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A SILENT JUNGLE: THE SOIL UNDER FOOT

Plants have been around for some 400 million years longer than we the people. They became quite adaptable: they manage to make their own food while being rooted to one place; they communicate, coordinate and cooperate with other living beings; and they influence the community around them to a surprising degree. They just do most everything a lot slower than we are used to seeing.

Of those plants not floating freely in water most maintain a visible and green above ground half that manufactures its own food through the chlorophyll in its leaves, and an invisible, dark, below ground half, where roots collect water and minerals for transport to the branches and leaves. In the daylight half, the leaves combine carbon dioxide from the air and water and minerals from the roots in a process of photosynthesis that creates carbohydrates, proteins and other plant foods, using sunlight as a catalyst, while exhaling oxygen as a waste product. In the dark half below ground the roots anchor the plant while receiving newly made nutrients from the leaves. The plant root system may be much larger and extend much farther than the leaf crown, although usually the roots do not go very deep, only a couple of feet or so. But a plant is not an isolated entity, far from it. Each plant is part of an extremely complex, stable food web with billions of members active in a small space underground. Some of those work together, other ones attack and eat each other; they never rest, always they work in silence and in darkness, and usually they are extremely slow by our standards. Roots, soil, organic matter and microorganisms are intertwined in a slow struggle for exploitation and attack, competition and cooperation, where at every moment countless living creatures watch for prey or become food, sense but cannot see each other, and try to influence their environment in ways that we judge beneficial or harmful; the outcome of their encounters may determine the plant's success or failure.

We the people have a huge and usually negative influence on the underground jungle because we tend to disturb and compact the soil, over-fertilize with synthetic fertilizers, and overdose with pesticides and insecticides, thus killing off many beneficial microorganisms, and reducing the system's efficiency. Scientists still don't know most of the genera and species involved in the food web, but they do know that the more attention we pay to the rules and natural inhabitants of this world, the more complex and stable the system becomes, and the better and less expensively this no waste, all recycle, plant social system and food web work for us. The healthier the underground food web, the fewer outside agents (fertilizers, pesticides, even water) we need, and the more productive our plants.

So who are the main characters in the underground jungle?

A. **Soil.** Soil is defined by texture: sand, silt or clay; structure; permeability; pH or acidity; organic content; humus and mulch; layers; compaction, fertility, humidity, mineral content, constituent air and water content. Microbes, fungi and earthworms play a huge role in improving soil.

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- B. **Roots.** Tiny roots push their way among the soil particles, seeking water and minerals, fending off attackers. They get a lot of help from the fungi and other microorganisms that accompany them.
- C. **(Micro) organisms:**
1. **Viruses.** Thousands of times smaller than bacteria, they are the most abundant biological entities on earth, but we know little about them; they have no cells, may not be alive but spread disease.
 2. **Bacteria.** At 1-4 microns a piece, a quarter to half a million will fit in the period at the end of this sentence. They are everywhere, have been around for over 3 billion years, digest food material outside their body and multiply by frequent division; they are the primary decomposers for cellulose/recently dead plant material, cycle elements, create soil improving biofilms and bioslime.
 3. **Archaea.** Outwardly resembling bacteria, they often live in extreme environments (geysers, oceans, deserts, under ice); they are able to change atmospheric nitrogen into plant usable form and, like bacteria, they break down tissue so that it becomes available to other creatures.
 4. **Fungi.** Neither plants nor animals, only about 10% of the estimated > 1 million kinds are known. At 2-15 microns long, and .2-3.5 microns wide, they grow thousands of water and phosphorus seeking hyphae, extremely thin and long threads, that range wide and far, creating microtunnels; a teaspoon of soil may contain several yards. Mycorrhizae intimately associate with plant roots; the fungus grows on or inside the roots, finds minerals for its host, kills attackers such as nematodes, and receives carbon containing sugars in return. Fungi break down tough woody material such as lignin. Agricultural soils are usually bacteria dominated, shrub and forest soils fungi dominated.
 5. **Algae.** Usually of little concern to the gardener, algae have no true roots, leaves or stems; they make their own food; a teaspoon of soil contains 10,000 to 100,000 green cells.
 6. **Slime Molds.** Amoeba-like slime molds feed on decaying material; thousands of individuals can join together and start moving as one big organism.
 7. **Protozoa.** At 5-500 microns long, some of the 60,000 kinds eat 10,000 bacteria per day, while other ones establish symbiotic relationships with bacteria. Flagellates (one of 3 basic types) digest the wood swallowed by termites; some archaea generate methane gas inside other protozoa.
 8. **Nematodes.** Nonsegmented, blind roundworms, averaging 2 millimeters long (2000 microns) and 50 microns wide, only some 20,000 of 1,000,000 have been identified. One teaspoon of soil may contain 40-50 individuals that happily eat plants, other microbes, organic material and each other.
 9. **Arthropods.** With their segmented limbs and bodies (head, chest, abdomen) and chitin exoskeleton, these bugs (flies, beetles, spiders, mites, ants, insects, etc.) constitute three fourths of all living organisms, but not of all biomass. They are shredders and recyclers of organic material.
 10. **Earthworms.** Good soil can harbor 10-15 earthworms per square foot, ranging from a few millimeters to several centimeters long. Prowling for food they can move 18 tons of soil per year per acre, eating and shredding leaves and other organic material, digging horizontal and vertical tunnels, aerating soil, and leaving their fertile poop (vermicastings) behind; they are very beneficial.
 11. **Gastropods.** Few people love slugs and snails, but they speed up decomposition, and graze as much below ground as above.
 12. **Higher animals:** Reptiles, Birds, Mammals. Less soil dwellers than soil influencers, animals scratch, dig, and bury; people often do more harm than good to the soil and its inhabitants.

Ecological or sustainable gardening, permaculture, biodynamic agriculture and other beneficial ways of sustainably working with nature seek to (re)create healthy food webs and grow healthy plants. They work by using nature based methods, applying compost, mulch, compost teas and organic fertilizer as needed; they avoid rototilling and digging as much as possible; they recycle and reduce waste. We can restore even severely disturbed soils, and then maintain them at optimum levels. To employ effective methods we first need to know the facts. Books such as 'Teaming with Microbes', by Jeff Lowenfels and Wayne Lewis, are a good place to start, as are some CalRecycle publications, such as 'Compost Microbiology and the Soil Foodweb'.

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