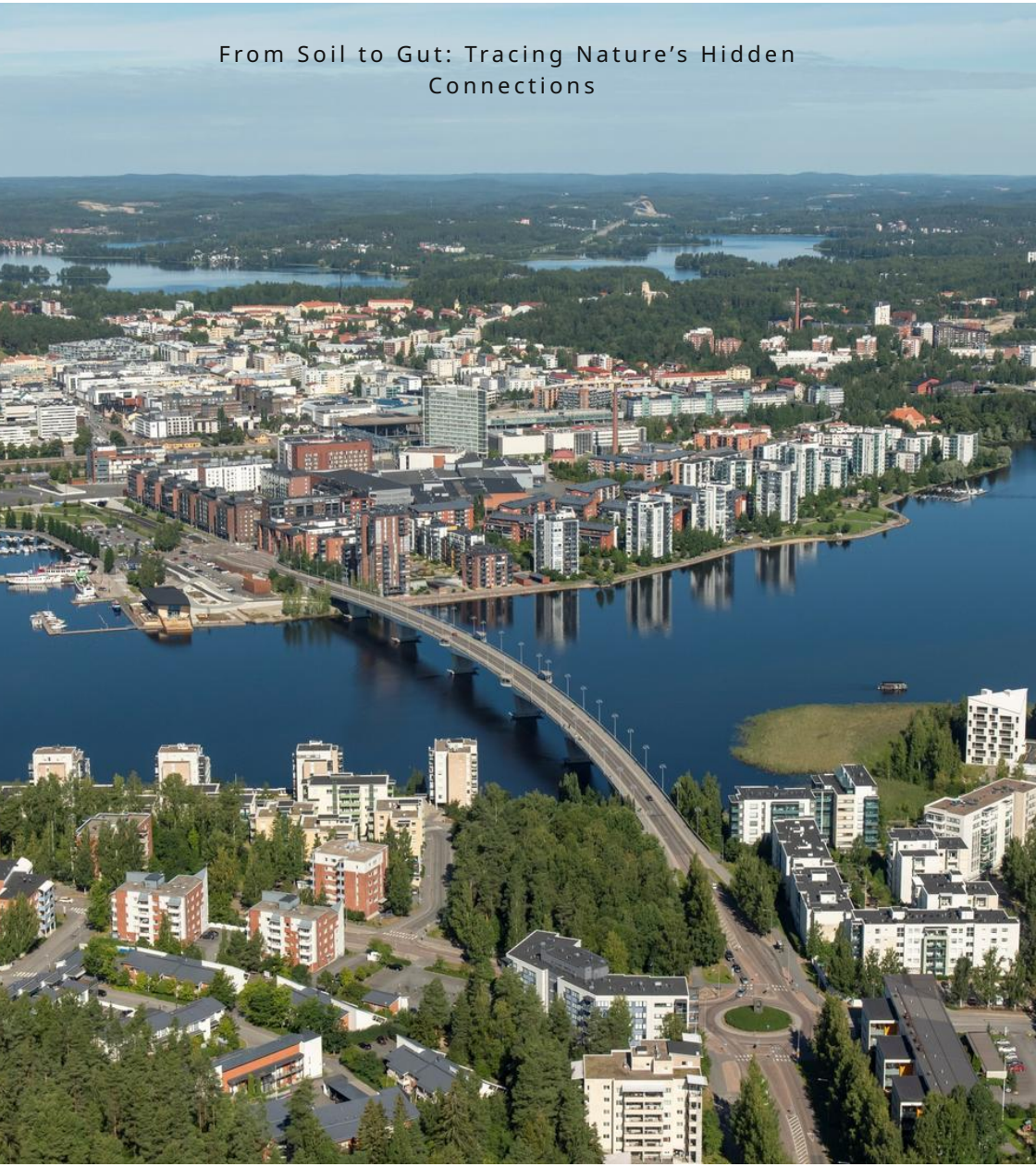
PROJECT

SOIL2GUT

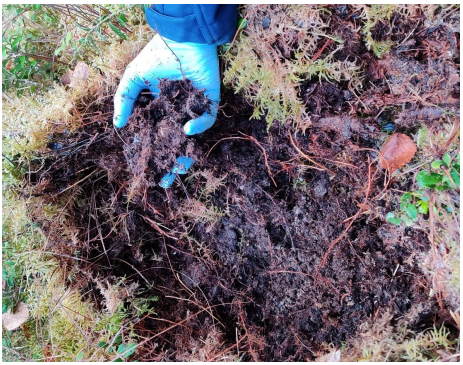
From Soil to Gut: Tracing Nature's Hidden Connections



Funded by
the European Union

LIFE BENEATH OUR FEET

Soils are among the richest habitats on Earth.
Just one gram can contain billions of bacteria, fungi, protists and viruses that keep ecosystems alive.
They break down organic matter, recycle nutrients and store carbon, helping plants and animals to thrive.
Healthy soils mean healthy life above ground.
By interacting with plants, animals and humans, soil microbes influence the balance of nature and even our own wellbeing.
But urbanization and land-use change are reducing our contact with natural soils.



THE GUT MICROBIOTA

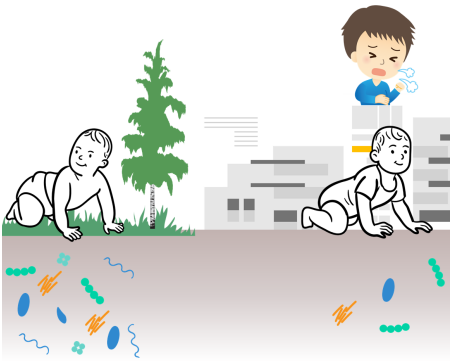
All animals, including humans, host millions of microorganisms in their intestines — the gut microbiota.
These microbes help us digest food, regulate metabolism and support our immune system.
When this balance is disrupted, it can affect our health.
Scientists have discovered a strong link between **environmental biodiversity** and the **diversity of our gut microbes**.
Less contact with nature means less microbial diversity in our bodies, which can weaken our defences.
In contrast, time spent in biodiverse environments, like forests and natural soils, enriches our microbiota and supports health.

HUMAN IMPACT ON MICRO BIODIVERSITY

Human activity is transforming the living world beneath our feet.
Today, about half of all habitable land on Earth is used for farming, forestry or cities, and in Europe, less than 20% of land remains undeveloped.
Urban areas are growing fast: in 1950, less than one-third of people lived in cities; by 2050, it will be more than two-thirds.
At the same time, over **one million species** are threatened with extinction, and soils alone may contain **a quarter of all biodiversity**.

MICROBIAL CONSEQUENCES

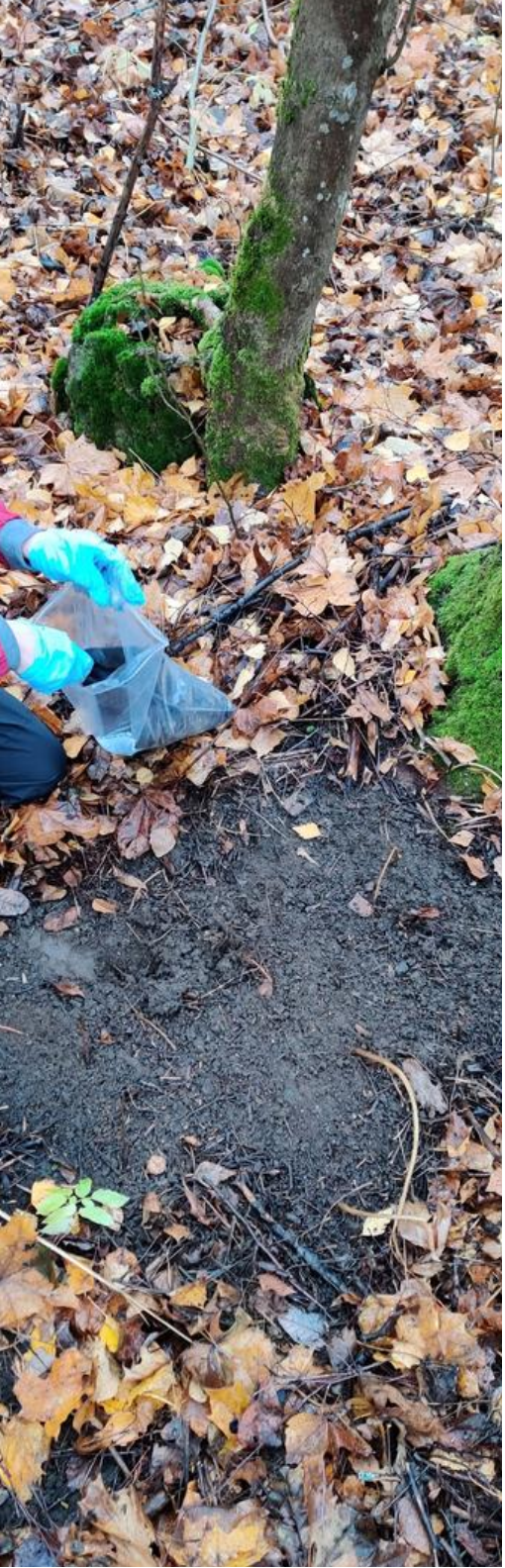
Intensive agriculture reduces soil diversity, favouring some microbes at the expense of others.
City life limits our exposure to diverse environmental microorganisms, replacing them with human-associated microbes.
This loss of microbial contact is linked to more allergies, autoimmune diseases, and chronic inflammation.



WHY IT MATTERS

The **biodiversity hypothesis** suggests that contact with diverse environmental microbes trains our immune system.
People and animals living in rural, microbially rich areas tend to have less asthma and fewer allergies than those in cities.
Urban green spaces can help, but not all greenery is the same.
Studies show that urban parks may host mixed microbial communities from soils, plants, animals, and humans, while pristine forests contain different microbiota characteristic of undisturbed soils.
So the key question is:

Can city woodlands really support our microbial health, or do pristine forests still hold something unique?



PROJECT SOIL2GUT

SOIL2GUT is a research project funded by the Horizon Europe programme of the European Union aimed to investigate the effects of forest soils containing different soil microbiota, both bacteria and fungi, on the gut microbiota and the immune system of wild rodents in order to improve strategies for creation and use of greenspaces.

WHY STUDY WILD ANIMALS?

Most of what we know about gut microbes comes from humans and laboratory animals like mice and rats. These models are useful, but they don't reflect the full complexity of life in nature.

Wild rodents offer a more realistic picture. They live in changing environments and face real-world challenges such as habitat loss, pollution, and climate change. Studying them helps scientists understand how human activity affects wildlife from gut microbes to immune systems.

In the wild, animals interact with soils, plants, predators, and microbes all at once. These interactions shape both their biology and their microbiota in ways that cannot be recreated in a lab. By studying wild species, researchers can connect biodiversity, environment, and health, bridging the gap between controlled experiments and real ecosystems.

WHY BANK VOLES?

The **bank vole** (*Clethrionomys glareolus*) is a small rodent found across Europe and western Asia.

It thrives in forests and fields, feeding on seeds, berries, fungi, and insects.

Because it's widespread, easy to study, and closely linked to soils and vegetation, it serves as an excellent indicator of environmental change. Bank voles help researchers explore:

- **Disease ecology** – they can host pathogens such as hantaviruses and *Borrelia* (Lyme disease).
- **Pollution effects** – studies have examined how heavy metals, radiation (e.g. Chornobyl), and chemicals affect their health and gut microbiota.
- **Genetics and adaptation** – they reveal how populations respond to habitat loss and stress.
- **Microbiota–environment links** – showing how soil, habitat quality, and diet shape gut microbes and immune responses.

In short, studying wild animals like the bank vole helps us understand how **nature, microbes, and health** are connected in a rapidly changing world.

BIODIVERSITY INTERVENTION EXPERIMENT

To understand how contact with natural environments affects health, researchers designed a simple experiment with **bank voles born in captivity** from wild mothers.

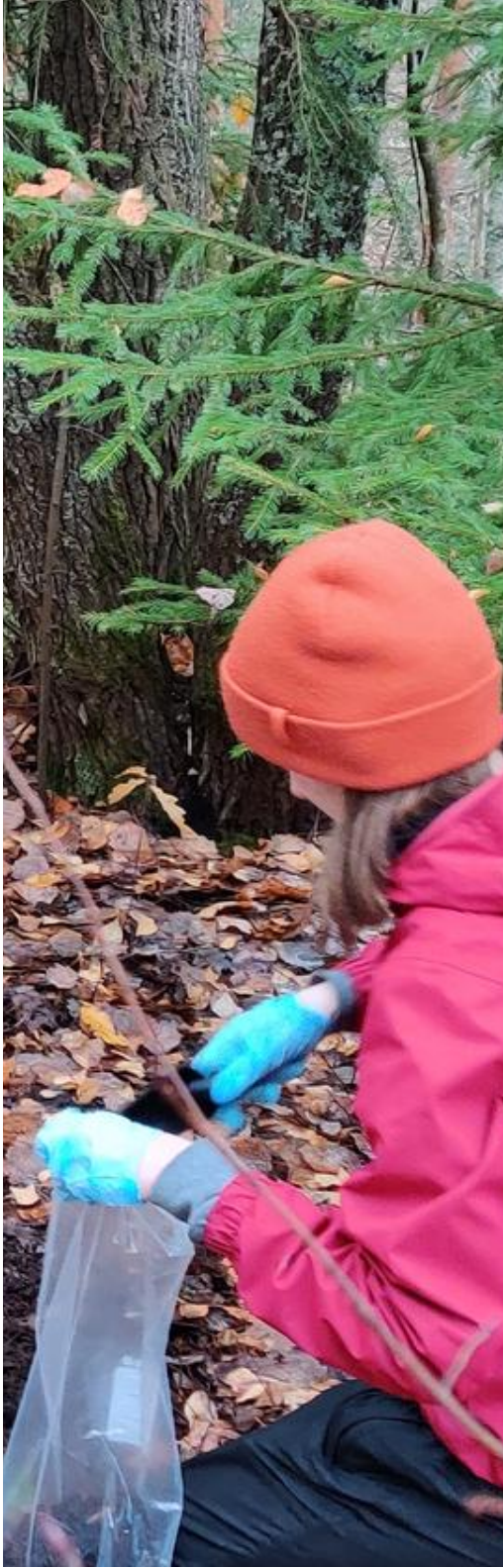
For **four weeks**, the young animals lived in special cages containing **soil mixtures** collected from **national parks** or **urban forests**.

A **control group** was kept in sterile cages with clean wood shavings, without soil microbes.

At the start, all pups had already inherited a natural gut microbiota from their mothers through birth and nursing.

Scientists collected **faecal samples** at the beginning and end of the experiment from **99 animals** to study changes in their gut microbes.

They also analyzed **colon tissue** from **30 animals** to measure how the exposure to different soils influenced their **immune activity**.



STUDY SITES: URBAN FORESTS AND NATIONAL PARK

The study took place in **central Finland**, around the cities of **Jyväskylä, Mikkeli, and Kuopio** — areas where urban neighbourhoods blend with green parks and forest patches.

For comparison, researchers also used soil from **three national parks**: **Pyhä-Häkki**, **Leivonmäki**, and **Etelä-Konnevesi**, which host old conifer forests that have been left almost untouched by humans.

HOW THEY ANALYZED THE DATA

To study how soil exposure affected the gut and immune system of bank voles, researchers used **DNA and RNA sequencing** — powerful tools that reveal which microbes live in the gut and how genes respond.
They analysed:

- **Bacteria and fungi** in soil and faecal samples, using high-precision DNA sequencing.
- **Gene activity** in colon tissue, to detect changes in gut health and immune function.

Specialized computer programs helped process and interpret the large amount of sequencing data.

MAIN FINDINGS

Bacteria

The gut bacteria of bank voles stayed stable, even after soil exposure.
→ Bacteria from soil and food did **not** colonize the gut.
→ Gut bacteria seem **resistant to short-term environmental change**.

Fungi

Fungal communities changed much more.
→ Several fungi found in the gut came **directly from soil and food**.
→ Fungi are **sensitive indicators** of environmental influence on the gut microbiota.

Immune system

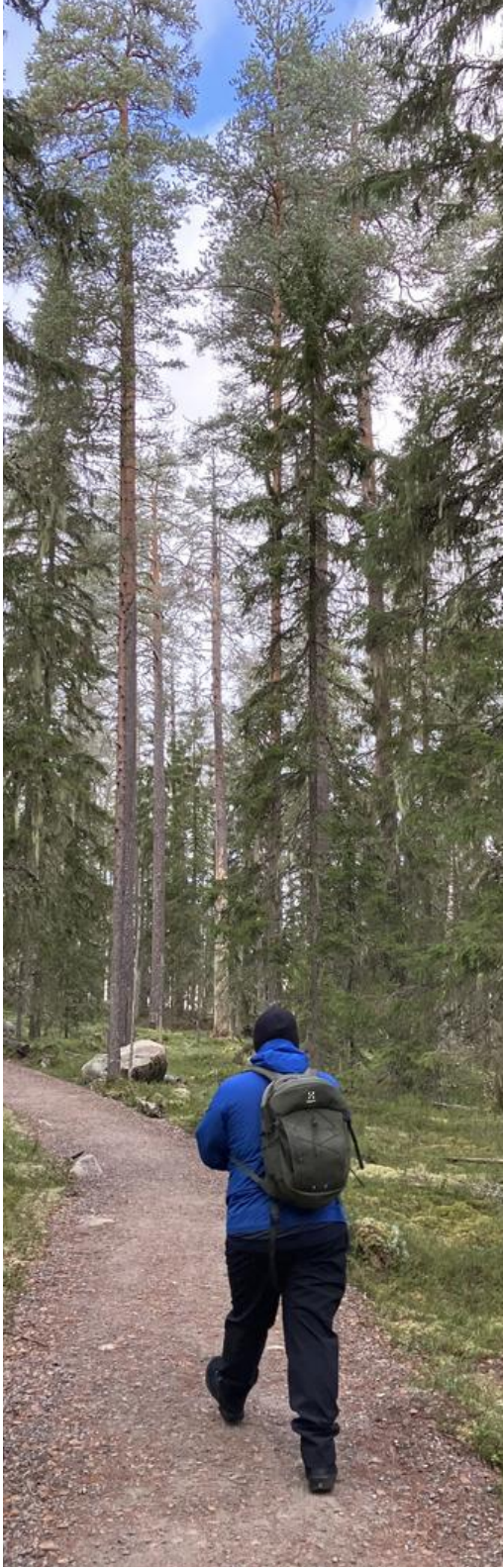
Voles exposed to **urban soil** showed signs of mild colon inflammation.
→ Urban environments may contain **microbes or chemicals** that activate the immune system.
→ No inflammation was seen in animals from **sterile cages**.

CONCLUSIONS

Our study shows that gut bacteria were quite stable, while gut fungi had stronger links with soil and food, although individuals differed in their response.
The mild inflammation seen in voles exposed to urban soil suggests that **not all microbial exposures are beneficial**. What matters is also **the origin and composition of microbes** encountered.

Understanding this complexity helps explain how contact with nature can influence the health of both wildlife and humans, whether in a city park or a pristine forest. Spending time in natural places offers more than just fresh air — it also reconnects us with the **invisible microbial world** that supports health and resilience.

Encouraging children and communities to explore forests means building both **knowledge of nature and stronger consciousness of health advantages**.



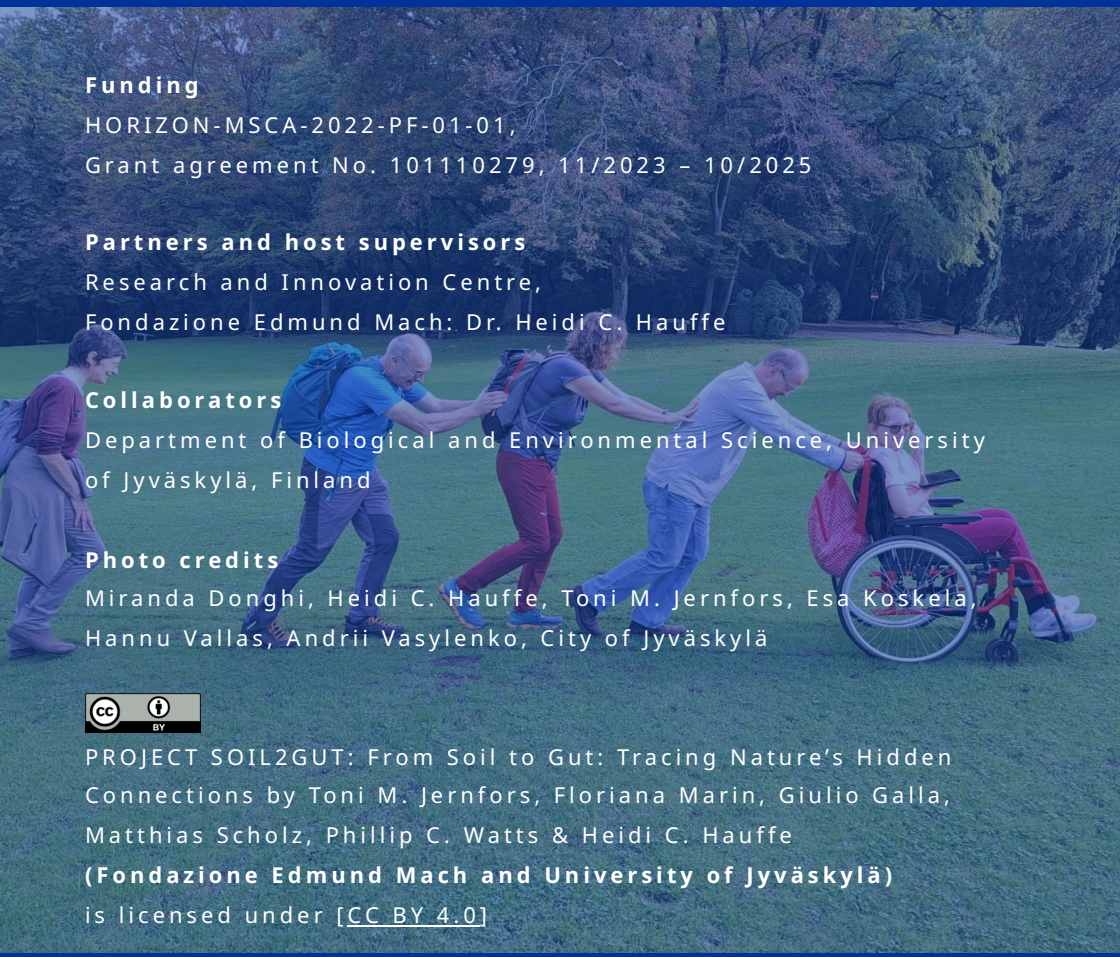


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Photo credits

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