USDA

United States Department of Agriculture

Soil Health:
What makes a soil healthy?

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Illinois Soil and Water Conservation District Employees Association 2023 Winter Training

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Natural Resources Conservation Service

nrcs.usda.gov/

Defining Soil Health

The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans.

Defining Soil Health

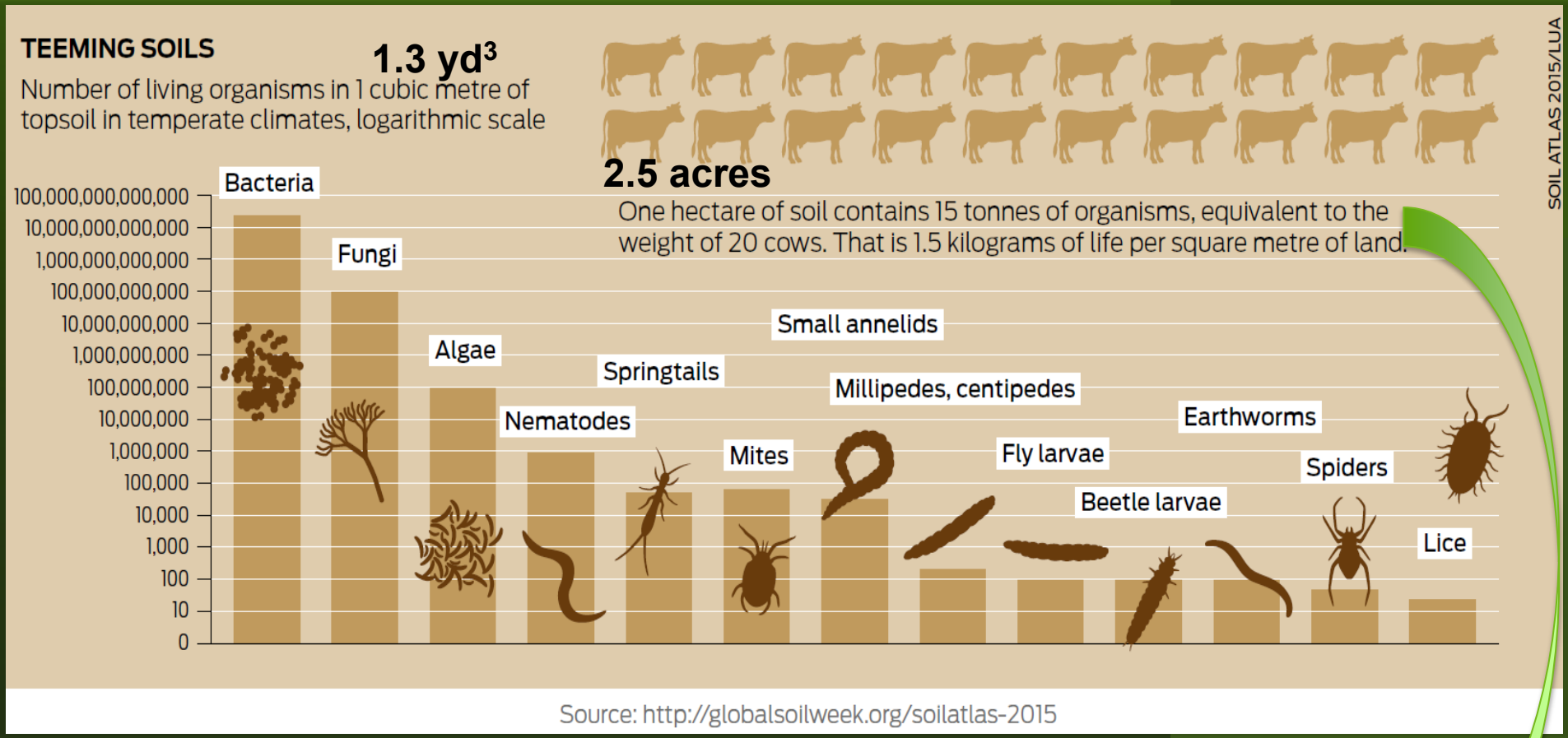
The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans.

Soil Health Functions

- Produce food, feed, fiber, & biofuels
- Capture, filter, and store water
- Cycle and recycle nutrients
- Protect plants from pathogens and stress
- Store C and moderate release of gases
- Resist erosive forces
- Resilience to weather extremes

Defining Soil Health

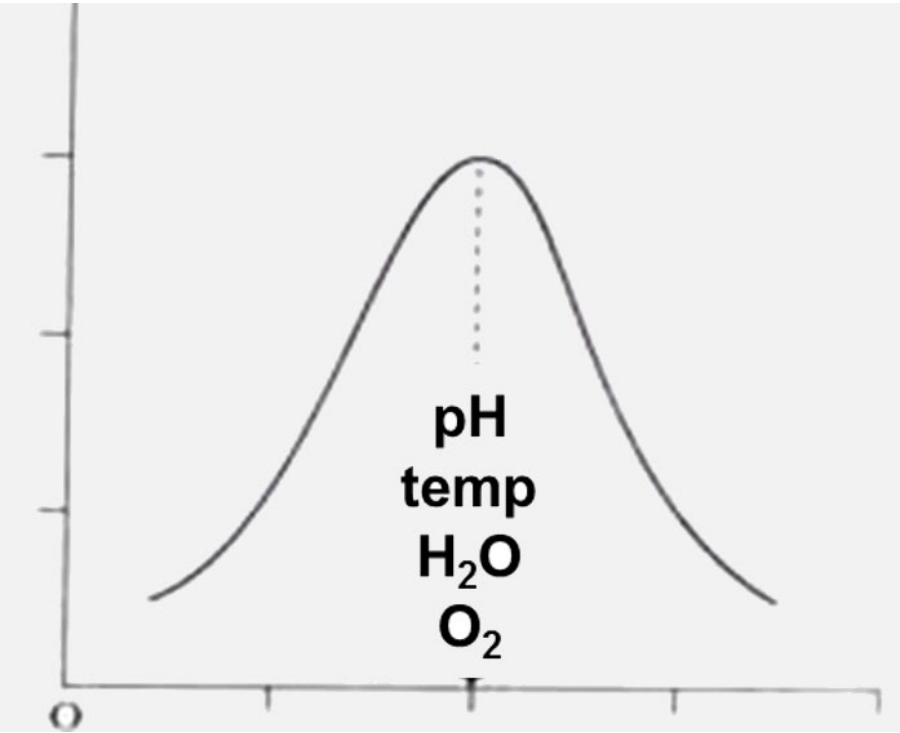
The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans.



One acre of soil contains 6.5 tons of organisms, equivalent to around 8 cows per acre.

A single teaspoon of healthy soil can contain more than a BILLION microorganisms.

Optimal Activity Occurs When Conditions are 'Just Right'



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

> 90% bacteria in soil are inactive!

How do we create 'Just Right' conditions?

4 Soil Health Principles

- Minimize Disturbance
- Maximize Soil Cover
- Maximize Continuous Living Roots
- Maximize Biodiversity

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*Modified from USDA –NRCS-Principles for High Functioning Soils Factsheet

Soil Health Principles

Protect Soil Aggregates & Organic Matter

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Initial Benefits: Maximize Soil Cover

- ↓ Erosion
- ↑ Infiltration
- ↓ Evaporation
- Moderate Soil Temp
- ↑ Habitat for Soil Organisms
- ↑ Food for Biota
- Mitigate Compaction from Machines & Livestock

Minimize Disturbance

Excessive (chronic) Disturbance can:

- ↓Habitat for soil organisms
- Destroy soil structure

Dr. Don Reicosky

Soil Health Principles

Feed & Fuel Soil Biology

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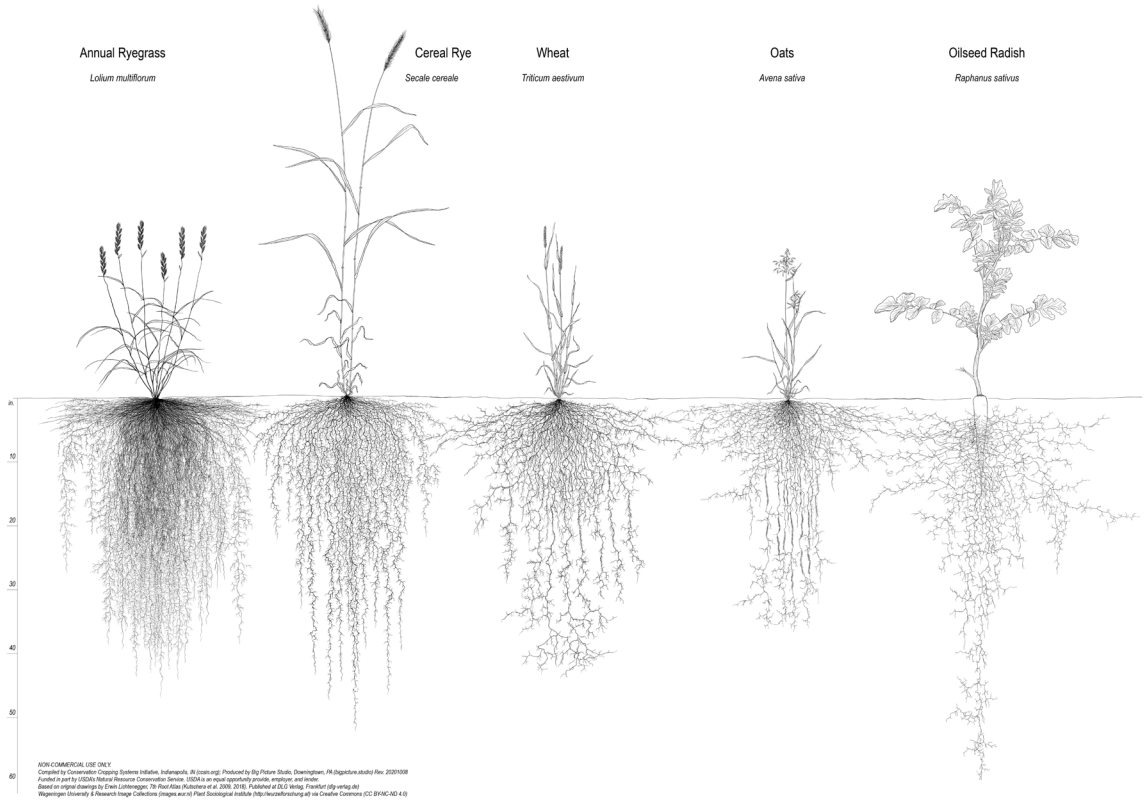
Root Diversity

Average Root Structures of Common Cover Crops



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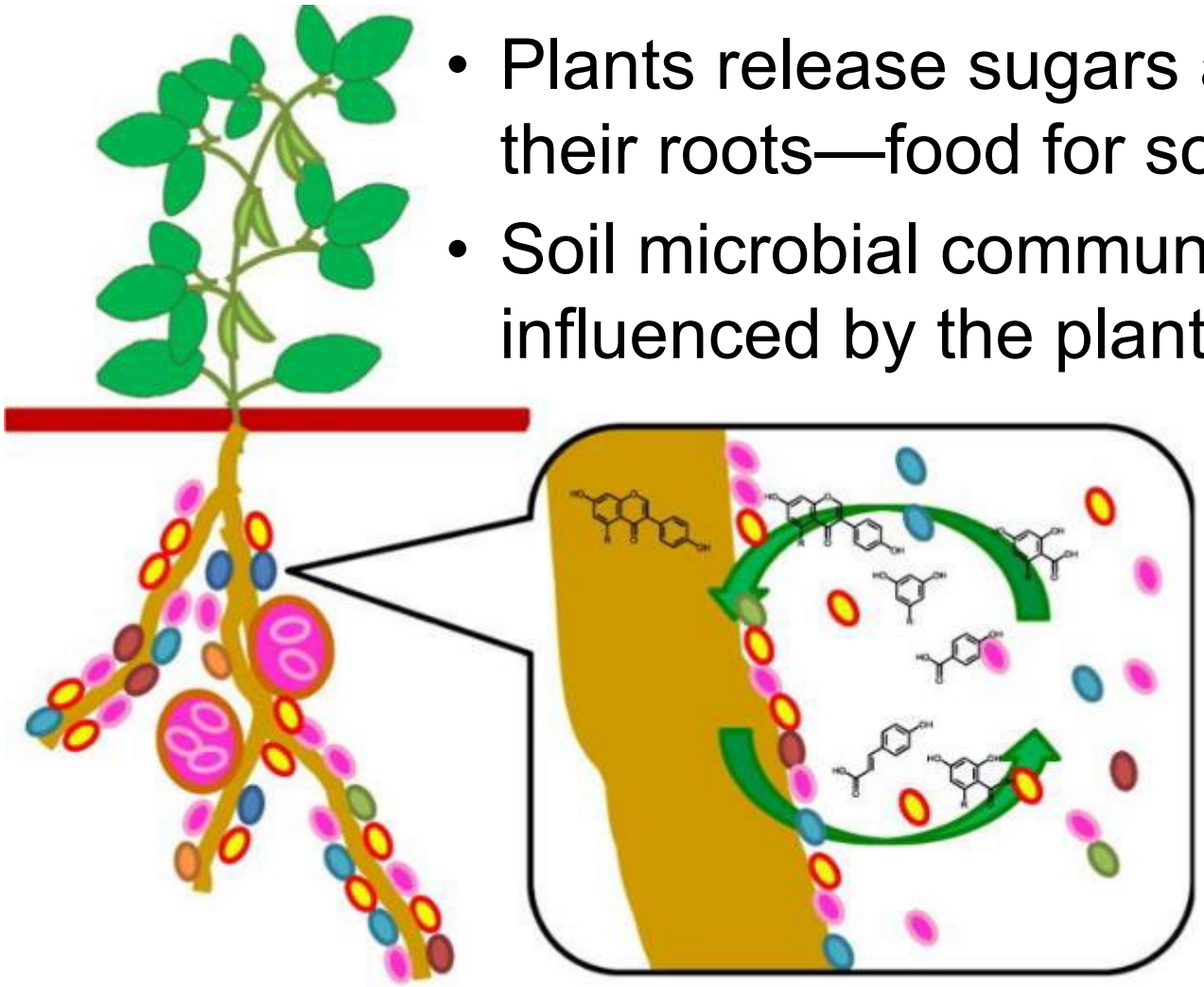
Root Exudates

- Plants release sugars and proteins from their roots—food for soil organisms.
- Soil microbial communities are influenced by the plant species.



Effect of root-secreted metabolites in the rhizosphere

plant diversity

=

microbial diversity

Sugiyama, A. 2019. *Journal of Advanced Research*

FEED and FUEL Soil Biology

- Stimulate below-ground diversity
- Increase soil organic matter
- Improve nutrient cycling
- Enhance plant growth
- Break pest cycles
- Increase predator & pollinator populations

What practices to use?

- Crop Rotation
- Cover Crops
- Reduced Tillage or No-till

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Crop Rotation

3 of 4 Soil Health Principles

- **Soil cover**
- **Biodiversity**
- **Continuous living roots**

NRCS Definition:
A planned sequence of crops grown on the same ground over a period of time.

Cover Crops


SARE, Remsburg

3 of 4 Soil Health Principles

- **Soil cover**
- **Biodiversity**
- **Continuous living roots**

NRCS Definition:
Grasses, legumes, and forbs planted for seasonal vegetative cover.

Bonus Benefits Possible!

- **Weed Suppression**
- **N Scavenging**

Reduced Tillage or No-till

3 of 4 Soil Health Principles

- **Disturbance**
- **Soil cover**
- **Biodiversity**
  - Food source & habitat

NRCS Definitions for Residue and Tillage Management:
Limiting soil disturbance to manage the amount, orientation, and distribution of crop and plant residue on the soil surface year round.

Reduced Tillage or No-till

3 of 4 Soil Health Principles

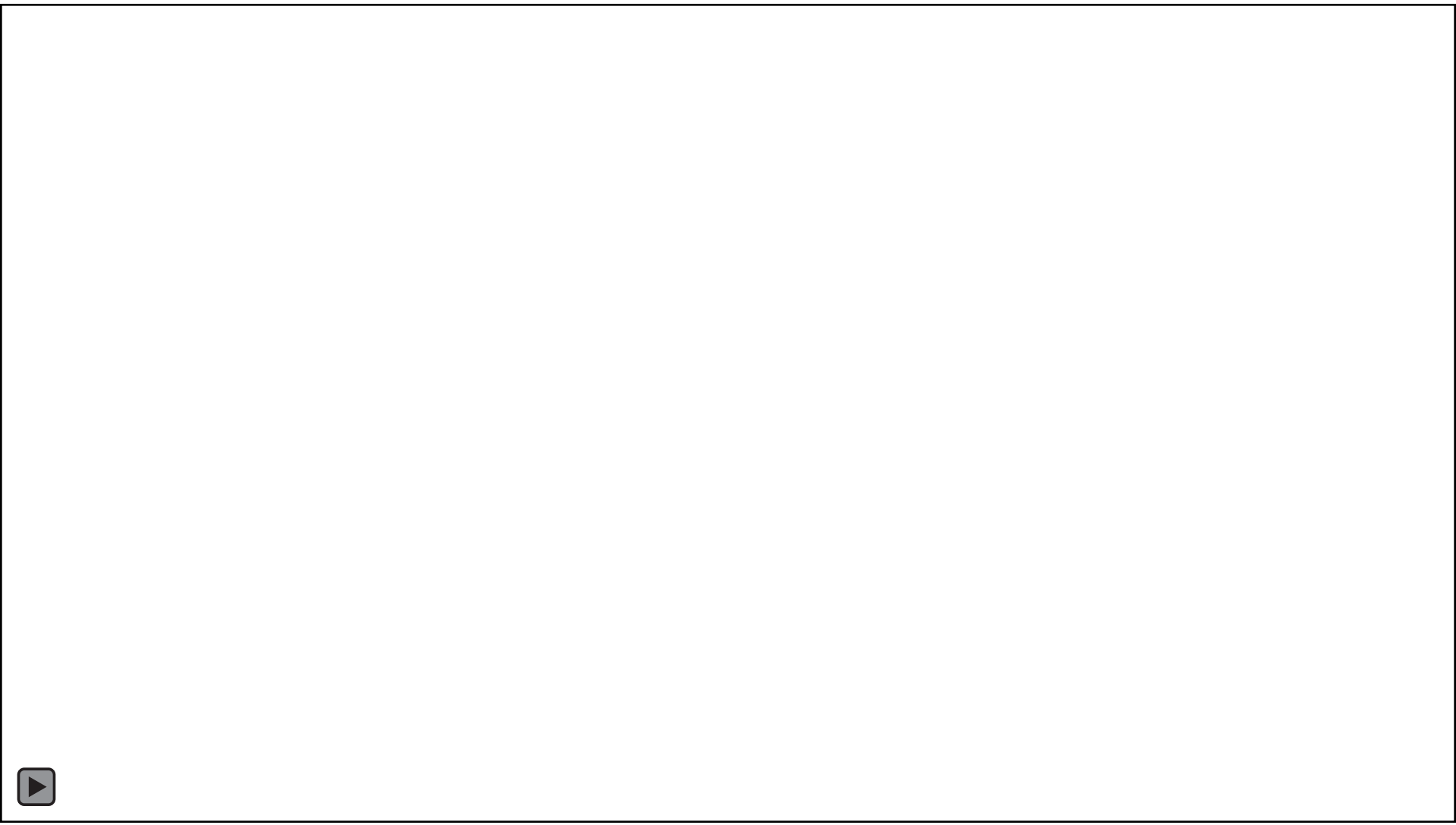
- **Disturbance**
- **Soil cover**
- **Biodiversity**
  - Food source & habitat

Strip-Till

Soil Health Demonstrations

- Slake Test
- Tabletop Infiltration
- Slump Test

Slake Test



Slump Test

Soil Health Demonstration Videos

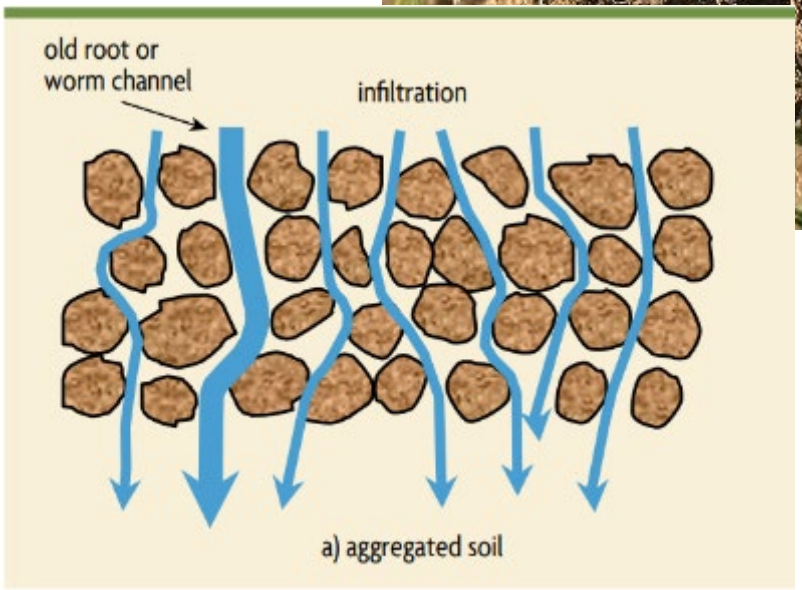
Univ of IL Extension Video Series—Soil Health Check-Up

https://www.youtube.com/playlist?list=PLIq7XlTOe3alHZjAxofvY-7QNnafinWF5

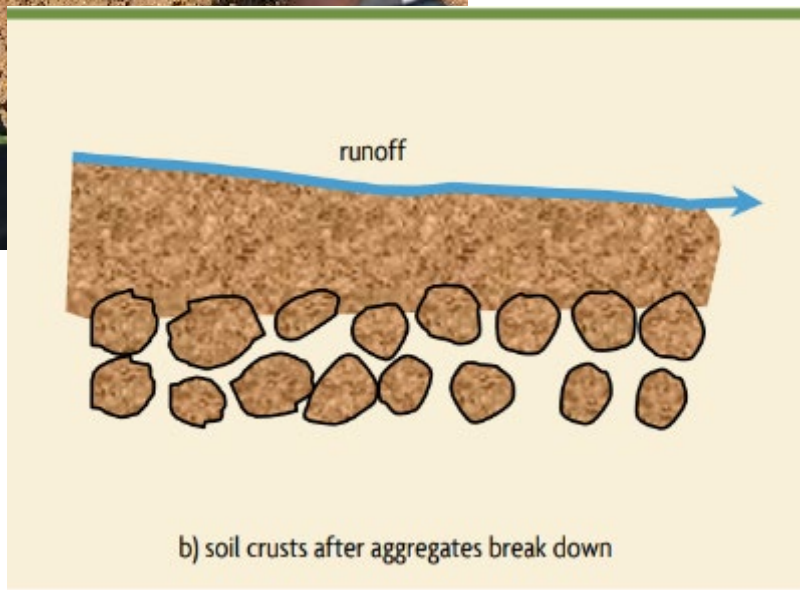
Soil Health Nexus-Demonstration Videos

https://soilhealthnexus.org/resources/soil-health-demonstration-videos/

Soil Structure & Soil Aggregates



You want this…

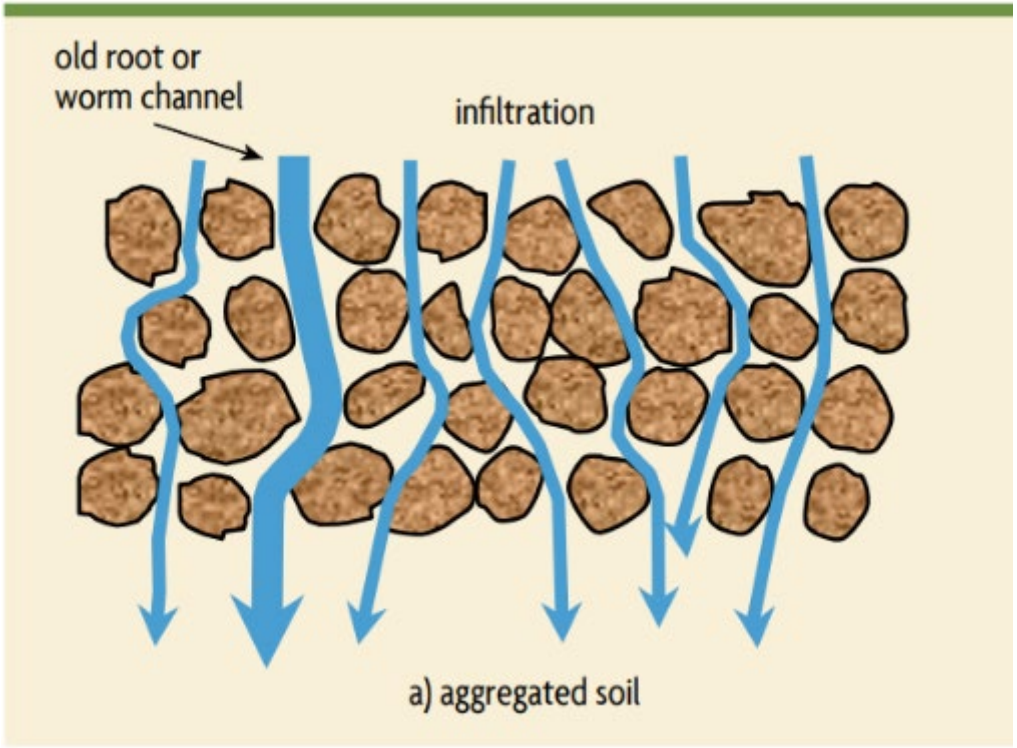


NOT this!

Figures: Building Soils for Better Crops, Fourth Edition-SARE

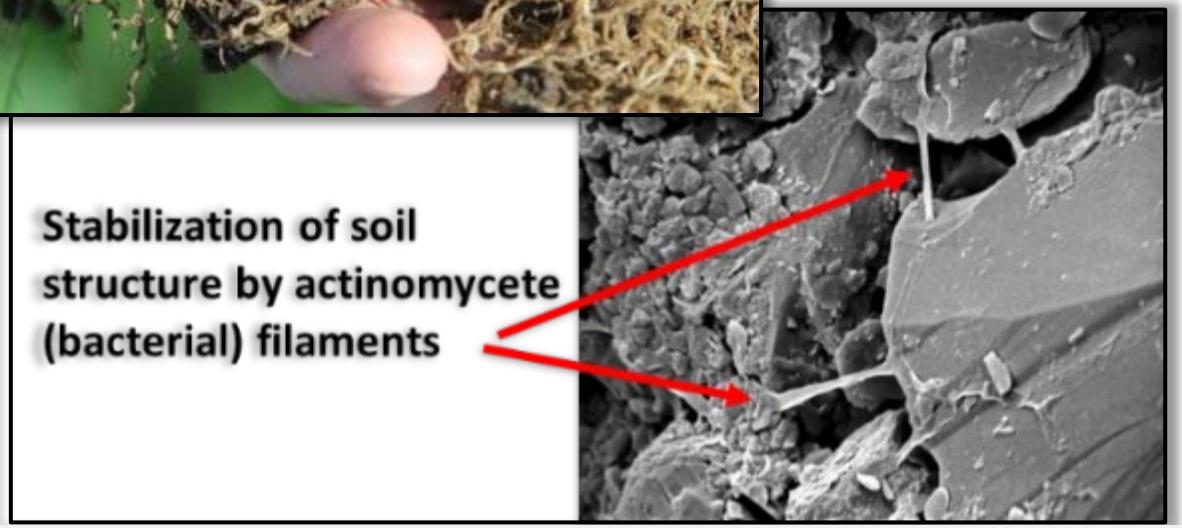
Good aggregation can …

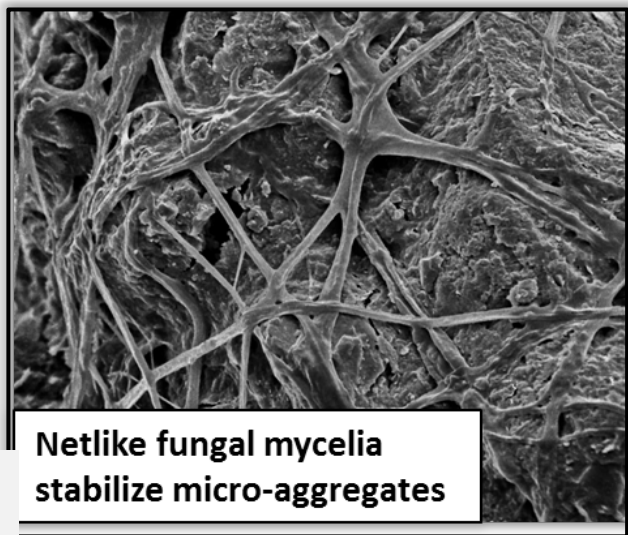
Increase Water Infiltration



Role of Soil Organisms—Physical Stability

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



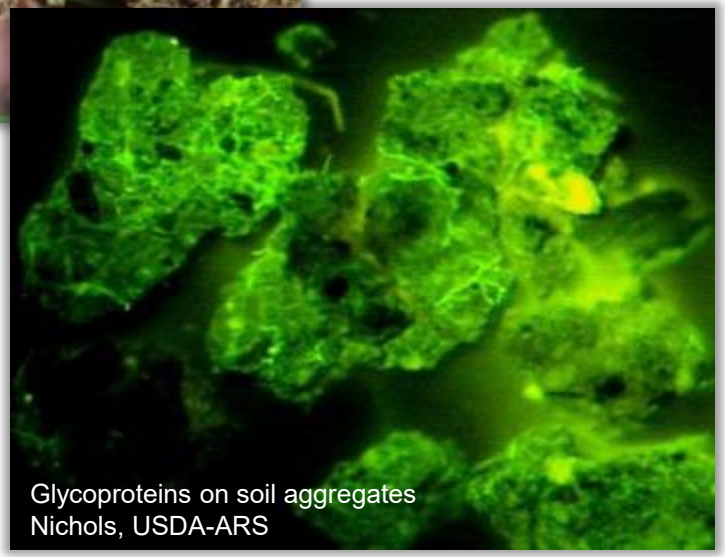


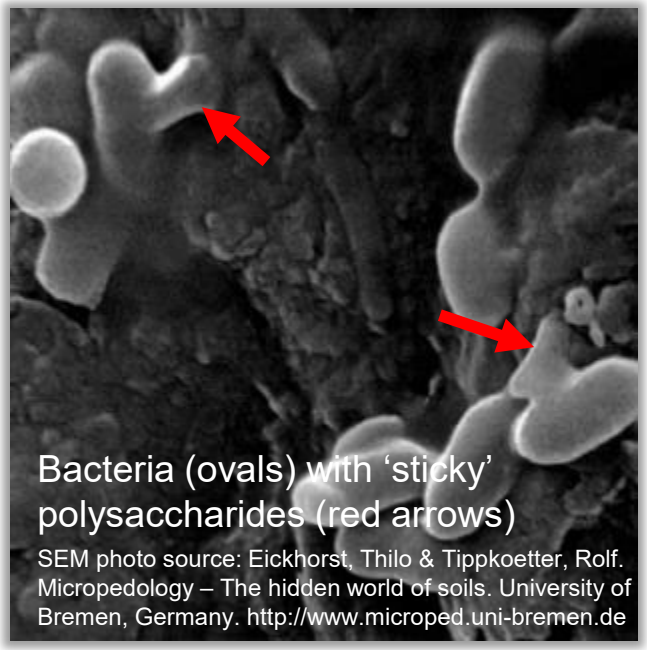
SEM photo source (accessed on 6/2/2016): Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. http://www.microped.uni-bremen.de

Role of Soil Organisms—Chemical Stability


Image source: Aaron Roth, NRCS-OR

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

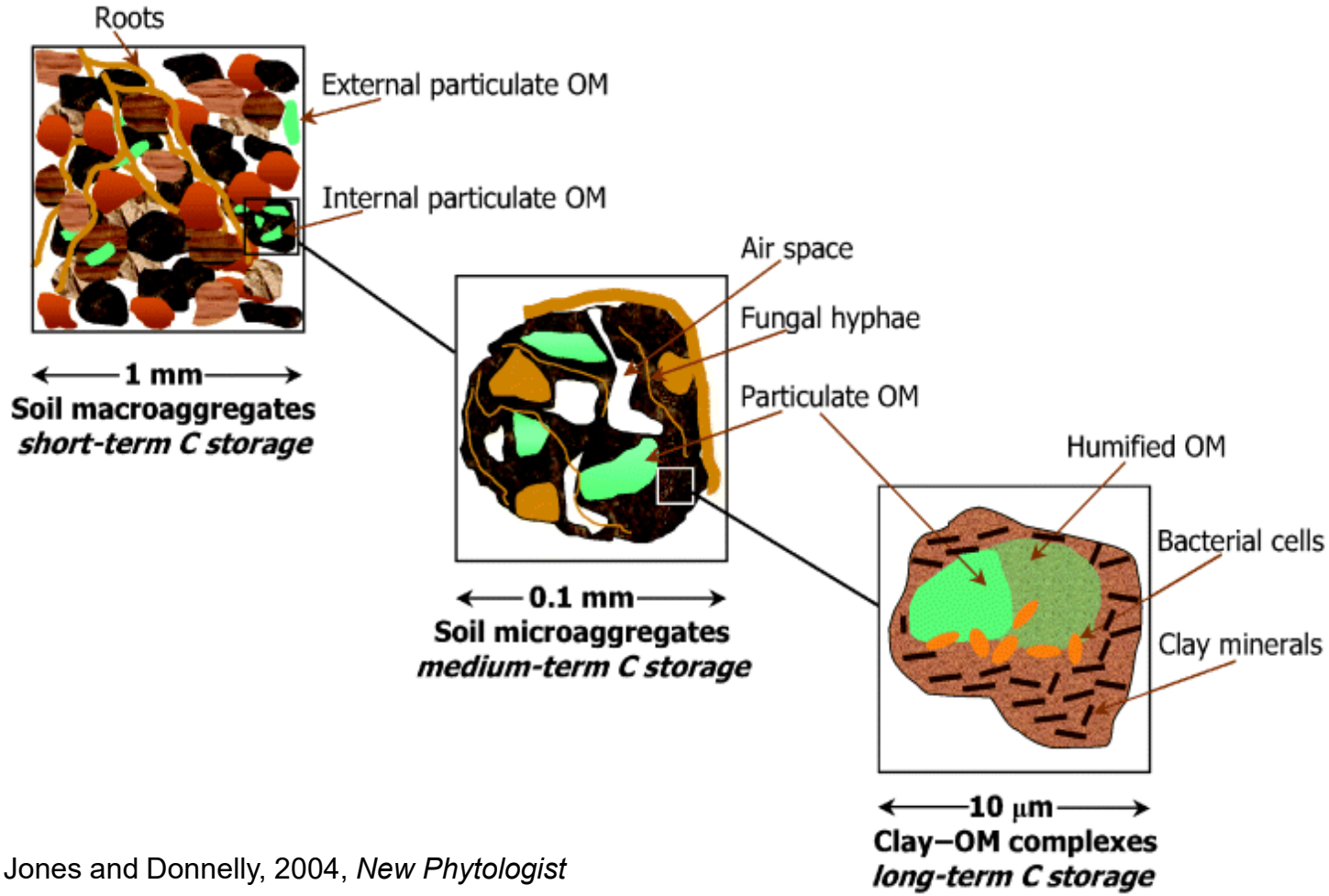

Glycoproteins on soil aggregates
Nichols, USDA-ARS


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

Good aggregation can …

Protect Soil Organic Matter



Jones and Donnelly, 2004, *New Phytologist*

Continuous Flow of C Drives System

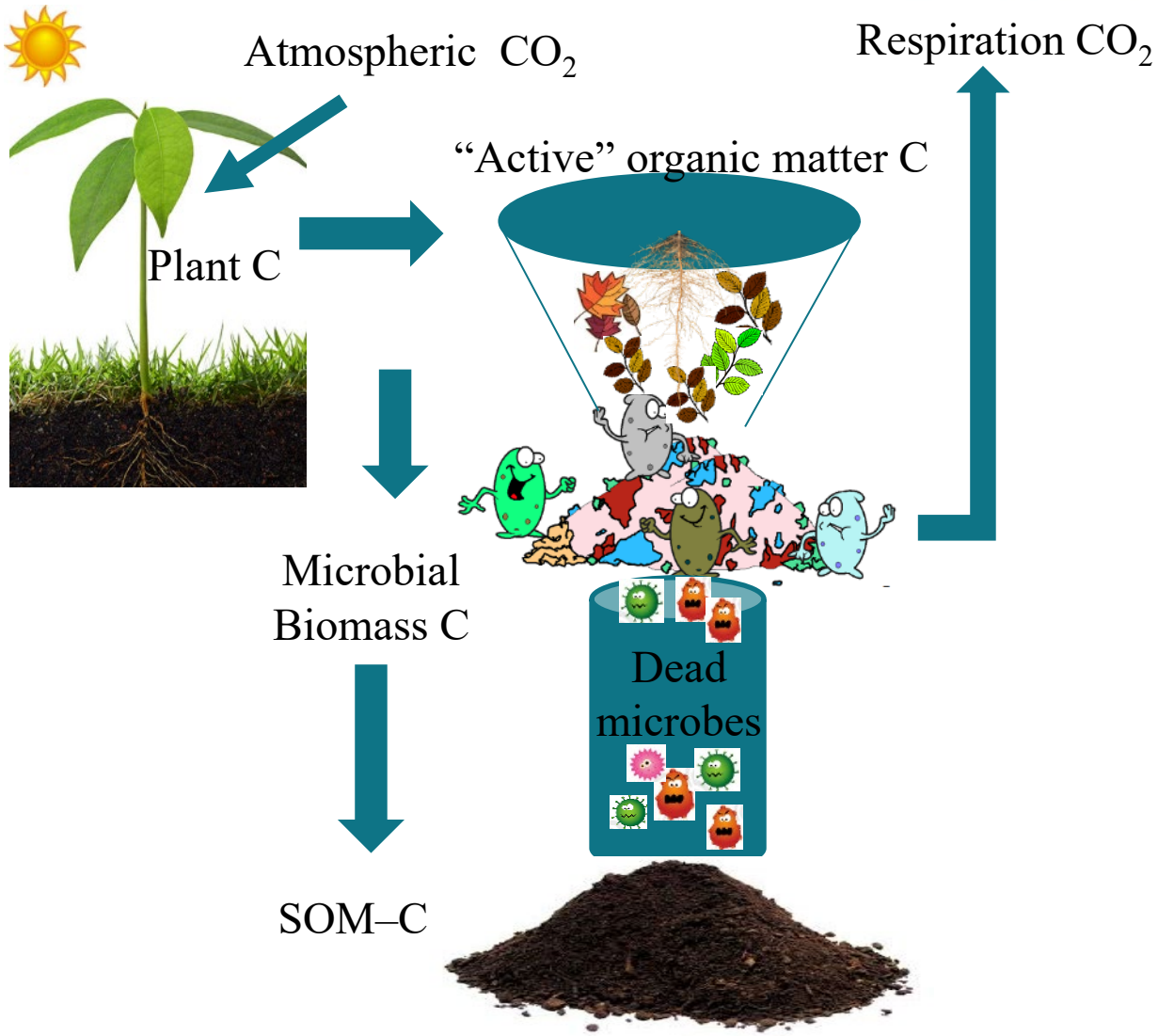
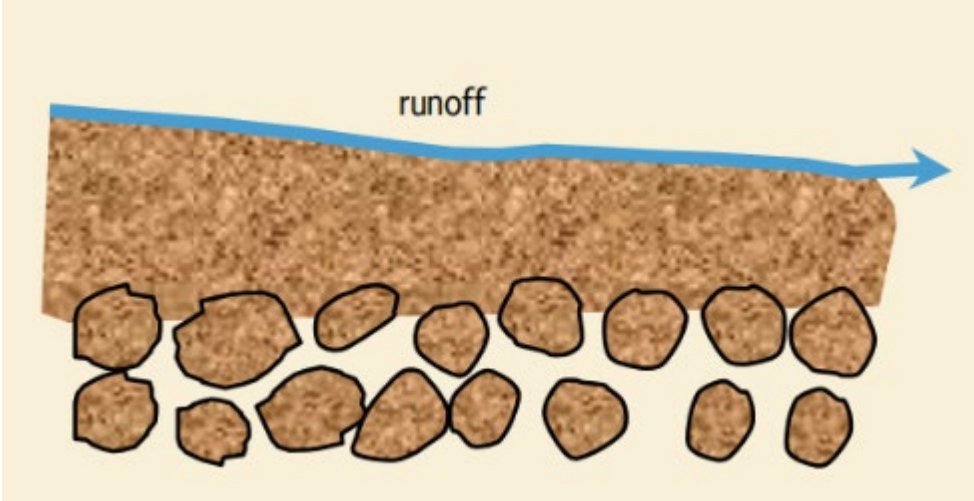


Image courtesy of Dr. Chenhui Li

Poor aggregate stability can cause

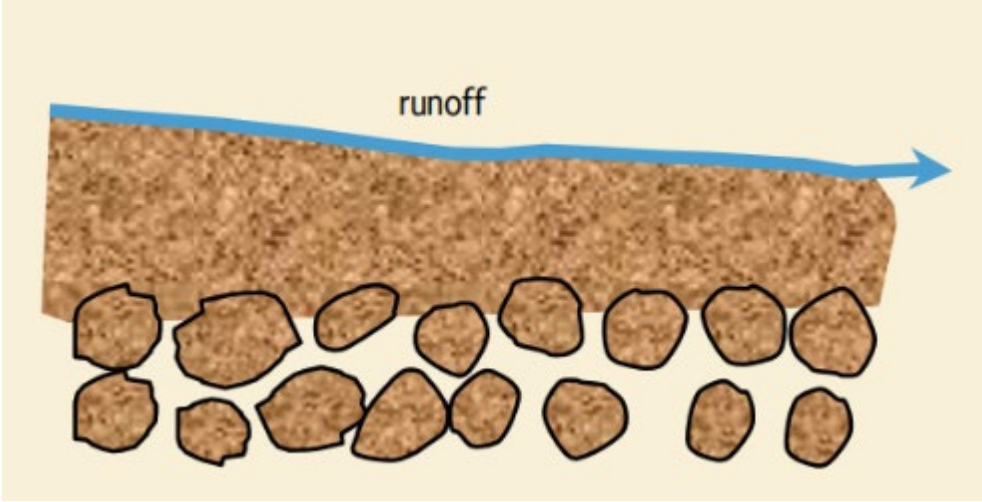
Runoff



Erosion

Poor aggregate stability can cause

Ponding

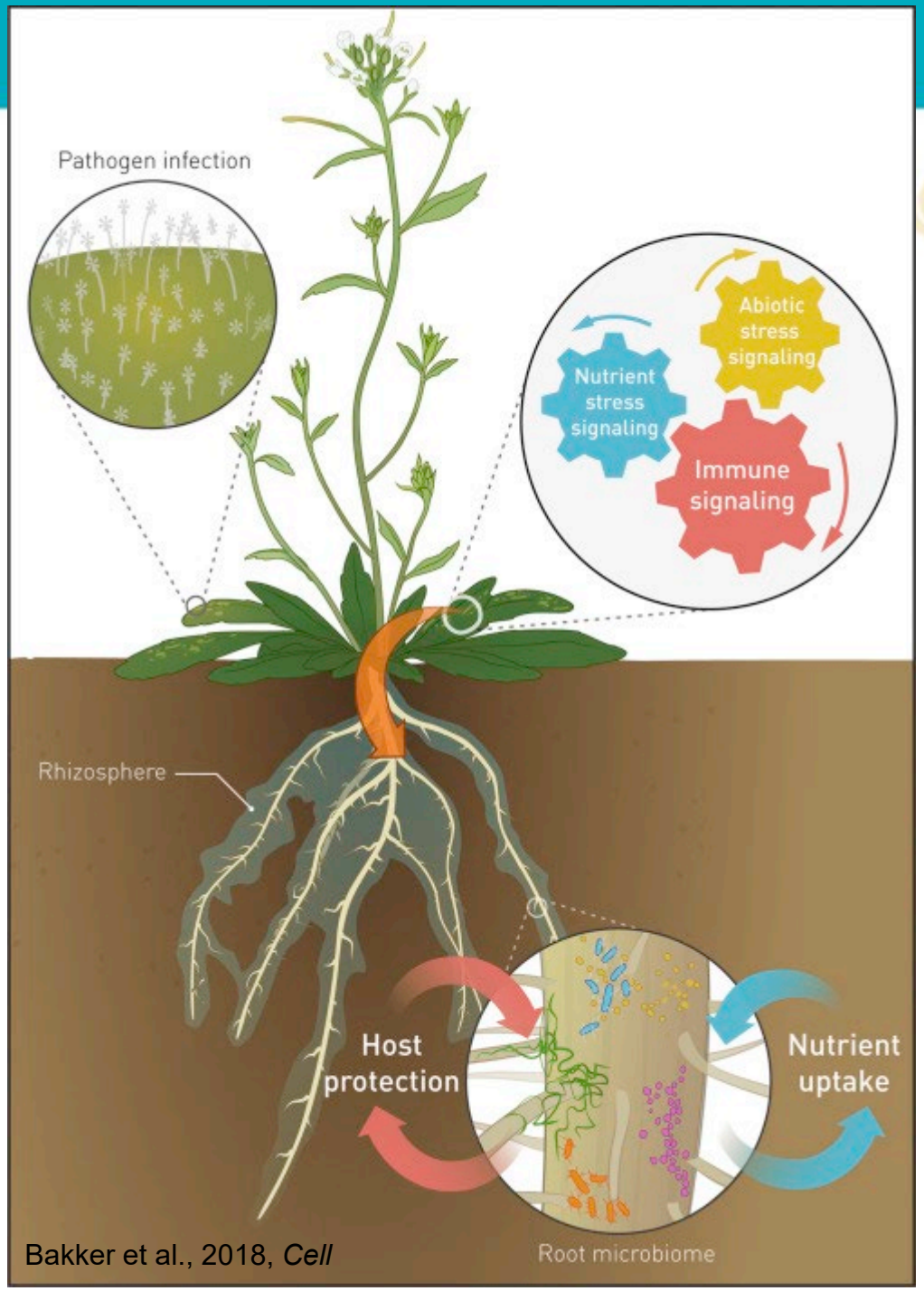


Poor aggregate stability can cause

Increased Risk of Compaction

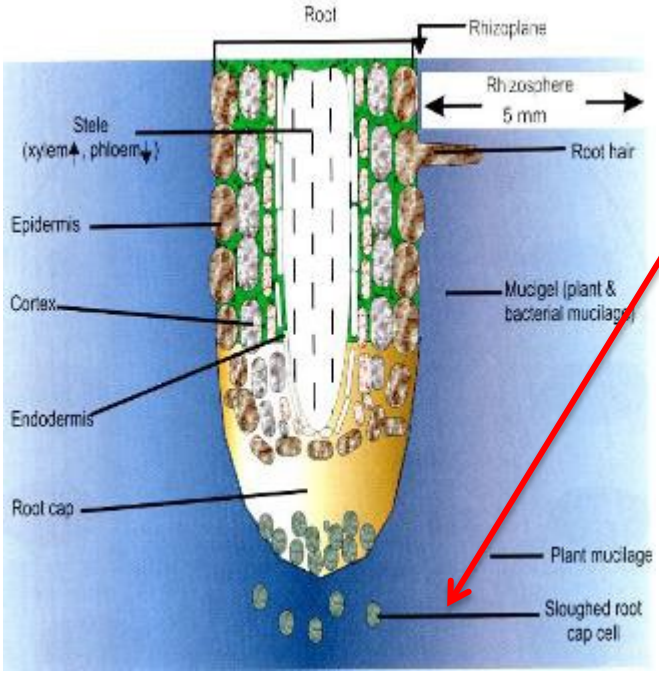
Plant-Microbe Interactions

- **Root exudates influence microbes living nearby.**
- **Chemicals released can change based on plant stress.**
- **Microbiome can change to:**
  - Increase nutrient availability
  - Provide defense against pathogens

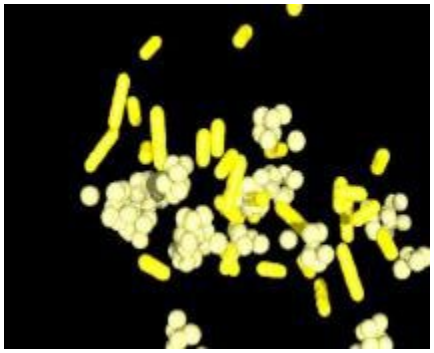


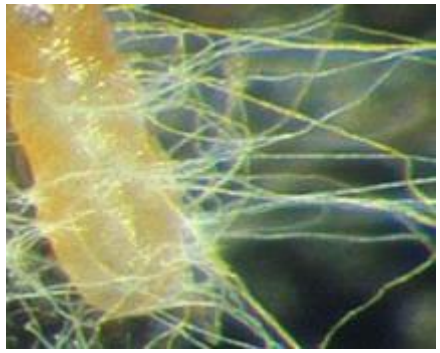
Bakker et al., 2018, *Cell*

Plant Roots Attract Microbes



Exudates: carbohydrates and proteins secreted by roots



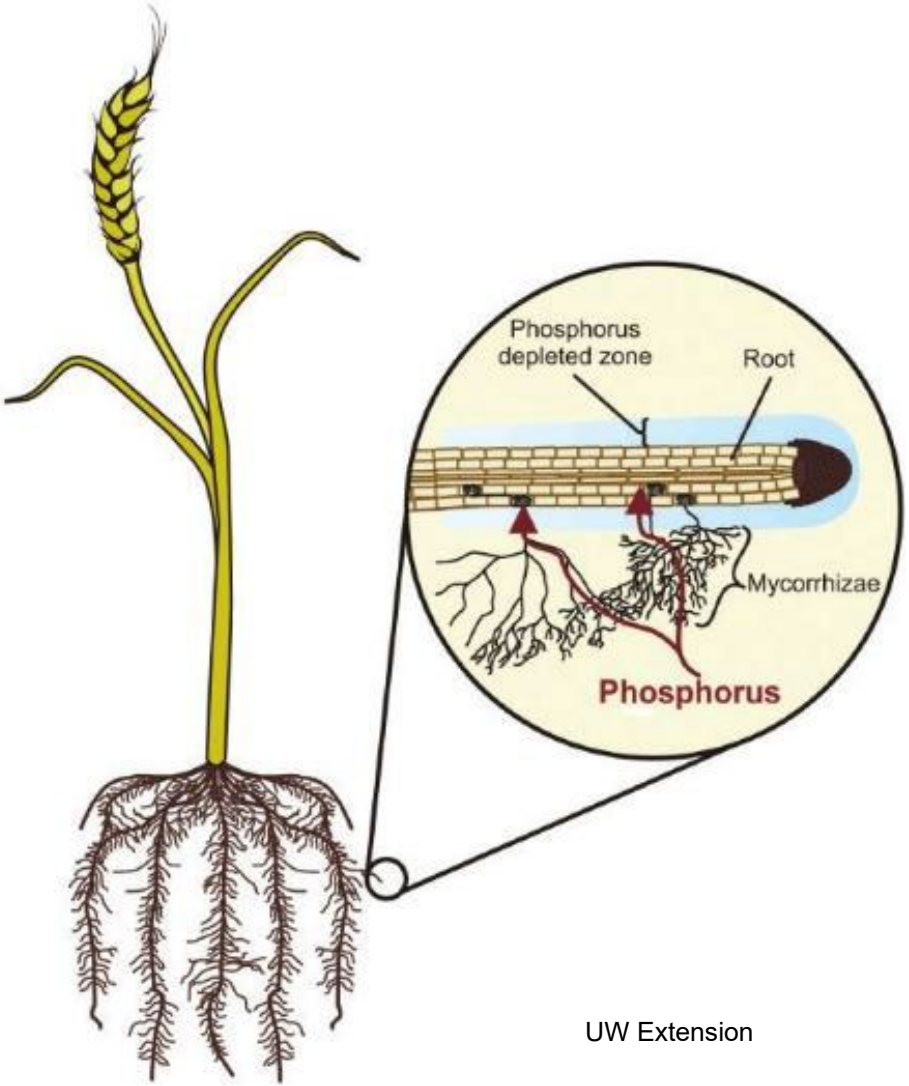


Root exudates attract bacteria

Nematodes and protozoa consume microbes and excrete plant available nutrients

Extend Reach to Nutrients

Mycorrhizal Fungi



UW Extension

Mycorrhizae

Mykós (fungus)- riza (root)

- Plants use 5-20% of C from photosynthesis to ‘feed’ fungi
- Increase root surface area at least 10x
- Increase nutrient uptake especially P and Zn
- Suppress pests and diseases
- Build soil aggregates

N-Fixing Bacteria with Legumes

Bradyhizobium Japonicum
for Soybean & Cowpea

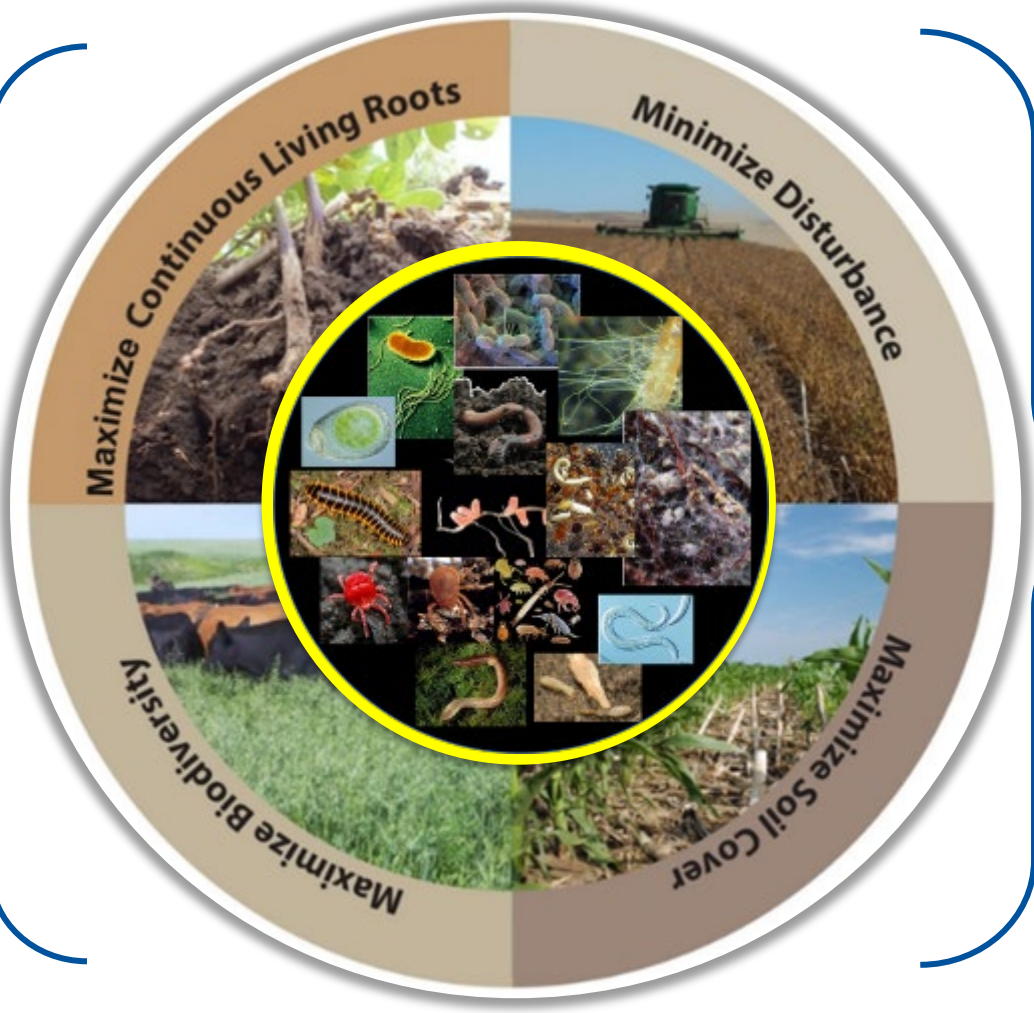
Photo: Getty Images

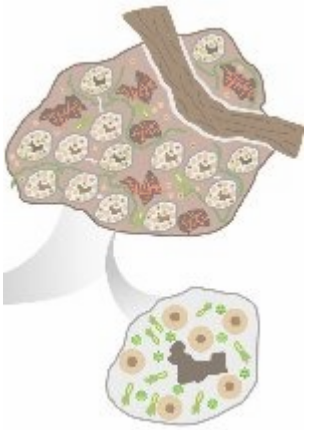
Rhizobum trifolii
for most Clovers


Photo: Science Source

Living organisms are what makes a soil healthy!

Feed & Fuel Soil Biology





Protect Soil Aggregates & Organic Matter

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Thank You!

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Soil Health Resources

USDA-NRCS Soil Health Page

https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health

Illinois NRCS Soil Health Page

https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/illinois/soil-health-illinois