WOOD-WIDE WEB **Fungi provide the social network for forest trees.** Fungi build a network in the soil that forest trees use to transfer nutrients and information. Researchers are trying to decode the 'chats' taking place in the roots.

In order to study the 'Internet of the forest', the WSL researcher Simon Egli needs to be able to rely on a very sensitive nose – not his own, but that of Miro, his dog. No sooner does Simon give the command: "Find," than Miro pulls at his lead and starts whizzing through the tall grass with his nose close to the ground. After just thirty seconds, he is burrowing under a beech tree sending earth clumps flying. "Stop," shouts Simon pulling Miro back. "Otherwise he'll immediately eat what he's found himself," he laughs.

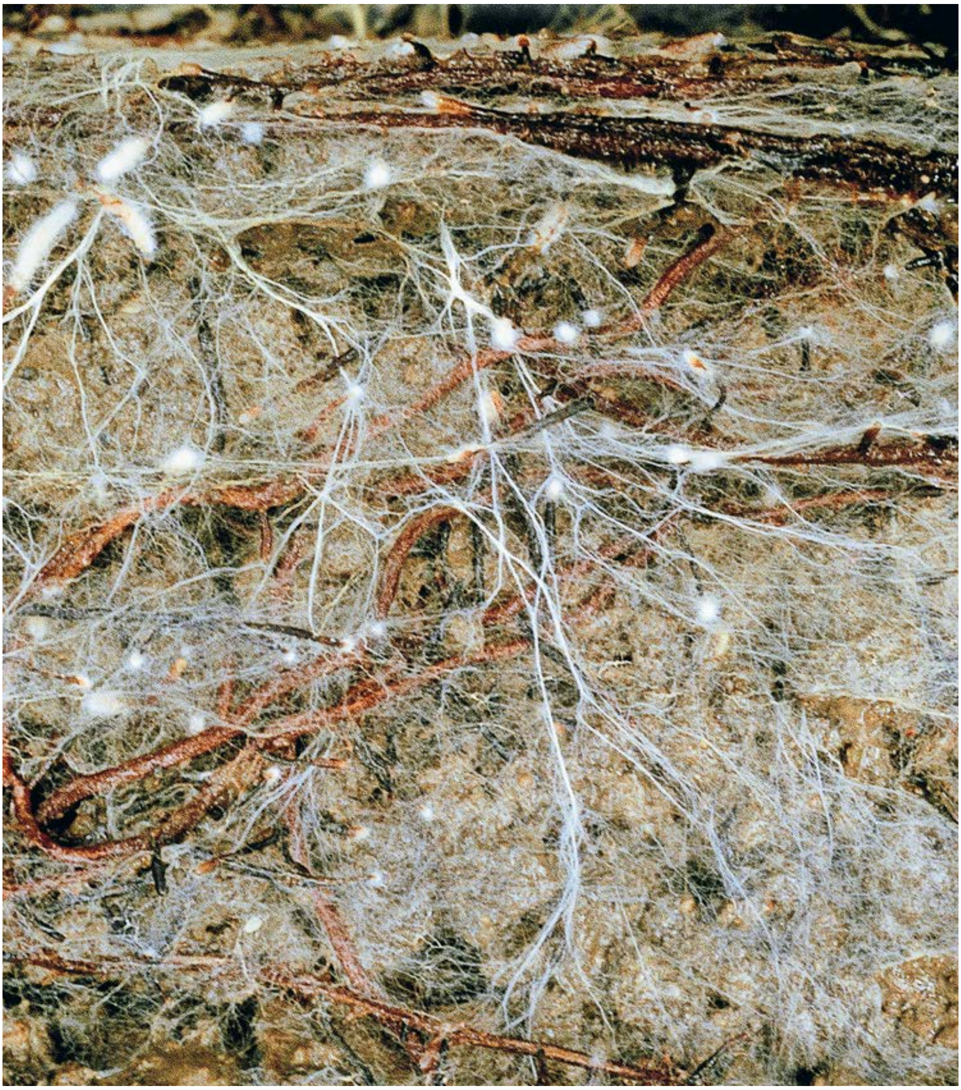

Photo: Simon Egli, WSL

The 'Internet of the forest' consists of fungal threads (white), which coat the tips of plant roots (brown) and even grow into them. The combination is known as 'mycorrhiza' ('fungus roots').

Simon digs out a black lump about the size of a walnut with a small scoop. It's a burgundy truffle *(Tuber aestivum),* still rather unripe, with a conspicuous smell like freshly cut grass. Its market value in early summer is three hundred francs per kilogram, but just before Christmas it is worth two to three times as much. Without Miro, a well-trained truffle dog, this delicacy would not have come to light.

Simon is not just interested in truffle tubers, i.e. in the fruiting bodies of the fungus, but also in the much larger underground network of fungus threads all around the at least one-hundred-year-old beech. The tree is one of a small group in a meadow on the edge of the forest in Birmensdorf. The site – whose exact location is kept secret – is part of a European-wide network for monitoring truffles. The scientists involved want to find out more about the biology of this species of fungus and, in addition, how the network links the trees beneath the surface.

In the roots, fungus threads form a 'Wood-Wide Web' that connects the trees in a community – not just with their immediate neighbours – but over dozens or even hundreds of metres and across species. The researchers are only now beginning to understand – with the help of genetic methods – what is happening beneath the forest floor.

Truffles are mycorrhizal or symbiotic fungi, like many well-known forest mushrooms, such as porcini and chanterelle. This means that both the tree and the fungus benefit from each other: the fungus supplies the tree with nutrients and water, and receives in return carbon in the form of sugar. The fungus threads coat the root tips, growing between the root cells and forming there the so-called Hartig net, where the nutrient exchange takes place. The fungi thus

Miro out searching for truffles for the researcher Simon Egli. This kind of hunting dog is particularly suitable for this job as it has a very sensitive nose.

Photo: Gottardo Pestalozzi, WSL

enlarge the trees' network of roots as much as one hundred times. Ninety per cent of all plants live in symbiosis with mycorrhizal fungi. Sometimes as many as a hundred different fungus species grow on just a single tree.

Sugar for their offspring

In the 1980s, biologists discovered, to their great surprise, that forest trees exchange sugar with each other through their roots. This discovery was possible thanks to a new technique for marking carbon-containing molecules so that they can be detected in very small quantities. Today we know that up to thirty percent of the sugar produced by a tree flows to the fungi. Studies have shown that trees can even send sugar over the fungal network to their seedlings. "We could consider this as one way trees look after their offspring," explains Martina Peter, a biologist and Head of the Research Group 'Mycorrhiza' at WSL.

The truffle-monitoring network, which is managed at WSL, should clarify how the underground 'exchange platform' between trees and fungi is structured. Since 2011, fourteen volunteer truffle hunters and their dogs have searched once every three weeks a total of 26 sites in Switzerland, Germany, Hungary and Great Britain. They weigh the truffles they track down – sometimes as many as fifty per site, record their number and how ripe they are, and send a small slice to the mycorrhiza lab at WSL for genetic analysis. The rest they can keep.

As soon as Miro has detected a truffle – and received a piece of sausage as a reward – Simon sticks an orange plastic peg in the ground to mark the place. Various instruments mounted in white plastic boxes on the tree trunk continuously measure the soil moisture, the soil temperature and the tree's

Photo: Simon Egli, WSL

The truffle tuber is only the fruitbody of the fungus. This one has chosen a very special place to grow.

growth. "We still know hardly anything about the growth dynamics of truffles," says Simon. "We'd like to understand them better and see how they relate to the growth of the tree."

Communication research in the genetics lab

Only genetic analysis can determine whether the unearthed truffles all come from the same fungus and whether there are several different individuals per tree. That's why Martina samples DNA from the truffle slices in the lab to distinguish the individuals via their genetic fingerprints. At one truffle network site in Southern Germany, a bachelor student determined, for the first time, the interconnections beneath the surface: a single fungus linked together three oak trees, a spruce, a birch and a hornbeam over a distance of up to twenty metres. Another fungus linked an oak and a hornbeam. "Several individual truffles may also share a tree and span distances of over one hundred metres," says Martina.

It is still, however, very unclear how the root-web is structured in detail. WSL researchers are currently pursuing this question in further field and greenhouse experiments. For the past two years, several saplings of Swiss indigenous tree species and of the non-indigenous Douglas fir have been growing in yellow plant boxes in the grounds of WSL. Researchers treat them with gas containing marked carbon isotopes to see whether the Douglas fir is as well 'logged into' the underground Internet as the other trees – and whether the drought influences the fungal connections.

For more information on mycorrhizal fungi, see: *www.wsl.ch/mycorrhiza*

Martina is also beginning to find out how information is transmitted in the 'Wood Wide Web': her investigations indicate that, in roots living in symbiosis with fungi, certain genes involved in transporting carbon are more strongly activated. The fungus seems to really 'persuade' the tree to release sugar: "This shows that the fungus in the 'Internet of the forest' is not just a 'cable', but is also an active filter and 'switchboard'," says Martina.

Today, moreover, we know that trees exchange small messenger molecules via the fungal network, which enables them to inform each other and apparently even send warnings about pests. Other researchers have shown that trees 'notice' when their neighbours' leaves are being tapped by aphids. They begin to produce repellants even before their own leaves are attacked.

Meanwhile Miro has found all the truffle tubers and is happily munching on soil full of the fine-smelling fungal threads. If truffles could be found without having to rely on dogs' noses as sensitive as his, the monitoring network could certainly be much larger: "Burgundy truffles are more common than previously thought," says Simon. Despite their reputation as an exclusive culinary speciality, they are actually quite widespread in mixed beech forests growing on calcareous soil – such as in the Jura and on the Central Plateau in Switzerland. "The truffle's extensive distribution means it is an important fungus for our research on mycorrhiza." *(bki)*