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Soil Biology

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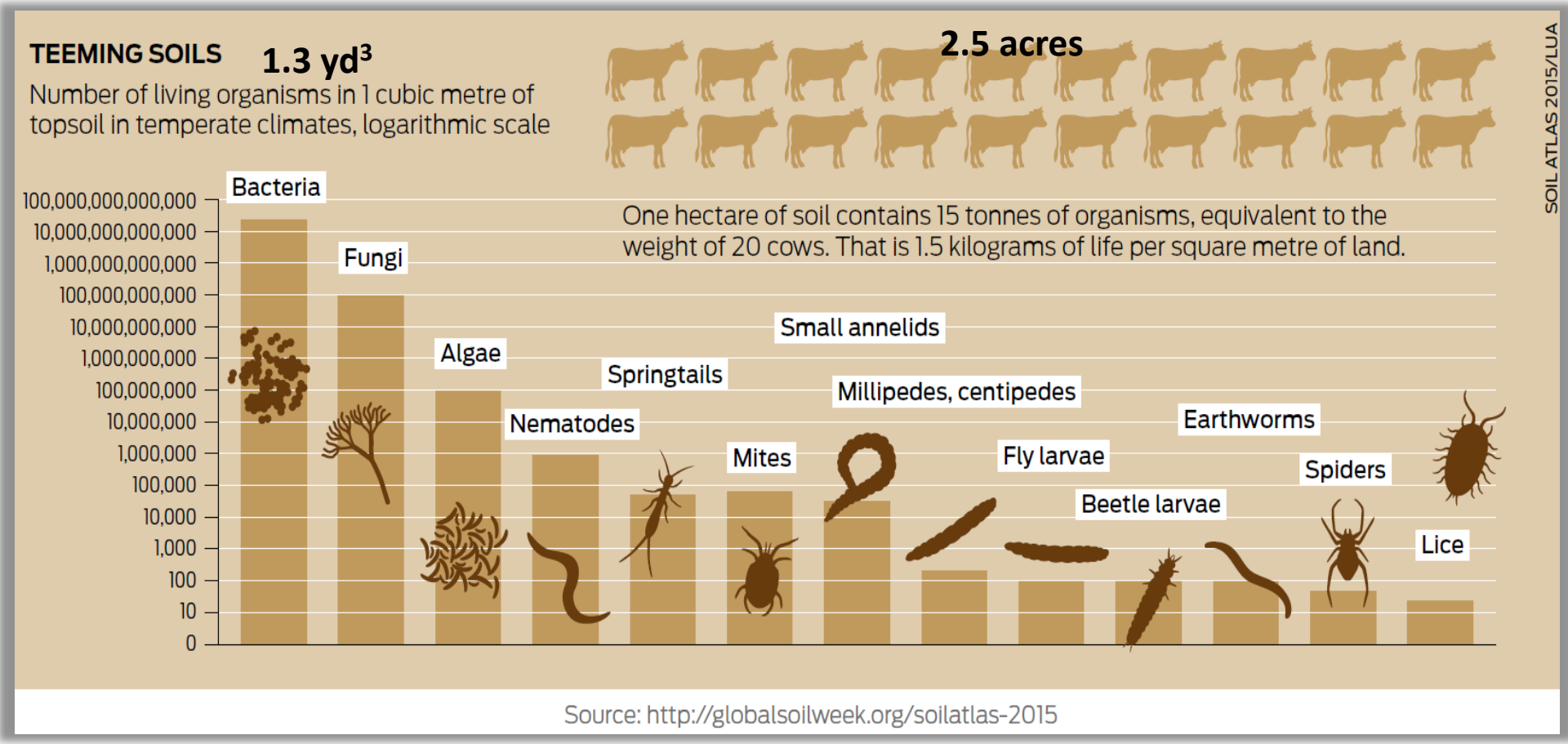
Objectives

1. List 1 key activity performed by each of the 3 functional groups for soil organisms
2. List 2 soil organisms that represent each functional group
3. Describe biological hotspots & how they relate to key ecosystem functions

Soils Host Vast Numbers, Mass, and Diversity of Organisms



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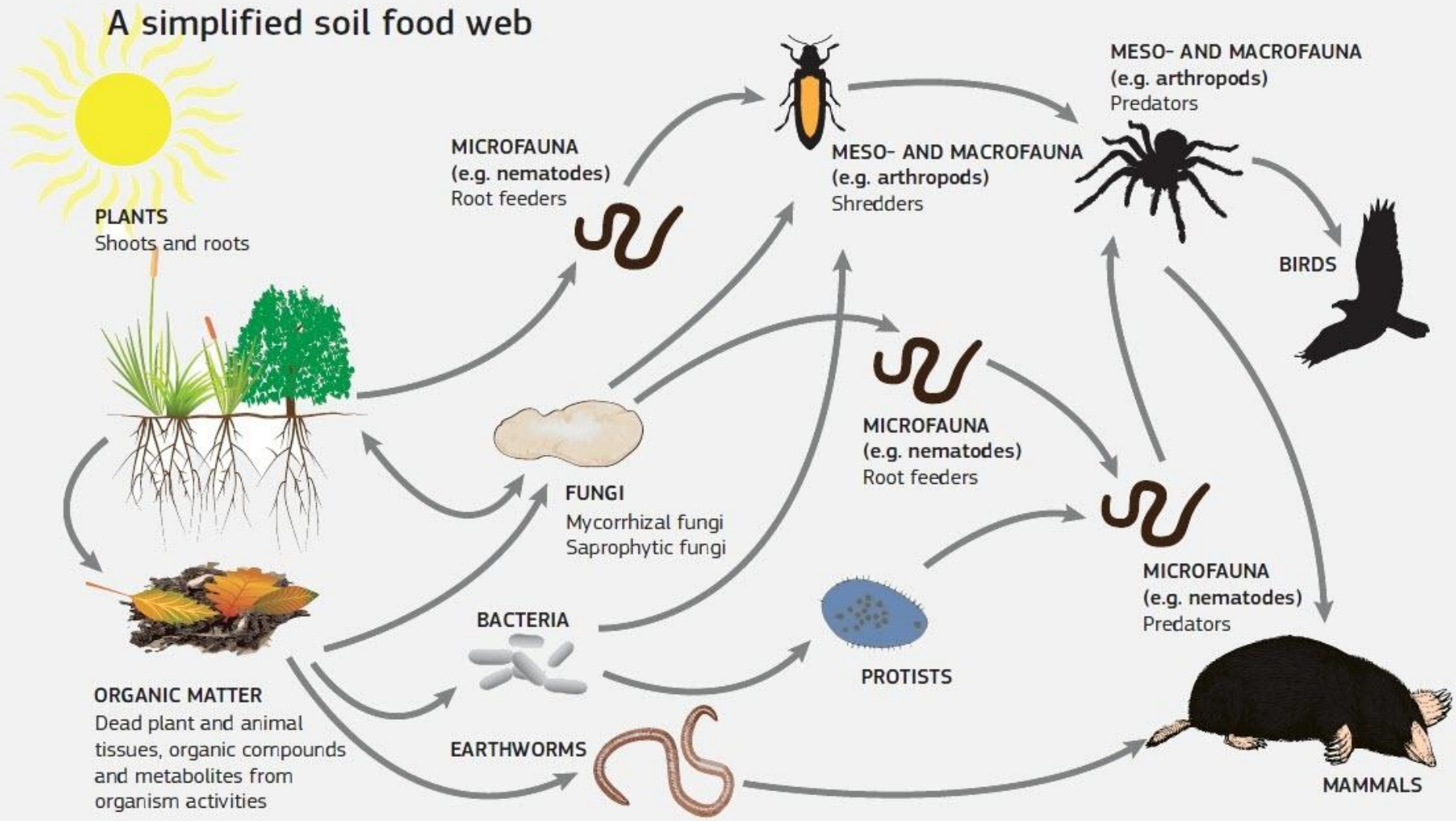
A simplified soil food web



Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al. Luxembourg, European Commission, Publications Office of the European Union: **176p.**

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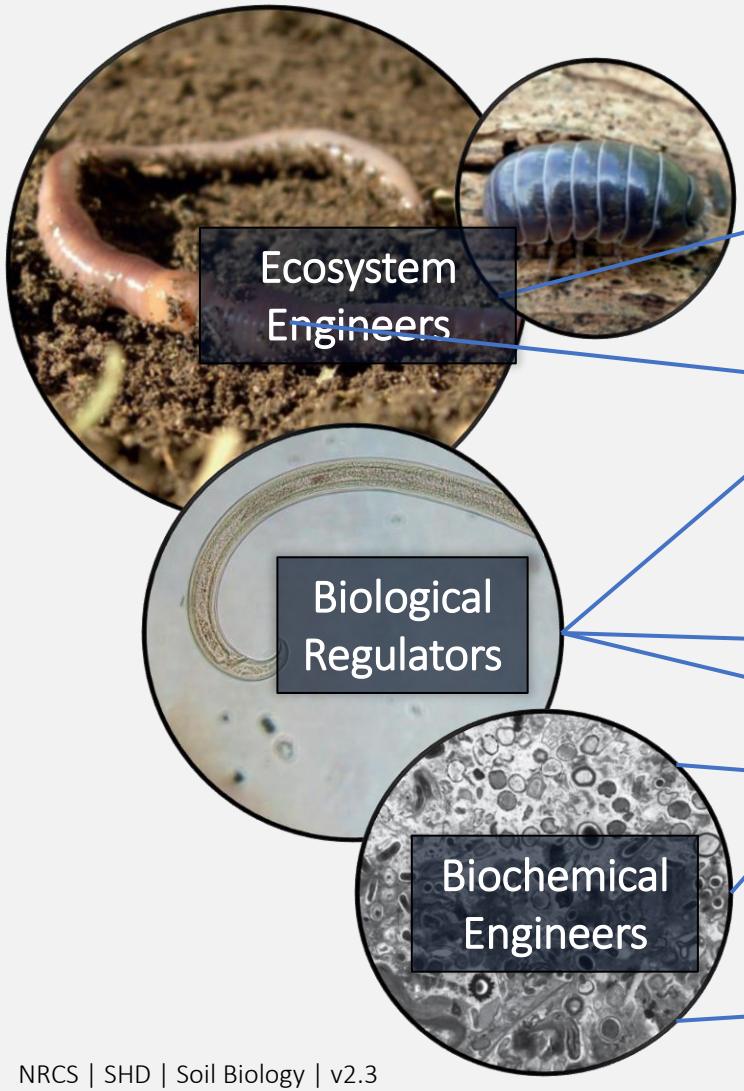
Soil Organisms 3 Functional Groups

Key Ecosystem Functions



Decomposition & C Cycling

Ecosystem Resiliency

Building soil, creating aggregates & pores

Population Regulation

Nutrient Cycling

Plant Productivity

Turbe et al., 2010;
Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.

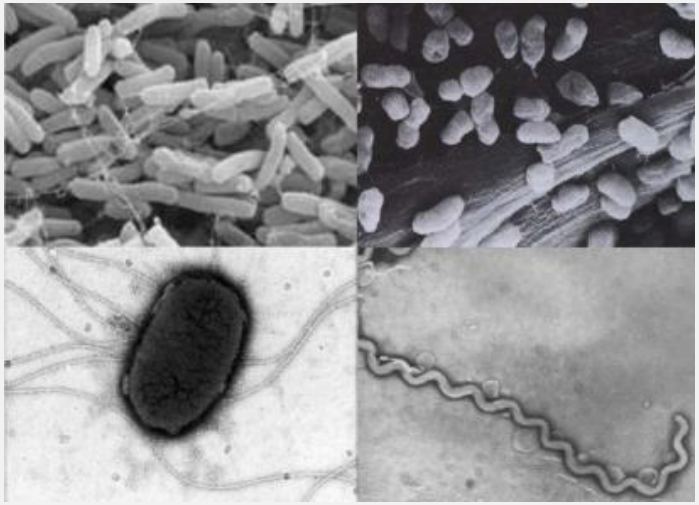
Ecosystem Engineers

Functional group	Function	Representative members
Ecosystem Engineers	Build pore networks and aggregates	Plant roots, earthworms, larger invertebrates (e.g., millipedes, centipedes, beetles)

Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

Chemical Processors (Engineers)

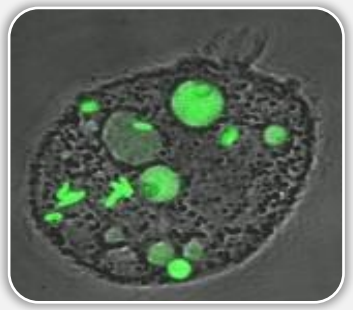
Functional group	Function	Representative members
Chemical Processors	Regulate 90% of energy flow in soil; Build soil organic matter & aggregates	Soil microbes (bacteria, fungi, protozoa)



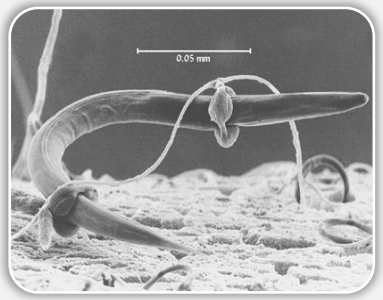
Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

Biological Regulators

Functional group	Function	Representative members
Biological Regulators	Regulate populations of other soil organisms	Protozoa, nematodes, and other small invertebrates (e.g., springtails, mites but also microbes)



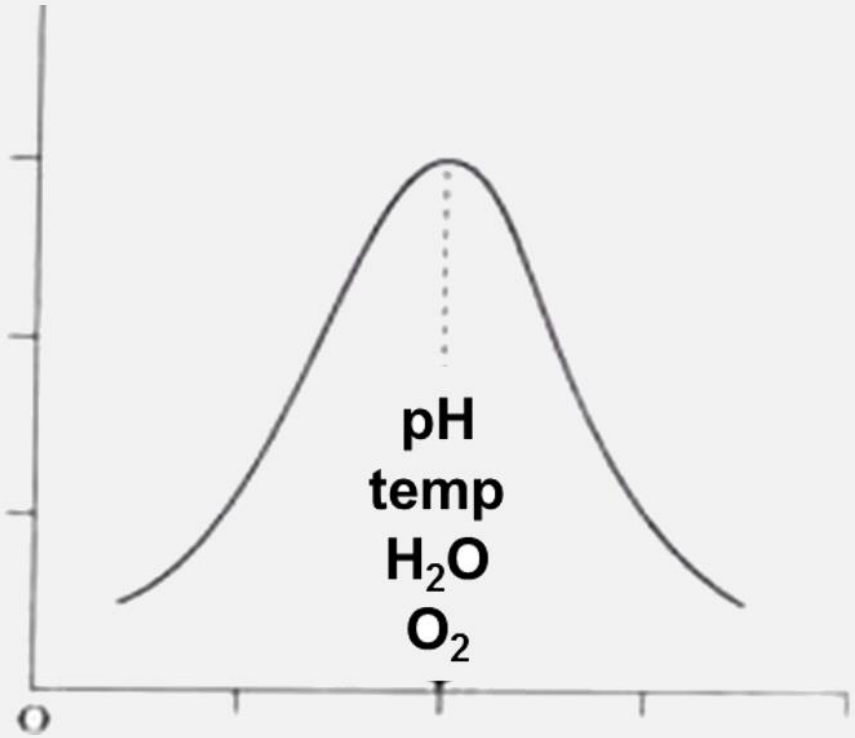




Modified from Turbe et al., 2010; Images from: Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

Optimal Activity in Most Ag Systems Occurs When Conditions are 'Just Right'

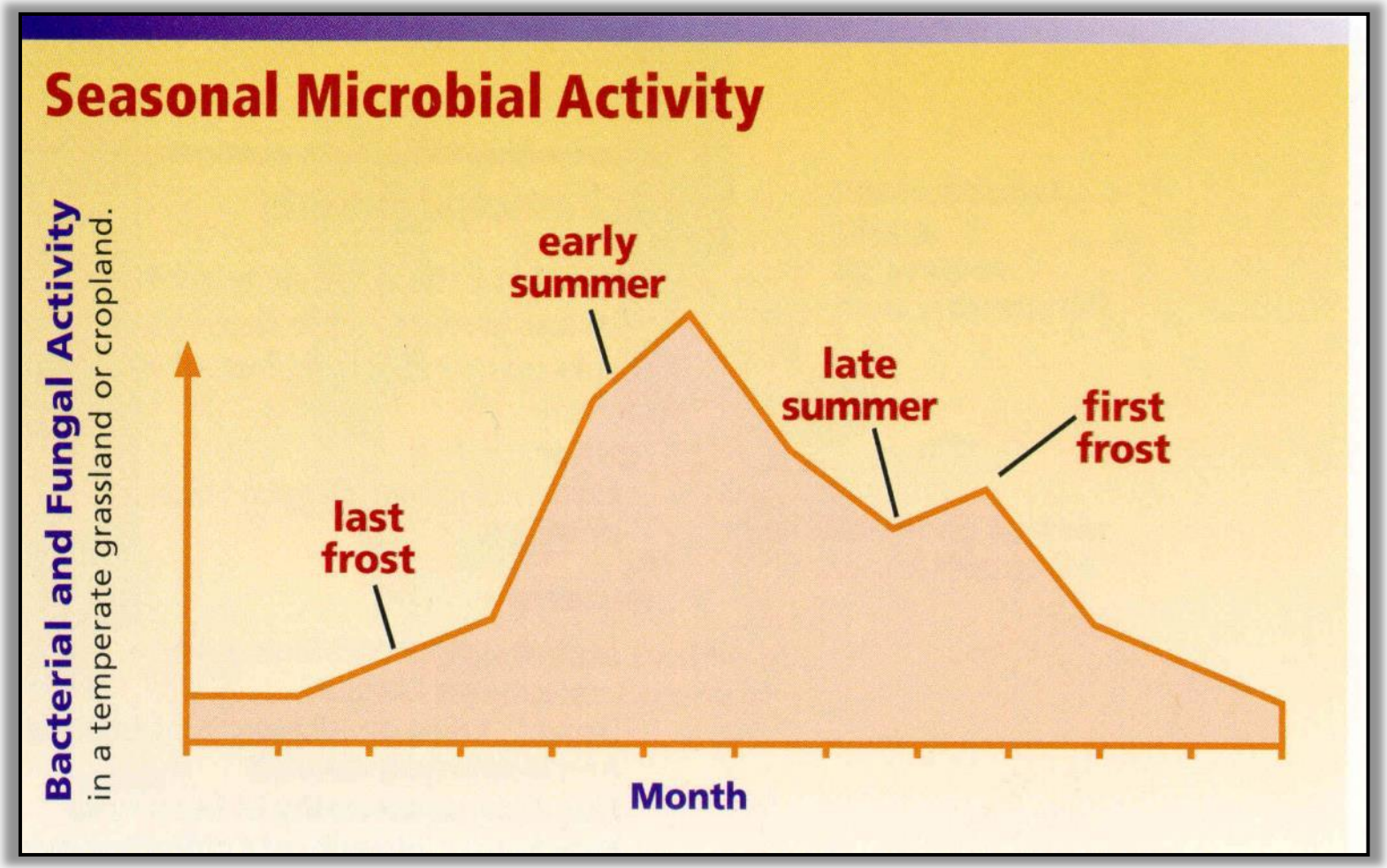
> 90% bacteria in soil are inactive!



Near neutral pH
Moderate temps
Moist conditions
Aerated
Abundant food (C)

Seasonal Microbial Activity

Microbes are impacted by temp and moisture



Soil Fauna Awaken Soil Microbes

15 week time lapse

Made by: Wim van Egmond
https://vimeo.com/222168889

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Continuous Flow of C Drives System

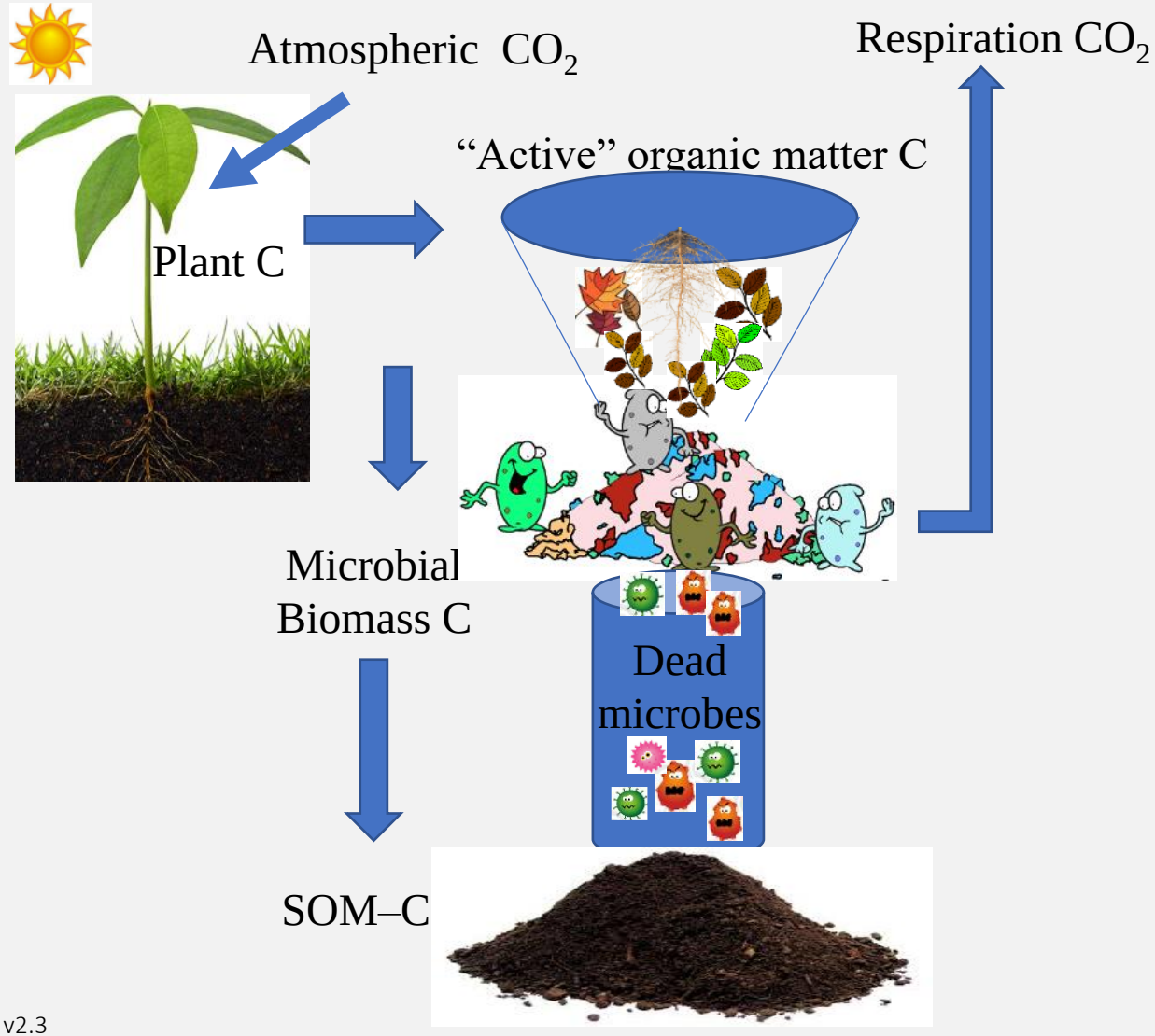

Image courtesy of Dr. Chenhui Li

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Knowledge check – poll question

Which soil organism functional group is responsible for 90% of the energy flow in soil?

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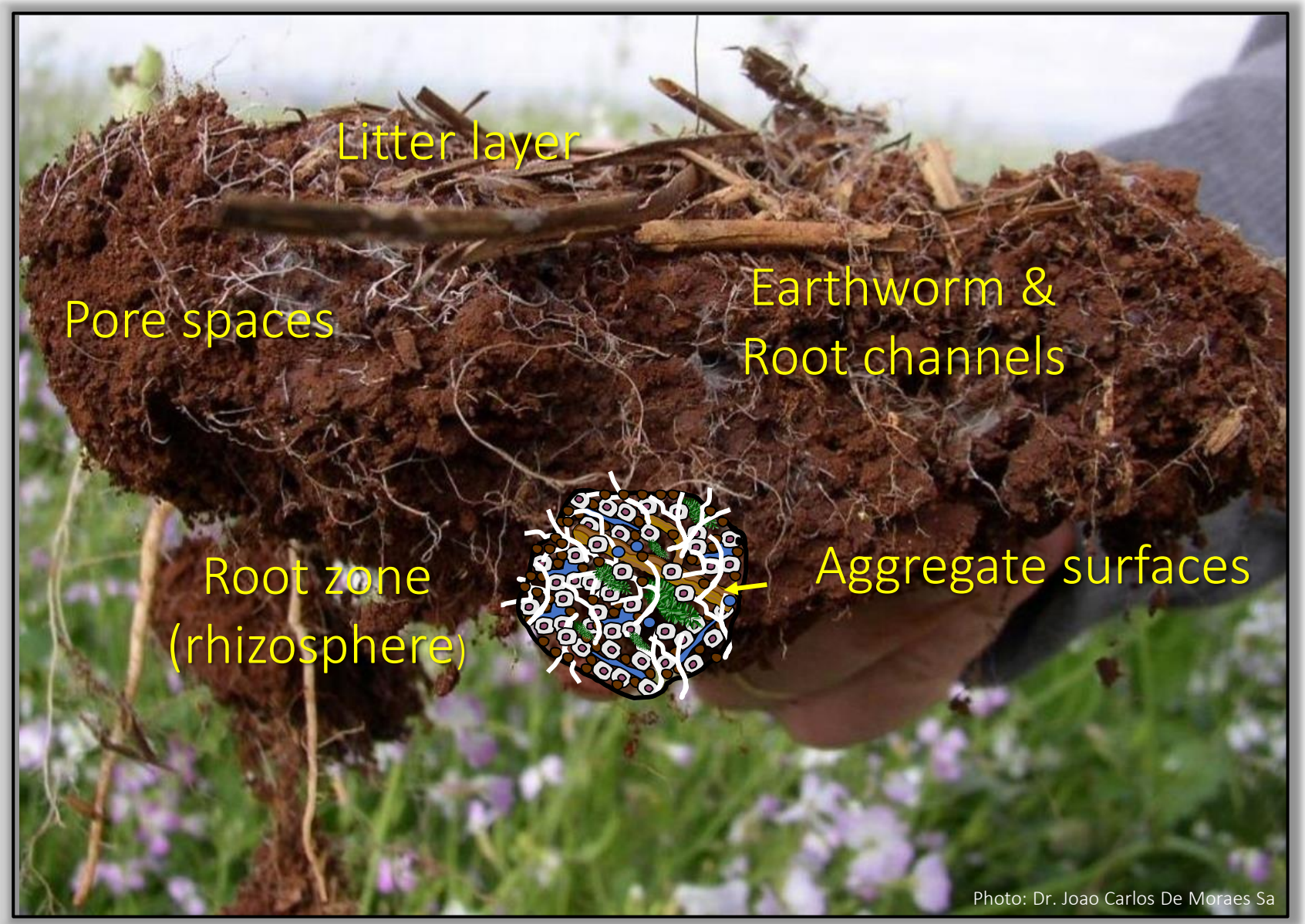
Biological Hot Spots



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Hot Spot for Ecosystem Engineers
Litter Layer

Protects soil

Conserves soil temp & moisture

Carbon source for soil organisms

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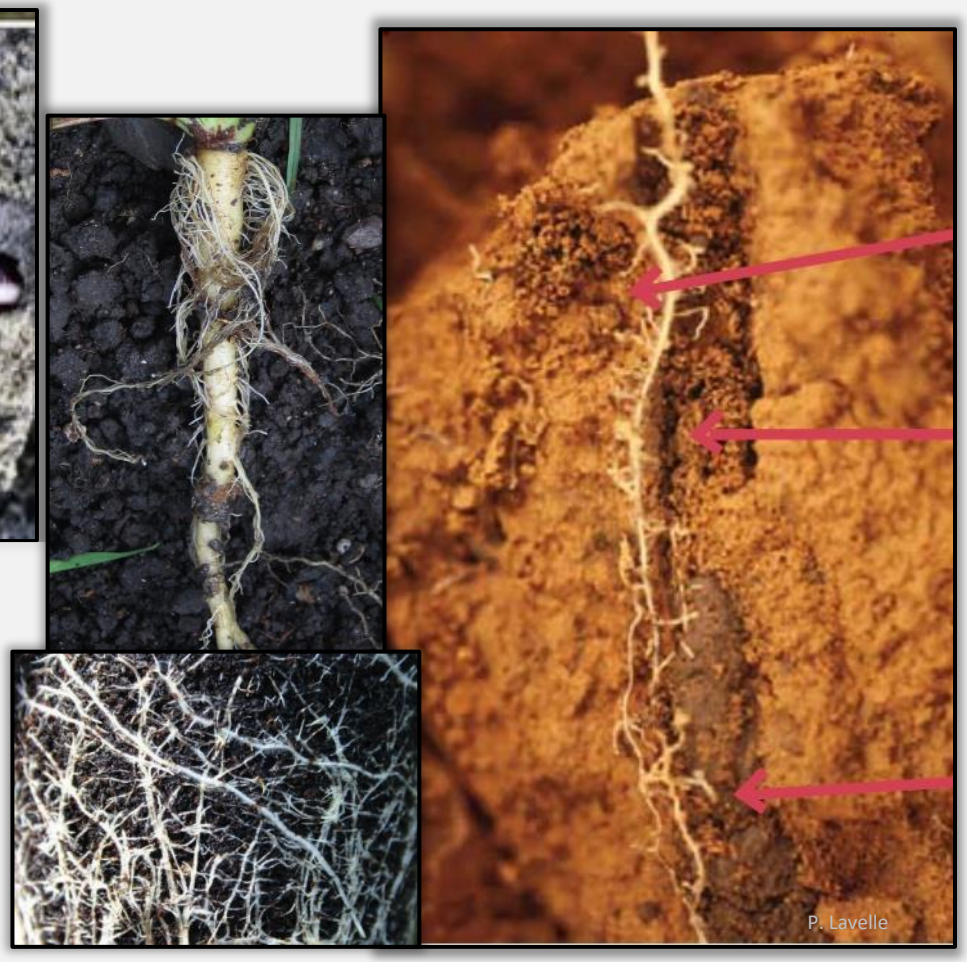
Turbe et al 2010; Orgiazzi, Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.

Hot Spot for Ecosystem Engineers Earthworm and Root Channels



Mixes and moves residues

Large pores

Nutrient rich

Microbial enriched

Air and water flow

Roots grow & take advantage

Beare et al. 1995. Plant & Soil 170:5-22; Kuzyakov et al. 2015. Soil Biol Biochem 83:184-199

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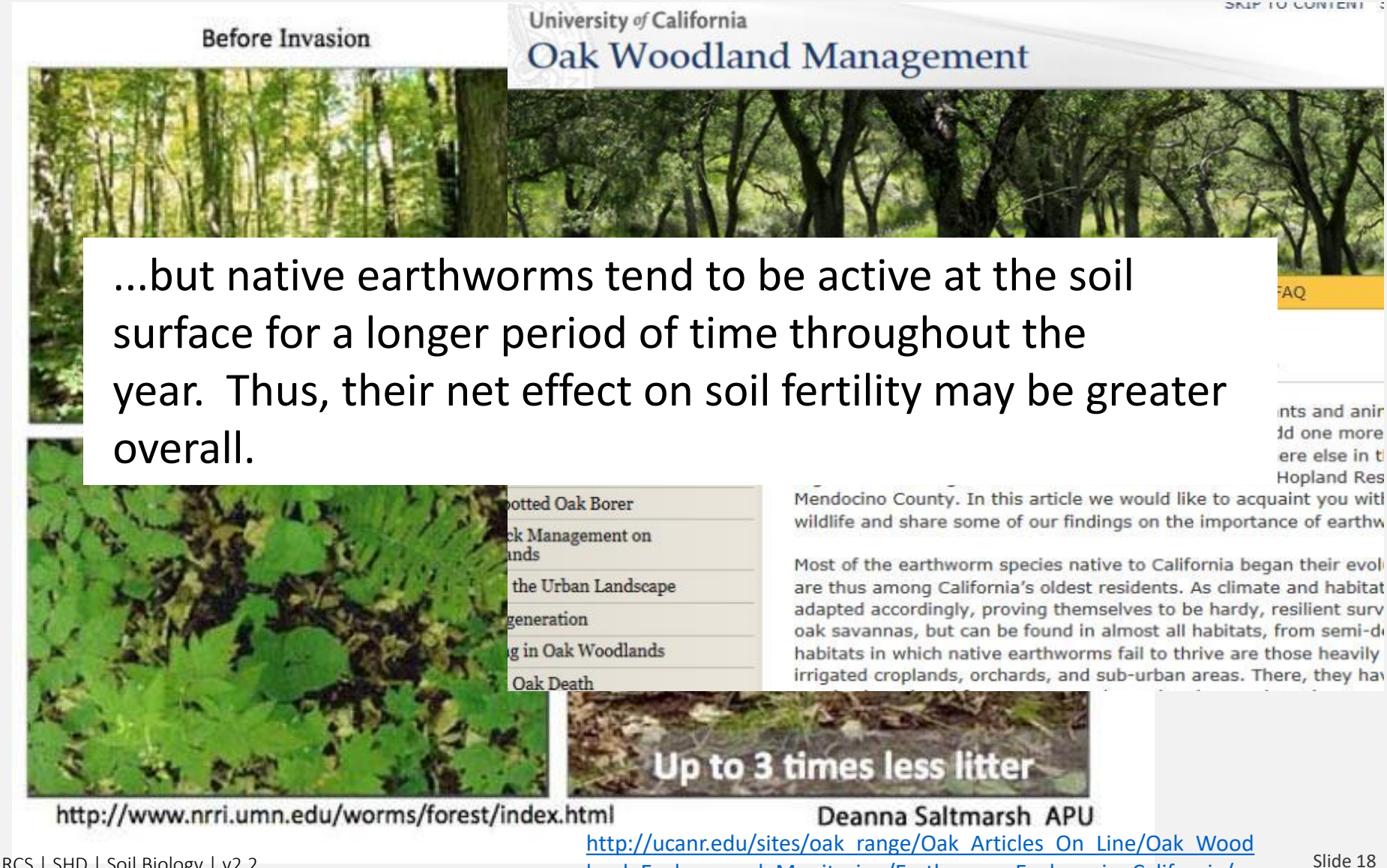
Not all Earthworms are Beneficial



http://ucanr.edu/sites/oak_range/Oak_Articles_On_Line/Oak_Woodland_Ecology_and_Monitoring/Earthworm_Ecology_in_California/

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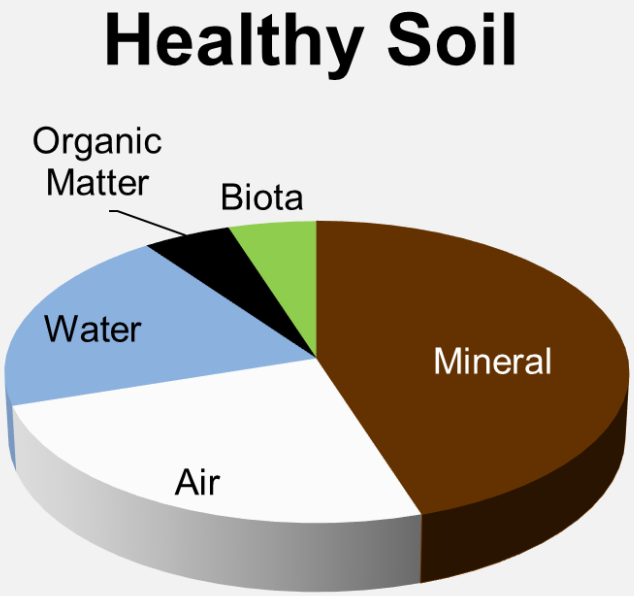
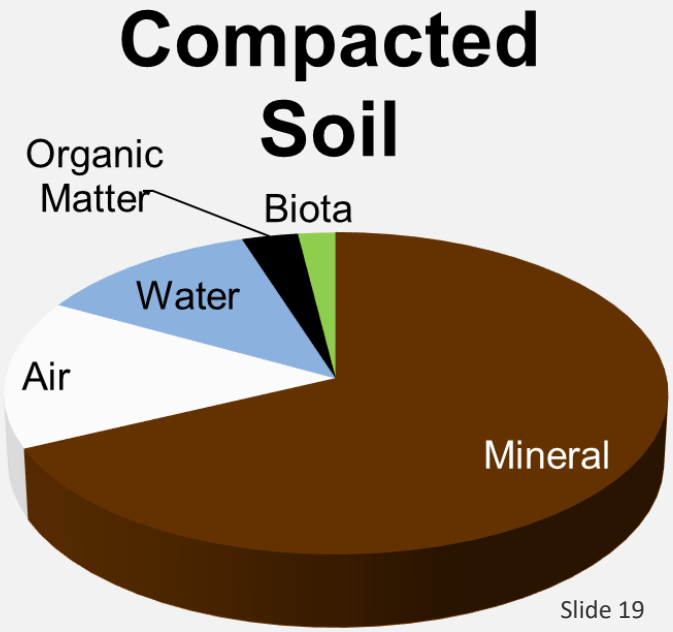
Hot Spot for Chemical Processors & Regulators in Pore Spaces

- Created via roots, organisms & SH management
- "Lungs & circulatory system"
- Air flow
- Water flow, storage, & availability
- Biological highways

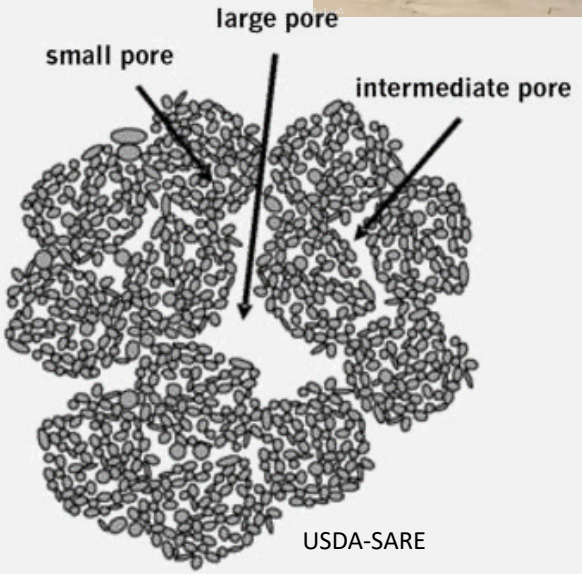




Aggregate Surfaces

- Built with minerals and organic materials
- Creates stability and resists erosion
- Protects organic matter and microbes
- Physically supports pore spaces
- Created by microbial glues, fungal hyphae, dead cells


J Moore Kucera



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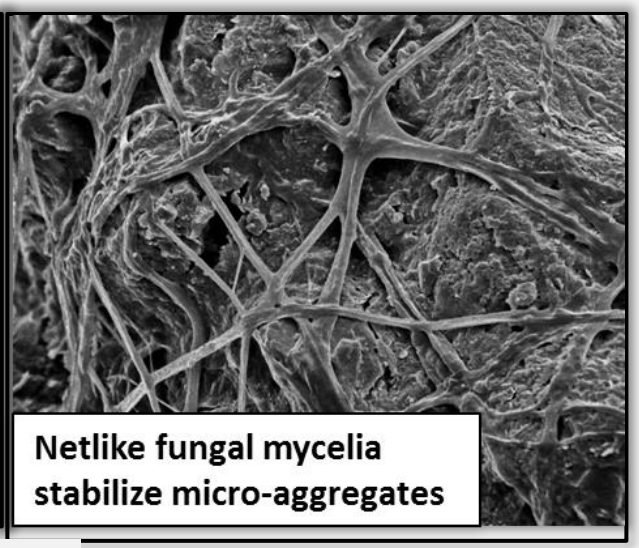
Soil Organisms Physically Stabilize Soil Aggregates

- Plant roots enmesh soil particles
- Earthworm casts
- Fungal and bacterial filaments physically enmesh soil particles



SEM photo source (accessed on 6/2/2016): Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. http://www.microped.uni-bremen.de

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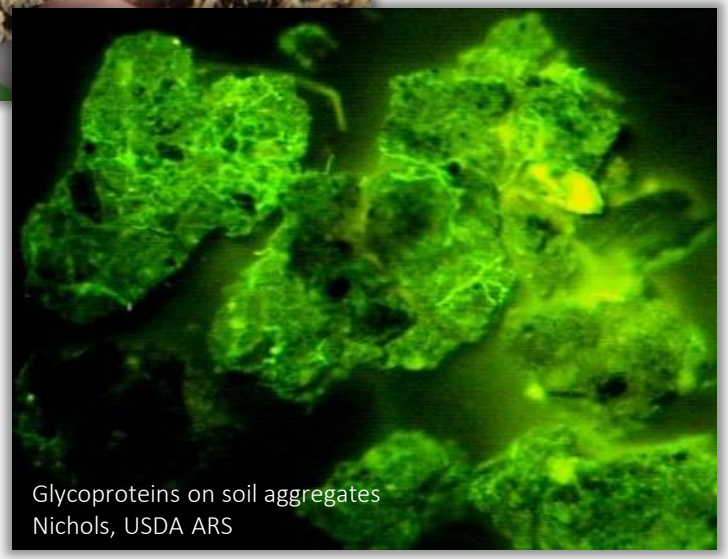
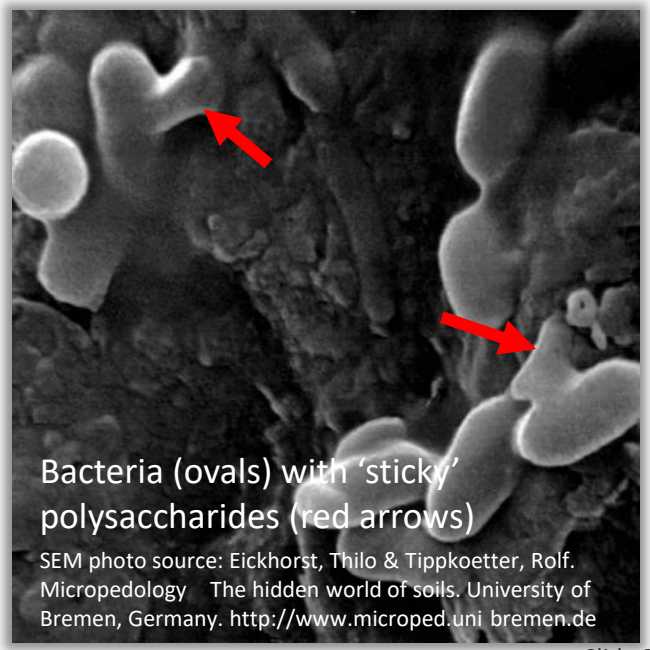
Soil Organisms Chemically Stabilize Soil Aggregates


Image source: Aaron Roth, NRCS OR

- Polysaccharides released by bacteria bind particles
- Soil proteins and other biochemicals bind soil particles


Glycoproteins on soil aggregates
Nichols, USDA ARS


Bacteria (ovals) with 'sticky' polysaccharides (red arrows)

SEM photo source: Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology The hidden world of soils. University of Bremen, Germany. http://www.microped.uni bremen.de

Hot Spot For Chemical Processors & Regulators - Rhizosphere

- Root exudates & chemical signals stimulates microbes & predators
  - Symbiosis
  - Protection
  - Chemical signaling
  - Nutrients
  - Resilience

Orgiazzi, Bardgett, Barrios et al., 2016. Global Soil Biodiversity Atlas.

Root Zone (Rhizosphere): Key Organisms

Bacteria

- Most numerous
- 2-5% of SOM but responsible for 90% of energy flow
- 1 g can contain 10 million bacteria and one million species.
- 0.5-3 tons per acre (Killham 1994)

Fungi

- Saprophytic
- Mycorrhizae
- Pathogenic
- Up to 5 tons per acre

Protozoa & Nematodes

*Consume microbes and recycle nutrients to plant roots

Turbe et al 2010; Coleman & Crossley 1996; Nannipieri & Badalucco 2003; Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al.

Rhizosphere Key Organisms
Mycorrhizae

Mykós (fungus)- riza (root)

- Plants use 5-20% of C from photosynthesis to ‘feed’ fungi
- Fungi increase adsorptive root surface area at least 10x
- Fungi increase nutrient uptake especially P and Zn
- Fungi suppress pests and diseases
- Fungal networks build soil aggregates

N-Fixing Bacteria (Rhizosphere)

Bradyhizobium Japonicum
for Soybean & Cowpea

Photo: Getty Images

Rhizobum trifolii
for most Clovers


Photo: Science Source

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Knowledge Check - Poll Question

How many types of biological hotspots are there in the soil ecosystem?

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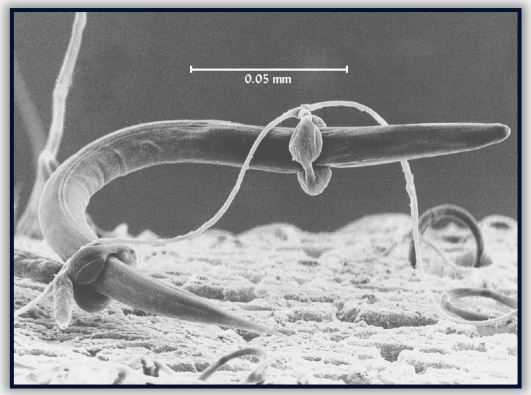
How Can the Soil Microbiome be Manipulated?

- Select different plant species, varieties, or control at various plant stages (e.g., crop rotation, cover crop selection, planting timing and termination)
- Fertilization (4 R's)
- Soil amendments, including biologicals (promise but fraught with issues)
- Manage the environment to minimize stress (e.g., pathogens, drought, temperature extremes, etc.)
  - Temperature
  - Moisture
  - Maximize presence and duration of hot spots

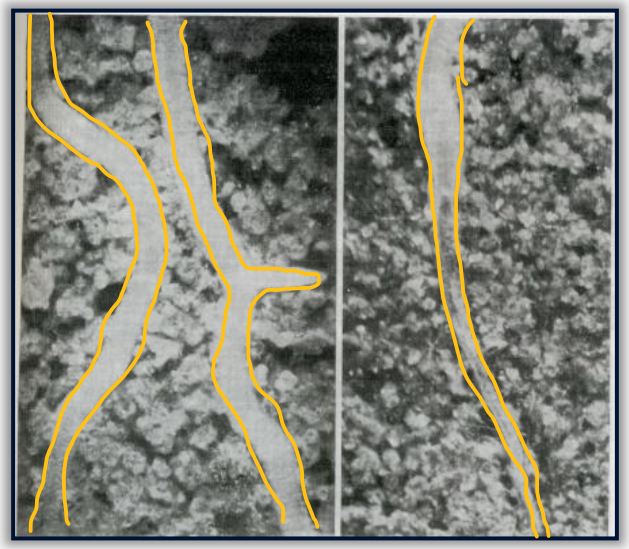
Belowground Competition

Nematode-trapping Fungi



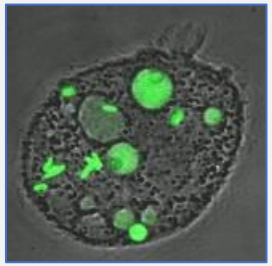
Vampyrellids (protist) eating a fungal root pathogen involved in take-all disease

Protection from *Rhizoctonia solani*



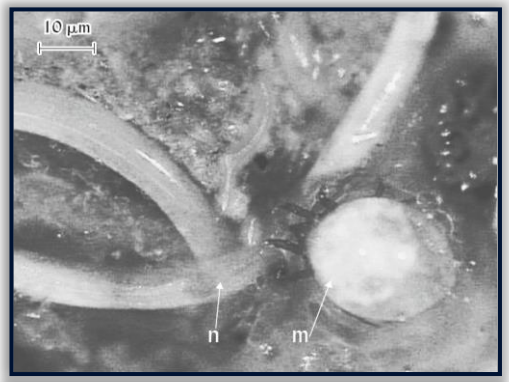
Roots with springtails

Roots without springtails



A single protozoan can eat billions of bacteria each day!

Mite preying on a nematode



Soybean cyst nematode parasitized by the fungus *Hirsutella minnesotensis*

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Summary: Managing for Soil Biology

- Most ag soils are carbon depleted
- Disturbances destroys habitat and hyphal networks
- Bare, fallow fields provide little protection, no C
- Agrichemicals have mixed effects
- Many fertilizer concentrations too high for symbiosis

- Manage for hot spots
- Support biology to build aggregates and create pore space
- Protect the habitat
- Feed the soil so it can feed us
- Optimize biological nutrient cycling
- Optimize plant-microbe interactions for plant defense optimization

What do Soil Organisms Need?

- How can we feed belowground life?
  - Choose practices that provide diverse, near continuous inputs and build reserves (SOM)
- How can we provide & protect habitat?
  - Choose practices that minimize disturbance of habitat (aggregates) and food sources (SOM + residue)
  - Choose practices that support a stable habitat from major swings in temperature, water, & chemistry

Biological Hot Spots to Optimize Function

Litter Layer

Photo source: NRCS

Rhizosphere

Root/Worm Channels

Photo source: P. Lavelle; J Moore-Kucera

Aggregate Surfaces

Photo source: J Moore-Kucera

Pore Space

Photo source: Barry Fisher, NRCS

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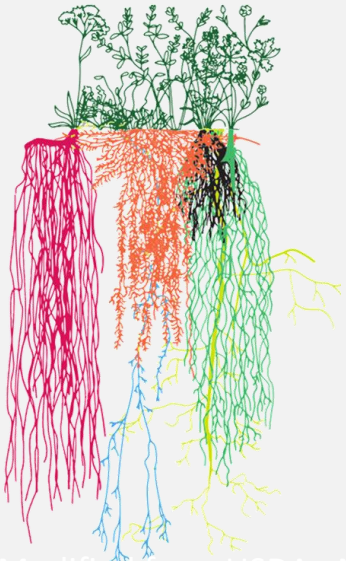
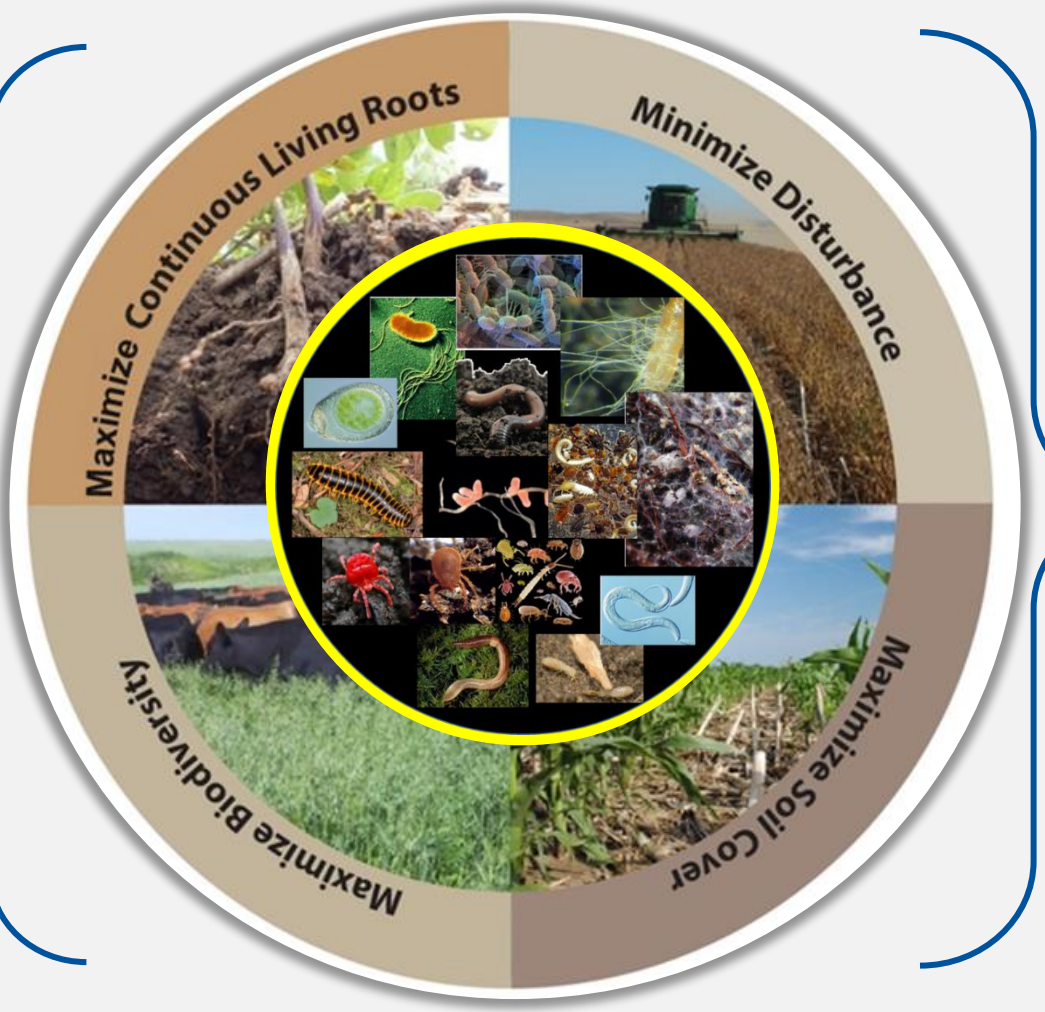
Root cartoon and organism images: Orgiazzi , Bardgett, Barrios et al. 2016. Global Soil Biodiversity Atlas.; Slide design by J Moore-Kucera

Soil Health Principles

Feed & Fuel Soil Biology





Protect Soil Aggregates & Organic Matter

*Modified from USDA_NRCS Principles for High Functioning Soils Factsheet

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Knowledge Check – Poll Question

Is Mycorrhizal Fungi beneficial to plants?


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Meeh, NRCS