General Concepts

The soil food web is the community of organisms that are interdependent for sources of carbon and energy.

Communities are variously defined but a common thread in the definitions is interaction for resources, including food and space:

"...(communities are) not mere assemblages of species living together, but form closely-knit communities or societies similar to our own." C. Elton (1927) "an assemblage of populations of plants, animals, bacteria and fungi that live in an environment and interact with one another, forming together a distinctive living system with its own composition, structure, environmental relations, development and function" R. Whittaker (1975) "A collection of organisms in an environment" J. Emlen (1977) "Organisms that interact in a given area" P. Price (1984) "Associations of plants and animals that are spatially delimited and that are dominated by one or more prominent species or by a physical characterisitic" R. Ricklefs (1990) "Community: the species that occur together in space and time" Begon, Harper, and Townsend (1996)	**Background Music** *The Nematodes' Pic* Lyrics: Kathy Merri Vocals: Pointless Si

From Lewis Carroll:

> Big fleas have little fleas
> Upon their backs to bite'em
> And little fleas have smaller fleas
> And so *ad infinitum*

Resources and Roles in Foodwebs

1. Organisms can be classified as autotrophs or heterotrophs.
2. *Autotrophs* obtain their carbon and energy by fixing atmospheric CO_2 using light as an energy source (photosynthesis). Green plants are autotrophs. Some autotrophic bacteria use chemical reactions as the energy

source, e.g. S-reducing bacteria use electrons from sulphur and reduce it to H_2S.

3. *Heterotrophs* obtain their carbon and energy from other organisms. They consume them while still alive (parasites), or kill them in the act of consumption (predators), or feed on their waste products, excretions, secretions, or remains (detritivores). Most organisms other than green plants are heterotrophs.
4. The food supply to soil organisms originates through two main channels:

- The photosynthetic activities of plants. Plant roots leak - root exudates; root tissues are sloughed during growth, when damaged, or when no longer useful to the plant. Herbivores graze on or parasitize plant roots. All the organisms exploiting the primary producer in this manner become food and energy sources for other organisms in the soil foodweb.
- Plant residues, manure and other organic material falling on or applied to the soil surface, or incorporated into the soil. All the organisms decomposing this material also become food and energy sources for other organisms in the soil foodweb.

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Foodweb Structure

1. Bacteria, fungi, plant-parasitic nematodes, root-grazing insects, gophers, etc. feed directly on plant roots as primary consumers. They are subject to parasitism and predation by other organisms; they die, defecate, excrete, etc. and provide food for other organisms.
2. Bacteria and fungi assimilate plant secretions, and plant debris. They decompose dead organic matter of intrinsic or extrinsic origin. In general, more resistant substrates and substrates with higher C:N ratios are more likely to be exploited by fungi than by bacteria, while more labile substrates and those with lower C:N ratios may be predominated by bacteria.
3. Nematodes (e.g. Tylenchida: Aphelenchina andomnivorous Dorylaimida) and arthropods (Collembola and mites) feed on fungi. Nematodes (e.g. Rhabditida), and Protozoa (flagellates and amoebae) feed on bacteria. Predaceous nematodes (e.g. *Mononchus*), omnivorous nematodes (e.g. *Labronema*), arthropods (e.g. mites, Collembola), Protozoa (e.g. amoebae), Tardigrades, etc. feed on nematodes. Arthropods (e.g. predaceous mites) feed on mites; Collembola and mites are parasitized by bacteria and fungi.
4. At every trophic interaction, the debris and leakage become substrate for other organisms; the wastes and secretions of the new owners of the carbon molecules originally fixed by the autotroph are substrate for other organisms.
5. Carbon, Nitrogen, and other molecules are mineralized during the metabolic processes of all organisms in the web through respiration, osmoregulation, etc. The mineralized molecules (CO_2, NH_4, NO_3, etc) are available to plants, bacteria and fungi in the soil, or are returned to the atmosphere.
6. Organisms in the soil tend to be aggregated in areas where carbon and energy originally enters the foodweb, e.g., in the plant rhizosphere, close to the soil surface, or in the tillage zone.
7. The size of the foodweb is limited by the amount of carbon and energy entering it. As much as 90% of the remaining resources may be lost at each trophic interchange. That limits the length of chains or channels running through the web to four or five interchanges. In other words, a carbon molecule entering the web is unlikely to pass through more than five different organisms without being respired. In foodwebs limited in size by minimal carbon input the number of interchanges will be fewer as there are insufficient resources to support organisms at higher trophic levels. In that case, turnover of the microbial biomass may be small and minerals will be immobilized.
8. Organisms at higher trophic levels in the soil foodweb are often more susceptible to disturbance than those smaller-bodied organisms at lower trophic levels. Further, the organisms at lower trophic levels are often opportunists, responding rapidly to availability of resources. Consequently, foodwebs in disturbed systems tend to be predominated by primary decomposers and direct herbivores since their predators are absent. That again leads to immobilization of minerals by the opportunists and to a lack of biological regulation of their abundance and dynamics.

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Function of Soil Foodwebs

- Decomposition of organic matter
- Cycling of minerals and nutrients
- Redistribution of minerals and nutrients in space and time
- Reservoirs of minerals and nutrients
- Sequestration of carbon
- Detoxification of pollutants
- Modification of soil structure
- Community self-regulation
- Biological regulation or suppression of pest species
- Etc.

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Structural and Functional Relationships

Connectance: proportion of the potential links in the foodweb that are actually realized.

Redundancy: the number of links in the food web that perform the same "function"; complex foodwebs should have greater redundancy.

Resilience: lack of change in the "function" of the food web when a link is broken or a node removed; greater redundancy leads to greater functional resilience.

Suppressive: when there are sufficient predators of various kinds in the food web that populations of opportunistic species are actually reduced, i.e. the integral effect of the food web is suppressive to the opportunistic organisms.

Conducive: there are few higher trophic layers in the food web so that there is little predation on opportunists. The structure of the soil community is such that it will "allow", or at least not prevent, increase of opportunists.

Regulated: somewhere between conducive and suppressive. Opportunists may not decline in number but will also not increase exponentially. Their populations are regulated at relatively constant levels by the combined effect of various predators in the food web.

Remember, the predators of nematodes are not only other nematodes but also certain fungi, mites, collembola, protozoa, some bacteria, etc. The more abundant these various guilds of organisms, the more likely that opportunistic prey species will be regulated or suppressed.

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Assessment and Monitoring of Soil Foodwebs

a. Structural Analysis

- ***Physical:*** Sample, extract, identify, enumerate each organism group - bacteria, fungi, protozoa, nematodes, arthropods, annelids, rodents…….., etc. (An enormous job!)
- ***Biochemical Analysis:*** PLFAs, DNA profiles, etc. indicate the presence of key organism groups or taxa. (Probably access relatively few taxa)
- ***Indicator Guilds:*** Monitor the presence and abundance of key taxa that are indicative of the presence of specific trophic guilds that perform critical or desired functions. (Soil nematode guilds occur at all trophic levels in food webs, they can be monitored by simple standardized techniques and are proving to be useful indicators of foodweb status).

Functional Analysis: Confirm that key functions are occurring at desired rates; measure rates of suppressiveness, decomposition, mineralization, respiration……etc. (Useful, but difficult to interpret in terms of the key players in the system).

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References

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