

# The Hidden World of Fungi

*Networks, Medicine, and the Wood Wide Web*

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## C1 Level Reading Material

Fleydo English School

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### Chapter I: Neither Plant Nor Animal

*The strange biology of a kingdom hidden in plain sight*

When most people think of **fungi**, they picture mushrooms — the familiar caps and stems that appear on forest floors, supermarket shelves, and pizza toppings. Yet the visible mushroom is merely the fruiting body, the reproductive organ of an organism whose true body — a vast, branching network of microscopic filaments called **mycelium** — lies hidden beneath the surface. If the mushroom is the apple, the mycelium is the tree. And what a tree it is: a single fungal colony can extend across hectares of soil, making some fungal organisms among the largest and oldest living things on Earth. The honey fungus (*Armillaria ostoyae*) in Oregon's Blue Mountains spans approximately 965 hectares and is estimated to be over 2,400 years old.

Fungi occupy their own **kingdom** in the biological classification system, separate from both plants and animals — a distinction that was not formally established until 1969, when the ecologist Robert Whittaker proposed the five-kingdom **taxonomy** that is still widely taught today. Unlike plants, fungi cannot perform **photosynthesis**; they lack chlorophyll and are incapable of producing their own food from sunlight. Unlike animals, they do not ingest food; instead, they secrete digestive enzymes externally and absorb the resulting nutrients through their cell walls — walls made not of cellulose (as in plants) but of **chitin**, the same tough polymer that forms the exoskeletons of insects.

The basic structural unit of a fungus is the **hypha** (plural: **hyphae**) — a tubular filament typically just a few micrometres in diameter. Hyphae grow at their tips, branching and fusing to form the three-dimensional mesh of mycelium that permeates soil, wood, leaf litter, and virtually every terrestrial **ecosystem** on Earth. The reproductive strategy of most fungi involves the production of **spores** — microscopic propagules released in astronomical quantities. A single giant puffball mushroom can release over seven trillion spores; the total mass of fungal spores circulating in the Earth's atmosphere at any given moment is estimated at 50 million tonnes.



Fungi engage in three fundamental ecological strategies. **Saprotrophic** fungi decompose dead organic matter, recycling nutrients back into the soil. **Parasitic** fungi feed on living organisms, sometimes killing their hosts. And **mutualistic** fungi form reciprocal partnerships with other organisms — partnerships so ancient, so widespread, and so ecologically consequential that they have fundamentally shaped the evolution of life on land.

## Chapter II: The Wood Wide Web

*How trees talk through fungal networks — and what they say*

The term "Wood Wide Web," coined by the journal *Nature* in 1997, describes the vast underground **mycorrhizal** networks through which fungi and plant roots form intimate, mutually beneficial partnerships. In a mycorrhizal association — from the Greek *myco* (fungus) and *rhiza* (root) — the fungus extends its hyphal network far beyond the reach of the plant's own roots, dramatically increasing the plant's access to water and mineral **nutrients**, particularly **phosphorus** and **nitrogen**. In return, the plant supplies the fungus with **carbon**-rich sugars produced through photosynthesis — **glucose** that the fungus, lacking chlorophyll, cannot manufacture for itself.

Approximately 90 percent of all land plants form mycorrhizal associations, and the relationship is ancient: fossil evidence suggests that mycorrhizal  **symbiosis** was already established when the first plants colonised land over 450 million years ago. Some botanists have argued that plants could not have made the transition from water to land without fungal assistance — that the entire terrestrial biosphere, in a very real sense, was co-created by the partnership between plants and fungi.

The Canadian ecologist Suzanne Simard's research has revealed that mycorrhizal networks do far more than simply connect individual trees to individual fungi. In a series of pioneering experiments beginning in the 1990s, Simard demonstrated that these networks facilitate the transfer of resources — carbon, water, nutrients, and even chemical warning signals — between trees, including trees of different species. Large, established trees, which Simard calls "**mother trees**," preferentially channel resources through mycorrhizal networks to struggling seedlings in the **understory**, particularly their own genetic offspring.

When a tree is attacked by insects, it can release chemical defence compounds that travel through the mycorrhizal network to neighbouring trees, effectively warning them to activate their own defences before the threat arrives. When a tree is dying — whether from disease, drought, or logging — it appears to "dump" its remaining carbon and nutrient reserves into the network, where they become available to surviving neighbours. The forest, Simard argues, behaves not as a collection of competing individuals but as a cooperative superorganism, bound together by the fungal internet beneath its roots.



## Chapter III: Medicine from the Mould

*From penicillin to psilocybin — the pharmaceutical treasure chest of the fungal kingdom*

In September 1928, the Scottish bacteriologist Alexander Fleming returned from holiday to find that a [petri dish](#) of *Staphylococcus* bacteria in his laboratory had been contaminated by a mould — *Penicillium notatum*. Rather than discarding the dish, Fleming noticed that the bacteria surrounding the mould had been killed, and recognised that the mould was producing a substance with powerful antibacterial properties. That substance — [penicillin](#) — would become the first [antibiotic](#), inaugurating a medical revolution that has saved an estimated 200 million lives and earned Fleming, along with Howard Florey and Ernst Boris Chain who developed it for mass production, the Nobel Prize in Physiology or Medicine in 1945.

Penicillin was only the beginning. Fungi have since yielded a remarkable pharmacopoeia. The [statins](#) — the world's most widely prescribed class of drugs for reducing cholesterol — were first isolated from the fungus *Aspergillus terreus*. [Cyclosporine](#), the [immunosuppressant](#) drug that made organ transplantation viable by preventing rejection of transplanted tissues, was derived from the soil fungus *Tolypocladium inflatum*. Griseofulvin, ergotamine, and caspofungin are just a few of the other clinically essential compounds that owe their existence to fungi.

Perhaps the most dramatic recent development is the renaissance of research into [psilocybin](#) — the [psychedelic](#) compound produced by over 200 species of mushrooms. After decades of prohibition following the excesses of the 1960s counterculture, psilocybin has re-emerged as the subject of rigorous [clinical trials](#) at institutions including Johns Hopkins University, Imperial College London, and New York University. These trials have produced remarkable results: psilocybin-assisted therapy has shown significant efficacy in treating depression, anxiety, addiction, and end-of-life distress in terminally ill patients, often after just one or two sessions.

The irony of antibiotic [resistance](#) — the growing inability of existing antibiotics to kill bacteria that have evolved defences against them — has brought the search for new antimicrobial compounds full circle. Soil fungi, which have been waging chemical warfare against bacteria for hundreds of millions of years, remain one of the most promising sources of novel antibiotics. Yet the vast majority of fungal species — estimated at over 90 percent — have never been scientifically described, let alone screened for pharmaceutical potential.



## Chapter IV: The Great Recyclers

*Decomposition, nutrient cycling, and the world without decay*

If all the world's fungi vanished overnight, the consequences would be swift and catastrophic. Dead organic matter — fallen leaves, dead trees, animal carcasses, agricultural waste — would simply

accumulate, undecomposed. Within years, the world's soils would become depleted of the nutrients that plants require for growth, and terrestrial ecosystems would collapse. **Decomposition**, the process by which complex organic compounds are broken down into simpler substances and returned to the soil, is the ecological service upon which all terrestrial life ultimately depends — and it is a service performed overwhelmingly by fungi.

Saprotrophic fungi are the primary agents of **nutrient cycling** in forest ecosystems. By secreting powerful extracellular enzymes — cellulases, ligninases, pectinases — they can break down the toughest biological polymers, including lignin, the structural compound that gives wood its rigidity and that virtually no other organism can digest. White-rot fungi, in particular, are the only organisms on Earth capable of fully degrading lignin, a capacity that has been likened to having the only key to the planet's largest locked storehouse of **carbon**.

The geological significance of fungal decomposition is profound. During the Carboniferous period (approximately 359–299 million years ago), before white-rot fungi had evolved the enzymes to digest lignin, dead trees accumulated in vast, undecomposed deposits that were eventually compressed into the coal seams that fuelled the Industrial Revolution. The evolution of lignin-degrading fungi effectively ended this process of large-scale carbon burial — a single evolutionary innovation by fungi fundamentally altered the Earth's carbon cycle and, by extension, its climate.

Fungi also play a critical role in **carbon sequestration**. Mycorrhizal fungi channel approximately 5 billion tonnes of carbon per year from the atmosphere into the soil through their symbiotic partnerships with plants — roughly equivalent to the annual carbon emissions of the United States. Recent research suggests that protecting and restoring mycorrhizal networks could be a significant component of climate change mitigation strategies.



## Chapter V: Fungi and the Future

*Mycoremediation, mycelium materials, and building a circular bioeconomy*

**Mycoremediation** — the use of fungi to degrade or sequester environmental **pollutants** — represents one of the most promising applications of mycology to the environmental crisis. Fungi have demonstrated the ability to break down a remarkable range of **toxins**, including petroleum hydrocarbons, pesticides, heavy metals, and even certain radioactive compounds. Following the Deepwater Horizon oil spill in 2010, researchers deployed oyster mushroom mycelium on oil-contaminated soil and observed dramatic reductions in hydrocarbon levels within weeks.

The material properties of mycelium are attracting intense commercial interest. Companies such as Ecovative Design and MycoWorks are developing **mycelium composites** — materials grown from fungal mycelium on agricultural waste **substrates** — that can replace plastic packaging,

polystyrene insulation, leather, and even building materials. These materials are biodegradable, require minimal energy to produce, and can be grown in virtually any shape. IKEA has announced plans to replace polystyrene packaging with mycelium-based alternatives, and Stella McCartney has launched a fashion line using mycelium "leather."

The vision of a fungal **bioeconomy** — an economic system in which biological processes replace petrochemical ones — is no longer speculative. Mycelium can be grown on agricultural waste, construction debris, or contaminated soil, transforming waste streams into valuable materials while simultaneously remediating environmental damage. Combined with the carbon-sequestering capacity of mycorrhizal networks, these technologies offer a pathway toward a genuinely **circular economy** in which waste is not merely reduced but eliminated by design.

The hidden world of fungi, it turns out, has been sustaining the visible world all along. From the mycorrhizal networks that nourish forests to the decomposers that recycle the dead into the living, from the moulds that gave us antibiotics to the mycelium that may give us sustainable materials, fungi are the unseen architects of life on Earth. As the mycologist Paul Stamets has written: "Fungi are the grand molecular disassemblers of nature." Learning to work with them, rather than ignoring them, may be among the most consequential choices humanity makes in the century ahead.

## Vocabulary Reference

Term	Definition
<b>Fungi</b>	A biological kingdom of spore-producing organisms including moulds, yeasts, and mushrooms
<b>Mycelium</b>	The branching network of fungal filaments; the main body of a fungus
<b>Hyphae</b>	Microscopic tubular filaments that form the mycelium
<b>Spore</b>	A microscopic reproductive unit produced by fungi
<b>Chitin</b>	A tough polymer forming fungal cell walls and insect exoskeletons
<b>Taxonomy</b>	The science of classifying organisms into groups
<b>Symbiosis</b>	A close, long-term biological interaction between two species
<b>Mutualism</b>	A symbiotic relationship benefiting both organisms
<b>Mycorrhizal</b>	Relating to the symbiotic association between fungi and plant roots
<b>Mother Tree</b>	A large, established tree that channels resources to seedlings via networks
<b>Saprotrophic</b>	Feeding on dead or decaying organic matter
<b>Decomposition</b>	The breakdown of organic matter into simpler substances
<b>Nutrient Cycling</b>	The movement of nutrients through an ecosystem
<b>Carbon Sequestration</b>	Capturing and storing atmospheric carbon dioxide
<b>Penicillin</b>	The first antibiotic, discovered from a Penicillium mould
<b>Antibiotic</b>	A substance that kills or inhibits bacteria
<b>Resistance</b>	The ability of bacteria to withstand antibiotic treatment
<b>Statin</b>	A class of drugs that lower cholesterol, derived from fungi
<b>Cyclosporine</b>	A fungal immunosuppressant enabling organ transplantation
<b>Psilocybin</b>	A psychedelic compound produced by certain mushrooms
<b>Clinical Trial</b>	A controlled study testing a medical treatment in humans
<b>Mycoremediation</b>	Using fungi to clean up environmental pollutants
<b>Pollutant</b>	A substance that contaminates the environment
<b>Substrate</b>	The material on which an organism grows or feeds
<b>Mycelium Composite</b>	A material grown from fungal mycelium on waste substrates
<b>Bioeconomy</b>	An economic system based on biological rather than petrochemical processes
<b>Circular Economy</b>	A system eliminating waste through continual reuse of resources
<b>Biodiversity</b>	The variety of life in a particular habitat or ecosystem

<b>Ecosystem</b>	A community of interacting organisms and their environment
<b>Photosynthesis</b>	The process by which plants convert sunlight into energy
<b>Phosphorus</b>	An essential mineral nutrient for plant growth
<b>Canopy</b>	The uppermost layer of branches and leaves in a forest
<b>Understory</b>	The layer of vegetation beneath the forest canopy

## Fill-in-the-Blank Exercise

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**Word Bank:** *mycelium, mycorrhizal, symbiosis, penicillin, decomposition, saprotrophic, carbon sequestration, mycoremediation, psilocybin, resistance*

1. The true body of a fungus is the vast underground network of \_\_\_\_\_, not the visible mushroom.
2. \_\_\_\_\_ networks connect tree roots with fungal hyphae, enabling nutrient exchange.
3. The partnership between fungi and plant roots is one of nature's oldest forms of \_\_\_\_\_.
4. Alexander Fleming's accidental discovery of \_\_\_\_\_ launched the antibiotic revolution.
5. \_\_\_\_\_ fungi are the primary agents of decomposition, breaking down dead organic matter.
6. \_\_\_\_\_ — the breakdown of complex organic compounds — is essential for nutrient recycling.
7. Mycorrhizal fungi channel approximately 5 billion tonnes of carbon per year through \_\_\_\_\_.
8. \_\_\_\_\_ uses fungi to degrade environmental pollutants such as petroleum and pesticides.
9. Clinical trials of \_\_\_\_\_-assisted therapy have shown significant efficacy in treating depression.
10. Antibiotic \_\_\_\_\_ — bacteria evolving defences against drugs — has made the search for new compounds urgent.

**Answers:** 1. mycelium 2. Mycorrhizal 3. symbiosis 4. penicillin 5. Saprotrophic 6. Decomposition 7. carbon sequestration 8. Mycoremediation 9. psilocybin 10. resistance

## Comprehension Quiz

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1. Fungi are classified in their own kingdom because they:

- A) Can perform photosynthesis
- B) Are neither plant nor animal — they absorb nutrients externally**
- C) Are all microscopic
- D) Only grow underground

2. The largest known organism on Earth is:

- A) A blue whale
- B) A giant sequoia tree
- C) A honey fungus colony in Oregon**
- D) A coral reef

3. In a mycorrhizal association, the fungus provides the plant with:

- A) Sunlight
- B) Carbon dioxide
- C) Water and mineral nutrients, especially phosphorus**
- D) Oxygen

4. Suzanne Simard's research demonstrated that:

- A) Trees compete for all resources
- B) Trees share resources and signals through mycorrhizal networks**
- C) Fungi are harmful to forests
- D) Only identical species can communicate

5. Penicillin was discovered by:

- A) Louis Pasteur
- B) Alexander Fleming**
- C) Howard Florey
- D) Robert Koch

6. The renaissance of psilocybin research has shown promising results in treating:

- A) Cardiovascular disease
- B) Depression, anxiety, and addiction**
- C) Bacterial infections
- D) Diabetes

7. White-rot fungi are ecologically unique because they:

- A) Can perform photosynthesis
- B) Are the only organisms capable of fully degrading lignin**
- C) Produce the most spores
- D) Are resistant to all diseases

8. During the Carboniferous period, dead trees accumulated as coal because:

- A) The climate was too cold for decomposition
- B) Lignin-degrading fungi had not yet evolved**
- C) There were no saprotrophic organisms
- D) The atmosphere lacked oxygen

**9. Mycoremediation has been successfully used to:**

- A) Increase crop yields
- B) Degrade petroleum hydrocarbons in contaminated soil**
- C) Replace all synthetic fertilisers
- D) Genetically modify plants

**10. Mycelium composites are attracting commercial interest because they:**

- A) Are cheaper than all existing materials
- B) Are biodegradable and can replace plastics and packaging**
- C) Conduct electricity
- D) Are edible