Cowgate and the Wood Wide Web

Deborah Gasking

What is everywhere; but easy to miss?
What's inside you and on you?
What sustains you and all that you depend upon?
They eat rock, make soil, digest pollutants, nourish and kill plants.
What reduces collapse disorder in honeybees?
What can survive in space and influence the composition of earth's atmosphere?
What can digest a most common litter problem – cigarette butts?
They are used to make alcohol, vaccines, antibiotics, anti-virals and fizzy drinks.

No, not a Christmas cracker conundrum…
The answer is (drum roll) fungi!

Five hundred million years ago

Plants made their exit from a watery life because of their collaboration with fungi – their root system for tens of millions of years. But first, colonies of lichens – a union of algae and fungi – needed to establish on glacial and volcanic rock to make soil in which plants could grow. This ancient association between plants and fungi gave rise to all recognisable life on land.

Hundreds of species exist in the leaves and stems of a single plant, weaving their way between the plant's cells, helping defend those plants against disease. No naturally grown plant is without these fungi; they are as much a part of the plant as its roots and leaves.

Metabolic wizards

Many fungi create multi-cell networks – (hyphae), - branches of fine tubular structures, fusing and tangling in an unruly filigree of mycelium: an exploratory, irregular process – rather than a 'thing', – through which water and nutrients flow.

The metabolic ingenuity of the hyphae allows fungi to forge a wide variety of relationships, such as with the leafcutter ant whose colonies, often larger than 30 metres across with over eight million ants, revolve around a fungus which they cultivate and feed with the leaf fragments. This fungus then becomes their nutritious larder.

There again

Fungi can cause diseases in nature such as Dutch elm disease, chestnut blight; also rice blast fungus which ruins crops that could have fed over sixty million people a year. This impact is increasing across the world, and widespread use of antifungal chemicals has led to new fungal superbugs.

Chestnut Blight

But
The relationship between fungi and plants is now called mycorrhizal, an extremely important and effective way of extending the root area of plants by as much as a hundred times. Mycorrhizal mycelium is a sticky living seam that holds soil together. Remove the fungi and the ground washes away: mycorrhizal fungi increase the volume of water that the soil can absorb, which reduces the leaching out of nutrients by rainfall by as much as 50%. Today, more than 90% of all plant species depend on mycorrhizal fungi. Plants' relationships with mycorrhizal fungi underpin much of life on land. For a thriving relationship, they must have a good metabolic match – the plant photosynthesises carbon, sugars, and lipids on which mycorrhizal fungi, growing within the plant roots, feed. The plants gain water and minerals from the fungi's scavenging.

A scarcity of phosphorous could limit plant growth, but mycorrhizal fungi excel at mining phosphorous from soil and transplant it to their plant partners; the plants grow bigger and better, drawing down carbon dioxide from the atmosphere. The more plants live, the more they die and thence more carbon becomes buried in soils and sediments. Less carbon is then in the atmosphere.

Part of the Fungi Network

But
A large study published in 2018, suggested that the 'alarming deterioration' of the health of trees across Europe was caused by a disruption of their mycorrhizal relationships, brought about by nitrogen pollution.

More good stuff
Research has shown that beneath every forest and wood there is a complex underground web of roots, fungi, and bacteria, helping to connect trees and plants to one another. This subterranean social network, nearly five hundred million years old, has become known as the Wood Wide Web. It allows another level of interaction – not only back and forth between the fungus and the plant, but also between neighbouring plants using fungi as a thoroughfare. As the fungal threads spread, they can link up to multiple plants, creating webs known as Common Mycorrhizal Networks. Through these networks, plants can exchange sugars, nutrients, water and more.

Individual trees often share with those in need. 'Mother' trees send carbon to seedlings and dying trees donate nutrients to their neighbours. Phosphorous has been observed to pass from the roots of dying plants to those of nearby healthy plants that shared a fungal network. Donations of nutrients and water take place across a 'source-sink' gradient, whereby a plant that is rich in a particular resource will give its excess to those in need.

It appears that by staying connected, plants can provide mutual support and help shape the ecosystems they inhabit. With all their inhabitants linked up,

forests look less like collections of individuals, and more like giant superorganisms.

However
The Wood Wide Web is not confined to woods. Mycorrhizae occur anywhere you find vegetation. The networks they form are complex, often encompassing not just multiple plants but multiple species and, depending on the type of fungi involved, different materials can be exchanged. In the past few years, researchers have demonstrated that plants connected to the Wood Wide Web can exchange more than just nutrients.

For example, when broad bean plants come under attack by aphids, they release chemicals that not only repel their attackers, but also attract wasps that prey on the aphids. It is an ingenious, two-pronged defence strategy.

Self-serving?
When different species of plant are connected to the same fungal network, they will invest less in sustaining the fungi. If fungal networks are benefitting a plant's rivals, why invest in them?

Like its online counterpart, the Wood Wide Web has a dark side. For every birch donating carbon to its fir neighbours, there is an orchid stealing carbon from nearby trees. For every plant that informs others of a disease outbreak, another sends out toxins to kill its rivals.

And there is more
No single fungus has the monopoly in the Wood Wide Web. Ecosystems are riddled with non-mycorrhizal mycelium. Decomposer fungi range widely over large distances, linking decaying leaves with fallen twigs, large rotting stumps with decomposing roots; record-breaking networks of honey fungus stretch for kilometres. These fungi make up webs based around consuming plants rather than sustaining them.

A number of plant species produce chemicals that stunt or kill plants growing nearby.

Bacteria
Metabolic wizards that can explore, scavenge, and salvage, mycelia are rivalled only by bacteria. Fungal networks provide highways for bacteria to migrate around the obstacle course of soil. Predatory bacteria sometimes use mycelial networks to pursue and hunt their prey.

Yet some, living within fungal hyphae themselves, enhance fungal growth, stimulate metabolisms, produce key vitamins, and even influence fungal relationships with their plant partners. One fungal species, the thick-footed morel, actually farms bacteria that live within its networks as a food source.

Abundancy
We all live and breathe fungi in the form of their spores which are discharged explosively, some accelerating 10,000 times faster than a space shuttle launch, – up to hundreds of kilometres per hour.

Mycorrhizal fungi are so prolific, their mycelium makes up between a third and a half of the living mass of soils. The total length of mycorrhizal hyphae (long filament branches in fungi) in the top ten centimetres of soil is around half the width of our galaxy.

However
Losing chunks of the Wood Wide Web could well increase "the feedback loop" of warming temperatures and carbon emissions.

Which could also influence
Fungi can break down some of our planet's most stubborn substances such as rock, crude oil, polyurethane plastics, and explosive TNT. Chernobyl, site of the nuclear disaster, is home to a large population of fungi, some of which actively grow towards radioactive particles, appearing to harness the radiation.

Other clever stuff
Some fruiting bodies, like the shaggy ink cap mushroom, can push through asphalt and lift heavy paving slabs. Some varieties of mycelium conduct waves of electricity.

And so, back to where we started
What can be used to filter polluted water, including removing heavy metals? A Finnish firm use this approach to reclaim gold from electronic waste!
What are used in a Danish harbour to mop up fuel spills?
What have African termites been using in their nine metre high mounds for over twenty million years to decompose wood for them to eat?
They induce visions, produce food, and make medicines.
They grow building material and textiles that are lightweight, water-resistant and fire retardant to, replace plastics and leather.
And what species remains more than 90% undocumented?

Shaggy Ink Cap Mushroom