Soils for Master Gardeners

Matt Halldorson

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THE UNIVERSITY OF ARIZONA

What is Soil?

- Upper layer of earth in which plants grow
- Can be inches to 100+’ in depth
- Constant physical and biological changes
- Created over thousands of years

Principal Components

Minerals-decomposed "parent" material

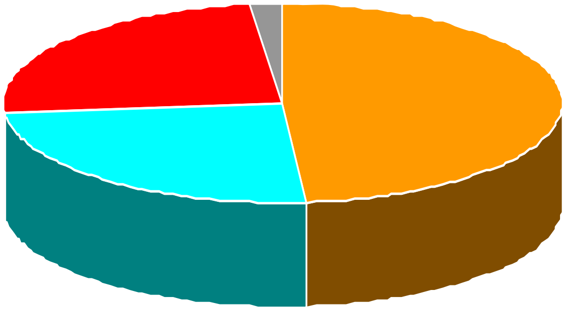
Organic Matter -plant/animal residues

Air-held in pores

- Necessary for biological respiration

Water-held in pores

- Necessary for plants/animals

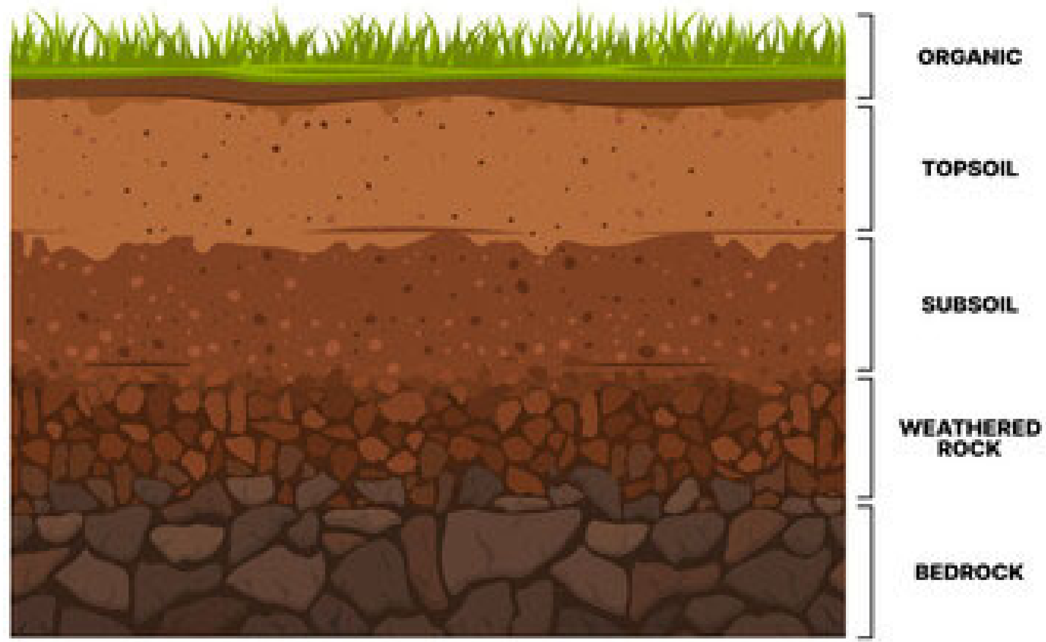


Soil Formation

- 5 Factors:
  - imate
  - rganisms
  - elief/Topography
  - arent Materials
  - ime

Climate

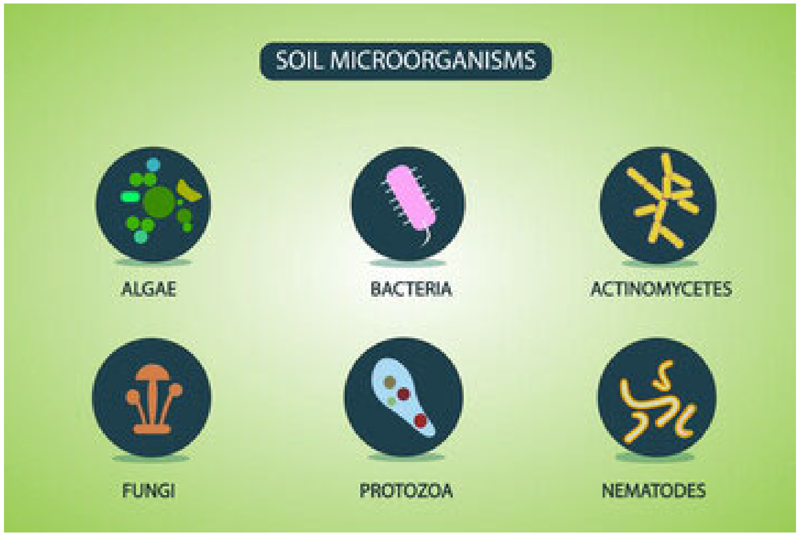
- Temperature
  - Cracking
  - Chipping
  - Swelling
  - Shrinking
  - Expose larger surfaces to the environment
  - Higher temps speed up rxns
- Wind
  - Erosion



- Rainfall-once exposed, water is crucial in chemical reactions that continue to breakdown parent material

Organisms

- Contribute to structure and breakdown organic matter
- Micro-organisms
  - Bacteria
  - Fungi
  - Actinomyces
- Plants
- Vertebrates
- Invertebrates
  - Earthworms
  - Insects



Relief/Topography

- Relief-elevation differences-contributes to effect of gravity
- Aspect- position it faces (south facing slope)
- General shape
- Effect how factors affect a site
    - Solar radiation
    - Precipitation
    - Wind
    - drainage

Parent Materials:
Rocks the soil was formed from

- Determine the amount and types of nutrients present

1. Residual-formed in place
   a) Rock
   b) Organic deposits

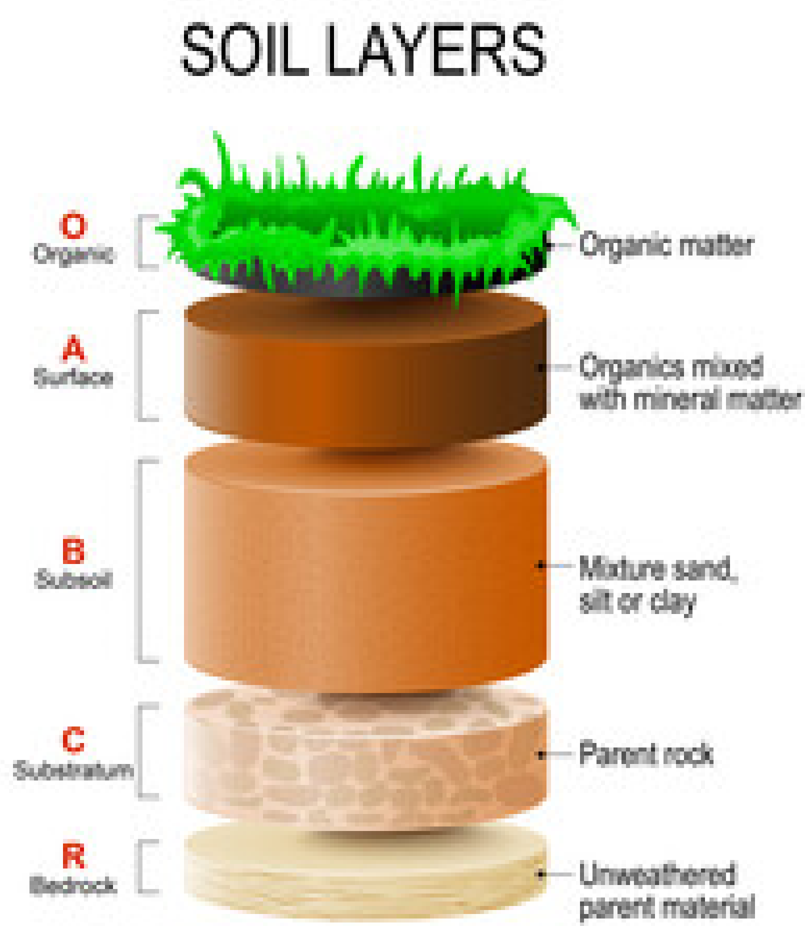
2. Transported- formed elsewhere and moved to the current site
   a) Colluvial (gravity)
   b) Alluvial (stream), marine (ocean), lacustrine (lake)
   c) Eolian, Loess (Wind)
   d) Glacial (ice)

Time

- Length of time a soil has been forming dictates horizon expression
- Degree of the 4 other factors (ClORP)
- Some features form quickly, some slowly
- Relatively quickly at first, then slow

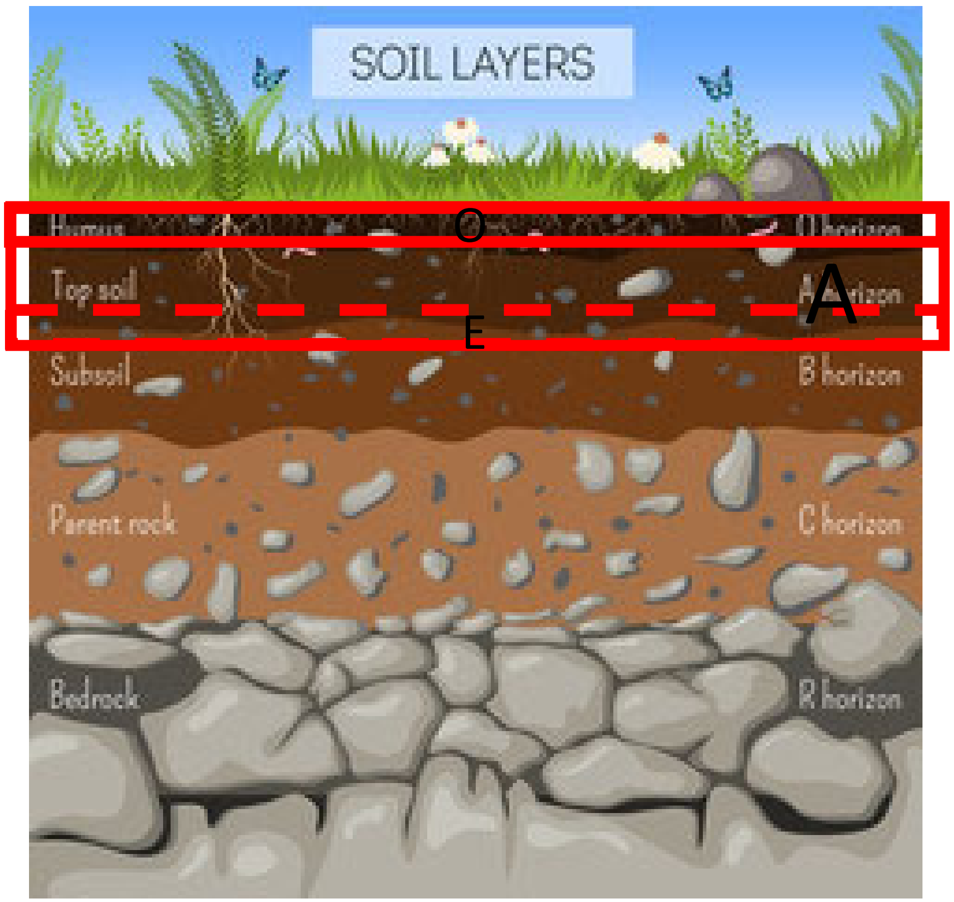
Soil Profile

- A vertical section of a soil
- As soils age, they develop distinct horizons



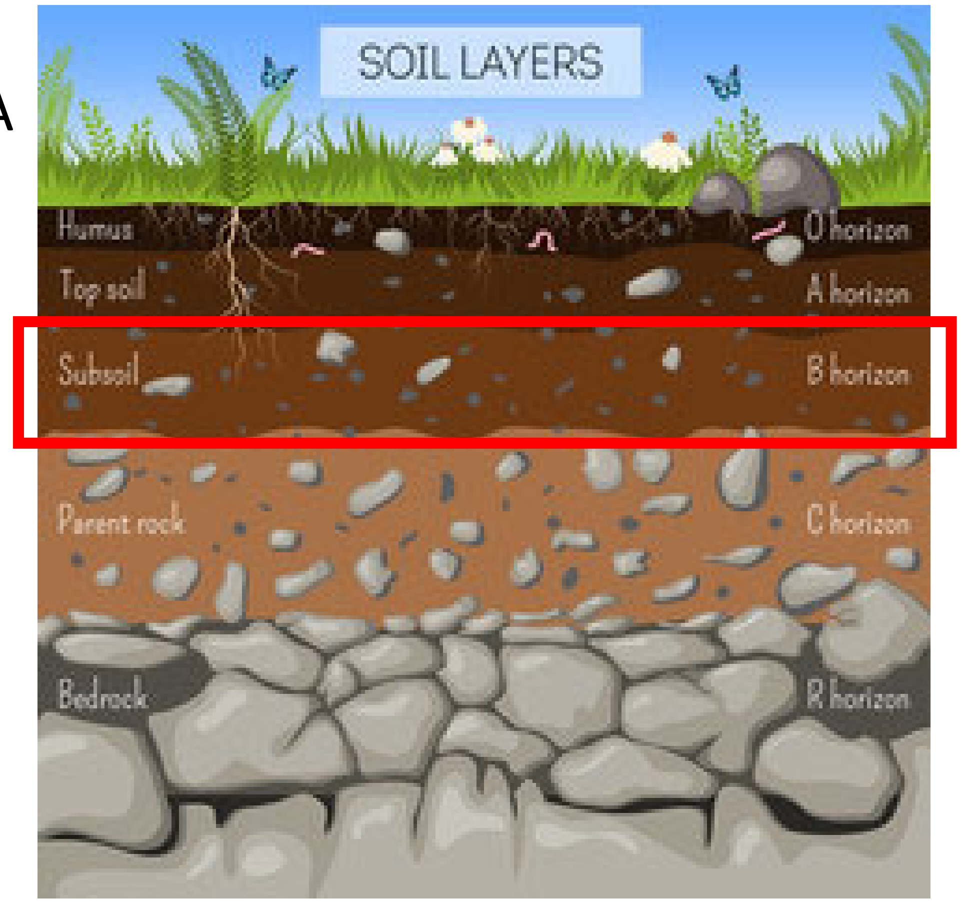
A (and O and E) Horizon-Topsoil

- Upper-most horizon
- Thickness: inches to feet
- Most influenced by climate
- Most enriched by accumulation of organic matter
- Greatest biological activity



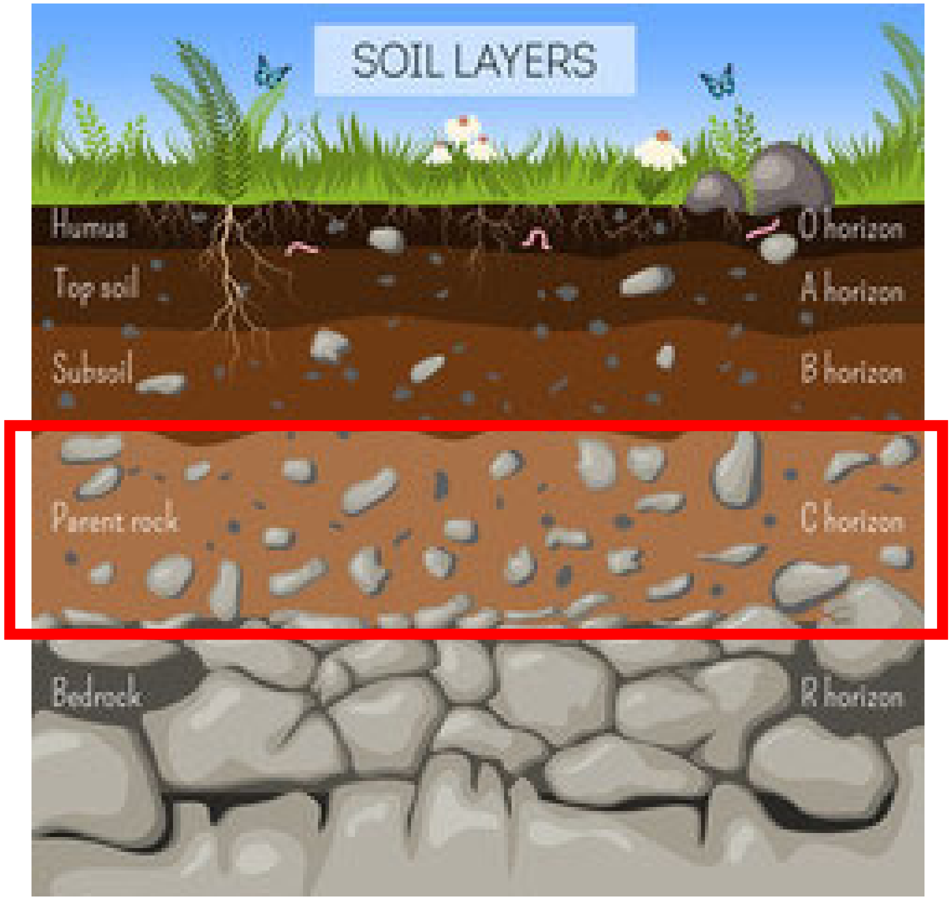
B Horizon-Subsoil

- Accumulates leached materials from A Horizon
- Clay, Ca^{2+}, and other salts
- More compact than A Horizon



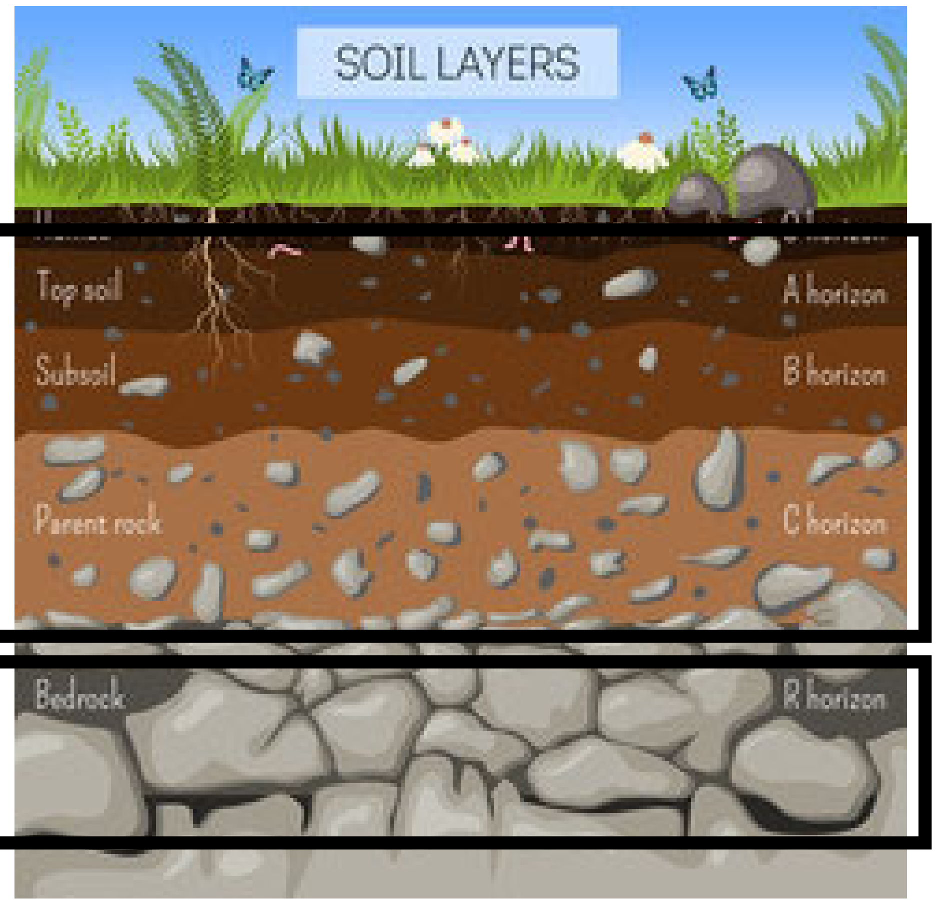
C Horizon-Parent Material

- Little clay, organic matter
- Little biological activity
- If developed "in place", has the same parent as A & B
- Transported- materials from another location



R Horizon- Bedrock

“Blanket rock”
A+B+C

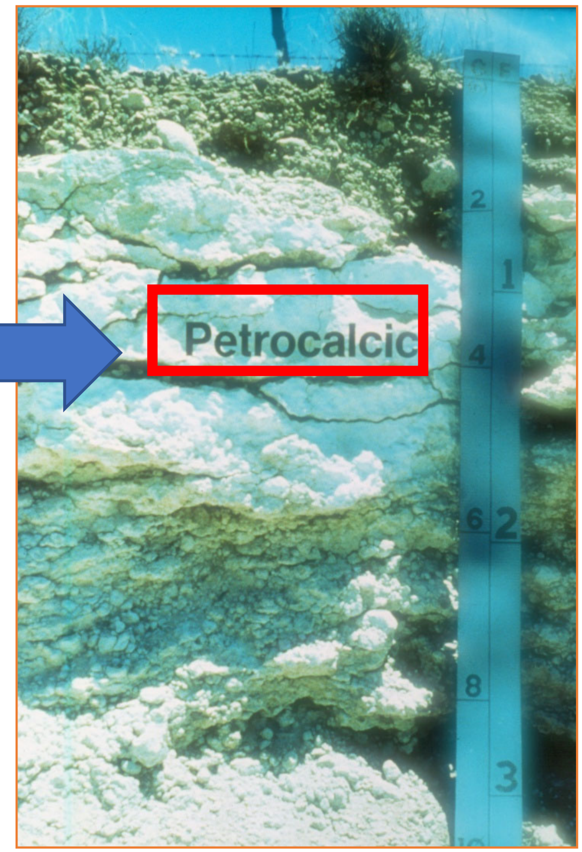


R horizon-Bedrock layer below the A+B+C

Arid Soil Horizons

Sodium
Chloride

Calcium
carbonate
(Caliche)



Properties of Soil

- Minerals
- Texture
- Bulk Density
- Structure
- Porosity
- Depth
- Organic Matter
- Color

Soil Minerals

- Sand/Silt are primary minerals: quartz, feldspar, mica, hornblende, and augite
- Clay is secondary minerals: kaolinite, montmorillonite, and illite
- Bound in crystalline structures

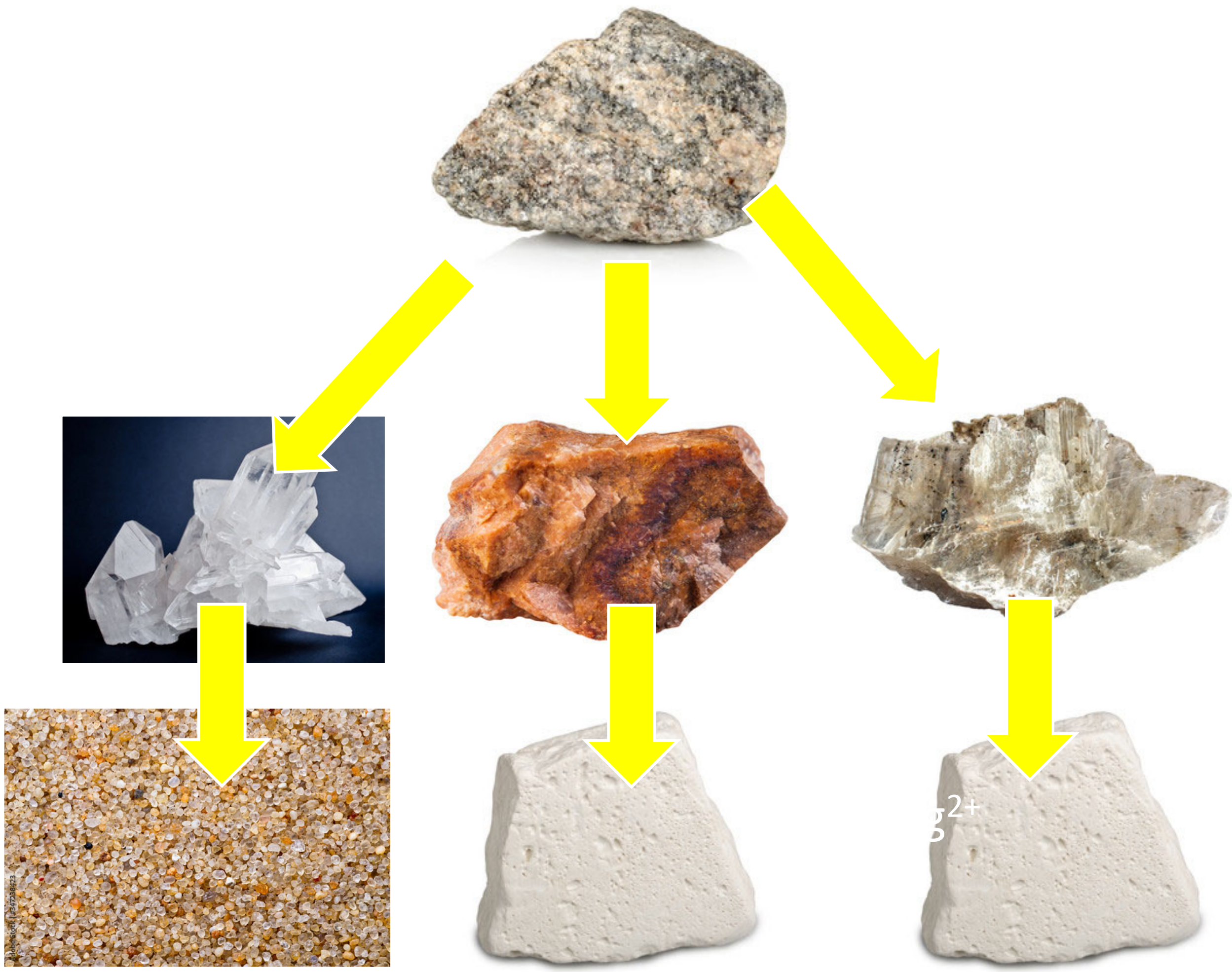
- As primary minerals weather to become secondary, elements are released

Feldspar

Mica

Kaolinite

Weathering and elemental release Example: Granite



Soil Mineral Particles

Mineral particles are the solid portion of soil

- Sand- largest (0.05mm to 2mm)
- Silt- (0.002mm to 0.05mm)
- Clay- (<.002mm)

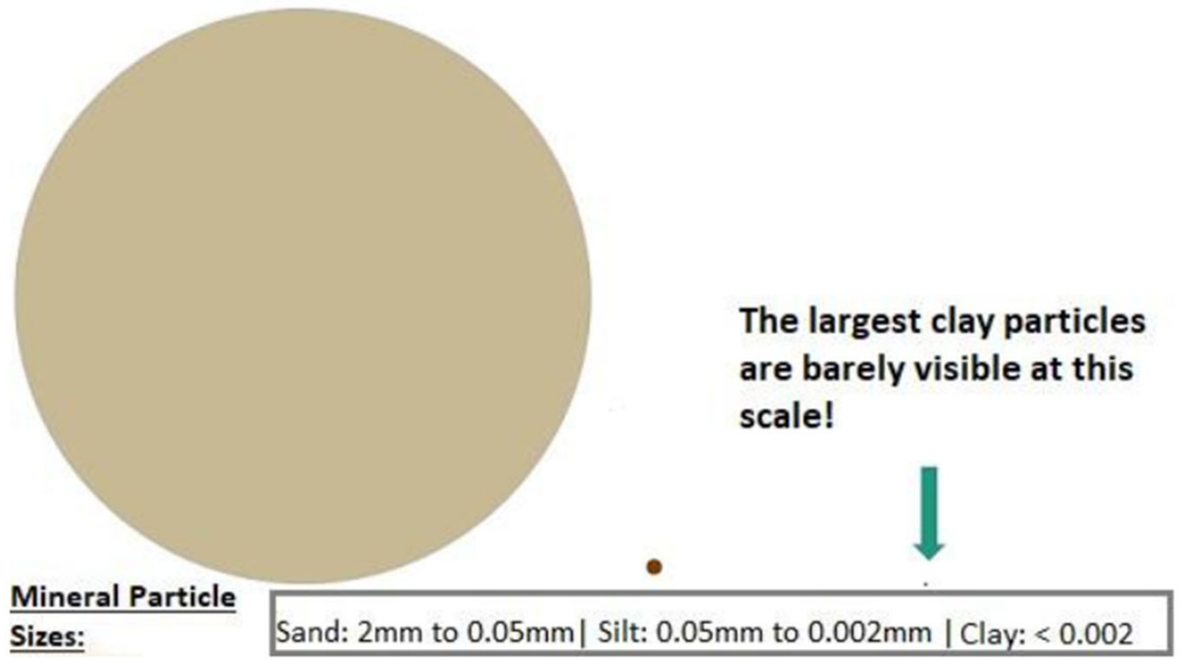
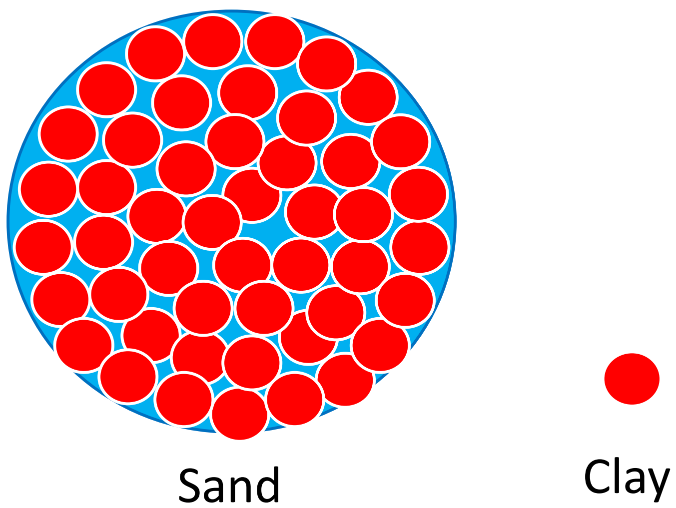


Photo: Melissa L. Wilson, Ph.D.

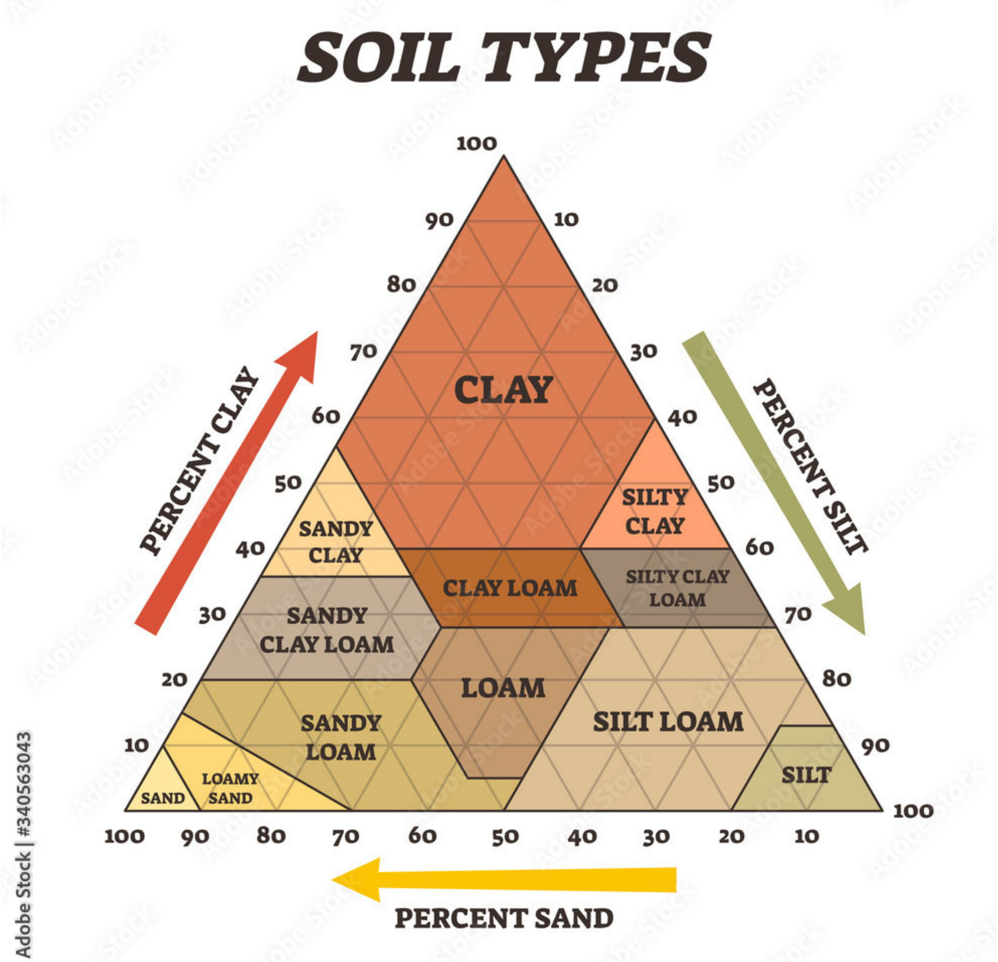
Surface Area to Volume (SA:V)

- Surface area per volume of soil increases as particle size decreases
- Important factor for physical and chemical reactions that occur in soil
- Clay has1000s X more surface area than silt, almost a million X more SA per gram than sand, so it is much more reactive than sand



Soil Texture

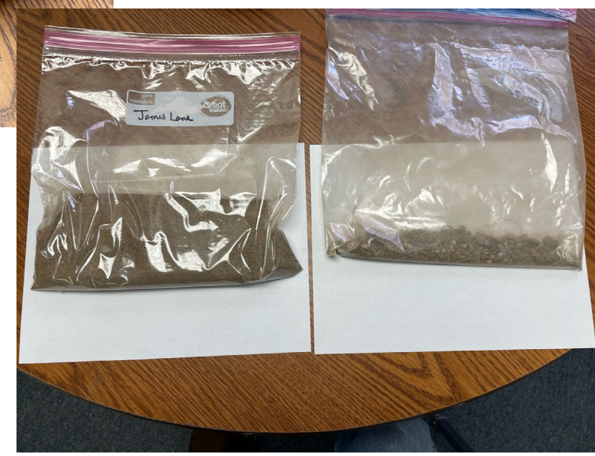
- Relative proportions of sand, silt, and clay
- Determines water holding capacity
- 12 soil texture classes to describe



Determining Texture: The "Jar Test"

- Straight-edged, clear jar
- Permanent Marker
- Ruler
- Watch/stopwatch
- 1 tablespoon powdered dishwashing detergent
- Old colander (preferably 2mm)

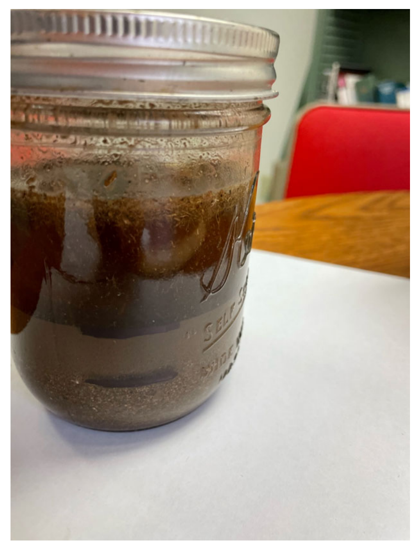
The "Jar Test"



1. Sieve (2mm) the soil- remove rocks, debris, OM
2. Fill jar 1/3 full of soil
3. Fill remainder of jar with water, leaving some room at the top

“The “Jar Test”

1. Add 1T of detergent
2. Shake vigorously and let sit for 1 minute
3. Draw a line on jar where sand layer has formed at bottom
4. Let sit for 2 hours
5. Draw a line on jar where silt layer has formed

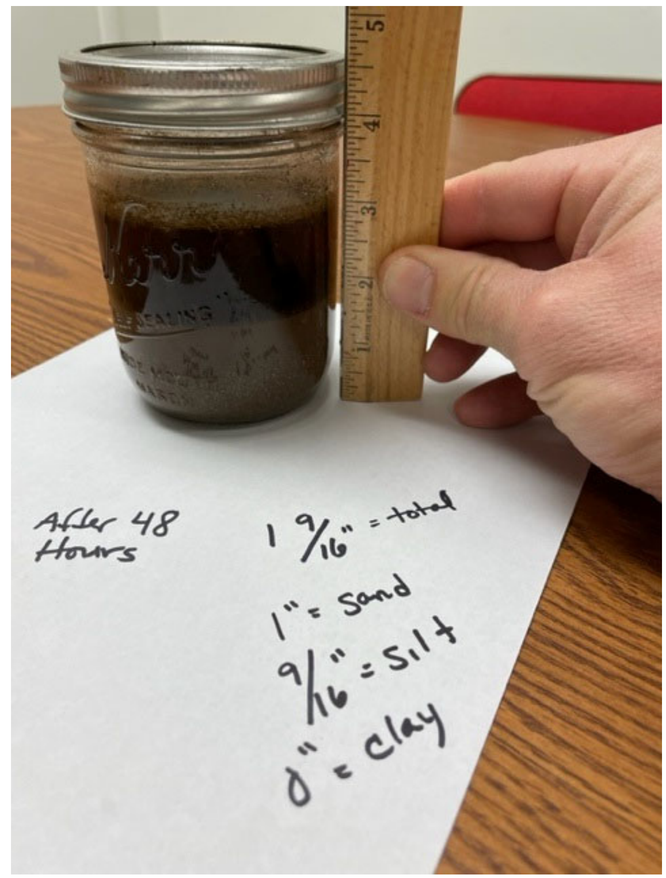


The "Jar Test"

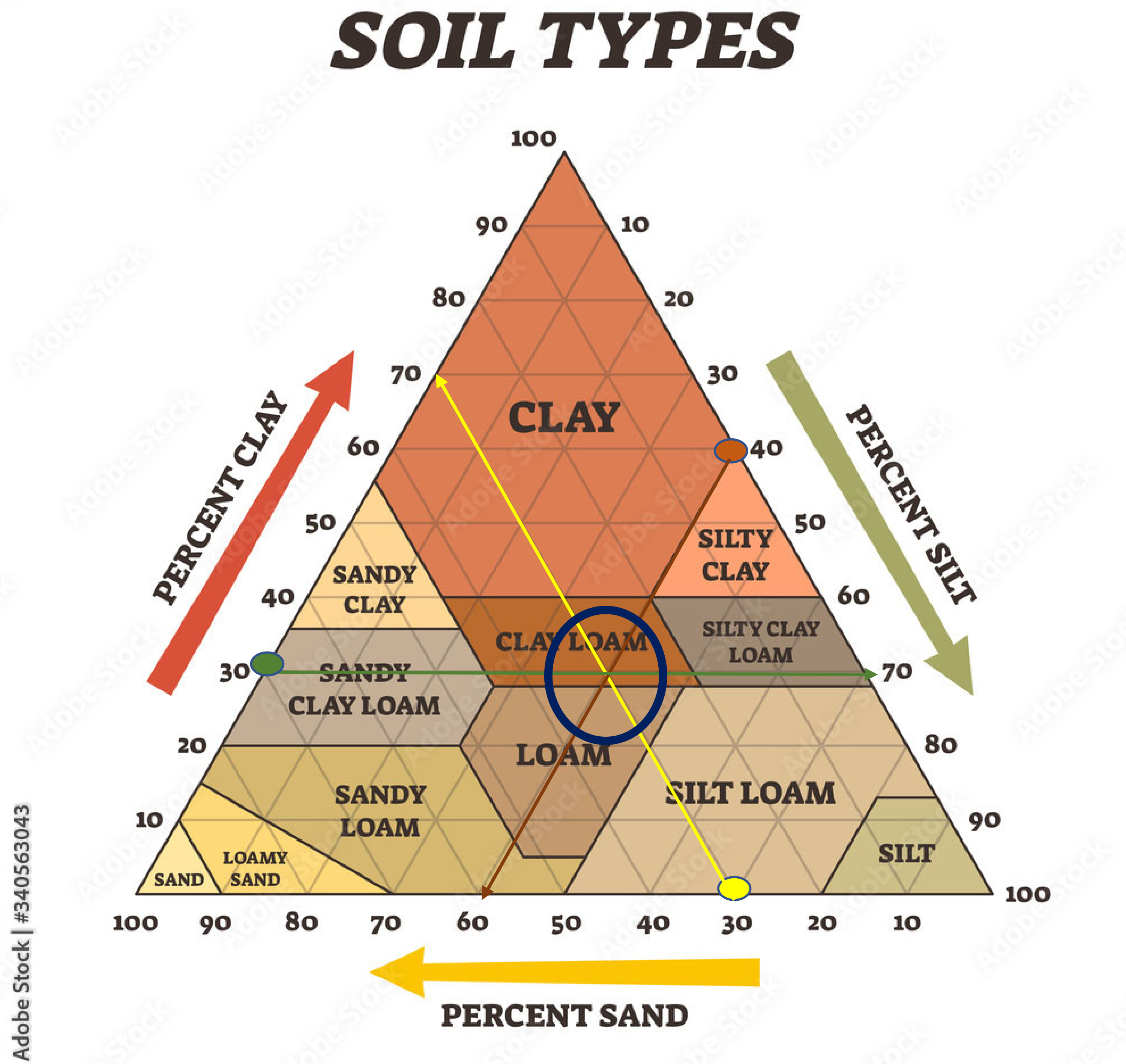
1. Leave jar for 48 hours
2. Mark the third settled layer-this is the clay layer
3. Measure each layer and the total of all layers
4. Calculate the percentage:

Example:

1.0" sand/1.56" total= 0.64 x 100 = 64% sand

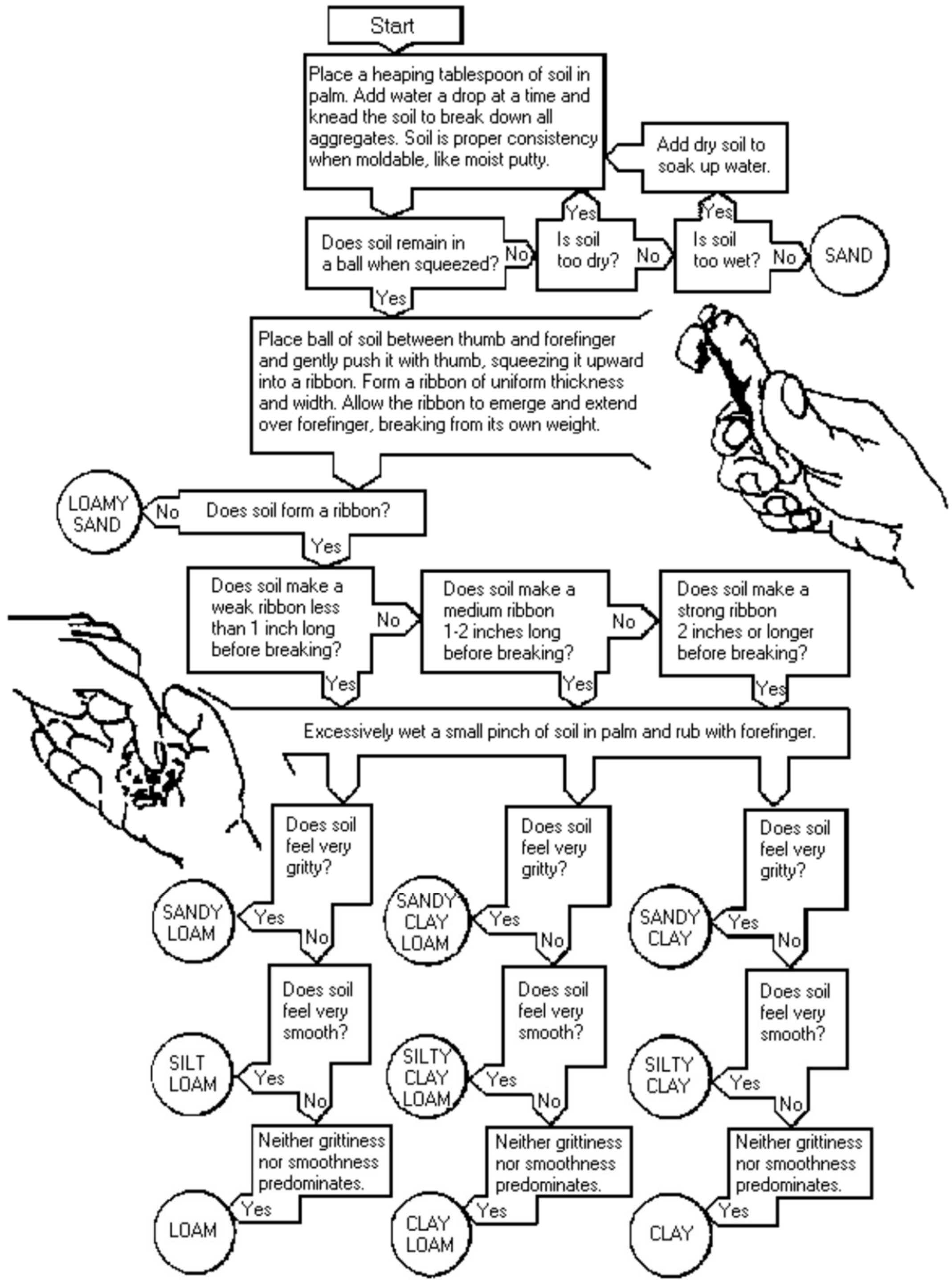


30% Sand
40% Silt
30% Clay



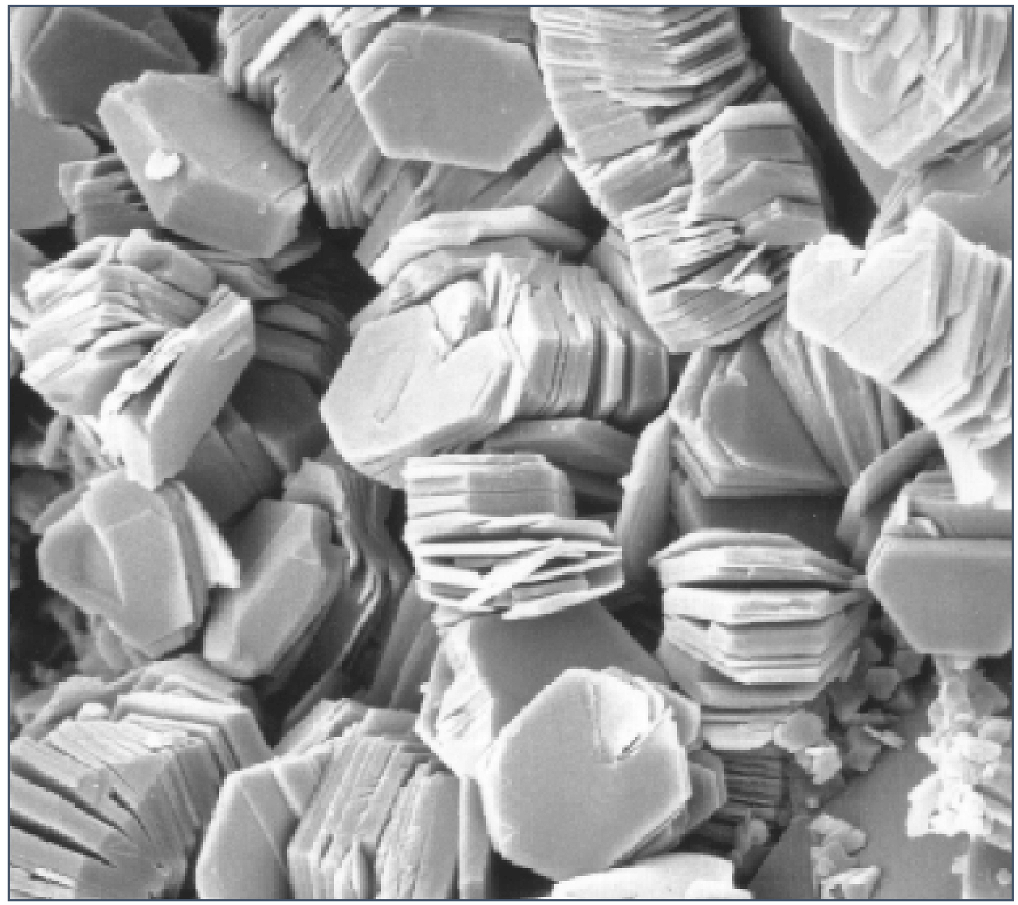
Soil Texture by “feel” method

- 1. Pass soil through a 2mm sieve
- 2.Wet soil to proper consistency
- 3. Does soil form a ball? No→ Sand
- 4. Yes→ Does it form a ribbon? No→ Loamy Sand
- 5. Yes→ Measure ribbon sections
- 6. Feel an excessively wet, small pinch and describe its grittiness/smoothness


Start
Place a heaping tablespoon of soil in palm. Add water a drop at a time and knead the soil to break down all aggregates. Soil is proper consistency when moldable, like moist putty.
Add dry soil to soak up water.
Does soil remain in a ball when squeezed?
No
Is soil too dry?
Yes
No
Is soil too wet?
Yes
No
SAND
Yes
Place ball of soil between thumb and forefinger and gently push it with thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over forefinger, breaking from its own weight.
LOAMY SAND
No
Does soil form a ribbon?
Yes
Does soil make a weak ribbon less than 1 inch long before breaking?
No
Does soil make a medium ribbon 1-2 inches long before breaking?
No
Does soil make a strong ribbon 2 inches or longer before breaking?
Yes
Yes
Yes
Excessively wet a small pinch of soil in palm and rub with forefinger.
Does soil feel very gritty?
SANDY LOAM
Yes
No
Does soil feel very gritty?
SANDY CLAY LOAM
Yes
No
Does soil feel very gritty?
SANDY CLAY
Yes
No
Does soil feel very smooth?
SILT LOAM
Yes
No
Does soil feel very smooth?
SILTY CLAY LOAM
Yes
No
Does soil feel very smooth?
SILTY CLAY
Yes
No
Neither grittiness nor smoothness predominates.
LOAM
Yes
Neither grittiness nor smoothness predominates.
CLAY LOAM
Yes
Neither grittiness nor smoothness predominates.
CLAY
Yes

Special Properties of Clay

- High surface area and surface area/weight
  - Size and structure (layered, capable of expansion/shrinking)
- Sites for microbial growth

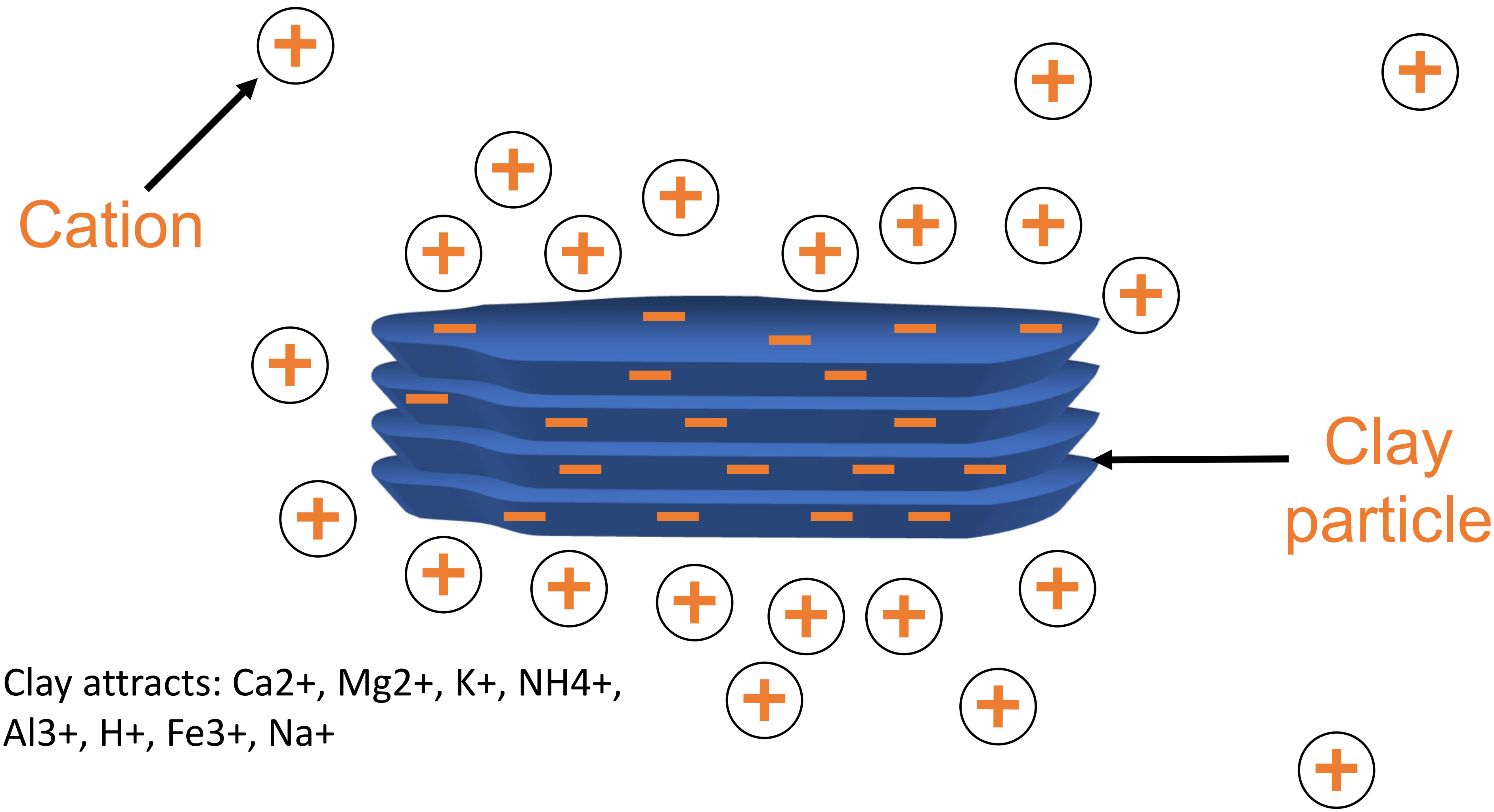


Electron Micrograph showing “sheets” of clay

Special Properties of Clay

- Particles carry net negative charges
  - Attract positively charged nutrients (adsorption)
- Cation Exchange Capacity- how many positively-charged ions can be held by a surface
  - There is a constant exchange between clay and soil solution

Cation Exchange Capacity



Clay attracts: Ca^{2+}, Mg^{2+}, K^+, NH_4^+, Al^{3+}, H^+, Fe^{3+}, Na^+

Clay repels: NO_3^-, SO_4^{2-}

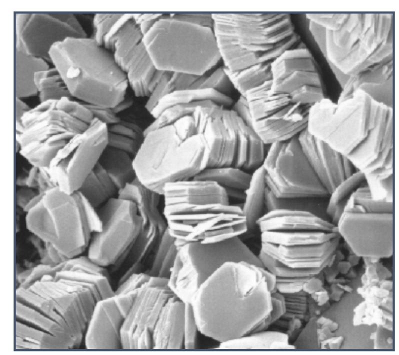
Effect on plant growth

Coarser Soils:

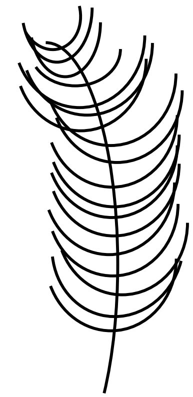
- Changes temperature faster
- Better infiltration and aeration
- Less water/nutrient-holding capacity

Finer soils

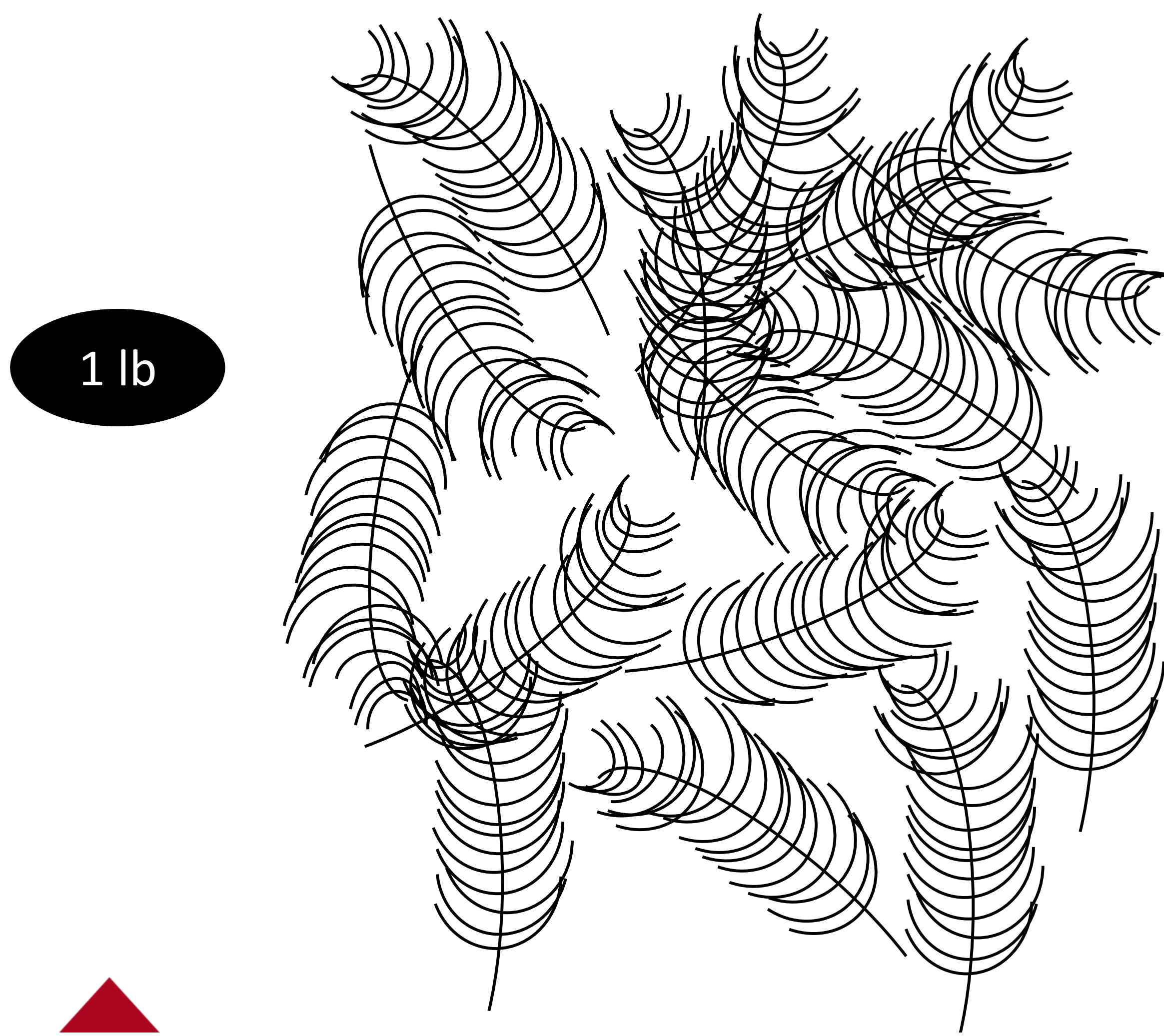
- Greater surface area
- More water/nutrient-holding capacity
- Silt weathers faster
- Can become impervious



Bulk Density

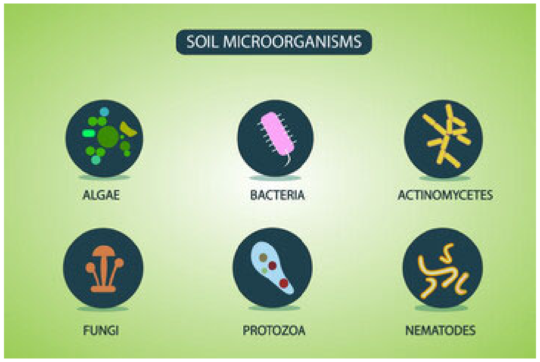


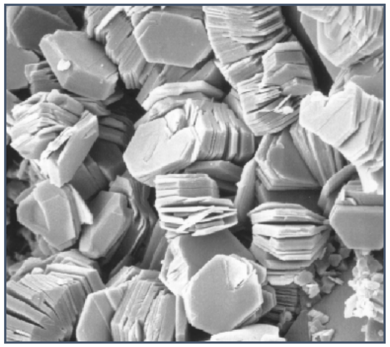
- Weight per volume of a substance
- Describes the amount of air or pore space in a soil
- As particle size decreases, BD decreases because some of the volume is occupied by air
- Does not describe the size of pores



Soil Structure

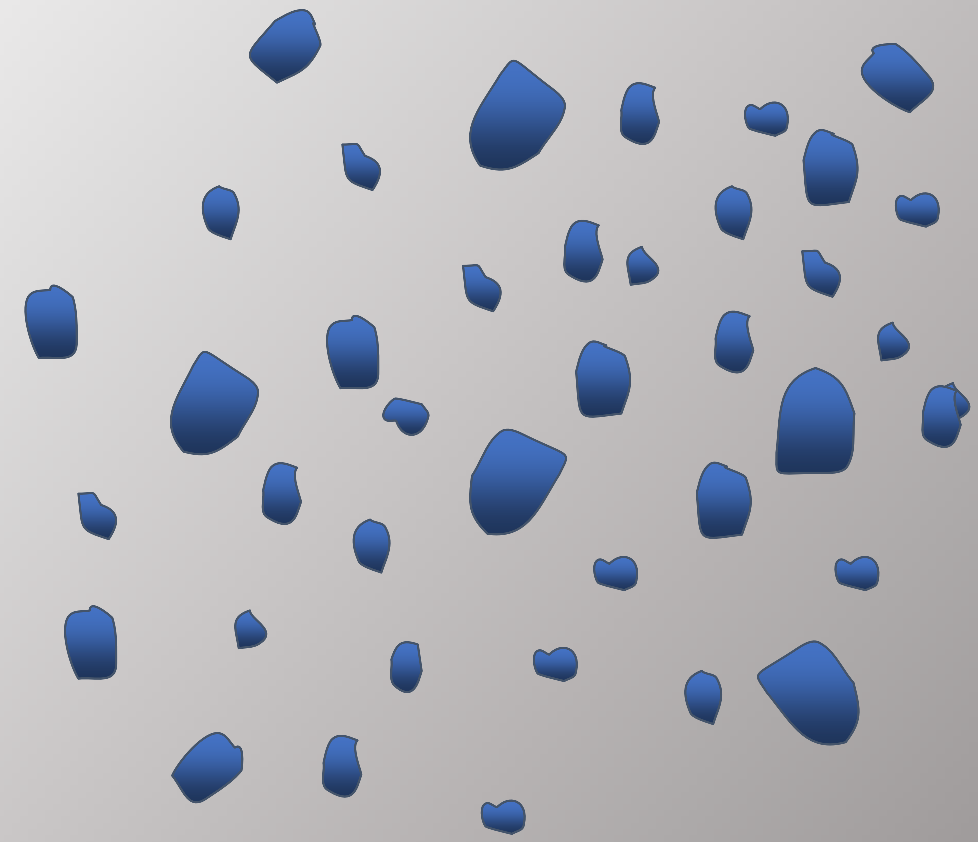
- Soil particles exist as aggregates
- Structure refers to the arrangement of aggregates
- Effects air: water relationship
- Enhanced by:
  - Clay
  - Organic matter
  - Microbial exudates
  - Earthworm activity
- Destroyed by:
  - Tillage
  - Compaction





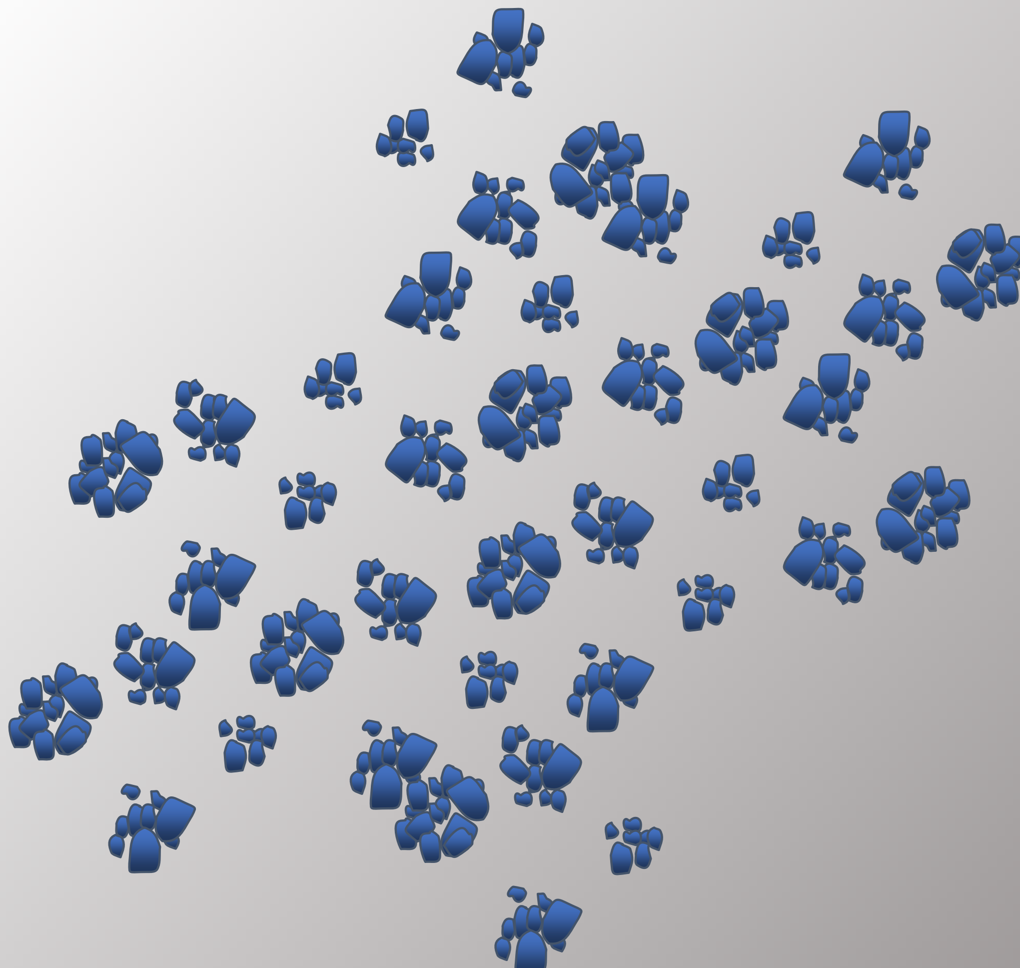
Soil Aggregates: Single Grain

- Individual grains not held together
- Common in Sands



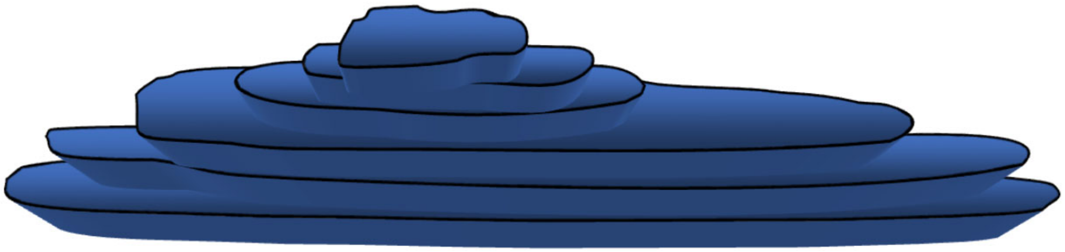
Soil Aggregates: Granular

- Porous granules held together by organic matter and clay
- Common in A horizons



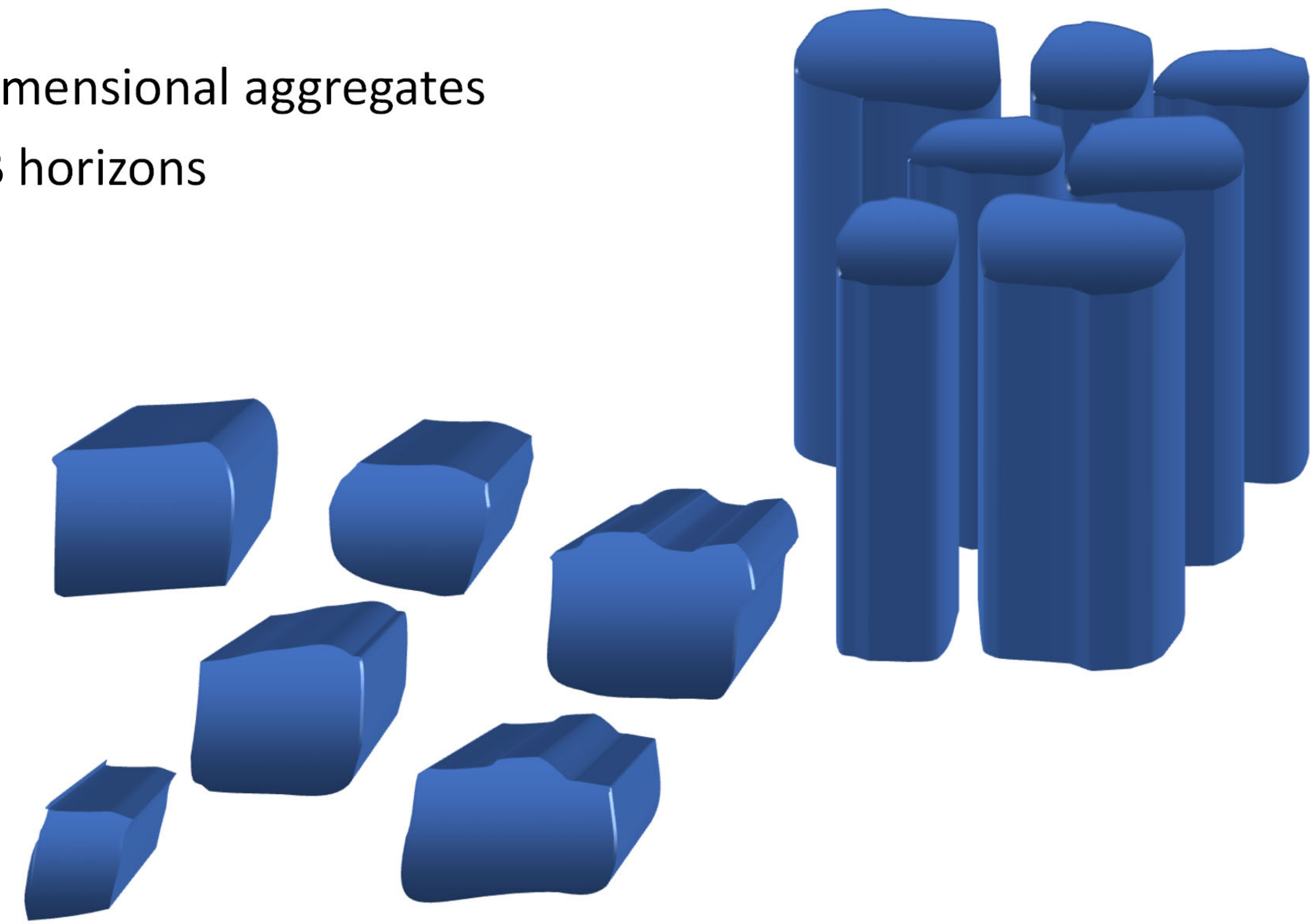
Soil Aggregates: Platy

- Flat aggregates
- Found in compacted layers of the A and E horizons



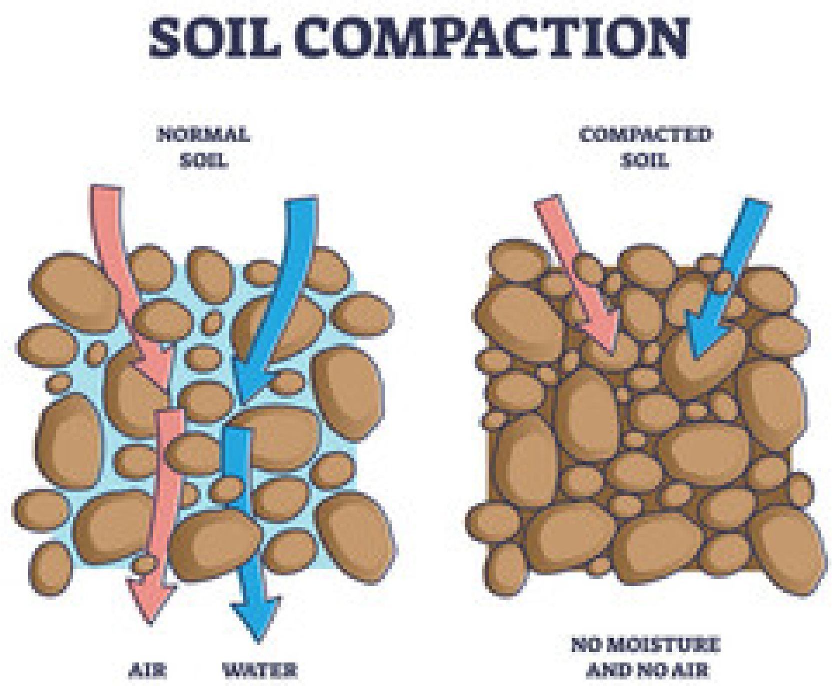
Soil Aggregates: Blocky, Columnar & Prismatic

- Vertical or equidimensional aggregates
- Found in clayey B horizons



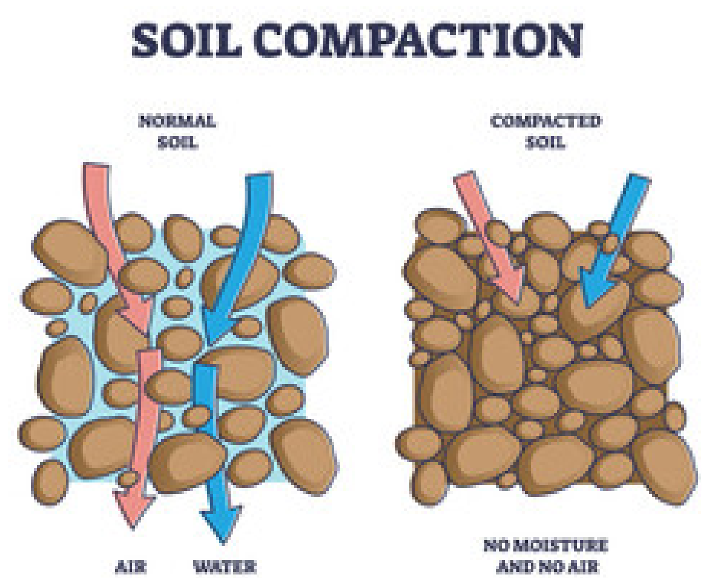
Soil Porosity

- Pores-tiny voids between soil particles and aggregates
- Hold air, water, and dissolved mineral nutrients

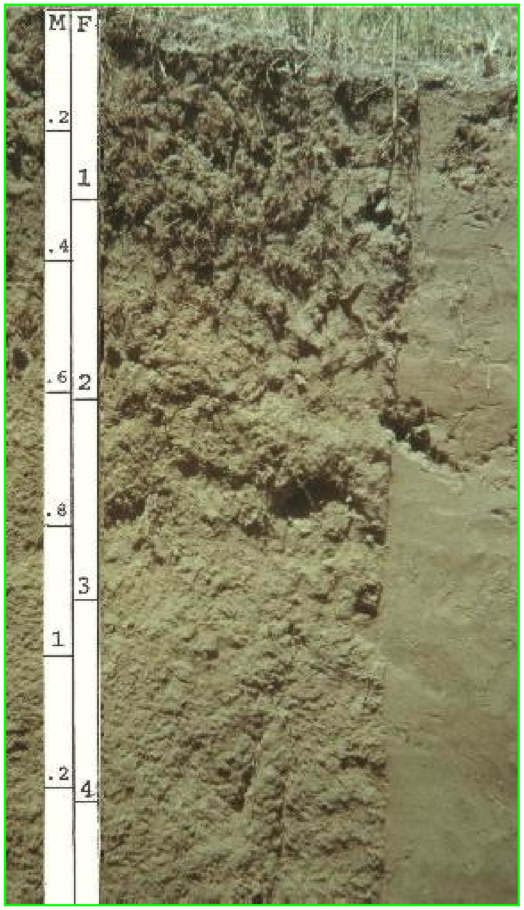


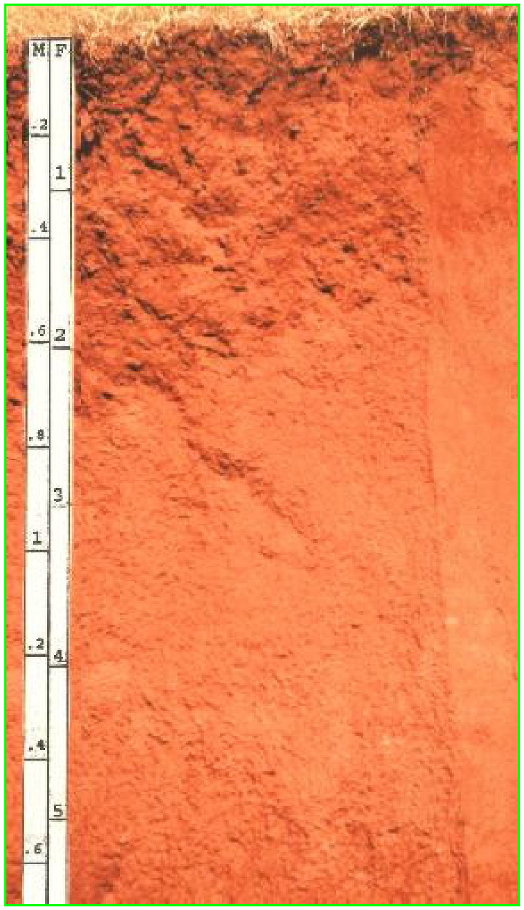
Managing a Soil's Physical Properties

- Physical properties are important for:
  - holding nutrients, water, air
  - Drainage
  - Add organic materials
- Compaction destroys structure
- Preventing Structure breakdown
- Rejuvenating structure



Soil Color





Soil Depth

- Greater water-holding capacity
- Greater nutrient-holding capacity
- Less impediment to root growth

Organic Matter

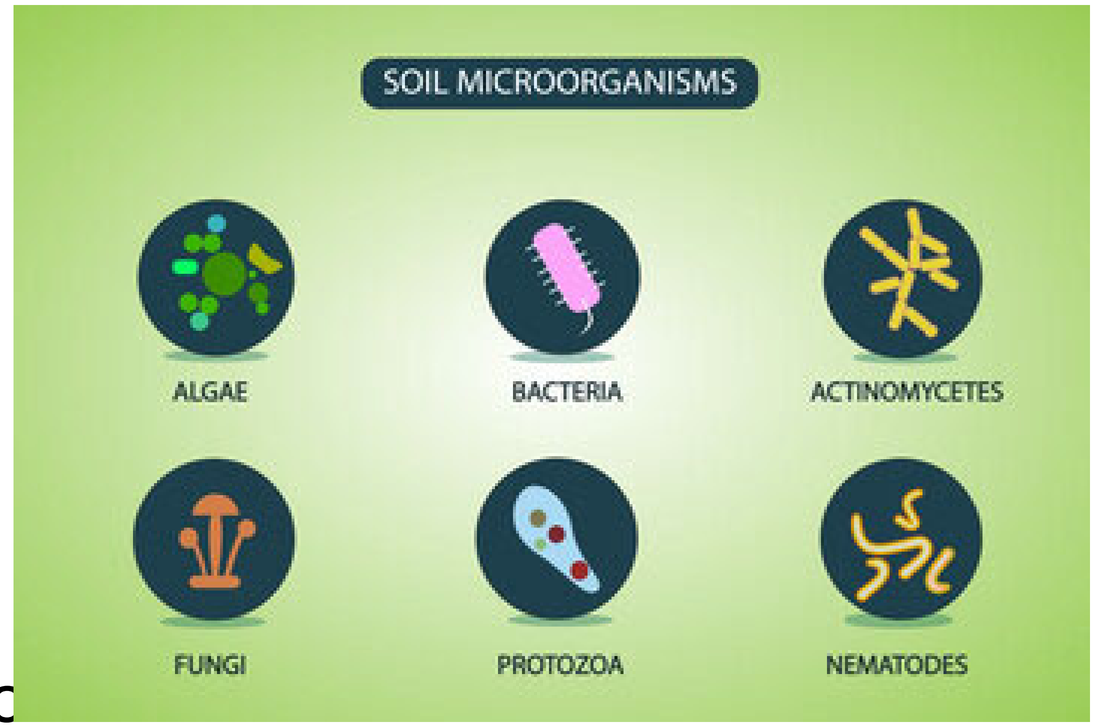
- Comprised primarily of Carbon & Nitrogen
  - Living organisms (fungi, bacteria, earthworms)
  - Plant and animal residues (decomposing)

- Decomposers are using C&N and releasing nutrients

- Benefits:
  - CEC (4-50x higher than clay) per weight
  - Water-holding capacity
  - Soil aggregation
  - Reservoir for nutrients

Beneficial Soil Organisms

- Saprophyte-organism that derives its food from dead/decaying organic matter
  - Bacteria
  - Fungi
  - Actinomycetes
  - Algae
  - Nematodes
- Rhizobium bacteria- fix atmospheric N2 and convert to plant-available forms

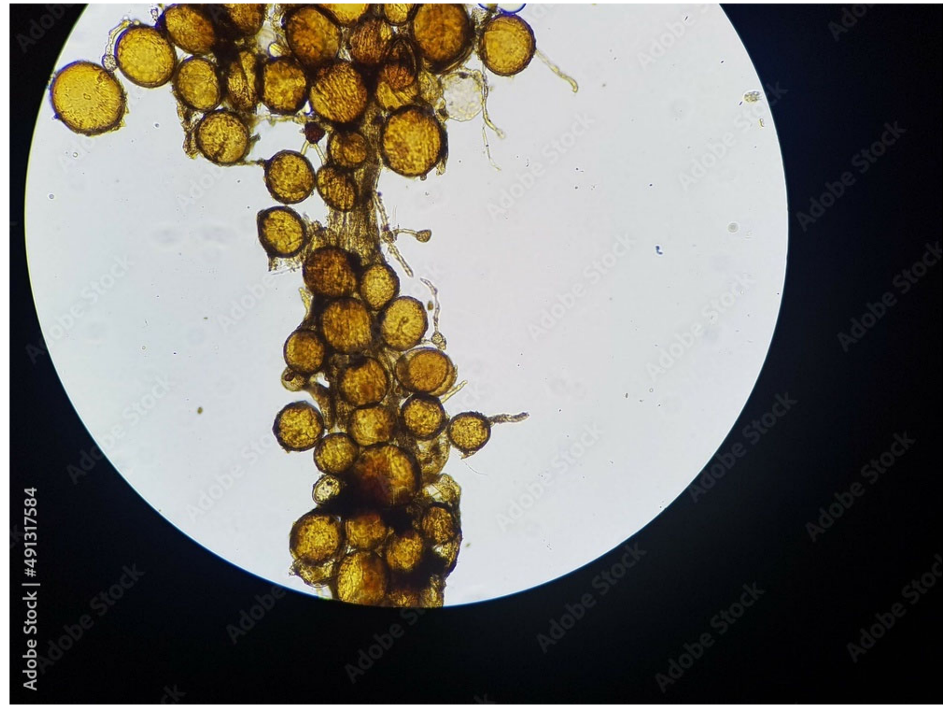


Earthworms

- Feed on plant residue and microbes
  - Aerate soil
  - Casts and excreta are rich in nutrients and contribute to soil structure
  - Redistribute microbial community

Mycorrhizae

- Fungi with a generally symbiotic relationship % of with plant species
- Plants form root associations with fungi
- Plants provide carbon, fungi provide nutrients



Nutrients/Fertility

- Taken up by roots in soil solution
- Either “searched” or “waited” for
- Fertilizer=Nutrient supplements
- Divided up as macro and micronutrients

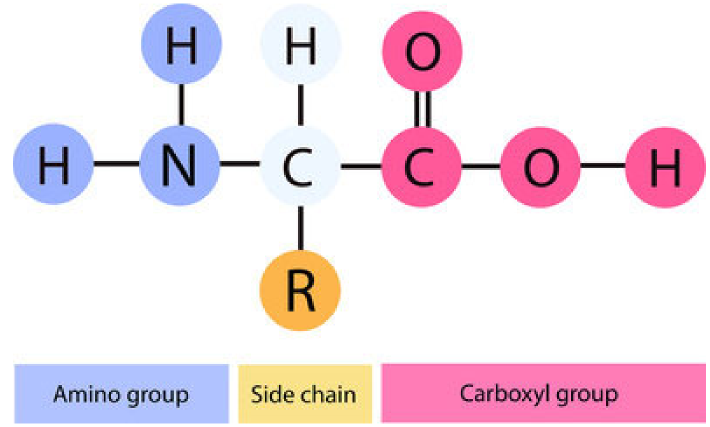
Essential Plant Macronutrients

Element	Chemical Symbol	Chemical forms absorbed	Concentration in Dry Matter (%)	Source
Primary Macronutrients				
Carbon	C	CO_2	45	Air
Hydrogen	H	H_20	6	Water
Oxygen	O	O_2	45	Air, Water
Nitrogen	N	NO_3^-, NH_4^+	1.5	Soil*
Potassium	K	K^+	1	Soil
Phosphorus	P	H2PO4-, HPO42-, PO43-	0.2	Soil
Secondary Macronutrients				
Calcium	Ca	Ca^{2+}	0.5	Soil
Magnesium	Mg	Mg^{2+}	0.2	Soil
Sulfur	S	SO_4^{2-}	0.1	Soil*

Essential Plant Micronutrients

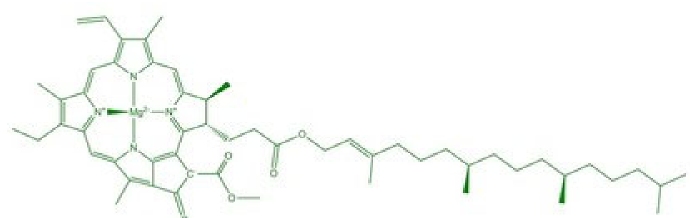
Element	Chemical Symbol	Chemical forms absorbed	Concentration in Dry Matter (ppm)	Source
Micronutrients				
Boron	B	BO_3^{3-}	20	Soil
Chlorine	Cl	CL^-	100	Soil
Copper	Cu	Cu^+, Cu^{2+}	6	Soil
Iron	Fe	Fe^{3+}	100	Soil
Manganese	Mn	Mn^{2+}	50	Soil
Molybdenum	Mo	MoO_4^{2-}	0.1	Soil
Nickel	Ni	Ni^{2+}	0.1	Soil
Zinc	Zn	Zn^{2+}	20	Soil

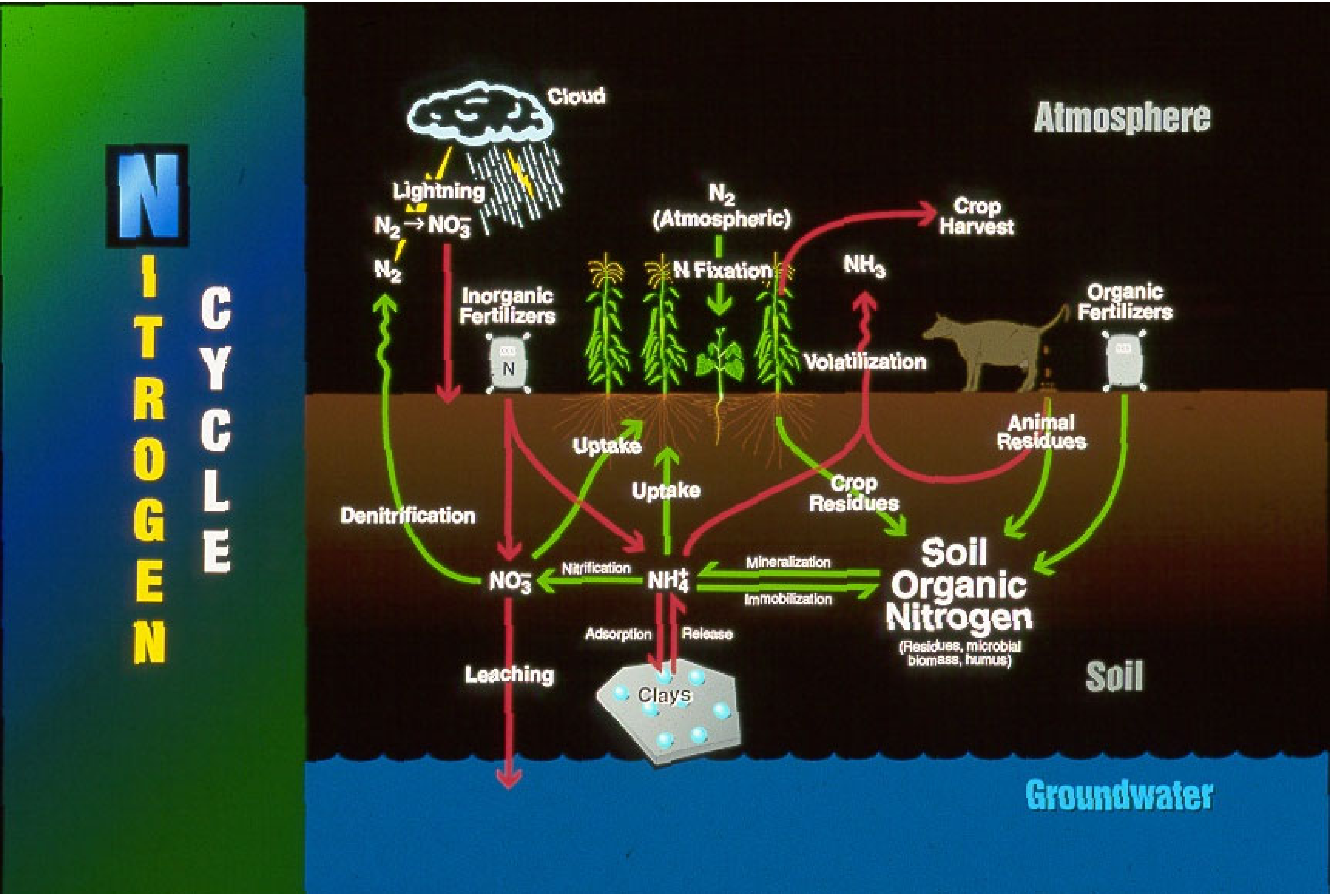
Nitrogen



- Significant limiting factor in plant growth
- Plant use: amino acids, proteins, enzymes, chlorophyll
- Deficiency symptoms: yellowing older leaves, stunted growth
- Too much nitrogen can lead to too much vegetative growth

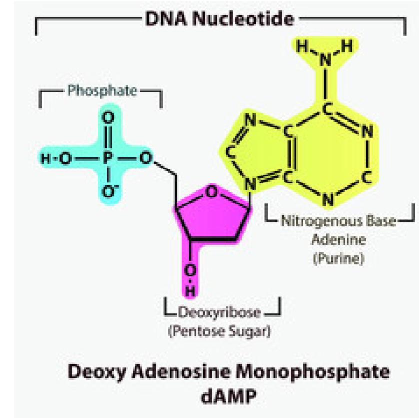
Chlorophyll a





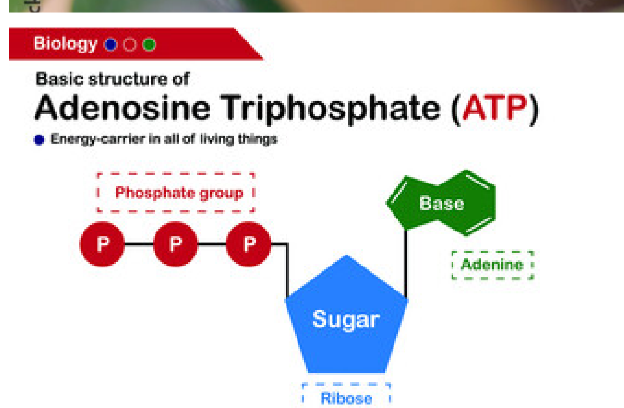
NITROGEN CYCLE
Cloud
Atmosphere
Lightning
$N_2 \rightarrow NO_3^-$
N_2
N_2 (Atmospheric)
N Fixation
Crop Harvest
NH_3
Inorganic Fertilizers
N
Organic Fertilizers
Volatilization
Animal Residues
Uptake
Uptake
Crop Residues
Denitrification
Soil Organic Nitrogen
(Residues, microbial biomass, humus)
NO_3^-
Nitrification
NH_4^+
Mineralization
Immobilization
Adsorption
Release
Leaching
Clays
Soil
Groundwater

Phosphorus



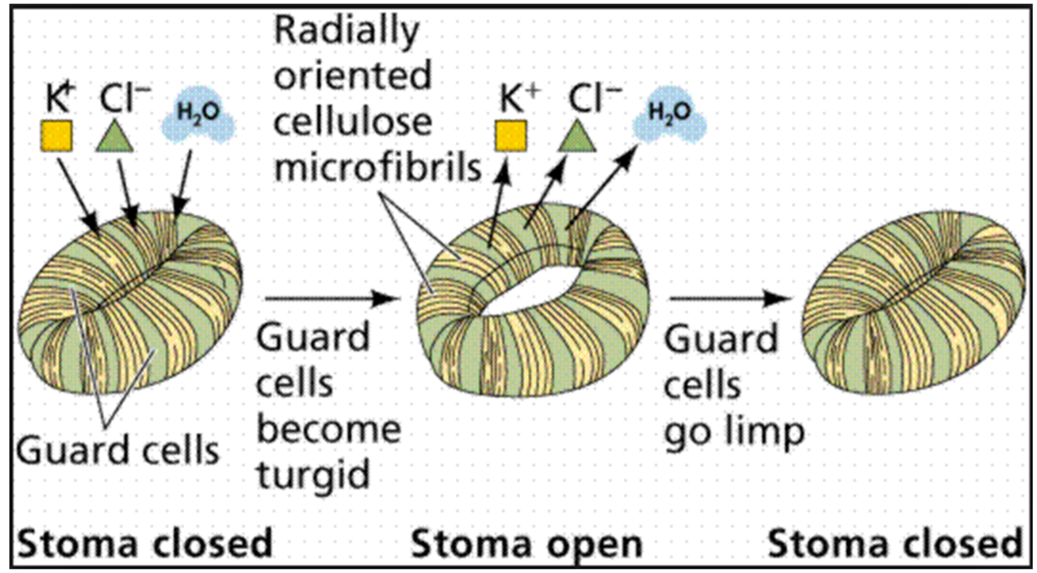
- Important for nucleic acids, cell membranes, ATP (energy-carrying molecule)

- Deficiency can show reddening, interveinal chlorosis, dark green coloration, delayed maturity, poor overall growth



Potassium

- Stomate opening/closing, protein synthesis, osmotic relations, sugar translocation
- Deficiency-leaf margin burning and necrosis



Sulfur

- Essential to several molecules made by plant, e.g. specific amino acids. Lowers pH in soil.
- Low Sulfur symptoms: pale green leaves
- Deficiency is rare due to:

-fungicide

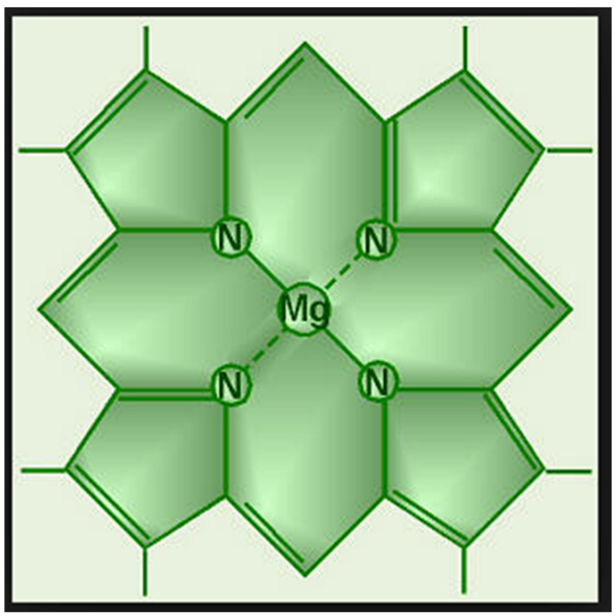
-irrigation water

-fertilizers (e.g., potassium sulfate,

ammonium sulfate)

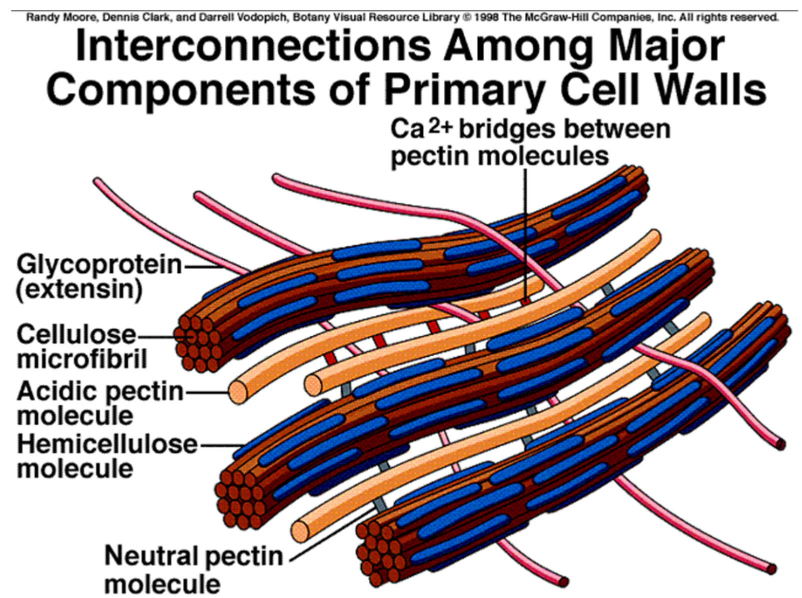
Magnesium

- Key component in the production of chlorophyll
- Deficiencies start with pale leaves which later turn red



Calcium

- Cell wall component and signaling ion
- Low Calcium symptoms: small, pale leaves, less disease resis blossom end-rot.
- Deficiencies only usually occur in low pH soils



Boron & Zinc: Fruit-set nutrients

Boron

- Key in attaining a solid fruit-set (pollen tube formation)

Zinc

- Necessary for the assembly of several proteins
- Deficiency inhibits pollen formation

Nutrient Mobility: Soil

- Can plants "sit and wait" or do they have to "go and get it"?

Low Mobility:

- Phosphorus (HPO_4^{-2})
- Calcium
- Magnesium
- Nitrogen (NH_4^+)

High Mobility:

- Nitrogen (NO_3^-)
- Boron
- Chlorine

Medium Mobility:

- Potassium

Nutrient Mobility: Plant

Mobile

- Nitrogen
- Potassium
- Phosphorus
- Sulfur

Immobile

- Calcium
- Iron
- Copper
- Boron
- Zinc

What's the significance of plant mobility??

Fertilization

- Fertilizer- “a substance used to make soil more fertile (productive)”
- “Complete” fertilizer has some amount of N-P-K
- Inorganic fertilizers- synthesized fertilizers
  - Fast-acting, require no incorporation, precise amounts, propensity to leach, often higher concentrations of NPK

Fertilizer Analysis

- Label must contain percent (by weight) of
  - total nitrogen (N)
  - available phosphate (as P_2O_5)
    - P_2O_5 times 0.43 = P
  - soluble potash (as K_2O)
    - K_2O times 0.83 = K
- Other nutrients may be specified

Slow-release fertilizers

- Release nutrients (usually nitrogen) over a long period of time
  - slowly soluble materials
    - urea formaldehyde
  - granules coated with resins or sulfur
    - sulfur-coated urea
    - Osmocote®
  - materials that must decompose to release nutrients
    - organic fertilizers

Organic Fertlizers

Examples:

- Manure
- Compost
- Feather or bonemeal
- Fish emulsion

- Slow-release through microbial action,
- Variable nutrient content
- Improve soil structure, water-holding capacity
- Low burn potential
- More expensive
- Lower content than synthetic
- Contain micronutrients

Organic Fertilizer Nutrient Content

Manure Type (Dry	% N	% P_2O_5	% K_2O
Chicken Manure	2.0-4.5	4.6-6.0	1.2-2.4
Steer Manure	0.6-2.5	0.9-1.6	2.4-3.6
Dairy Manure	0.6-2.1	0.7-1.1	2.4-3.6
Avg Home Compost	1.5	1.3	1.36
Bone meal	3	15	0
Fish Emulsion	5	2	2

Common incomplete fertilizers

Fertilizer	N	P_2O_5	K_2O
Ammonium Nitrate	34	0	0
Ammonium Sulfate	21	0	0
Monoammonium Phosphate	11	48	0
Muriate of Potash	0	0	60
Potassium Sulfate	0	0	52
Super Phosphate	0	20	0
Triple Super Phosphate	0	45	0
Urea	46	0	0

Fertilizer formulations

- Fertilizers can be combined with herbicides
  - common in turf formulations (Weed 'n Feed)
- Fertilizers
  - granular solids
  - slow-release granules
  - Liquids/ concentrates
  - water soluble powders
  - slow-release spikes/tablets

Fertilizer Application Methods

- **Broadcasting:** uniform distribution, often by use of spreader
  - May need incorporation
- **Banding:** narrow bands that can be spread, sprayed, or shanked-in
  - Good for immobile nutrients
- **Foliar:** applying liquid fertilizer solutions to plant leaves
- **Fertigation:** adding liquid fertilizer through the irrigation system

Avoid Unnecessary or Over-fertilization

- Annual flowers, vegetables, fruit trees and lawns need added fertilizer
- Native plants don’t need fertilizer
- Shrubs that are fertilized are going to attract herbivores
- Too much nitrogen can:
  - Burn roots
  - Cause plants not to flower
  - Cause environmental damage
  - Cause uncontrolled growth

Fertilizer Calculations

- Twenty 10 x10 flower beds
- 2lbs Nitrogen per 1000ft^2
- Fertilizer is 10-12-12

How many pounds of fertilizer do you need?

Solution

- Area of garden bed=10ft x 10ft=(100ft^2/garden bed)

- 20 garden beds x (100ft^2/garden bed)= 2000ft^2

- 2000ft^2 x (2lbs N/1000ft^2)=4lbs of Nitrogen total

- 4lbs N x (1lb 10-20-10 fert./0.10lbs N)=40lbs of 10-20-10 fertilizer

Fertilizer Calculations

- 20x10ft garden
- 2lbs of Phosphorus per $1000ft^2$
- Fertilizer is 20-10-5

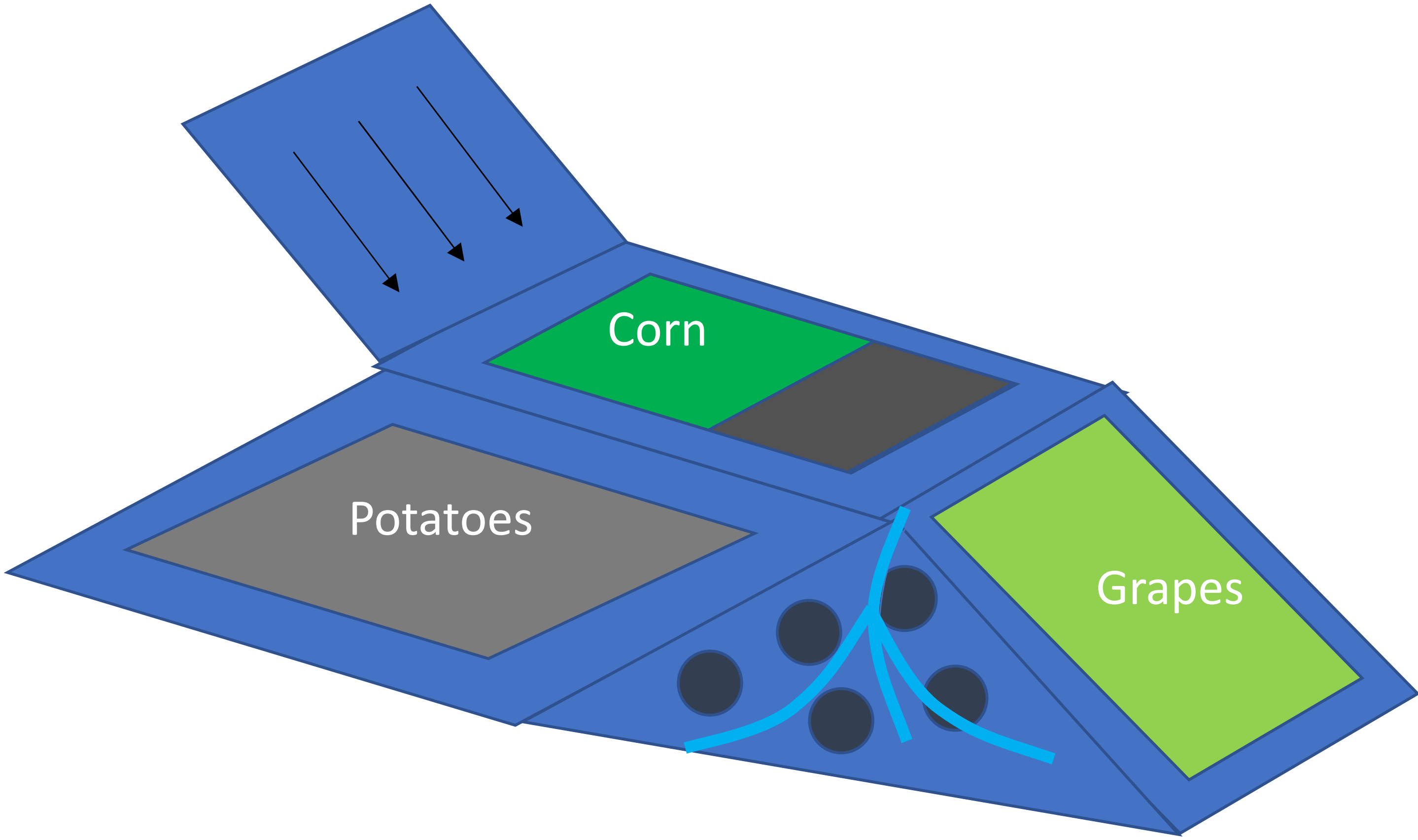
How many pounds of fertilizer do you need?

Solution

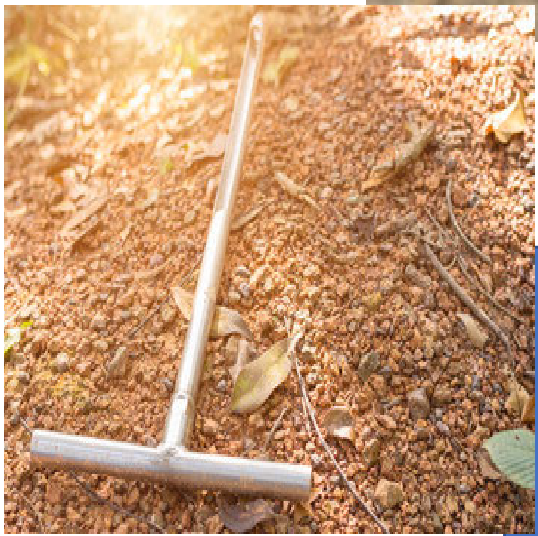
- Area of garden=20ft x 10ft=(200ft^2/garden)
- 200ft^2 x (2lbs P/1000ft^2)=0.4lbs of Phosphorus total
- 0.4lbs Phosphorus x (1lb P_2O_5/0.43lbs Phosphorus)=0.93lbs P_2O_5
- 0.93lbs P_2O_5 x (1lb 20-10-5/0.1lb P_2O_5)= 9.3lbs 20-10-5

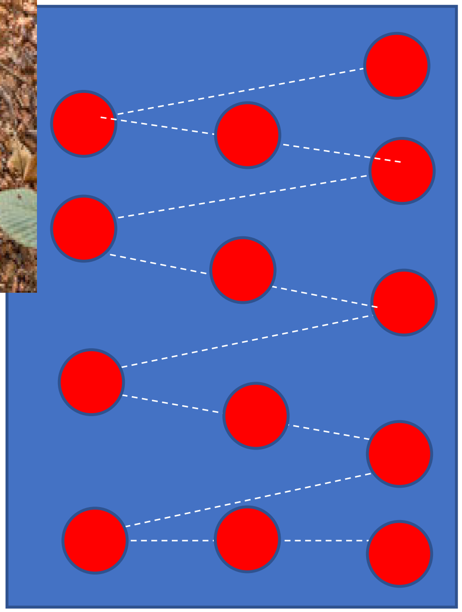
Soil Sampling Methodology

- Identify areas with differences:
  - Crops grown
  - Vigor differences
  - Slope
  - Soil type
  - Erosion
- Sample separately



Soil Sampling Methodology





1. Use a soil core or shovel to take several (5-15) cores of soil from throughout each area/zone and make a composite sample
   - Depth depends on rooting depth of plants
2. Mix sub-samples in a bucket and pull approximately 1 pint's worth. Allow sample to air dry and put into a paper bag
3. Select the proper test

Choosing the proper test

- Routine testing:
  - pH
  - Organic matter
  - Salinity
  - NO3-N, P, K, Ca, Mg, Na, and S
- Micronutrients:
  - Zn, Fe, Mn, Cu, B
- Detailed Salinity:
  - pH, EC, SAR, ESP
- Others: CEC

Composting

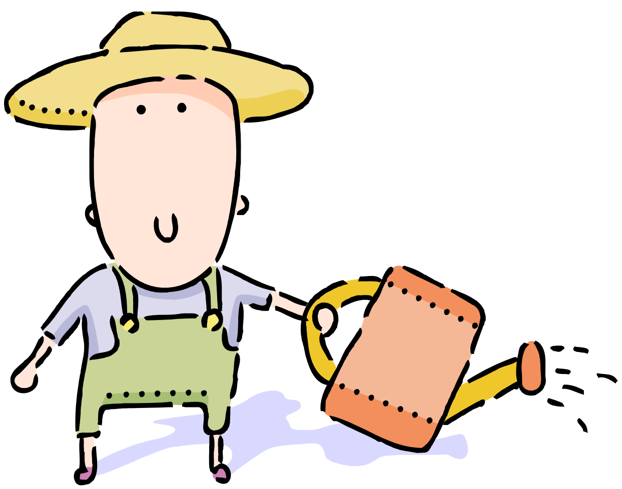
- Storing organic residues (vegetable, yard waste) in a pile with favorable decomposer conditions
- Can be turned into organic matter/humus in 6 weeks

Why Compost?

- Recycle waste materials
- Enhance soil structure
- Reduce soil losses from erosion
- Improve oxygen availability in soil
- Increase organic matter
- Recycle essential plant nutrients
- Increase biological activity

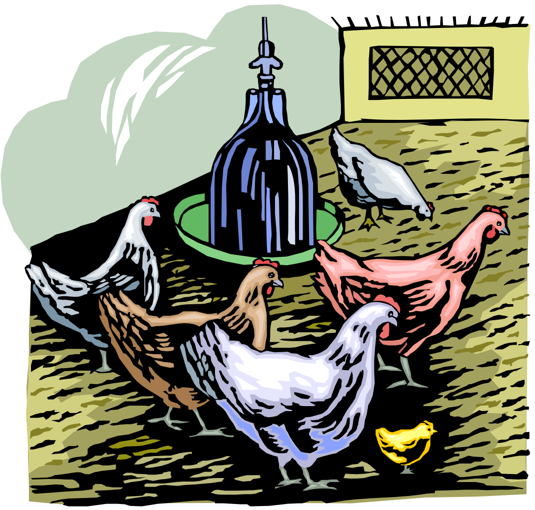
What Makes Compost?

- Raw materials (chemical composition)
- Organisms present
- Moist, oxygen-rich environment
- A dedicated space
- An observant, yet patient gardener



Raw Materials

- Kitchen waste
- Yard Waste
- Shredded paper/newspapers
- Floor sweepings
- Vacuum cleaner contents
- Wood ashes (some, not a lot)
- Shredded green yard waste
- Animal manure
- Spoiled hay
- Be creative – watch for materials



Materials NOT to Compost

- Meat/Fat Scraps
- Grease/Oil
- Pet Waste (parasites may be present)
- Large Woody Material
- Diseased Plants
- Weeds Gone to Seed
- Toxic Materials (paint chips, etc.)

C:N Ratio

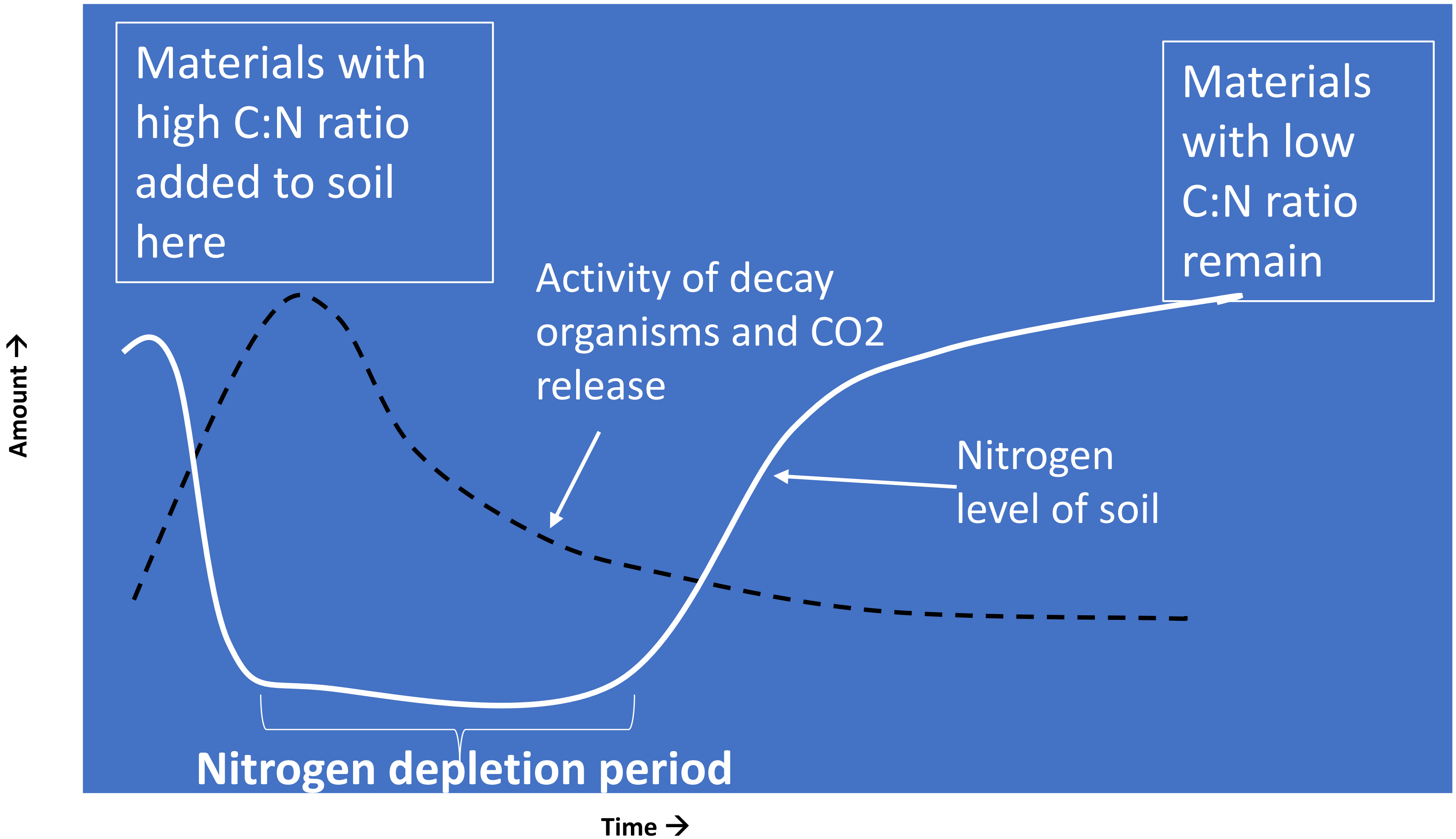
When there is too much carbon, the compost pile works slowly because the microorganisms have too little nitrogen to build up their populations.

When there is too much nitrogen, microorganisms cannot get enough carbon to satisfy their needs. The result is often an ammonia odor.

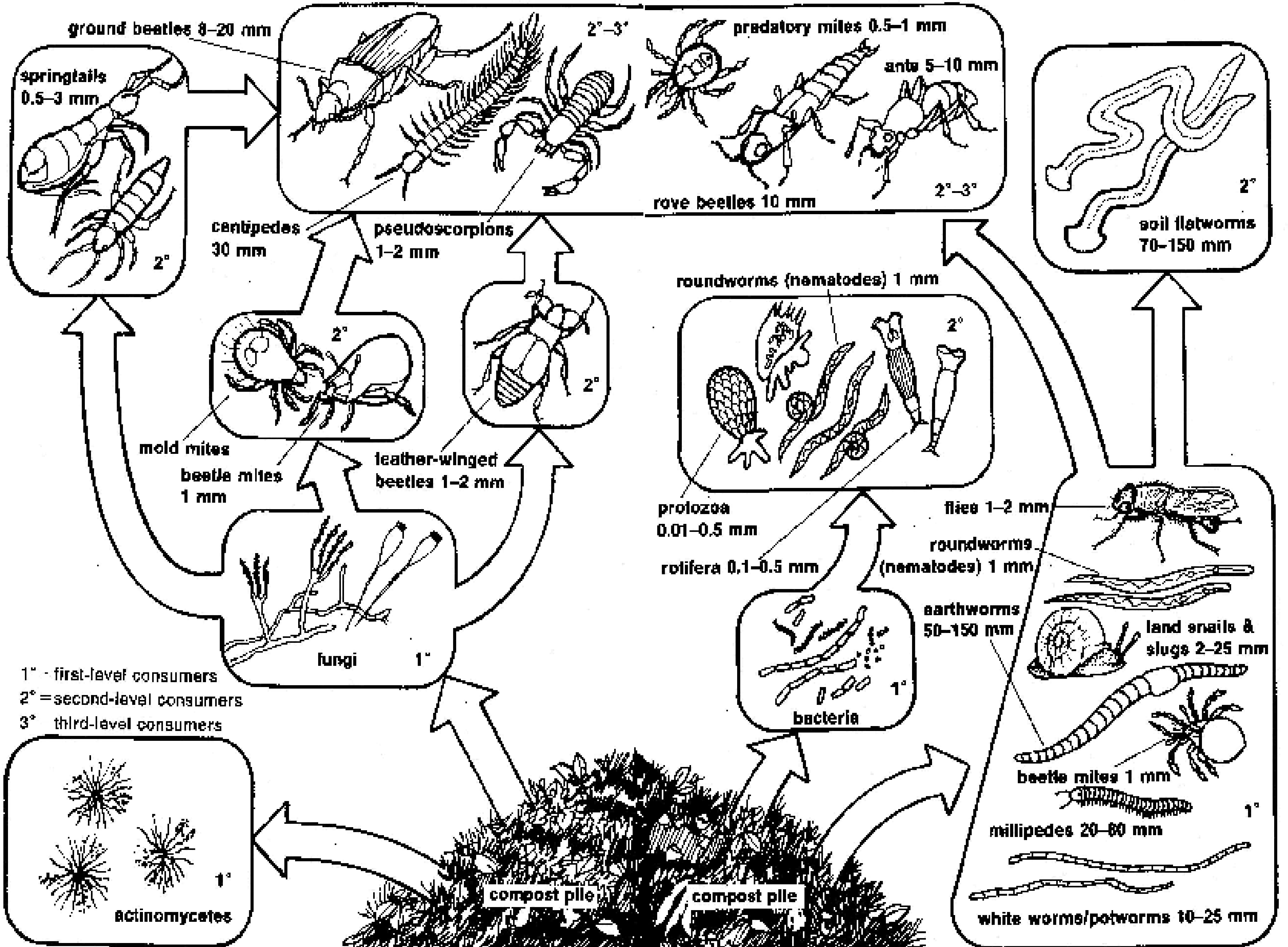
C:N Ratios of Some Materials

Food wastes	15:1
Sawdust, wood, paper	400:1
Straw	80:1
Grass clippings	15:1
Leaves	50:1
Fruit wastes	35:1
Rotted manures	20:1
Cornstalks	60:1
Alfalfa hay	12:1

Carbon:Nitrogen Ratios



Adapted from MG Text


ground beetles 8–20 mm
2°–3°
predatory mites 0.5–1 mm
ants 5–10 mm
springtails 0.5–3 mm
2°
rove beetles 10 mm
2°–3°
2°
soil flatworms 70–150 mm
centipedes 30 mm
pseudoscorpions 1–2 mm
roundworms (nematodes) 1 mm
2°
2°
2°
mold mites
beetle mites 1 mm
feather-winged beetles 1–2 mm
protozoa 0.01–0.5 mm
rotifera 0.1–0.5 mm
flies 1–2 mm
roundworms (nematodes) 1 mm
earthworms 50–150 mm
land snails & slugs 2–25 mm
fungi
1°
bacteria
1°
1° - first-level consumers
2° = second-level consumers
3° third-level consumers
beetle mites 1 mm
1°
millipedes 20–60 mm
1°
actinomycetes
compost pile
compost pile
white worms/potworms 10–25 mm

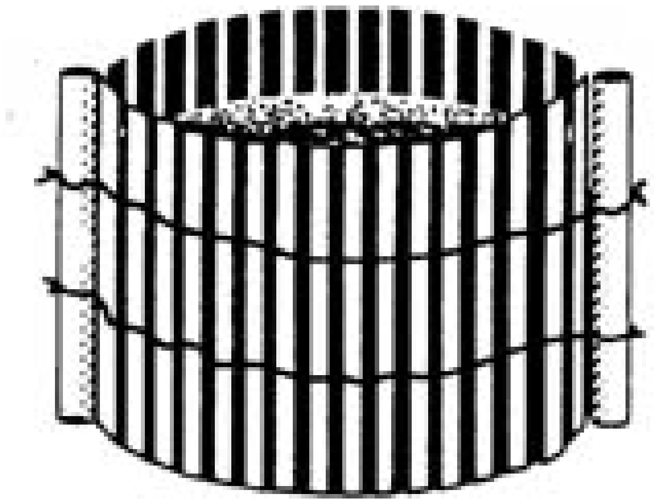
Composting Tools

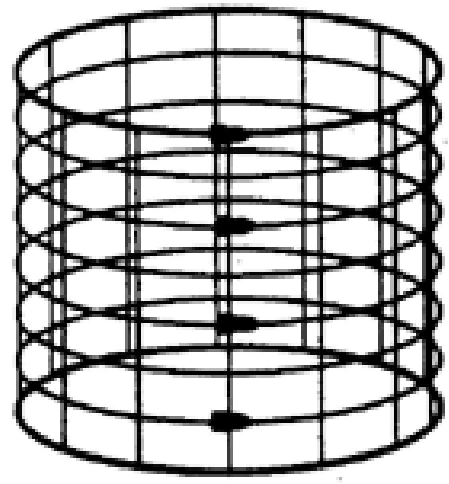
- Essential
  - Spading or Pitchfork
  - Water Source
- Optional
  - Thermometer
  - Bin(s)
  - Chipper
  - Turning Tool

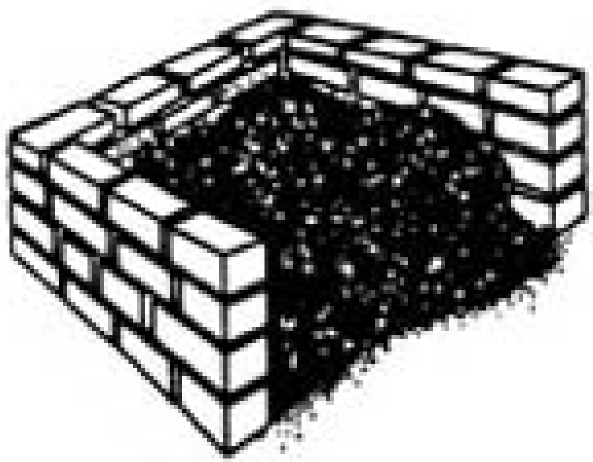
Initial Pile Construction

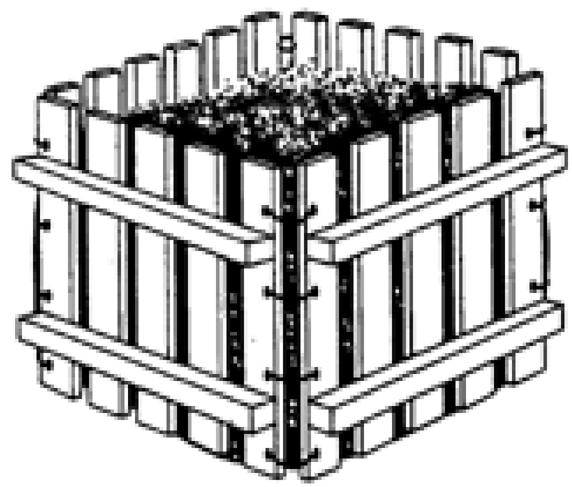
- **1st layer:** 3-4" of chopped brush or other coarse material (air circulation)
- **2nd layer:** 6-8" of mixed scraps, leaves, grass clippings, etc.
- **3rd layer:** 1"of soil serves as a microbial inoculant
- **4th layer:** (optional) 2-3" of manure to provide the nitrogen needed by microorganisms
- Repeat until desired height/volume

Methods: Homemade Bins









Methods: Rotating Drum

C:N Ratio of Green & Brown Composting Ingredients

Ingredient	C:N ratio
Greens	
Alfalfa hay	12:1
Fruit/Vegetable wastes	12:1 to 35:1
Grass Clippings	12:1 to 25:1
Manures	20:1 to 25:1
Browns	
Cornstalks	60:1
Leaves	30:1 to 80:1
Straw	40:1 to 100:1
Sawdust	500:1
Wood	700:1

Composting

Do's

- Keep moist
- Keep warm
- Turn often
- Use 50/50 brown to green ratio
- Cover food scraps
- Use multiple bins

Don'ts

- Add animal-based waste
- Add seeds

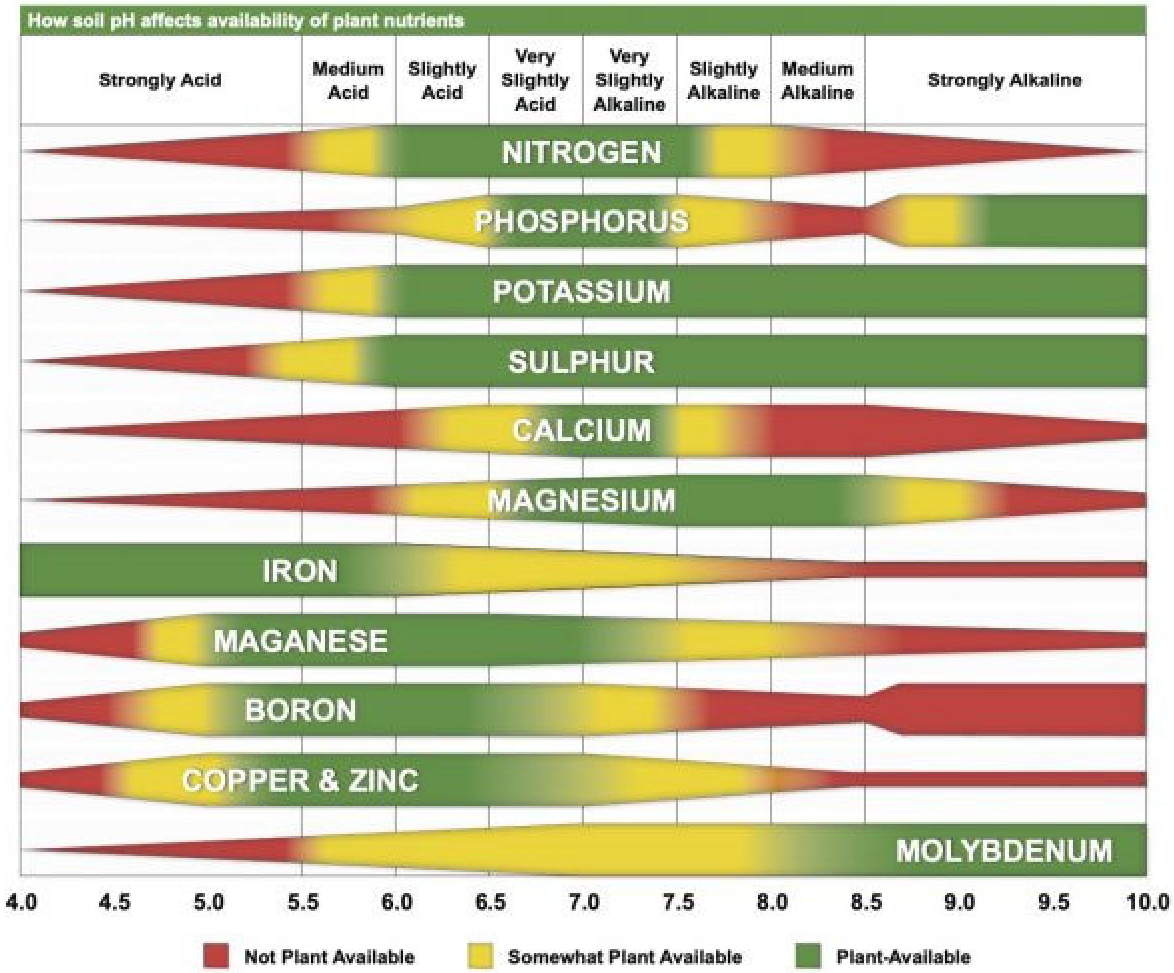
Vermiculture

- Raising “red worms” in boxes and feeding them food scraps
- Worms eat their own weight in food each day

Soil pH

- Concentration of hydrogen ions in a solution
- Scale of 0 to 14
- Pure water is 7
- pH 7 is neutral, above is basic, below is acidic
- Scale is logarithmic, i.e., a pH of 4 is 10x more acidic than a pH of 5

pH Affects nutrient availability

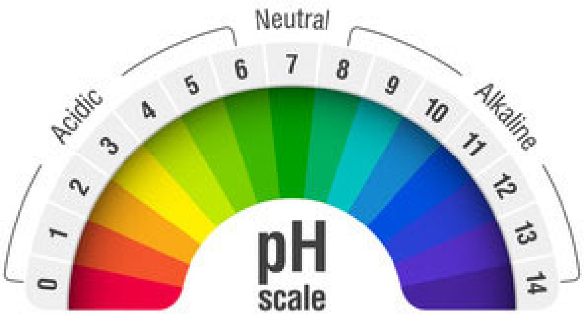


Example: Iron Chlorosis

Adjusting pH

- If too low (unlikely in AZ), add lime (CaCO3)
- If too high, add elemental sulfur (2-4lbs/100 ft_2)
- Soil bacteria convert sulfur to sulfuric acid, lowering the pH

$$2S + 3O_2 + H_2O \rightarrow 2H_2SO_4$$

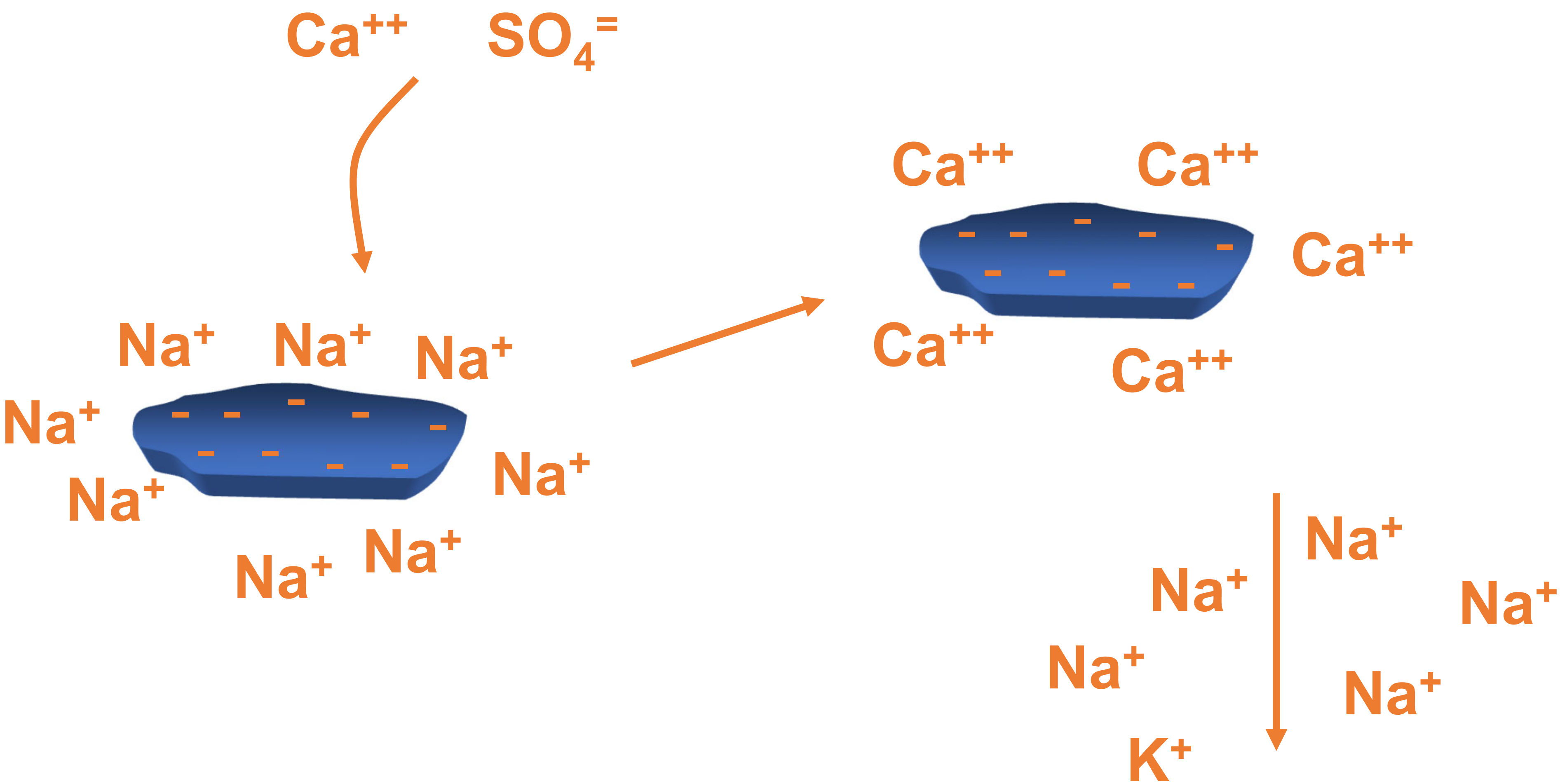


Saline (salty) soils

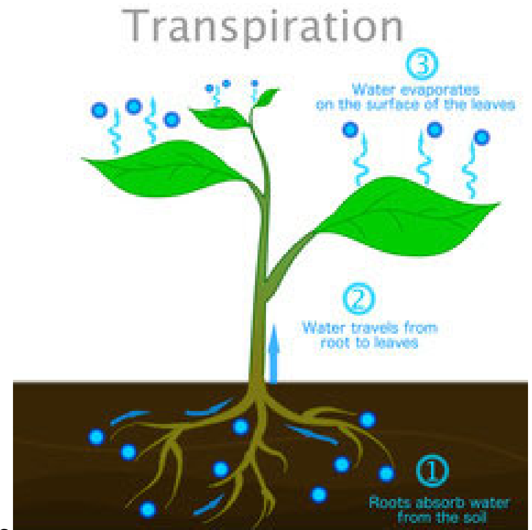
- Develop in arid climates because water evaporates from surface leaving soil crust
- Growers often leach salt down with water
- Makes it hard for plants to pull water up

- Sodic soils- specifically sodium salts
  - Gypsum used to amend (20lbs/100ft2)

Adding Gypsum to Sodic Soils



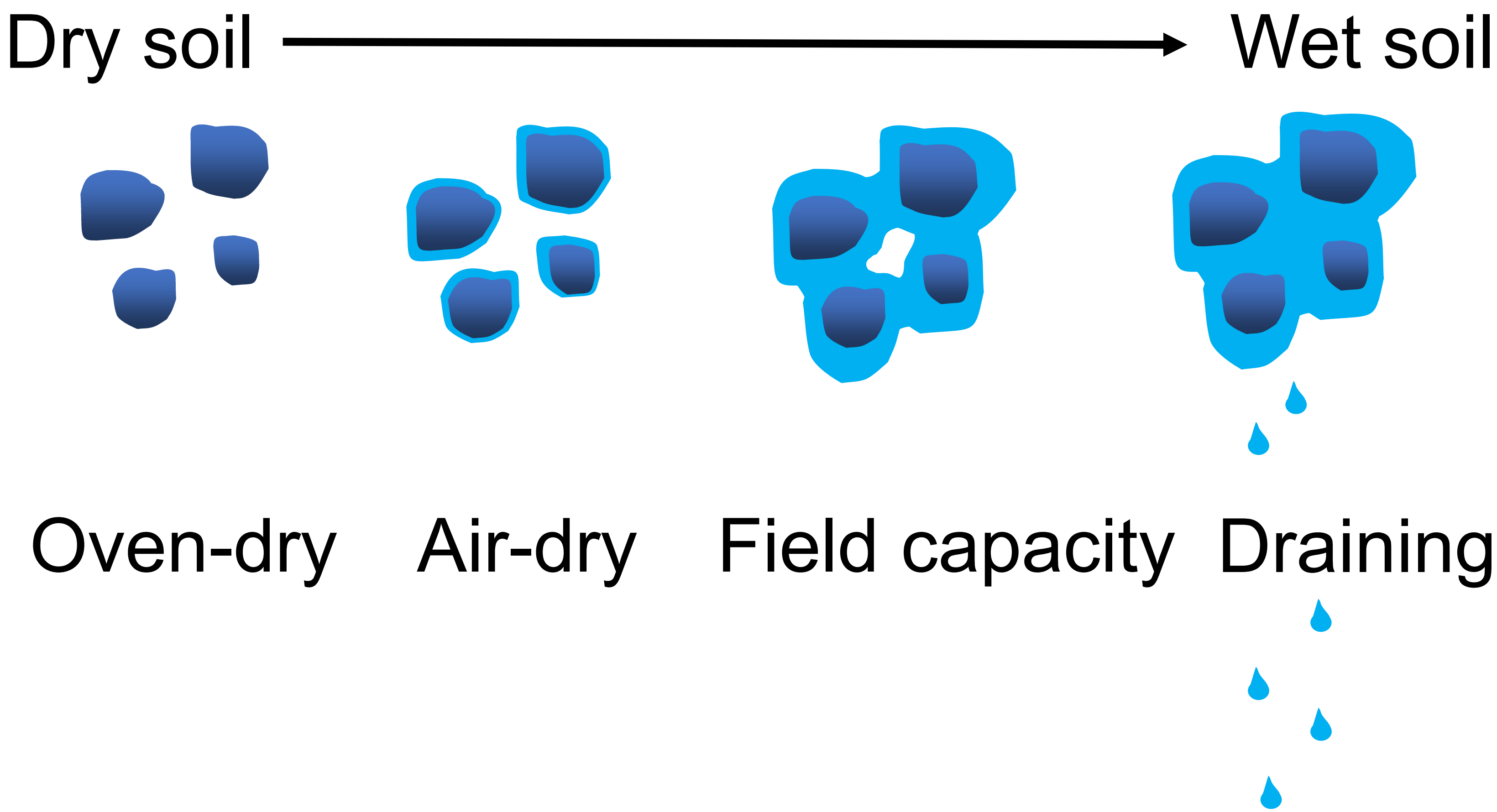
Soil & Water



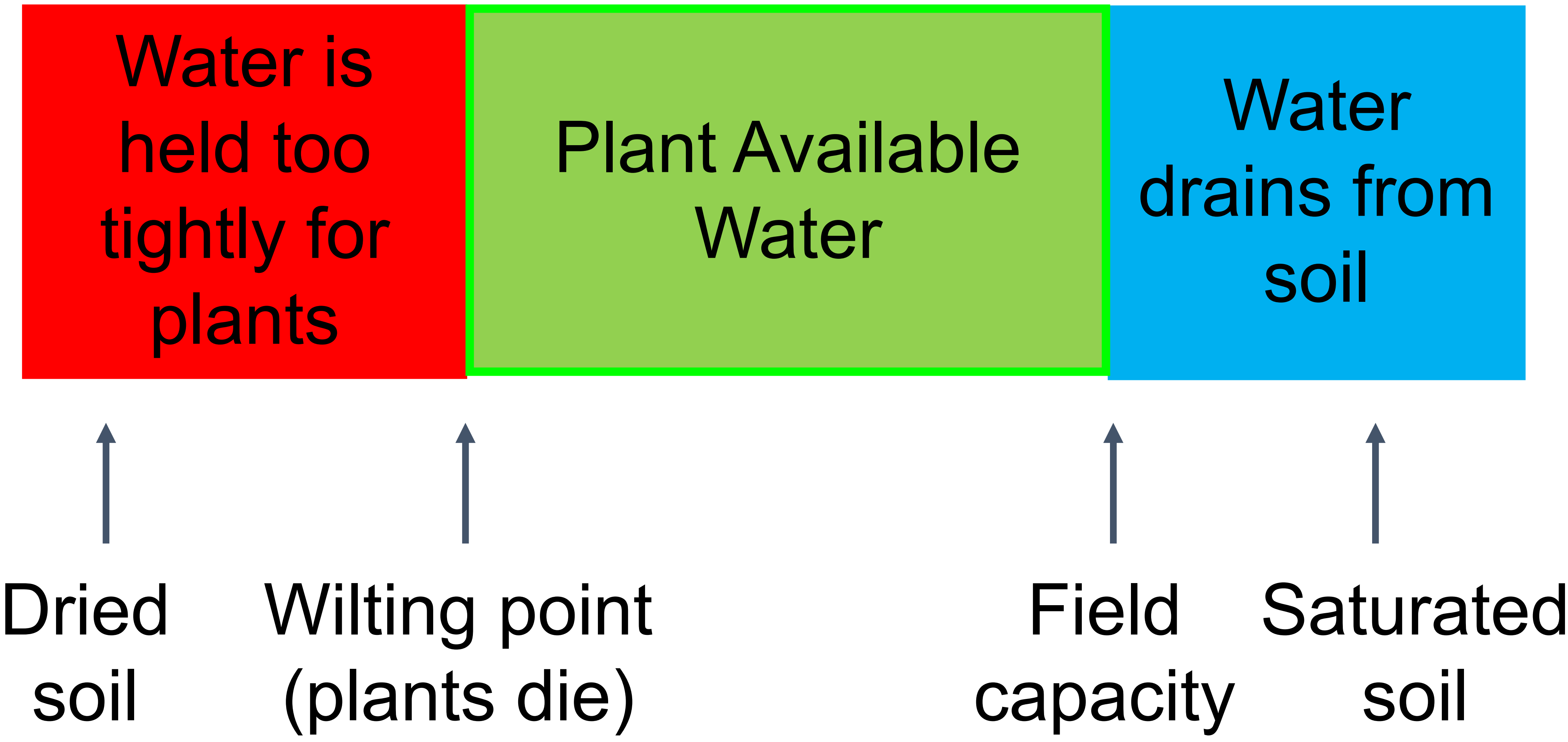
- Nutrients are dissolved in water
- Water is bound to soil by adhesion
- The closer the water is to a soil particle, the more tightly it is bound
- Influenced by texture, structure, OM
- Plants must “pull” water up against this force
- Water moves from high to low concentrations

Soil Water

Water is attracted to particle surfaces



Available Soil Water



Water Availability