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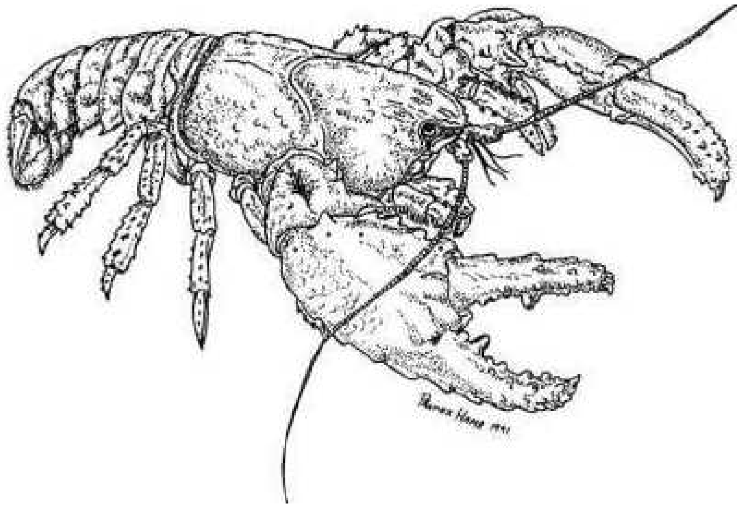

Soil Biology 1

by **Sue Gebicki**

1. soil from Black Sugarloaf

2015 was the International Year of Soils designed to create awareness of the importance of healthy soil, the amount of damage that we have inflicted on soils around the world, and to teach how to maintain soils in good condition and prevent further loss.

Soil is one of nature's most complex ecosystems and one of the most diverse habitats on Earth. It contains an amazing number of different organisms, all interacting, contributing to global cycles and making a large proportion of life possible.

Soils are a product of physical, chemical and biological processes, and while there has been much research into the physical and chemical aspects of soils, there has been comparatively little research into soil biology and ecosystems. Although soils are home to over a quarter of all living species on earth, to date it is estimated that only 1% of soil bacteria and fungal species, 4% of mites, 15% of collembola, 1.3% of nematodes, and 7.5% of protozoa have been identified. To add to the difficulty of research, soil microbes can readily exchange genetic information leading to a very fast and ongoing diversification of microbes in natural environments (Monier *et al*., 2011). Furthermore processes within the soil are not the result of a single organism but of microbial communities which closely interact with each other (Aneja *et al*., 2006). Even the development of symbiotic interactions between plants and microbes are much more complex than described in textbooks as they include the involvement of a diverse number of 'helper organisms' which contribute to the process.

Actions of soil organisms and organic matter

Organisms in the soil act together in complicated relationships of predators, prey, parasites, decomposers and soil reorganisers, maintaining a healthy equilibrium which sustains soil fertility. These organisms:

- **Organise soil structure** to bind soil particles together in stable aggregates. This is necessary for the presence of air spaces, or macropores, which determine how readily a soil can transmit water, allow root growth and provide air for soil organisms.
- **Break down inorganic matter** into constituent minerals. The weathering of rocks is enhanced by organic acids, siderophores (iron-chelating compounds) and protons produced by fungal, microbial and plant root action.
- **Decompose organic waste and pollutants**, and bind heavy metals and pesticides. Soil from waste sites have been found to have higher concentrations of gene sequences from certain bacterial groups known to degrade common pesticides like hexachlorocyclohexane. Some microorganisms have developed and adopted different detoxifying mechanisms such as biosorption, bioaccumulation, biotransformation and biomineralization which can be exploited for bioremediation.
- **Provide carbon storage**. Soils in combination with plant biomass hold approximately 2.5 times more carbon than the atmosphere (Singh *et al*. 2010).
- **Process organic matter**. Microorganisms decompose organic matter, using the carbon and nutrients for their own growth and releasing excess nutrients into the soil for use by plants.
- **Change soil to allow water purification and buffer water flows.** The rate of erosion increases with faster water flow. A healthy soil will act like a sponge, reduce evaporation and filtering the water before releasing it slowly in dry periods which aids in maintaining environmental flows in creeks and rivers.
- **Fix nitrogen**. Some organisms in soil and plant roots convert atmospheric nitrogen to ammonia compounds, which are then available for plants. The process is not yet completely understood, but biological nitrogen fixation contributes approximately 60% of nitrogen fixed on earth.
- **Control pests**. For example, some protozoa consume pathogenic fungi.
- **Create humus** (decomposed organic matter). Humus retains moisture and forms the structure of the soil. It is covered in negatively charged sites that bind to positively charged ions (cations) of plant nutrients. This is important for the supply of nutrients to plants, reduces the potential toxicity of plant nutrients and prevents the leaching of trace elements into the subsoil. Humus suppresses plant disease by stabilizing soil enzymes, thus restricting the action of potential plant pathogens which rely on enzymes to break down plant defences. It also liberates carbon dioxide from calcium carbonates present on the soil. The carbon dioxide can be taken up by plants or form carbonic acids, which act on soil minerals to release plant nutrients.
- **Buffers pH**. Humus produced by soil biota neutralizing the soil which frees any trace elements that are unavailable to plants in very acid or

alkaline soils.
- **Maintains soil temperature**. The actions of soil organisms affect the colour of soil which in turn affects its ability to absorb infra red radiation. Air pores and humus in the soil provide insulation.
- **Provide a reservoir of plant nutrients**.
- **Promote plant growth** by producing auxins, gibberellins and antibiotics.
- **Return nutrients** to their mineral forms which plants can then access.
- **Regulate and influence** the composition of the atmosphere.
- **Affect flowering time**. Experiments have shown that plants in pots inoculated with microbes from different sites, that are sown at the same time and given the same conditions, flower at different times.
- **Enhance drought tolerance** of plants through active water absorption by the greater root mass provided by mycorrhizal fungi and growth promoting rhizobacteria.
- **Reduce the concentration of sodium salts** and an increase in the concentration of other elements through the application of humins, humic acids, fulvic acids and specific soil organisms. This could be essential for the recovery of vast areas of excessively saline land which have been rendered unproductive by unsuitable land clearing and irrigation.
- **Positively influence seed germination and seedling development**.
- **Enhance root initiation and increased root growth** with the application of humic acids and/or fulvic acids, which are present in humus.
- **Maintain strong genetic pools for plants**. Weak plants are further weakened and killed by pathogens in the soil, preventing them from cross pollinating and passing their genes on to other plants.

Soil organisms

Soil contains organisms from every kingdoms of classification. A typical healthy soil may contain many species of invertebrates including several species of earthworms, 20–30 species of mites, 50–100 species of insects, tens of species of nematodes, hundreds of species of fungi and perhaps thousands of species of bacteria and actinomycetes.

Bacteria

Bacteria are the most numerous of soil organisms, with up to one billion per gram. They are generally about 1 micron in length or diameter and usually occur as single cells. Various bacteria contribute to soil health with the decomposition of organic compounds, nutrient cycling, humus production, soil aggregation, nitrogen fixation, plant growth formation and control of plant pathogens. Other bacteria, such as the denitrifying bacteria are anaerobic (active where oxygen is absent) and convert nitrate to nitrogen or nitrous oxide in saturated soils. Bacteria are found in highest numbers in the rhizosphere which is the area around the root zone. Plants exude carbon-rich materials to stimulate bacteria and in return benefit from a wide range of functions. Here they are presented according to their function:

- **Decomposers** break down a wide range of compounds into simpler forms that become available to plants and animals in the soil. They are especially important for retaining nutrients in their cells, thus preventing their loss from the soil.
- **Mutualists** form associations with plants, for example the Rhizobia which form nodules on legume roots and fix nitrogen from the air.
- **Pathogens** select weak plants and organisms and hasten their breakdown and recycling.
- **Chemoautotrophs** obtain energy from non-carbon sources such as sulphur, nitrogen, methane or sodium. Some of these are important to nitrogen cycling and degrading pollutants.

Fungi


2. *Mycena austrororida*

Fungi grow long threads called hyphae that mass to form mycelium, which absorb nutrients from the roots they have colonised and surface organic matter. The hyphae are usually a few thousandths of a millimetre wide.

Fungi are important in the soil by performing services related to water dynamics, nutrient cycling and disease suppression. They are also important decomposers and their hyphae bring soil particles together into stable aggregates. Fungi can be grouped into broad categories:

- **Mycorrhizal fungi** live in close association with plant roots, either inside or outside the roots depending on the type. They effectively increase the root zone and thus the accessibility of soil nutrients, particularly nitrogen and phosphorus. Arbuscular mycorrhiza are the most common and widespread involving 80% of plant species.
- **Parasitic fungi** invade weak plant and animal tissue. They ensure plant health by removing the diseased and weak. Some, such as the nematode-trapping fungi, parasitise disease-causing nematodes.
- **Saprotrophic fungi** (decomposers) get energy from organic matter. Nutrients are recycled from organic matter to the fungal biomass, and eventually back to the rhizosphere when the hyphae are consumed or die.

As an interesting aside, scientists studying the evolution of fungi have found evidence that the end of the carboniferous age may have been brought about by the evolution of fungi able to digest lignin. Prior to that, much dead vegetation was decomposed at such a slow rate that it was possible for it to be buried by natural processes, and eventually physically and chemically acted on to produce the vast coal reserves that we dig up and burn today.


3. *Cortinarius metallicus*

Protists

Protists and other similar single-celled organisms, several times larger than bacteria, have a nucleus and live in wet environments. About 1,500 of about 50,000 known species live in soils, more than a billion amoeba and up to several million ciliates have been found per square metre in the top 50 mm of some soils,. They have developed the ability to shut down their bodies and form a cyst when soils dry out to varying degrees.

The two main groups of soil protists are the ciliates and the flagellates. Along with the amoeba they play an important part in boosting the nitrogen available to plants as they feed primarily on soil bacteria, which are rich in nitrogen. The protists cannot absorb all the nitrogen, so excrete the excess as ammonium, which is readily used by plants. They also regulate populations of bacteria because their grazing stimulates the growth of bacteria which are an important food source for other soil organisms and help suppress disease by competing with or feeding on pathogens. One group of amoebae, the vampyrellids - so called as they attach to the surface of hyphae, generate enzymes that eat through the fungal cell wall then suck dry or engulf the cytoplasm inside the fungal cell - include root pathogens in their diet.

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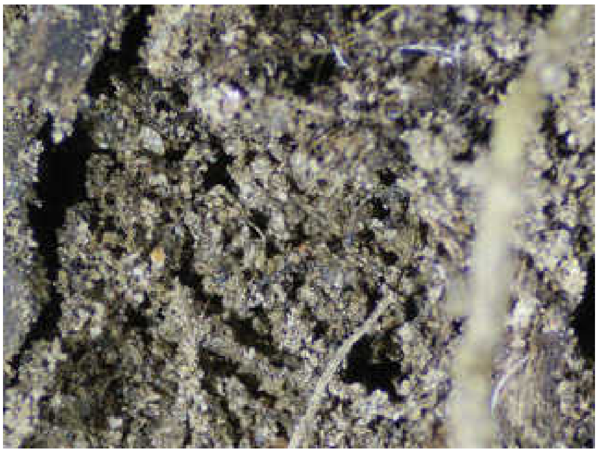
4. cow paddock soil


5. plantation soil

All photos taken by Sarah Lloyd; soil photos taken with DSLR camera on stereo microscope.

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