

The Marvel of SOIL BIODIVERSITY

The multitude of organisms actively making up the soil biomass are crucial to the survival and growth of all plants and animals.

Most people are familiar with the concept of biodiversity. Its health and functional benefits are derived from the presence of many different plant and animal species in an environment. Biodiversity ‘hotspots’ support a vast variety of plant and animal species; an example being a tropical rainforest with up to 80,000 plant, 50,000 insect, 1,500 bird, and 2,000 mammal/amphibian species. However, the corresponding level of biodiversity present in the underlying soil environment is much greater than above-ground, with over 100,000 known species of bacteria and fungi, 25,000 species of nematodes, 40,000 species of mites, and 7,000 species of earthworms. Collectively these organisms constitute the soil biomass and their activities determine the



Leo M. Condon
PROFESSOR OF BIOGEOCHEMISTRY,
LINCOLN UNIVERSITY, CANTERBURY

survival and growth of all plants and animals in natural and managed ecosystems.

THE MAGNITUDE

In addition to the high level of biodiversity found in soil, the numbers of individual species present and their combined size is

enormous. One gram of soil (equivalent to 1/5 of a teaspoon) may contain up to 1 billion bacteria and 10 metres of fungal hyphae (which play a crucial role in maintaining soil structure through aggregate formation), while the total topsoil biomass can be up to 1.5kg per square metre or 15 tonnes per hectare.

CLASSIFICATION BY SIZE

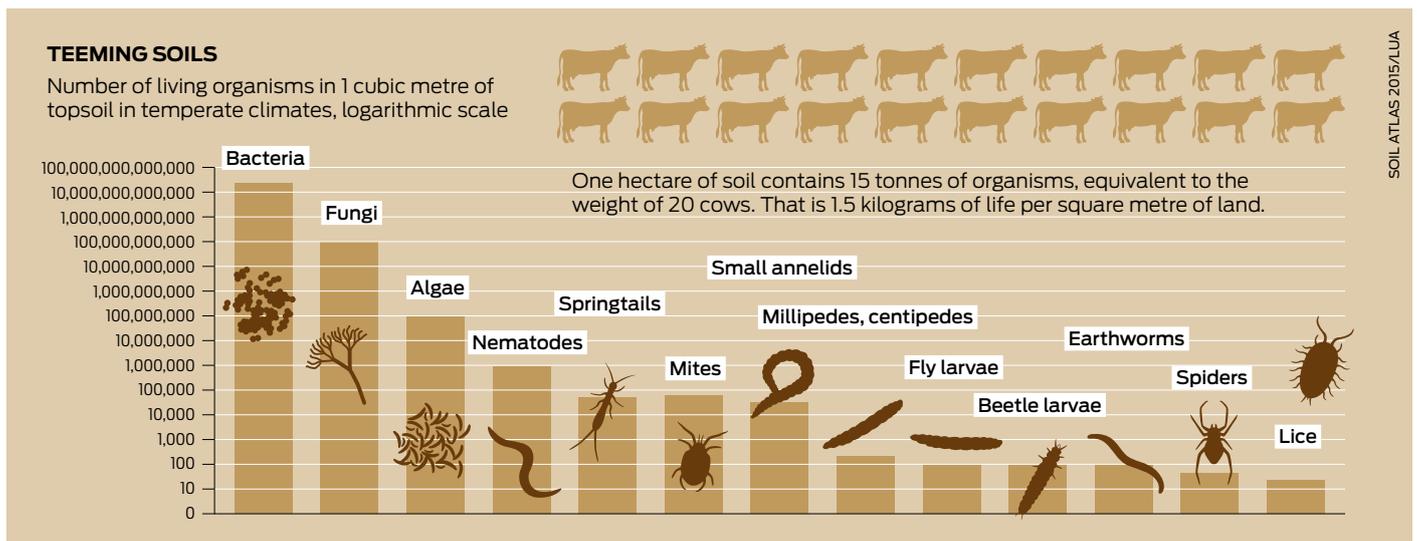
The various components of the soil biomass are classified by their relative size:

- **Microflora** is made up of the smallest organisms – bacteria (<2µm) and fungi – which constitute over 90% of the total biomass in most soils.
- **Microfauna** (10µm–0.1mm) makes up the remaining 10% and includes protozoa and nematodes.
- **Mesofauna** (0.1–2mm) are mainly flightless insects (arthropods), such as mites and springtails.
- **Macrofauna** (2–20+mm) includes earthworms, termites and molluscs (slugs, snails).

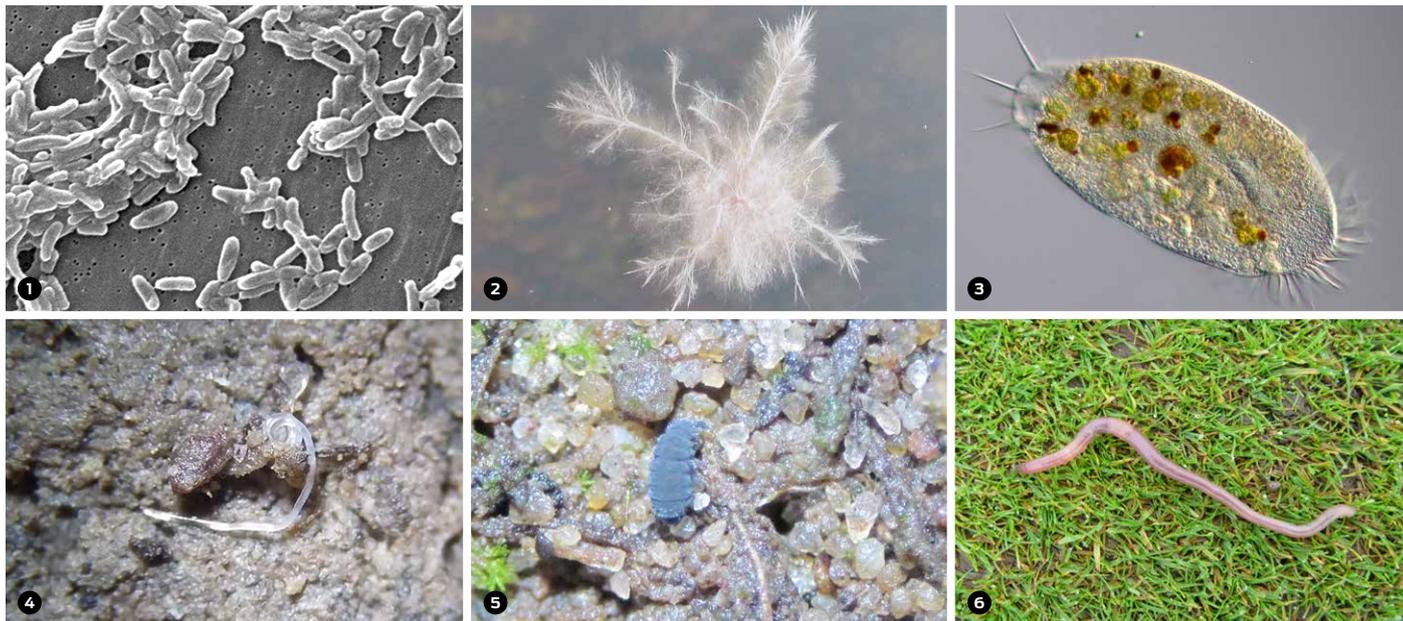
COMPLEX FOOD WEB

The soil biomass obtains energy and nutrients mainly from the breakdown of organic matter derived from plants and animals, which includes dead plant material (shoots and roots), animal excreta (urine, dung) and remains of animals and other organisms. These materials contain energy generated from plant photosynthesis (i.e. the conversion of atmospheric carbon dioxide to sugars using energy obtained from sunlight), together with nutrients obtained primarily from the soil.

The collective actions of the various components of the soil biomass ensure that the energy is utilised (and carbon dioxide returned to the atmosphere), with the nutrients being released for reuse by plants and animals.



Source: <http://globalsoilweek.org/soilatlas-2015>



1. A grouping of *Ralstonia mannitolilytica* bacteria (harvested from a pure culture). 2. Red Thread Acid Agar Fungi. 3. Protozoa. 4. Nematode dagger. 5. Springtail juvenile. 6. Earthworm.

The breakdown of organic matter in soil is mostly carried out by bacteria and fungi to obtain the energy and nutrients required for their growth and reproduction. In this regard they can compete with plant roots for available nutrients. However, bacteria and fungi are continually consumed (grazed) by microfauna, such as protozoa and nematodes, which release nutrients that are available for uptake by plant roots. The protozoa and nematodes are, in turn, preyed upon by other nematodes and insects (mites, springtails) which also release nutrients for plants.



While these worm casts are a nuisance on fine turf, they are proof of worms at work, helping to breakdown organic matter.

Earthworms play a crucial role in facilitating organic matter decomposition by other organisms by breaking up large plant fragments and mixing soil ('bioturbation'). Earthworms can turn over up to 70 tonnes

of topsoil per hectare annually in temperate soils, compared with up to 1,000 tonnes per hectare in moist, tropical soils.

The interrelated activities of the various component organisms of the soil biomass represents a complex food web which ensures that organic matter and nutrients are effectively and efficiently recycled – which is essential to sustain plant growth.

INFLUENCES ON ACTIVITY LEVELS

Biological activity in the soil is determined by a complex combination of factors. In addition to the obvious influence of environmental conditions (such as temperature and moisture), the quantity, availability and nature of organic matter, as well as nutrient inputs, all play a crucial role.

The addition of nutrients in the form of fertilisers or manures can significantly increase plant (and animal) production, which in turn will increase organic matter inputs with consequent impacts on the size and activity of the soil biomass.

Furthermore, the soil biomass and biological activity are greatest in the immediate vicinity (1–3mm) of live plant roots, due to the presence of energy-rich, soluble, carbon compounds (mainly carbohydrates) that continually exude (leak) from roots. This zone is known as the 'rhizosphere' and is effectively the engine-room of the soil-plant system. Plants provide readily available energy for bacteria and fungi which, in turn, acquire nutrients from soil within and outside the rhizosphere, which are then released as a consequence of grazing by protozoa and nematodes. In this way, plants directly manipulate and manage the activities of

various organisms in the rhizosphere in order to obtain required nutrients from the soil.

On the other hand, the rhizosphere also provides a habitat for organisms that can attack and harm plants (pathogens), including various species of bacteria, fungi and nematodes. In the absence of available organic matter (e.g. outside of the rhizosphere or at lower depth) and under cold and/or dry conditions, bacteria and fungi (and the other dependent organisms) cannot grow and effectively hibernate until organic matter becomes available and/or environmental conditions improve.

SOURCE OF HEALTH DISCOVERIES

For bacteria and fungi, in particular, the soil is very competitive environment, especially in the rhizosphere. Many of these organisms have developed means of suppressing the activity of competitors. Accordingly a number of antibiotics used in human and veterinary medicine have been discovered in soil, including streptomycin and vancomycin. Consequently, the soil is seen as an important source in the search for new antibiotics to counter drug-resistant bacteria. ●

Links:

Soil Biodiversity: <http://esdac.jrc.ec.europa.eu/content/global-soil-biodiversity-atlas>

Soils are Living: <https://www.youtube.com/watch?v=Qas9tPQKd8w>

Worms at work (bioturbation): <https://www.youtube.com/watch?v=n3wsUYg3XV0>

Decomposition: <https://www.youtube.com/watch?v=8SGnQkI3-rE>

Soil and Antibiotics: <http://www.fairfaxcounty.gov/nvswcd/newsletter/soilmedicine.htm>
<http://www.smithsonianmag.com/science-nature/new-antibiotic-dirt-soil-can-kill-drug-resistant-bacteria-180953828/>