about 90 percent of *all* land-based species live *in* the soil, not on it. Most of these are microscopic, but they're incredibly plentiful: there are more microbes in a handful of dirt than people on the planet.

And they're also incredibly important: without soil microbes, plants might not exist.

Plants require nitrogen and other trace elements, and it's soil bacteria, and the single-celled organisms that eat them, that process these elements into forms that the plants can use.

With this knowledge, agricultural researchers are reintroducing bacteria into depleted soils to increase the health and nutrition of crops.

Most plants also depend on soil fungi, and this relationship is symbiotic.

The fungi penetrate or encase the roots of plants to draw out what they can't make themselves: sugars from photosynthesis.

In exchange, the fungus filaments stretch deep into the soil, gathering water and nutrients from a volume 100 times greater than the roots could reach on their own.

This fungal network can even join plants together beneath the soil, which allows amazing things to happen—and we'll talk more about that on another *EarthDate*.

Bureau of Economic Geology

Background: The Secret Life of Soil

Synopsis: In *EarthDate* Episode 029, we talked about the characteristics of soil and how it forms from rocks. Now, let's turn to the mysteriously powerful secret life of soil! From bacteria and fungi to single-celled protozoa, to microarthropods like mites, to tiny nematodes, to wriggly centipedes and earthworms, the soil that provides structural support for Earth's plants is alive! Ninety percent of all land-based species live in soil, but most are too tiny for us to see without a microscope. Some of these microbes have a symbiotic relationship with plants, directing essential nutrients and water to plant roots and even helping plants to communicate.

- A handful of dirt contains more microbes than there are people on Earth and more biodiversity than is found in all the animals (including insects) of the Amazon Basin.
  - Studies of the human gut microbiome paved the way for studies of the soil microbiome.
  - Soil microorganisms provide water and essential nutrients to the roots of plants.
    - Scientists track the movement of carbon, nutrients, and water through the soil and plant ecosystems using isotopes; they use DNA to track relationships among organisms.
  - Bacteria are the largest number and most diverse of species in the soil. Some bacteria convert atmospheric nitrogen into forms that plants can use through *nitrogen fixation*.
    - Protozoans are single-celled organisms that feed on bacteria and other microbes, releasing as much as 80 percent of the nitrogen that plants use.
- Some types of fungi develop amazing symbiotic relationships with plant roots; these *mycorrhizal associations* enhance the plant's soil nutrient and water uptake.
  - Mycorrhizal associations—or *mycorrhizae* (my-kuh-RYE-zee), Latin for "fungus roots"—refer to the area of actual connection of fungal filaments (also called *mycelia*) to the plant roots.
    - The mycelia are about 60 times finer than root tips and may be kilometers long.
    - The connection to fungal filaments extends the soil-contact exposure of the root system about a hundred times farther than its actual root zone.
    - Some fungal filaments penetrate the root tips, while others create an external sheath around the tips.
    - Along with roots, these fungal networks help to hold soil together.
  - All gymnosperms (pines and firs) must form mycorrhizae with fungi to get their nutrients. About 80 percent of all other plant types also depend on these mycorrhizal associations.
  - The fruiting structures of these fungi are mushrooms and truffles that pop up on the forest floor.
- Scientists have found mycorrhizal associations to be a mutually beneficial relationship.
  - A plant uses sunlight, water, and CO_2 during photosynthesis to manufacture sugars—simple carbohydrates—that provide energy for itself.
    - Plants share these carbohydrates with fungi in the soil through their mycorrhizae, and other soil microbes like bacteria also benefit.
    - In return, the soil microbiome basically digests nutrients like nitrogen, potassium, phosphorus, and various trace elements so plants can readily assimilate them.
    - Then, the mycorrhizal fungi channel water and these essential nutrients directly to the root tips.
    - Forest ecosystems are able to provide defensive signals using chemical, hormonal, and electrical signals transmitted via mycorrhizal connections. We'll talk about this phenomenon in another *EarthDate* episode.
- Although we are learning volumes about the contribution of soil microbes to our lives, what Leonardo da Vinci wrote 500 years ago is probably still true: "We know more about the movement of celestial bodies than about the soil underfoot."
  - The Earth Microbiome Project is designed to analyze and map microbial communities in soils and waters around the world.
  - The next big revolution in human health may center on reintroducing microbes to depleted soils to improve the productivity and nutritional value of crops.

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