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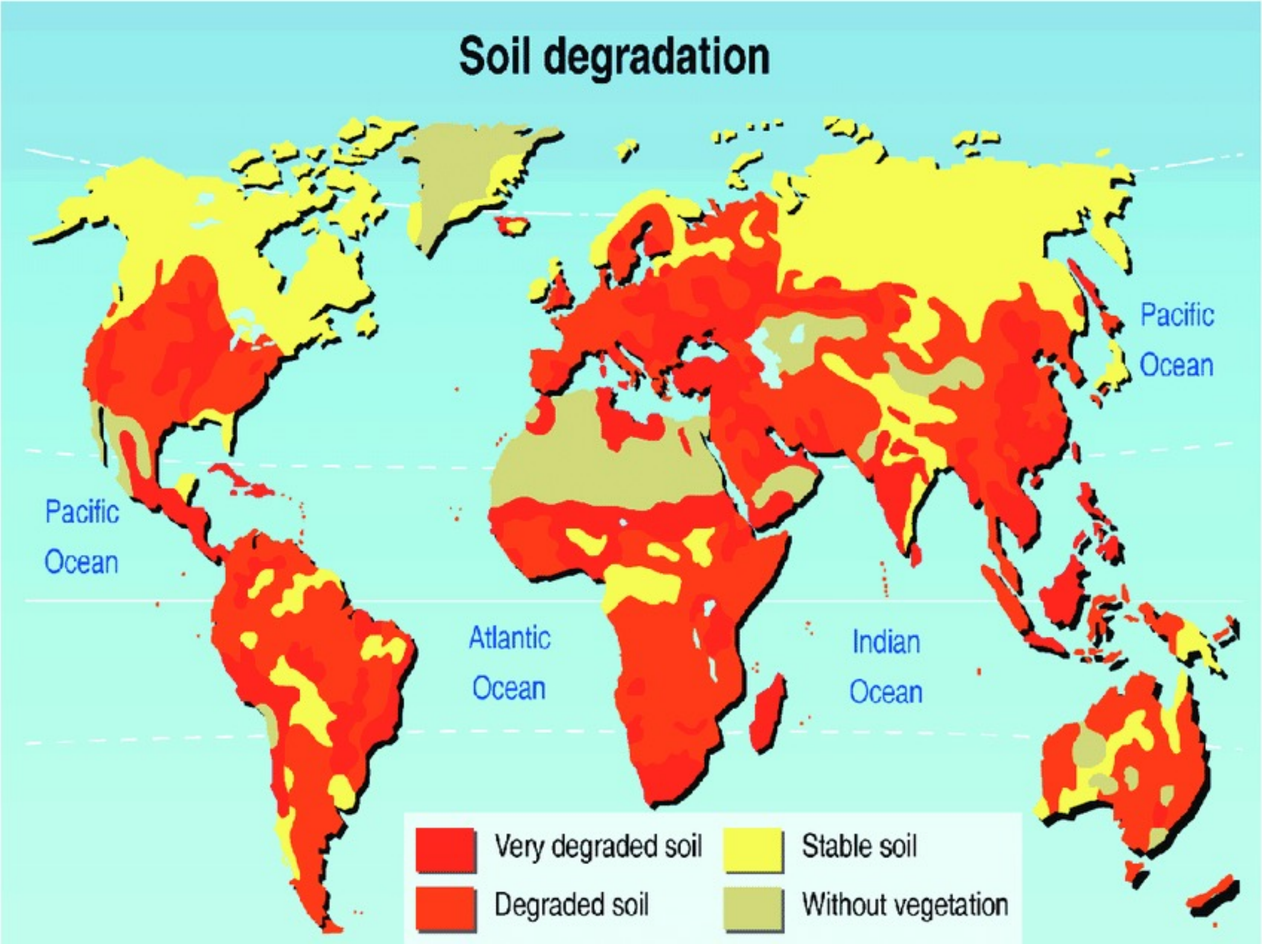
Soil Microbiome and Soil Health

Created by Dr. Daisy Myint

Global Pandemic



Source: UNEP, International Soil Reference and Information Centre(ISRIC), World Atlas of Desertification, 1997. Phillippe Rekacewicz, UNEP/GRID-Arendal

10 main threats to soil's ability to function:

1. Soil Erosion,
2. Soil Organic Matter Loss,
3. Nutrient Imbalance,
4. Soil Acidification
5. Soil Contamination
6. Waterlogging
7. Soil Compaction
8. Soil Sealing
9. Salinization
10. **Loss Of Soil Biodiversity.**

Soil Fertility

- **Soil Fertility/Quality:** Capacity of the soil to support the growth of agricultural plants
- Depends on physical, chemical and biological factors
- *The continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal and human health* (Doran et al. 1996; Doran and Zeiss 2000)

Physical Fertility

- **Physical Fertility** refers to the physical properties of the soil. These include the following:
- **Soil structure.** The arrangement of aggregates(particles of clay, silt and sand),plus voids and other spaces determine soil structure.
- **Soil texture.** This is the relative amount of clay, silt and sand particles.
- **Water absorption & holding capacity.** refer to water movement via rain or irrigation and active gravitational flow (infiltration, permeability, and percolation), and one that refers to water movement once gravitational flow has stopped (capillary action).
- **Root penetration.** The ability of plant roots to grow and move within the soil (degree of difficulty).

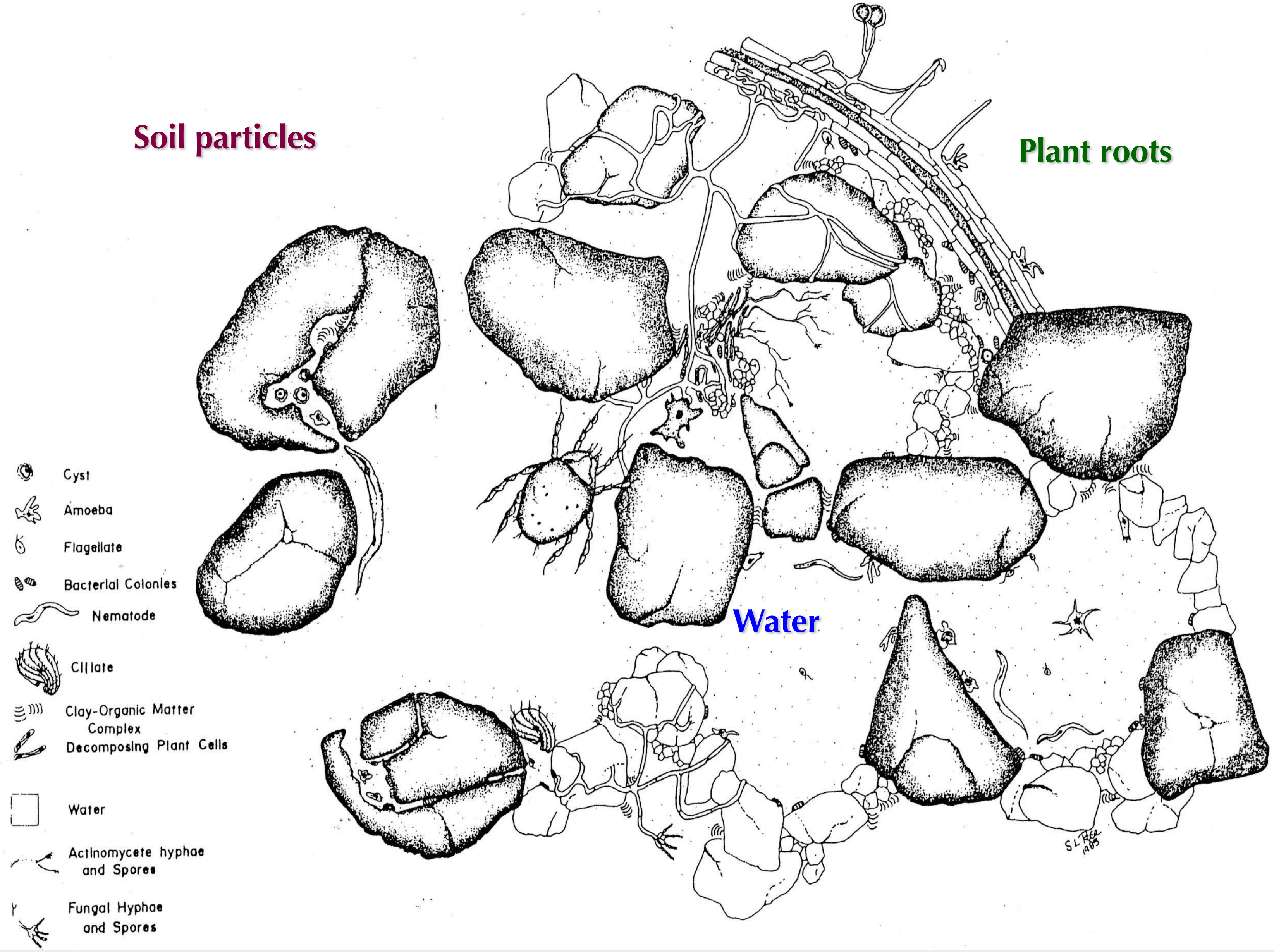
Chemical Fertility

- Chemical fertility refers to the nutrient levels and chemical conditions such as acidity, alkalinity and salinity in soil. Components are:
- **Macronutrients:** Nitrogen, Phosphorous, Potassium, Calcium, Sulphur, Magnesium, Carbon, Oxygen, Hydrogen.
- **Micronutrients:** Boron, Iron, Chlorine, Manganese, Zinc, Copper, Molybdenum, Nickel.
- **Toxic Heavy Metals:** Arsenic, Aluminum, Chromium, Mercury, Lead, Cadmium (note that some micronutrients are also heavy metals, but are not considered toxic in normal concentrations.)

Biological Fertility:

- Biological Fertility refers to the many varied organisms and microorganisms that live in the soil and interact with the other two fertility components.
- These organisms live on soil particles, on organic matter, and on other larger organisms within the soil.
- They are responsible for many vital processes in the soil, including advancement of the nutrient and carbon cycles.
- Few soil organisms are considered pests.

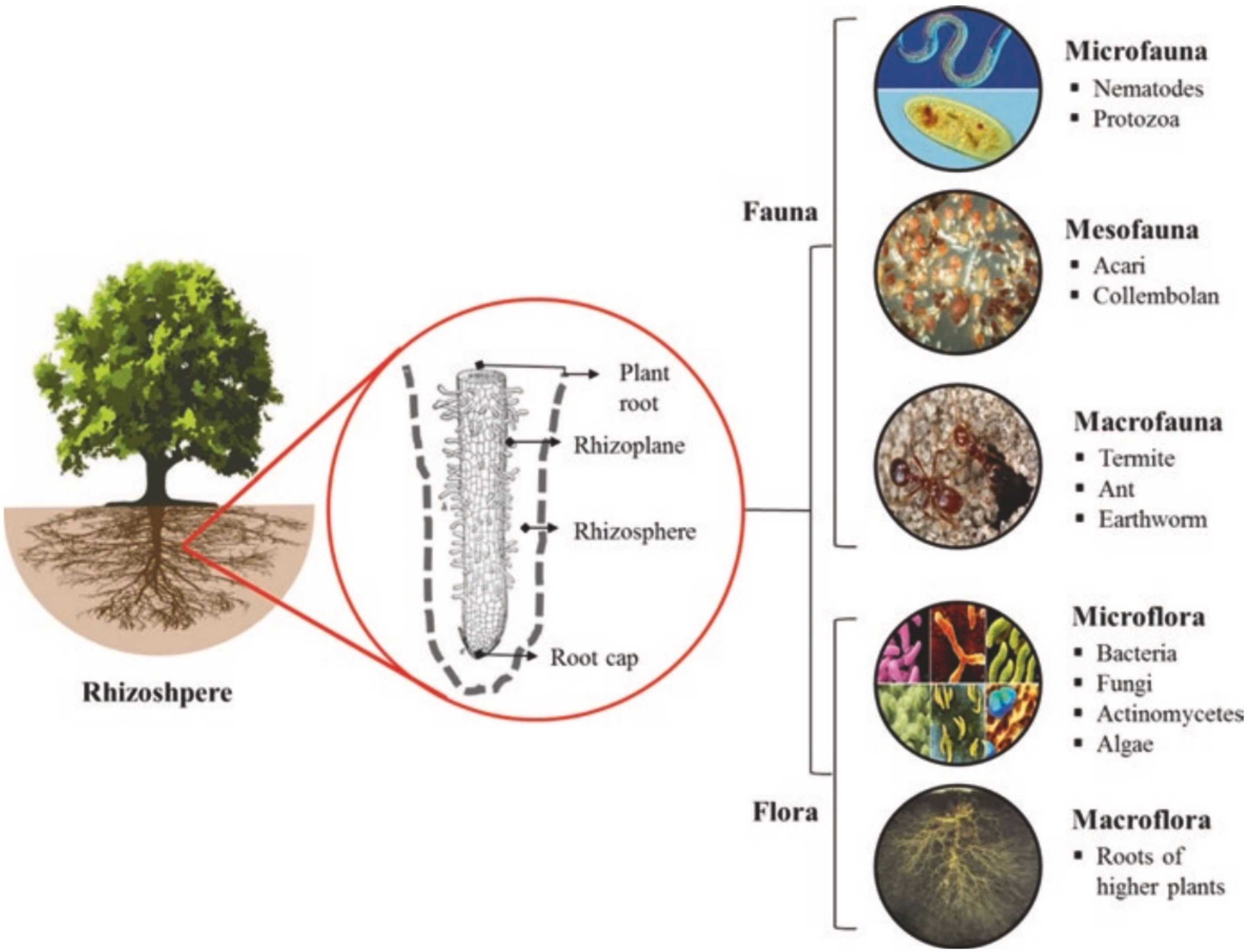
Soil Habitat



Trophic relationships among different groups of soil organisms

Soil habitat

- Totality of living organisms inhabiting soil, including plants, animals, and microorganisms, and their abiotic environment

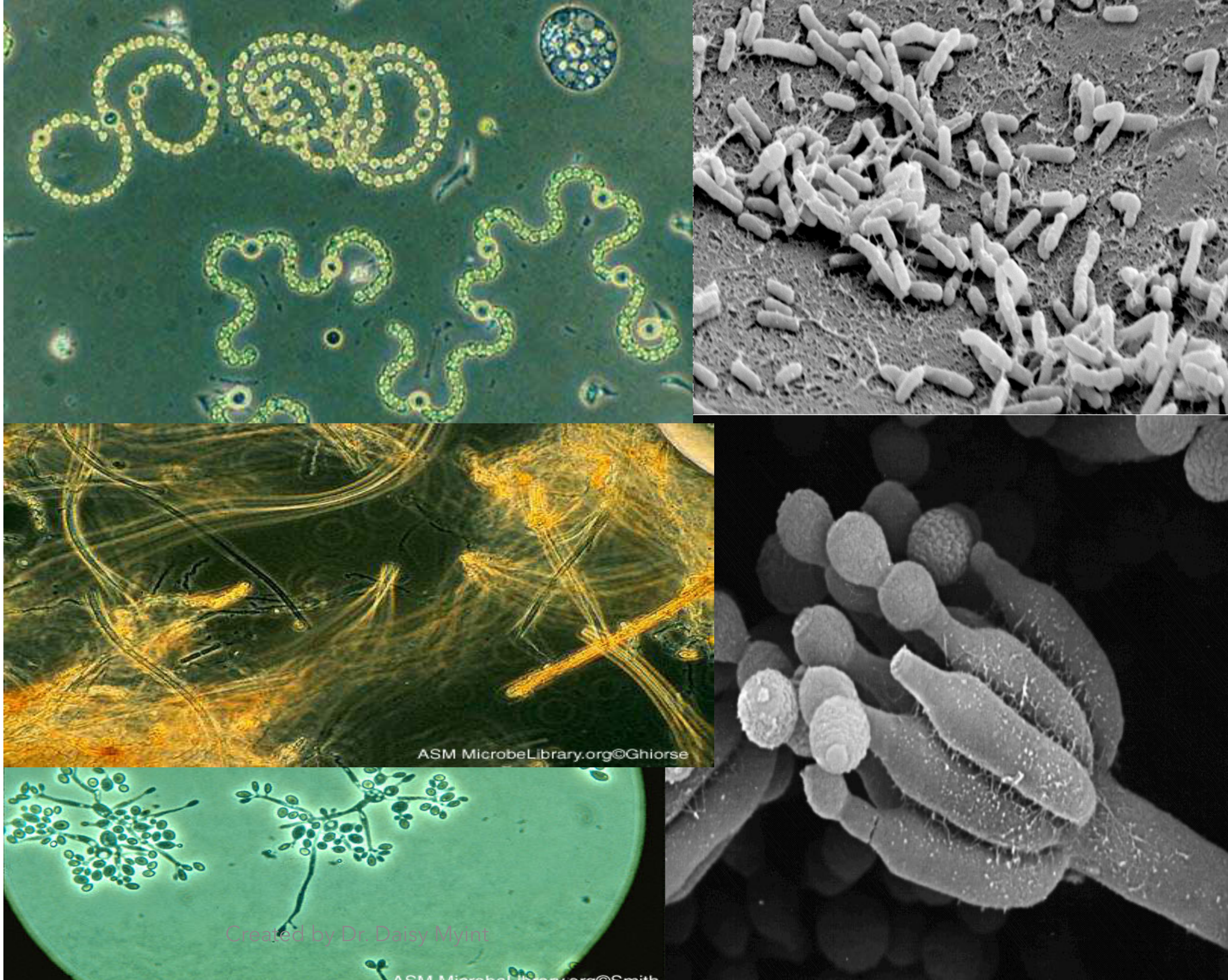


Definition of soil microbiome

- **Community of microorganisms (bacteria, fungi, archaea, protozoa, and nematodes, living within the soil environment)**
- Nutrient cycling, decomposition of organic matter, soil structure formation, and overall soil health
- Influenced by various factors (soil pH, moisture content, temperature, and organic matter content, as well as human activities such as land management practices and pollution)
- Understanding the composition and functions of the soil microbiome is essential for sustainable soil management and agricultural productivity.

Soil is alive…

- For example, in 1g of soil:
- >100,000,000 bacterial cells
- >11,000 species of bacteria
- Also fungi and larger animals



How Many Microbes?

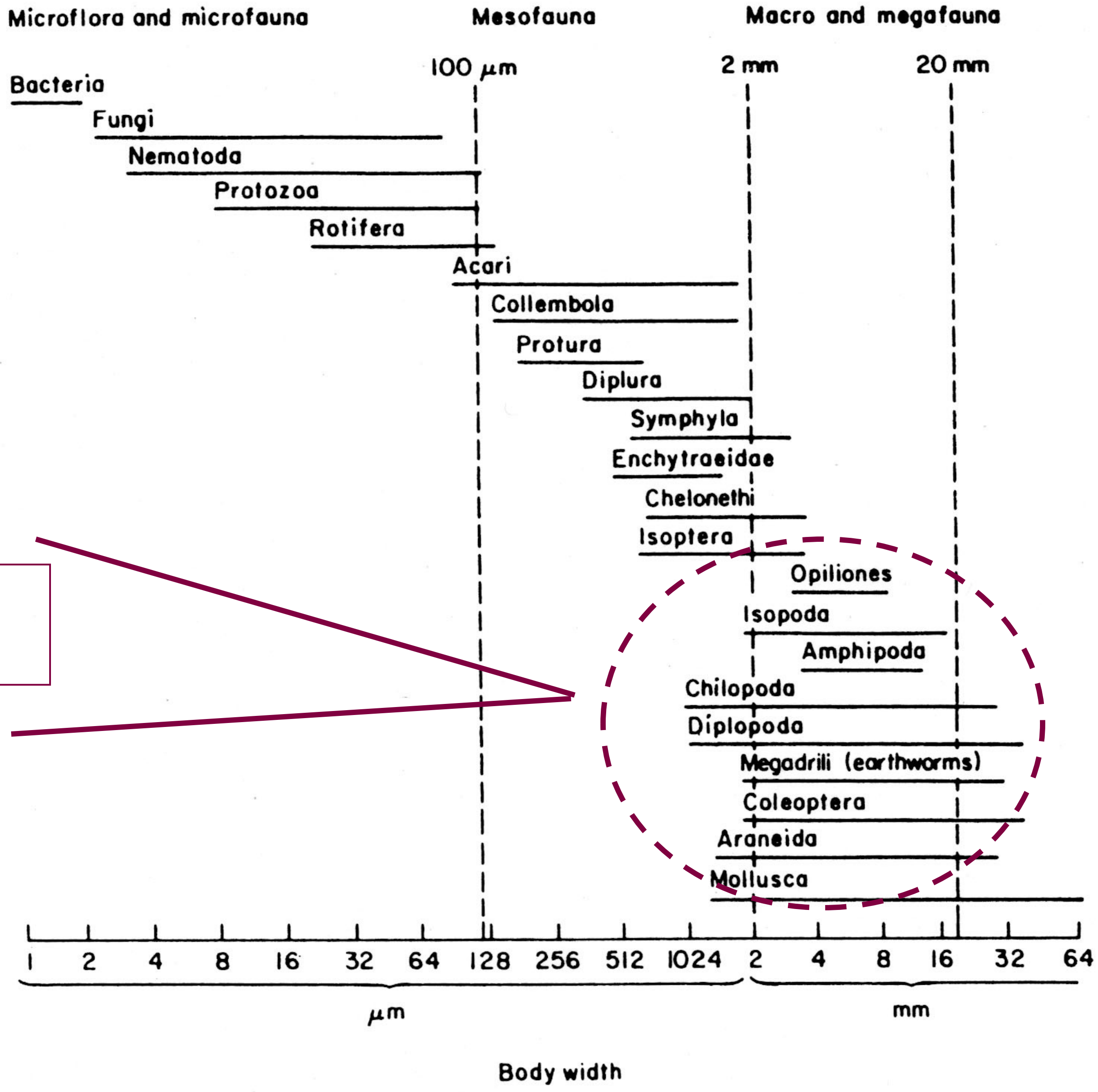
In one hectare (2.5 acres) of topsoil (6” deep), the mass of soil microbes (biomass) is approximately equivalent to:

A. 1 sheep (150 lbs)
B. 1 cow (1,500 lbs)
C. 1 African elephant (10,000 lbs)
D. 3 African elephants (30,000 lbs)

Soil is the most complex habitat on earth and supports a **HUGE** number of organisms (mostly microscopic)

Who's there?

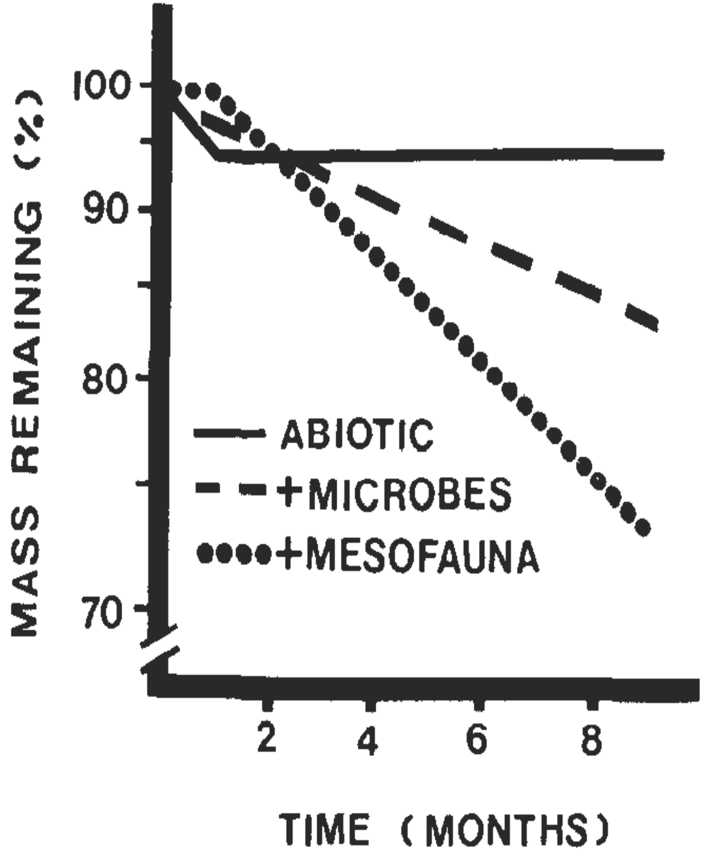
Macrofauna: Soil 'Engineers'



Size classification of organisms in decomposer food webs by body width

Soil Animals

Soil animals are important for

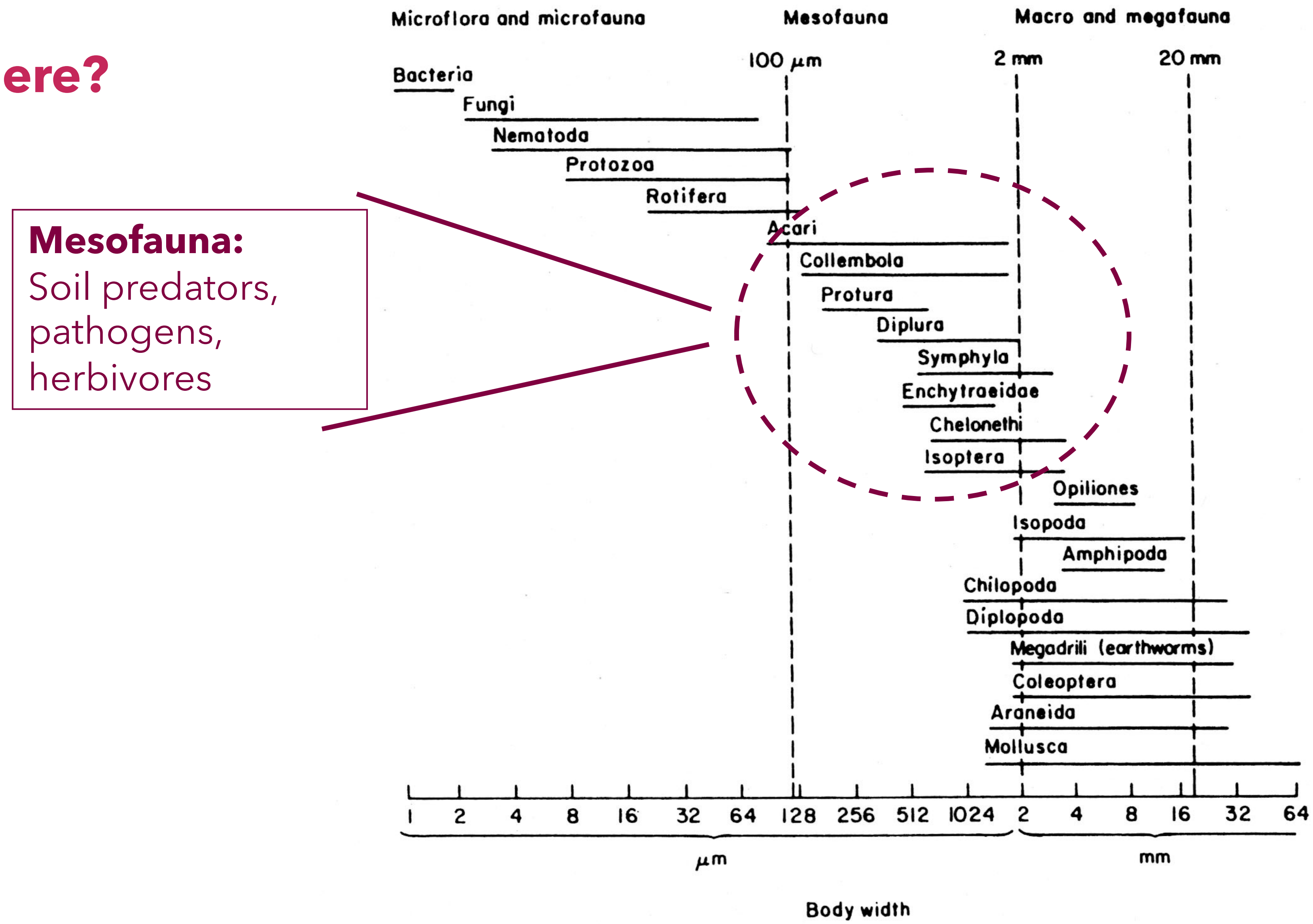


Decomposition rate of blue grama *(Bouteloua gracilis)*

1. Decomposition (shredding residues)

2. Mixing soil (aeration)

Who's there?



Size classification of organisms in decomposer food webs by body width

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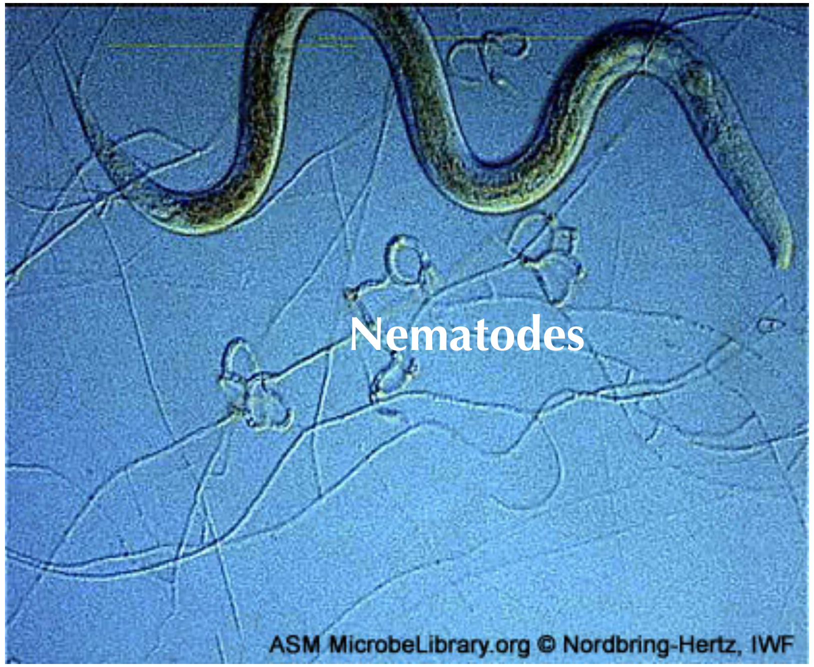
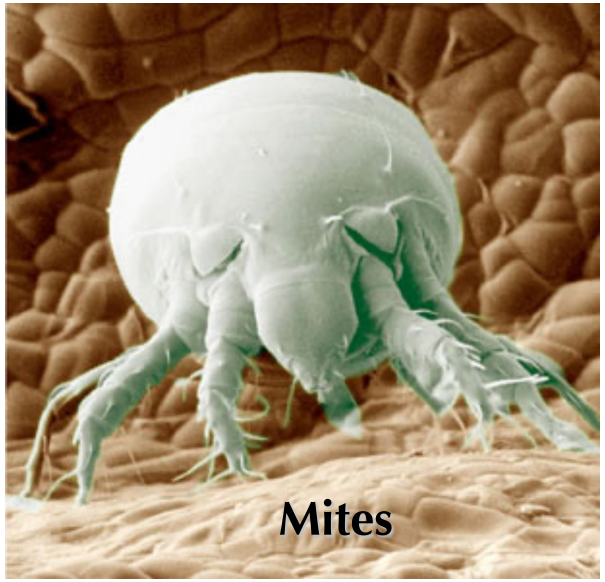
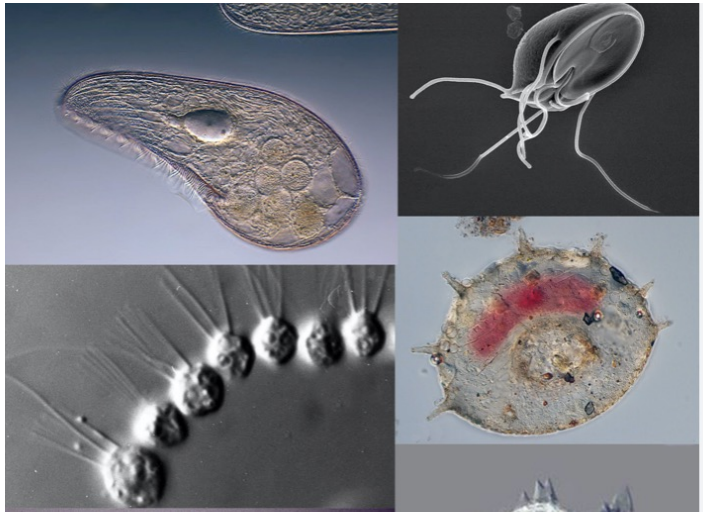
Soil mesofauna







Protozoa

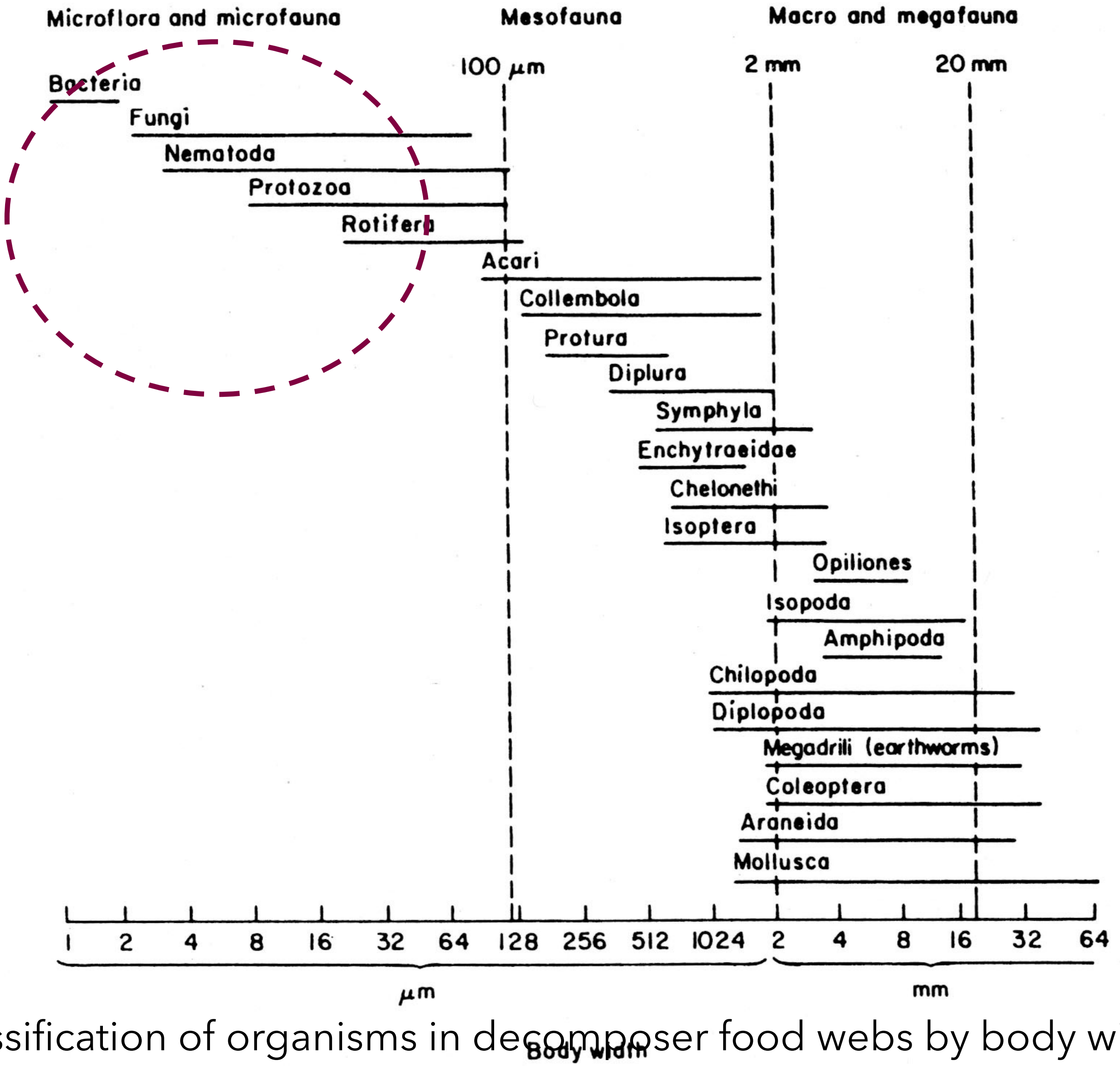
Soil mesofauna are important for

1. Residue decomposition

1. Predation

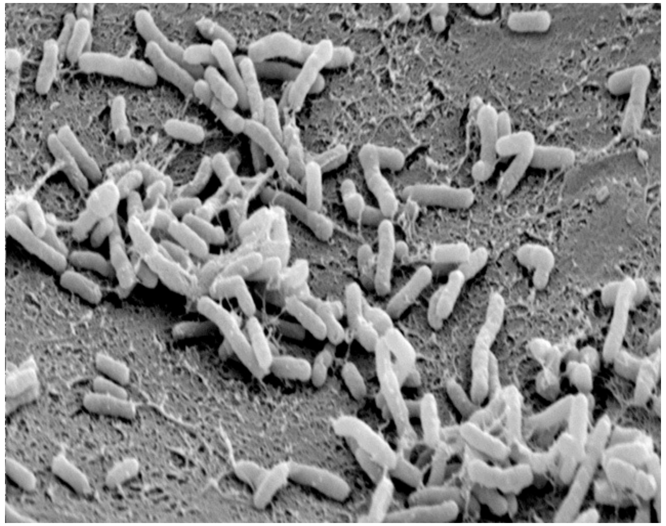
1. Pathogenesis

Microorganisms:
Soil process controllers

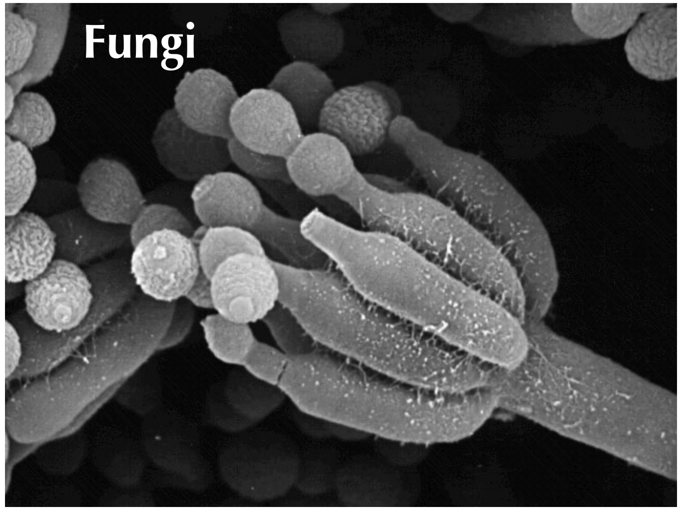


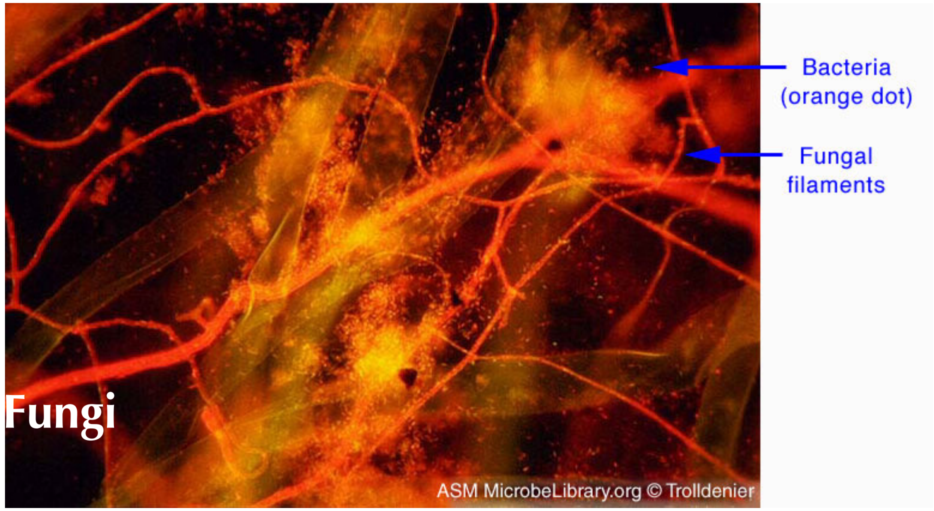
Size classification of organisms in decomposer food webs by body width

Soil microorganisms



Bacteria





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Key Microorganisms (Agriculturally Important Microorganism-AIM)

- Bacteria
- Fungi
- Archaea
- Protozoa
- Nematodes

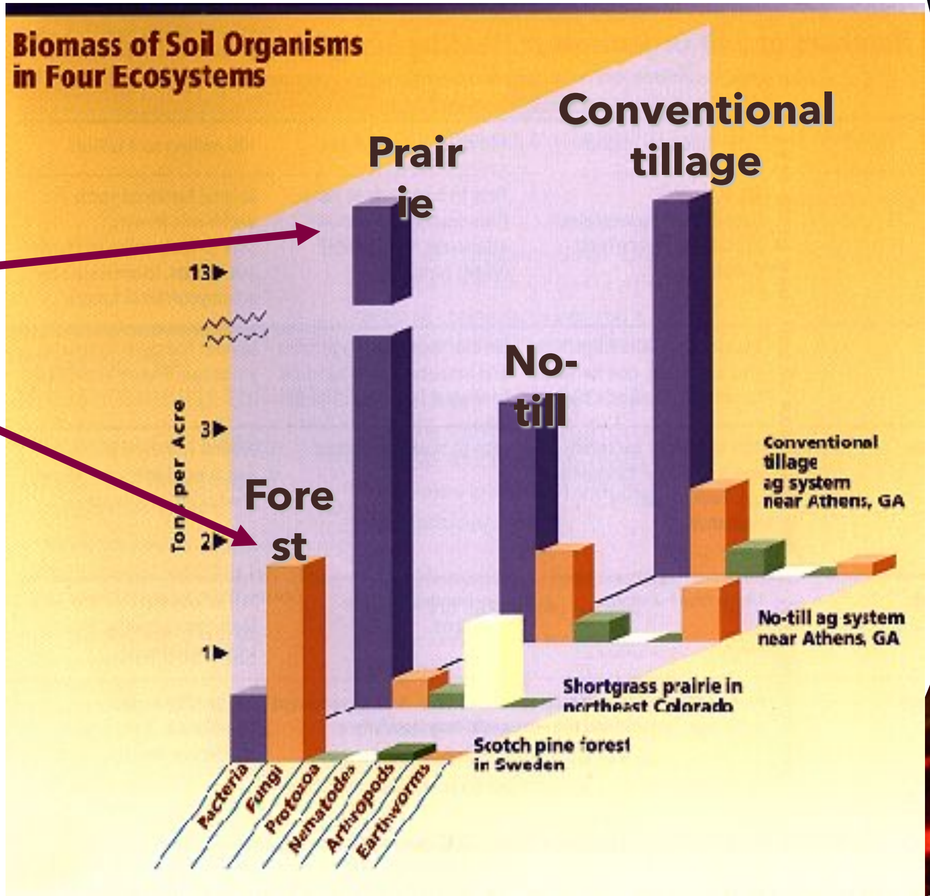
Bacteria

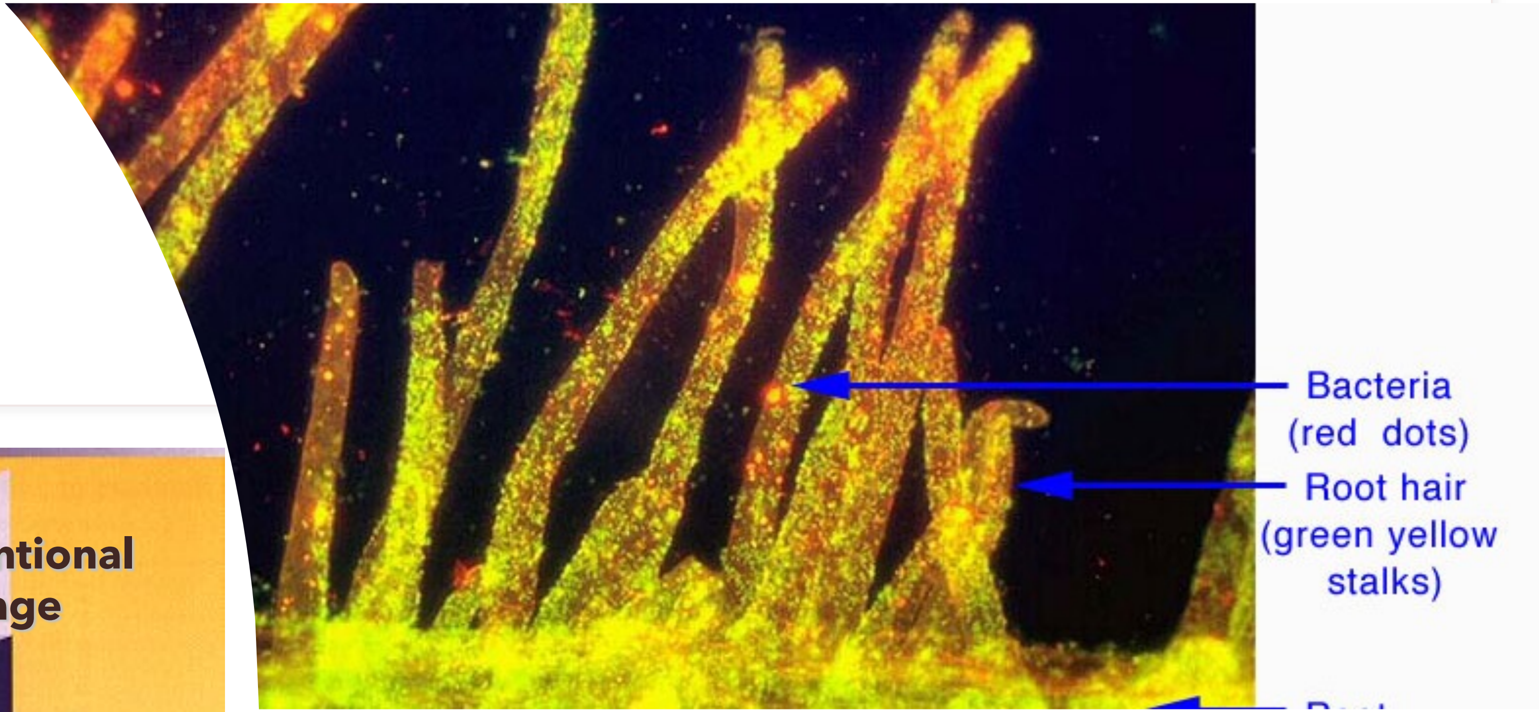
- **Bag of enzymes/ Fertilizer soluble bags**
- Description:
    - Single-celled, abundant, diverse
- Size: 0.001 mm
- Typical amount in aggregate soils: 100M to 1B in a tsp.
- **Action in Soil:**
    - Decompose OM
    - Immobilize nutrients in the rooting zone
    - Convert Ammonium to Nitrate, and Nitrate to Nitrogen gas
    - Nitrogen content-10-30%(3 to 10 C:N ration> other microbes)

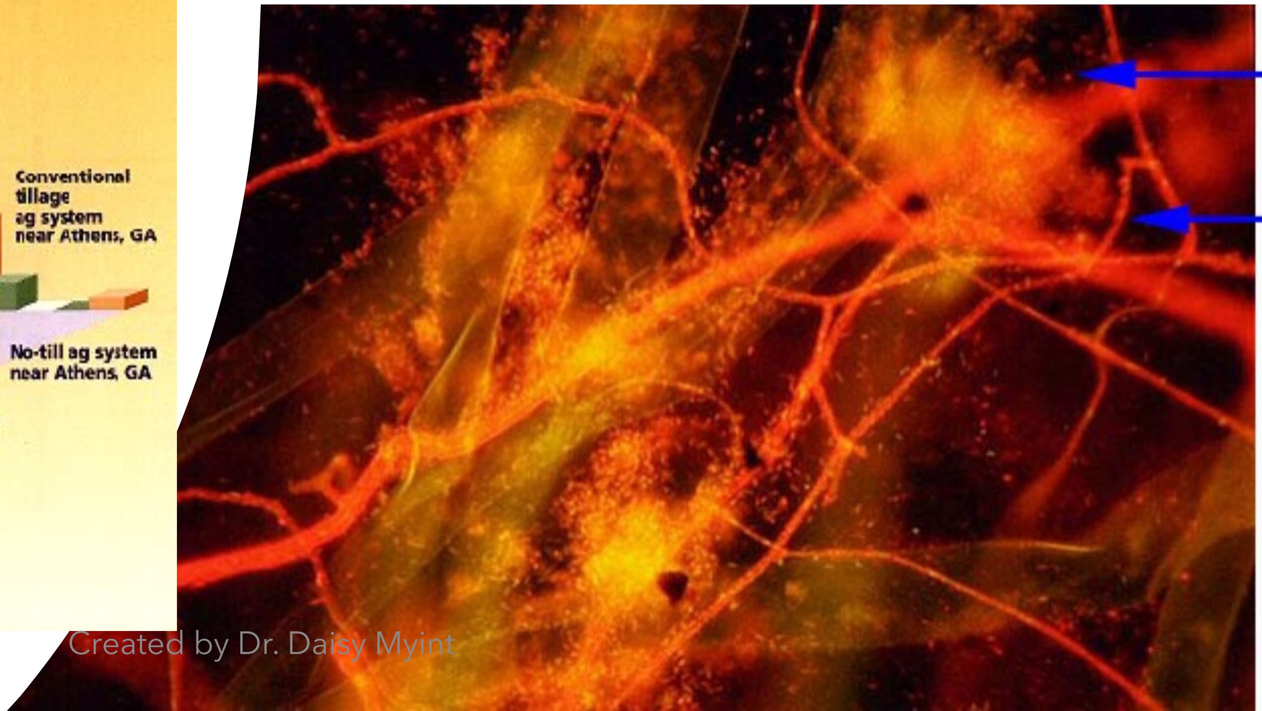
Bacteria

Bacteria

Fungi







Bacteria

Functional group

- Decomposers
- Mutualists
- Pathogens
- Lithotrophs

❖ **Nitrogen fixing bacteria**

❖ Azospirillum

❖ Azotobacter

❖ Actinomycetes

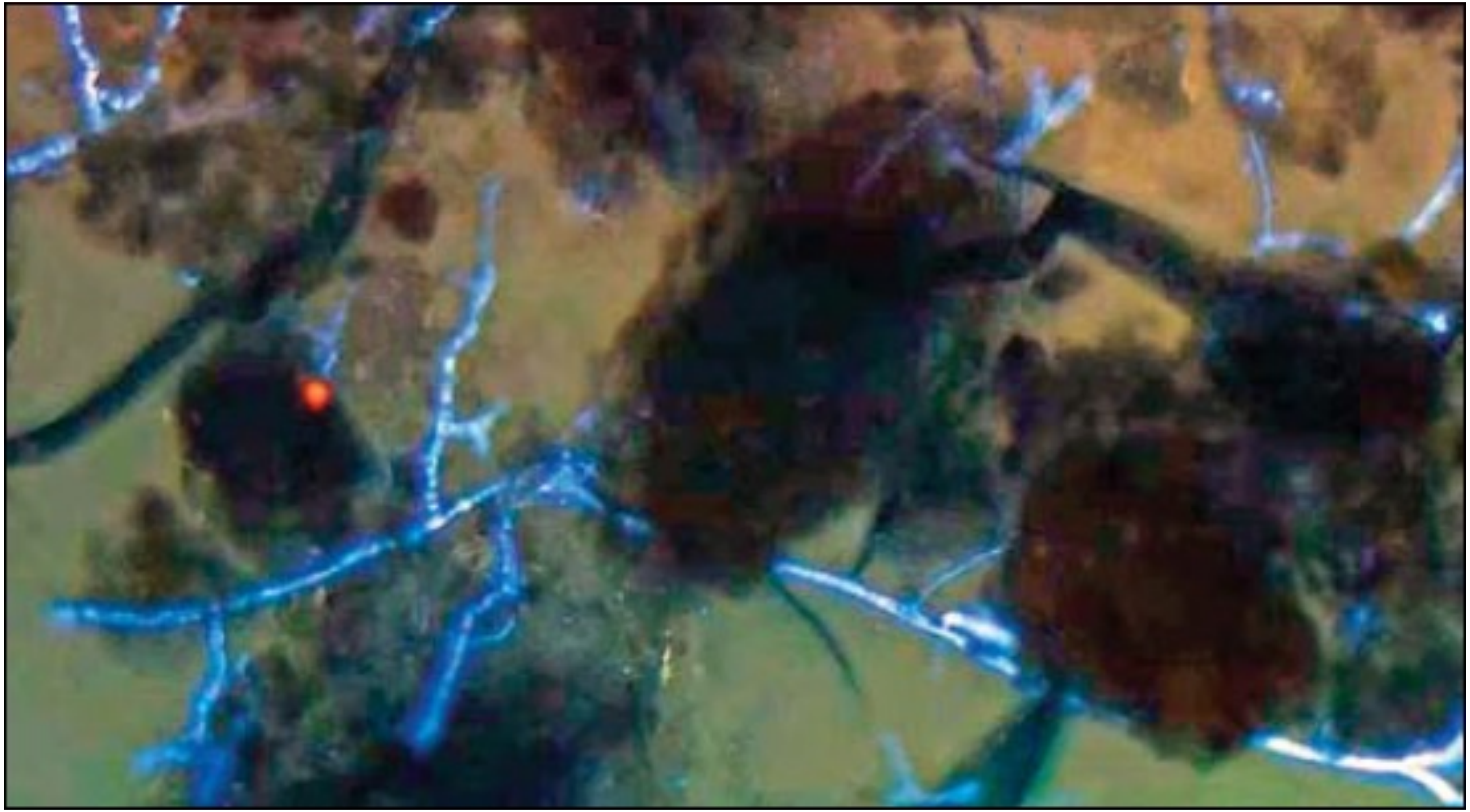
❖ Cyanobacteria

❖ **Rhizobacteria**

Fungi

- Description:
    - Grow in long filaments called hyphae
- Size: 5 μm in diameter
- Typical amount in aggregate soils: Several yards in a tsp.
- **Action in Soil:**
    - Decompose OM
    - Immobilize nutrients in the root zone
    - They release acids that help make Phosphorus more available to plants.

A mycorrhizal fungi growing into plant cells where it has formed tree-like structures (arbuscules) that allow phosphorus to be transferred from the fungi to the plant. (image: Lynette Abbott).



Fungal hyphae (shown in blue) extending through soil

Fungi

- Very productive inhabitants of soil due to their high plasticity and ability to adopt different forms in response to adverse or unfavorable
- Stabilization and decomposition of soil organic matter
- Transformation of dead organic matter into carbon dioxide, organic acids, and biomass.
- Biosorbent of toxic metals such as cadmium, copper, mercury, lead, and zinc, by collecting them in their fruiting bodies
- Fungi are more resistant than bacteria and actinomycetes for the fluctuating soil disruptions, or no soil disturbs
- Live in a wide range of pH and temperature
- Various biotic/abiotic factors regulate the diversity and activity of fungi

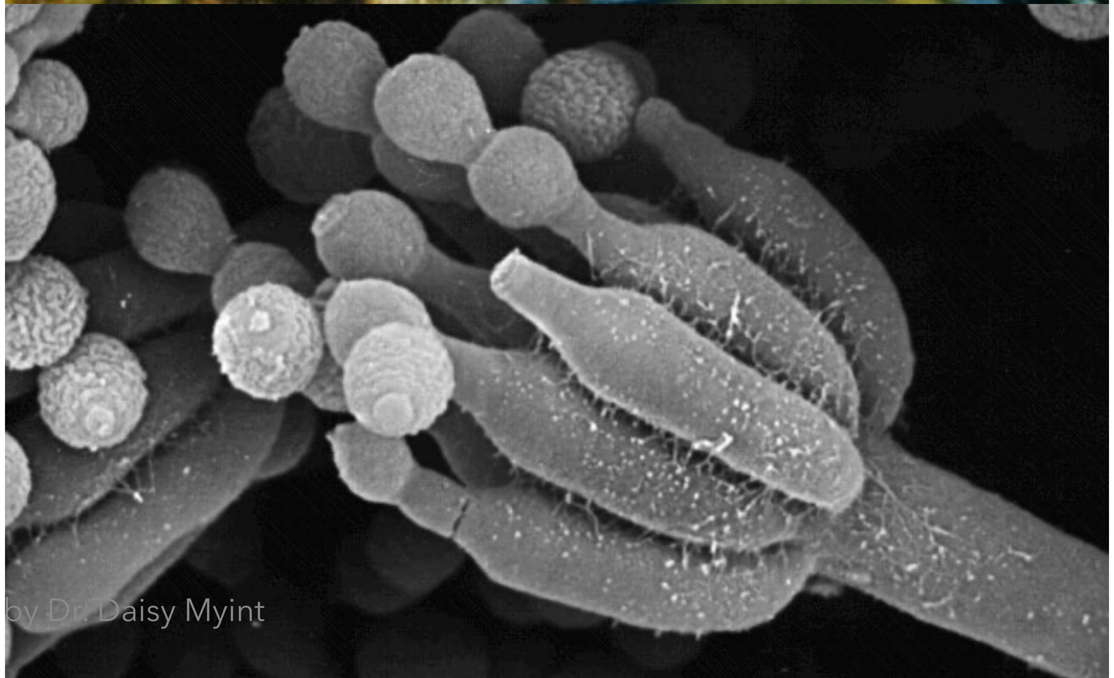
Fungi

- Filamentous growth
- Functionally critical!

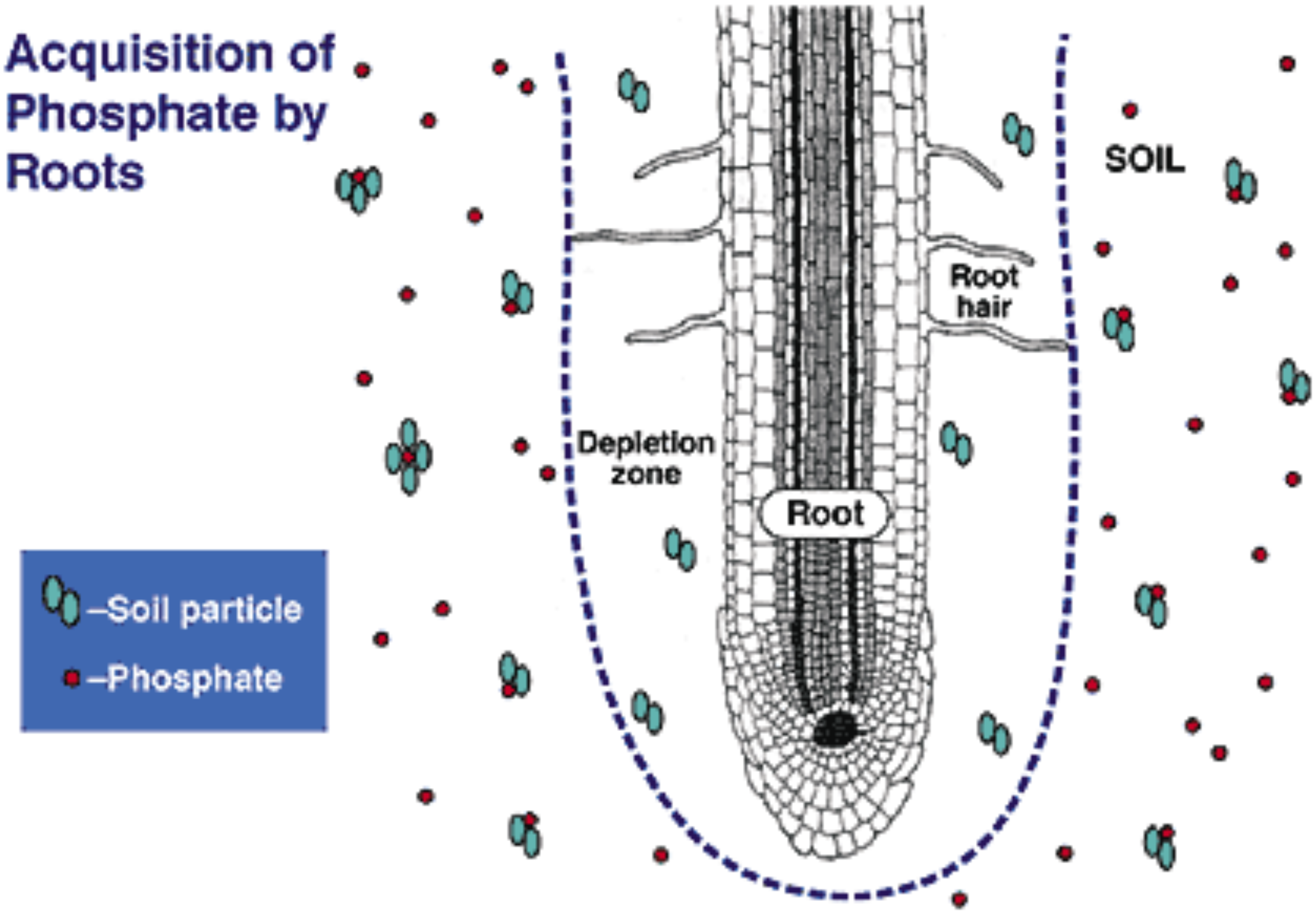
-Wood degrading
-Mycorrhizal association

- *myco* (fungus) + *rhiza* (root)

(Symbiotic structure formed by a fungus plus a plant)



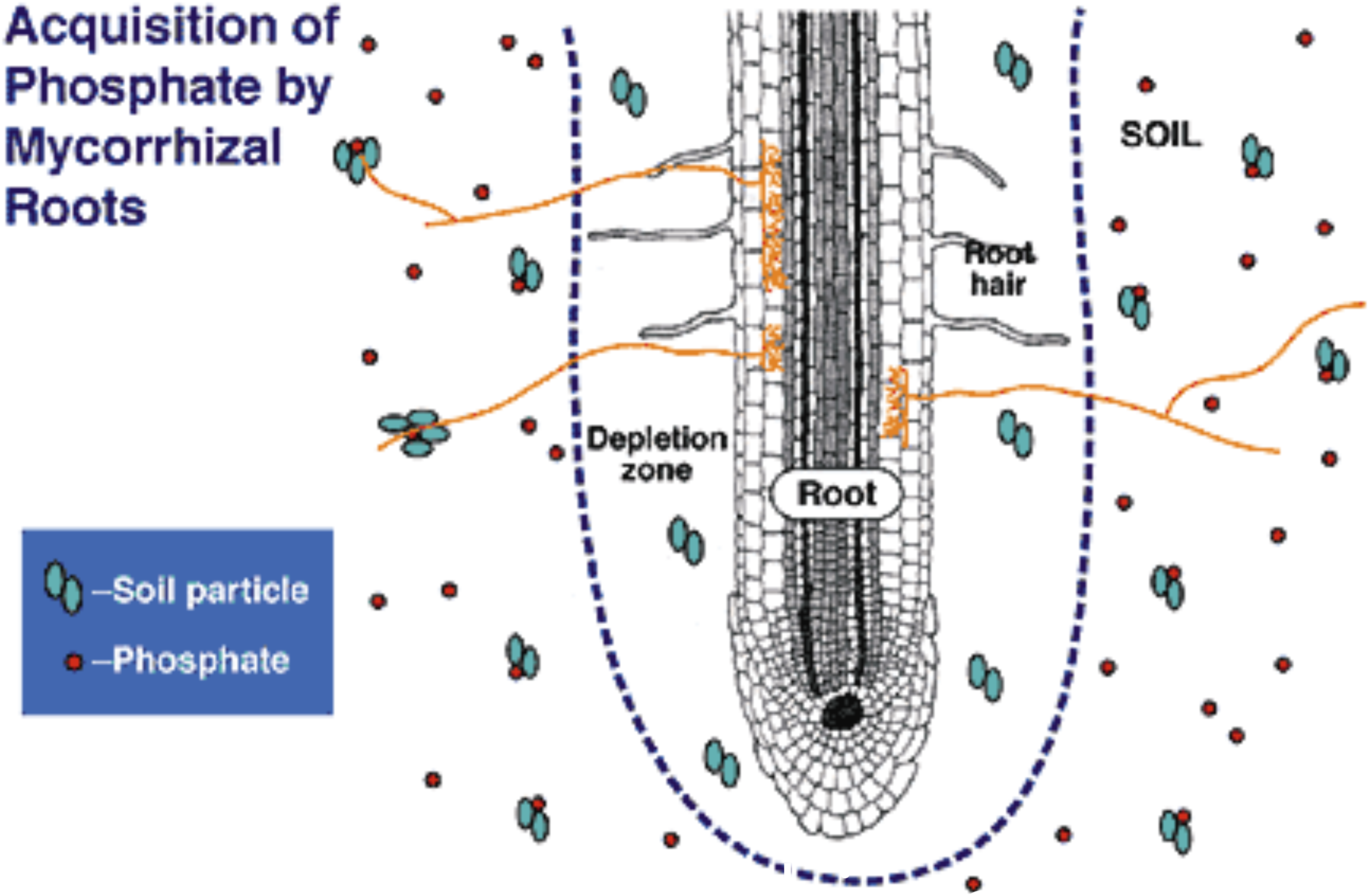
Acquisition of Phosphate by Roots



Created by Dr. Daisy Myint

Source: Harrison et al 1999

Acquisition of Phosphate by Mycorrhizal Roots



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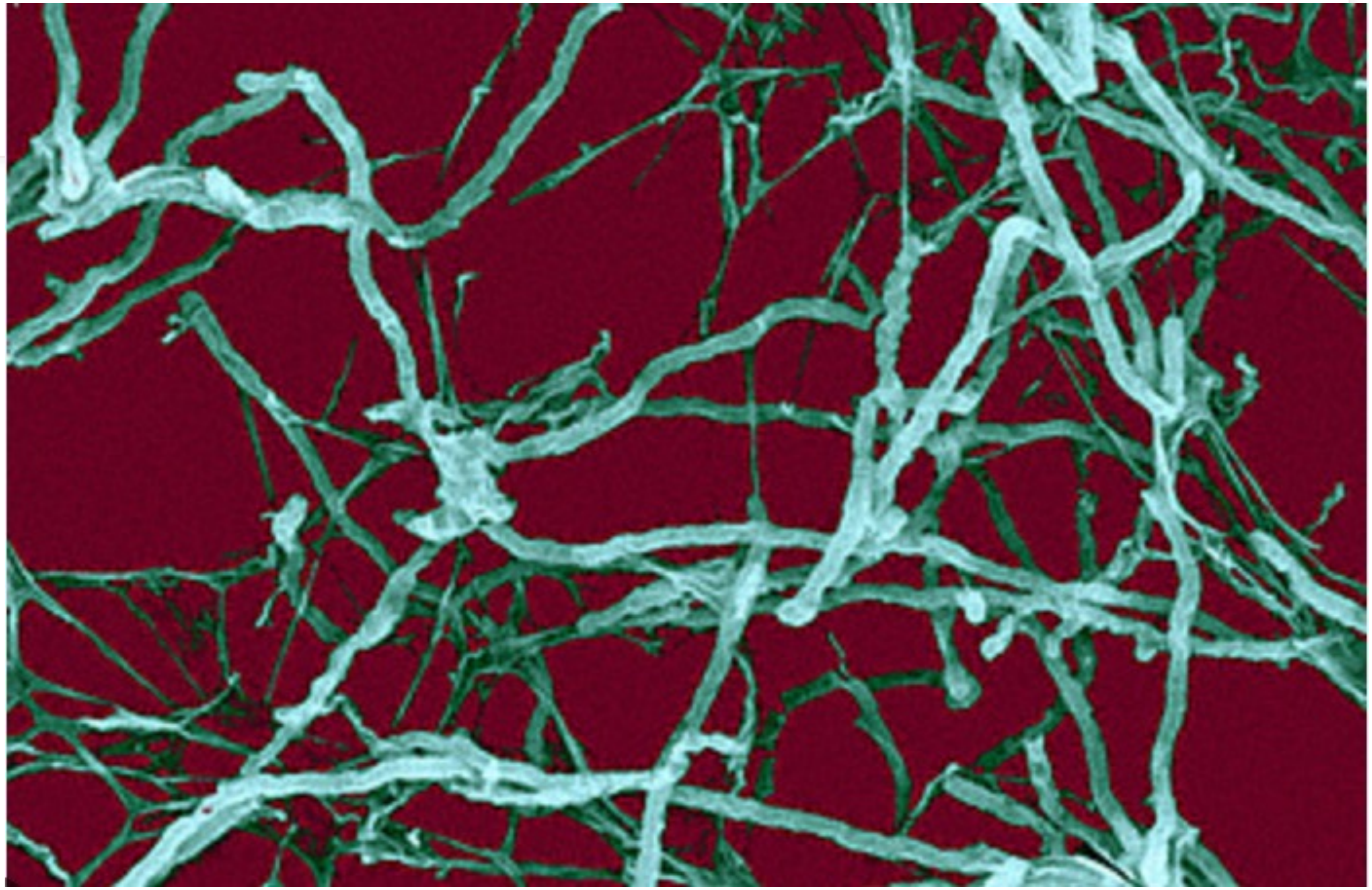
Source: Harrison et al 1999

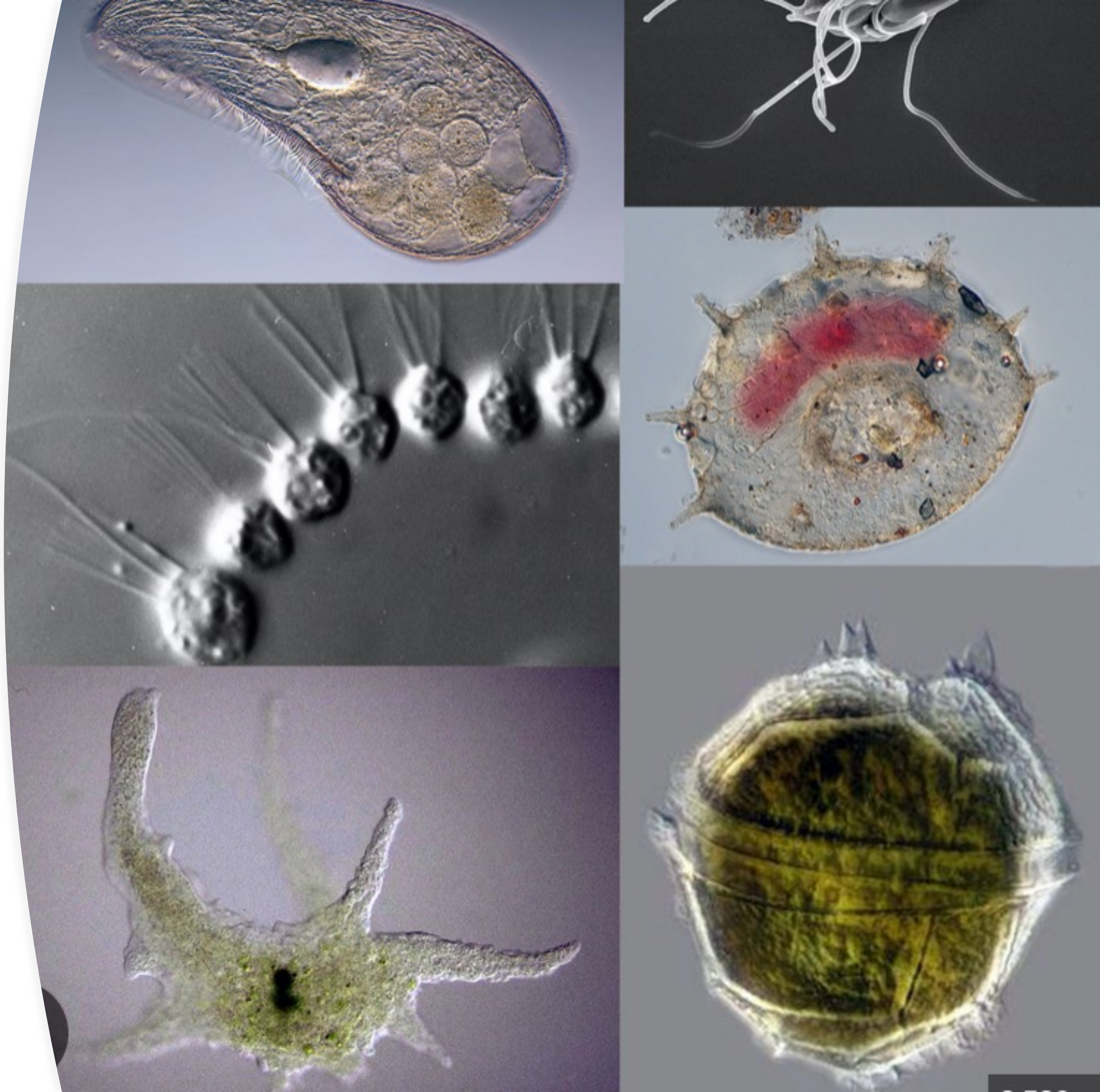
Actinomycetes

- Unicellular, aerobic organism
- Special class of bacteria, prokaryotic
- Look more like fungi
- Function similar to Bacteria, Fungi
- Produce compounds that give soil its distinctive aroma
- Give the earthy smell of fresh soil – geosmin (organic compound) produced by actinobacteria, dominant in alkaline (basic) soils
- Source of antibiotics



Protozoa

- Description:
    - One-celled organism
- Size: 5-500 μm
- Typical amount in aggregate soils: Several thousands in a tsp.
- **Action in soil:**
    - Stimulate and control growth of bacteria
    - Release Ammonium
    - Help accelerate decomposition when they graze on bacteria, fungi and plant residues



Nematodes

- Description:
  - Roundworms, Not segmented as earthworms
- Size: 50 µm wide, 1 mm long
- Typical amount in aggregate soils: ten to twenty in a tsp.
- **Action in soil:**
  - Control many disease-causing organisms
  - Used for the biological control of soil-inhabiting insect pests.

Algae

- Love moist habitat (flooded soils of swamps, rice fields)
- Both singe-celled and multicellular
- Capable of N fixation
- 2-50μm in size
- Grow near or on the surface to capture sunlight for energy

Arthropods

- Includes insects, mites, spiders, springtails, & millipedes
- Frequently seen on the soil surface are shredders.
- Size: Microscopic to inches
- Typical Amount in Aggregate Soil: Several hundred in a cubic foot
- **Action in Soil:**
  - Shred organic material
  - Stimulate microbial activity
  - Mineralize plant Nutrients
  - Control pests

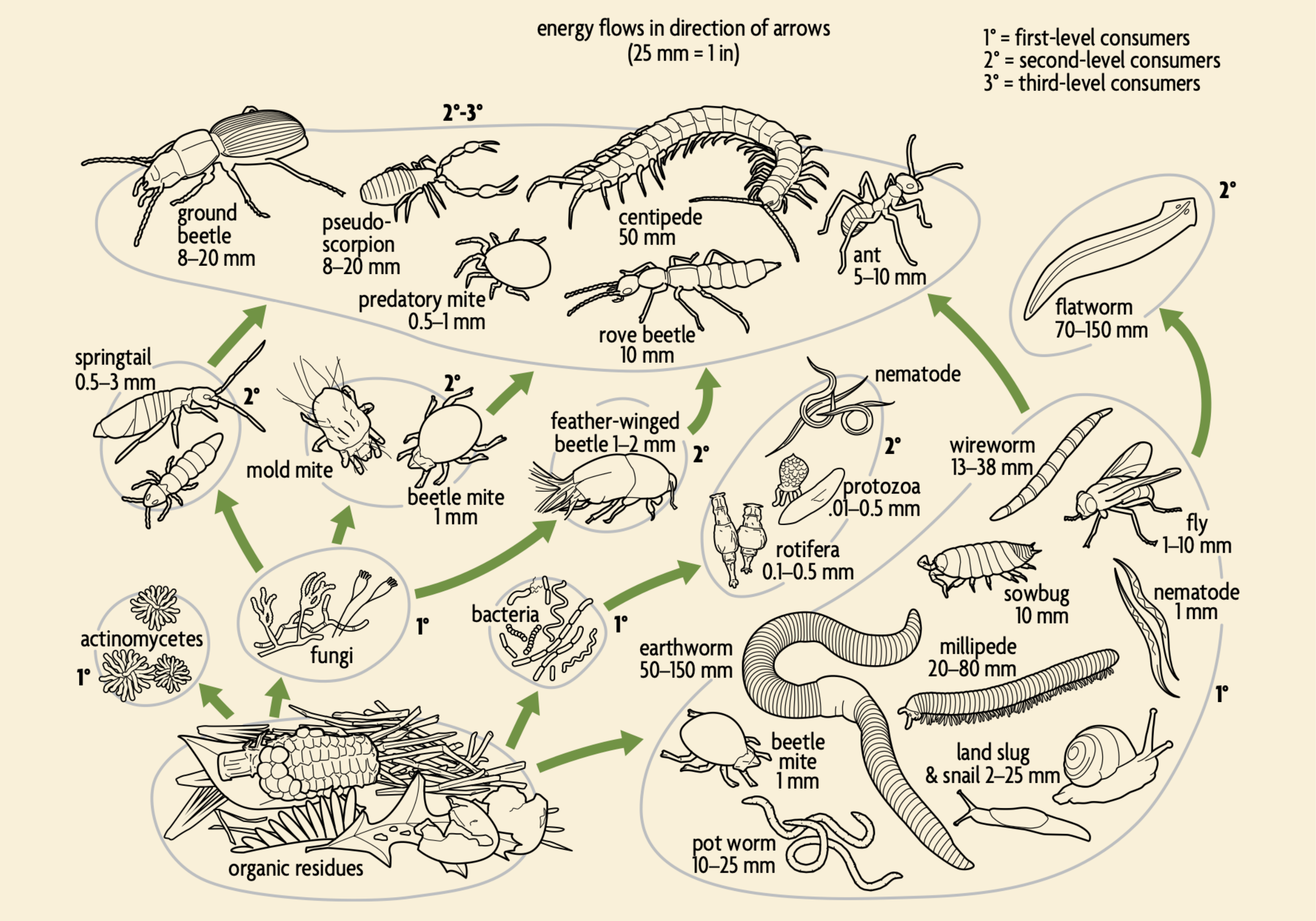
Earthworms

- Size: inch or more long
- Typical amount in aggregate soil: Five to thirty in a cubic foot
- **Action in Soil:**
    - Burrowing activity mixes and creates macropores that increase water infiltration and flow and help aerate soil.
    - Soil passage through the guts increases aggregation and nutrient cycling.

Earthworm

- The number of earthworms (zero to over 1 million per acre)
- Under conditions for earthworms prefer, 800,000 small channels per acre that conduct water into your soil during downpours.
- Moving soil from surface to down from about 1 to 100 tons per acre each year
- One acre of soil 6 inches deep weighs about 2 million pounds, or 1,000 tons.
- So 1 to 100 tons is the equivalent of about .006 of an inch to about half an inch of soil.
- A healthy earthworm population may function as nature's plow and help replace the need for tillage by making channels and by bringing up subsoil and mixing it with organic residues.

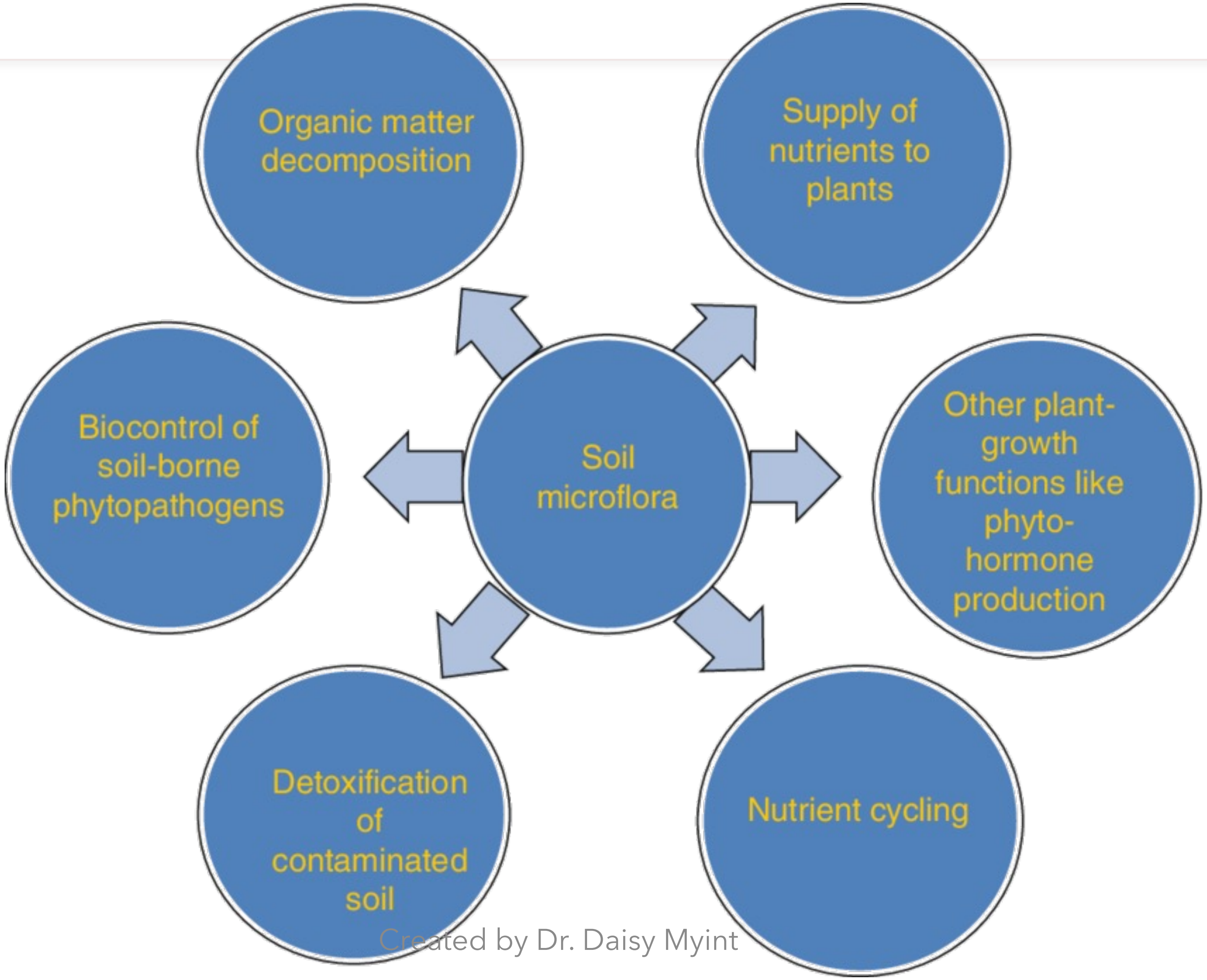
Relationship to soil quality?



The soil food web. Modified from D.L. Dindal (1972). Illustration by Vic Kulihin.

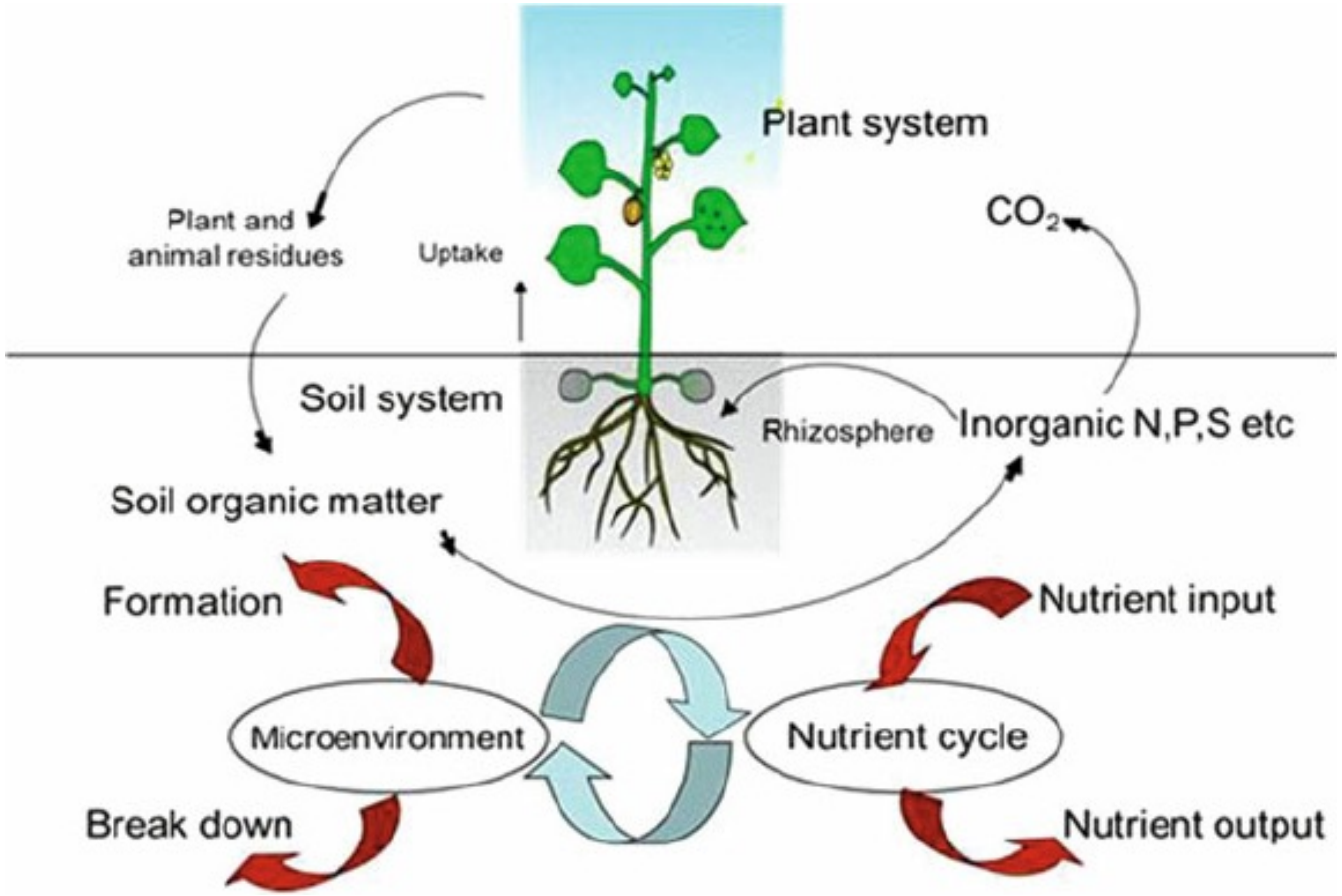
Importance of Soil microbiome for soil health

Function of Soil microbiome



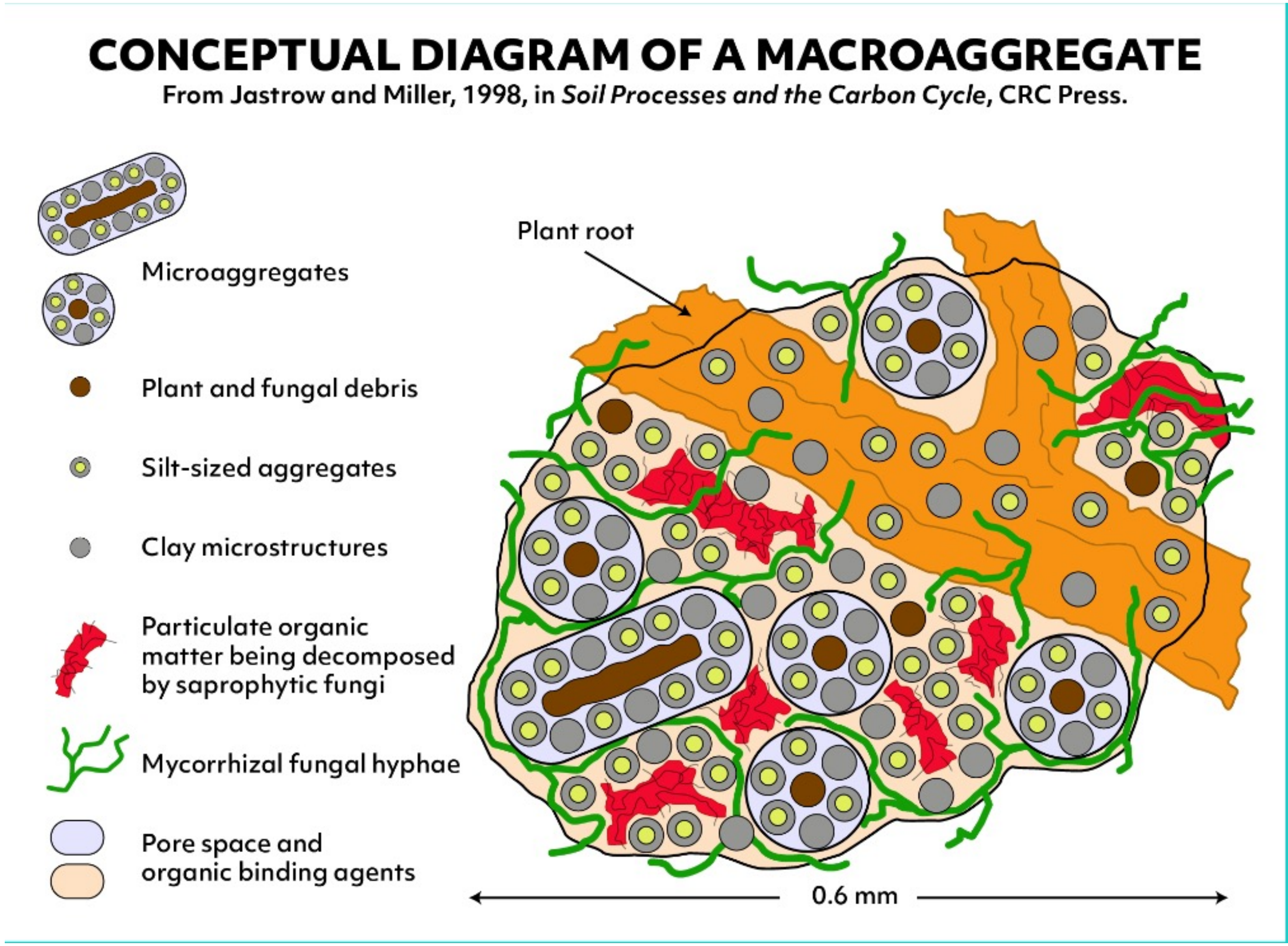
1.Nutrient Cycling

- Soil microbes are involved in the decomposition of organic matter, releasing nutrients like nitrogen, phosphorus, and sulfur in forms that plants can absorb.
- This process, known as mineralization, replenishes soil fertility, supporting plant growth and productivity.
- Microbes also facilitate nutrient transformations, such as nitrogen fixation and phosphorus solubilization, further enhancing nutrient availability in soil.



2. Soil Structure and Aggregation

- Fungi and bacteria, produce substances like glomalin and polysaccharides that promote soil aggregation.
- Soil aggregation improves soil structure, porosity, and water infiltration, preventing erosion and compaction.
- Healthy soil structure, facilitated by microbial activity, allows roots to penetrate easily and facilitates gas exchange and water retention.



3. Disease Suppression

- Soil microbes can suppress soil-borne plant pathogens through various mechanisms, including competition for resources, production of antimicrobial compounds, and induction of plant defense responses.
- Beneficial microbes help maintain a balance between pathogenic and non-pathogenic organisms, reducing the incidence and severity of plant diseases
- This natural disease suppression contributes to soil health and plant productivity.

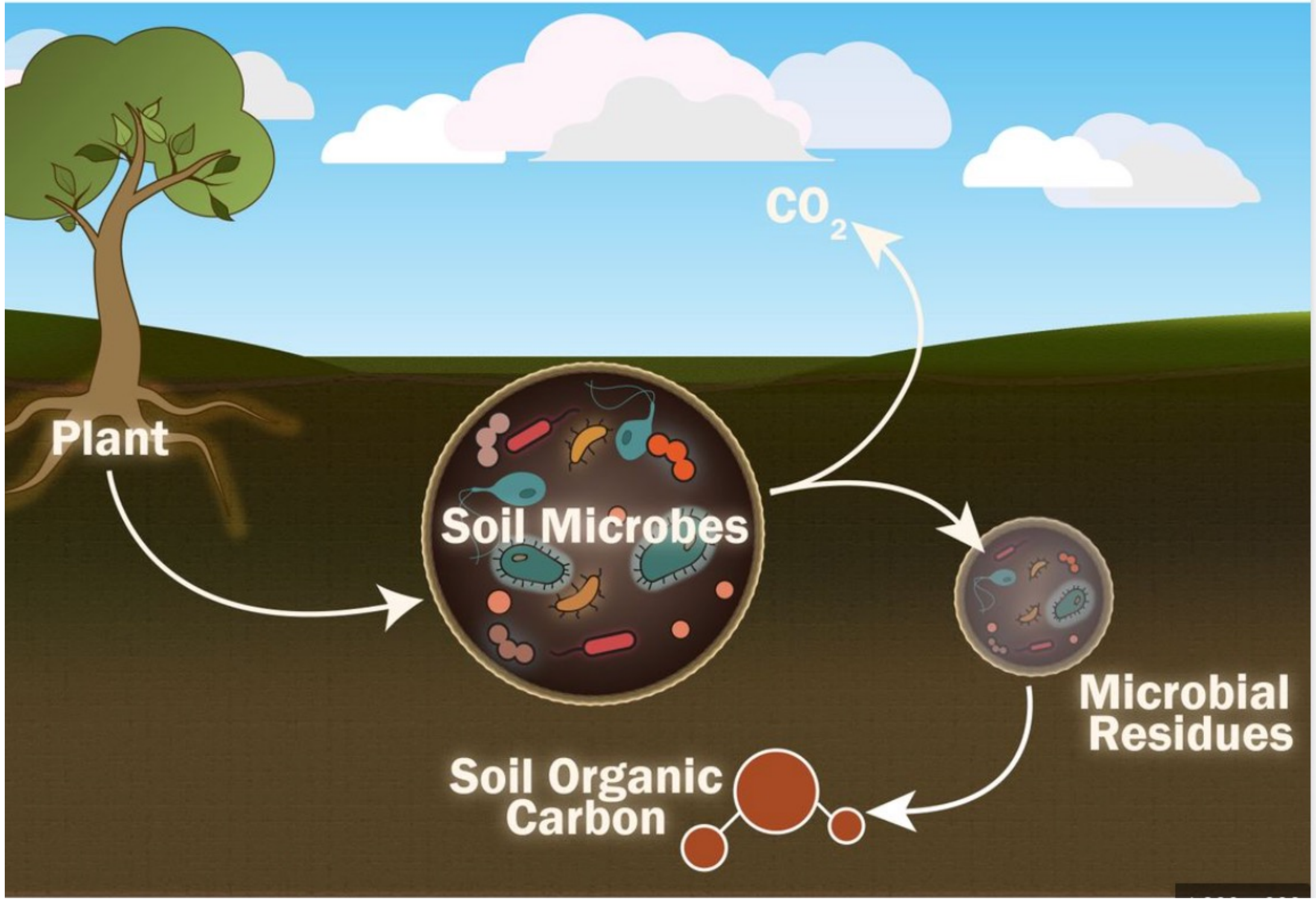
4. Stabilization of Soil pH

- Soil microbes influence soil pH through their metabolic activities, such as acid production or alkaline hydrolysis.
- Microbial processes help buffer changes in soil pH, maintaining a suitable environment for soil organisms and nutrient availability.
- Balanced soil pH is essential for optimal microbial activity, nutrient uptake by plants, and overall soil health.

5. Pollutant Degradation

- Certain soil microbes possess the ability to degrade or detoxify various pollutants, including pesticides, hydrocarbons, heavy metals, and organic contaminants.
- Microbial degradation processes help mitigate soil and water pollution, contributing to environmental remediation efforts and ecosystem health.
- Harnessing the pollutant-degrading capabilities of soil microbes can help restore contaminated soils and protect human and environmental health.

6.Carbon Sequestration



- Key players in the global carbon cycle, mediating the decomposition of organic matter and the stabilization of carbon in soil organic matter
- Microbial activities contribute to carbon sequestration, storing carbon in stable soil organic matter for extended periods.
- Increasing soil carbon stocks through microbial processes can help mitigate climate change by reducing atmospheric carbon dioxide levels.

Factors influencing on Soil microbiome

Created by Dr. Daisy Myint

Soil pH

- Soil pH significantly impacts microbial diversity.
- Different microorganisms thrive in different pH ranges.
- For instance, acidophilic bacteria thrive in acidic soils, while alkaliphilic bacteria prefer alkaline conditions.
- pH affects nutrient availability and can directly impact microbial metabolic activities.

Soil Moisture:

- The moisture content of soil influences microbial diversity.
- Microorganisms require water for their metabolic processes.
- Extreme moisture conditions can lead to anaerobic conditions, favoring certain types of microorganisms, while drought can limit microbial activity.

Soil Texture

- Soil texture, determined by the proportion of sand, silt, and clay, affects microbial diversity.
- Soil with high clay content tends to retain more water and nutrients, creating distinct microbial habitats compared to sandy soils.
- The pore size and structure of soil particles also influence microbial colonization and activity.

Organic Matter Content

- Soil organic matter serves as a substrate for microbial growth and activity.
- High organic matter content supports greater microbial diversity by providing a diverse array of carbon sources.
- Decomposition rates, influenced by organic matter content, impact microbial community dynamics.

Nutrient Availability:

- Availability of essential nutrients such as nitrogen, phosphorus, and sulfur influences microbial diversity.
- Nutrient limitation can constrain microbial growth and diversity, while excess nutrients can lead to shifts in microbial community composition.

Climate and Temperature

- Climatic factors such as temperature and precipitation patterns affect soil microbial diversity.
- Microbial communities vary with climate zones, and temperature directly influences microbial metabolic rates.
- Seasonal changes can also impact microbial diversity and activity.

Land Use and Management Practices

- Agricultural practices, land use history, and management techniques significantly impact soil microbial diversity.
- For example, tillage practices can disrupt soil structure and microbial habitats, while organic farming methods can promote microbial diversity compared to conventional practices.

Presence of Contaminants

- Pollution and contaminants, such as heavy metals, pesticides, and pollutants from industrial activities, can influence soil microbial diversity.
- Some microorganisms can degrade pollutants, while others may be sensitive to them, leading to shifts in microbial community structure.

Plant Diversity and Root Exudates

- Plant roots release exudates that serve as energy sources for soil microorganisms.
- Different plant species release different types and quantities of exudates, shaping microbial communities in the rhizosphere—the soil region influenced by root activity.
- High plant diversity can support greater microbial diversity due to a wider range of exudates.

Disturbances and Succession

- Natural disturbances like fires, floods, and human activities like land clearing can disrupt soil ecosystems and microbial communities.
- Successional processes following disturbances can lead to changes in microbial diversity as soil ecosystems recover and stabilize.

Strategies for enhancing soil microbiome

Created by Dr. Daisy Myint

1. Reduced Tillage and Minimal Disturbance:

- Reduced tillage and minimal soil disturbance practices help preserve the natural structure and microbial communities in soil.
- By minimizing disruption to soil aggregates and microbial habitats, these practices promote the diversity and activity of soil microbes.
- For example, no-till or conservation tillage systems in agriculture reduce soil erosion, preserve soil organic matter, and enhance microbial biodiversity compared to intensive tillage.

Diversity may be important in response to management

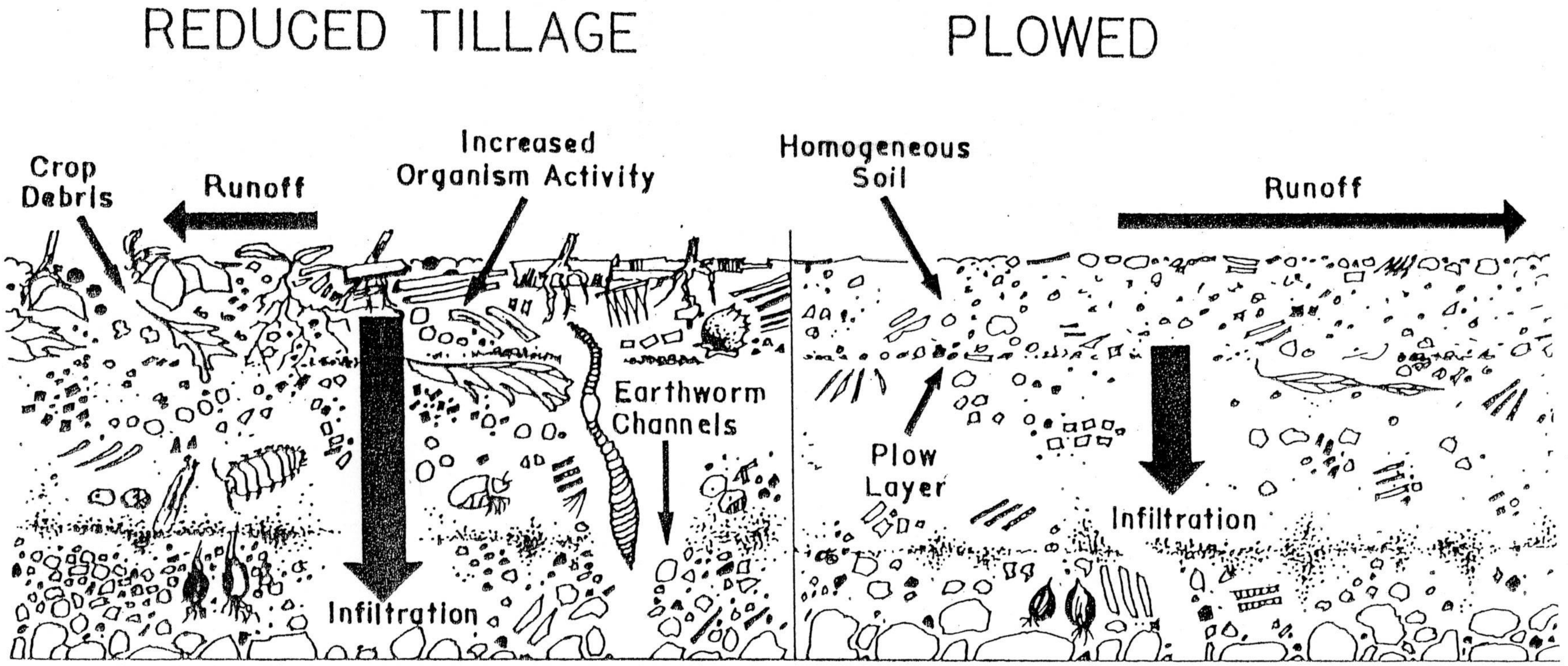


Fig. A comparison of biological, physical, and chemical properties of minimum tillage and plowed soils (from Stinner and Stinner 1989)

2. Cover Cropping and Crop Rotation

- **Cover cropping and crop rotation** provides a variety of carbon sources and habitats for soil microbes.
- Cover crops, such as legumes, grasses, and brassicas, can enrich the soil with organic matter and stimulate microbial activity.
- Crop rotation helps break pest and disease cycles while promoting beneficial microbial communities.
- For instance, planting leguminous cover crops like clover can enhance nitrogen-fixing bacterial populations in soil.

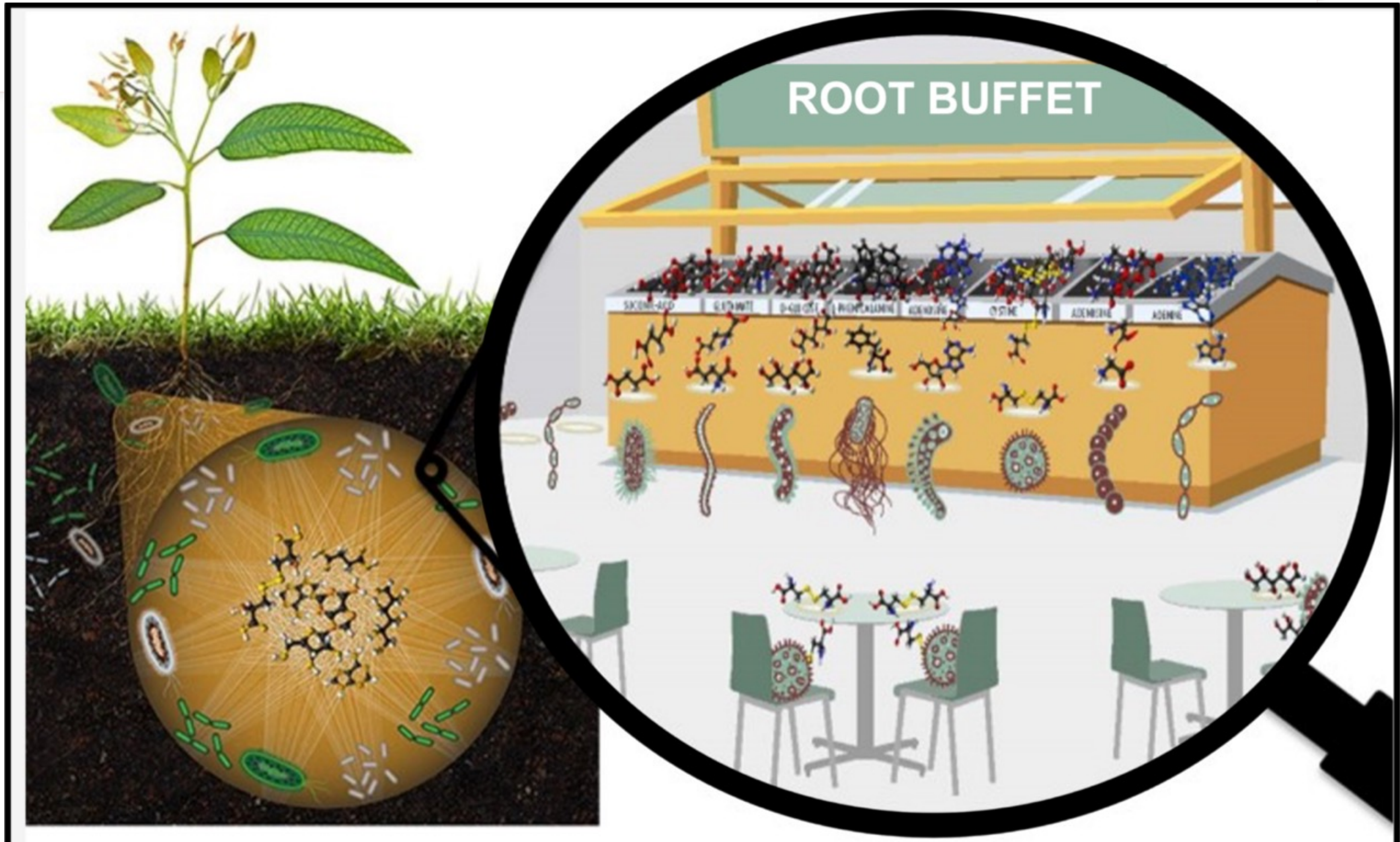
Root exudates(Rhizodeposits)

- Amino acids
- Enzymes
- Inorganic ions and gaseous molecules
- Organic acids
- Purine/nucleosides
- Sugars
- Vitamins

Depends on pH, soil type, oxygen status, light intensity, soil temperature, nutrient accessibility and the presence microorganism. plant species

Cover cropping

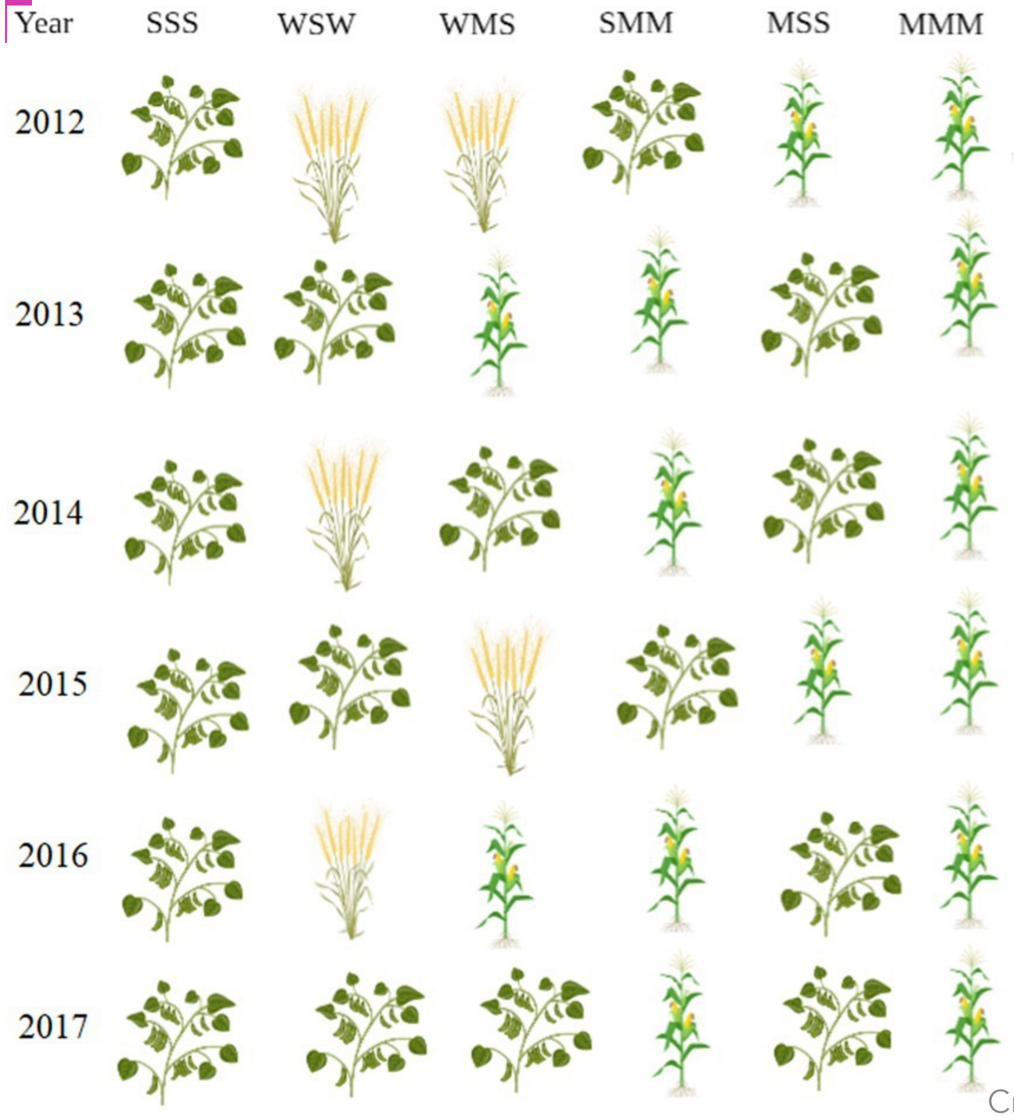
- Root exudates attract rhizosphere microbes
- Plant litter affects decomposer community
- Plant cover affects soil moisture

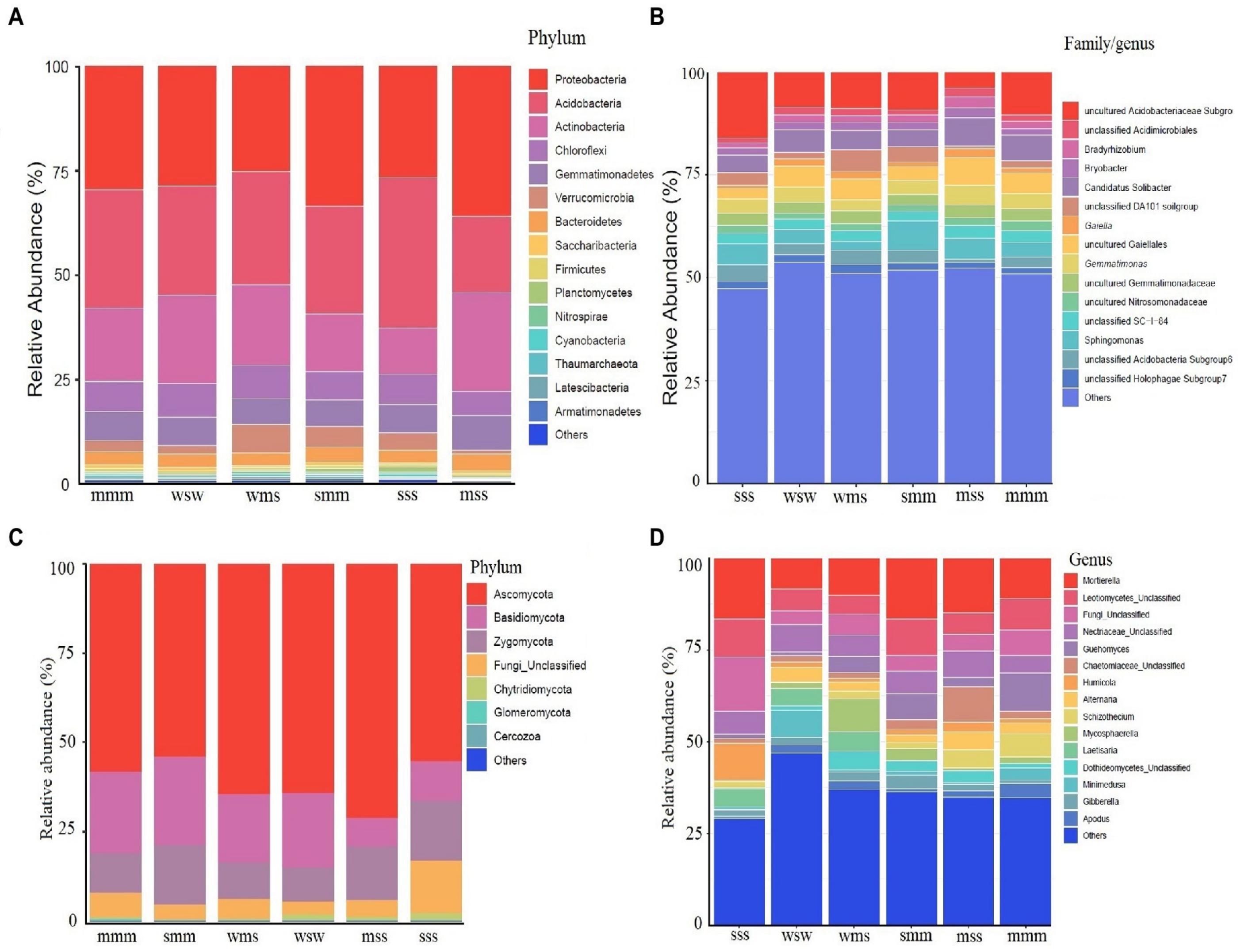


Trent Northen Lab

Crop Rotation

https://doi.org/10.3389/fmicb.2023.1095688





3. Organic Matter Addition

- Adding organic amendments, such as compost, manure, and crop residues, to soil can enrich the soil microbiome with diverse carbon sources and nutrients.
- Organic matter serves as a substrate for microbial growth and activity, promoting the decomposition of organic materials and nutrient cycling in soil.
- For example, incorporating composted organic materials into agricultural soils can increase microbial biomass, improve soil structure, and enhance nutrient availability for plants.

4. Biological Amendments (Biostimulants)

- Application of microbial inoculants, such as beneficial bacteria, fungi, and other microbial consortia, can introduce beneficial microorganisms into soil to enhance specific soil functions.
- For example, inoculating soil with mycorrhizal fungi can improve nutrient uptake by plants, while introducing nitrogen-fixing bacteria can enhance soil fertility.
- Biological amendments can be applied in agricultural, horticultural, and restoration contexts to promote soil health and ecosystem resilience.

ဇီဝလှုံ့ဆော်ပစ္စည်း (Biostimulants)

- Biostimulants are a diverse group of materials that are used to improve crop vigor, quality, and yield, as well as tolerance to abiotic stresses (drought, salinity, heat, etc.). [သီးနှံကျန်းမာရေး၊ အရည်အသွေး၊ အထွက်နှုန်းကို ပိုမိုကောင်းမွန်စေပြီး ရေငတ်ဒဏ်၊ ဆားငံဒဏ်၊ အပူဒဏ် အစရှိသည့် အဇီဝဖိအားများကို ခံနိုင်ရည်ရှိစေရန် အသုံးပြုသည့်ပစ္စည်း]
- Biostimulants can work in many different ways, including: 1) facilitating nutrient uptake, 2) enhancing the development of soil microorganisms, and 3) stimulating root growth to increase water use efficiency.[အာဟာရဓာတ်စုပ်ယူ၊ အဏုဇီဝသက်ရှိများ ကြီးထွားဖွံ့ဖြိုးစေ၊ ရေစုပ်ယူမှု ကောင်းစေရန် အမြစ်ကြီးထွားမှုကို လှုံ့ဆော်ပေး]

Biostimulants အမျိုးအစားခွဲခြားခြင်း

- mode of action and the origin of the active ingredient (ဝင်ရောက်သည့်လမ်းကြောင်း၊ မူလပါဝင်ပစ္စည်း)
- based on their action in the plants or, on the physiological plant responses rather than on their composition (အပင်အပေါ်အကျိုးသက်ရောက်မှု)
- final impact on plant productivity which suggests that any definition of biostimulants should focus on the agricultural functions of biostimulants, either on the nature of their constituents or on their modes of actions. (သီးနှံအထွက်နှုန်းပေါ်သက်ရောက်မှု)

Biostimulants အမျိုးအစား

- **Microbial inoculants (Biofertilizer)**
  - Free-living fungi
  - Arbuscular mycorrhizal fungi (AMF)
  - Free-living bacteria
- Protein hydrolysates and amino acids
- Humic Substances
  - Humic acids
  - Fulvic acids
- Seaweed extracts

5. Reduced Chemical Inputs

- Minimizing the use of synthetic fertilizers, pesticides, and herbicides can help preserve soil microbial communities and reduce their negative impacts on soil health.
- Excessive use of chemical inputs can disrupt microbial activity, reduce biodiversity, and lead to soil degradation.
- **Integrated pest management (IPM) strategies**, such as biological control and crop diversification, can help reduce reliance on chemical inputs while maintaining soil health and productivity.

6. Soil pH Management

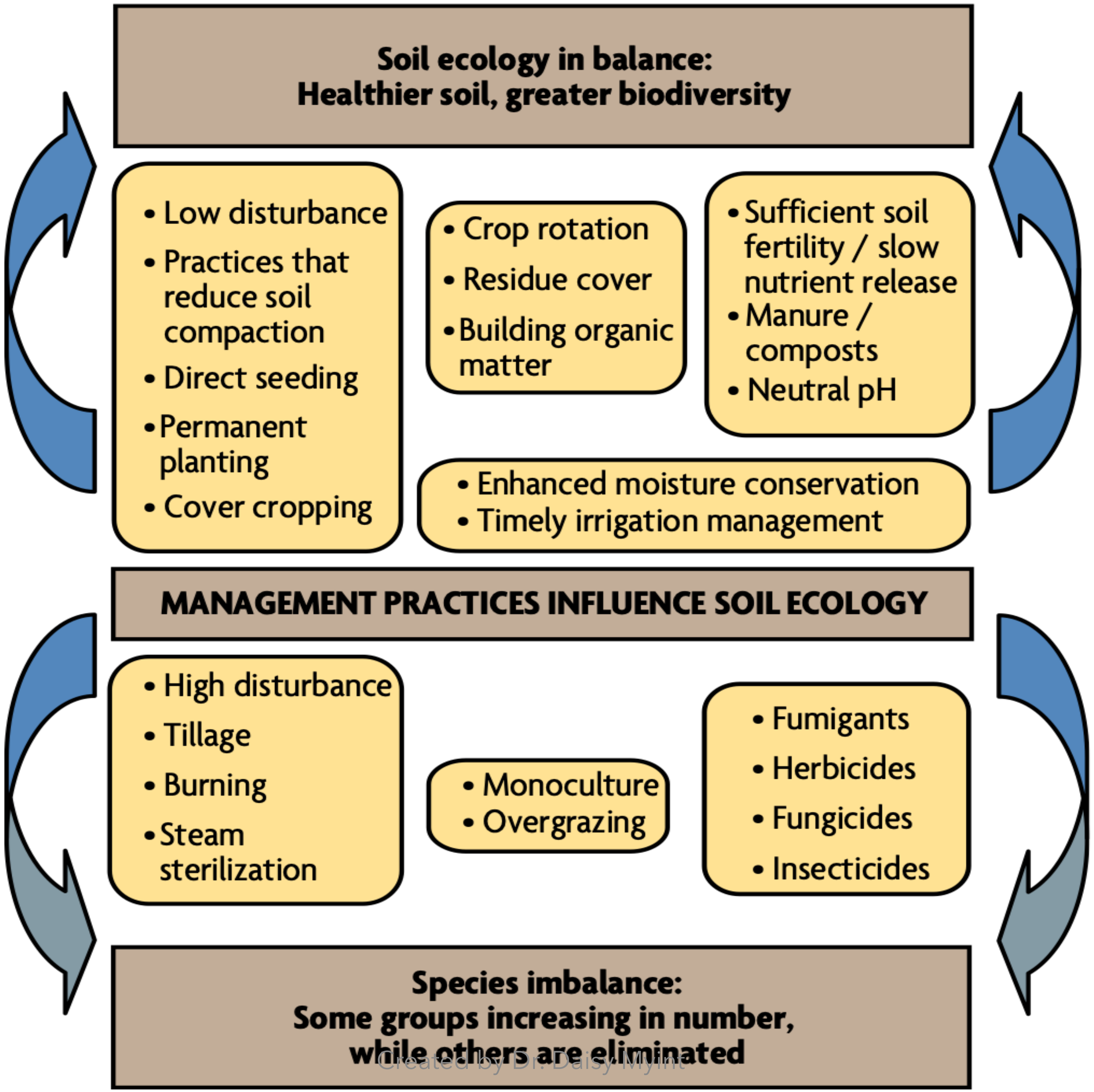
- Managing soil pH within optimal ranges for microbial activity is important for maintaining a healthy soil microbiome.
- Acidic or alkaline soil conditions can limit microbial diversity and activity.
- Lime application can help neutralize acidic soils, while sulfur amendments can lower soil pH if it is too alkaline.
- By optimizing soil pH, microbial processes such as nutrient cycling, decomposition, and biological nitrogen fixation can be enhanced.

7. Water Management

- Proper water management practices, such as irrigation scheduling, drainage improvement, and water conservation, can support a healthy soil microbiome.
- Soil moisture influences microbial activity, with both waterlogging and drought conditions negatively impacting microbial diversity and function.
- Implementing water-efficient irrigation techniques and optimizing drainage systems can help maintain suitable soil moisture levels for microbial activity.

8.Promotion of Soil Biodiversity

- Enhancing overall soil biodiversity, including microbial, plant, and animal diversity, contributes to soil health and ecosystem resilience.
- Protecting natural habitats, preserving native vegetation, and restoring degraded ecosystems can support diverse soil microbial communities.
- Additionally, creating habitat structures such as hedgerows, windbreaks, and riparian buffers can provide refuge and resources for soil organisms, enhancing soil biodiversity and ecosystem services.


Soil ecology in balance:
Healthier soil, greater biodiversity
• Low disturbance
• Practices that reduce soil compaction
• Direct seeding
• Permanent planting
• Cover cropping
• Crop rotation
• Residue cover
• Building organic matter
• Sufficient soil fertility / slow nutrient release
• Manure / composts
• Neutral pH
• Enhanced moisture conservation
• Timely irrigation management
MANAGEMENT PRACTICES INFLUENCE SOIL ECOLOGY
• High disturbance
• Tillage
• Burning
• Steam sterilization
• Monoculture
• Overgrazing
• Fumigants
• Herbicides
• Fungicides
• Insecticides
Species imbalance:
Some groups increasing in number,
while others are eliminated

ရိုင်ဇိုဘီယမ် (Rhizobium) ပြုလုပ်သုံးစွဲခြင်း

ရိုင်ဇိုဘီယမ် (Rhizobium)

- ပဲမျိုးစုံ၊ဆီထွက်သီးနှံ နှင့် အခြားပဲမျိုးနွယ်ဝင်အပင်များအတွက်မရှိမဖြစ်လိုအပ်
- နိုက်ထရိုဂျင်လိုအပ်ချက် ၈၀-၉၀% biological nitrogen fixation (BNF) ကနေရရှိ
- လေထဲမှ နိုက်ထရိုဂျင် ၅၀–၆၀ kg per ha in groundnut, ၁၀၀–၃၀၀ kg per ha in alfalfa, 50–110 kg/per ha in pulses ဖမ်းပေးနိုင်သည်။
- *Rhizobium* inoculation လုပ်ခြင်းအားဖြင့် အထွက်နှုန်း ၁၄-၅၃ % တိုးစေ
- မြေဆီဩဇာကို ထက်သန်စေပြီး နောက်သီးနှံအတွက် Nitrogen လိုအပ်ချက်ကိုလည်း လျော့ချပေးနိုင်

ရိုင်ဇိုဘီယမ် (**Rhizobium**) အမျိုးအစား

- *Rhizobium leguminosarum* with three var. *viz. trifolii, phaseoli* and *viceae*.
- *Rhizobium loti*
- *Rhizobium meliloti*

  The new genus *Bradirhizobium japonicum*

ရိုင်ဇိုဘီယမ်

- သက်တမ်းအလွန်တို
- သာမန်ပတ်ဝန်းကျင်အခြေအနေတွင် သက်တမ်း(၆) လခန့် နေနိုင်
- မွေးမြူထားသော ဘက်တီးရီးယားများ အလတ်ဆတ်ဆုံးအချိန်တွင် ပဲပင်အတွင်း ဝင်ရောက်ရန် အစွမ်းထက်ဆုံးဖြစ်သည်။
- ပထမတစ်လ သက်တမ်းတွင် ပဲပင်များအတွင်း ဝင်ရောက်အား အကောင်း ဆုံးဖြစ်
- နောက်ပိုင်းကာလတွင် အချိန်ကြာလာသည်နှင့်အမျှအားလျော့သွား
- အခြားဘက်တီးရီးယားများကဲ့သို့ spore formation မဟုတ်ခြင်းကြောင့် သက်တမ်း မရှည်ပေ
- Rhizobium မျိုးစိတ် သည် ပဲမျိုးအလိုက်ကွားခြားသည်
- ပဲတစ်မျိုးမှ ဘက်တီးရီးယားသည် အခြားပဲမျိုးသို့ တခါတရံ ဝင်ရောက်နိုင် သော် လည်း သီးသန့်လက်ခံပင်ရှိသည်။

S. No.	Crop	Fertilizer nitrogen equivalents (Kg N per ha)	
		Nitrogen fixed (kg N/ha/year)	Residual effect in succeeding crop
1.	Alfalfa (*Medicago sativa)*	100–300	
2.	Clover (*Trifolium spp*.)	100–150	83
3.	Chickpea (*Cicer arietinum*)	26–63	60–70
4.	Cowpea	53–85	60
5.	Green pea	50–55	30
6.	Groundnut	112–152	60
7.	Guar	37–196	
8.	Lentil (*Lens culinaris*)	35–100	18–30
9.	Pea (*Pisum sativum*)	46	20–32
10.	Pigeon pea	68–200	20–49
11.	Soybean	49–130	

ဘက်တီးရီးယားကို မွေးမြူပြီး လက်ခံပင်သို့ ထည့်သွင်းရာတွင် သတိပြုရမည့်အချက်များ

- မြေဆီလွှာတွင် နိုက်ထရိုဂျင်ဓာတ် ပါသောမြေဩဇာ များများမသုံးသင့်
- အစိုဓာတ်လုံလောက်စွာရှိရမည်
- အပူအအေးမလွန်ကဲရ
- Heavy metals များမရှိစေရ
- မှိုသတ်ဆေး၊ ဘက်တီးရီးယားသတ်ဆေး၊ ပိုးသတ်ဆေးများ သုံးစွဲထားသည့်အခြေအနေမဖြစ်ရ
- ထုံးများထည့်သွင်းထားခြင်းမရှိရ
- အလင်းရောင်တိုက်ရိုက်မကျရ။ နေရောင်ခြည်(၃) နာရီတိုက်ရိုက်ကျရောက်ပါက ထိုမြစ်ဖုပြုလုပ်ရန် အသုံးမပြုနိုင်ပေ
- ဘက်တီးရီးယားများအတွက် စားသုံးရန် ကာဗွန်အလုံအလောက်ရှိရမည်၊ လိုအပ်ပါက ကြိုတင်ထည့်ထားရမည်
- Survival, Growth and Effectiveness

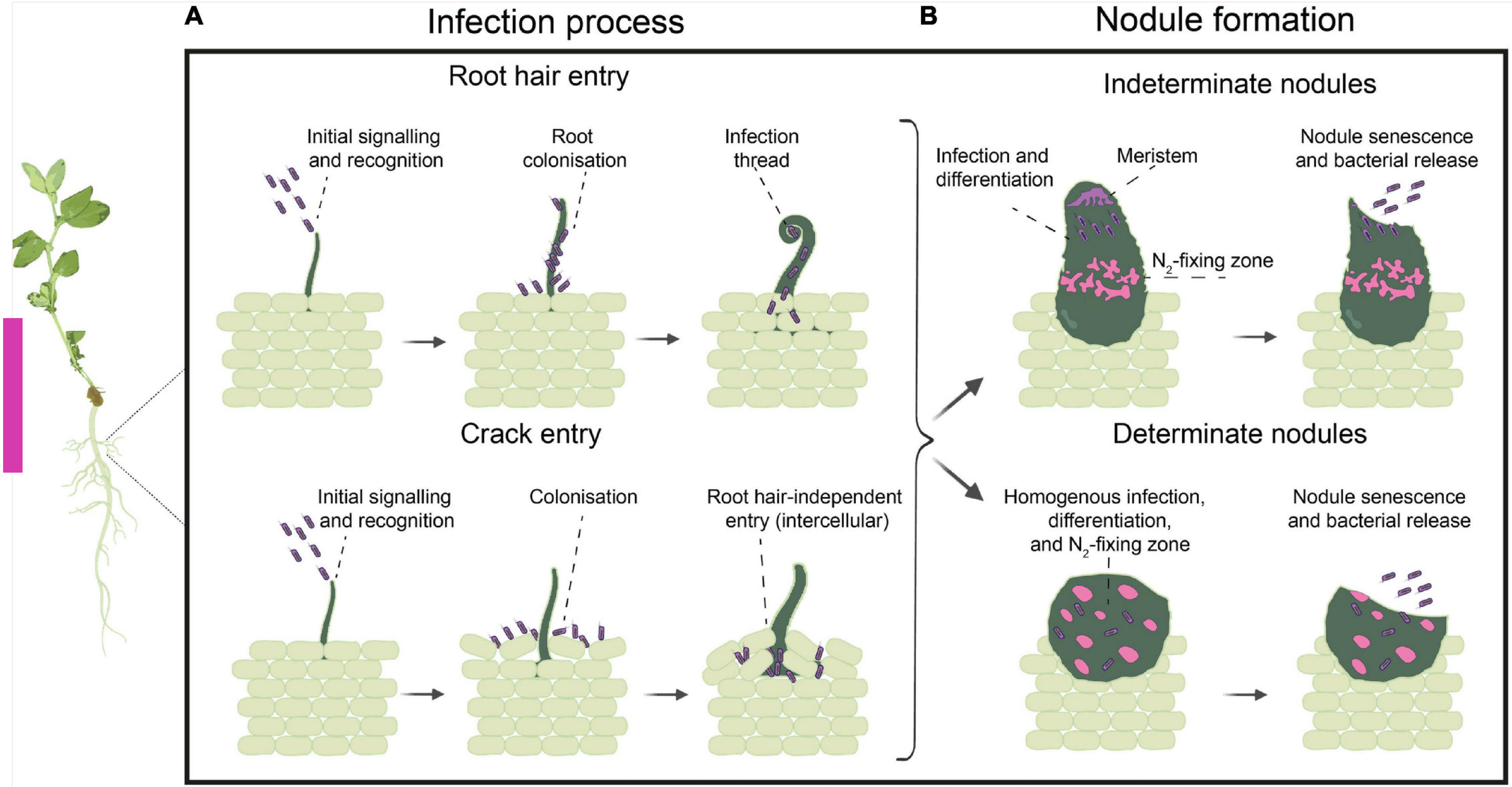
ရိုင်ဇိုဘီယမ်မြေဩဇာပြုလုပ်ခြင်း

မျိုးပင်စိုက်ပျိုးခြင်း

- မိမိစိုက်ပျိုးမည့် ပဲ မျိုးကို ကြိုတင်စိုက်ပျိုးထားရန်လိုအပ်ပါသည်
- ပဲပင် ပွင့်ခါနီးအချိန်တွင် ဘက်တီးရီးယားသိမ်းယူရမည်
- တစ်ဧက ပဲခင်းအတွက် ပဲပင် ၂၀-၅၀ ထိ စိုက်ပျိုးထားနိုင်သည်

မြစ်ဖုများရွေးချယ်ခြင်း

- ပဲပင်ငယ်များကို စဖူးပြီးပွင့်ခါးနီးချိန်တွင် နှုတ်ယူ၍ အမြစ်များကို ရေဆေးပါ
- ရေသောက်မြေအရင်းပိုင်းတွင် အကြီးဆုံး၊ အရောင်အရင့်ဆုံး၊ အဖောင်းဆုံးမြစ်ဖုများရှိသည်
- ရေသောက်မြေအလယ်ပိုင်း ဘေးမြစ်များ၏ အရင်းပိုင်းတွင် အလယ်အလတ်အရွယ်အစားရှိသည့်မြစ်ဖုများရှိသည်
- မြစ်ဖုအသေးများကို အသုံးမပြုရပါ



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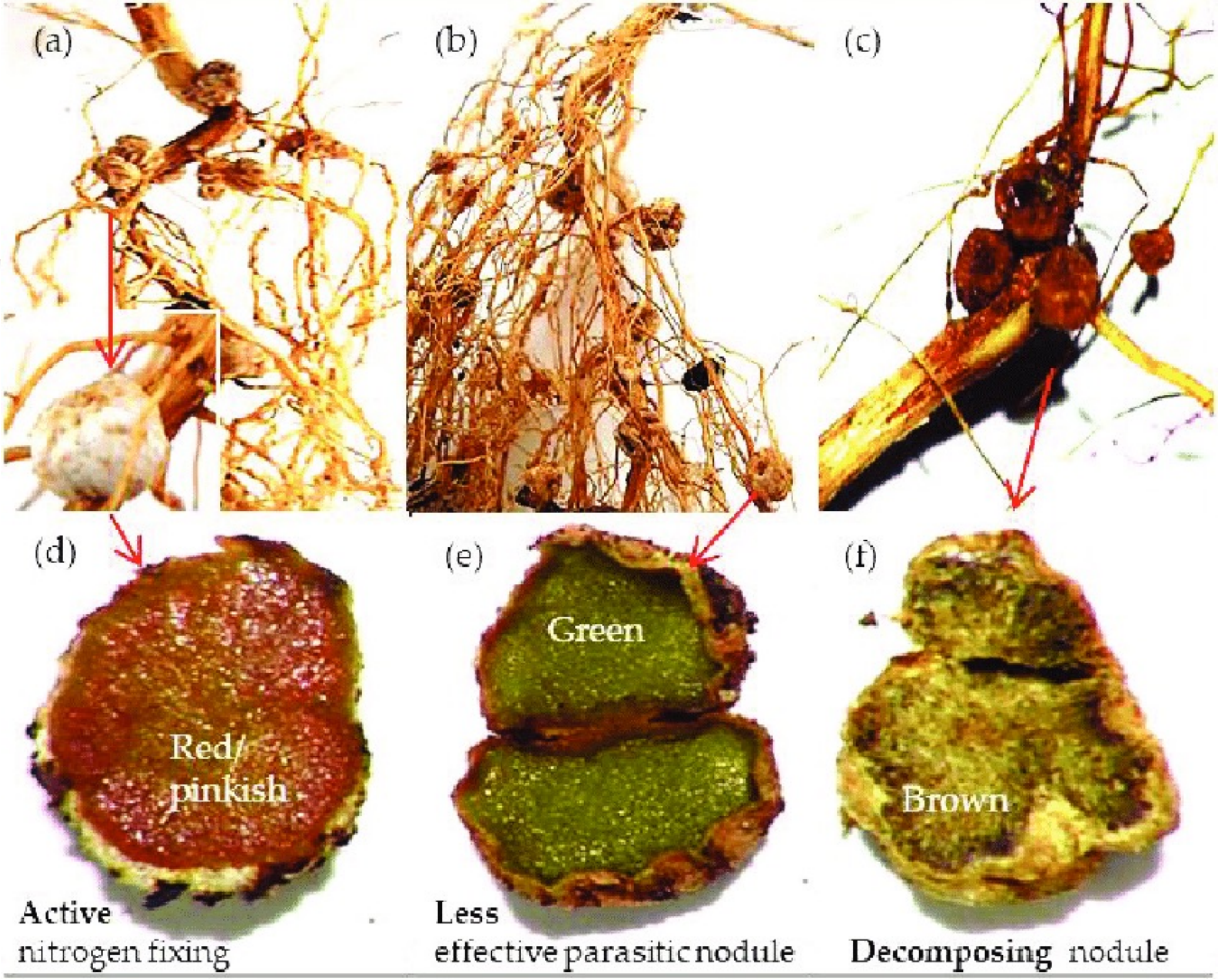
Created by Dr. Daisy Myint



Soybean plants with nodulated roots. (a) Healthy nodules on soybean control plants. (b) Roots of WT 1 with numerous mature nodule structures. (c) WT 2 stressed plant root showing poor nodulation. (d) Nitrogen (N) fixing nodules with Rhizobia as observed in the control. (e) Less effective nodules from WT 1 roots. (f) Decomposing root nodule of WT 2 plants.

ရိုင်ဇိုဘီယမ်မြေဩဇာပြုလုပ်ခြင်း

နွားနို့ကိုပြင်ဆင်ခြင်း

- နွားနို့ ၁ပိဿာကို ဆူအောင်ကြိုပါ
- မလိုင်များကို ဖယ်ပါ
- (ဇလုံထဲတွင်) အအေးခံပါ
- ကြက်သိမ်းနွေး အပူချိန်ရောက်သောအခါ ရေဆေးထားသော ပဲမြစ်ဖုများကို ခြေထည့်ပါ
- မြစ်ဖုများအတွင်းရှိနေသော ရိုင်ဇိုဘီယမ်များ နွားနို့ထဲတွင် ပွားများသွားမည်
- ၃-၅ ရက်ကြာလျှင် အသုံးပြုနိုင်ပါသည်

ရိုင်ဇိုဘီယမ်မြေဩဇာသိုလှောင်ခြင်းနှင့် အသုံးပြုခြင်း

၄ ပြည်	+	၅၀ သား	+	၄ ပြည်	+	နွားနို့နဲ့ပွား ထားသည့် ပဲမြစ်ဖု
ခဲမြေ(Peat) သို့ အုန်းခွံမှုန့် အဆွေးသို့ လွှစာမှုန့် အဆွေး		ထန်းလျက်ရည် (သို့) တင်လဲရည် ၅၀ သား		မီးသွေး၊ ဆန်ကွဲကြေ		

- ➢ လေဝင်လေထွက်ကောင်းသော ပလပ်စတစ်အိတ်မျိုးတွင် ၁ ကီလိုစီ ထည့် အထုပ်ထုပ်ပါ
- ➢ အေး၍ နေရောင်ခြည်တိုက်ရိုက်မကျရောက်သော နေရာတခါင် သိုလှောင်ထားပါ
- ➢ သက်တမ်းမှာ ၆ လဖြစ်၍ စောစောအသုံးပြုပါ

ရိုင်ဇိုဘီယမ်မြေဩဇာအသုံးပြုခြင်း

၁။ မျိုးစေ့အဆင့်တွင်အသုံးပြုခြင်း

- ဘက်တီးရီးယားမွေးထားသော နို့ ၃-၅ ရက်ကြာတွင် အသုံးပြုမည့်ပဲစေ့များကို လူးနယ်ခြင်း
- နို့ချဉ်(သို့)လွှာစာမှုန့်ဆွေးအတွင်း သိုလှောင်ထားသော ဘက်တီးရီးယားကိုလည်း သုံးနိုင်

၂။ ပင်ပေါက်အဆင့်တွင် အသုံးပြုခြင်း

- စိုက်ပျိုးပြီးပဲပင်များတွင် မြစ်ဖုဖြစ်မှုအားနည်းပါက ဘက်တီးရီးယားမွေးထားသည့် နို့ချဉ်(သို့) သိုလှောင်ထားသည့် ဘက်တီးရီးယားကို ပက်ဖျန်းပေးနိုင်ပါသည်
- ကြီးထွားမှုမြန်သဖြင့် အပူချိန် ၂၈-၃၀°C တွင် ၃-၅ ရက်အတွင်း ဘက်တီးရီးယားအစုအဝေးဖြစ်သွား
- ပုံမှန်အခြေအနေတွင် ၁၀-၁၄ ရက်အတွင်းအပင်အတွင်းဝင်ရောက်နိုင်
- နောက်အကျဆုံး ၂၁-၂၈ ရက်အတွင်း မြစ်ဖုများကို သာမန်မျက်စိဖြင့် မြင်နိုင်သည်

Indigenous microorganism မွေးမြူထုတ်လုပ်ခြင်း

လေထုထဲမှ Microbes များကို ဖမ်းယူခြင်း

လိုအပ်သောပစ္စည်းများ

(ဇီဝဖျော်ရည်ပြုလုပ်နည်း)

- ➢ဆန်နို့ဆီဗူး (၁) လုံး
- ➢ဖွဲနု(၁) ပြည်
- ➢ငှက်ပျောသီးမှည့်(၆) လုံး
- ➢ထန်းလျက် (၅) ကျပ်သား
- ➢ရေ (၆) ဂါလံ

- ➢ ဆန်ကိုချက် ပြီးထမင်းရသောအခါ ဆန်ကော(သို့) ပလပ်စတစ်ဗန်း တစ်ခုအတွင်း စက္ကူ/ငှက်ပျောဖတ် ခင်းထည့်ပါ
- ➢နေရောင်တိုက်ရိုက်မကျသည့် အရိပ်ရနေရာ/အိမ်တွင်း တစ်နေရာမှာ ထားပါ (ကြွက်/ ပိုးဟပ်/ ယင်ကောင်မကျအောင် သတိပြု)
- ➢၃ ရက်ကျော်လျှင် လေထဲမှ Microbes များပေါက်ပွားလာမည် (သိုး)
- ➢ရေ ၈ ဂါလံခန့်ဆန့်သည့်ပလပ်စတစ်ပုံး(သို့) စဥ့်အိုးထဲထည့်ပါ
- ➢ရေ (၆)ဂါလံဖြည့်ပါ
- ➢ငှက်ပျောသီး(၆)လုံး+ထန်းလျက်(၅)ကျပ်သားကို ခြေထည့်ပါ
- ➢(၂) ရက် တစ်ကြိမ် ခန့်မွှေပါ
- ➢၃ ရက်ကျော်ပါက ထမင်းသိုးထဲမှ Microbes ထိုအရည်ထဲတွင် ထပ်ဆင့်ပွား သဖြင့် စိမ်ရည်ဖြစ်(ဇီဝဖျော်ရည်)

ဇီဝမြေသြဇာပြုလုပ်ခြင်း (၁၂၃၄ ဇီဝမြေသြဇာ)

လိုအပ်သောပစ္စည်းများ

- ဇီဝဖျော်ရည် (၁) ဆ
- ဖွဲနု(၂) ဆ
- စပါးခွံစပ်ဖွဲပြာ (၃)ဆ
- နွားချေးဆွေး (၄) ဆ

- ဖွဲနု(၂) ဆ + စပါးခွံစပ်ဖွဲပြာ (၃)ဆ + နွားချေးဆွေး (၄) ဆကို သမအောင်ရော
- အထက်မှ ပြုလုပ်ပြီးသား ဇီဝဖျော်ရည်ကိုဖျန်း သမအောင်မွှေပါ
- ပစ္စည်းအားလုံး ရေကောင်းစွာစိုရမည်
- သို့သော်လက်ဖြင့်စုပ်ကြည့်ပါက ရေတစ်စက်ချင်းကျမလာရ
- အကယ်၍ ဇီဝဖျော်ရည်ဖြင့် လိုအပ်သော အစိုဓာတ်မလောက်ပါက သာမန်ရေဖြင့် အကူသုံးပေးနိုင်သည်
- အမြင့် (၄ ပေ)၊ အကျယ် (၆ ပေ) ထက် မပိုသည့် အပုံ ပုံ
- ပလပ်စတစ်နဲ့ဖုံး
- ၃ ရက်တခါ ပြန်ဖျန့်မွှေ၊ ရေဖျန်း၊ ပြန်ပုံ ၊ ပြန်အုပ်
- ၄ကြိမ်ခန့် အထက်ပါအတိုင်းပြုလုပ်ပြီးပါက အသုံးပြုနိုင်သည့် **ဇီဝမြေသြဇာ ရရှိ**
- **ချက်ချင်းမသုံးချင်ပါက အိတ်သွတ်သိုလှောင်နိုင်**