The Latest Dirt: Research-Based Innovation in Soil Health

El Dorado Workshop
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Physical Characteristics of Soil Plant Roots and the Rhizosphere

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Topics to be Covered

- Physical Characteristics of Soil
  - Soil texture and its effects water & nutrient retention
  - Soil organic matter and soil aggregation
  - Soil structure and effects of tilling & compaction
- Plant Roots and the Rhizosphere
  - Root structure and Rhizosphere
  - Mycorrhizae

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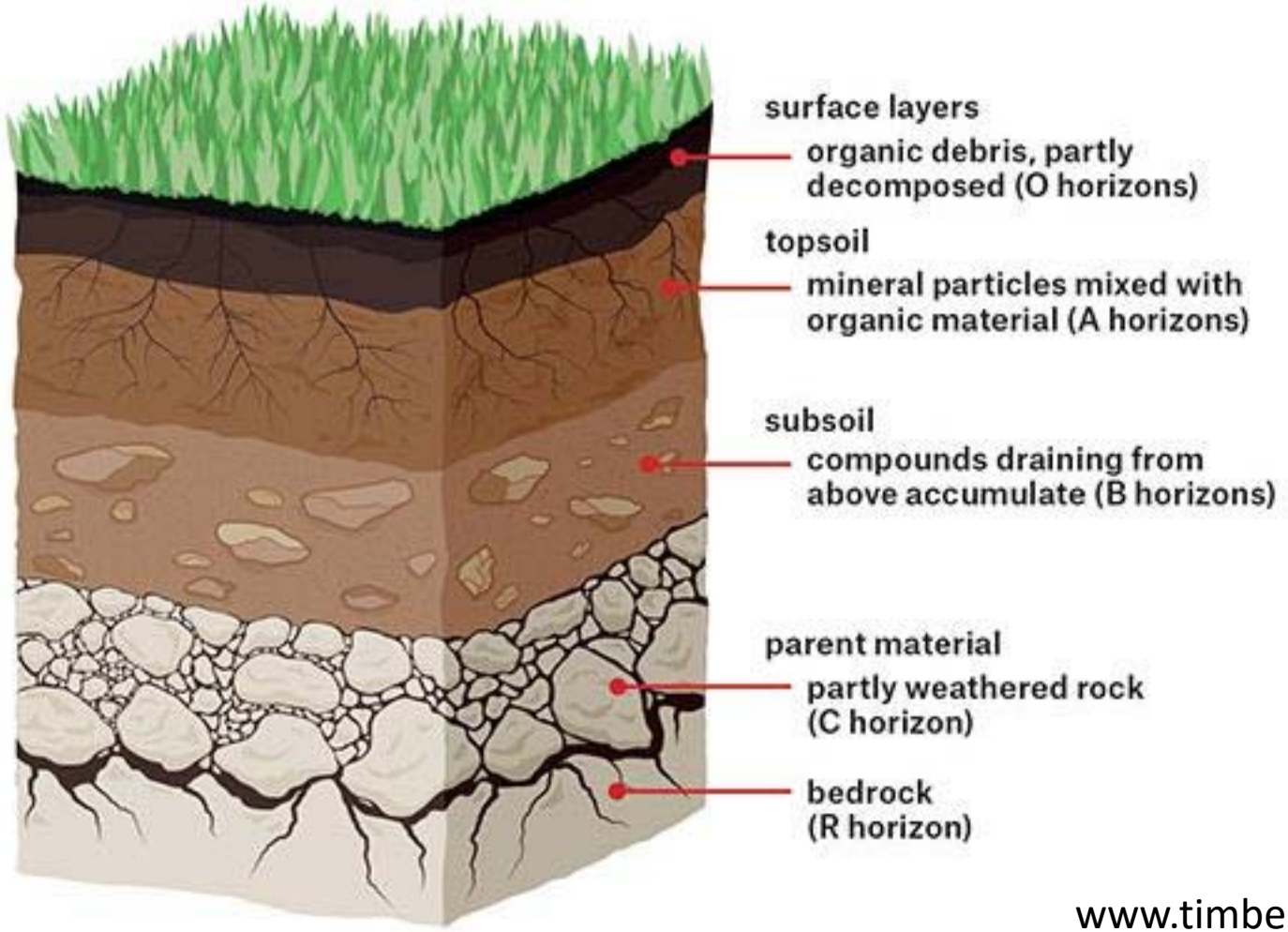
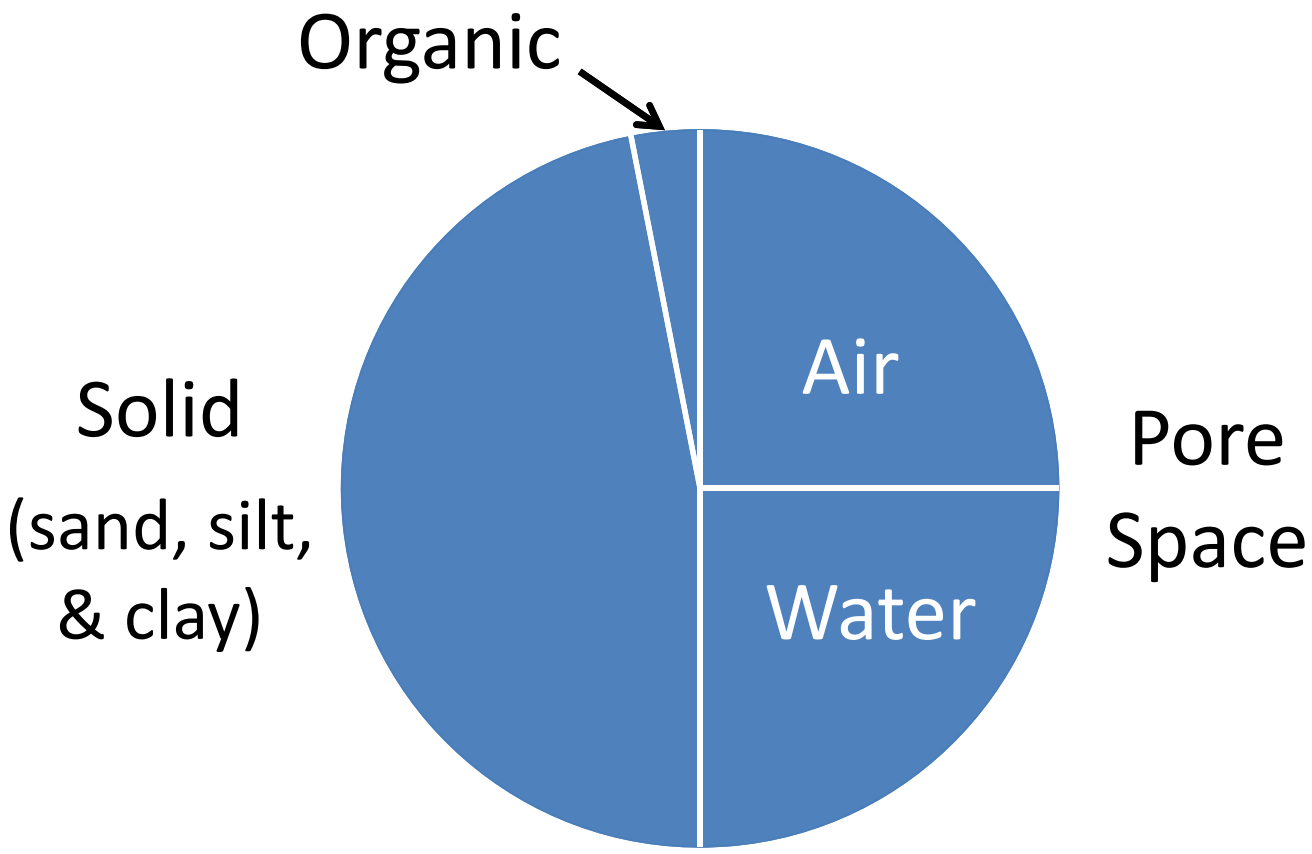
Typical Soil Profile



www.timberpress.com

Makeup of Soils



Physical Characteristics of Soil

Sandy loam

✓Texture

Clay loam

✓Structure

Soil Texture vs. Structure

Texture: Percent sand/silt/clay

- Examples: sandy loam, clay loam

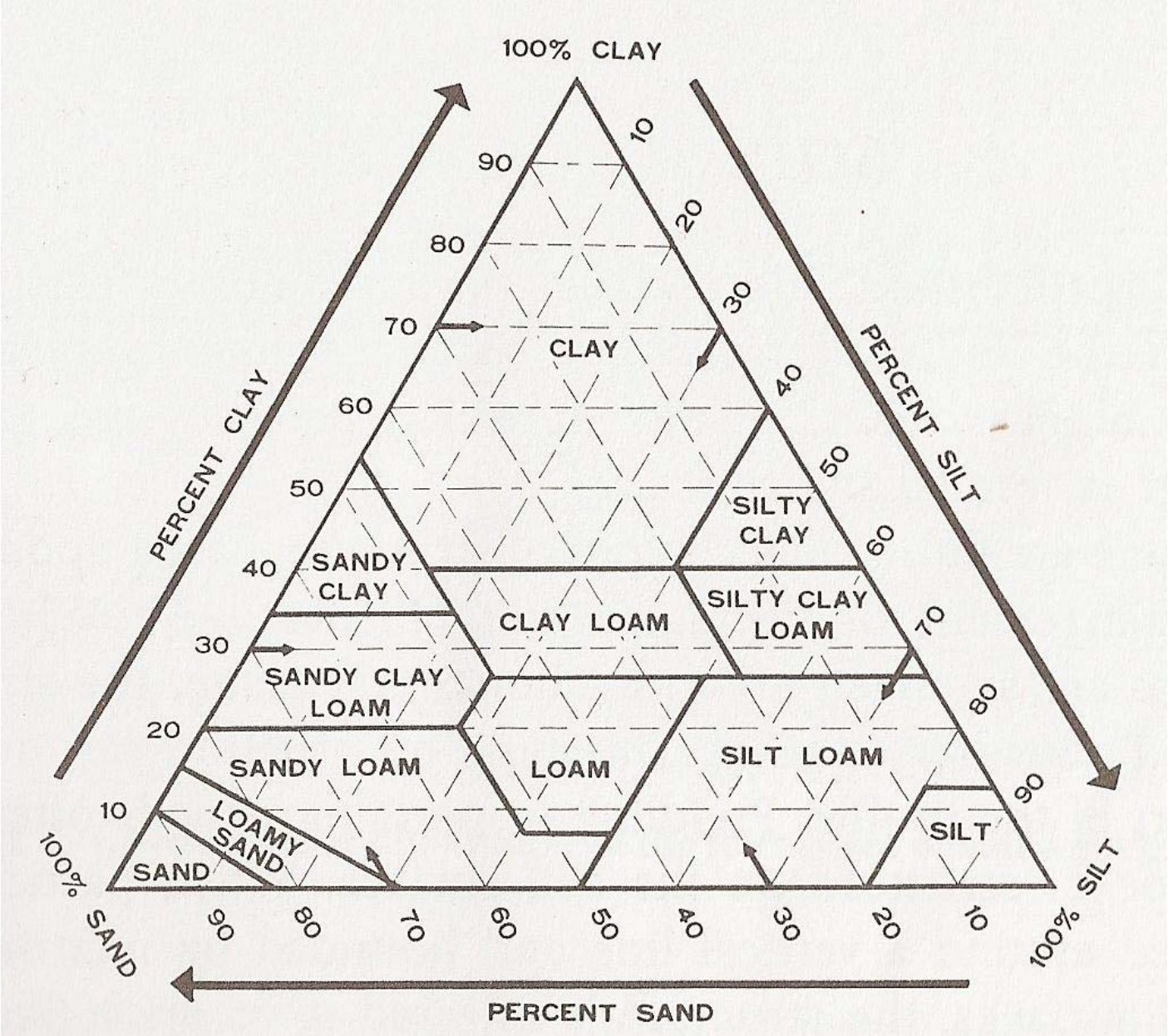
Impractical to change

Structure: Arrangement of particles into aggregates, clods, crusts, pans, etc.

- Affected by compaction

Can be changed – for better or worse

Soil Texture



The Soil Triangle

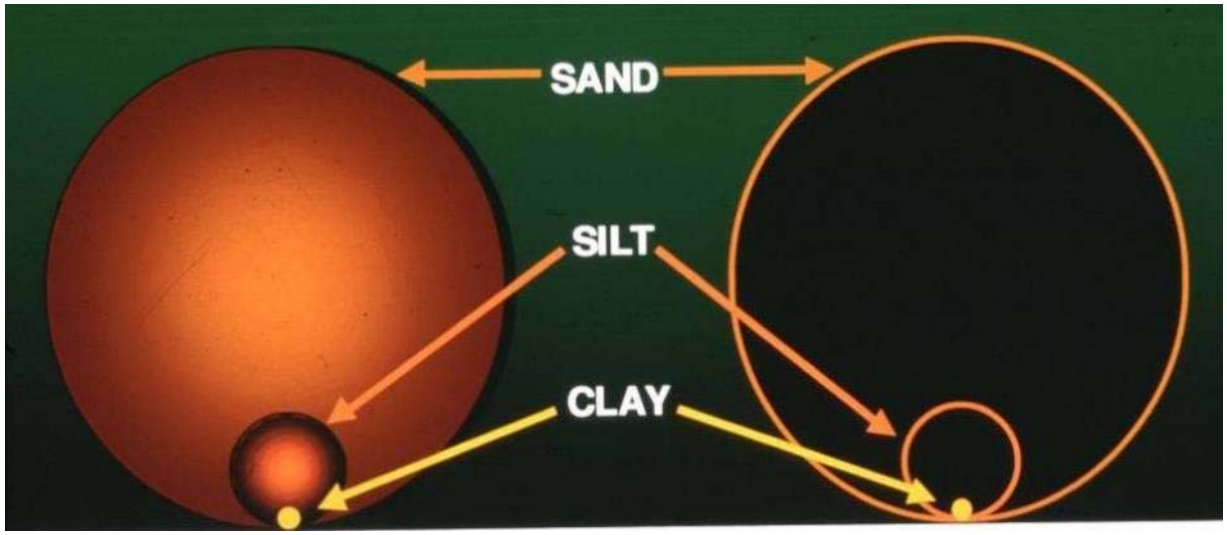
(Based on lab analysis)

Soil Particle Sizes

Sand 2.00 to 0.05 mm

Silt 0.05 to 0.002 mm

Clay 0.002 to <0.0002 mm

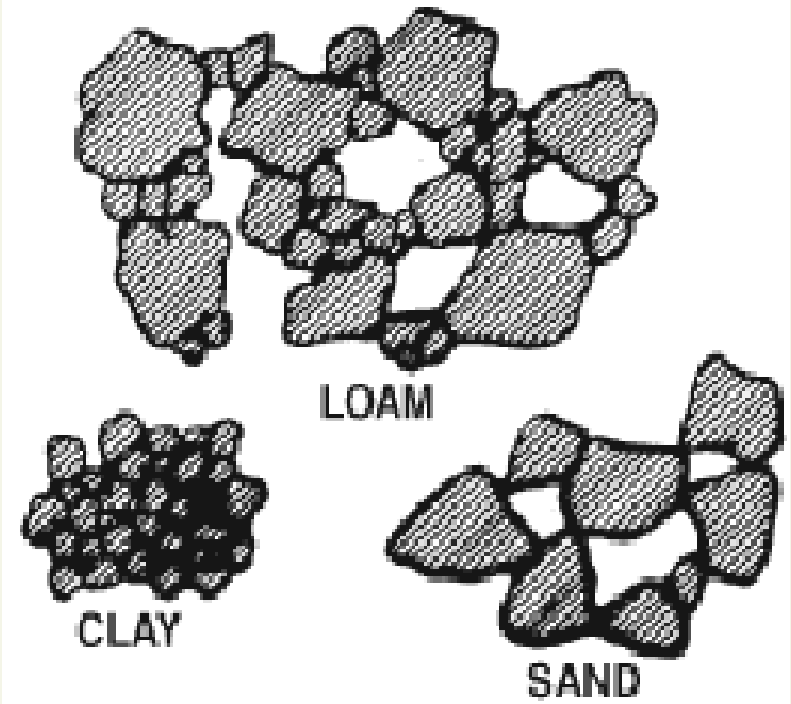


Soil Texture

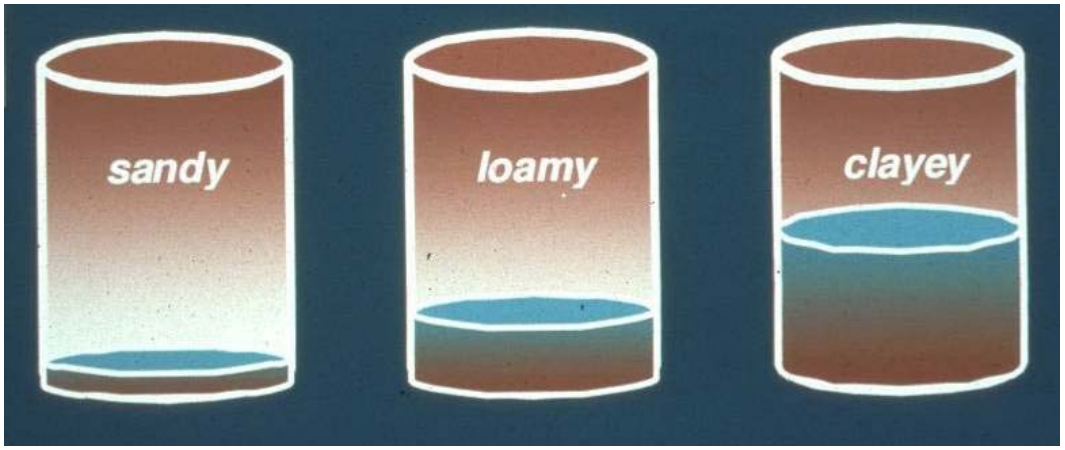
Loamy sand
Sandy loam
Loam
Silty loam
Clay loam
Clay
Silty clay
Sandy clay

LIGHT

HEAVY

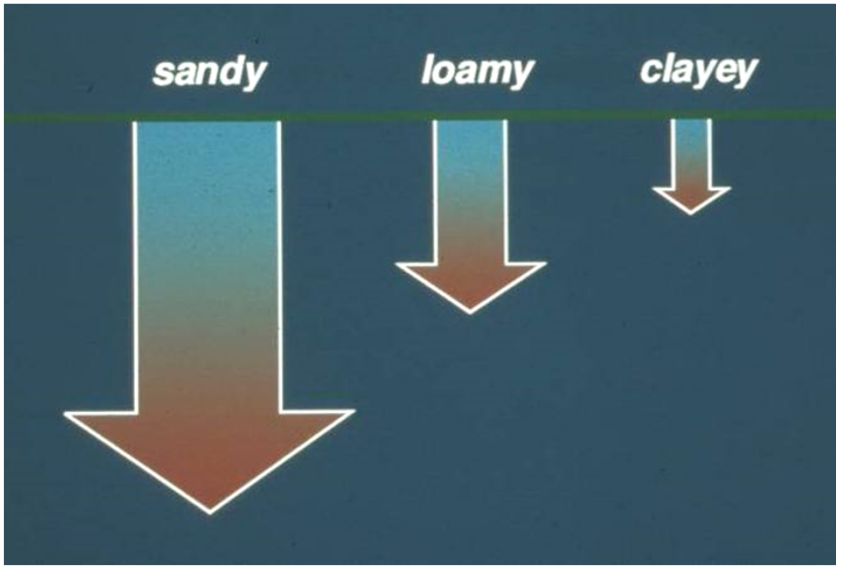


Soil Texture Affects Soil Moisture

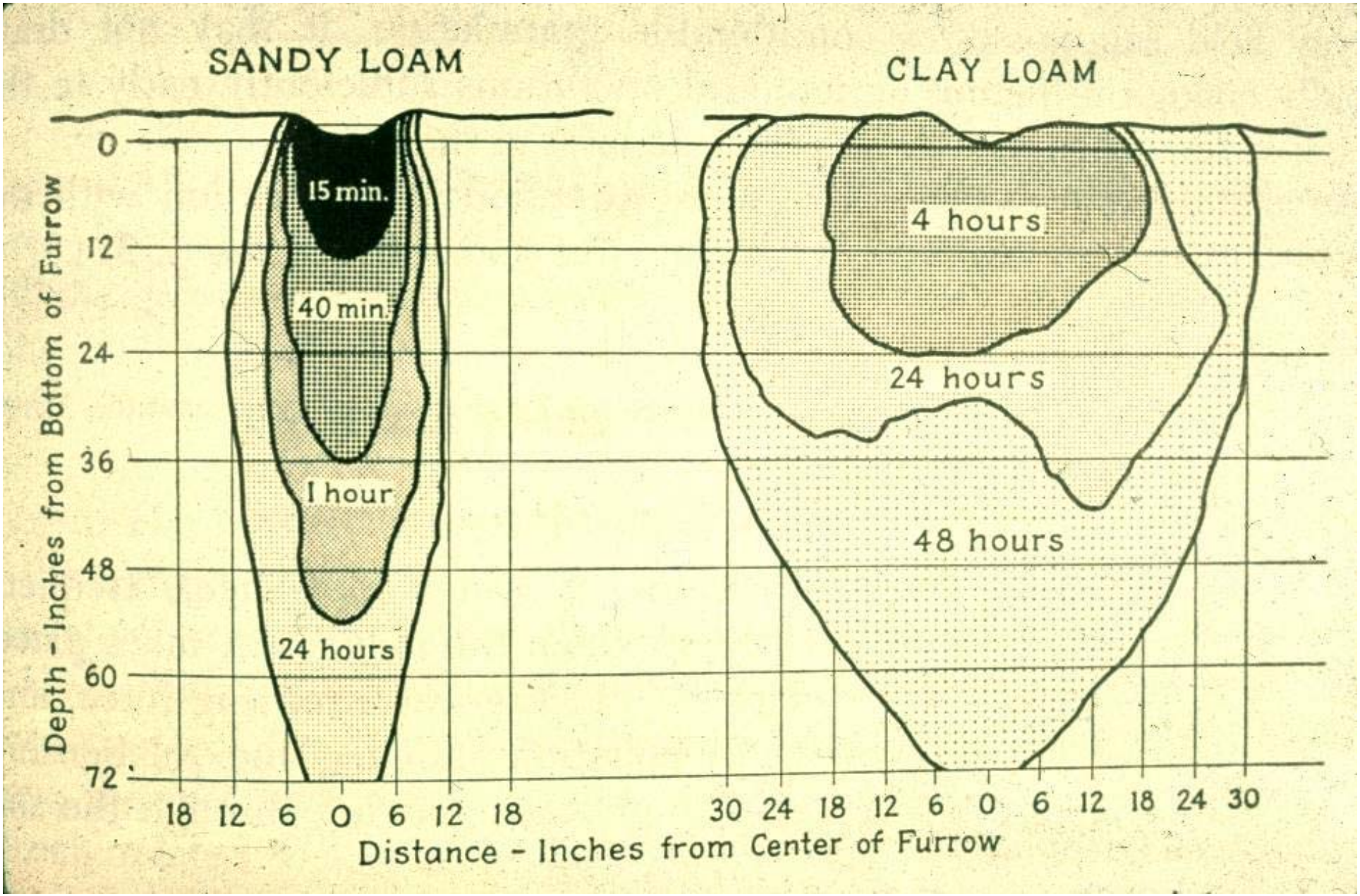


Water Holding Capacity

Permeability



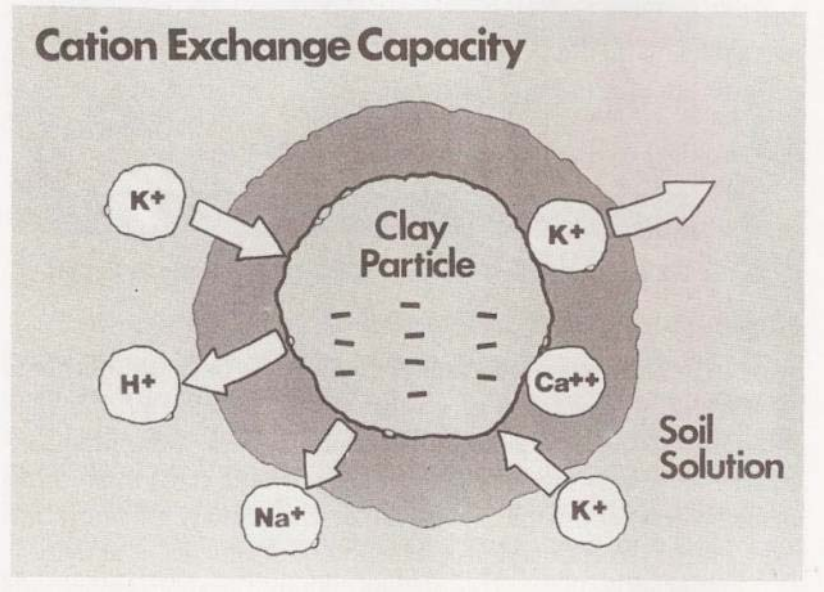
Water Infiltration through Soils



Capillary Water Movement in Clay Loam Soil

Cation Exchange Capacity (CEC)

- A measure of soil fertility (soil analysis)
- Cations in soil solution in dynamic equilibrium with clay & humus particles
- Varies by soil type and % organic matter



High vs. Low CEC

CEC 11-50

- High clay or OM content
- Greater capacity to hold nutrients
- More lime or sulfur needed to adjust pH
- High water-holding capacity

CEC 1-10

- High sand content
- N & K leaching more likely
- Less lime or sulfur needed to adjust pH
- Low water-holding capacity

Typical CECs Based on Soil Texture

Soil Texture	Typical CEC Range
	meq/100g
Sand	2 – 6
Sandy Loam	3 – 8
Loam	7 – 15
Silt Loam	10 – 18
Clay & Clay Loam	15 – 30

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Soil Organic Matter

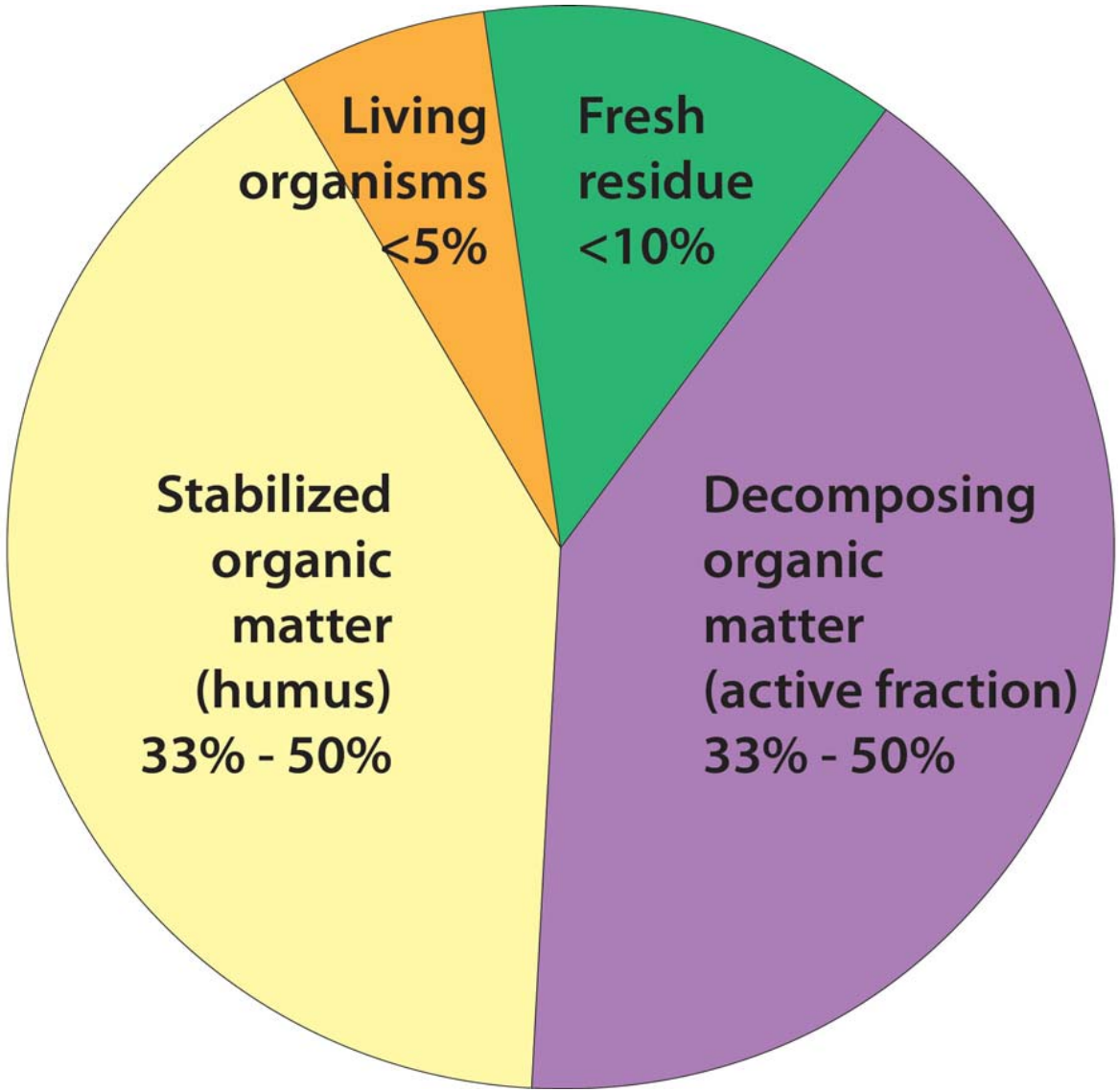
- Serves as energy source (food) for microbes, which promote aggregation
- Essential nutrients are obtained by plants as OM decomposes
- Enhanced by OM additions but destroyed by cultivation

Soil Organic Matter Loss

Recent Research

Sources: Univ. of Minnesota, Ohio State Univ.

Makeup of Soil Organic Matter

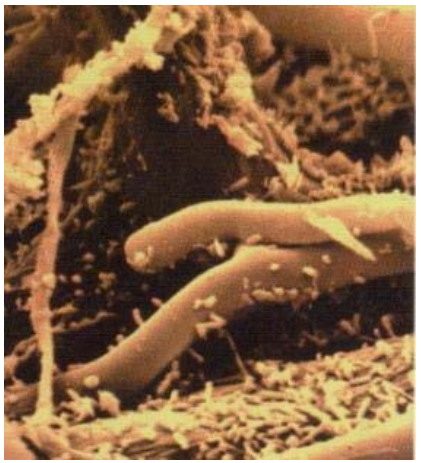


Humus

- What's left over after organic matter decomposes
- Cannot be seen by naked eye
- Very reactive (CEC)
- In equilibrium with organic matter additions

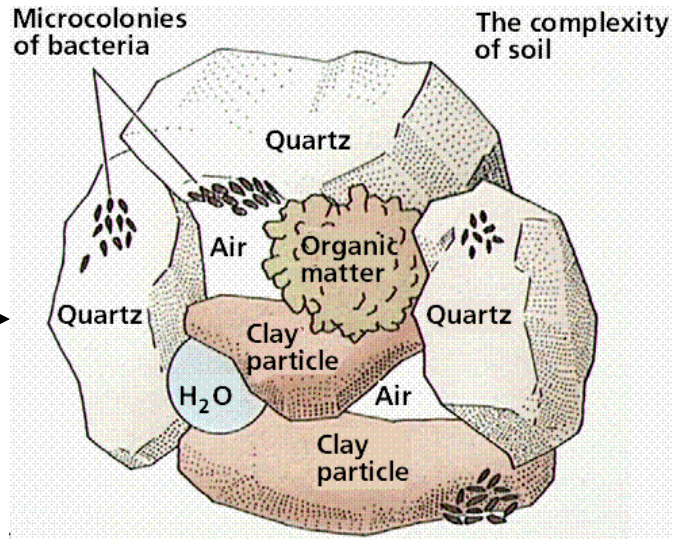
Soil Aggregate Formation

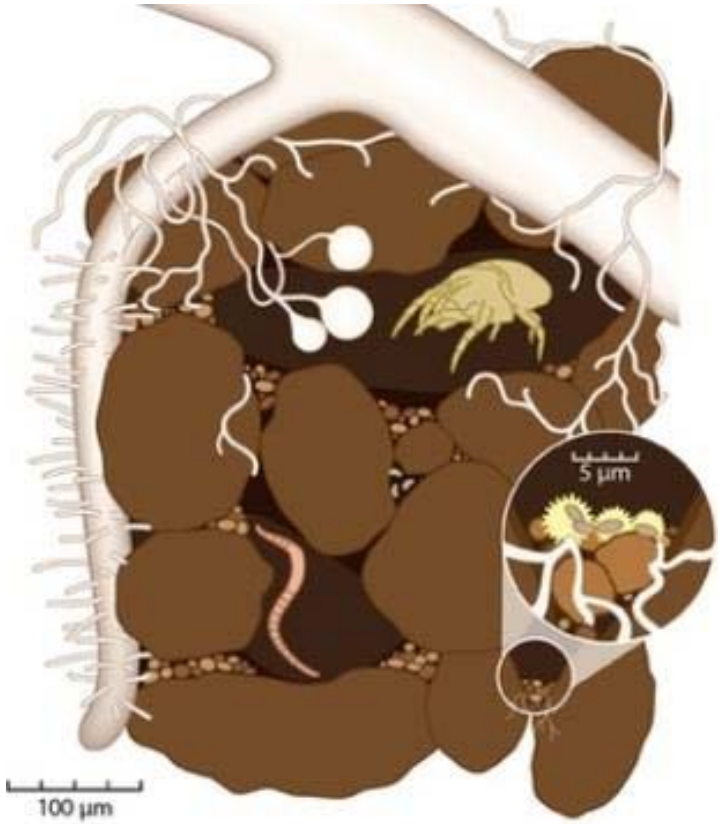
Humus, OM, plant & microbial exudates, and earthworm castings act as "binding" agents



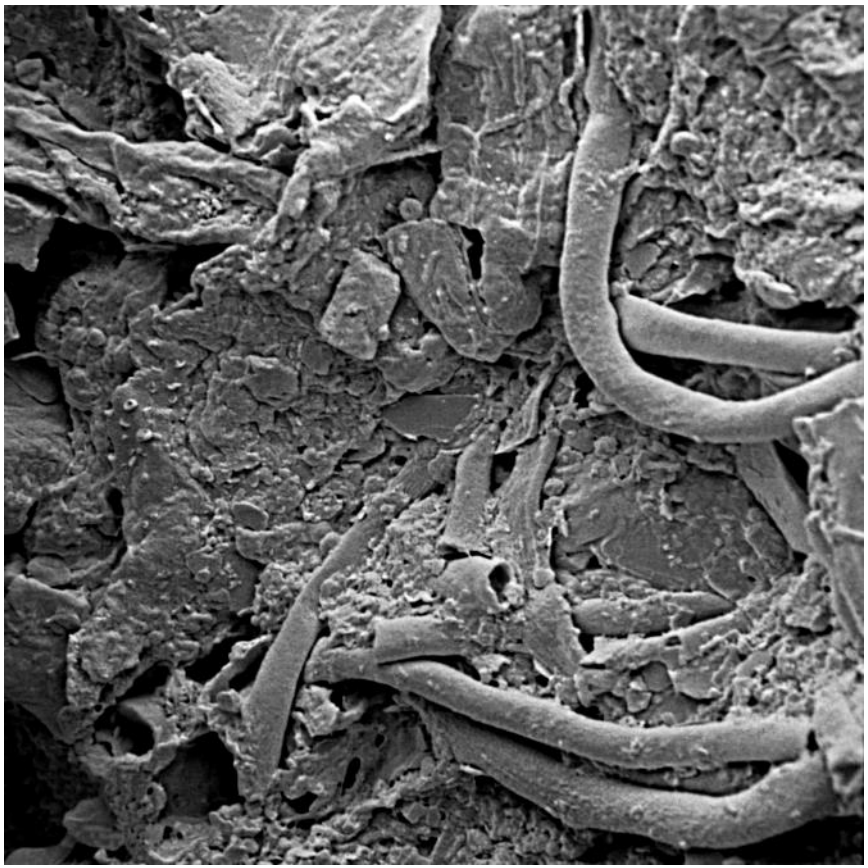
Soil Aggregation

- Bacterial polysaccharides, etc. – micro-aggregate formation
- Fungal hyphae – enmeshing micro-aggregates into macro-aggregates



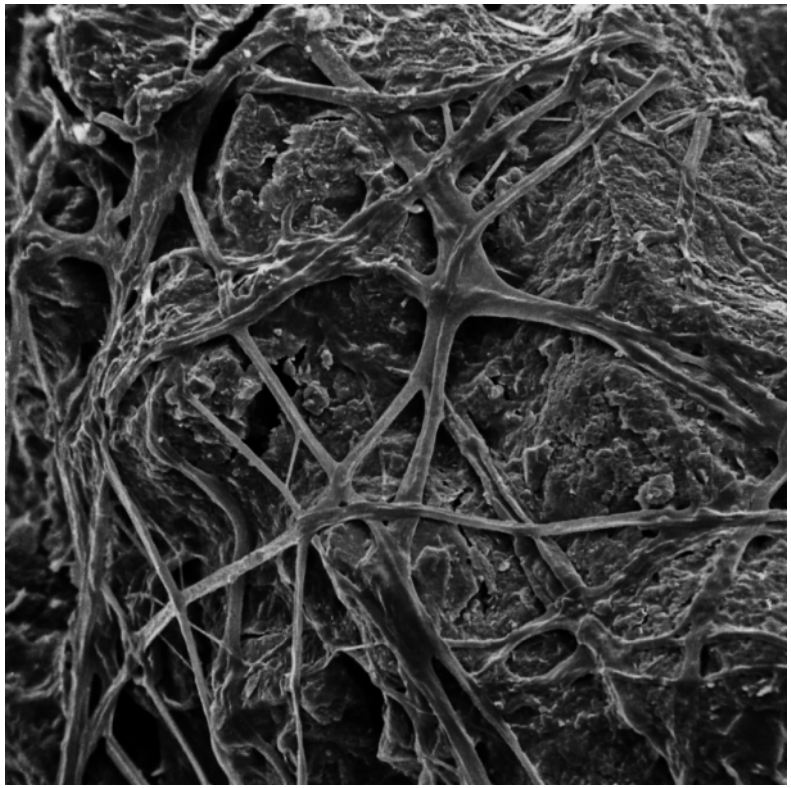


Fungal hyphae growing through the soil



http://www.microped.uni-bremen.de/SEM_index.htm

Netlike fungal mycelia can stabilize micro-aggregates



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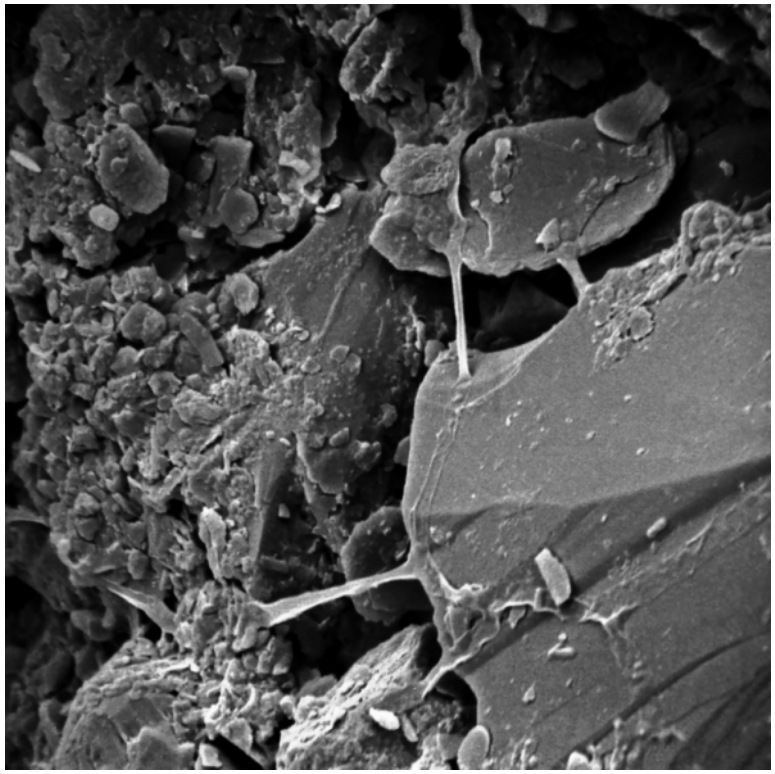
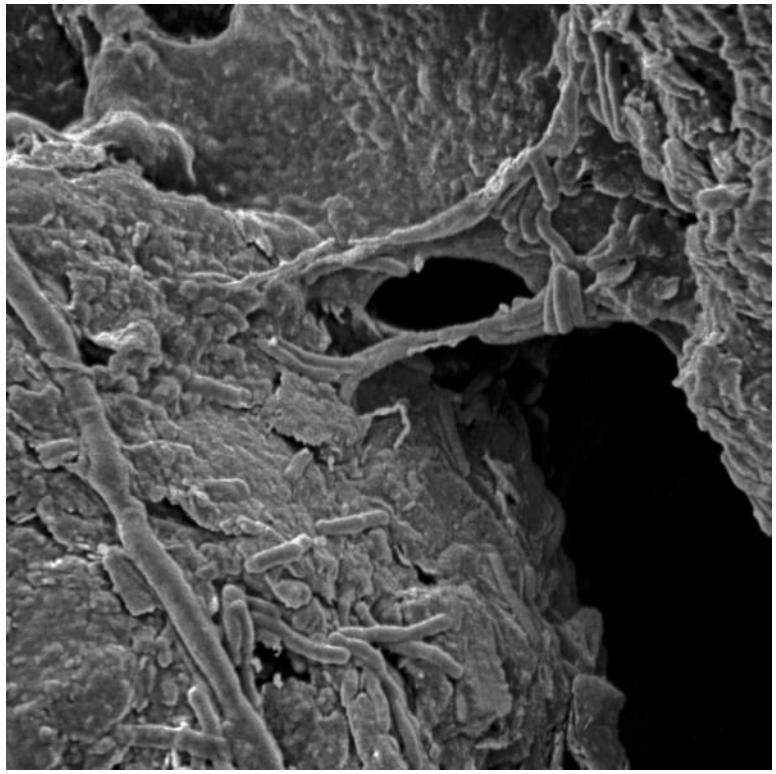
Stabilization of Soil Structure by Actinomycete Filaments





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Tillage vs. No-Till

Effects on Soil Aggregation

No-till Tilled

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Soil Structure

Structure - the arrangement of soil particles into aggregates

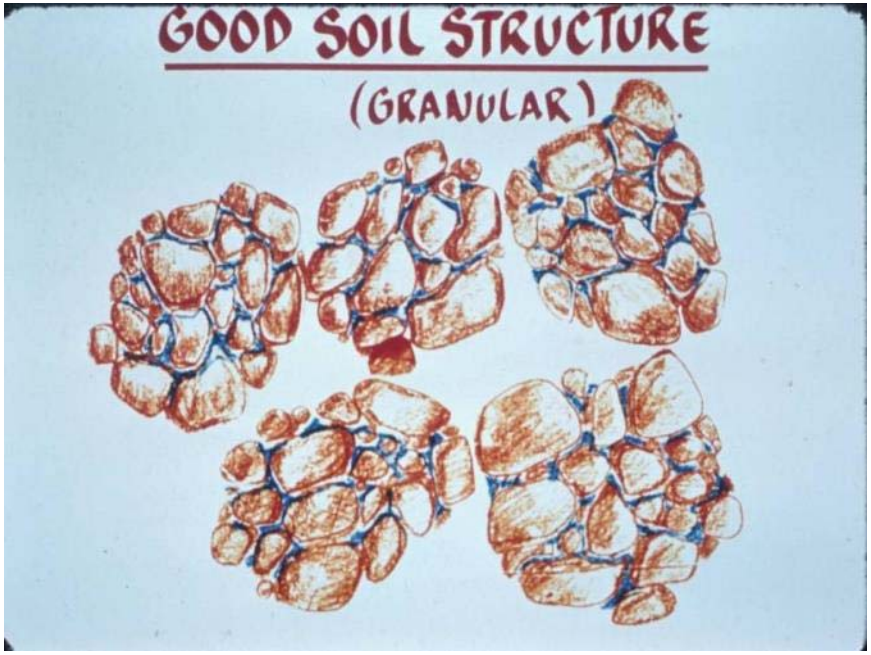
Good structure: holds water (micropore space) and has air space (macropore space)

Poor structure: lacks adequate macropore space

A Key Goal = Good Soil Tilth

Soil Structure May Vary Greatly

Good vs. Poor Soil Structure



Effects of Compaction on Soil

- Soil structure is destroyed – pore space is severely reduced
- Soil drains slowly and is prone to being anaerobic
- Compacted soil physically impedes root growth

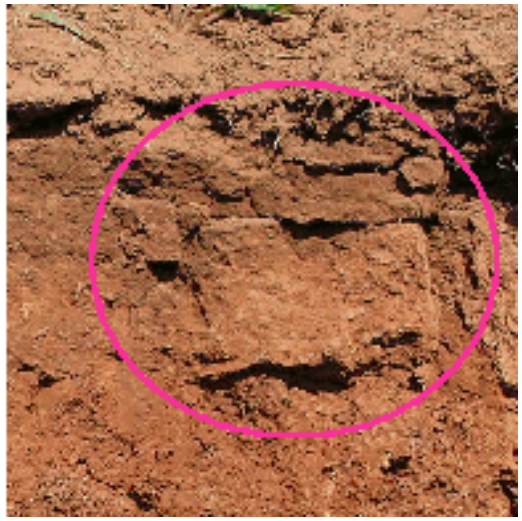
Some Soil Layers Restrict Air, Water, and Root Penetration

- Hardpan – cemented (by silica, iron, carbonates)
- Traffic or compaction pan – caused by vehicles, tillage implements, feet, hooves
- Crust – brittle, compact/hard when dry
- Claypan – higher clay than overlying layer

Tire Compaction

Avoid Traffic on Wet Soil

No compaction, good aggregation

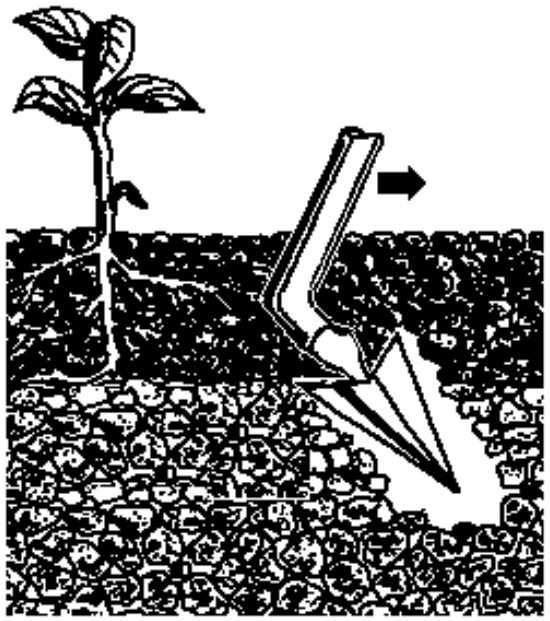


Compaction, no aggregates

Plow Pan

Plow Pan

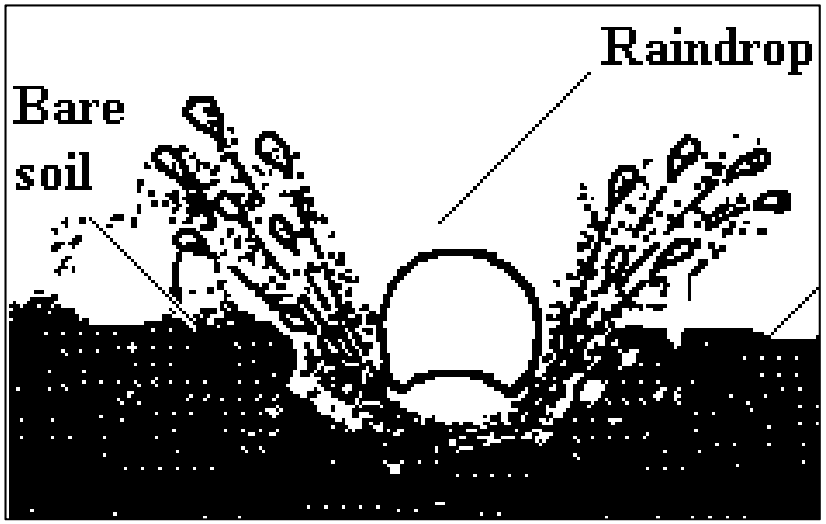
Disked Soil
(18 mo. Ago)



Ripping to break up plow pan

Crust Forms on Unprotected Soil

Rainfall or Sprinklers



Cemented Hardpan

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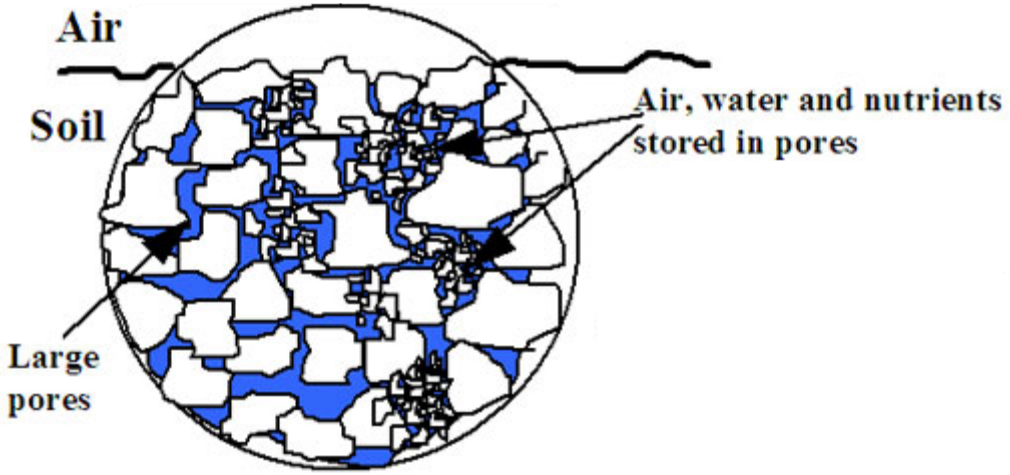
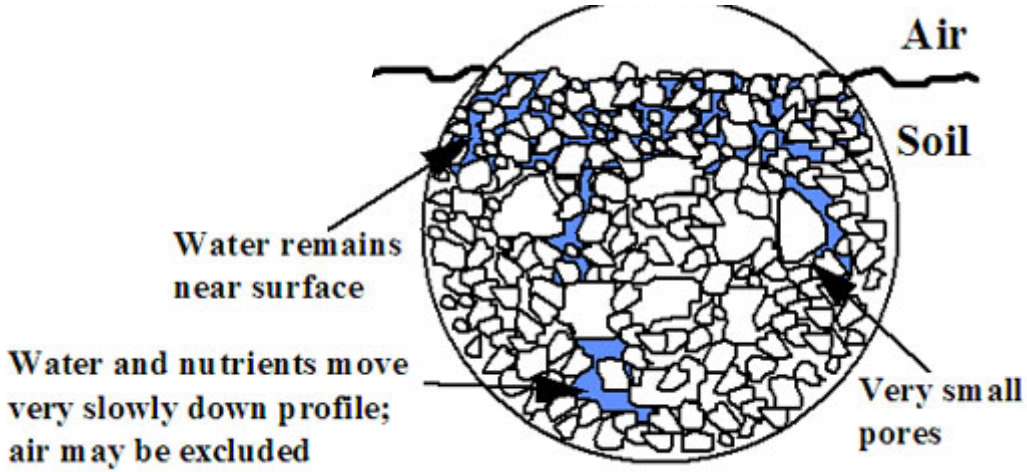
Water Movement in Soils



Well Structured Soil

Poorly Structured/ Compacted Soil



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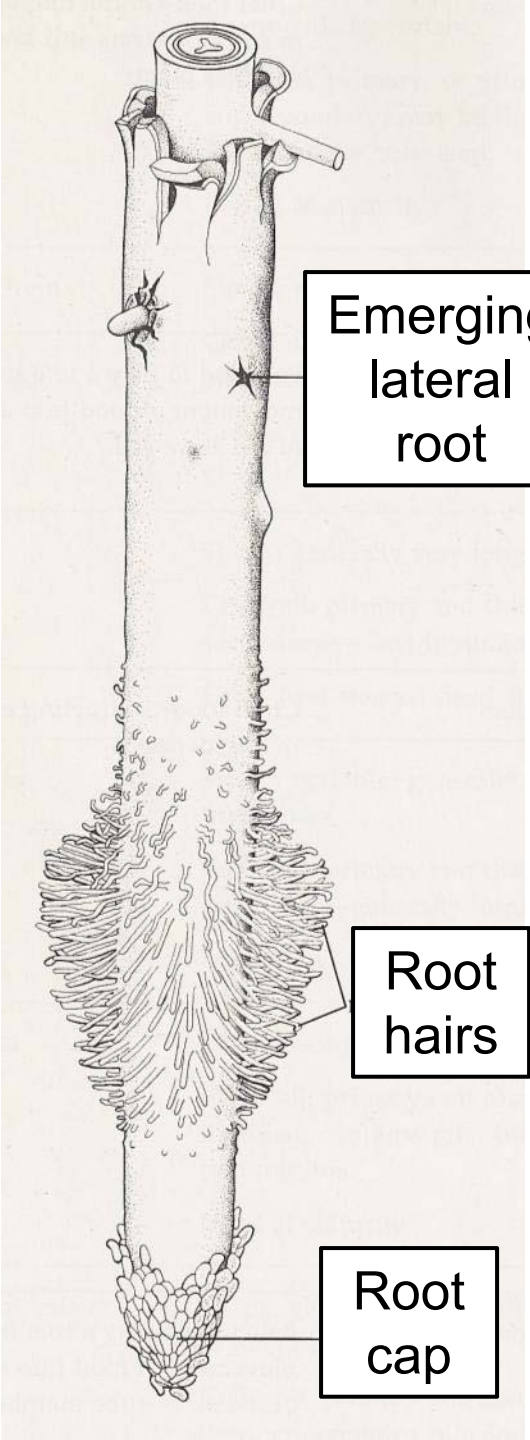
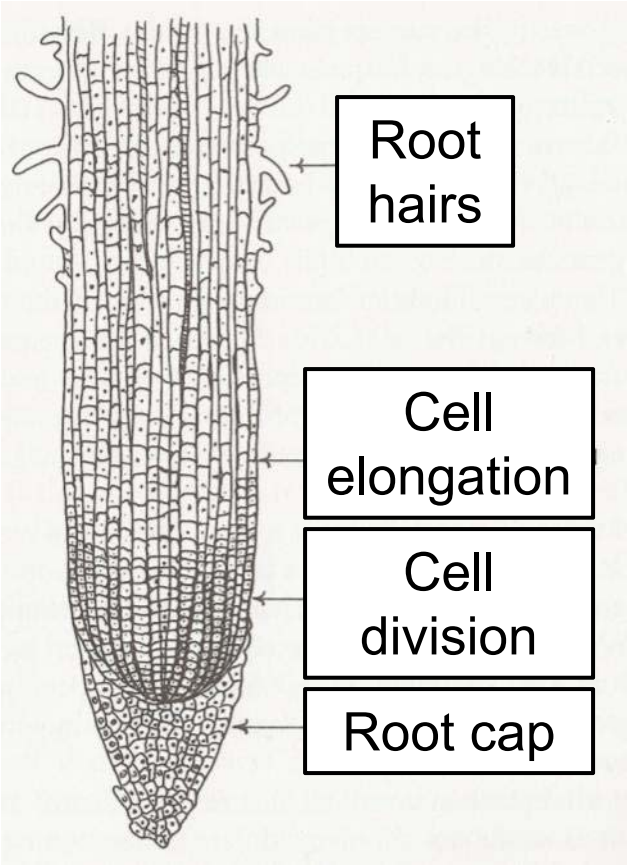
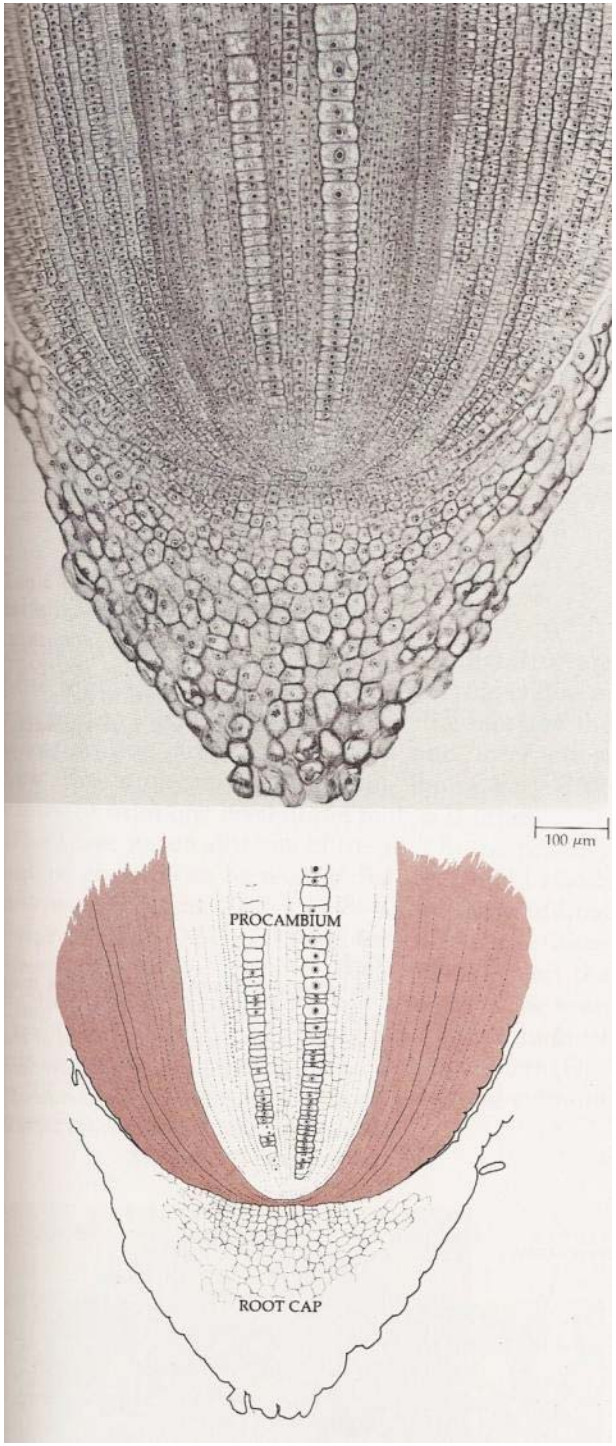
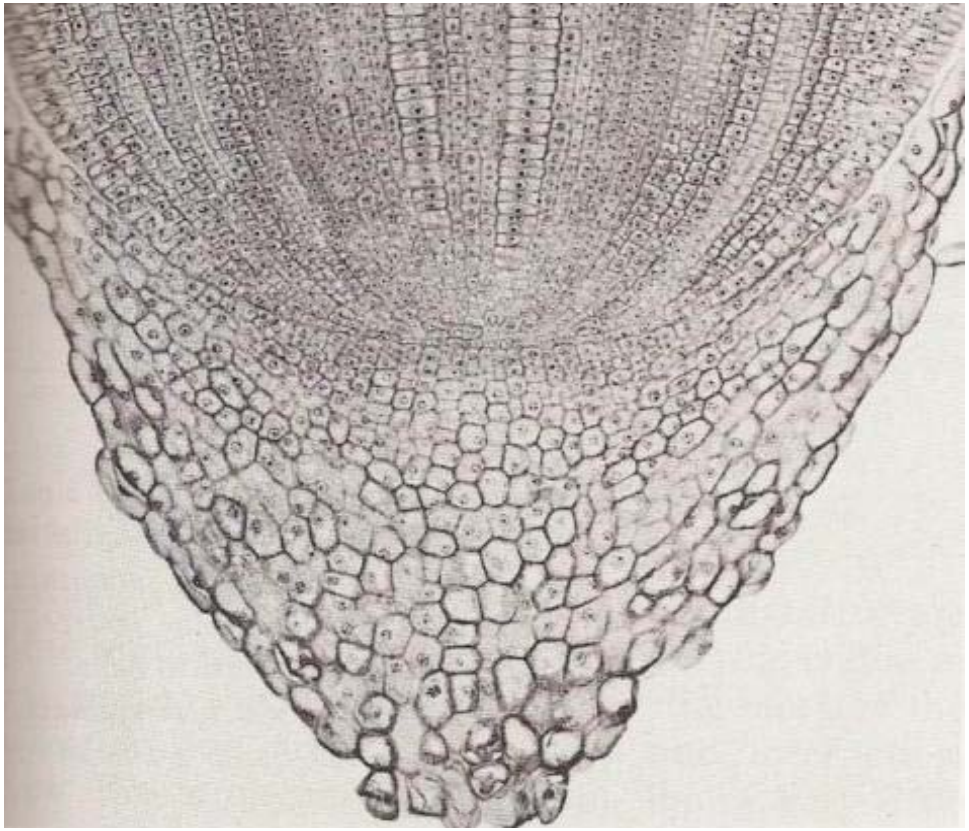
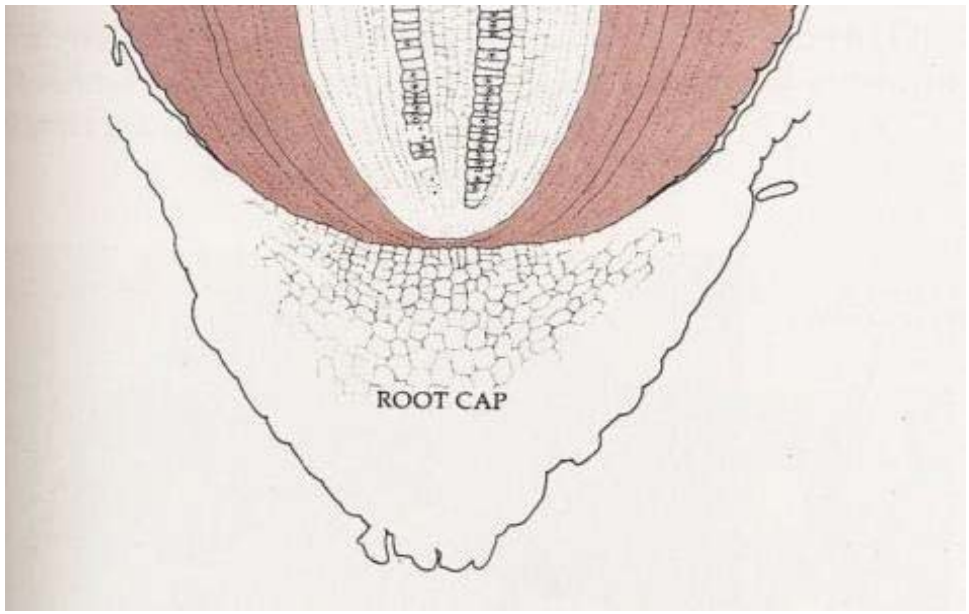
Anatomy of Young Roots







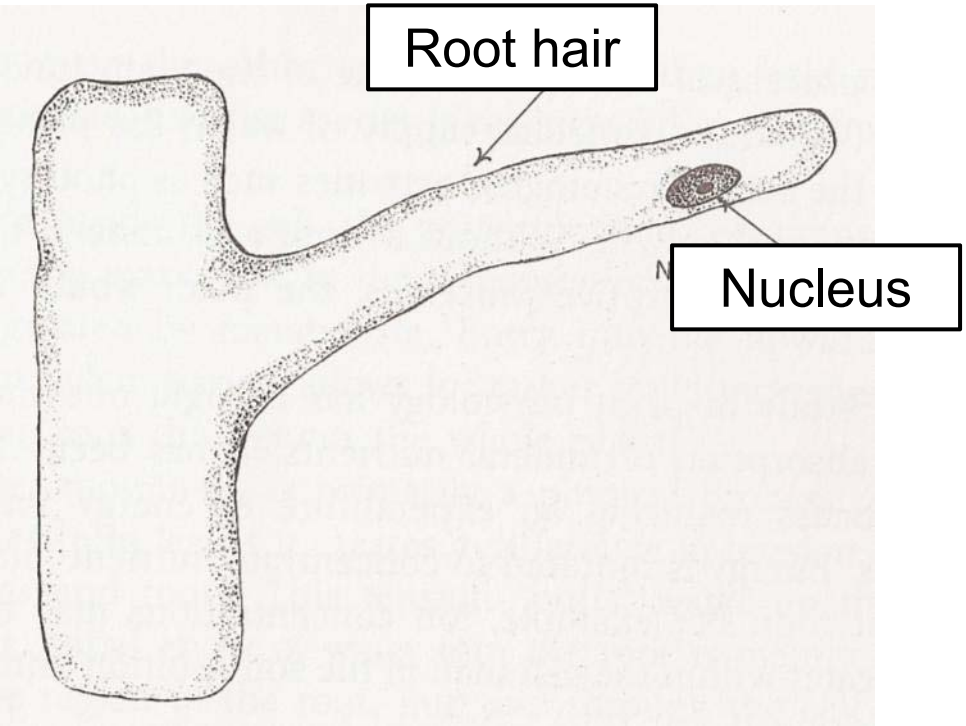




Root Cap

- Covers apical meristem
- Grouping of cells held within slimy “mucigel”
- Protects & lubricates root tip as it grows
- Cells slough off, improving soil aggregate formation

Root Hairs



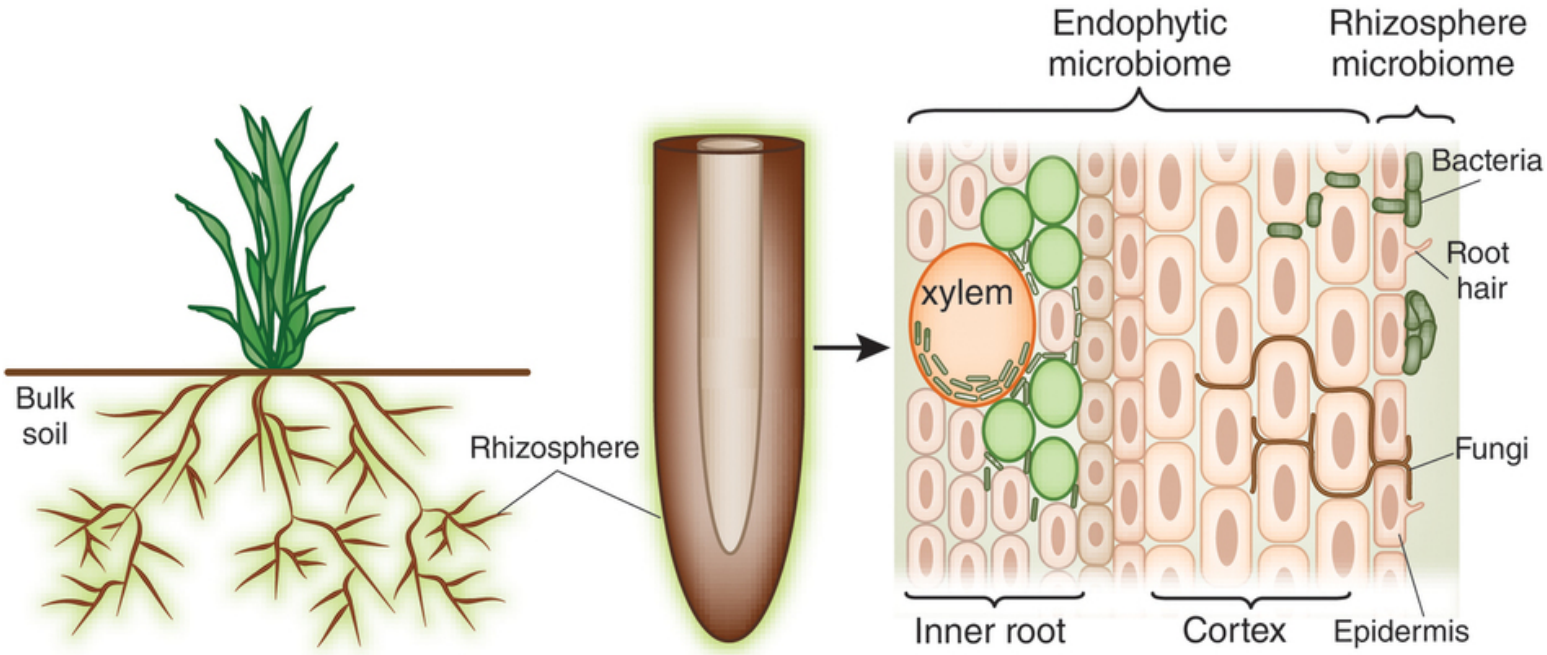
- Cells, not roots!
- Greatly increase root surface area
- Very short lived

The Rhizosphere

- Thin region of soil that is directly influenced by root secretions (exudates) and soil microbes
- Exudates include amino acids, sugars, & acids
- Functions of exudates:
  - Protect against pathogens
  - Obtain nutrients
  - Stabilize soil aggregates

Plant Roots Feed the Microbes!

- Use 25-40% of carbohydrate supplies to feed microbes
- Use hormones to attract and “farm” bacteria, fungi, and other organisms to help recycle soil nutrients & water



Sources:
1. J. Hoorman, Ohio State Univ.
2. www.nature.com

Rhizosphere

- Living roots release organic substances into the rhizosphere
- There are over 1000 times more microbes associated with a live root than in the bulk soil

Source: J. Hoorman, Ohio State Univ.

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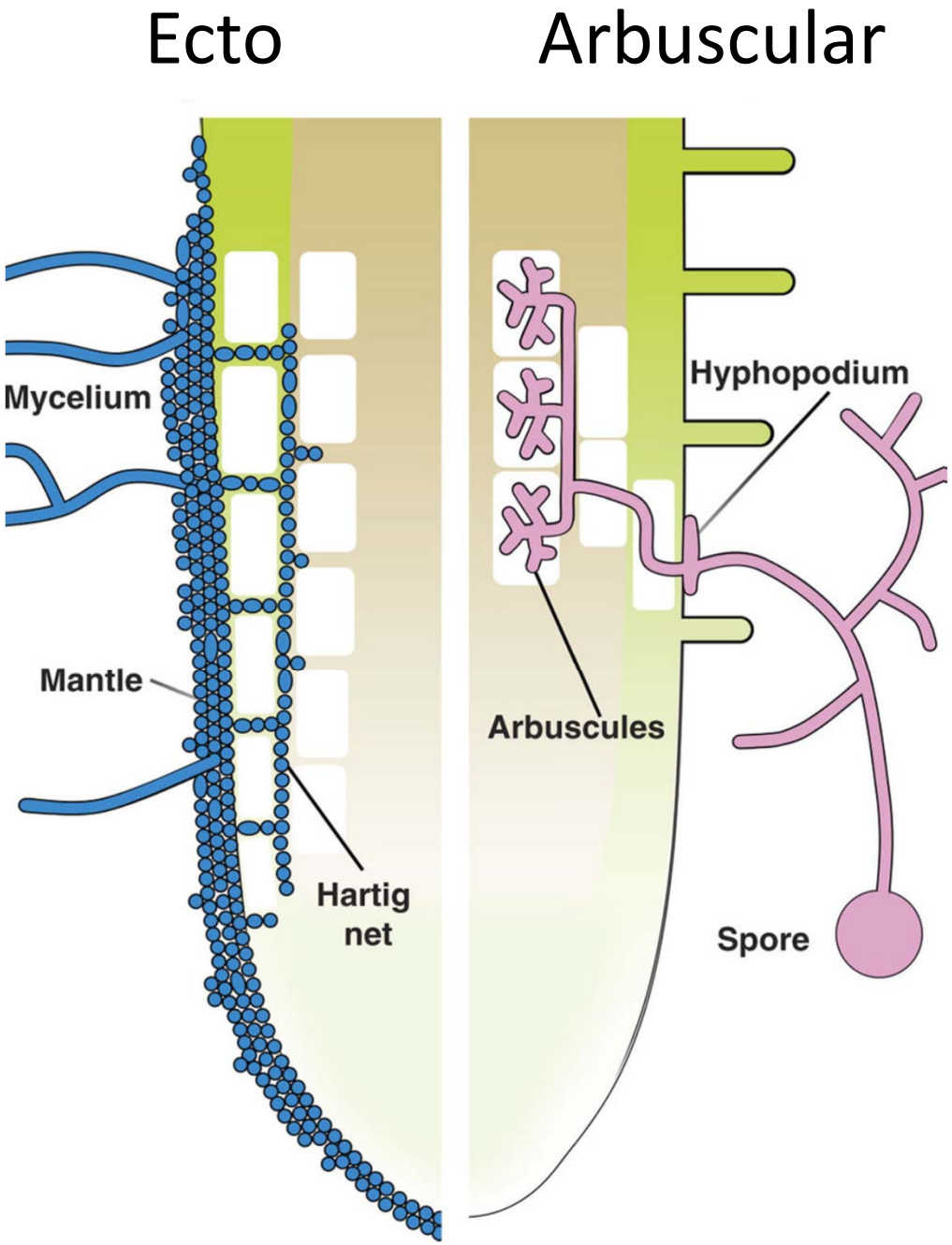
Mycorrhizae

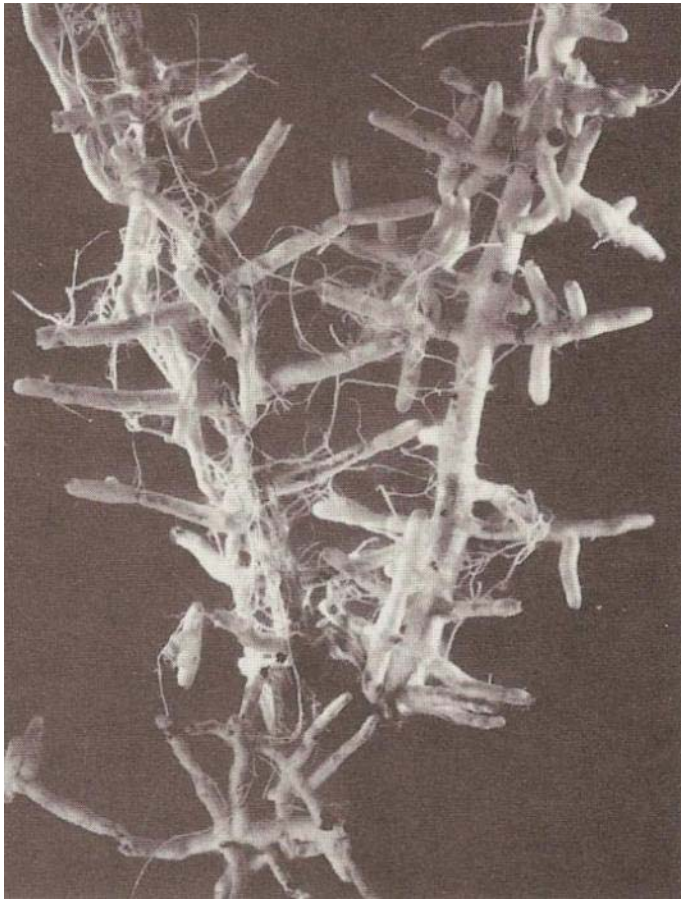
("Fungus-Roots")

- Fungal infection of roots – symbiotic relationship
- Fungi – receive sugars; Plants – phosphorus & water
- Help roots explore up to 20x the volume of soil
  - Increases plant resistance to drought
- Lacking only in sedges & brassicas (cabbage fam.)
- Poor growth without myc. where nutrients limited
- Soil inoculation helpful only in poor/disturbed soils
- Two main types: Ecto- and endo-mycorrhizae

Mycorrhizal Fungus



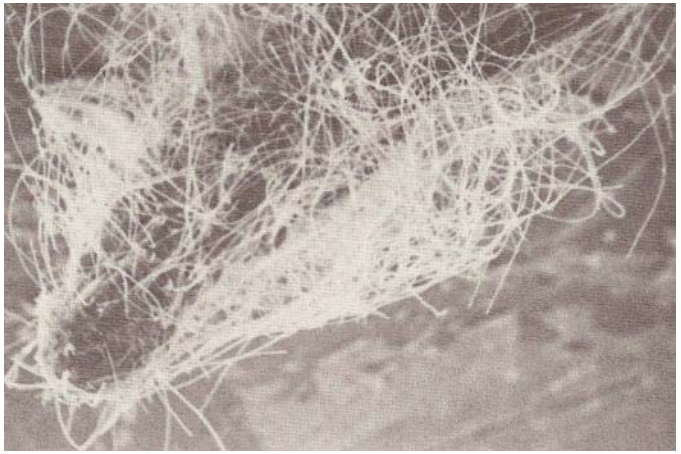
Sources: Bonfante & Genre 2010, Astrid Volder, UCD

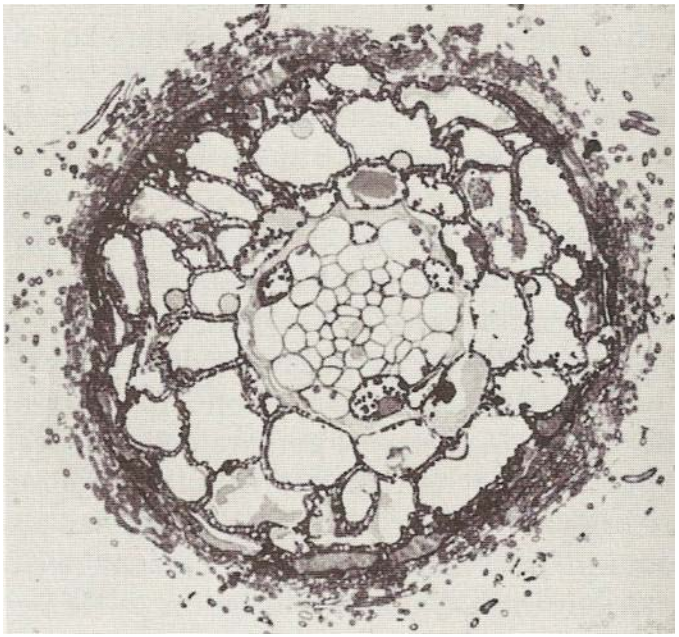


Mycorrhizal Fungi

Ecto-Mycorrhizae

- Grow on trees in pine, oak, beech, birch, and willow families
- Grow outside and between cells of young roots



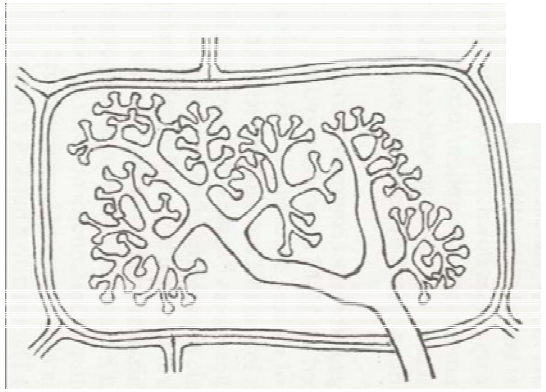


Infection directly into root cells

Mycorrhizal Fungi

Endo-Mycorrhizae

- Most important is vesicular-arbuscular myc. (VAM or AMF)
  - Vesicle = bladder-like structure
  - Arbuscule = branched structure
- 80% of plant species
- Most crops (monocots & dicots), hardwoods, non-pine conifers



Mycorrhizae

Poor growth of forest trees without mycorrhizae where nutrients limited

Add Mycorrhizal Inoculants?

- Plants often choose fungi selectively
- Research shows that the wrong fungi, or wrong combination, can impair plant growth
- Adding purchased AMF not wise:
  - Often dead in the bag
  - May not be the correct species
  - Adding fungi has unknown effects on the growth of that plant, the soil organisms in your area, etc.

https://TechInsiderScience/videos/927452267363450/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