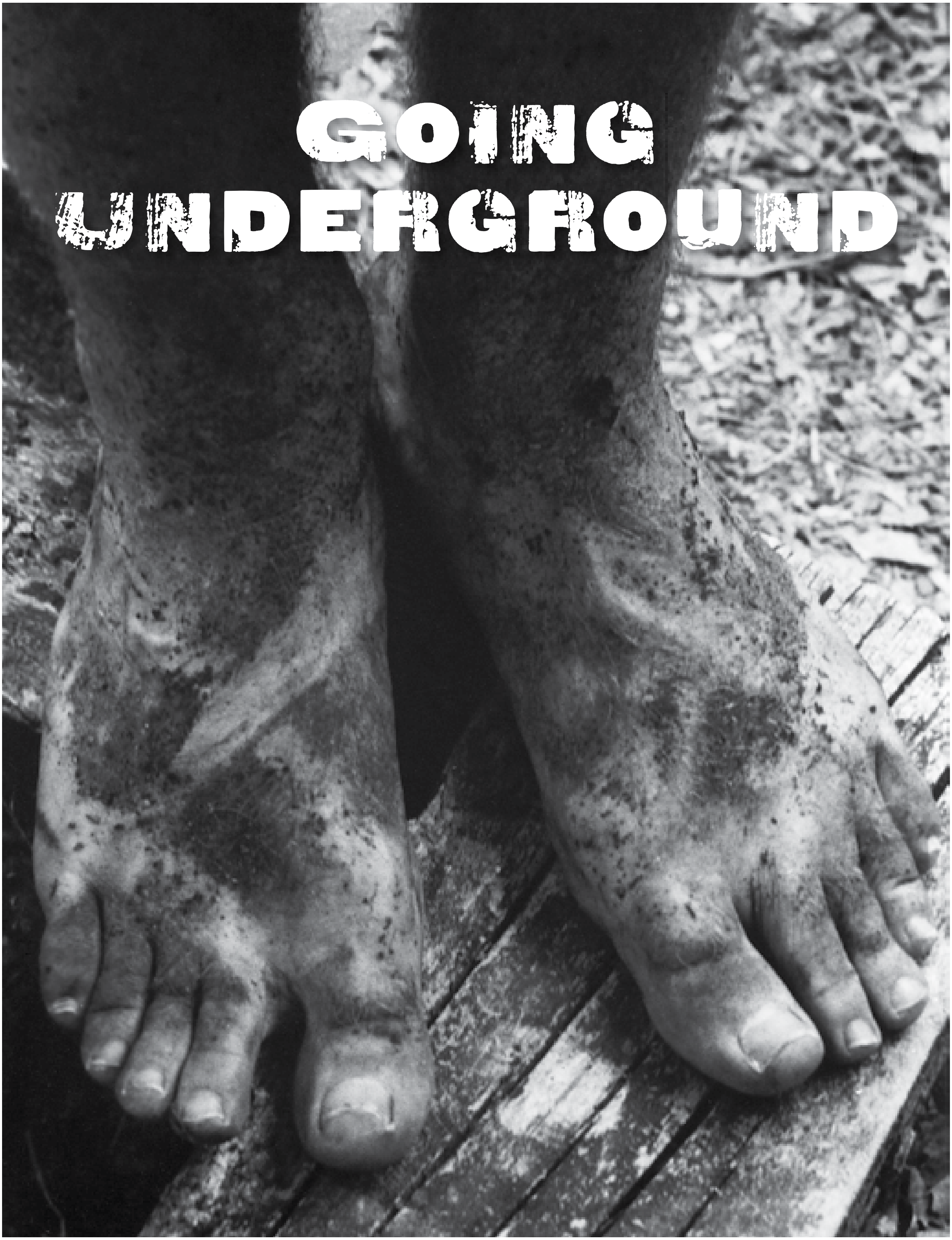
GOING UNDERGROUND



RACHEL J. ELLIOTT

Paul Stamets On The Vast, Intelligent Network Beneath Our Feet

DERRICK JENSEN

For several years people from different places and backgrounds kept recommending the same oddly titled book to me: Paul Stamets's Mycelium Running: How Mushrooms Can Help Save the World *(Ten Speed Press). Everyone told me it was one of the most mind-bending texts they'd ever read. With so many recommendations, I perversely hesitated to pick the book up, and when I finally did, I prepared myself to be disappointed.*

I wasn't. Stamets fundamentally changed my view of nature — in particular, fungi: yeasts, mushrooms, molds, the whole lot of them.

When we think of fungi, most of us picture mushrooms, those slightly mysterious, potentially poisonous denizens of dark, damp places. But a mushroom is just the fruit of the mycelium, which is an underground network of rootlike fibers that can stretch for miles. Stamets calls mycelia the "grand disassemblers of nature" because they break down complex substances into simpler components. For example, some fungi can take apart the hydrogen-carbon bonds that hold petroleum products together. Others have shown the potential to clean up nerve-gas agents, dioxins, and plastics. They may even be skilled enough to undo the ecological damage pollution has wrought.

Since reading Mycelium Running, *I've begun to consider the possibility that mycelia know something we don't. Stamets believes they have not just the ability to protect the environment but the intelligence to do so on purpose. His theory stems in part from the fact that mycelia transmit information across their huge networks using the same neurotransmitters that our brains do: the chemicals that allow us to think. In fact, recent discoveries suggest that humans are more closely related to fungi than we are to plants.*

Almost since life began on earth, mycelia have performed important ecological roles: nourishing ecosystems, repairing them, and sometimes even helping create them. The fungi's exquisitely fine filaments absorb nutrients from the soil and then trade them with the roots of plants for some of the energy that the plants produce through photosynthesis. No plant community could exist without mycelia. I've long been a resident and defender of forests, but Stamets helped me understand that I've been misperceiving my home. I thought a forest was made up entirely of trees, but now I know that the foundation lies below ground, in the fungi.

Stamets became interested in biology in kindergarten, when he planted a sunflower seed in a paper cup and watched it sprout and lift itself toward the light. Somewhere along the way, he developed a fascination with life forms that grow not toward the sun but away from it. In the late seventies he got a Drug Enforcement Administration permit to research hallucinogenic psilocybin mushrooms at Evergreen State College in Washington. Stamets is now fifty-two and has studied mycelia for more than thirty years, naming five new species and authoring or coauthoring six books, including Growing Gourmet and Medicinal Mushrooms *(Ten Speed Press) and* The Mushroom Cultivator *(Agarikon Press). He's the founder and director of Fungi Perfecti (www.fungi.com), a company based outside Olympia, Washington, that provides mushroom research, information, classes, and spawn — the mushroom farmer's equivalent of seed. Much of the company's profits go to help protect endangered strains of fungi in the old-growth forests of the Pacific Northwest. I interviewed Stamets in June 2007.*

Jensen: How many different types of mushrooms are there?

Stamets: There are an estimated one to two million species of fungi, of which about 150,000 form mushrooms. A mushroom is the fruit body — the reproductive structure — of the mycelium, which is the network of thin, cobweblike cells that infuses all soil. The spores in the mushroom are somewhat analogous to seeds. Because mushrooms are fleshy, succulent, fragrant, and rich in nutrients, they attract animals — including humans — who eat them and thereby participate in spreading the spores through their feces.

Our knowledge of fungi is far exceeded by our ignorance. To date, we've identified approximately 14,000 of the 150,000 species of mushroom-forming fungi estimated to exist, which means that more than 90 percent have not yet been identified. Fungi are essential for ecological health, and losing any of these species would be like losing rivets in an airplane. Flying squirrels and voles, for example, are dependent upon truffles, and in old-growth forests, the main predator of flying squirrels and voles is the spotted owl. This means that killing off truffles would kill off flying squirrels and voles, which would kill off spotted owls.

PAUL STAMETS

That's just one food chain that we can identify; there are many thousands more we cannot. Biological systems are so complex that they far exceed our cognitive abilities and our linear logic. We are essentially children when it comes to our understanding of the natural world.

Jensen: In your book you say that animals are more closely related to fungi than they are to plants or protozoa or bacteria.

Stamets: Yes. For example, we inhale oxygen and exhale carbon dioxide; so do fungi. One of the big differences between animals and fungi is that animals have their stomachs on the inside. About 600 million years ago, the branch of fungi leading to animals evolved to capture nutrients by surrounding their food with cellular sacs — essentially primitive stomachs. As these organisms evolved, they developed outer layers of cells — skins, basically — to prevent moisture loss and as a barrier against infection. Their stomachs were confined within the skin. These were the earliest animals.

Mycelia took a different evolutionary path, going underground and forming a network of interwoven chains of cells, a vast food web upon which life flourished. These fungi paved the way for plants and animals. They munched rocks, producing enzymes and acids that could pull out calcium, magnesium, iron, and other minerals. In the process they converted rocks into usable foods for other species. And they still do this, of course.

Fungi are fundamental to life on earth. They are ancient, they are widespread, and they have formed partnerships with many other species. We know from the fossil record that evolution on this planet has largely been steered by two cataclysmic asteroid impacts. The first was 250 million years ago. The earth became shrouded in dust. Sunlight was cut off, and in the darkness, massive plant communities died. More than 90 percent of species disappeared. And fungi inherited the earth. Organisms that paired with fungi through natural selection were rewarded. Then the skies cleared, and light came back, and evolution continued on its course until 65 million years ago, *bam!* It happened again. We were hit by another asteroid, and there were more massive extinctions. That's when the dinosaurs died out. Again, organisms that paired with fungi were rewarded. So these asteroid impacts steered life toward symbiosis with fungi: not just plants and animals, but bacteria and viruses, as well.

Jensen: Can you give some examples of these partnerships?

Stamets: A familiar one is lichens, which are actually a fungus and an alga growing symbiotically together. Another is "sleepy grass": Mesoamerican ranchers realized that when their horses ate a certain type of grass, the horses basically got stoned. When scientists studied sleepy grass, they found that it wasn't the grass at all that was causing the horses to get stoned, but an endophytic fungus, meaning one that grows within a plant, in the stems and leaves.

Here's another example: At Yellowstone's hot springs and Lassen Volcanic Park, people noticed that some grasses could survive contact with scalding hot water — up to 160 degrees. Scientists cultured these grasses in a laboratory and saw a fungus growing on them. They thought it was a contaminant, so they separated the fungus from the grass cells and tried to regrow the grass. But without the fungus the grass died at around 110 degrees. So they reintroduced this fungus and regrew the grass, and once again it survived to 160 degrees. That particular fungus, of the genus *Curvularia*, conveyed heat tolerance to the grass. Scientists are now looking at the possibility of getting this *Curvularia* to convey heat tolerance to corn, rice, and wheat, so that these grasses could be grown under drought conditions or in extremely arid environments, expanding the grain-growing regions of the world.

Other researchers took a *Curvularia* fungus from cold storage at a culture bank and joined it with tomatoes, expecting that it would confer heat tolerance. But the tomatoes all died at 105 degrees. They discovered that the cold storage had killed a virus that wild *Curvularia* fungus carries within it — which was odd, since you'd think cold storage would keep the virus alive. When they reintroduced the virus back into the *Curvularia* cultures and then reassociated the fungus with tomato plants, the plants survived the heat. So this is a symbiosis of three organisms: a plant, a fungus, and a virus. Only together

A mycelial "mat," which scientists think of as one entity, can be thousands of acres in size. The largest organism in the world is a mycelial mat in eastern Oregon that covers 2,200 acres and is more than two thousand years old.

RACHEL J. ELLIOTT

could they survive extreme conditions.

These examples are just the tip of the iceberg. They show the intelligence of nature, how these different entities form partnerships to the benefit of all.

Jensen: Of course this raises the question of boundaries: Is that tomato-fungus-virus one entity or three? Where does one organism stop and the other begin?

Stamets: Well, humans aren't just one organism. We are composites. Scientists label species as separate so we can communicate easily about the variety we see in nature. We need to be able to look at a tree and say it's a Douglas fir and look at a mammal and say it's a harbor seal. But, indeed, I speak to you as a unified composite of microbes. I guess you could say I am the "elected voice" of a microbial community. This is the way of life on our planet. It is all based on complex symbiotic relationships.

A mycelial "mat," which scientists think of as one entity, can be thousands of acres in size. The largest organism in the world is a mycelial mat in eastern Oregon that covers 2,200 acres and is more than two thousand years old. Its survival strategy is somewhat mysterious. We have five or six layers of skin to protect us from infection; the mycelium has one cell wall. How is it that this vast mycelial network, which is surrounded by hundreds of millions of microbes all trying to eat it, is protected by one cell wall? I believe it's because the mycelium is in constant biochemical communication with its ecosystem.

I think these mycelial mats are neurological networks. They're sentient, they're aware, and they're highly evolved. They have external stomachs, which produce enzymes and acids to digest nutrients outside the mycelium, and then bring in those compounds that it needs for nutrition. As you walk through a forest, you break twigs underneath your feet, and the mycelium surges upward to capture those newly available nutrients as quickly as possible. I say they have "lungs," because they are inhaling oxygen and exhaling carbon dioxide, just like we are. I say they are sentient, because they produce pharmacological compounds — which can activate receptor sites in *our* neurons — and also serotonin-like compounds, including psilocybin, the hallucinogen found in some mushrooms. This speaks to the fact that there is an evolutionary common denominator between fungi and humans. We evolved from fungi. We took an overground route. The fungi took the route of producing these underground networks that are highly resilient and extremely adaptive: if you disturb a mycelial network, it just regrows. It might even benefit from the disturbance.

I have long proposed that mycelia are the earth's "natural Internet." I've gotten some flak for this, but recently scientists in Great Britain have published papers about the "architecture" of a mycelium — how it's organized. They focused on the nodes of crossing, which are the branchings that allow the mycelium, when there is a breakage or an infection, to choose an alternate route and regrow. There's no one specific point on the network that can shut the whole operation down. These nodes of crossing, those scientists found, conform to the same mathematical optimization curves that computer scientists have developed to optimize the Internet. Or, rather, I should say that the Internet conforms to the same optimization curves as the mycelium, since the mycelium came first.

(end of excerpt)