Laccaria spp. fruiting at the site where a possum carcass decomposed, in South Island, New Zealand. Photo by Toshimitsu Fukiharu, 1997.

FUNGI AND THE FOREST
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The Birth of the Forests: The Creation of Fungi and Plants

About 900 million years ago, the ancestors of fungi diverged from the ancestors of animals and emerged on Earth. They dwelt in the water as parasites of aquatic creatures, living by decomposing their bodies.

Then 400 million years ago, fungi and plants sought a larger world and emerged onto the land together. Before then, the land was devoid of forests – a nearly naked world.

When they left the water, the fungi and plants had to face new challenges in the form of gravity and desiccation. They formed an alliance and invented systems called "mycorrhizae." They became symbiotic organisms, strengthening their roots by pulling water and nutrients from the soil and spreading their threads throughout the ground. They gained the ability to grow into the third dimension and reach towards the sky.

The mycorrhizal systems transport the products of photosynthesis (sugars) from the plants to the fungi. Nutrients (inorganic salts) and water flow in the other direction from fungi to the plants. They are symbiotic—each supplies the other with the substances that they would struggle to acquire on their own. Even today, virtually all land plants have mycorrhizae, continuing a relationship between the plants and fungi that began 400 million years ago. It is thought that nearly all the water and inorganic salts that plants receive from the soil pass through fungi. Plants need fungi to survive. When we humans look at the forest, we can see only the plants, but we are actually looking at symbiotic organisms created by the fusion of plants and fungi.

After emerging onto the land, the fungal and vegetal symbionts experimented with many types of mycorrhizal systems. One of them was called ectomycorrhiza, in which hyphae envelop the surfaces of roots, like stockings woven from fine fungal threads. These stockings protected the symbionts against cold and desiccation, allowing them to explore even colder, drier climates.

The families of symbiotic organisms that developed these high-performance systems (such as *Fagaceae* (beech), *Pinaceae* (pine), and *Betulaceae* (birch) built what have become some of the most successful forests in existence today. Except in deserts, the ectomycorrhizal families dominate the canopies of Europe and the rest of the northern hemisphere. As these forests expanded between 100 and 200 million years ago, the number of ectomycorrhizal fungi species exploded thanks to their symbiosis with plants.

These forests were symbiotic entities made up of fungi and plants. They came to cover every corner of the planet, releasing new versions of mycorrhizae and diverse forms of vegetal and fungal life.

The networks of hyphae created by these vegetal-fungal symbiotic entities spread through the soil, connecting plants that might appear isolated on the surface. Not only do "mother trees" send nutrients to new shoots; plants communicate information to each other. The networks of hyphae woven by ectomycorrhizal fungi are essential infrastructure for sharing information and materials in forests.

Of course, fungi have another essential function: to break down the organic substances produced by the photosynthetic processes of vegetal-fungal entities. Fungi return all the dead leaves and branches that accumulate on the forest floor, and all the fallen trees, to the soil.

Formed over eons as they made their homes on Earth, forests are elaborate organisms within which many different fungi and plants live symbiotically, each able to make the most of their special abilities.

The Birth of Ammonia Fungi and Coprophilous Fungi

Animals came to live in the forests made by fungi and plants. They gradually grew larger, some becoming titans like the dinosaurs, creating cycles of birth and death within the forests. This led to some problems.

As animal bodies decompose, they release toxic ammonia into the soil. The ammonia kills soil-borne microbes, creating "microbial wastelands" – tears in the forest's organic tapestry. In order to mend these tears and restore the wastelands, forests created new fungi. These are called ammonia fungi, a group made up of saprobic and ectomycorrhizal fungi. Ammonia fungi specialize in quickly colonizing places soiled by ammonia, which other fungi avoid. They extend their hyphae, and restore the soil to its previous state, while regenerating mycorrhizal roots. The displaced saprobic and ectomycorrhizal fungi return as the soil recovers. When the original fungal inhabitants have returned, ammonia fungi disappear from the surface and wait within the soil for new wastelands to appear. The forests create many such groups of fungi and plants, which stand by to repair all kinds of tears. Ammonia fungi suited to different types of soil live in every forest in the world, though their species may be different.

Animal droppings can also cause problems, by releasing ammonia as they decompose. But droppings are also a blessing. The organic materials and nitrogen packed into the droppings launch microbes into a feeding frenzy. Coprophilous fungi emerged and quickly dominated this attractive food source. Coprophilous fungi embed their spores in the plants that animals eat (for example, by sticking their spores to leaves) and germinate in their digestive systems. As soon as they are released with an animal's droppings, they begin their work taking control of the resource and breaking it down into food.

In most cases, droppings are small, such as those of deer or rabbits. Fungi enjoy feasts, but they feast on ships that are destined to soon go down. This is why coprophilous fungi have devised ingenious life boats. Some species, such as *Pilobilus* and *Sphaerobolus*, shoot clumps of spores over long distances.

Others, such as inky cap fungi, accelerate the production of mushrooms (the organs which produce those spores). Each species of coprophilous fungus has its own solution to the problems caused by animal droppings in the forest.

The Mushrooms That Clean Mole Toilets

This is one particularly intriguing example of something created by the forest. There is a species of fungus called the rooting poison pie, which specializes in cleaning the toilets used by moles. These mushrooms were recorded in a French atlas in the late 18th century as *Hebeloma radicosum*. The name means "a long-rooted relative of the *Hebeloma*" but it was more than 200 years later that the true meaning of its name was understood. A mycologist in an island country in the Far East became curious about the mushroom's long root and tried digging beneath it to see what was there. Underneath, he discovered a mole's toilet. The mycologist continued to dig more than 100 similar spots, only to find that they were all mole toilets. Afterwards, this curious phenomenon became known in other countries, and when people dug under Swiss and English mushrooms, they too found mole toilets.

Moles dig underground tunnels in search of places with good drainage and insects to eat. When they find a suitable spot, they dig a round room below, using fallen leaves rolled up to create bedding for a comfortable nest. The typical lifespan of a mole is three to five years, but some nests might be used across generations for more than 20 years. This was another discovery made by researchers in the East. Moles want to live in comfort, but they always face the problem of where to put their droppings. They build toilets in the corridors surrounding their round nests, using one spot for a time before moving on to another further along. This approach eventually reaches a limit, and it does not help that decomposition is challenging in an underground toilet. Enter *Hebeloma radicosum*. For a mushroom, an underground toilet makes it easy to take control of the moles' droppings. To the moles' benefit, the fungi takes the droppings away by absorbing them and carrying them above the surface in the form of mushrooms. These ectomycorrhizal fungi are also symbiotic with beech trees, which means that the trees of the forest also play a role in helping keep things clean for the moles. Moles live in the forest with the help of these toilet-cleaning specialists. The moles' toilets need little maintenance. The ones humans use need sewers and water treatment plants. Are our toilets "advanced" in comparison?

The relationships between the plants, mushrooms and moles in the forest offer insight into other relationships in the forest, different from the connections that ammonia fungi or coprophilous fungi have. The moles' toilets teach us how amazing an organism the forest is, and how little humans still know about its secrets.

All Animals, Plants and Fungi Are Born and Die in the Forest

The forests created by the fungi and plants drew animals into their fold, becoming a place for them to be born, grow and die. The forests became places of life and of death. Ammonia fungi, coprophilous fungi, and *Hebeloma radicosum* are important parts of the forest system. Humans still know little about the forest, but if we ask it our questions, then it will answer in a way we might understand.

The Birth of Humanity

Animals cannot live without forests, the sustenance they provide, and the lives and deaths to which they are home. This is why it was taboo for animals to devour the forests. Animals cannot easily digest the constituents of plant life – lignin and cellulose. And if animals were to eat the forests, they would be devouring their own homes. In the long history of Earth, no animal has chosen to eat the forests.

Fungi were the same. They focused on eating the dead: fallen trees, old leaves and dead branches. They never wanted to devour the living forests. (Some may sicken plants, but no fungi ever emerged to consume all of the plants of the forest.)

Only one organism in the forest violated this taboo: humans. Humans are just one of the many species born in the forest, but they are destroying its cycles of birth and death. We must let fungi and other living things teach us what it means to know, understand and learn about the forests as fellow organisms.

Toshimitsu Fukiharu is a mycologist who studies the natural history of mushrooms, with a particular focus on ammonia fungi that grow on decaying organic matter. He is the editor and author of *Mushroom Botanical Art*, a book showcasing 18th- and 19th-century illustrations of mushrooms and fungi.

This manifesto is part of *FUNGI: Anarchist Designers*. This exhibition, curated by anthropologist Anna Tsing and architect-artist Feifei Zhou, presents fungi as radical designers in a world beyond human control. On show at the Nieuwe Instituut from 21 November 2025 to 9 August 2026. With the support of het Cultuurfonds, Mondriaan Fonds, Graham Foundation and Iona Stichting.