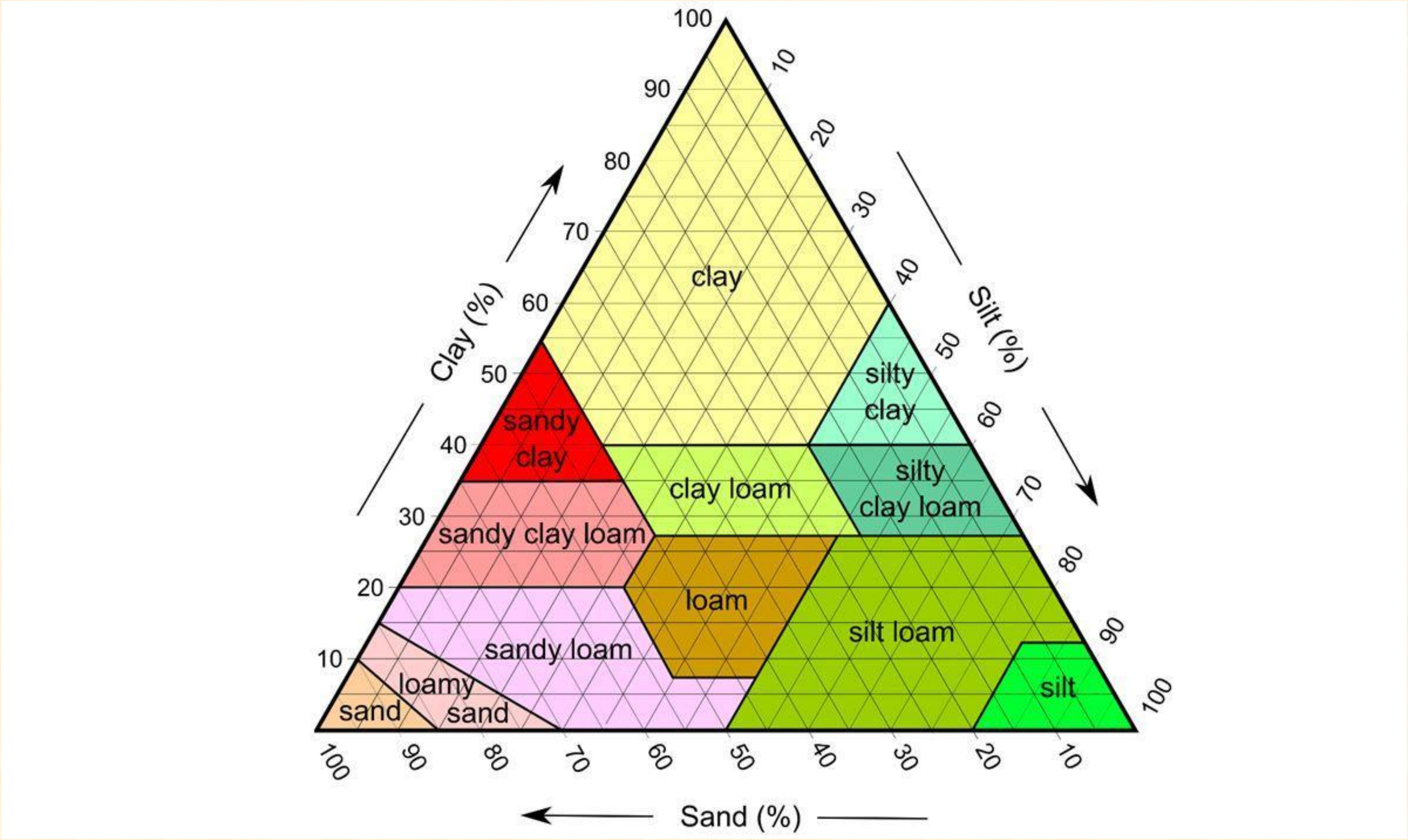
Soil Health Basics



Soil Health Terms

- **Aggregate Stability**
  - The ability of soil aggregates to resist degradation. An aggregate is many soil particles held together in a small mass.
- **Cation Exchange Capacity (CEC)**
  - The capacity of soil to hold nutrients for plant use. Specifically, CEC is the amount of negative charges available on clay and humus to hold positively charged ions.
  - Ca, Mg, K, NH_4 are cations, NO_3, SO_4, PO_4 are anions
- **Disturbance**
  - An event or its change in intensity or frequency which alters the structure or functional status of an ecosystem (such as soil). Examples of disturbances that can affect soil include drought, fire, harvest, tillage, compaction, overgrazing, or addition of pesticides.

- **Organic Matter**
  - Any material that is part of or originated from living organisms. Includes soil organic matter, plant residue, mulch, compost, and other materials.
- **Soil Resilience**
  - The capacity of a soil to recover its functional capacity after a disturbance (including rebuilding soil organism populations).
- **Tilth**
  - The overall physical character of soil with regard to its suitability for crop production.
- **Water Holding Capacity**
  - The amount of water that can be held in soil against the pull of gravity.

Soil Ecology Terms

- **Actinomycetes**
  - A large group of bacteria that grow in long filaments that are too small to see without magnification. Actinomycetes generate the smell of "healthy soil," and are important in decomposing cellulose, chitin, and other hard-to-decompose compounds, especially at higher pH levels. Many produce antibiotics.
- **Arbuscular Mycorrhizae**
  - The group of endomycorrhizal fungi important in non-woody plants, including many agricultural crops. *See Mycorrhizal Associations*.

- **Exudates**
  - Soluble sugars, amino acids and other compounds secreted by roots, as waste or in exchange with soil organisms for water, nutrients, and protection from disease-causing organisms. In a typical growing season plants will exude about twice the weight of their root systems in exudates to feed the soil organisms.
- **Fungi**
  - Multi-celled, non-photosynthetic organisms that are neither plants nor animals. Fungal cells form long chains called hyphae and may form fruiting bodies such as mold or mushrooms to disperse spores.

- **Mycorrhizal Associations**
  - A symbiotic association of certain fungi with roots. The fungi receive energy and nutrients from the plant. The plant receives improved access to water and some nutrients.
    - **Vesicular-Arbuscular Mycorrhizal (VAM) Fungi**
      - Greatly reduced under conventional systems
      - Are critical in the establishment and growth of most cereals and especially warm season grasses like corn and sorghum.
      - Dependent plants often have smaller root systems, as they rely on this relationship for survival. *See Root Volumes later in the presentation.*
      - VAM Fungi are also known to increase resistance of the plant host to root diseases.
- **Rhizosphere**
  - The narrow region around roots where most soil biological activity occurs.
    - Soil organisms take advantage of the sloughed and dead root cells and the root exudates found in this region.
    - The rhizosphere is the area where water and nutrients are gathered and taken up into the plant. The larger the rhizosphere the better the potential uptake, and the better the plants ability to survive.

“Why do we treat our soils like dirt?”

Dr. Jill Clapperton, Co-founder of Rhizoterra

Doug Peterson **- Soil Health Initiative**

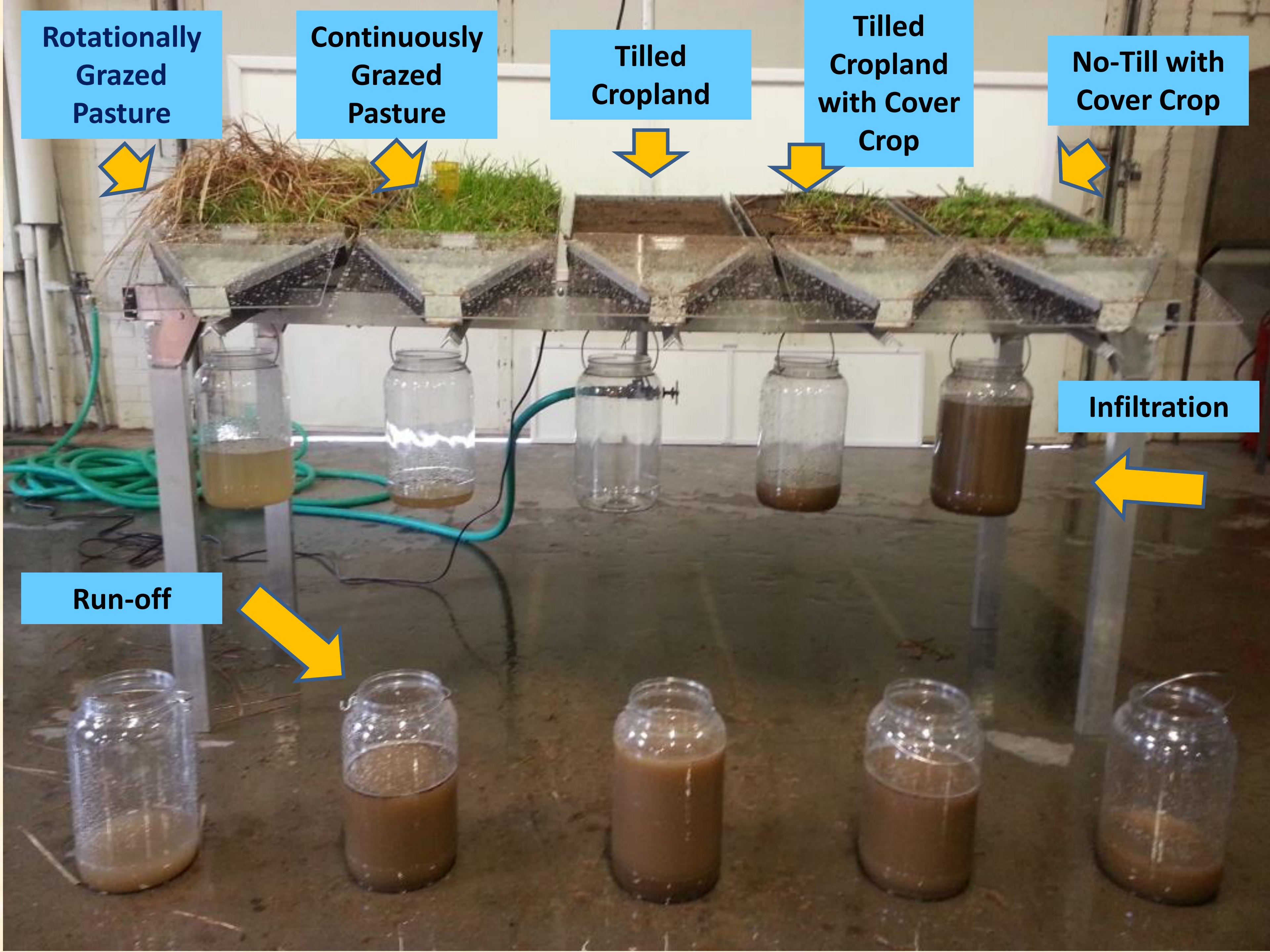
https://www.youtube.com/watch?v=XFFAKPwlH3o

Ray Archuleta **- Slake and Infiltration Test**

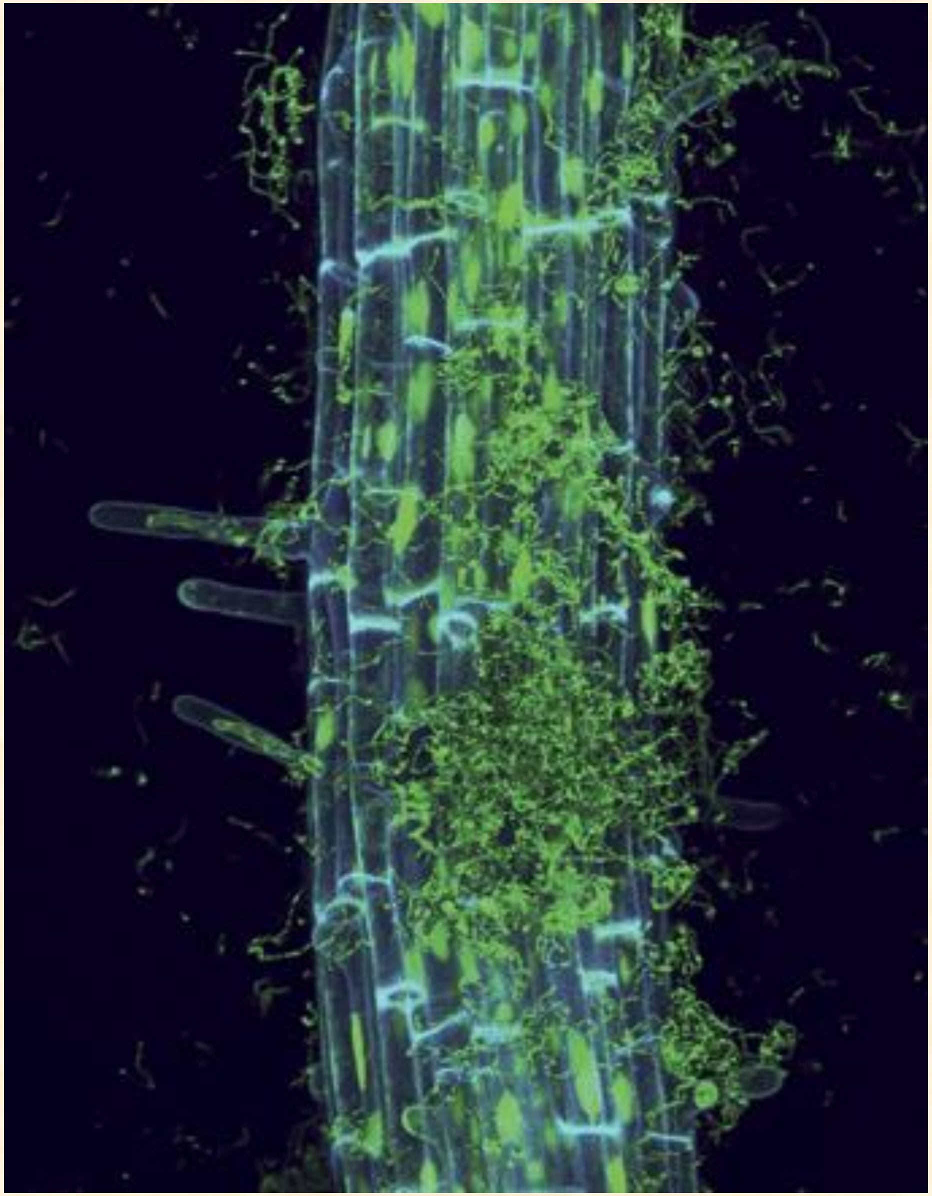
https://www.youtube.com/watch?v=CEOyC_tGH64

Doug Peterson **- Rainfall Simulator**

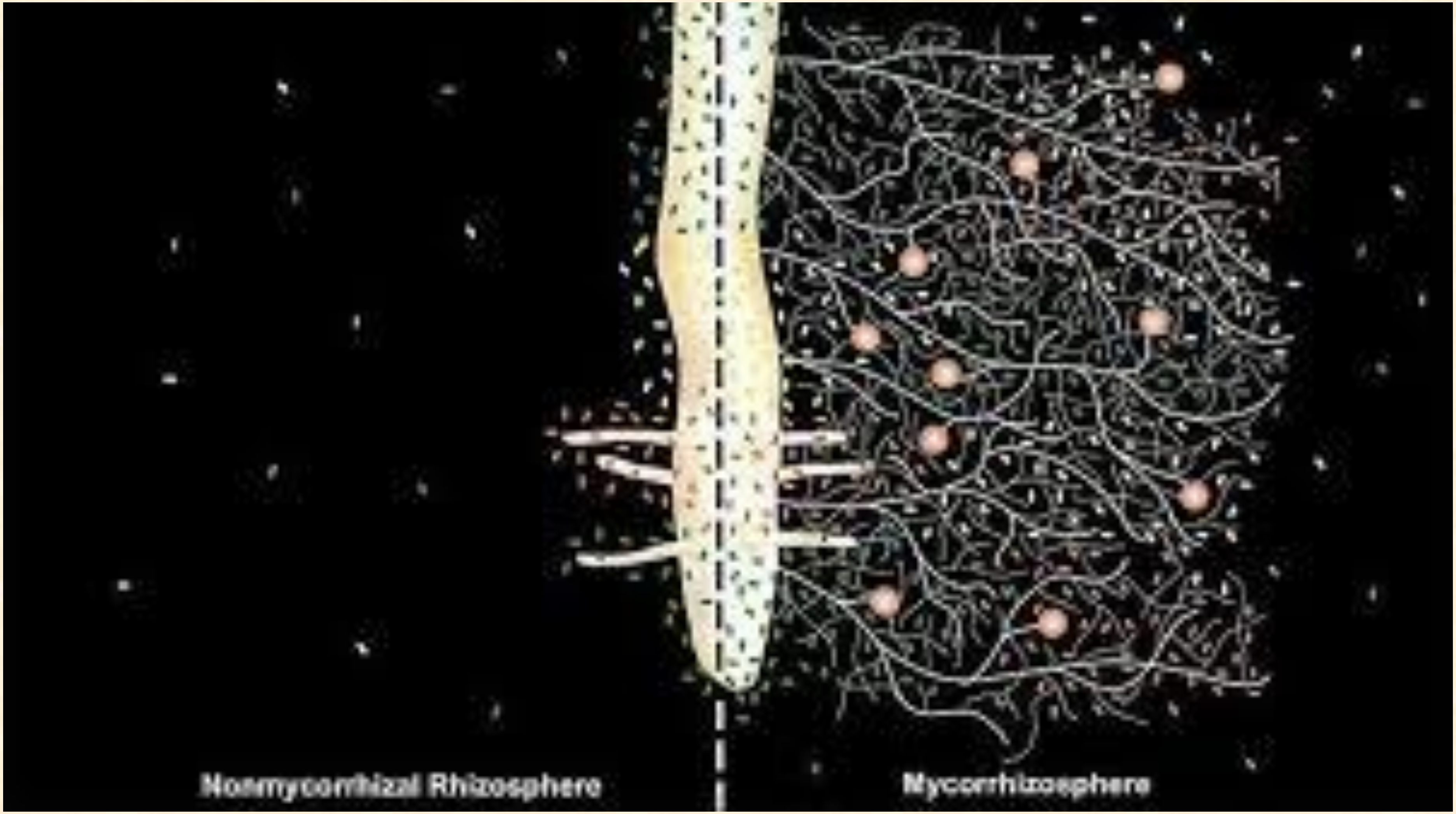
https://www.youtube.com/watch?v=n0EcpgkkXk


Rotationally Grazed Pasture
Continuously Grazed Pasture
Tilled Cropland
Tilled Cropland with Cover Crop
No-Till with Cover Crop
Infiltration
Run-off

The Rhizosphere



The Mycorrhizosphere



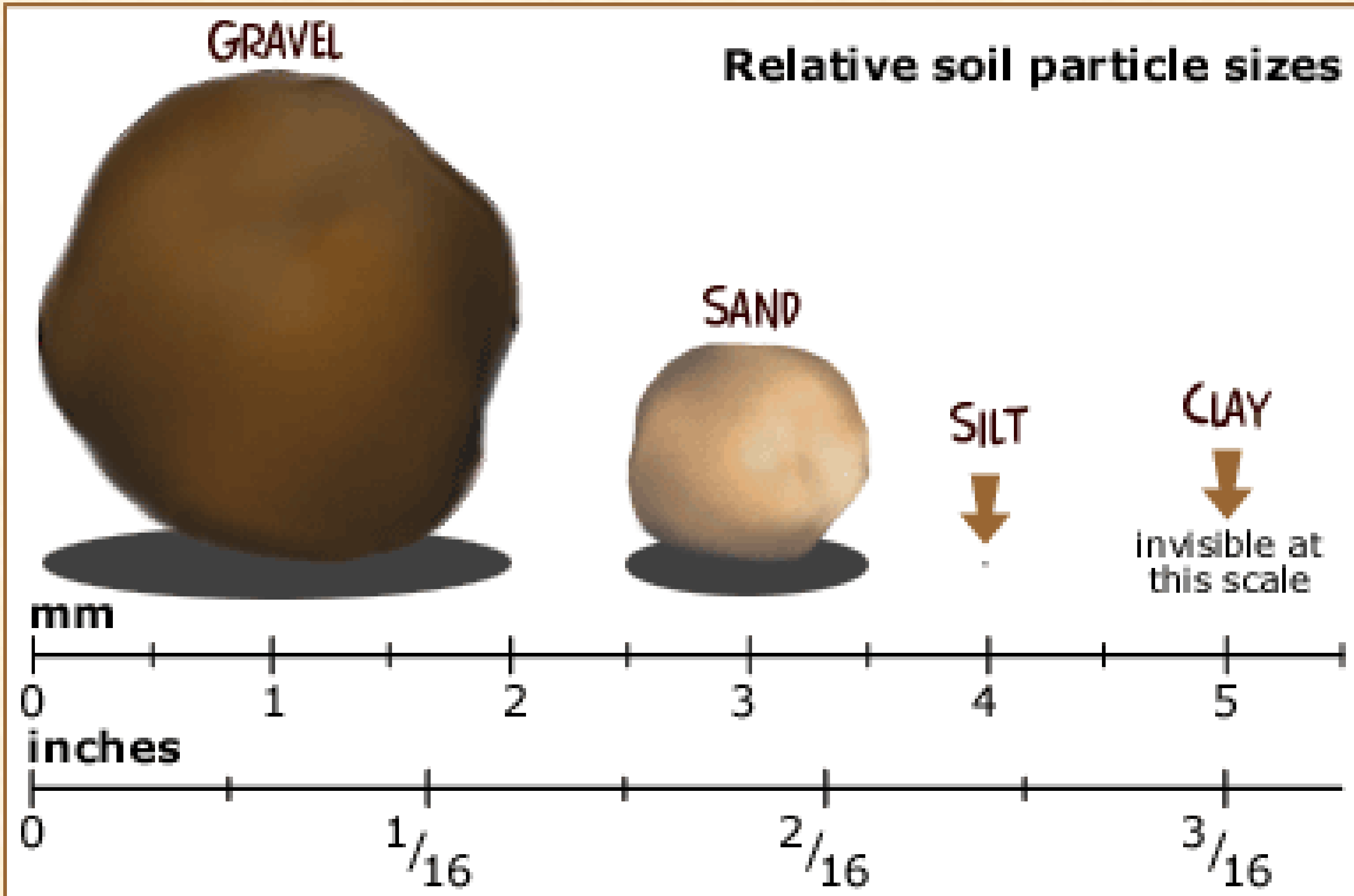
Allelopathy

- Generally referred to as a chemical inhibition of one plant species by another. However, we also see beneficial effects occur, as well as effects on organisms other than plants.
- How does this occur?
  - A plant releases biochemicals, known as allelochemicals, through root exudates, residue decomposition, or other processes.
  - These allelochemicals can then affect the growth, survival, and reproduction of other organisms.
- Relatively new field of study, the term was coined in 1937 by Hans Molisch.
- All plants give off allelochemicals, current research is looking at cover crops, weeds, and to some degree cash crops.
- Examples:
  - Rye
    - Pigweeds, lambsquarters, purslane, crabgrass
  - Brassicas – Rape, Mustards, Radish
    - Affects seen for several weeks or even months after termination
  - Corn – Roots inhibited between plants, root zones don’t cross
  - Soybeans – Competition results in higher root volume and less yield

C:N Ratio

- Soil Microorganisms ratio is near 8:1, require diet of 24:1 to stay alive
- Carbon is used for proteins, cell walls, etc.
- Nitrogen is used for proteins, nucleic acids, etc.
- Mineralization & Immobilization
  - Organic molecules are oxidized (chemical bonds broken), C and energy are taken by organism, while nutrient is converted to inorganic
  - Nutrients, organic and inorganic, are accumulated within the soil organism
- Adding higher ratio residue like wheat (80:1) requires more N to process the wheat stubble
  - Ties up more N in the soil and could create a deficit until the microorganisms die or N becomes available from another source
- Adding lower ratio residue like hairy vetch (11:1) will result in quick decomposition of the vetch and leave excess N in the soil
  - Excess N could be used to breakdown other residues or could be available to plants, or potentially lost through various means
- Important because of residue decomposition, nutrient cycling and availability, and soil organic matter accumulation
- Cover crops become important to achieving balance in the system

Some Quick Facts



Soil Organism Populations

Organism	#/Acre	Lbs./Acre
Bacteria	800,000,000,000,000,000	2,600
Actinobacteria	20,000,000,000,000,000	1,300
Fungi	200,000,000,000,000	2,600
Algae	4,000,000,000	90
Protozoa	2,000,000,000,000	90
Nematodes	80,000,000	45
Earthworms	40,000	445
Insects/Arthropods	8,160,000	830

Biological processes are responsible for about 75% of plant available N and 65% of plant available P in the soil.

A teaspoon of farm soil may contain tens of yards of fungi. The same amount of soil from a coniferous forest may hold tens of miles of fungi.

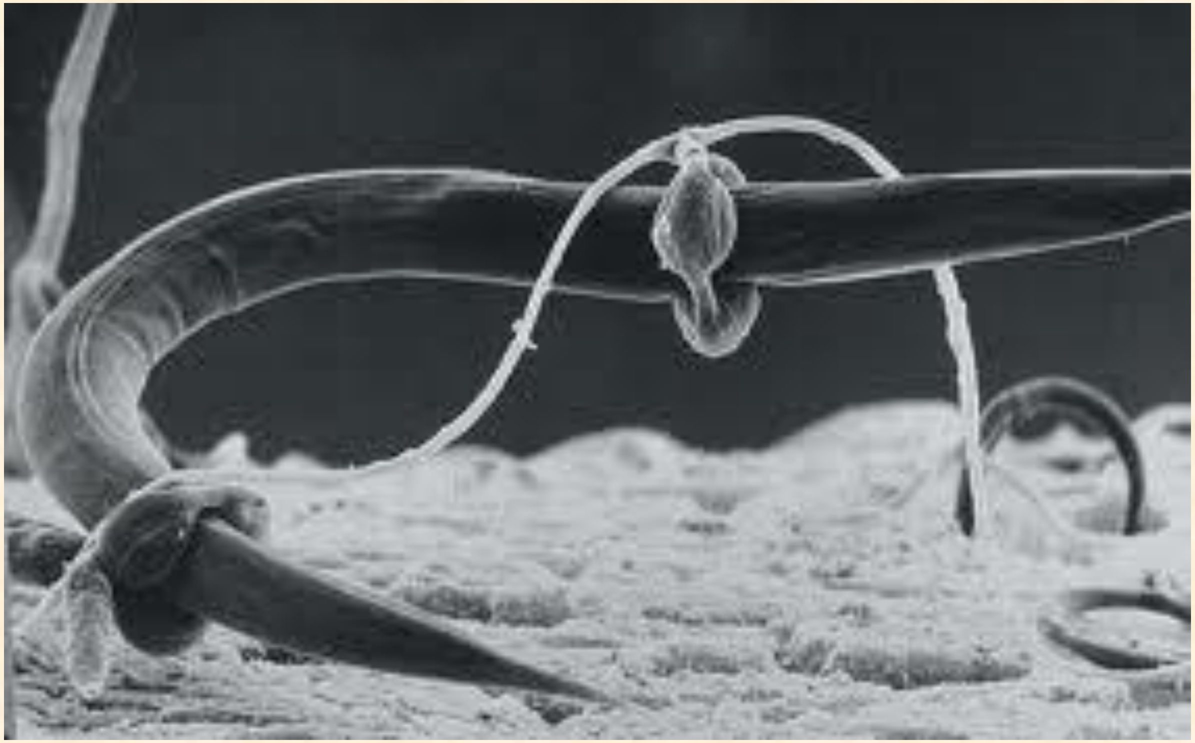
- Fungi help plants and soils in many ways
  - They are the #1 decomposer of organic material
  - By releasing water and nutrients in exchange for plant exudates (mycorrhizal fungi)
  - By releasing nutrients as they decay (much of which is nitrogen which was immobilized)
  - Some fungi produce Glomalin, a sticky protein which coats soil particles and acts as a glue. Glomalin is very important to the aggregate stability of the soil.
  - Fungi are fragile. Pesticides, compaction, inorganic fertilizers, and especially tillage can destroy fungal hyphae very quickly.

One cup of soil may hold as many bacteria as there are people on Earth.

- Why are bacteria important?
  - They are a primary decomposer of organic matter, second only to fungi.
  - They process plant material and retain vital nutrients, and excrete those nutrients for plant uptake after they are eaten or die.
  - Since most bacteria stay close to living plant roots the nutrients are released primarily within the rhizosphere, making plant uptake easy.
    - The concentration of organisms in the rhizosphere can be up to 500 times higher than in the bulk soil.
  - *Rhizobium* spp. live <u>in</u> root tissues of legumes and are the organisms responsible for Nitrogen Fixation (converting atmospheric nitrogen into a plant available form).

A single spade full of rich garden soil contains more species of organisms than can be found above ground in the entire Amazon rain forest.

- For instance, nematodes are amazingly diverse. 20,000 species have been described, but it is thought that 500,000 species may exist. Only about 5,000 soil species have been described.
- Not all nematodes are bad, but the one on the right is! This photo shows the nematode being captured by hyphal rings on a nematophagous fungus. Remember that fungi are very fragile and any number of factors can reduce their population.

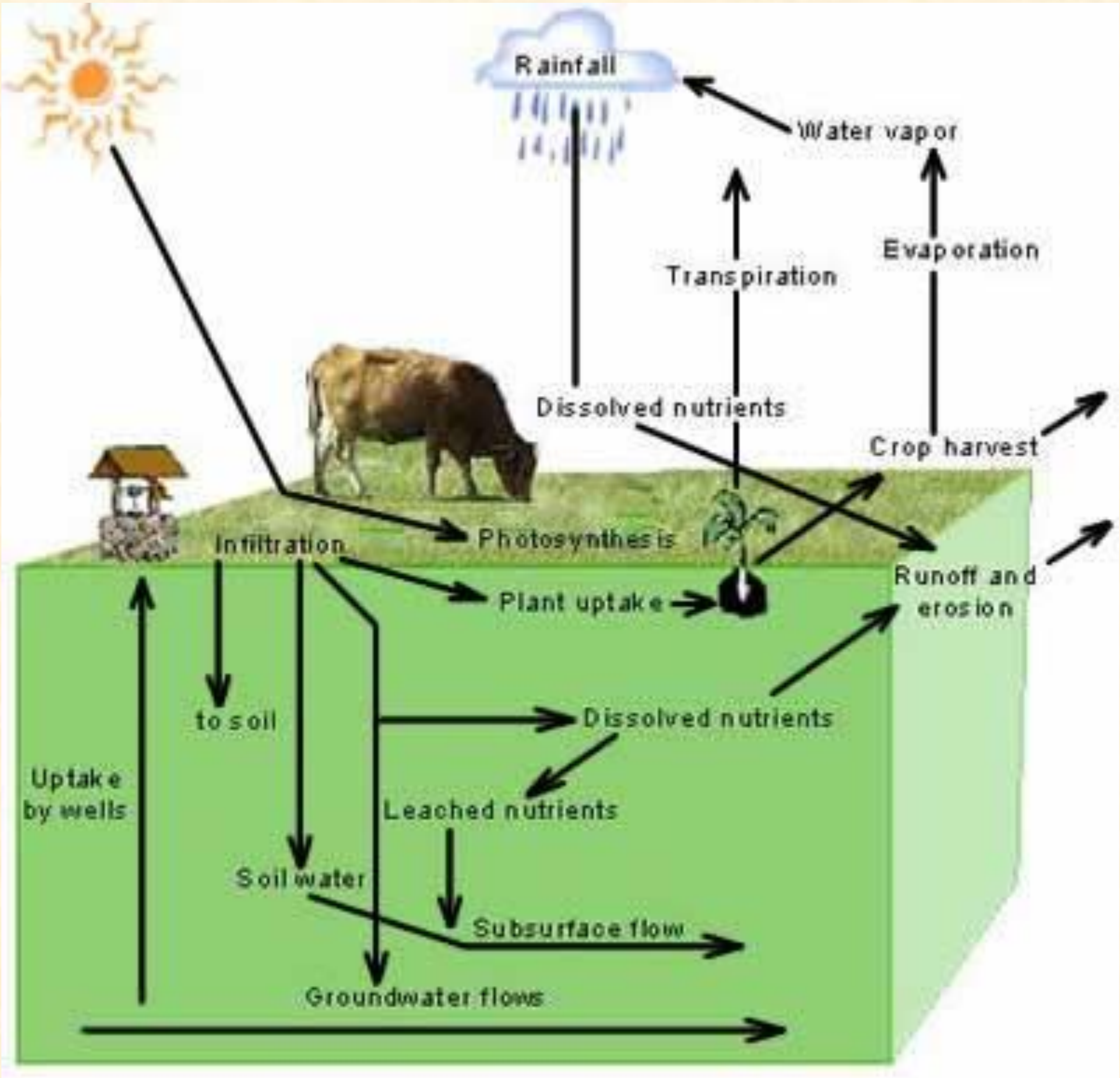


The plants growing in a 2-acre wheat field can have more than 30,000 miles of roots, greater than the circumference of the Earth.

- Roots only occupy about 3% of the soil volume or ***LESS***
  - Corn
    - 0.4%
  - Soybean
    - 0.4 to 0.9%
  - Winter Rye
    - 0.9%
  - Oats
    - 0.6%
  - Kentucky Bluegrass
    - 2.8%
- The rhizosphere surrounds these roots and is not much larger.
- Soil microorganisms can be very fragile. What we may view as small or insignificant changes to our systems can have a huge impact on them, since most of the population is concentrated in the rhizosphere.
- Whatever affects our microorganisms also has an affect on crop health and yield.

The air in the upper 8 inches of a *healthy*, well-drained soil is completely renewed about every hour.

- Many of the natural processes that affect nutrient cycling and crop productivity, including microorganisms themselves, are aerobic (they rely on oxygen).
- The ability to cycle fresh air through the soil is greatly reduced in compacted and heavily tilled soils.

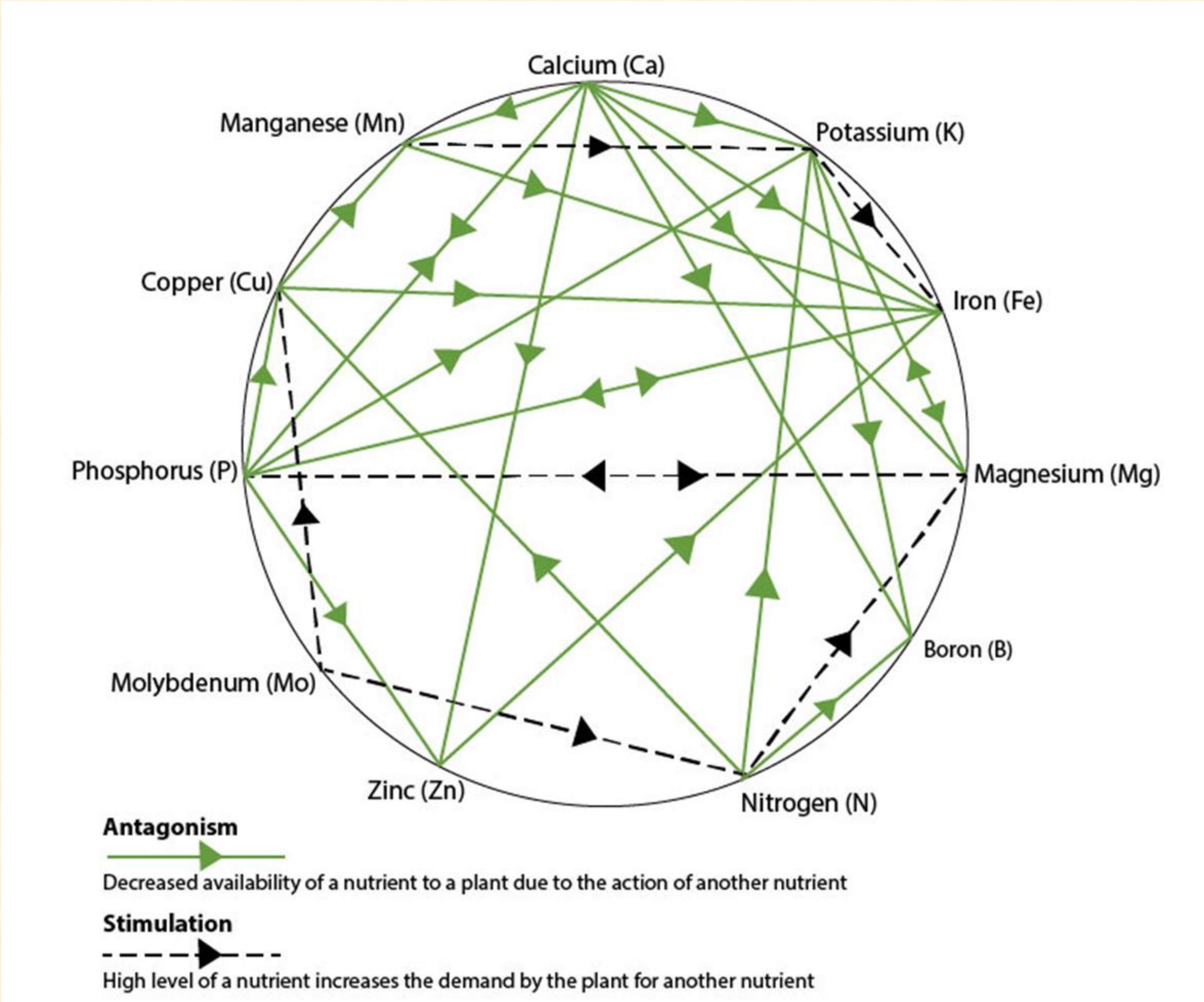


Earthworms move soil from lower strata up to the surface and move organic matter from the soil surface to lower layers. Where earthworms are active, they can turn over the top 6 inches of soil in ten to twenty years.

- Earthworms help by processing microorganisms and releasing plant available nutrients through their waste.
- Their activities increase aeration, water infiltration, nitrogen availability, and microbial activity.
- They also contribute to residue breakdown, as we will see in a video later.
- High earthworm populations are a sign of tilth and overall soil health.
- Some earthworm species can burrow as deep as 15 feet!
- The fastest way to increase populations is to reduce soil disturbance and direct-seed crops
- Directly and indirectly affect crop growth and yield in several studies

If you cut an earthworm in half, what do you get?

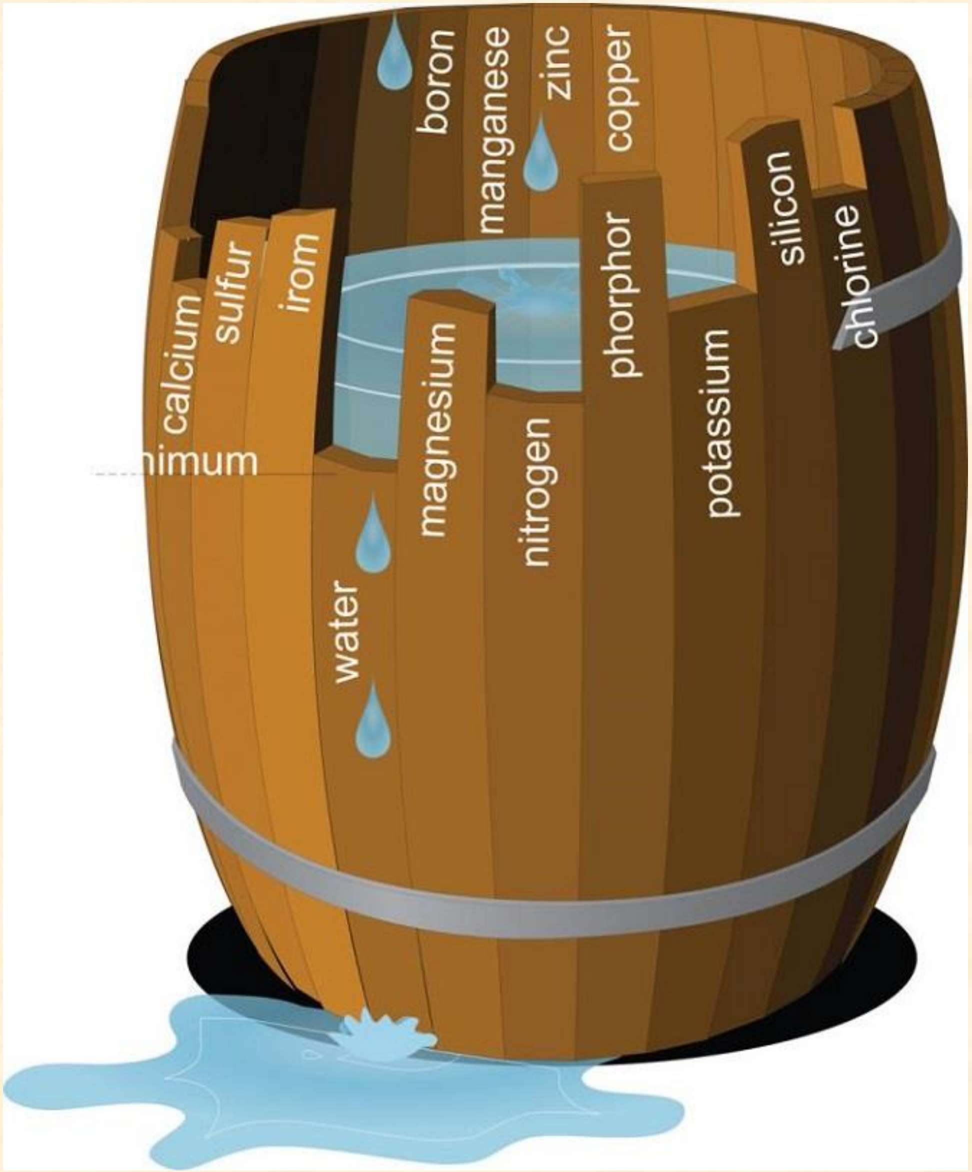
Mulder's Chart



- Stimulation (Synergy)
  - A high level of a nutrient increases the demand by a plant for another nutrient
    - Example: High levels of Molybdenum increase the demand by the plant for Copper. The same occurs in grazing animals where forages contain high levels of Molybdenum, Copper supplements are required to meet the higher demand.
- Antagonism
  - Decreased availability of a nutrient to a plant due to the action of another nutrient
    - Example: High levels of Nitrogen decrease the availability of Potassium to the plant. Potassium is vital to a large number of plant chemical processes, such as regulating NO_3 uptake by the plant.
- The interaction of soil minerals can have a huge impact on our cropping systems, and this shows how important it is for us to strive for a *balanced soil system*. If our soils are not balanced, and the microorganism populations are not plentiful, then deficiencies will result. This will result in lost yield potential.

Liebig's Law – Law of the Minimum

- Ag science principle developed in 1828 by Carl Sprengel and popularized by Justus von Liebig. Sometime's referred to as the "Barrel Stave Principle" based on the analogy used to illustrate it.
- Just as a barrel can only hold as much water as the shortest stave allows, so a crop can only yield as much as the most limiting nutrient in the system allows. The yields stand in direct relation to the most limiting nutrient.
- No matter how much more of the other nutrients are added, it will have little affect.
- Only one nutrient at a time will limit the crop.
- Balancing our soils and increasing overall soil health allows us to reduce limiting factors, such as water as seen in the picture.



Liebig's Law does not apply only to nutrients…

When we focus on soil health and manage the system as a whole, as an ecosystem, we begin to balance that whole. Nature strives for balance, so why do we fight it? It may take some time to achieve, but our work will be rewarded in the end.

- http://managingwholes.com/ (Metronome Video)

Questions?