THE TEEMING LIFE
BENEATH OUR FEET

PINE COUNTY MASTER GARDENER HORTICULTURE
DAY - 2014
The Soil Food Web

First trophic level: Photosynthizers
Second trophic level: Decomposers, Mutualists, Pathogens, Parasites, Root-feeders
Third trophic level: Shredders, Predators, Grazers
Fourth trophic level: Higher level predators
Fifth and higher trophic levels: Higher level predators

Credit: Soil Biology Primer - NRCS
What is a Trophic Level?

Hmmm, you weren’t listening...
What is a Trophic Level?

Closer...oh wait, no you’re not.
What is a Trophic Level?

AKA: Food Chain or Energy Chain
COMPLEXITY OF THE SOIL FOOD WEB

Number of Functional Biological Groups

Credit: Soil Biology Primer - NRCS
WHERE DOES LIFE START?

WITH ORGANIC MATTER
WHERE DOES ORGANIC MATTER COME FROM?

GROWING ROOTS AND PLANT RESIDUE
ORGANIC MATTER

Growing Roots + Plant Residue

Supports Trophic Level Populations
WHAT IS IN ORGANIC MATTER?

- Carbon

**Cellulose**

**Chitin**

**Lignin**
WOW! THAT'S INTERESTING!!! OTHER SOURCES OF ORGANIC MATTER?
OTHER ORGANIC MATTER SOURCES:

• Living
  Bacteria
  Fungi
  Nematodes
  Protozoa
  Earthworms
  Arthropods
WHAT IS HUMUS?

Uhhh, No, That’s Hummus
SERIOUSLY, WHAT IS HUMUS?
HUMUS

- It’s Organic Matter
- It’s Broken Down…really broken down
- Soil Organic Matter is 50:50
  - Humus
  - Active Organic Matter
HUMUS

• More complex carbon compounds
• Used more by fungi
• Only fungi make enzymes needed to degrade humus
• Little available nitrogen
ACTIVE ORGANIC MATTER

• The portion available to soil microorganisms
• Simple organic compounds
• Bacteria use simple organic compounds
• Examples: root exudates (sugars, vitamins, amino acids) and fresh plant residues

"Root Exudates: the hidden part of plant defense." Baetz and Martinoia, 2013.
• Root Exudates
  • “Liberate” soil nutrients
  • Repel, inhibit or kill pathogens/insects
  • Repel competing plants
  • Acids, Sugars, Polysaccharides, ectoenzymes

SIDEBAR TIME

What exactly are “Root Exudates?”
“R” IS FOR RHIZOSPHERE

Graphic: Conservation Research Institute
“R” IS FOR RHIZOSPHERE

Figure 1
Schematic of a root section showing the structure of the rhizosphere.
Modified from http://cse.naro.affrc.go.jp.
RHIZOSPHERE DEPTH

Most Shallow

Deepest
WHERE ARE THE ORGANISMS?

Microbial Biomass Decreases With Depth

Why?

Credit: Soil Biology Primer - NRCS
WHEN IS IT THEIR TIME?

Seasonal Microbial Activity

Bacterial and Fungal Activity
in a temperate grassland or cropland.

- early summer
- late summer
- last frost
- first frost

Month

Credit: University of Illinois Extension
THE TEEMING LIFE

LEVEL BY LEVEL
1ST LEVEL: THE PHOTOSYNTHESIZERS!

Final Tour Date….you don’t want to know!
THE PHOTOSYNTHESIZERS!

- Some Bacteria
- Algae
- Plants!!!!
PLANTS

- Capture Energy (photosynthesis)
- Add Organic Matter to Soil
  - Debris
  - Roots
  - Metabolites
**The Soil Food Web**

- **Plants** (Shoots and roots)
- **Organic Matter** (Waste, residue and metabolites from plants, animals and microbes)
- **Bacteria**
- **Fungi** (Mycorrhizal fungi, Saprophytic fungi)
- **Nematodes** (Root-feeders, Fungal- and bacterial-feeders, Predators)
- **Arthropods** (Shredders, Predators)
- **Protozoa** (Amoebae, flagellates, and ciliates)
- **Animals**
- **Birds**

**Trophic Levels**

- **First trophic level**: Photosynthesizers
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- **Fourth trophic level**: Higher level predators
- **Fifth and higher trophic levels**: Higher level predators

Credit: Soil Biology Primer - NRCS
2ND LEVEL:

- Decomposers: Bacteria and Fungi
- Mutualists
- Pathogens
- Parasites
- Root Feeders
SOIL BACTERIA

Credit: Soil Biology Primer - NRCS
DECOMPOSERS

- Retain Nutrients
- Create Sources of Energy
- Bind Soil Aggregates
- Fight off Pathogens
- “Fix” Nitrogen
SOIL BACTERIA

Bacteria on the hyphae of a fungus

Credit: Soil Biology Primer - NRCS
• Form Nodules on roots of Legumes
• Convert nitrogen to a “plant-usable” form
• Bacteria receive Carbon from host

SIDE BAR
TIME...
Featuring the Nitrogen-Fixing Bacteria: Rhizobium!

Photo: Purdue University

Photo: Iowa State University
“FIXING” NITROGEN

Image Credit: U.S. EPA
## Typical Numbers of Soil Organisms in Healthy Ecosystems

<table>
<thead>
<tr>
<th></th>
<th>Agricultural Soils</th>
<th>Prairie Soils</th>
<th>Forest Soils</th>
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<tbody>
<tr>
<td><strong>Bacteria</strong></td>
<td>100 million to 1 billion.</td>
<td>100 million to 1 billion.</td>
<td>100 million to 1 billion.</td>
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<tr>
<td><strong>Fungi</strong></td>
<td>Several yards. (Dominated by vesicular-arbuscular mycorrhizal (VAM) fungi).</td>
<td>Tens to hundreds of yards. (Dominated by vesicular-arbuscular mycorrhizal (VAM) fungi).</td>
<td>Several hundred yards in deciduous forests. One to forty miles in coniferous forests (dominated by ectomycorrhizal fungi).</td>
</tr>
<tr>
<td><strong>Protozoa</strong></td>
<td>Several thousand flagellates and amoebae, one hundred to several hundred ciliates.</td>
<td>Several thousand flagellates and amoebae, one hundred to several hundred ciliates.</td>
<td>Several hundred thousand amoebae, fewer flagellates.</td>
</tr>
<tr>
<td><strong>Arthropods</strong></td>
<td>Up to one hundred.</td>
<td>Five hundred to two thousand.</td>
<td>Ten to twenty-five thousand. Many more species than in agricultural soils.</td>
</tr>
<tr>
<td><strong>Earthworms</strong></td>
<td>Five to thirty. More in soils with high organic matter.</td>
<td>Ten to fifty. Arid or semi-arid areas may have none.</td>
<td>Ten to fifty in deciduous woodlands. Very few in coniferous forests.</td>
</tr>
</tbody>
</table>
DIFFERENT PLANTS...DIFFERENT BACTERIA

Three Corn Selections (left to right)

One Sugar Beet (far right)
What Are Mineralization and Immobilization?

Soil nutrients generally occur in two forms: inorganic compounds dissolved in water or attached to minerals, and organic compounds part of living organisms and dead organic matter. Bacteria, fungi, nematodes, protozoa, and arthropods are always transforming nutrients between these two forms. When they consume inorganic compounds to construct cells, enzymes, and other organic compounds needed to grow, they are said to be “immobilizing” nutrients. When organisms excrete inorganic waste compounds, they are said to be “mineralizing” nutrients.

Organisms consume other organisms and excrete inorganic wastes.

<table>
<thead>
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<td>NH₄⁺</td>
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<td>NO₃⁻</td>
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These nutrients are stored in soil organisms.

Organisms retain nutrients as they grow.

These nutrients are usable by plants and are mobile in soil.
THE FUNGI!

I'm a fun guy.
SOIL FUNGI

Figure 2 | The rhizosphere. The rhizosphere is a narrow zone of soil (a few millimetres wide) that surrounds and is influenced by plant roots. The schematic shows magnified pictures of the rhizosphere, containing saprophytic and symbiotic bacteria and fungi, including arbuscular mycorrhizal fungi (AMF). AMF inset modified, with permission, from REF. 158 © (2008) Macmillan Publishers Ltd. All rights reserved.
MYCORRHIZAL FUNGI

1. Form Symbiotic Relationships with Roots
2. Most Common Rhizosphere/plant Fungi
3. Increases Water Uptake Efficiency
4. Increases Nutrient Uptake Efficiency
5. Physical Protection for Roots
6. Chemical Protection for Roots
7. Increase Plant Productivity
8. AMF (arbuscular mycorrhizal fungi) are Most Important
The Beauty of AMFs.

Arbuscules

Germinating spore

(A) Vesicles in Cedrela

Credit: Mycorrhizas.info

Nature.com
“FEEDERS”: NEMATODES

*Most Soil Nematodes are Beneficial

Credit: Elaine R. Ingham
MEET THE “FEEDERS”

• Nematodes
• Protozoa
• Macroarthropods
• Feed On:
  • Fungi, Bacteria, Roots
• Important For:
  • Releasing Nitrogen for Plants
  • Stimulating fungal and bacterial populations,
  • Control of root-feeding pests

Photo Credit: Elaine Ingham
The Soil Food Web

First trophic level: Photosynthesizers

Second trophic level: Decomposers, Mutualists, Pathogens, Parasites, Root-feeders

Third trophic level: Shredders, Predators, Grazers

Fourth trophic level: Higher level predators

Fifth and higher trophic levels: Higher level predators

Credit: Soil Biology Primer - NRCS
SHREDDERS, PREDATORS, GRAZERS...OH MY!

WHO THEY ARE:
• Arthropods
• Predatory Nematodes
• Earthworms

WHAT THEY DO:
• Shred Plant Litter
• Habitat for Bacteria
• Enhance Soil Structure

Credit: French Forest Garden
Credit: Val Behan-Pelletier
ARTHROPODS

Millipede

Sow Bugs

Soil Mite
EARTHWORMS
The Soil Food Web

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Credit: Soil Biology Primer - NRCS
HIGHER LEVEL PREDATORS

WHO THEY ARE:
• Nematode-feeding Nematodes
• Larger Arthropods
• Mammals

WHAT THEY DO:
• Control Populations below
• Improve Soil Structure
• Carry Smaller Organisms
WHAT TO DO, WHAT TO DO?
DO: ADD ORGANIC MATTER

- Wood Chips
- Leaf Compost
- Garden Compost
- Food Compost (omit meat)
- Manure (decomposed...trust me)
- Biochar
ADDING ORGANIC MATTER

- Incorporate
  - Decomposed organic matter

- Top dress
  - Fresh organic matter
Biochar: What is It?

- "Black Carbon"
- Slow heat process of organics
- Wood chips, plant residue, manure...

SIDE BAR

What is biochar and what are its benefits?

Credit: greaterdemocracy.org
What is biochar and what are its benefits?

**Biochar: What does it Do?**

- Carbon Sequestration
- Improves Soil Structure

**+Potential:** Improved nutrient content, productivity

**-Potential:** Displace soil microorganisms, reduce productivity

Credit: USDA Agricultural Research Service
DO: IMPROVE POROSITY

• Cover Crops
• Add Organic Matter
• Add Coarse Minerals
DO: IMPROVE POROSITY

- Radial Trenching
- Soil Replacement
DO: COVER CROP

- Legumes
- Sudan Grass
- Buckwheat
- Rapeseed (canola)
- Oats
Figure 1. Disease-suppressive soils. For many soil-borne plant diseases, it has been found that the incidence of disease in some soils is lower than in surrounding soils, even though a virulent pathogen is present. Such disease-suppressive soils are especially well studied for take-all of wheat caused by *Gaeumannomyces graminis* var. *tritici*. During monoculture of wheat, take-all disease usually develops as depicted. An initial increase of disease severity as pathogen inoculum builds up with recurring presence of a susceptible host is followed by a decline of disease severity. This is typically associated with an increase of *Pseudomonas* spp. that produce the antifungal 2,4-diacetylphloroglucinol. The picture in the background shows an experimental field (Revoland, the Netherlands) in which wheat had been grown in rotation with other crops (left) or in monoculture (right). Following inoculation with *G. graminis* var. *tritici*, less disease developed in the wheat monoculture plot. Adapted from [11].
DO: LET LAND FALLOW
CONSIDER: CROP ROTATION

Table 1. Wisconsin seeding rate recommendations based on planting date.

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Seeding Rate for Sept 1 to Sept 15

Seeding Rate for Sept 15 to Oct. 1

Seeding Rate for Oct. 1 to Oct 10

University of Wisconsin
DO: PRAIRIE GRASSES VS TURF GRASSES
DO: PRAIRIE GRASSES VS TURF GRASSES

BTW: Kentucky Bluegrass is not native to North America

Credit: advancedcarepethospital.com
DO NOT: OVER GRADE
DO NOT: OVER-CHEMICAL

Credit: University of Washington
CHEMICALS: THE WORST FOR SOILS

- Herbicides: Pre- and Post-
- Insecticides
- Fungicides
- Synthetic Fertilizers – Salts raise pH
- Deicing Chemicals – Anything with Chloride

Credit: soillutions.uk
DO NOT: CULTIVATE IF NOT NECESSARY
DO NOT: CULTIVATE IF NOT NECESSARY

Greentalk.com “How to create a no-till garden bed.”
DO NOT: CULTIVATE IF NOT NECESSARY

No-Till Soybeans

Iowa State University Extension

Victorian No-Till Farmers Association
IF YOU CAN'T MANAGE WATER AND ORGANIC MATTER...

DO NOT WASTE YOUR MONEY ON AMENDMENTS...

Credit: American Forests
FOR MORE INFORMATION

• The potential of mulch to transmit three tree pathogens, Karel Jacobs, September, 2005.
• Arbuscular mycorrhizas and biological control of soil-borne plant pathogens. Azcon-Aguilar and Barea, 1996.
SOME GREAT VIDEOS
