ACLP II
ADVANCED
ARIZONA CERTIFIED
LANDSCAPE PROFESSIONAL

Soil Science

Workshop Objectives

- Physical properties of soil
  - Texture
  - Structure
  - Water & air space
- Chemical properties of soil
  - Salinity
  - CEC, SAR, ESP
  - Water and air interaction in soil
- Soil Biology
  - How living organisms in soil impact soil/ water/ plant relationships
- Management
  - Soil treatments
  - Water quality management

Soil Challenges in the Desert Southwest

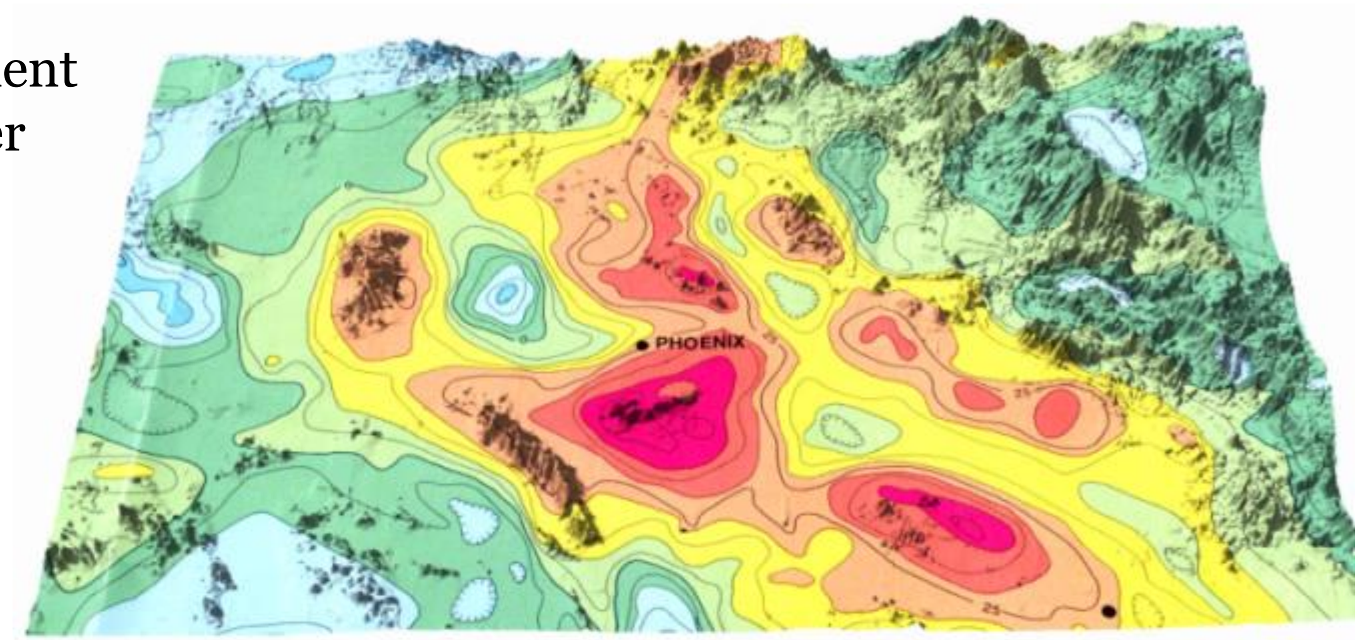
- Compaction
- Structure
- Poor microbiology
- Poor quality irrigation water
- Infiltration
- Salty conditions

- Does the plant belong here?
- Native vs. non-native
- Does the soil require modification?

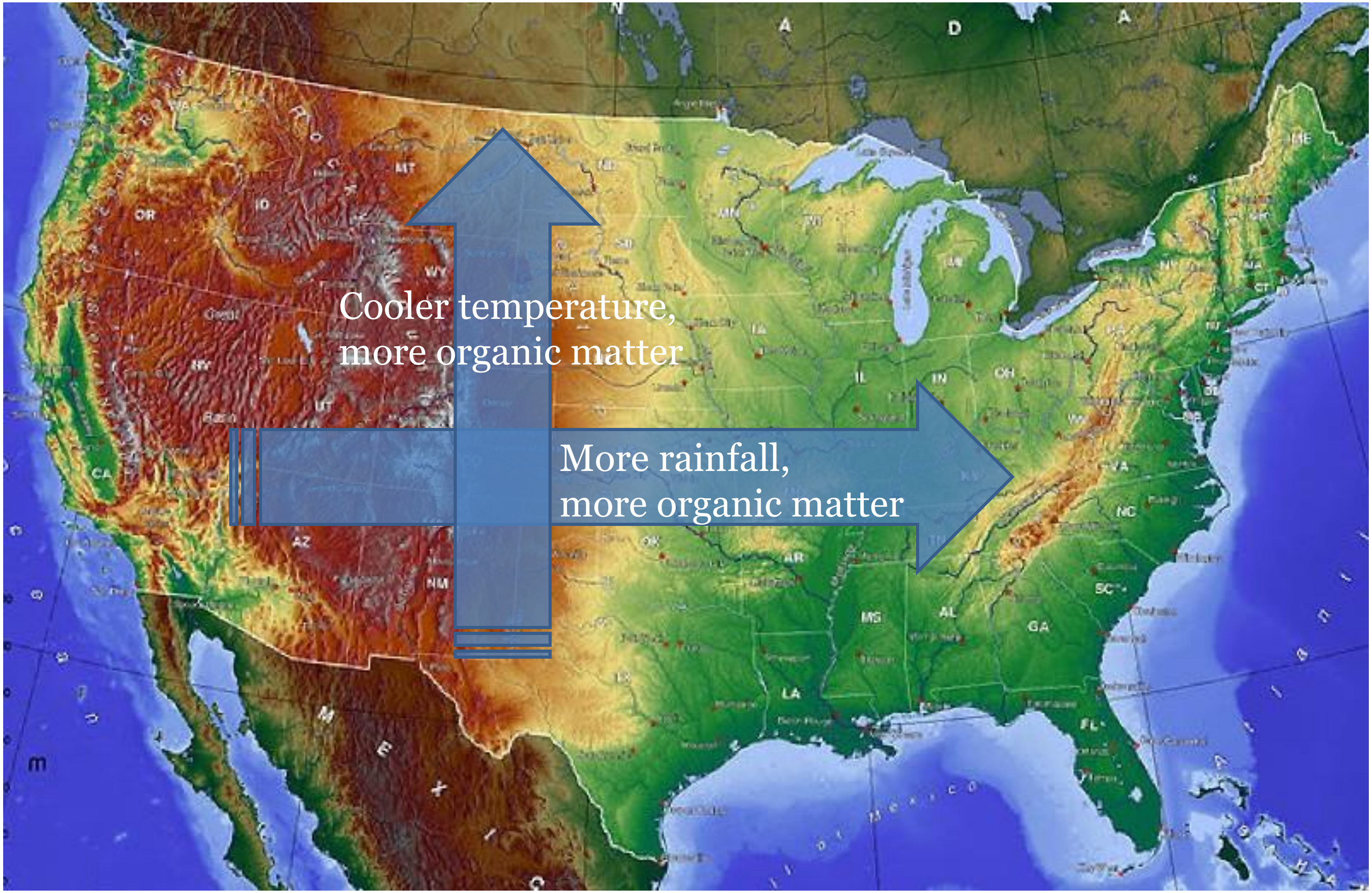
Where did our soils come from?

Soils form from minerals broken up by action of weathering, plant roots and the addition of decaying plant parts.

- **Parent material**
- **Topography**
  - soil development affecting water movement

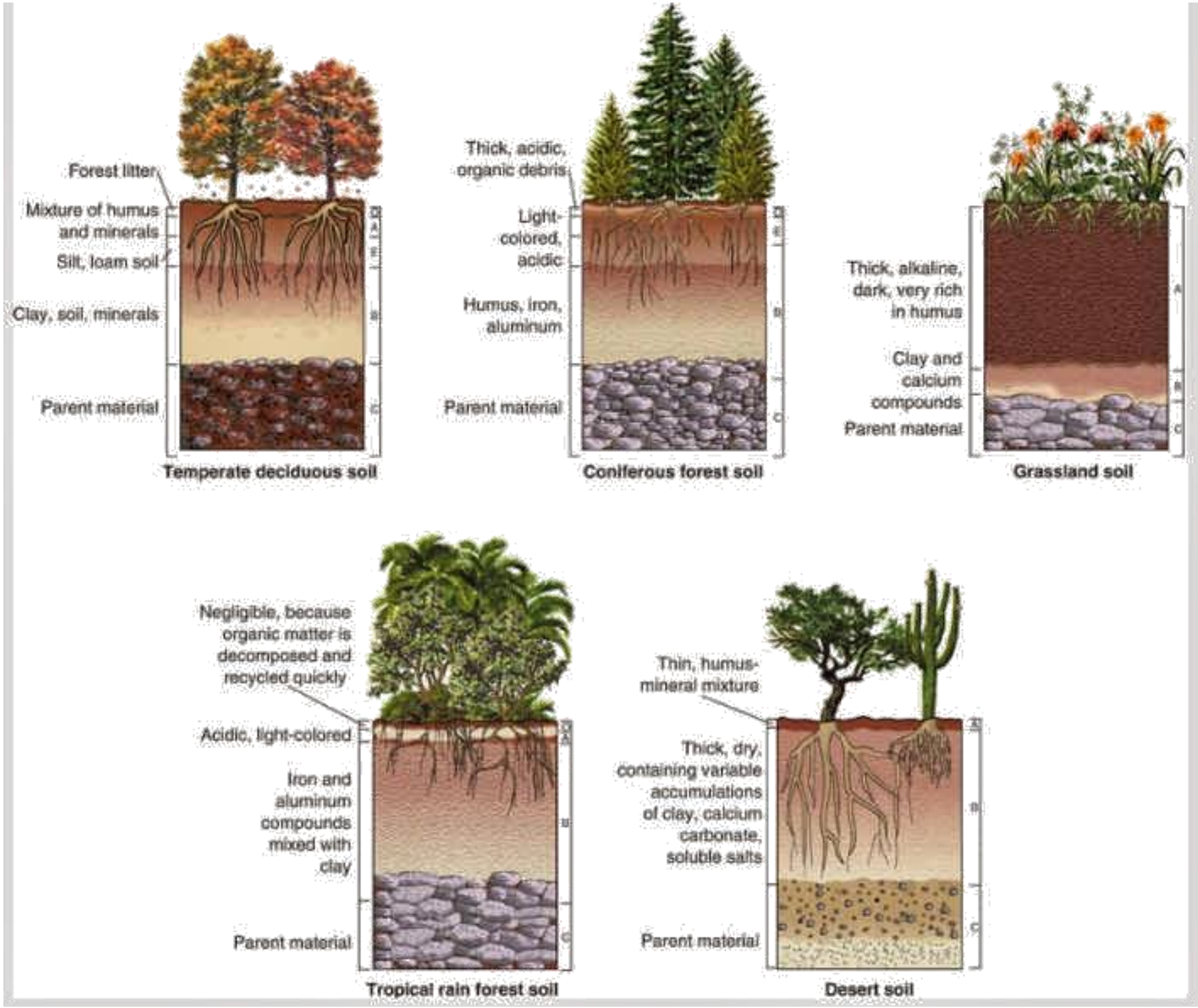


Climate

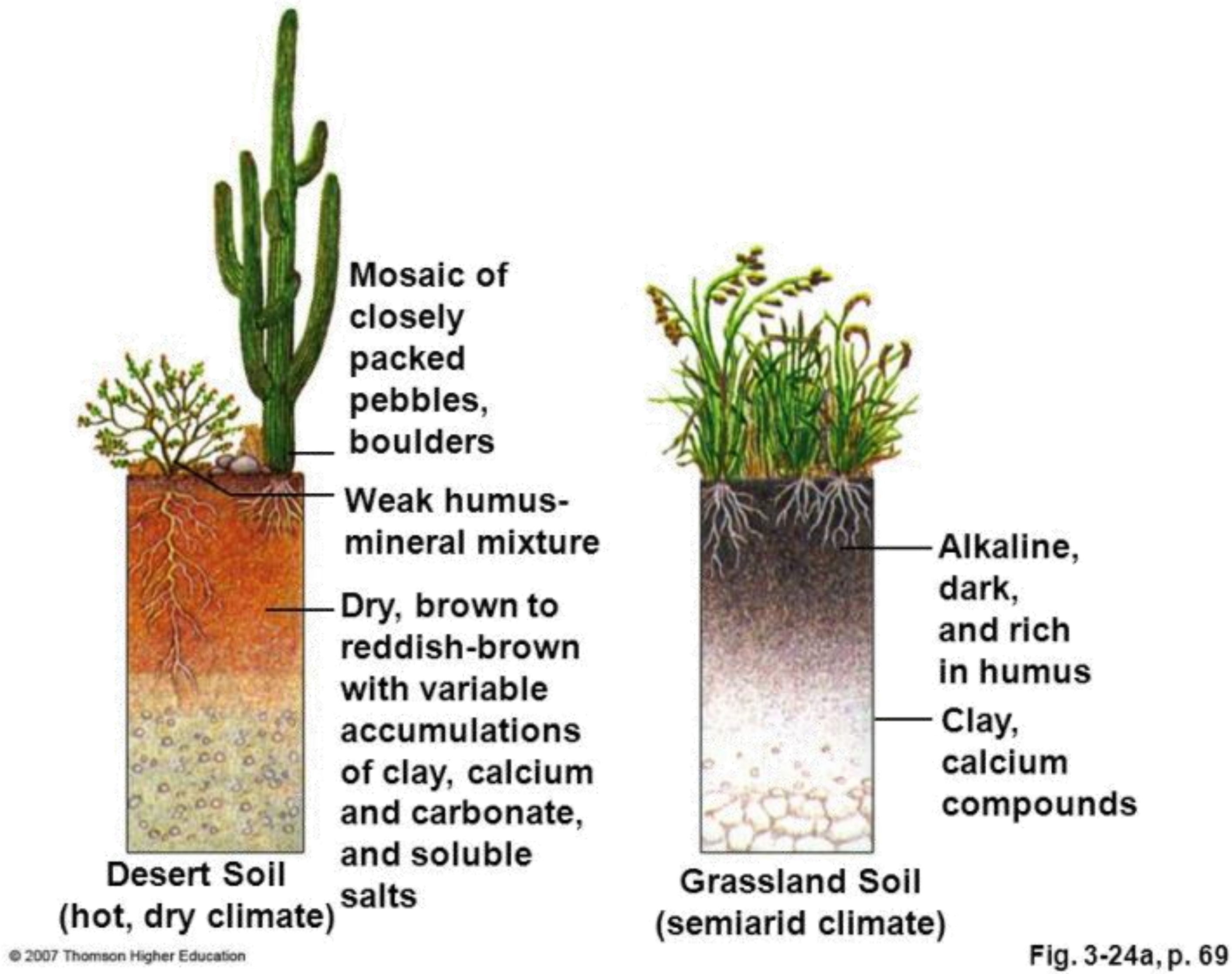


Cooler temperature,
more organic matter
More rainfall,
more organic matter

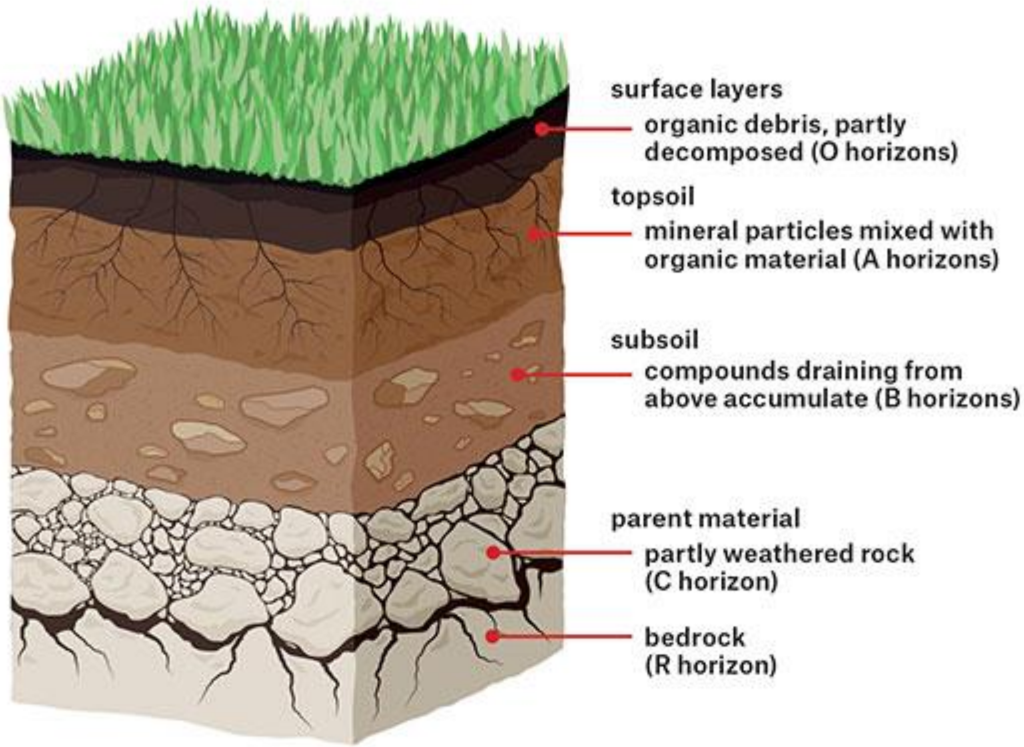
Organisms


Forest litter
Mixture of humus and minerals
Silt, loam soil
Clay, soil, minerals
Parent material
Temperate deciduous soil
Thick, acidic, organic debris
Light-colored, acidic
Humus, iron, aluminum
Parent material
Coniferous forest soil
Thick, alkaline, dark, very rich in humus
Clay and calcium compounds
Parent material
Grassland soil
Negligible, because organic matter is decomposed and recycled quickly
Acidic, light-colored
Iron and aluminum compounds mixed with clay
Parent material
Tropical rain forest soil
Thin, humus-mineral mixture
Thick, dry, containing variable accumulations of clay, calcium carbonate, soluble salts
Parent material
Desert soil

Desert Soil

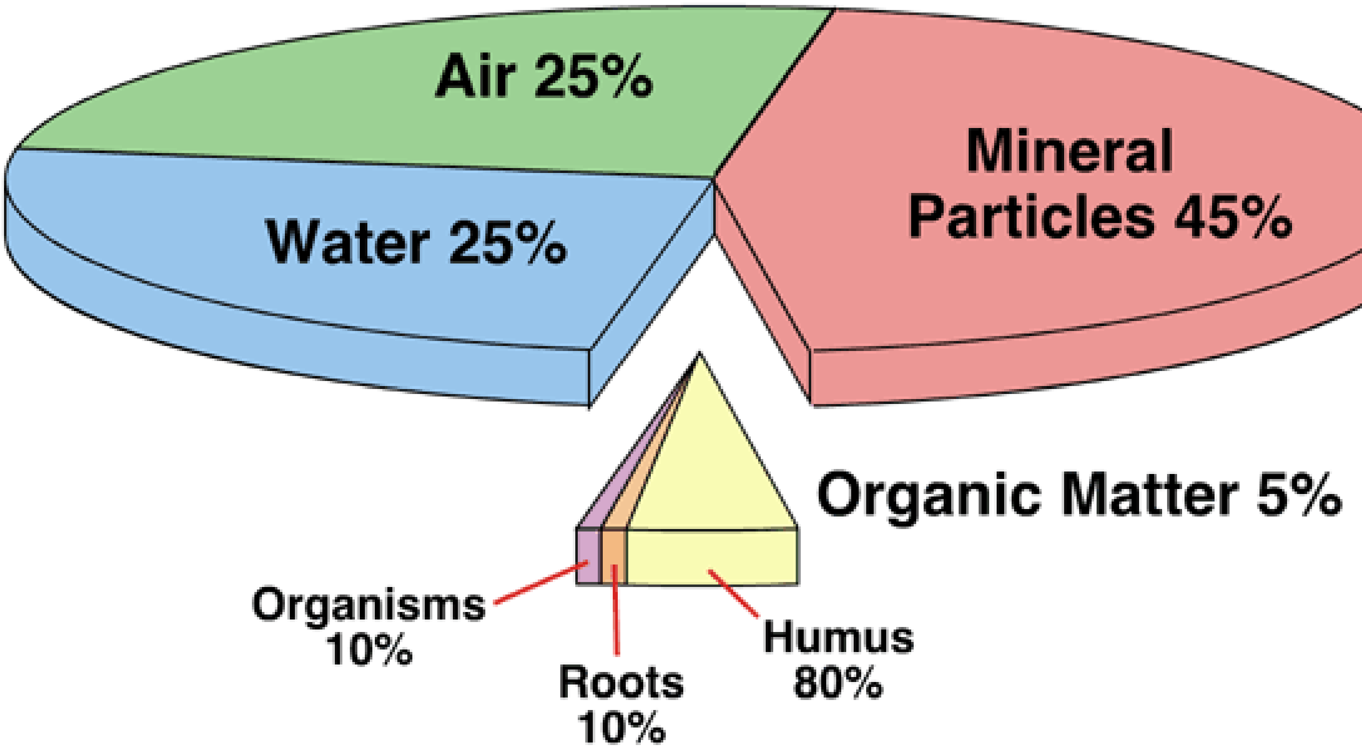

Mosaic of closely packed pebbles, boulders
Weak humus-mineral mixture
Dry, brown to reddish-brown with variable accumulations of clay, calcium and carbonate, and soluble salts
Desert Soil (hot, dry climate)
Alkaline, dark, and rich in humus
Clay, calcium compounds
Grassland Soil (semiarid climate)
© 2007 Thomson Higher Education
Fig. 3-24a, p. 69

Time



- Soils change over time due to aging process
- Humans

Soil Composition

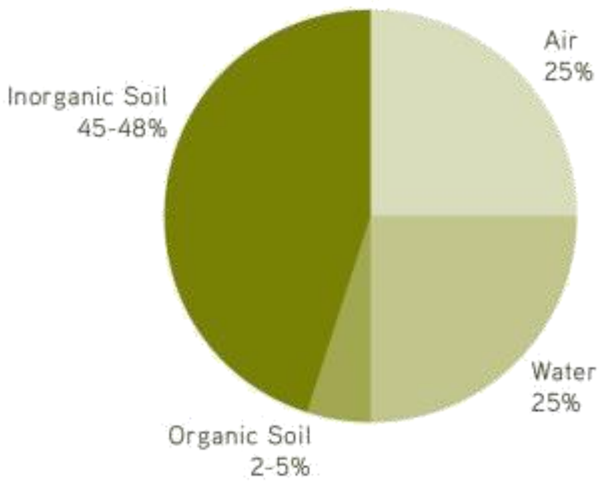


Is this our typical soil in the Desert Southwest?

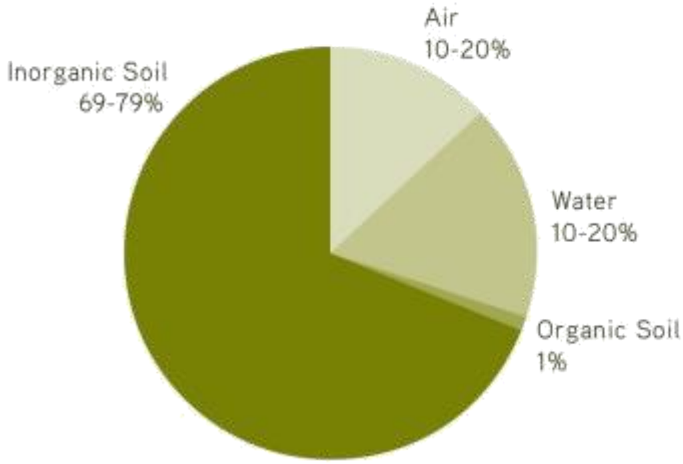
Urban Soil Challenges

Soil quality directly impacts plant life

- ✓ Establishment
- ✓ Growth
- ✓ Health
- ✓ Longevity



FOREST SOILS



URBAN SOILS

*Remember desert soil has less than 5% organic matter… why is that?

Urban Soil Challenges

- Urban soils are highly modified and degraded
- Physical, chemical or biological impairments
  - Chemical contaminants
  - Pollutants such as heavy metals and salts
  - Poor quality irrigation water leads to salinization
  - Soil degradation due to compaction from heavy equipment during construction
- Leads to limited root growth and tree stress
- Contributes to premature mortality

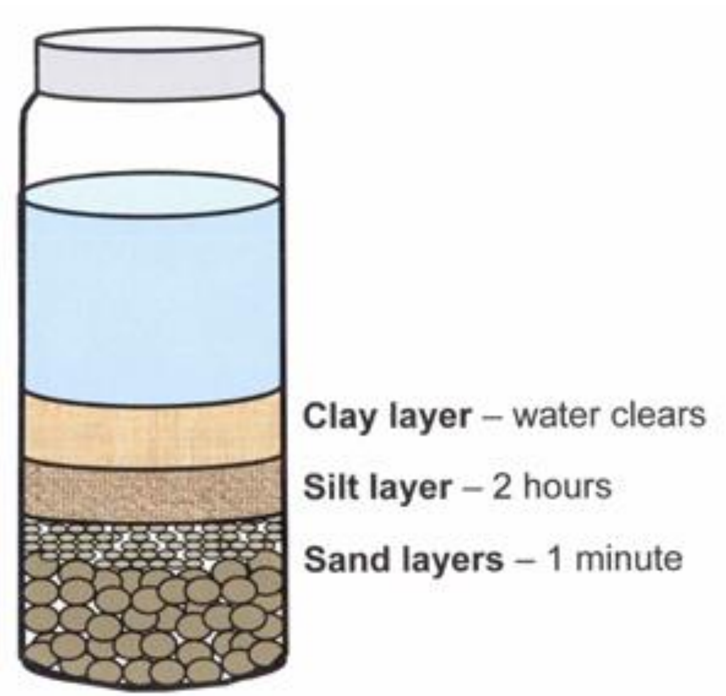
An urban soil profile showing that a fill was added near the surface of this soil. Credit: Natural Resources Conservation Service

How do urban soils become this way?

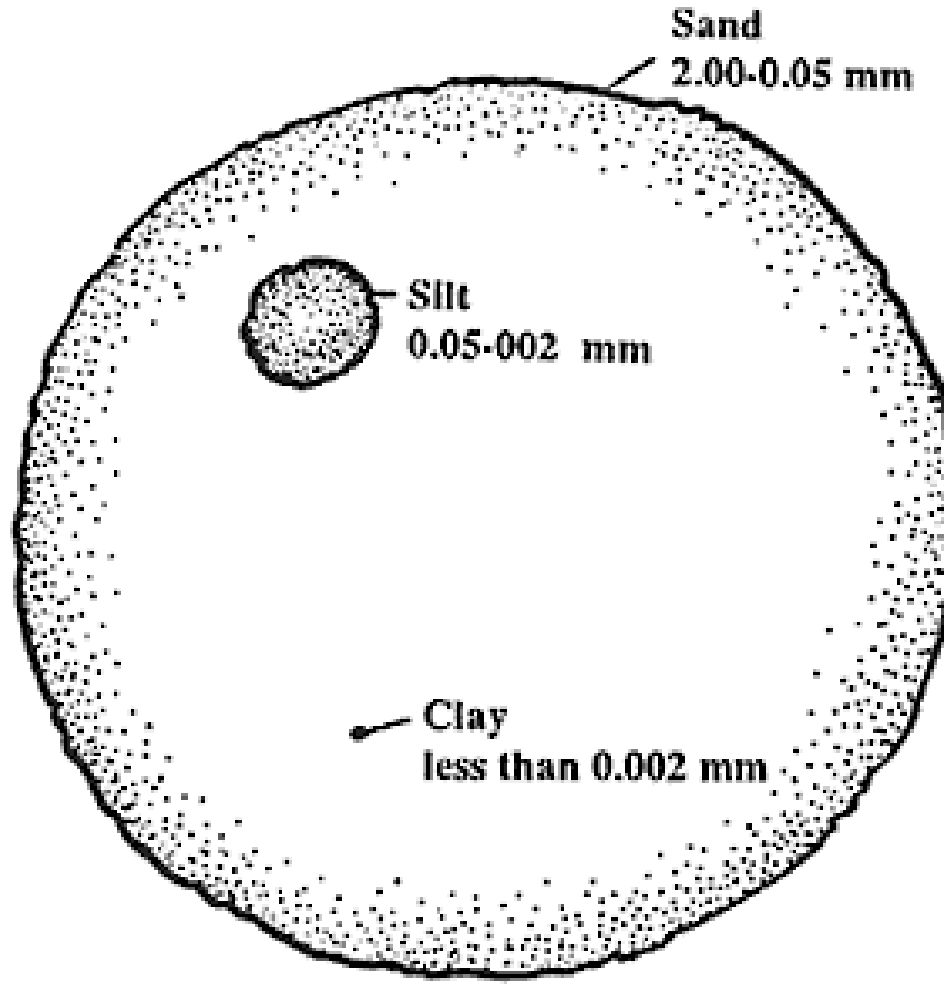
- Poorly timed irrigation systems can cause soil moisture problems
- Removal of organic matter influences soil fertility and moisture
- Excessive herbicide or fertilizers contaminate the soil
- Foot traffic from pedestrians and road vibrations compact the soil
- Backyard chemical spills, such as gasoline and oil, contaminate the soil

Physical Properties of Soil

Soil Texture Review



During the breakout session, determine the composition of our sample

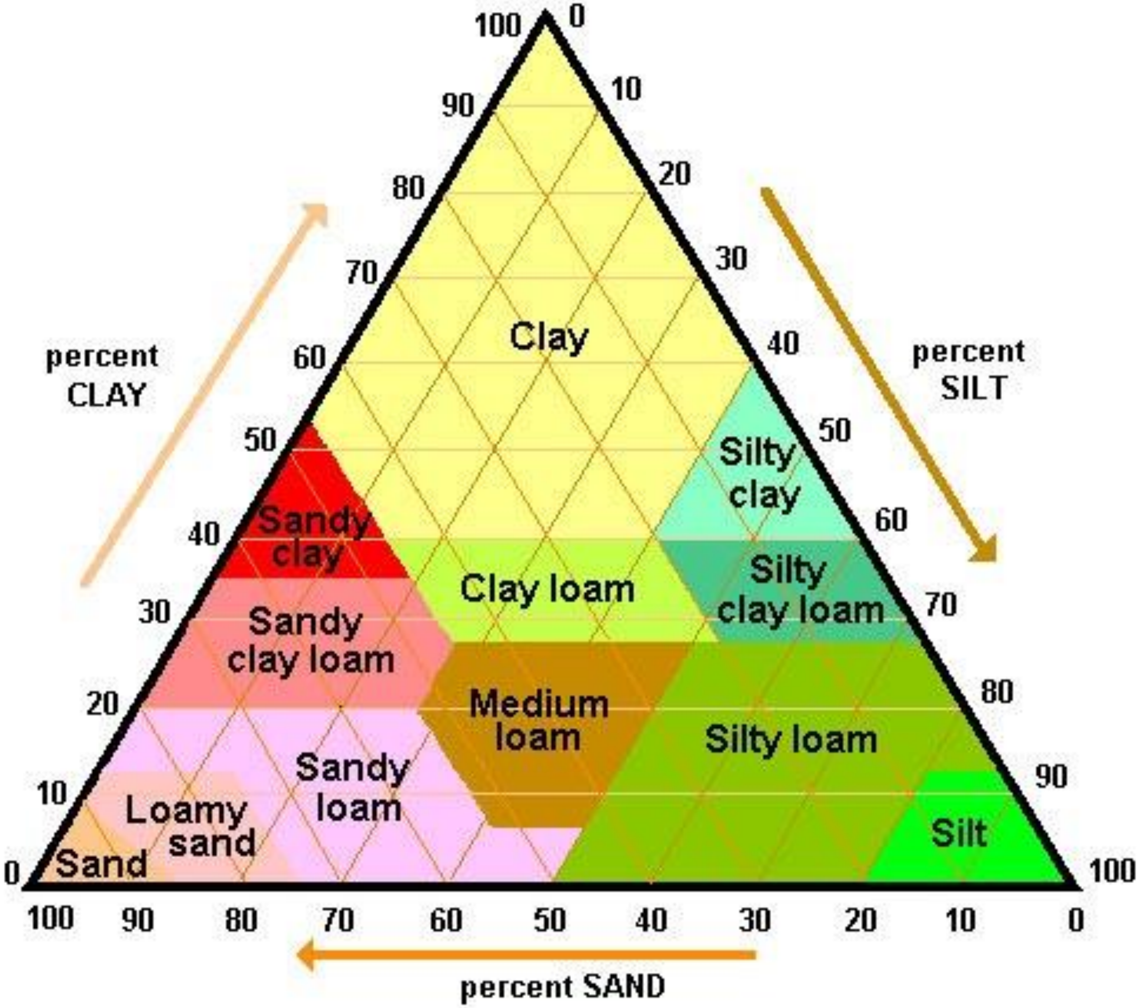


Soil Texture Review

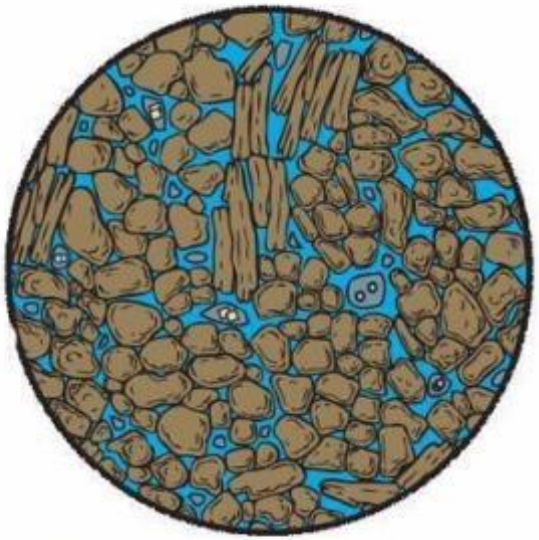
Separate	Diameter (mm)	Comparison	Feel
Very coarse sand	2.0-1.0	36”	Grains easily seen, sharp, gritty
Coarse sand	1.0-0.50	18”	
Medium sand	0.50-0.25	9”	
Fine sand	0.25-0.10	4 ½”	Gritty, each grain barely visible
Very fine sand	0.10-0.05	1 ¾”	
Silt	0.05-0.002	7/16”	Grains invisible to eye, silky to touch
Clay	<0.002	1/32”	Sticky when wet, dry pellets hard, harsh

Soil Texture Review

Why is this important?



Soil Density and Permeability



Lower bulk density
Lower weight
More pore space

Higher bulk density
Higher weight
Less pore space

Soil Structure Review

Natural organization of soil particles into discrete soil units- aggregates

- Structureless Soil
  - Massive
    - Hard packed clay
  - Single grain
    - sand
- Granular
- Platy
- Block
- Prismatic
- Columnar

Soil Structure

Infiltration & Percolation Rates

The rate that water enters (infiltrates) a soil and then moves through the soil profile (percolates) depends on soil structure

- Rapid infiltration with granular and loose, single grained structureless soil
- Moderate infiltration with block-like and prismatic structure
- Slow infiltration with clay and solid, massive ‘structureless’ structure

Factors Influencing Infiltration

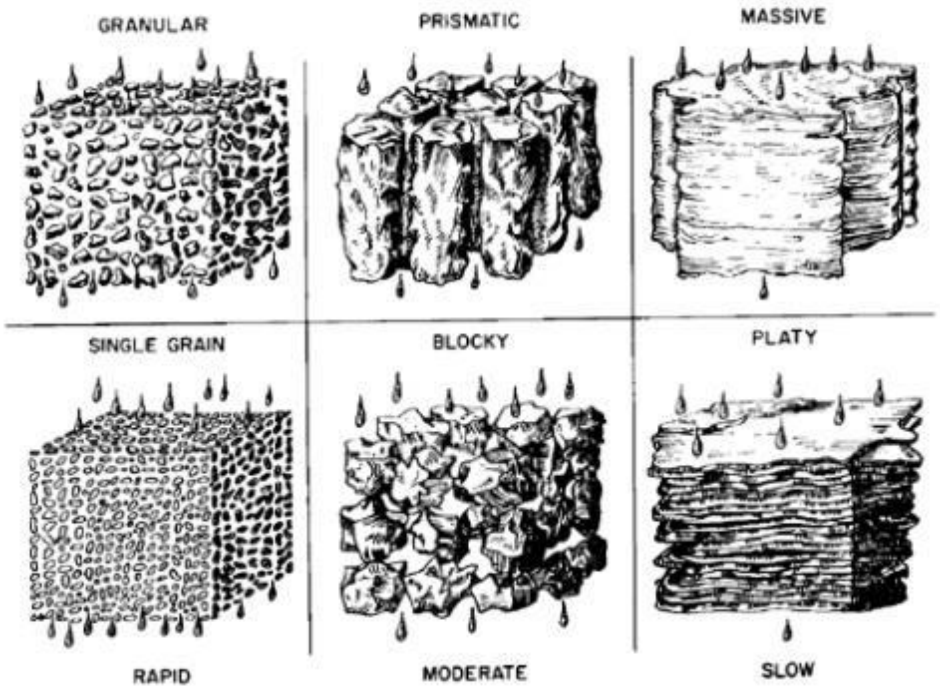
- **Surface entry**
  - If surface area is bare, this retards infiltration
- **Percolation**
  - Infiltration is bounded by rate of percolation
    - Soil type
    - Composition
    - Permeability
    - Porosity
    - Stratification
    - Organic matter
    - Presence of salt
- **Soil moisture**
- **Climate condition**
- **Degree of saturation**
  - The more saturated the substrate, the less infiltration

Factors Influencing Infiltration

- **Human activities**
  - Roads, parking lots, buildings are not permeable
  - Runoff challenges
  - Reduction of vegetation also decreases permeability
- **Porosity**
  - Open space in substrate
  - Generally the greater the porosity, the greater the infiltration
- **Vegetation**
  - Plant foliage physically prevents rain from reaching soil
  - Reduces velocity of water, allowing more time for ground to absorb water
  - Ground without vegetation usually has high runoff and low infiltration rates

Factors Influencing Infiltration

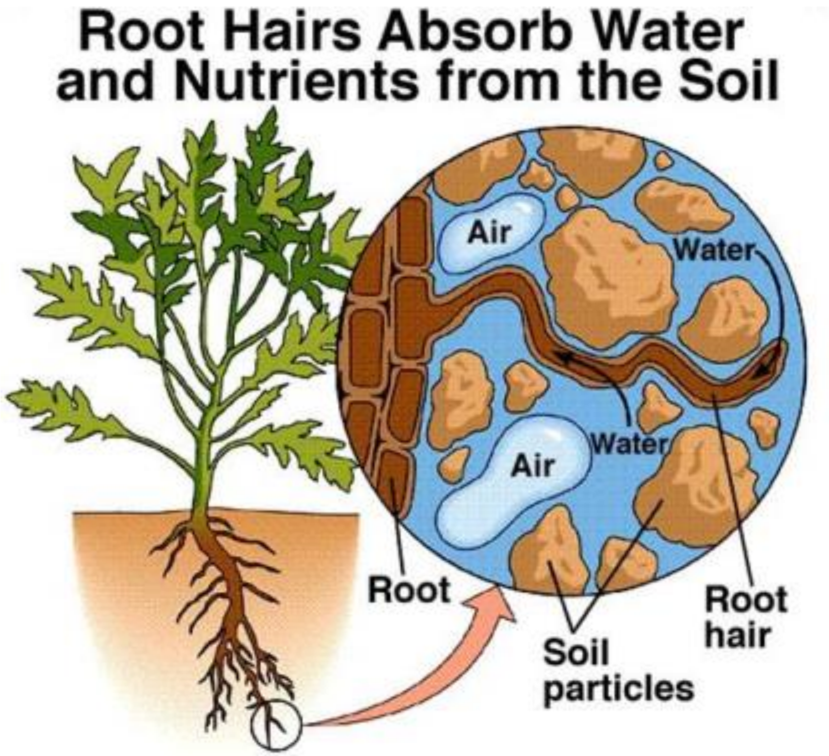
- **Permeability**
  - Ability of substrate to allow fluids to pass through
  - Impermeability may be due to tight packing or cementing of particles, which seals off pores
- **Grain of soil particle**
  - Rounded particles have greater porosity
    - More pore space= higher porosity/ greater infiltration
  - Angular particles
    - Less pore space= less porosity/ less infiltration

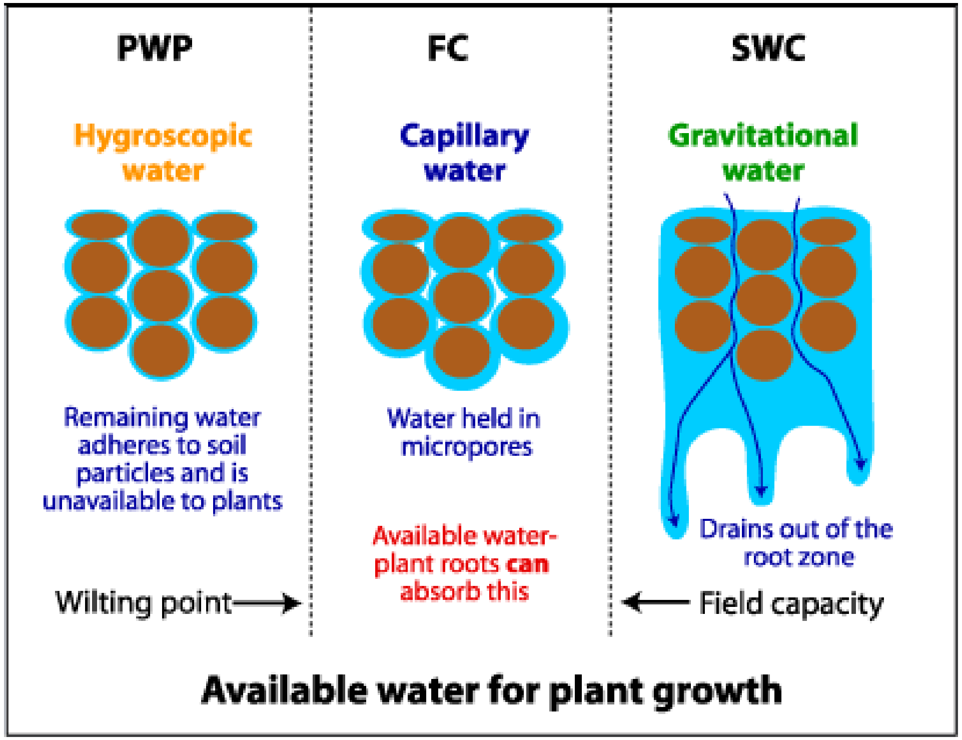


Soil Moisture

How can you tell if the moisture is appropriate for the plant?

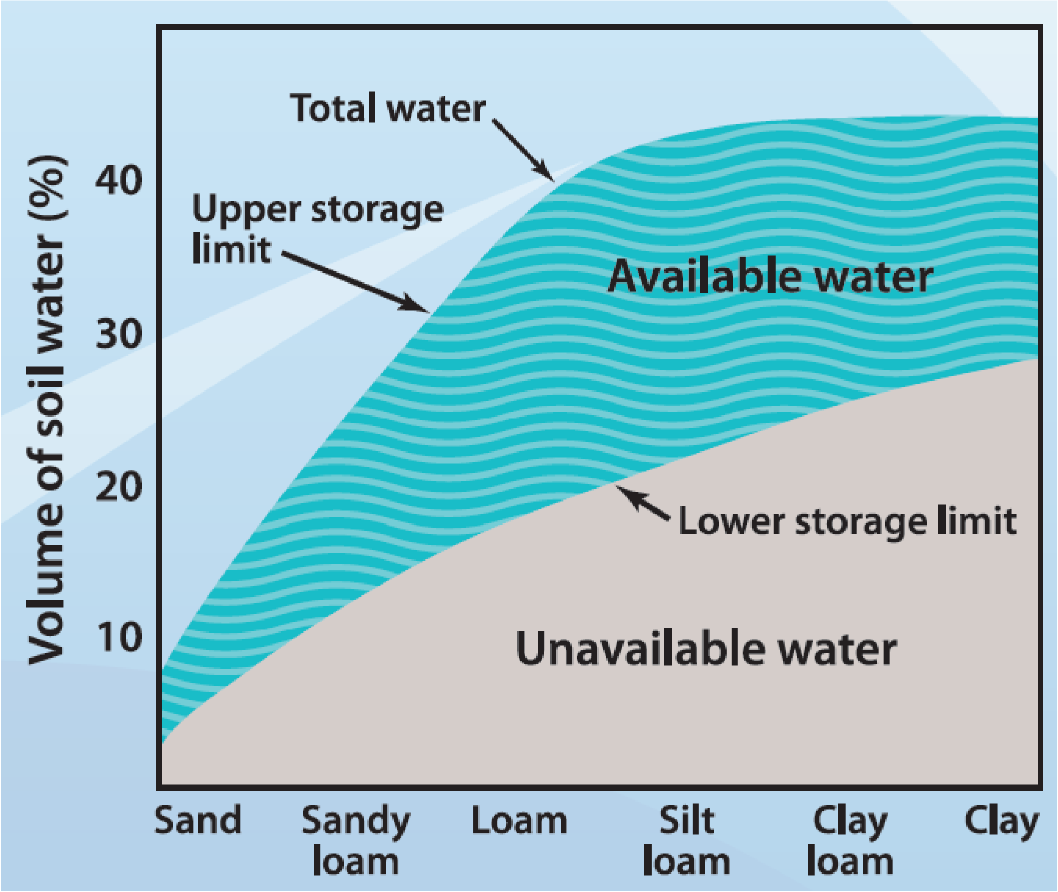
Available Water





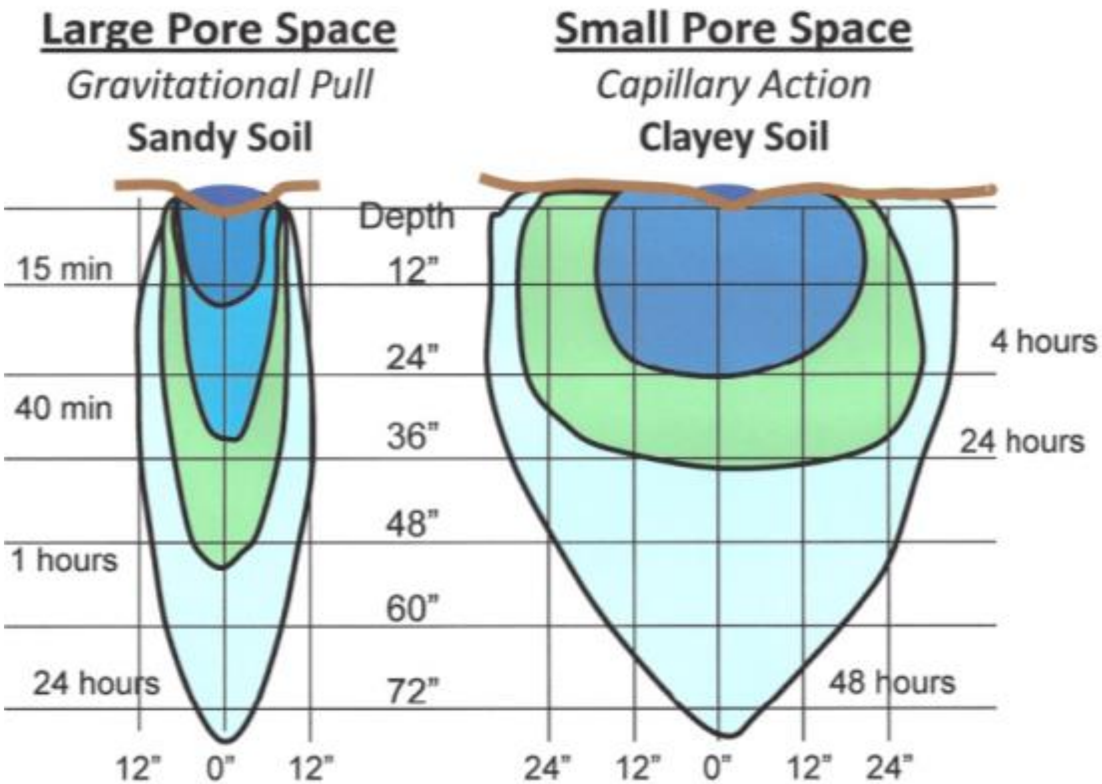
- Cohesion – "like sticking to like"
  - Water molecules stick together
- Adhesion – "sticking to unlike"
  - Water molecules stick to certain surfaces
- Capillary action – drawing of water in a narrow tube

How Plants Use Water



It is important to know your soil texture for proper water management for your plants.

Water Retention and Movement



Water Management

- How will you manage a clay soil differently from a sandy soil?
- What is an example of a watering schedule for each?

How Plants Use Water

Effect of water stress

- Causes chemical changes in the plant
- Slow growing and stunted
- Leaves turn from shiny to dull
  - Grasses show footprints
- Chronic stress
  - Wilt and stop growing
  - Diminished crop
  - Discolored leaves, flowers
  - Marginal scorch
  - Dead patches in canopy
  - Death

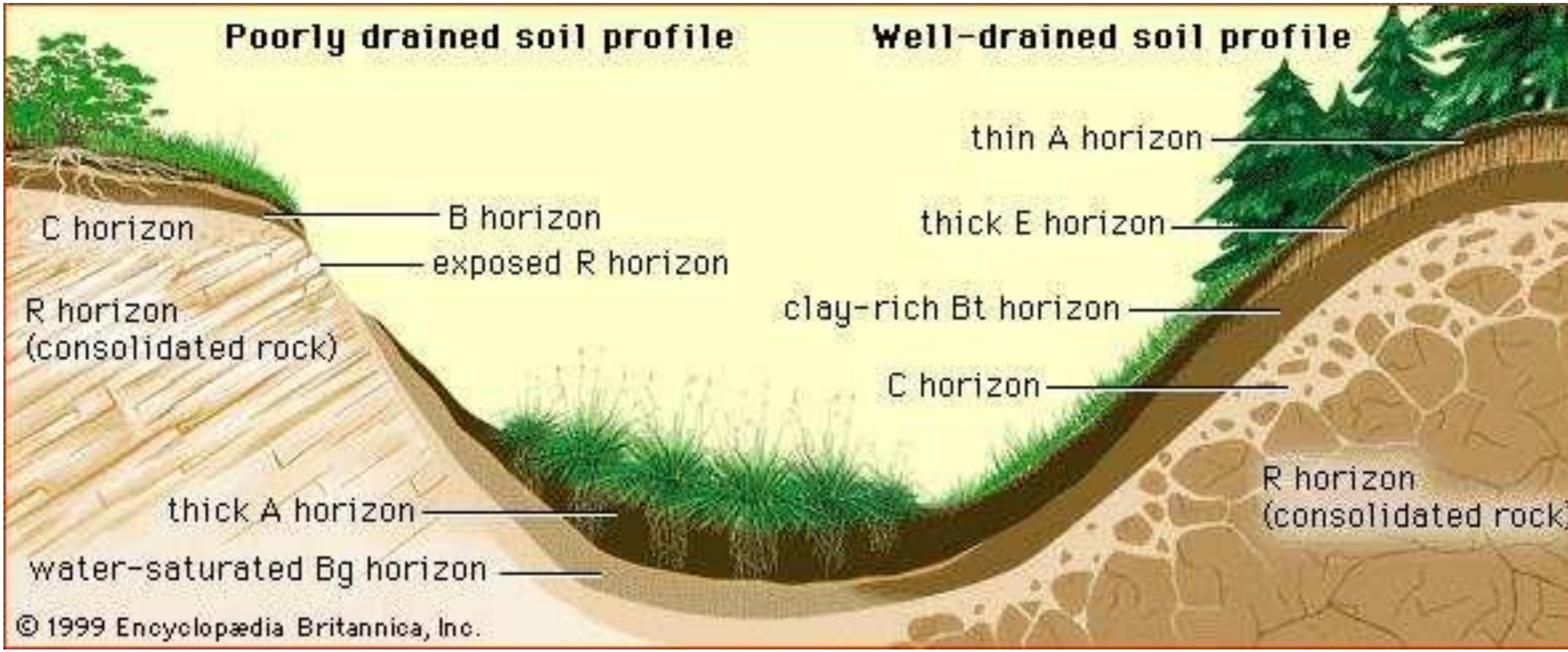
Effect of excess water

- Roots can not respire
- Toxic gases may develop, limiting root growth
- Root tissue dies and decomposes
- Slow or stunted growth
- Chronic stress
  - Wilt and stop growing
  - Wilting, yellowing of lower foliage
  - Drop of foliage
- Disease pressure
- Oxygen demands by roots vary by species and stage of growth

Water Conservation Goals

- Use water efficiently
  - Capture more water from precipitation
- Reduce consumptive use
  - Reducing evaporation
  - Reducing transpiration
  - Improve irrigation systems
- Capture water in soil
  - Improve filtration
- Capturing runoff
    - Improve water intake rate
  - Lower percolation
- Improving plant-use efficiency
- Water quality
  - Rainfall
  - Potable
  - Reclaimed

Drainage and Irrigation


Poorly drained soil profile
Well-drained soil profile
thin A horizon
C horizon
B horizon
exposed R horizon
thick E horizon
R horizon
(consolidated rock)
clay-rich Bt horizon
C horizon
R horizon
(consolidated rock)
thick A horizon
water-saturated Bg horizon
© 1999 Encyclopædia Britannica, Inc.

When and How to Water

Degree of Moisture	Feel	Amount of Available Moisture
Dry	Powdery dry	0
Low	Crumbly, will not hold together	< 25%
Fair	Somewhat crumbly, will hold together	25-75%
Good	Forms balls, sticks together slightly with pressure	50-75%
Excellent	Forms pliable ball	75-100%
Too wet	Can squeeze out water	Over field capacity

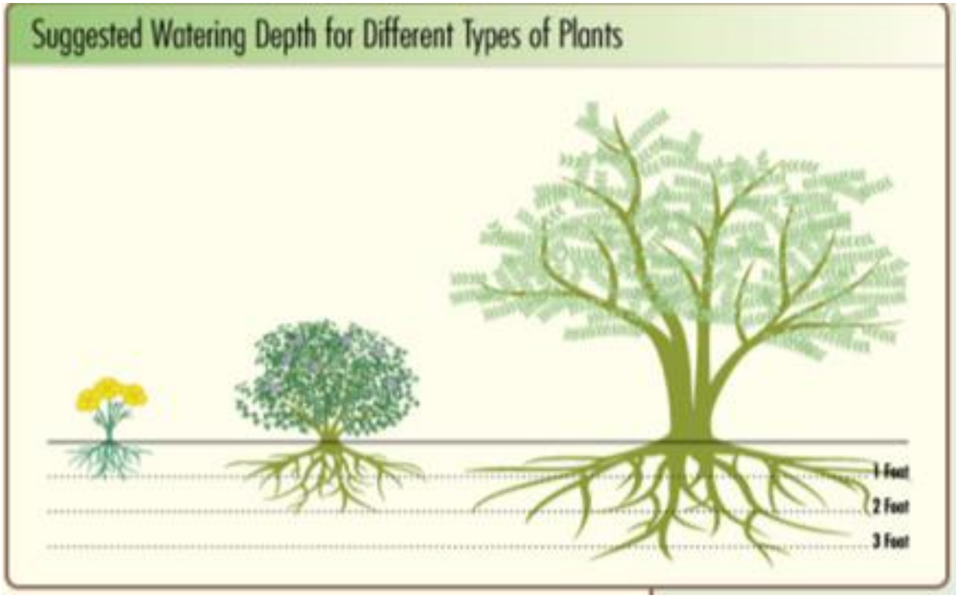
Irrigation: How Much to Water

Soil Texture	Available Water per Foot of Soil
Coarse	0.3-1.1 inches
Medium coarse	1.1-1.8 inches
Medium	2.0-2.9 inches
Medium fine	1.8-2.6 inches
Fine	1.2-2.0 inches

- Know your plant's requirements
- Be aware of microclimates and exposure changes
- Estimated plant age and root depth

Irrigation: How Much to Water

- Established shrub canopy
  - 1.5-4 times the canopy width
  - 12-24" depth
- Established tree canopy
  - 1.5-4 times the width
  - 12-36" depth



Irrigation: How Much to Water

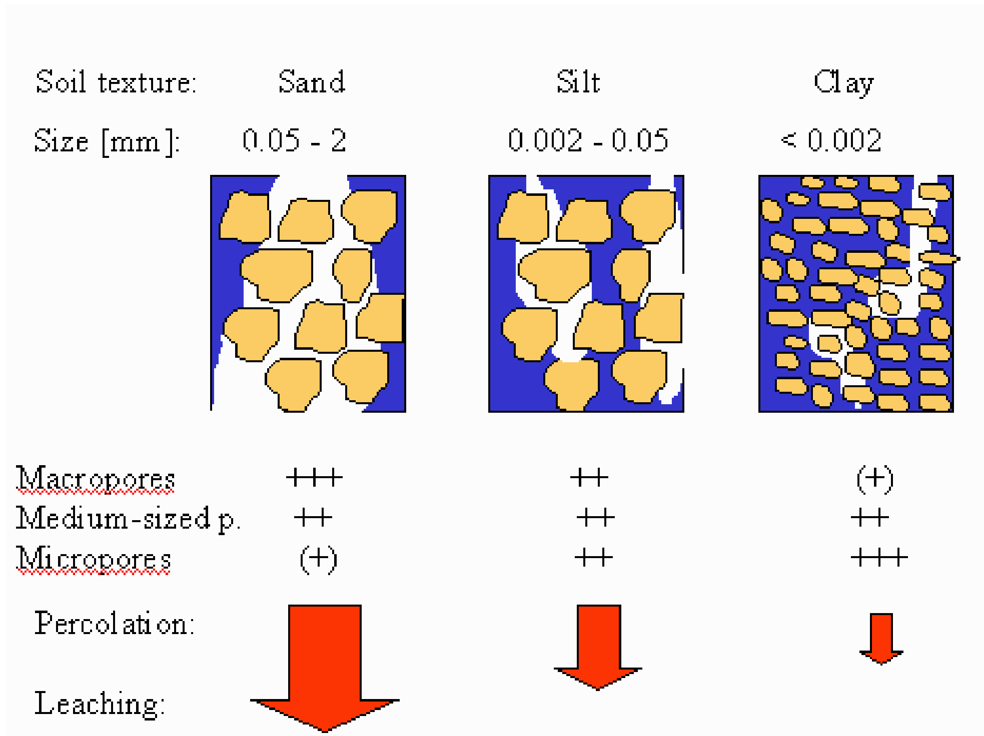
- Water should be delivered to at least half of the root zone
- Ideally applied outside the canopy drip line
- Wet the same area of soil to the same depth every time you water
- Deeper water encourages deeper root systems, which helps the plant resist longer periods of drought between irrigation cycles
- Vary intervals to account for seasonal changes
- Wait 18-24 hours after irrigation runs, probe soil to determine watering depth
  - Do not water beyond root zone, which wastes water
  - Rocky soils may be hard to probe, dig a hole instead

Soil Compaction

Which soil texture is more prone to compaction issues?

Why?

Pore space, water and gas contents & electron exchange are always changing



Soil Compaction

- How does compaction occur?
- How can you tell if an area is compacted?
- Surface compaction
- Subsurface compaction
- Penetrometer
    - Tool used to measure compaction levels in soil ($200+)

Progression of Soil Compaction

1. ***Compression***- loss of soil volume, leads to loss of total pore space and aeration pore space.
2. ***Compaction***- destruction of soil aggregates and collapse of aeration pores. Compaction is truly compaction; sand, silt and clay particles are affected. Facilitated by high moisture contents.
3. ***Consolidation***- deformation of the soil destroying any pore space and structure. Moisture is squeezed from the soil matrix. Leads to internal bonding, pore space is eliminated.

Compaction process does not have to occur in this order or to the same soil.

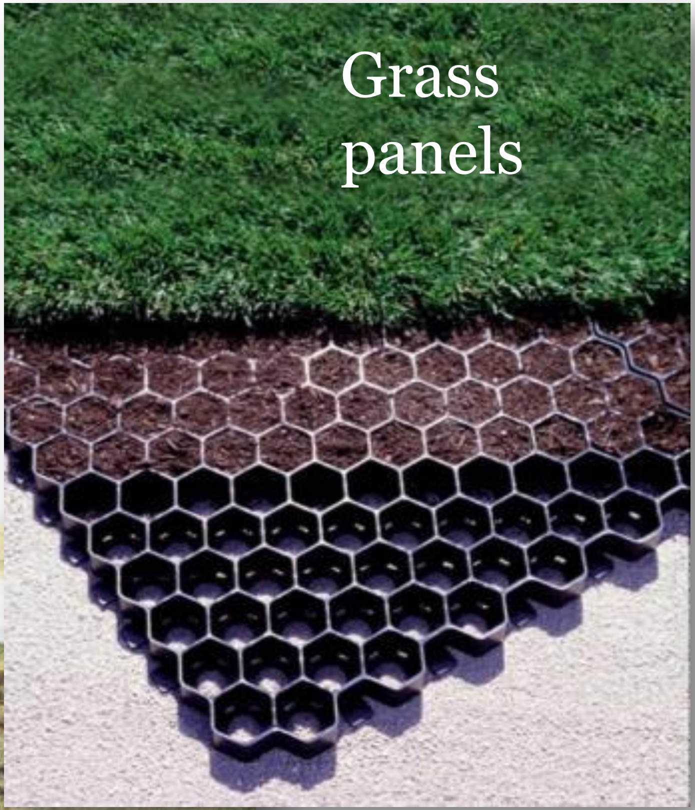
Preventing Soil Compaction

- Never work wet soil
- Use flotation tires, dual tires, or tracks on equipment
- Always inflate tires to the lowest safe psi
- Use shrub, mulch or fence borders to keep foot traffic away from planted areas in landscapes
- Build temporary ‘roadways’ for equipment, using a 6" to 10" bed of dry wood chip mulch over areas to be landscaped

What can be done to help compacted areas?

- Mechanically loosening of soil before planting
- Soil aeration by injecting pressurized air into ground
- Periodic aeration around areas with high foot traffic
- Vertical mulching (numerous auger holes filled with sand)
- Install subsurface drainage with perforated pipes connected to vertical pipes
- Addition of organic materials to provide sufficient aggregation agents, creating a stronger structure
- Introduction of earthworms, or other soil organisms to increase macropores
- Select species with inherent capacity to grow in compacted soils

What are some other options?



Soil Biology

Soil Composition

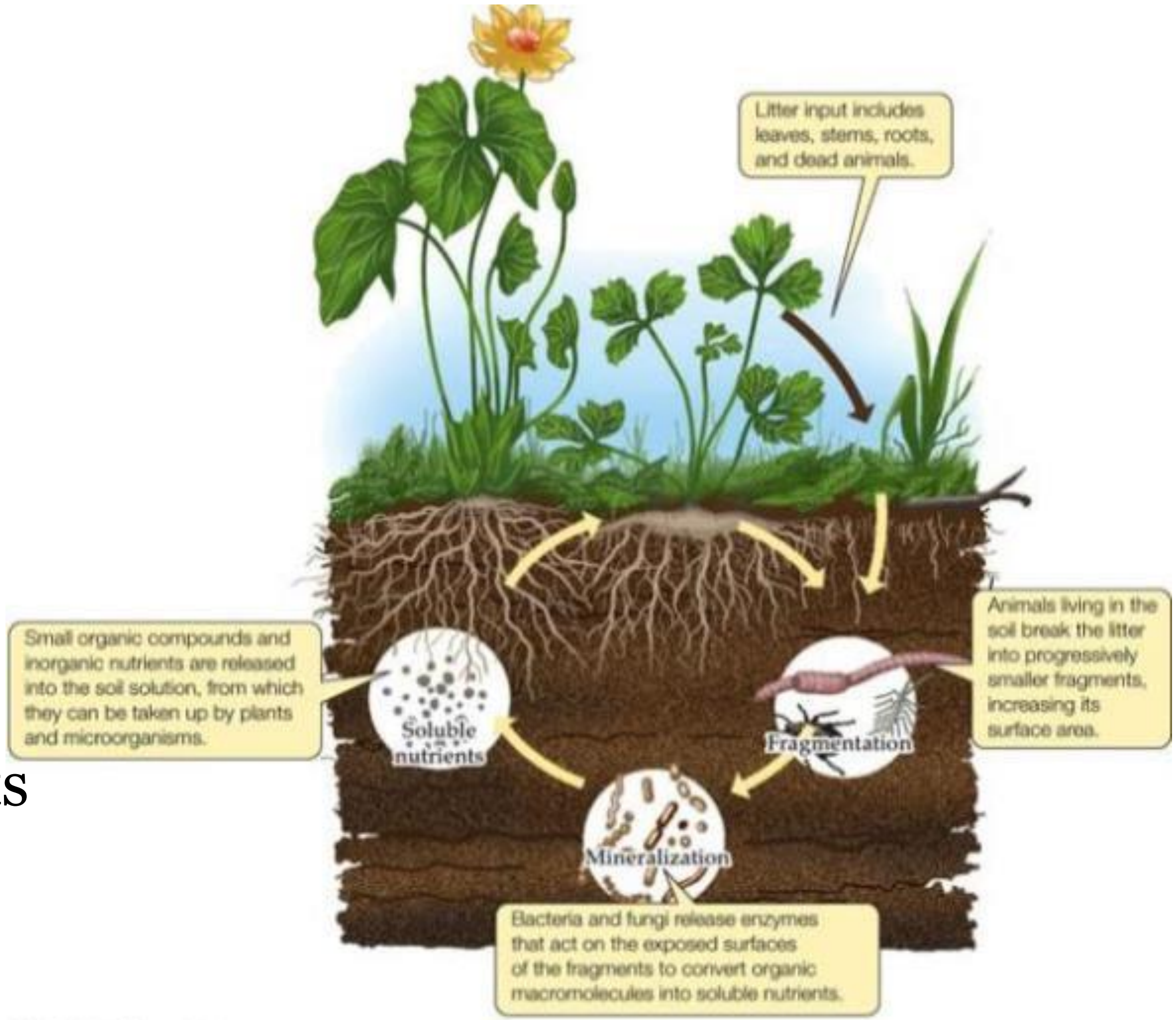
- Fragmented rock
- Organic matter
  - Decaying / plants / animals
- Living biomass
  - Bacteria, fungi, protozoa, (microbes) insects and worms

Why Soils Struggle

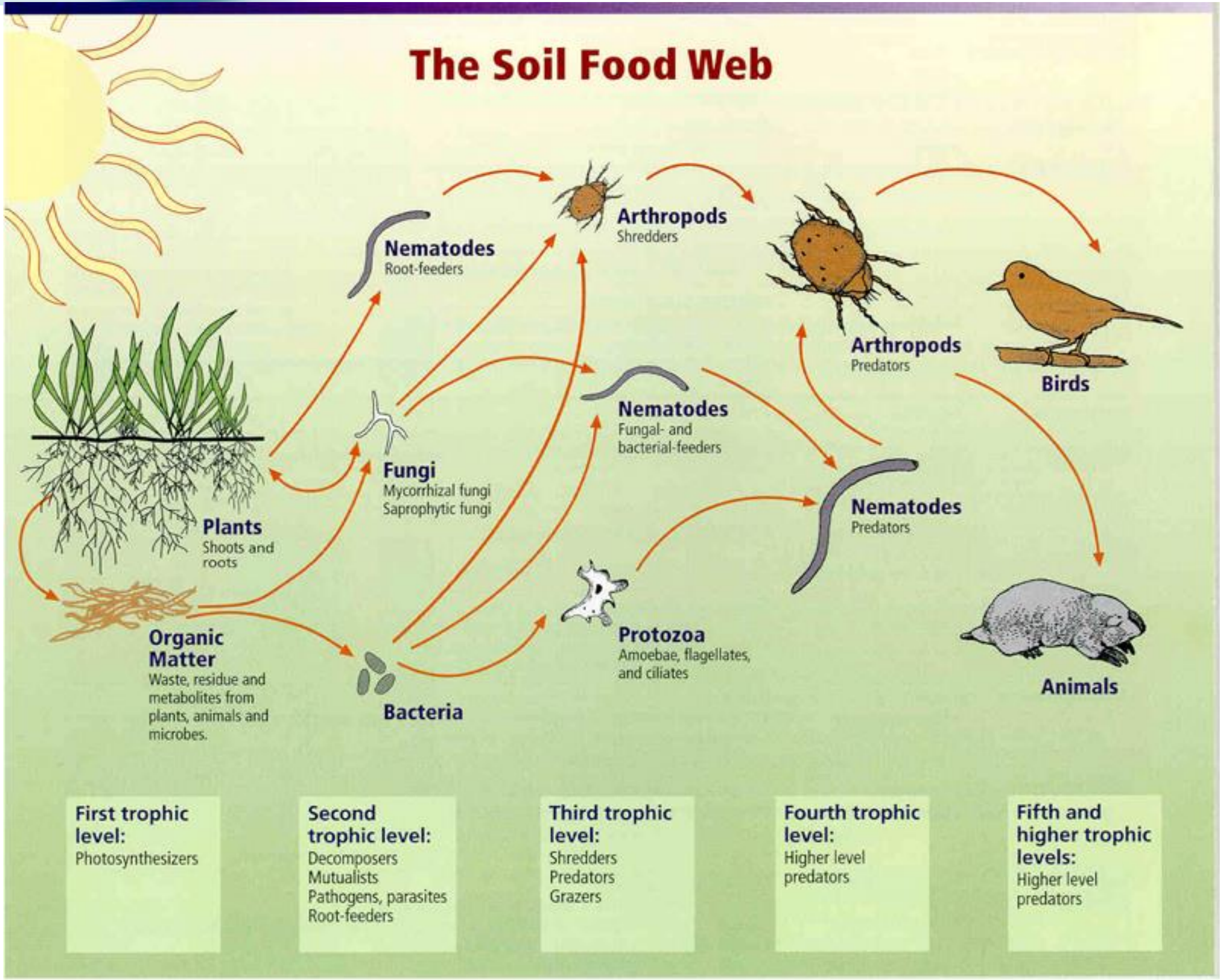
- Too much traditional fertilizers
- Too many pest control products
- Construction damage
- Reduced mechanical renovation
- Need to manage organics or lack of
- Good soil all starts with carbon

The Cycle of Decomposition

- Decomposition of organic matter to small particles by bacteria and fungi
- Keeps the nutrient cycle going
- Sequesters nutrients
- Life cycle

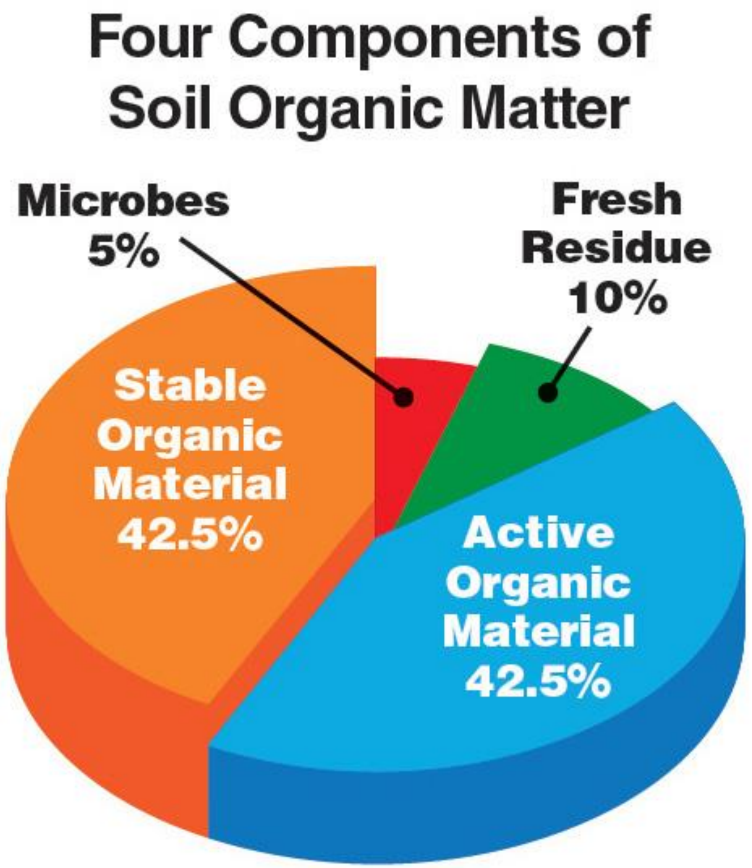


ECOLOGY 2e, Figure 21.6



Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

Organic Matter



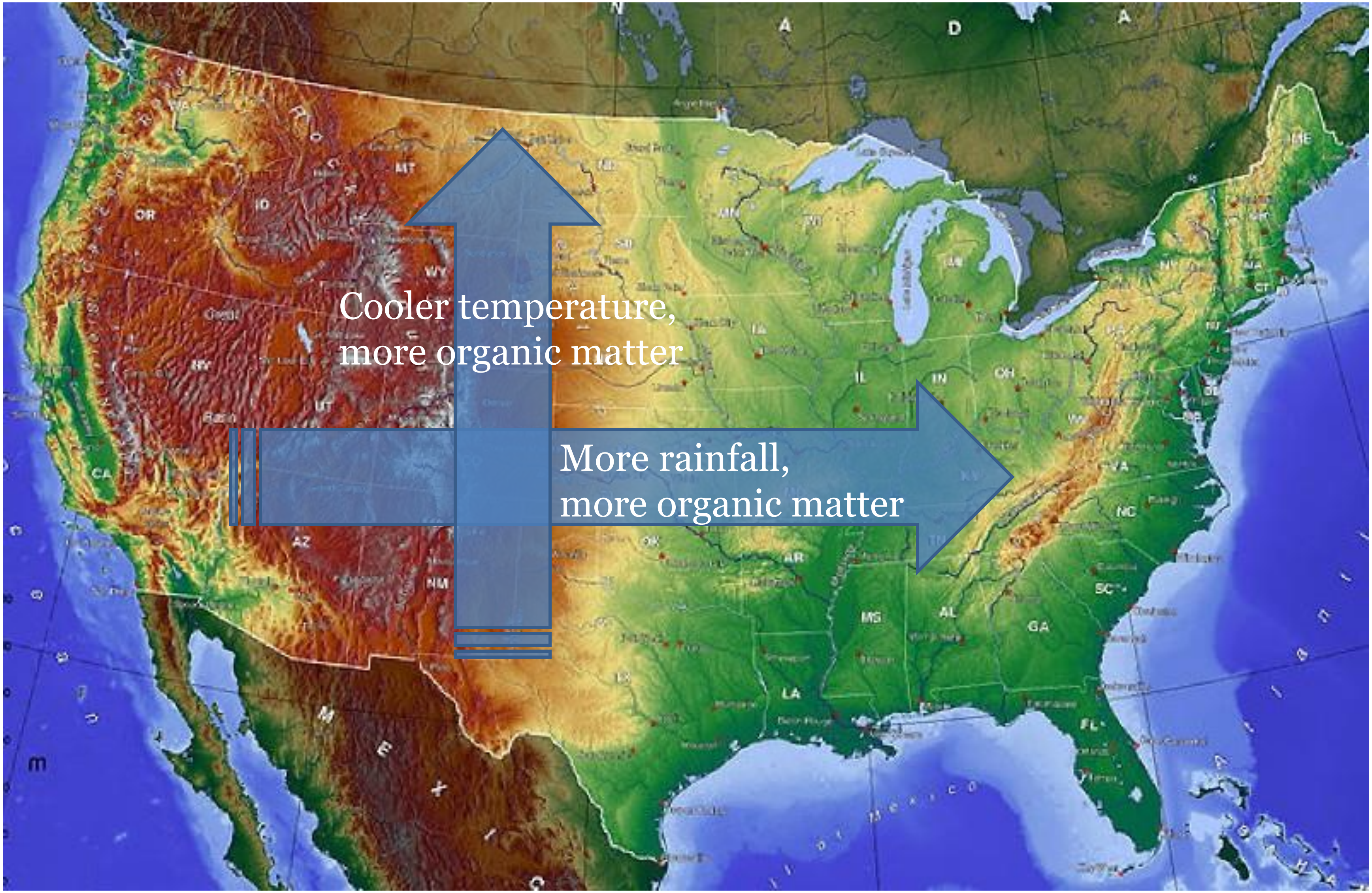
- Group of carbon containing compounds
- Originated from living material and have been deposited on or within earths structural components
- Contains minerals and trace elements
- High molecular weight substance

Benefits of Organic Matter

- Helps strengthen soil aggregates, thus improving soil structure
- Improve aeration and water infiltration
- Increases water-holding capacity
- Provides significant amounts of cation exchange capacity

Benefits of Organic Matter

- Provides buffering against rapid changes in soil pH when acid- or alkaline-forming materials are added to soil
- Forms stable organic compounds that can increase availability of micronutrients
- Serves as a slow-release source of many plant nutrients
- Services as an energy source for microorganisms

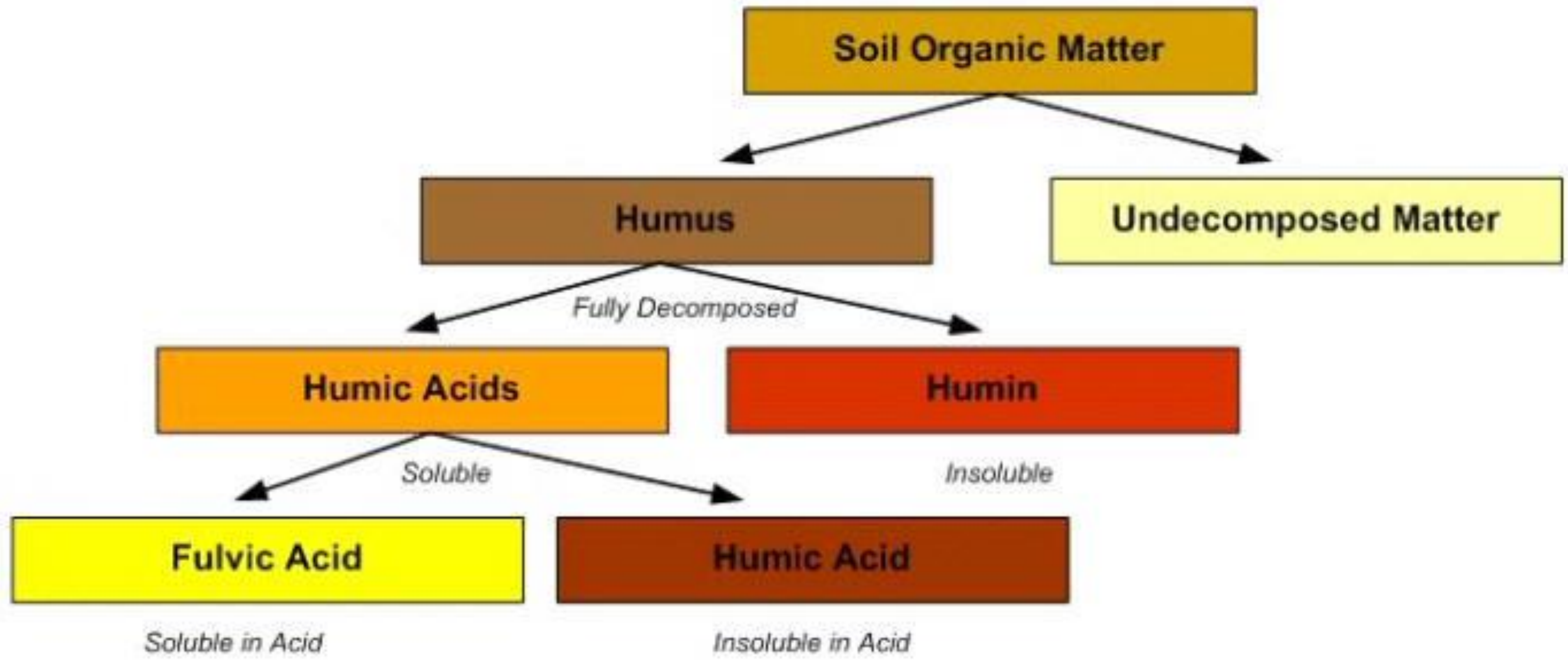

Cooler temperature,
more organic matter
More rainfall,
more organic matter

Sources of Humic Acid

Humus- well decomposed, stable part of organic matter in mineral soils

- Raw material
- Peat
- Leonardite
- Lignite
- Coal
- Diamonds

Isolation Of Humic Acid



Humic Acid Benefits

- Excellent foliar fertilizer carrier and activator
- Influences root growth
- Increases seed germination
- Increases carbohydrate production – leaf, stem
- Helps degradation of toxic substances
- Food source for microbes

Best Growing Conditions

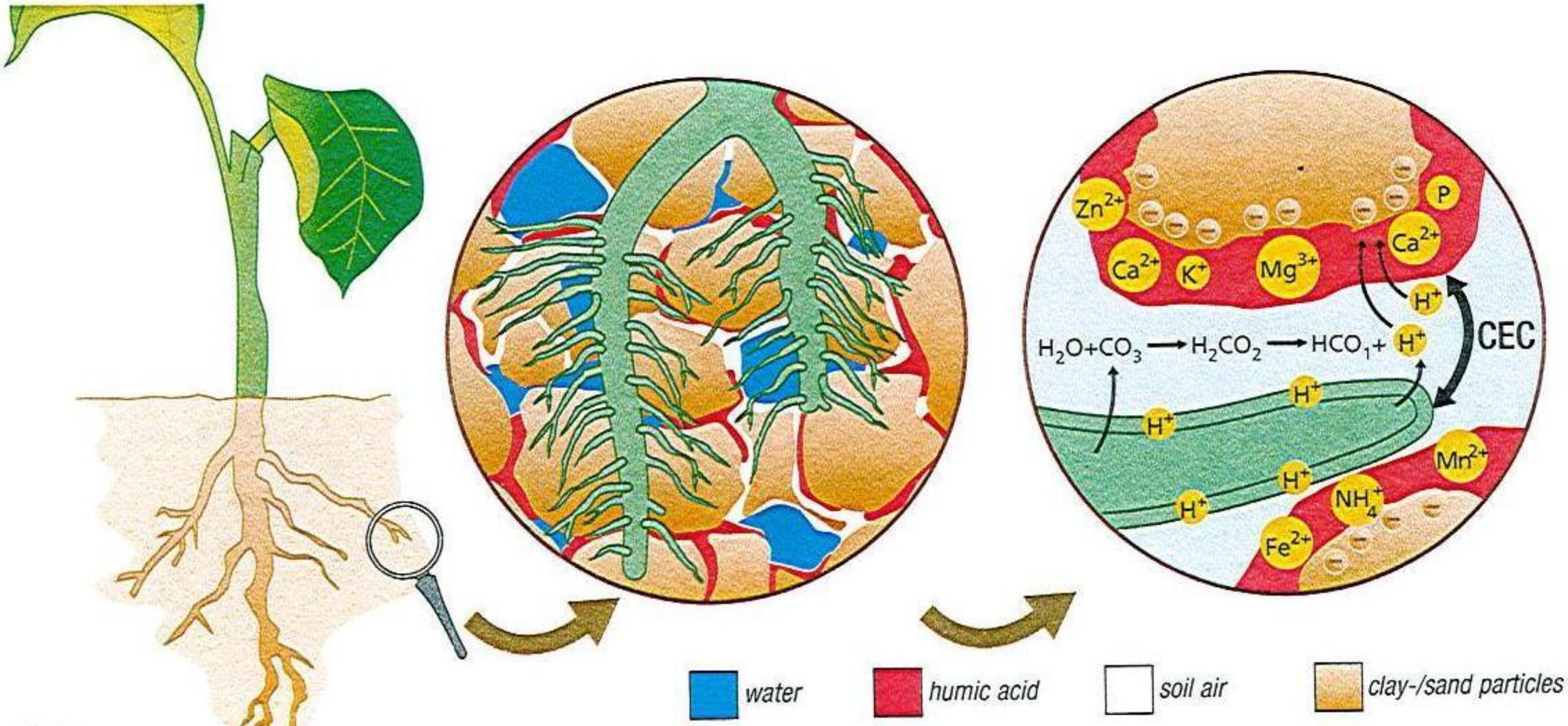


Fig. 7:
Humic acid optimises the soil for root development like e.g. nutrient uptake, soil aeration, water retaining capacity, cation exchange capacity (CEC) and formation of clay-humus complexes.

Organic Matter and Soil Structure

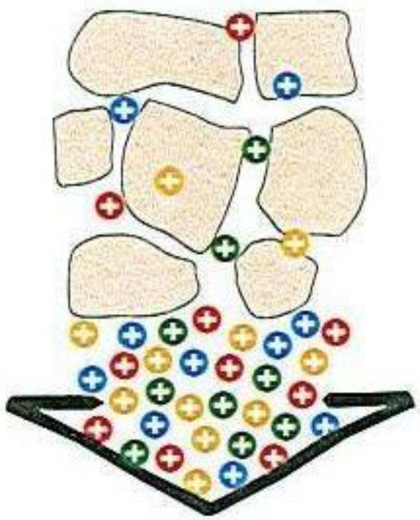


Fig. 4: Sandy soils poor in humus can't retain nutrients.

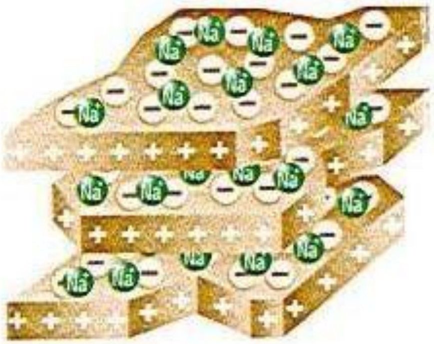


Fig. 5: Compact, hardly penetrable soil structure

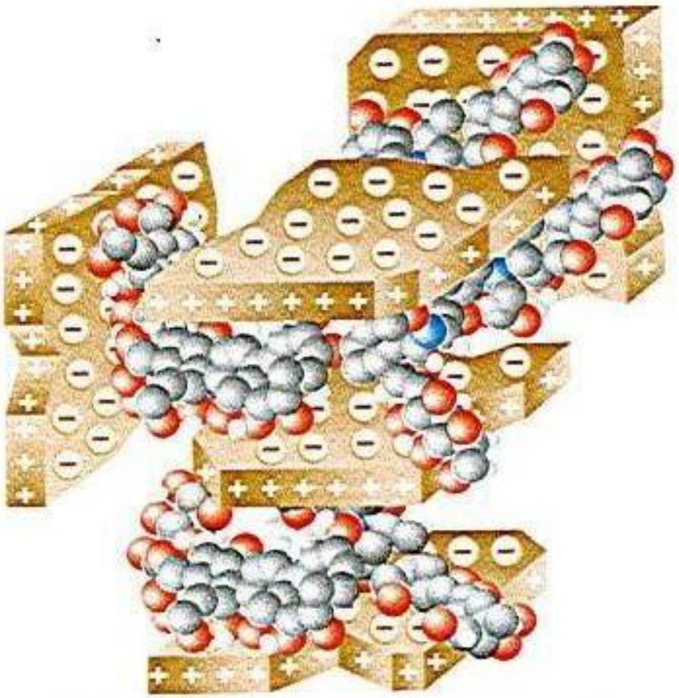


Fig. 6: Humic acid aerates compact soils.

Humic Acid

- Soluble in water under alkaline conditions
- Molecular weight- 10,000-100,000
- 60 different minerals
- Ion-exchange and metal –complexing (chelating) systems

Fulvic Acid

- Soluble in all pH solutions
- Molecular weight- 1,000-10,000
- Oxygen content 2x higher than humic acid
- Small size- enter plant roots, stems and leaves
- Trace elements
- Most effective carbon chelating compound

Nematodes

- Bacterial Feeders – Consume Bacteria, cycle nutrients
- Fungal Feeders – eat fungi
- Predatory Nematodes – eat nematodes and protozoa
- Omnivores – root feeders and plant parasites
- 100 nematodes per teaspoon grassland areas
- 500 nematodes per teaspoon forest areas

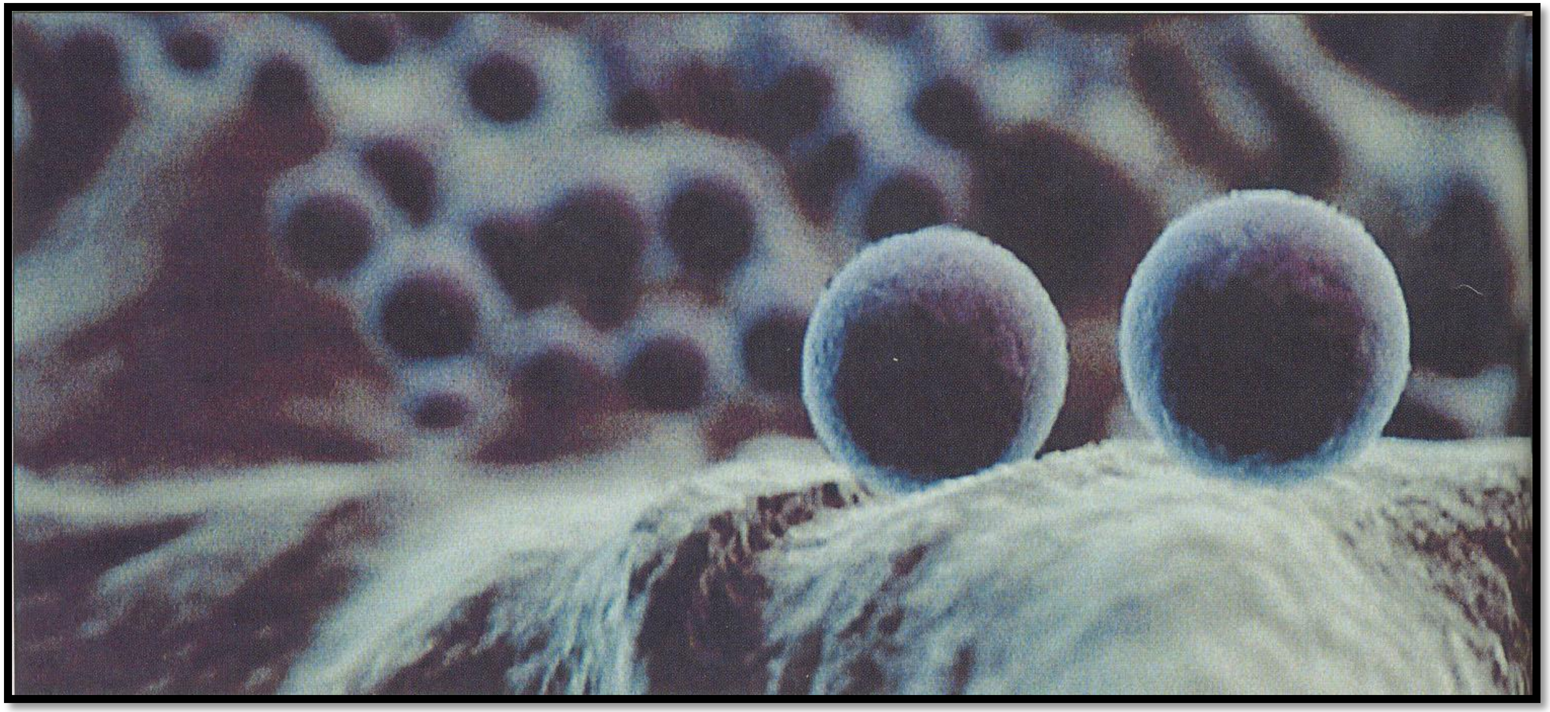
Nematodes

There are a few nematodes that cause plant disease, however, far more nematode species are beneficial organisms in the soil.

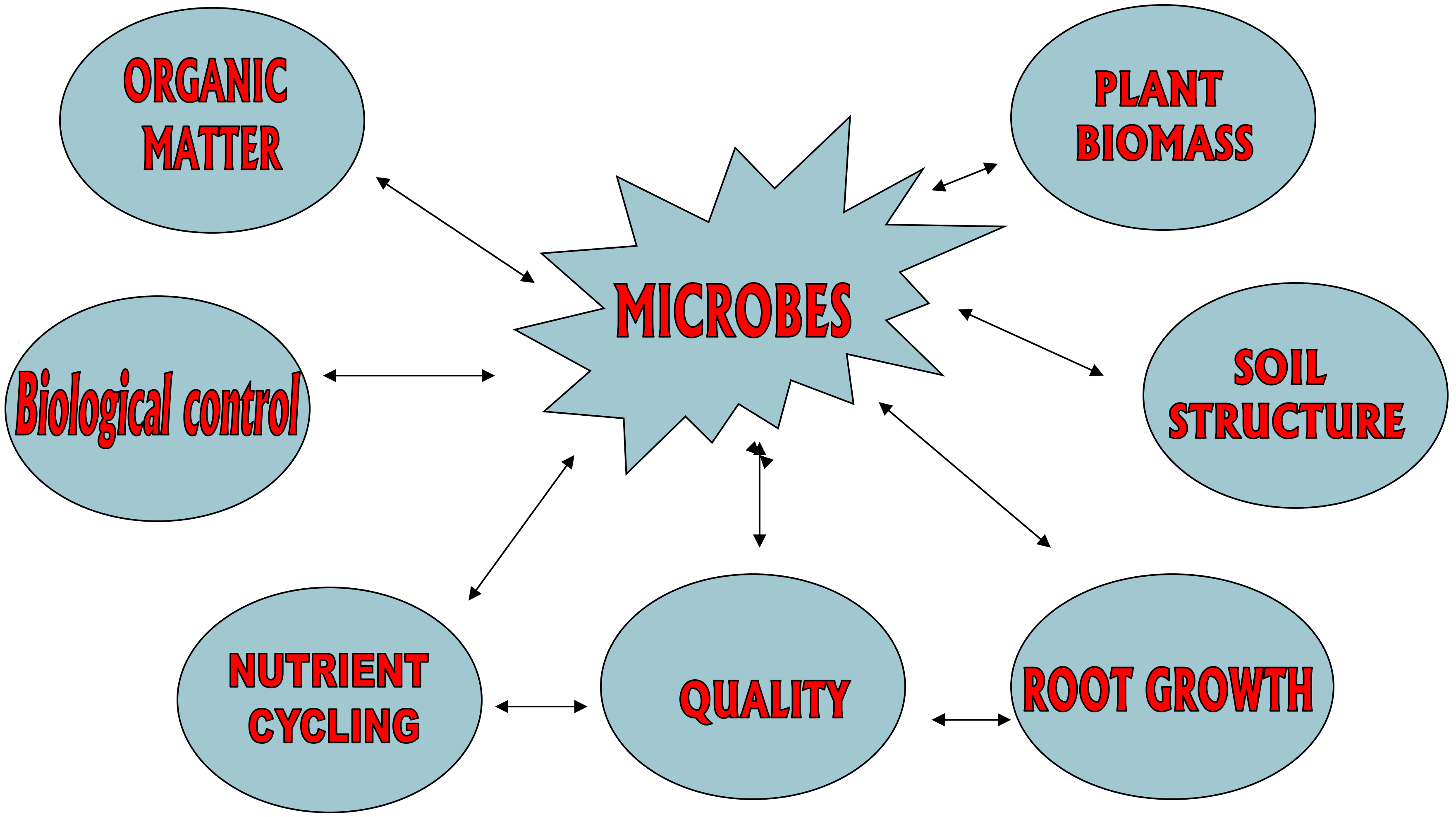
Earthworms

- Breakdown organic matter
- Castings- good source of carbon
- 1-0-0
- 1 million worms per acre
- 700 lbs of castings a day

Biological Microbes



Microbial Proliferation



Biofungicide

- Microbes- live in the soil or on the leaf surfaces
- They contain naturally occurring non-genetically engineered micro-organisms
- Produce antibiotics that kill organisms

LIVING BUGS

Conventional Fungicide

- Chemicals

    Contact- chemical must come in contact with pathogen

    Systemic-absorbed by plant

- Resistance
- Plant quality-rooting

Biofungicides

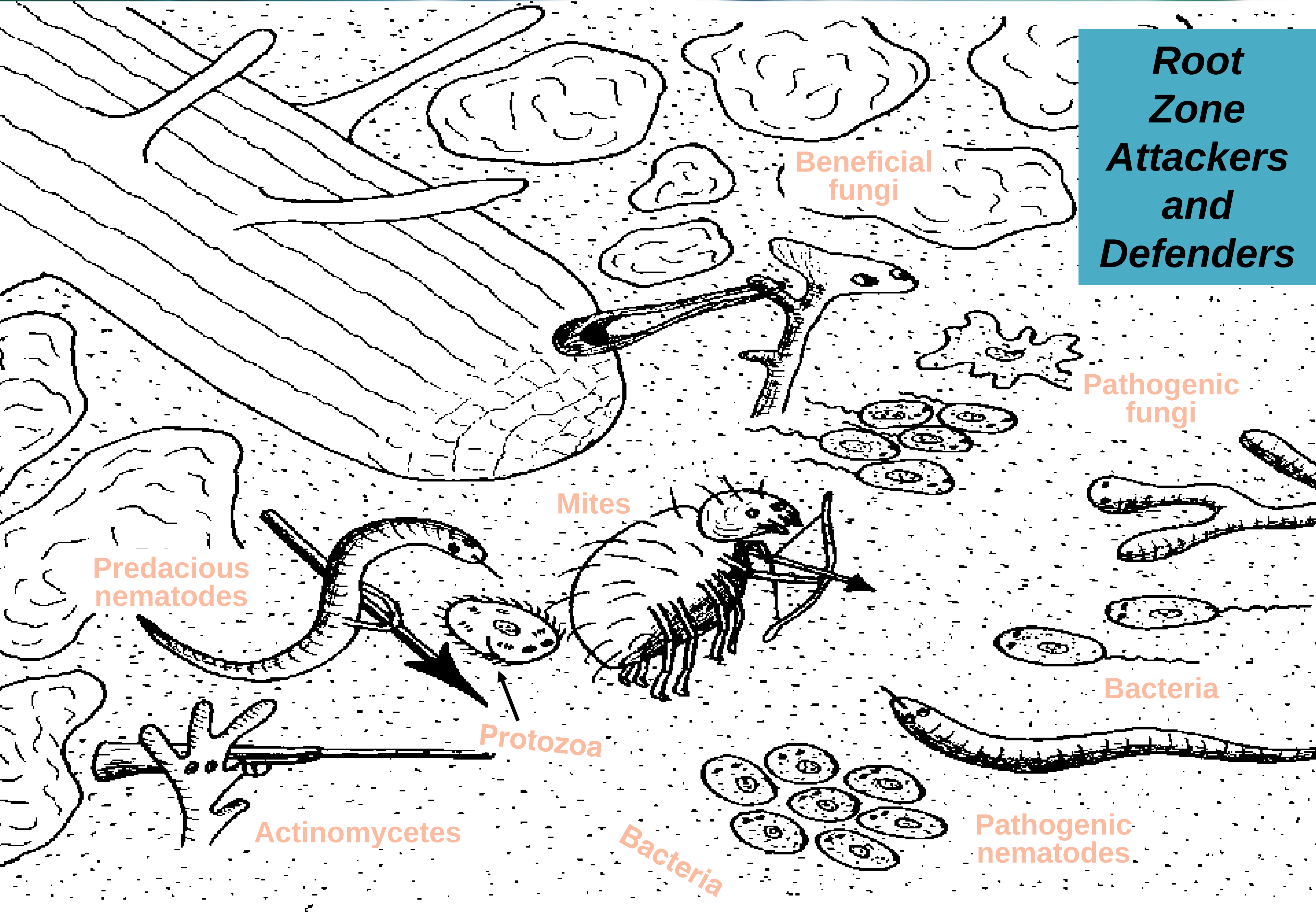
- Live in root zone
- Produce enzymes and antibiotics
- **Preventative** rather than curative
- Out-compete and attack the pathogen
- Mineralize soil- phosphorus, minors
- Increase water and nutrients uptake

Microbe values in soil (per gram of soil)

Bacterial/ Actinomycetes	**10 mil- 1 bil**
Fungi	10 mil- 100 mil
Algae/ Cyanobacteria	100,000- 1 mil
Protozoa	1000- 100,000
Viruses	100 bil

Aerobic- need oxygen- 6” inches
Anaerobic- do not need oxygen to generate energy

Root Zone Attackers and Defenders



Biologicals

- Niche occupation;
  - near root, stem or foliar
- Induced systemic reaction, within plant
- Some produce antibiotics – contact
- Some produce PGR's – root formation
- Gram positive – produce spores
- Gram negative – vegetative

Types of Microbials

- Bacillus
- Pseudomonas
- Trichoderma
- Streptomyces
- Mycorrhizae

Protozoa

- Grazers
- Grass roots support Bacteria-microbes
- Keep microbes in check
- Unlock (immobilized) nutrients

Actinomycetes

- A specialized group of mostly filamentous bacteria
- Known for their ability to produce many of our modern, medically useful antibiotics

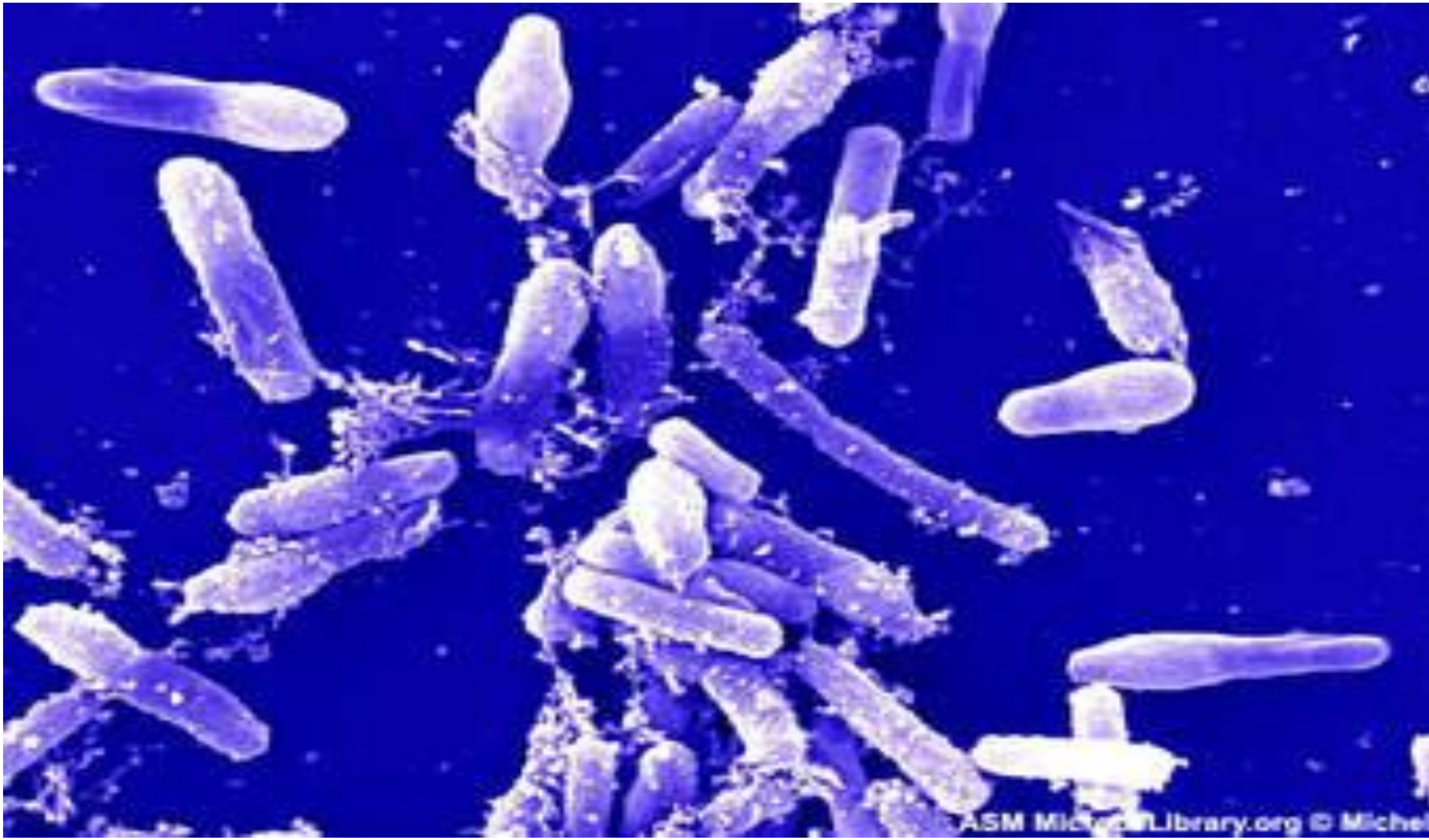
Algae & Cyanobacteria

- Problematic in wet turf
- Slick spots
- Closely mown turf
- Blue–green algae

Types of Microbes

- Bacillus: *B. subtilis, B. megaterium, B. licheniformis*
- Most common in soils, found world wide
- Rod shaped organism
- Rhizobacteria (root-colonizing)
- Enzymes: cell division in root tip
- Antibiotics: affect cell wall, reduced fungicides
- Feed on carbon, clean roots
- Gram positive, spore producing

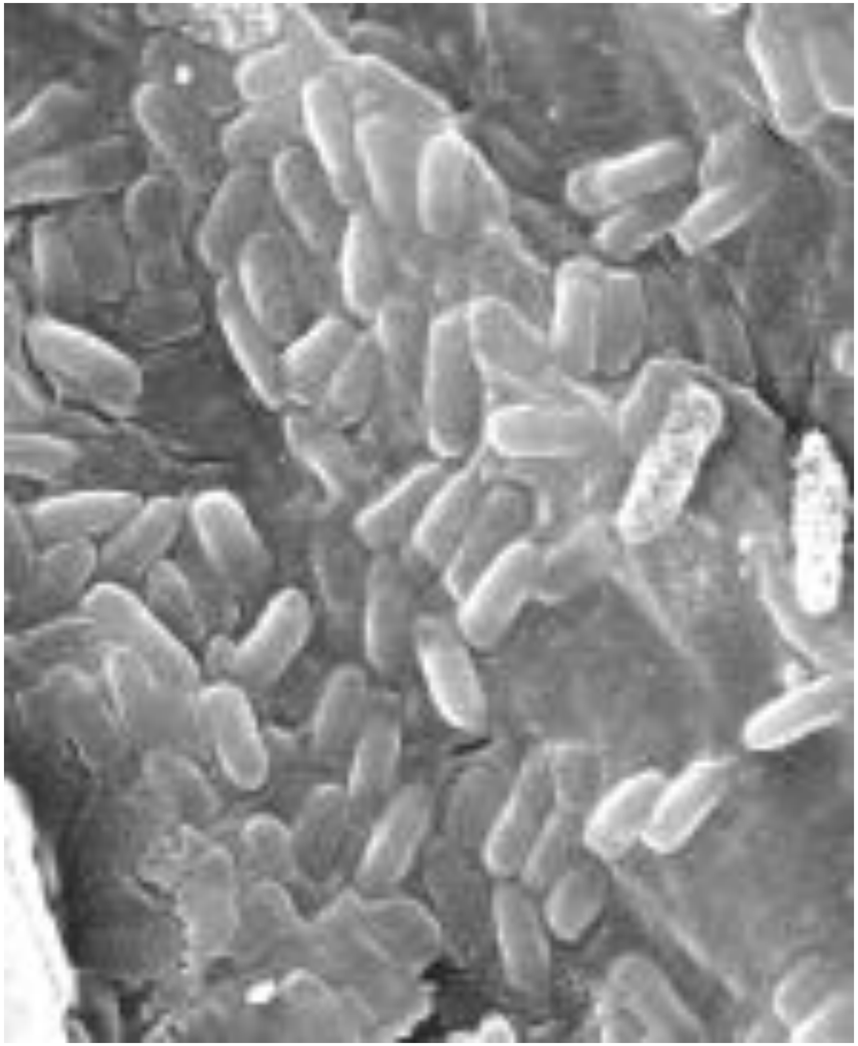
Bacillus

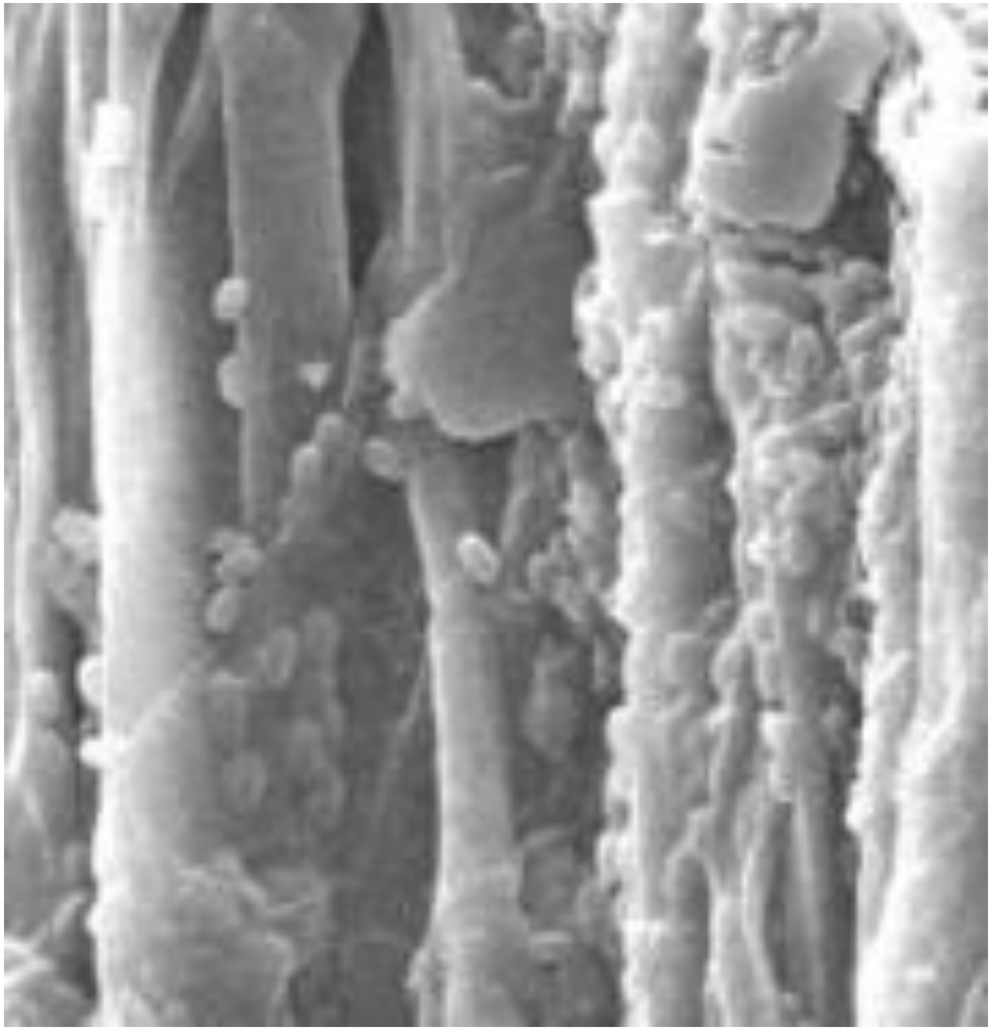


Beneficial Properties of Bacillus

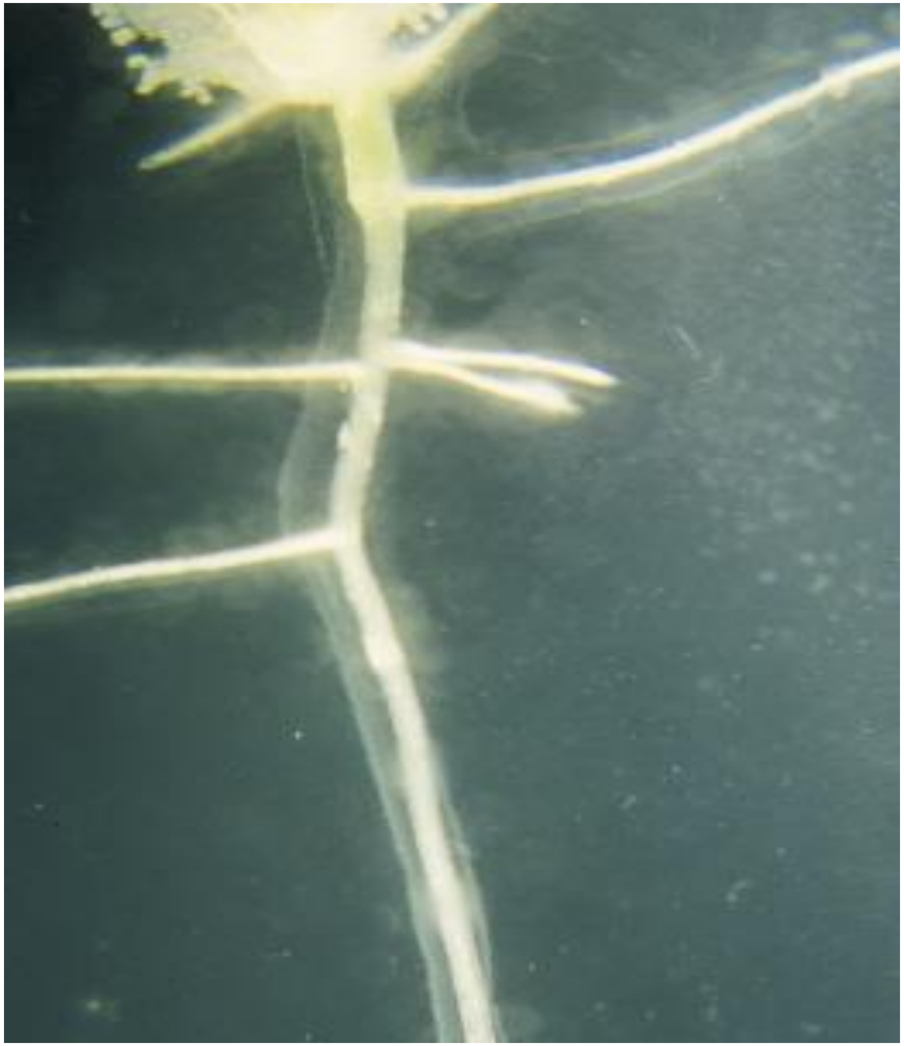
- Protects roots against fungal disease
- Microorganisms continually produce PGRs
- Produces sugar & enzymes as an energy source
- Increases drought tolerance

Bacillus subtilis GB03 on Root Surface





Tomato Roots Colonized



With and Without Bacillus

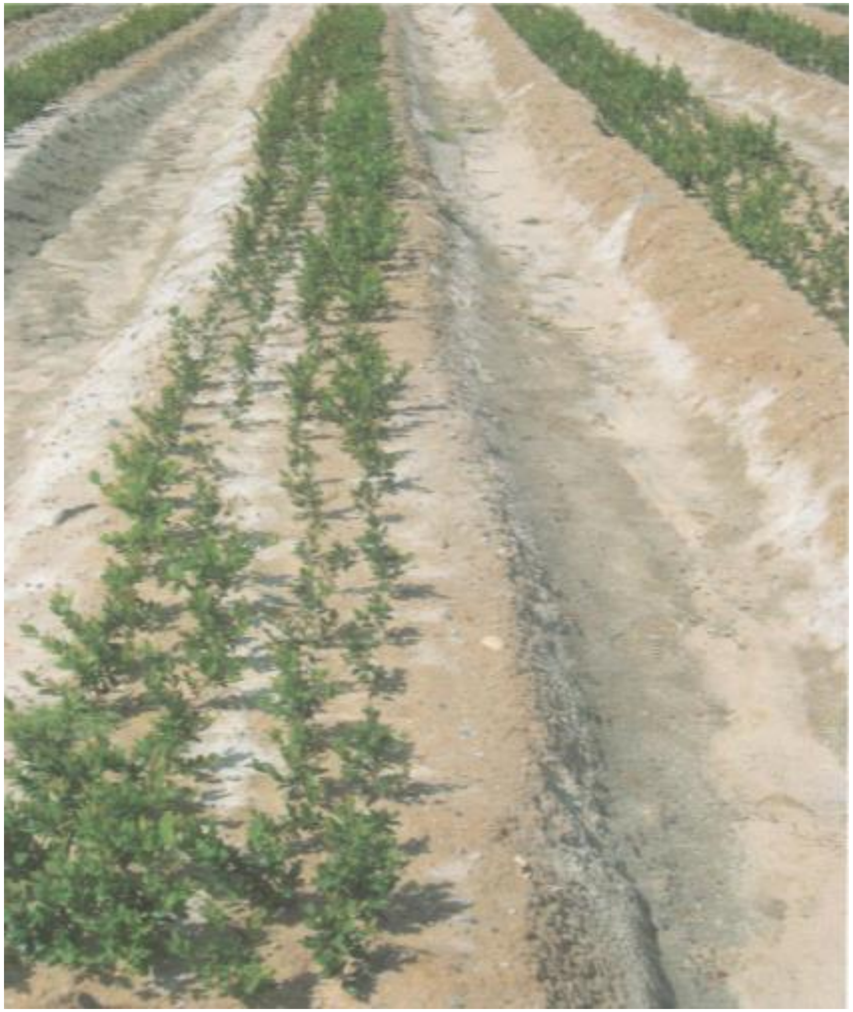
Without Bacillus

- Small root mass
- Brown (dead and dying) roots

With Bacillus

- Noticeable new root growth (no brown roots with Bacillus)
- Thick, white, healthy roots make for a better plant.

Salt Reduction with Bacillus



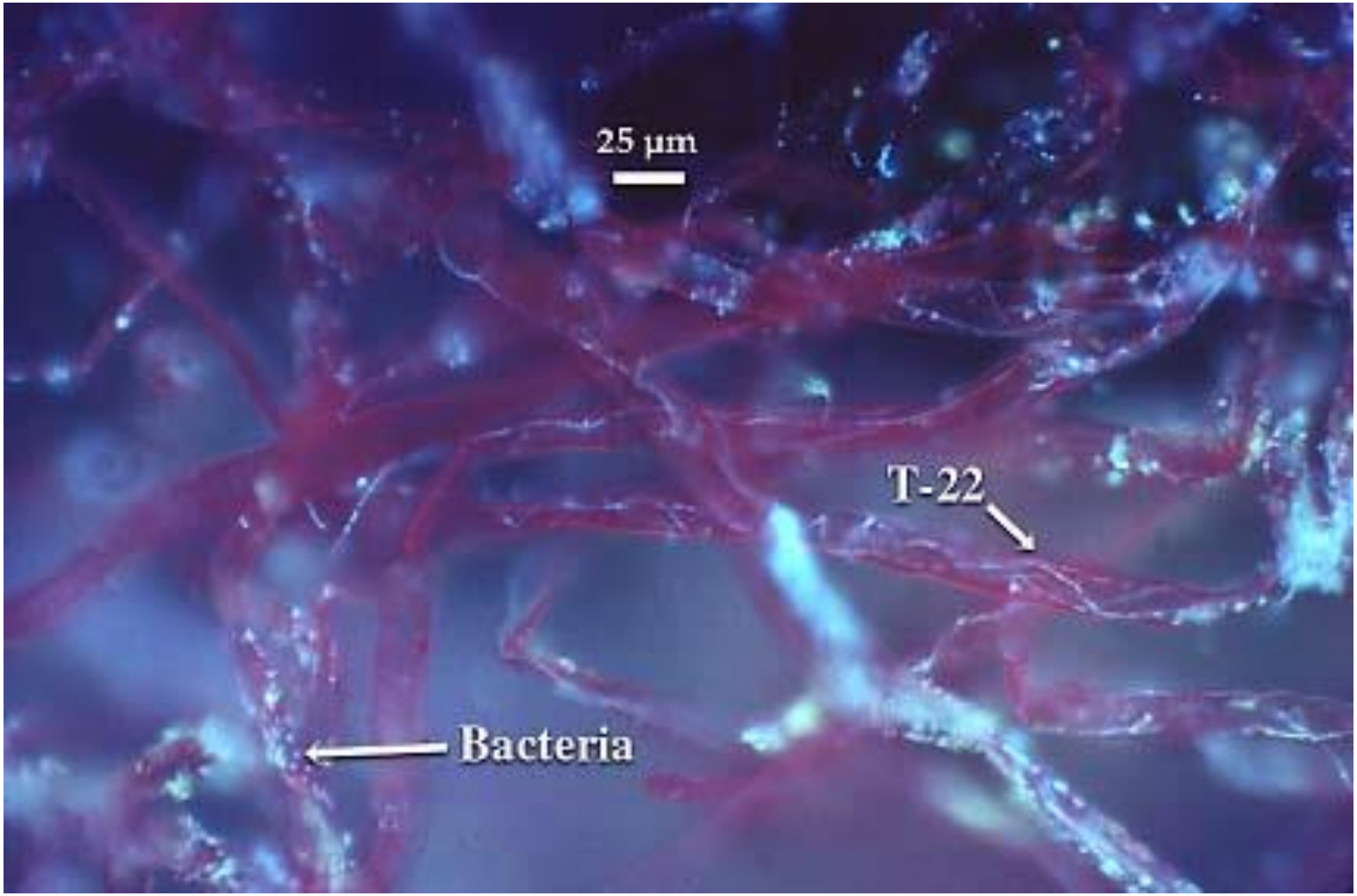
Improving Rooting

- *Bacillus subtilis* adheres to tap root & root hair surface
- Improves root branching, length & density
- Provides growth hormones
- Improves plant vigor
- Improves stress tolerance

Trichoderma

- Fungi
- Long treads, filaments that can stretch
- Hyphen; penetrate cell wall
- Most prevalent fungi in soil
- Grow to fungi, lection-mediated reaction
- No sexual stage-asexual spores

Trichoderma on Pythium



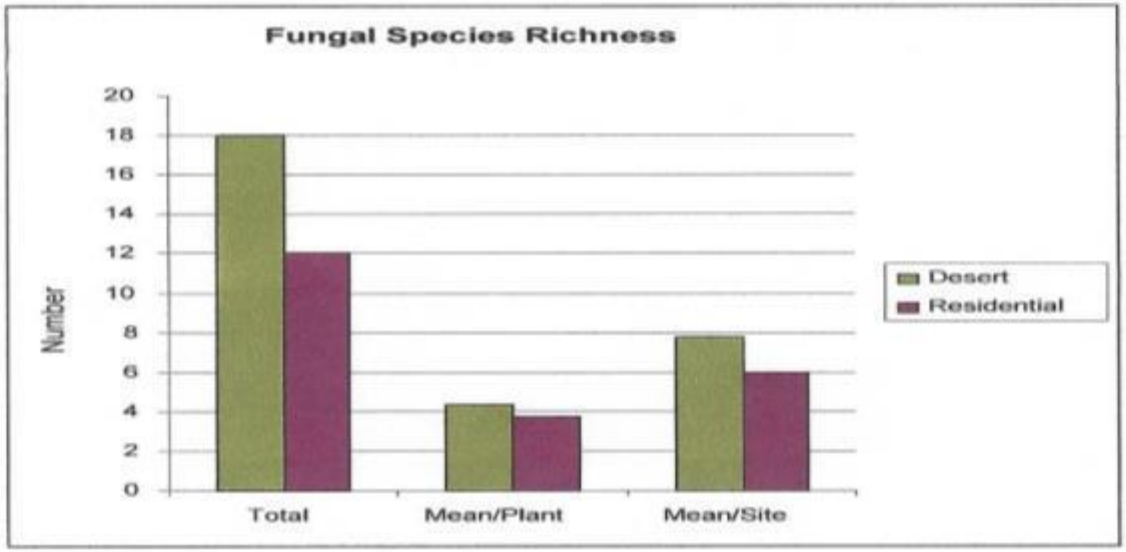
Mycorrhizae

- Fungi– not biological fungicide
- Mycorrhiza or “fungus root”
- Mycos – fungus, rhizae – roots
- Endomycorrhizae (in root) VAM –*Vesicular-arbuscular*
- Ectomycorrhizae (on root)
- Spores, as hyphae (filaments) colonized roots
- Coiled hyphae (arbuscules) – food for fungus and nutrients for the plant
- Hyphae – absorb nutrients and water
- Plant specific – so use cocktail

Mycorrhizae

Mycorrhizae

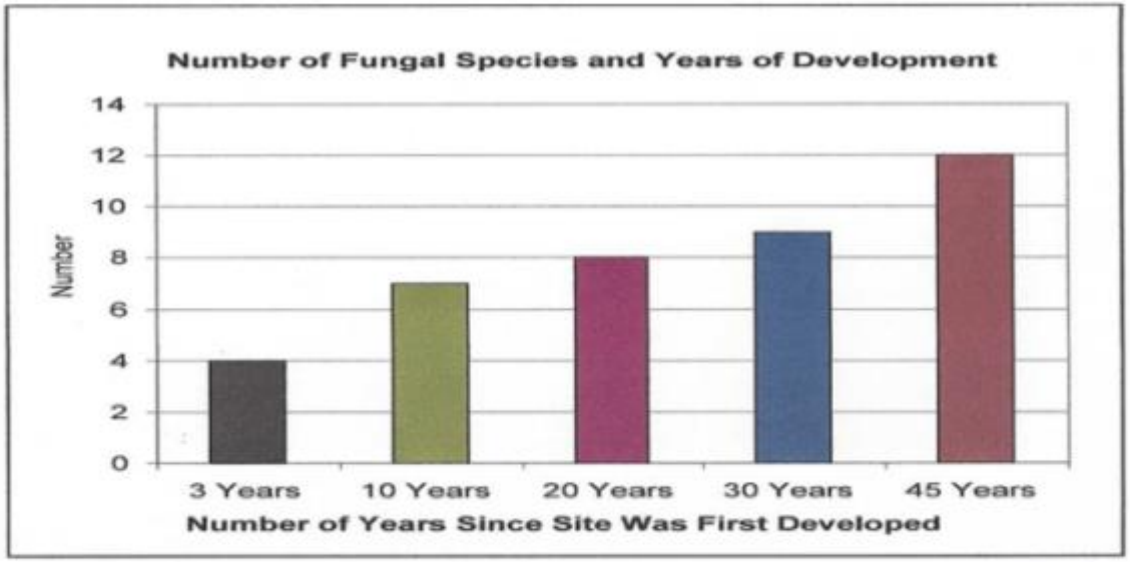
The following are graphs of Mycorrhizae species found in Phoenix area plants. Some of the plants were from the desert, others were from neighborhoods (residential)



Graph 1 Notes:

'Mean/Plant' refers to the average (mean) number of fungal types (species) found per plant root examined and within each type of site (desert or residential).

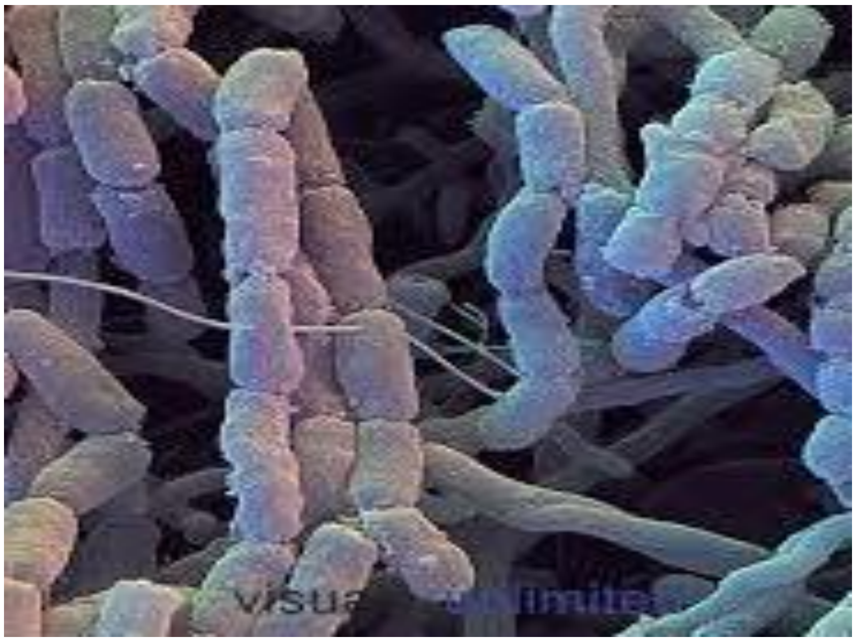
'Mean/Site' refers to the average (mean) number of fungal types (species) found per site (desert or residential).



Graph 2 Notes:

Number of years since development refers to when the neighborhood was constructed. Generally, after a neighborhood has been developed, the soil remains relatively undisturbed.

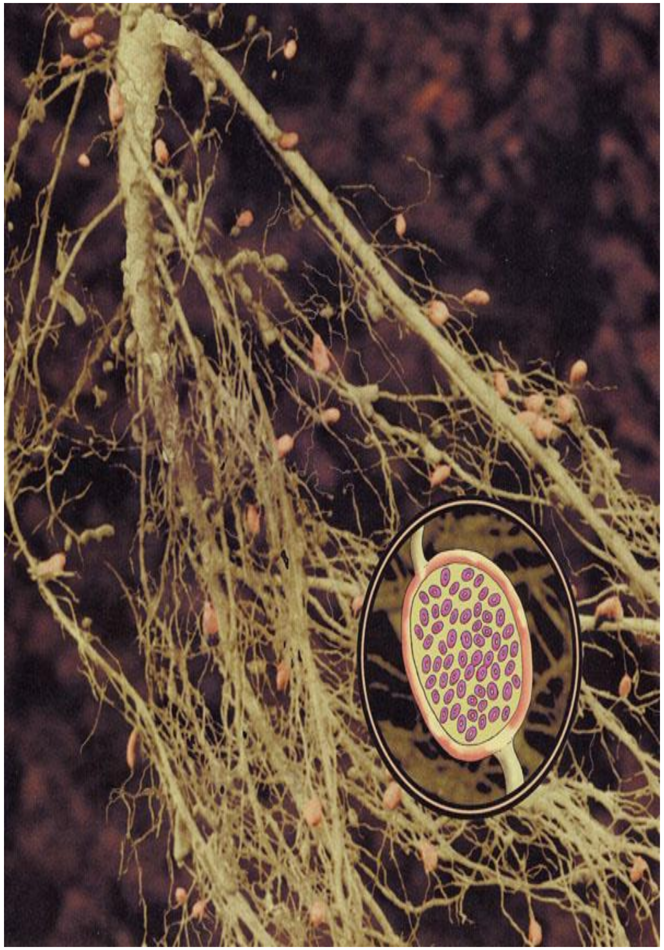
Streptomyces



- Bacteria- Actinomycetes
- Resemble fungi-branching filamentous structure
- Gram positive
- Rhizobacteria (root-colonizing)
- Produce geosmins-give soil its smell
- Eat almost anything – sugars, alcohols, amino acids, waste materials

Nitrogen-fixing Bacteria

- Symbiotic trade-off
- Plant gets nitrogen
- Microbes get food
- Azopspirillium- N-fixing auxins, cytokins
- Azobacteria- IAA,GA,
- Root stimulators



Nitrogen-Fixing Bacteria on the roots of Acacia

Key Factors in Popularity

- Plant survival and root health
- Symbiotic relationship
- Reduced EPA registrations
- Time and labor costs
- Reduction of chemicals
- Mineralize soil

What makes a good Biofungicide?

- Fast colonizer

  -bacteria

  -fungi
- Used with fungicides and enhances fungicides
- Gram positive (spore producing), gram negative - veg
- CFU count - colony forming units
- Storage / shelf life
- Formulation - food source activity and survival
- Powder or granular, liquid

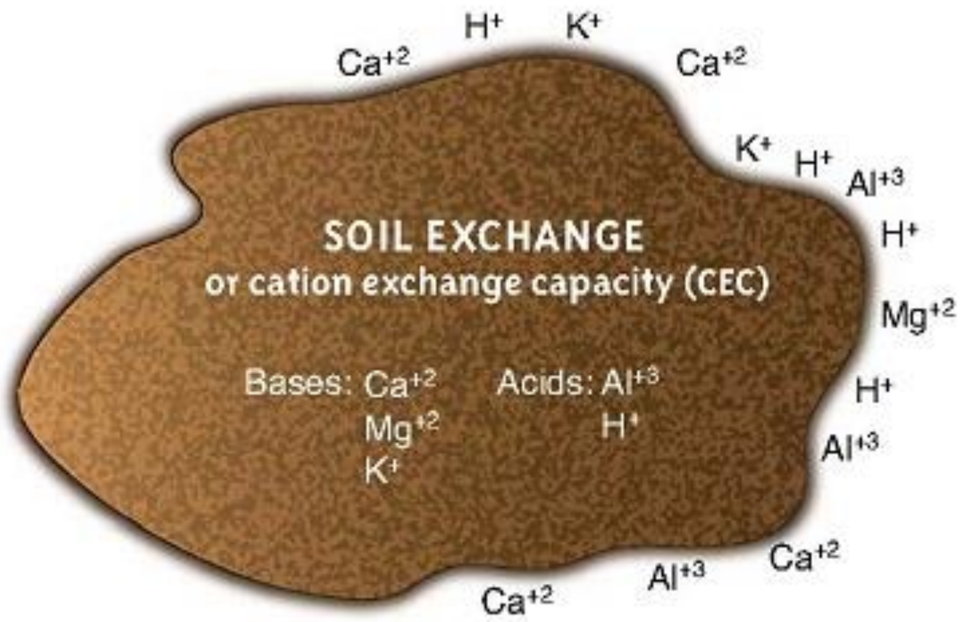
Possibilities Being Explored

- Increase the populations of GOOD GUYS
- Iturin - class antibiotics increases cell membrane permeability
- Root mass
- SAR Systemic Acquired Resistance
- ISR Induced Systemic Resistance: when a plant responds to a living microbe on the root or leaf surface to produce a chemical to fight disease

Happy Soils

- Biologically activate soil
- Restore fertility naturally
- Replace chemical sources of phosphorous, adds in nitrogen
- Stimulate plant growth
- Protection against drought and soil borne diseases

Chemical Properties of Soil



Essential Plant Nutrients

Macronutrients

- **Needed in larger amounts**
- Primary macronutrients
  - Nitrogen
  - Phosphorus
  - Potassium
- Secondary macronutrients
  - Calcium
  - Sulfur
  - Magnesium

Micronutrients

- **Needed in smaller amounts**
  - Iron
  - Boron
  - Manganese
  - Zinc
  - Copper
  - Chlorine
  - Molybdenum
  - Nickle*

* recently added

- Other essential plant elements include Hydrogen, Carbon & Oxygen

Plant Nutrients

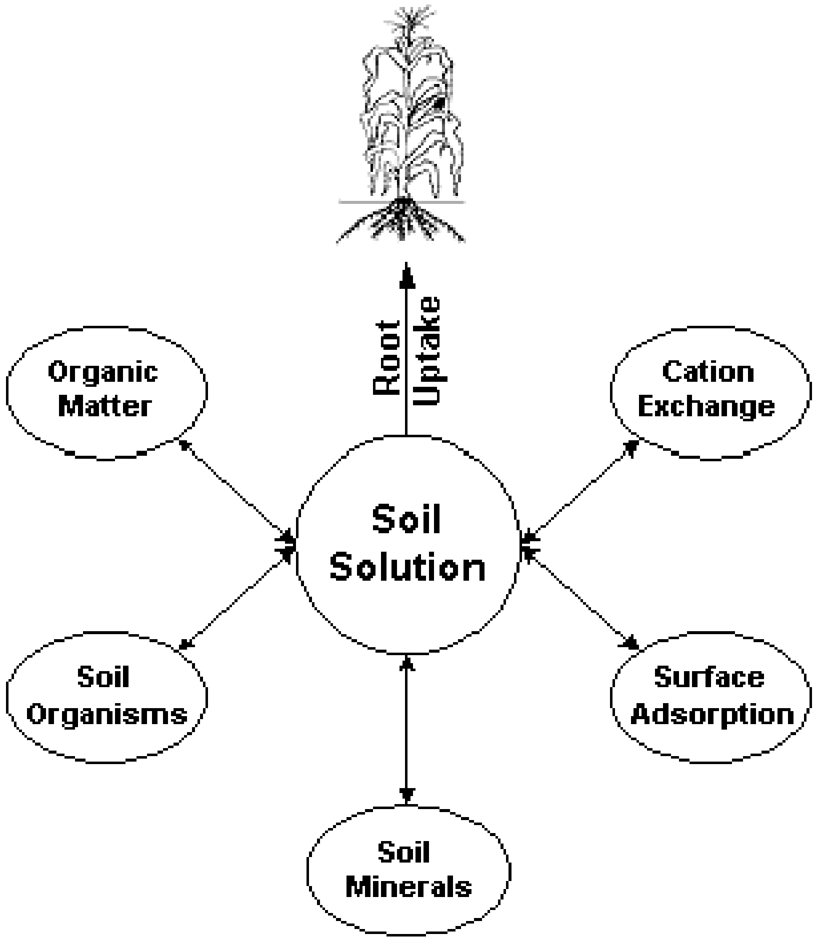
Essential plant nutrients by ionic groups.

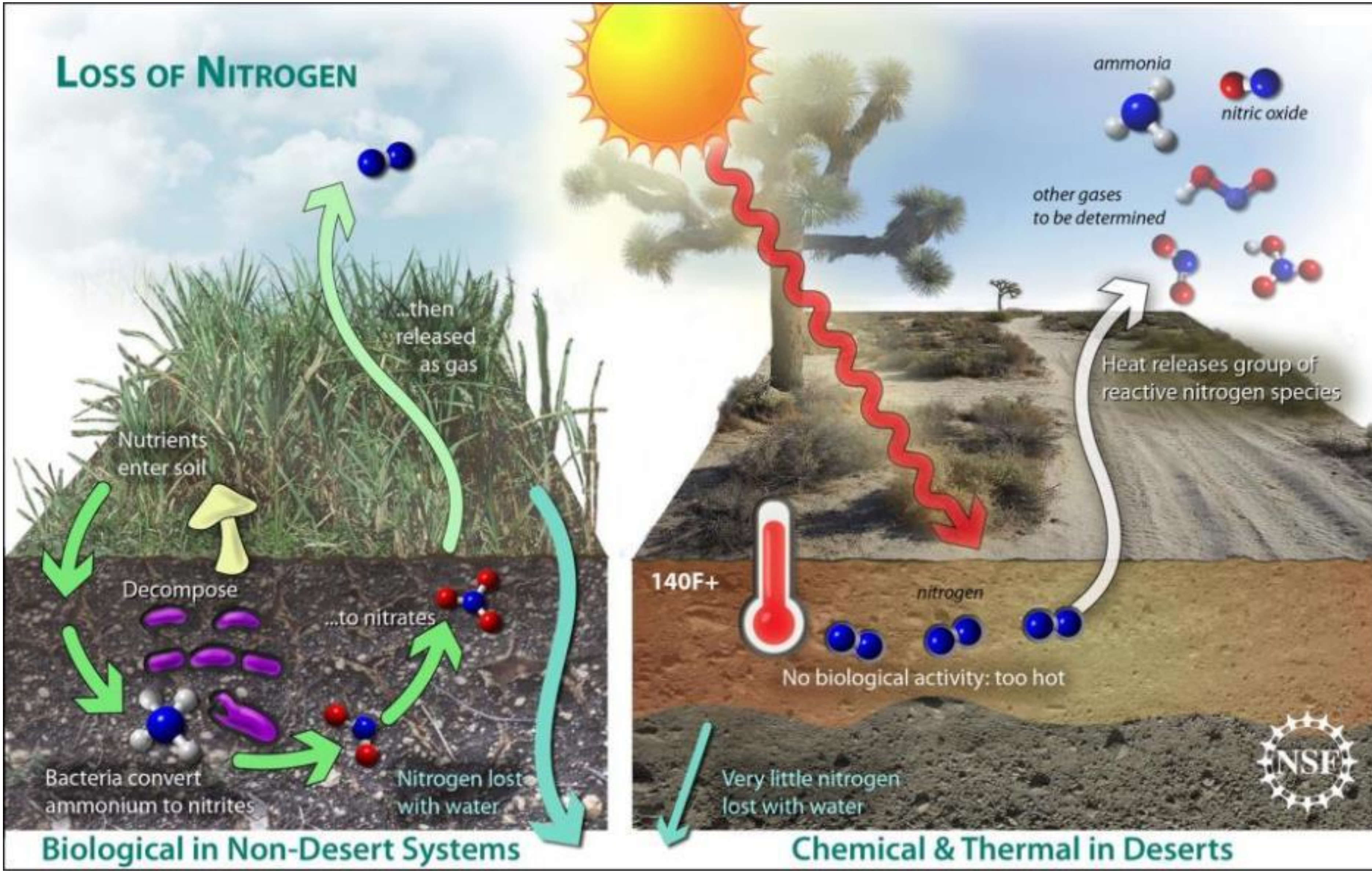
CATIONS			**ANIONS**		
Element	Chemical Symbol	Plant Available Forms	**Element**	Chemical Symbol	Plant Available Forms
Nitrogen (Ammonium)	NH_4	NH_4^+	Nitrogen (Nitrate)	NO_3	NO_3^-
Potassium	K	K^+	Phosphorus	P	PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$
Calcium	Ca	Ca^{2+}	Sulfur	S	SO_2, SO_4^{2-}
Magnesium	Mg	Mg^{2+}	Boron	B	H_3BO_3, $B_4O_7^{2-}$
Iron	Fe	Fe^{2+}, Fe^{3+}	Molybdenum	Mo	MoO_4^{2-}
Manganese	Mn	Mn^{2+}	Chlorine	Cl	Cl^-
Zinc	Zn	Zn^{2+}			
Copper	Cu	Cu^+, Cu^{2+}			

Macronutrients. Micronutrients.

Sources of Elements in Soil

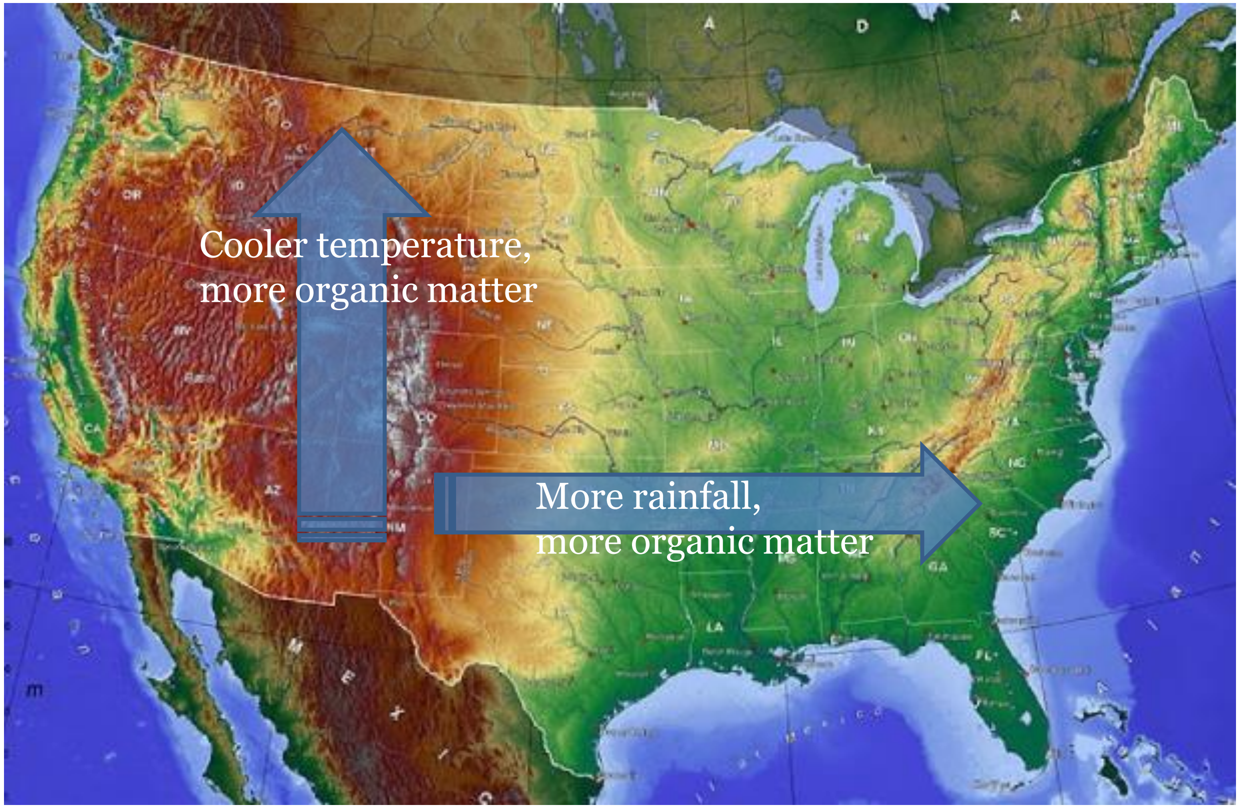
- Soil minerals
- Organic matter
- Adsorbed nutrients
- Dissolved ions



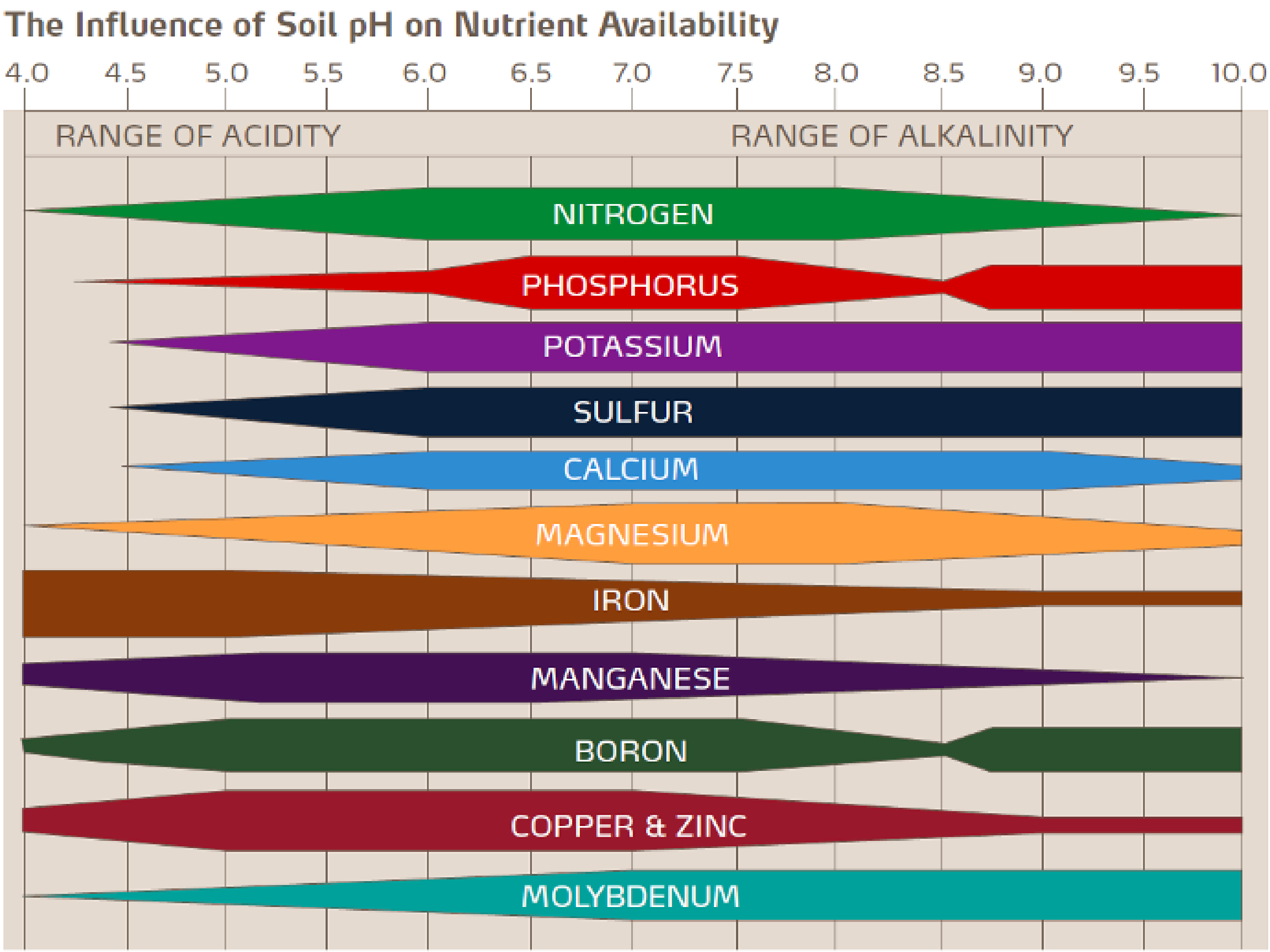

LOSS OF NITROGEN
ammonia
nitric oxide
other gases
to be determined
...then
released
as gas
Heat releases group of
reactive nitrogen species
Nutrients
enter soil
Decompose
...to nitrates
140F+
nitrogen
No biological activity: too hot
Bacteria convert
ammonium to nitrites
Nitrogen lost
with water
Very little nitrogen
lost with water
NSF
Biological in Non-Desert Systems
Chemical & Thermal in Deserts

Causes of Soil pH

- Precipitation
  - Precipitation exceeds evaporation
- Organic matter



Effects of pH on Plants



Effects of pH on Plants

pH 4.0-6.0	pH 5.0-6.5	pH 6.0-7.5	pH 5.0-7.5	pH 6.0-8.0
Potato	Apple	Apricot	Banana	Avocado
	Blackberry	Cherry	Rhubarb	Asparagus
	Cranberry	Grapevine	Strawberry	Ginger
	Gooseberry	Grapefruit	Raspberry	Leek
	Mango	Hazelnut	Carrot	Mint
	Melon	Hop	Cauliflower	Paprika
	Pineapple	Lemon	Sweet corn	Water cress
	Pomegranate	Lychee	Cucumber	
	Watermelon	Mulberry	Garlic	
	Basil	Nectarine	Lentil	
	Chicory	Peach	Parsley	
	Fennel	Plum	Pepper	
	Olive	Quince	Pumpkin	
	Peanut	Artichoke	Shallot	
	Sweet potato	Bean	Spearmint	
	Rice	Beetroot	Thyme	
	Rosemary	Broccoli	Tomato	
	Sage	Brussels sprouts	Turnip	
	Soybean	Cabbage		
		Calabrese		
		Celery		
		Chinese		
		Cabbage		
		Chives		
		Lettuce		
		Millet		
		Mushroom		
		Mustard		
		Onion		
		Pea		
		Peppermint		
		Radish		
		Spinach		

Other Factors Affecting Uptake

Raises Fertility	Lowers Fertility
High clay content	High sand content
High humus content	Loss of organic matter
Good structure	Compaction
Warm soil	Cold soil
Deep soil	Shallow soil
Moist soil	Dry or wet soil
Good drainage	Excess irrigation or drainage
Fertilization	Erosion
Desirable microbes	Root damaging pests
Near neutral pH	pH too acid or alkaline

Acidifying Soil with Elemental Sulfur

Change in pH Desired	SAND pints/ 100 ft²	LOAM pints/ 100 ft²	SAND lbs/ acre	LOAM lbs/ acre
0.5	2/3	2	360	1,100
1.0	1 1/3	4	725	2,200
1.5	2	5 ½	1,100	3,000
2.0	2 ½	8	1,350	4,400
2.5	3	10	1,650	5,400

*Do not apply more than 20lbs/ 1000 ft² per application
*Temporarily changes pH

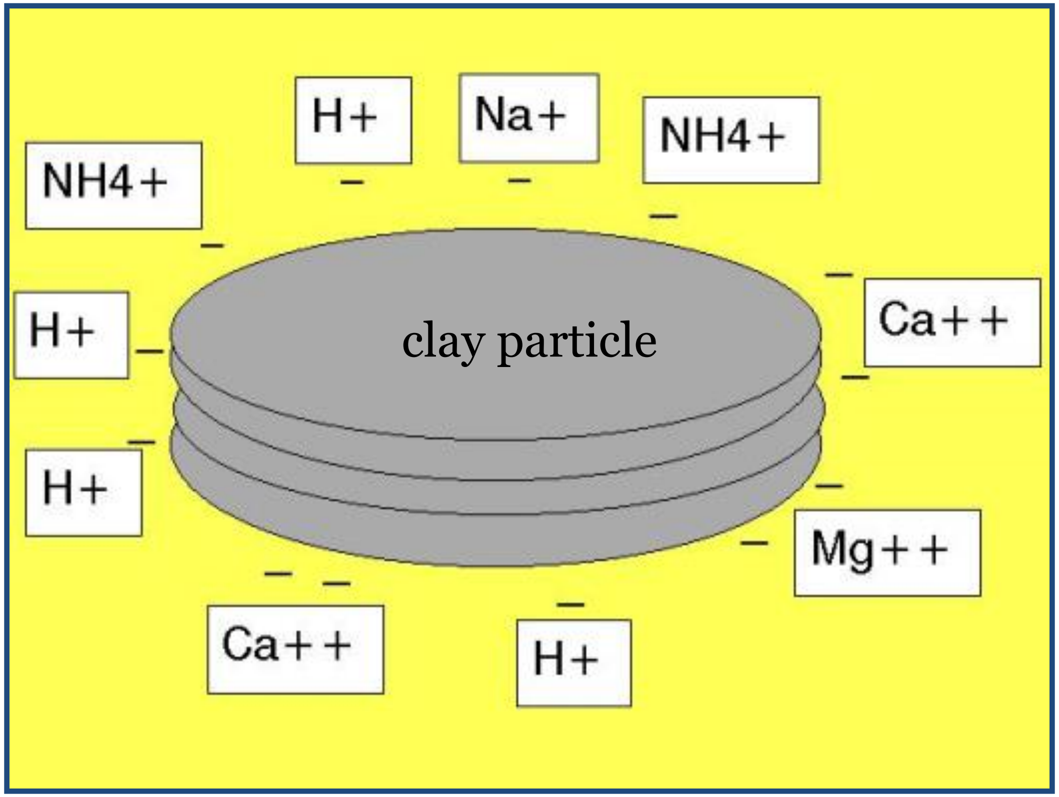
Rate:
Calculated rate (lb/volume) = sulfur recommendation (lb/A) ÷ 37,635,722 x soil volume (in^3)

Cation Exchange Capacity (CEC)

The total number of cations a soil can hold--or its total negative charge--is the soil's cation exchange capacity. The higher the CEC, the higher the negative charge and the more cations that can be held.

Cations held on the clay and organic matter particles in soils can be replaced by other cations; thus, they are exchangeable. For instance, potassium can be replaced by cations such as calcium or hydrogen, and vice versa.

Cation Exchange Capacity



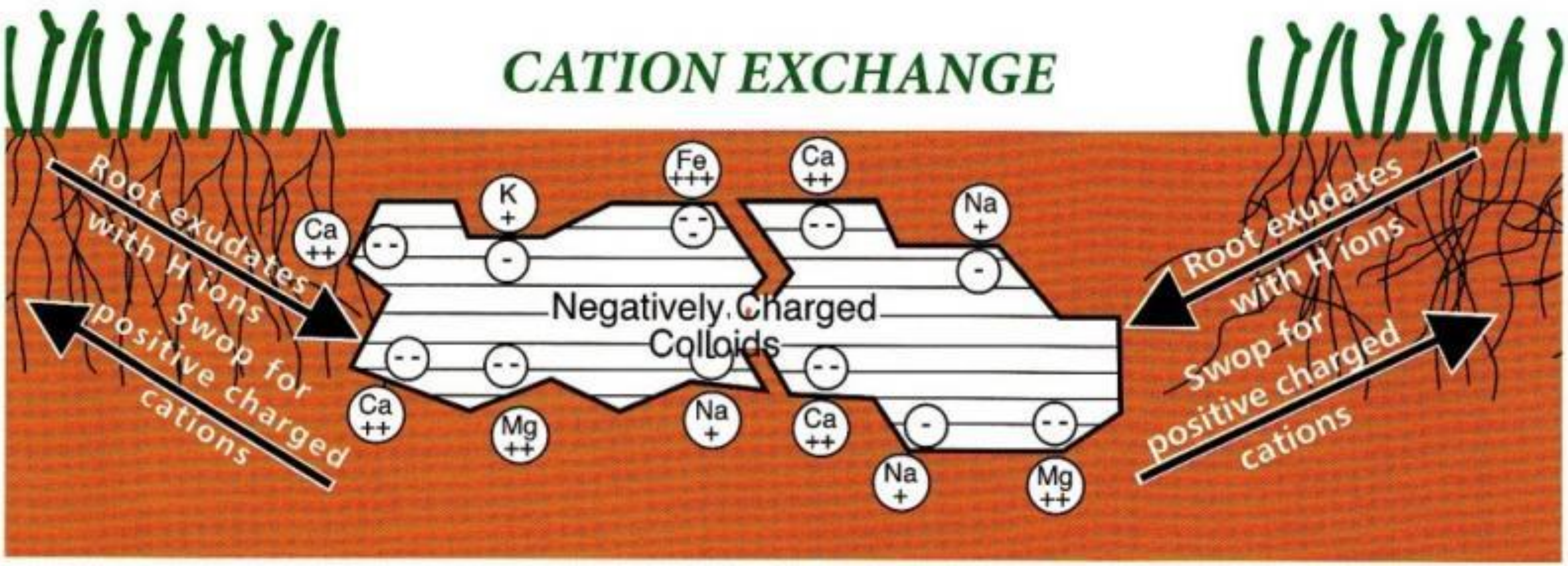
Cations

- NH_4^+, K^+, Fe^{++}, Ca^{++}

Anions

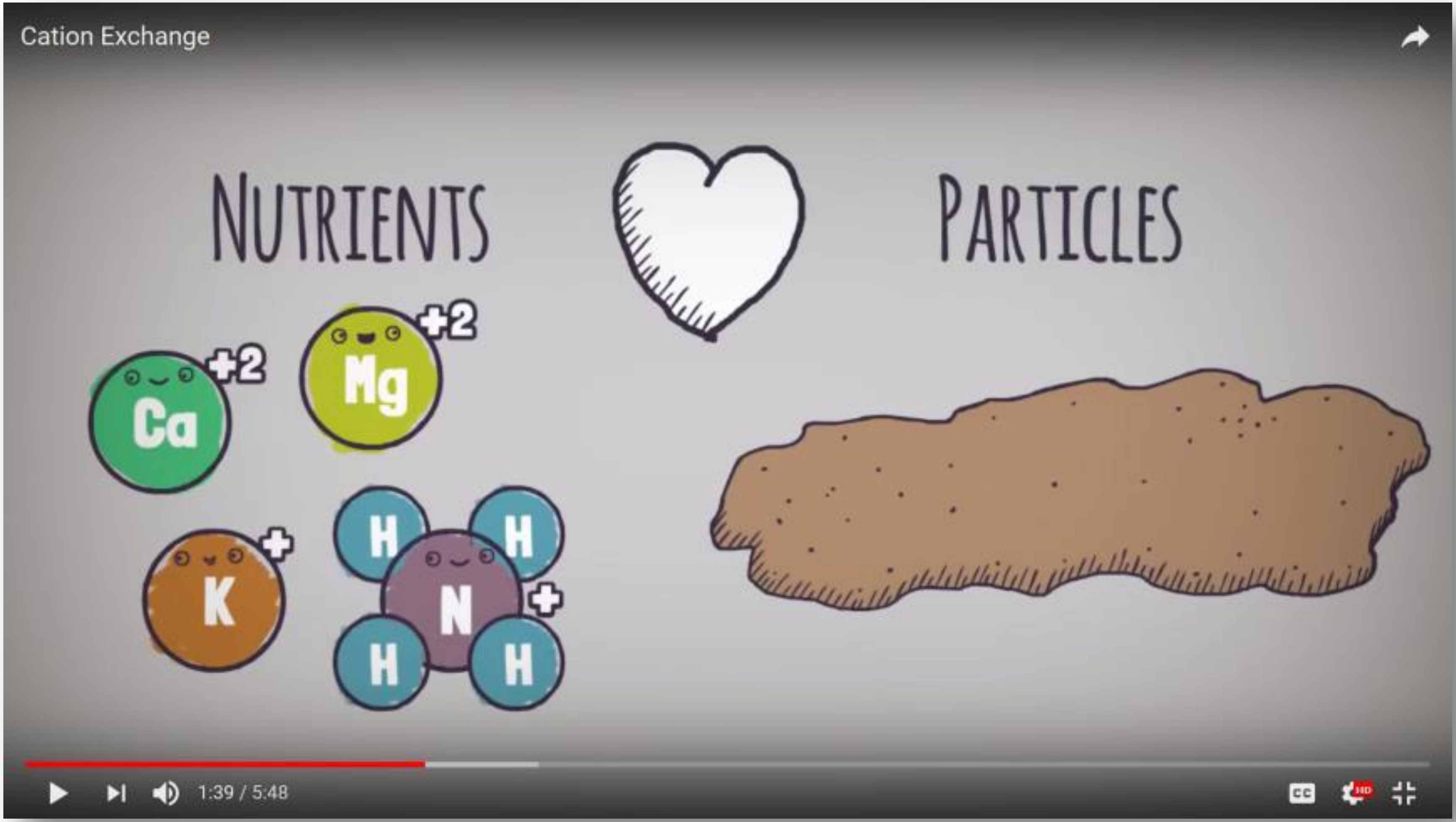
- NO_3^-, $SO4^{2-}$

Organic matter and clay carry a ***negative*** *charge*


CATION EXCHANGE
Root exudates with H ions
Swop for positive charged cations
Negatively Charged Colloids
Ca ++
K +
Fe +++
Ca ++
Na +
Ca ++
Mg ++
Na +
Ca ++
Na +
Mg ++
Root exudates with H ions
Swop for positive charged cations

Cation Exchange Capacity

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



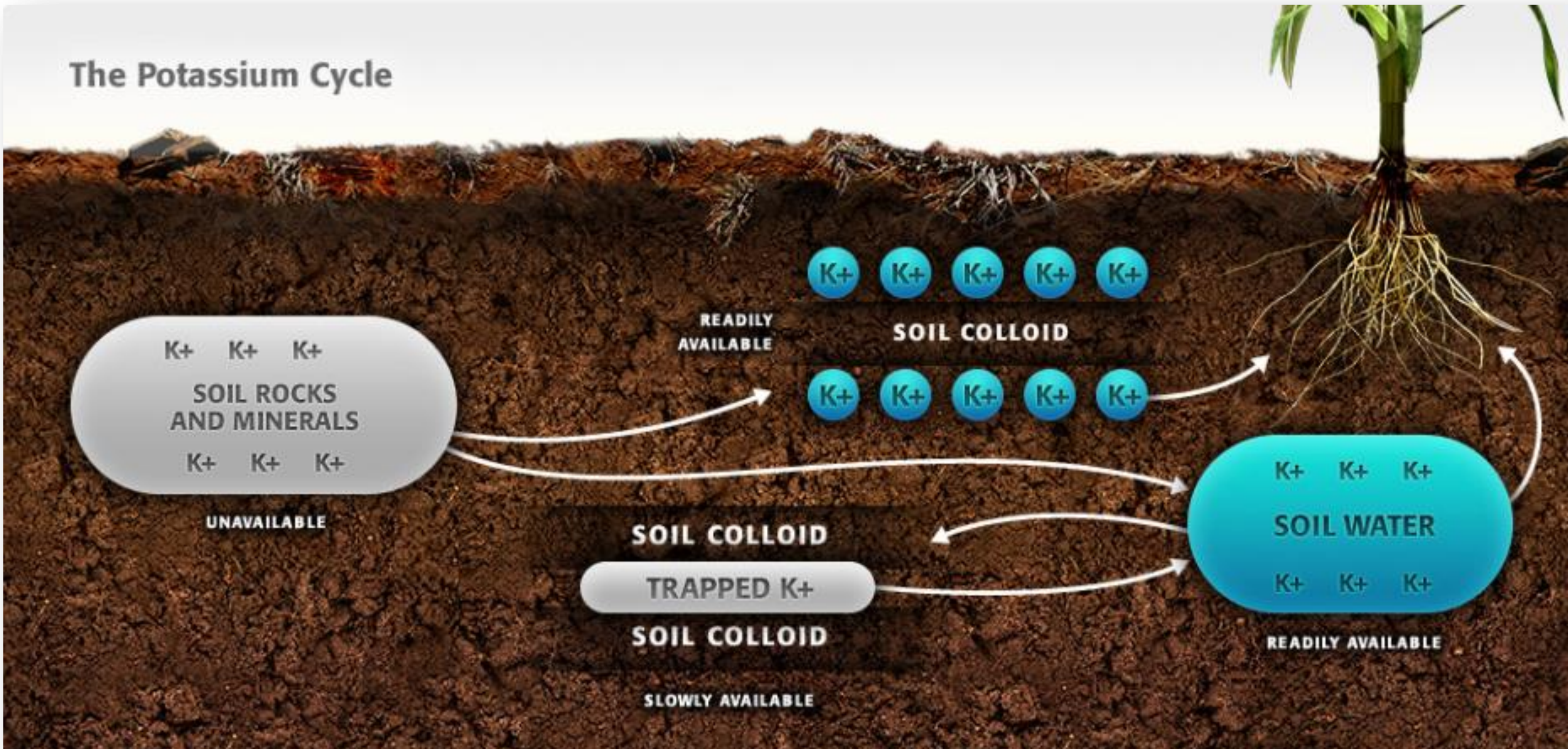
Terms to know

- **Base saturation**
  - Percentage of CEC sites that are occupied with bases (Ca^{2+}, Mg^{2+}, Na^{+}) instead of ions that make the soil acidic (H^{+}, or Al^{3+}) Often expressed as a percent
- **Exchangeable bases**
  - Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} adsorbed to CEC sites

- Soils with high base saturations are considered more fertile

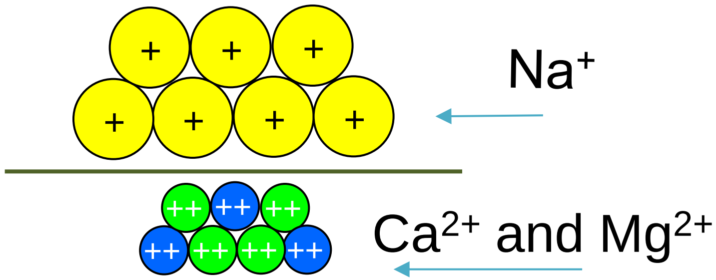
- Why?

Soil Colloid



Sodium Adsorption Ratio (SAR)

The ratio of 'bad' to 'good' flocculators gives an indication of the relative status of these cations:

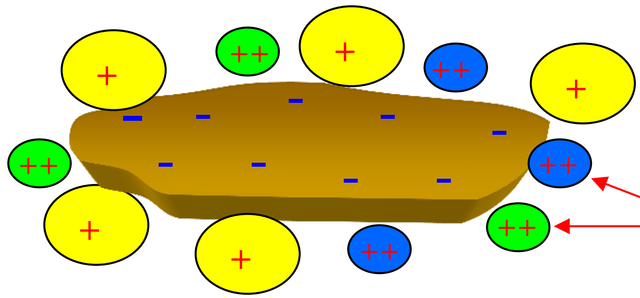


Mathematically, this is expressed as the 'sodium adsorption ratio' or SAR:

$$SAR = \frac{[Na^{+}]}{\sqrt{[Ca^{2+}] + [Mg^{2+}] \div 2}}$$

where concentrations are expressed in mmoles/L

Exchangeable Sodium Percentage (ESP)



Mathematically, this is expressed as the percentage of the CEC (cation exchange capacity) that is filled with sodium in units of charge per mass ($cmol_c/kg$)

An alternative to SAR is ESP (Exchangeable Sodium Percentage)

SAR and ESP are approximately equal numerically

$$ESP = \frac{Na^+}{\text{Cation Exchange Capacity}}$$

Test soil to determine sodium level

Soil sodium tests:

SAR - sodium adsorption ratio

ESP - exchangeable sodium percentage

If SAR or ESP are ≥ 10 the soil is likely to disperse.

You should consider treating the soil.

Lower ESP and SAR numbers are always good

Chemical Properties of Soil

- Soil report- what does it mean?
- The important details on a soil report
  - EC
  - CEC
  - ESP
  - SAR (water)
- Is pH really that important?

MOTZZ LABORATORY, INC.

Soil Analysis Report

Harmony Horticultural Consulting
[redacted]

Project: [redacted]
Sampler:
Date Received: 9/14/2012
Date Reported: 9/19/2012

PO Number: Flower Beds

Lab Number: 906095-01
Sample ID: Flower Beds
Description: 09/14/12

Crop: Landscape
Growth Stage:

Soil Complete Test

Test	Method	Result	Units	Levels
pH	1:1	7.6	SU	Medium
Electrical Conductivity, EC	1:1	2.1	dS/m	Medium
Calcium, Ca	NH4OAc (pH 8.5)	4,300	ppm	Very High
Magnesium, Mg	NH4OAc (pH 8.5)	620	ppm	Very High
Sodium, Na	NH4OAc (pH 8.5)	580	ppm	Very High
Potassium, K	NH4OAc (pH 8.5)	390	ppm	High
Zinc, Zn	DTPA	33	ppm	Very High
Iron, Fe	DTPA	77	ppm	Very High
Manganese, Mn	DTPA	23	ppm	High
Copper, Cu	DTPA	4.5	ppm	Very High
Nickel, Ni	DTPA	0.52	ppm	
Nitrate-N, NO3-N	Cd Reduction	13	ppm	Medium
Phosphate-P, PO4-P	Olsen	150	ppm	Very High
Sulfate-S, SO4-S	Hot Water	73	ppm	Very High
Boron, B	Hot Water	2.4	ppm	High
Free Lime, FL	Acid Test	None		
ESP	Calculated	8.4	%	
CEC	Calculated	30.2	meq/100g	

Levels are generalized and apply to most cropping environments.
Low means a high probability that applying nutrient will elicit a growth response.
Medium means a moderate probability of plant growth from application.
High means little or no response expected from application of this nutrient.
Very High means adding the nutrient may reduce growth or cause imbalance.

3540 E Corona Ave. Phoenix AZ 85040 602-454-2376 (Phone) 602-454-9243 (Fax)

- Higher CEC=high clay
- Higher CEC= high organic matter
- Clay minerals and organic matter have a CEC that varies with pH
- As pH increases, so do the number of negative charges on the clay or organic matter particles, and so does the CEC

Salt-affected Soil Classification

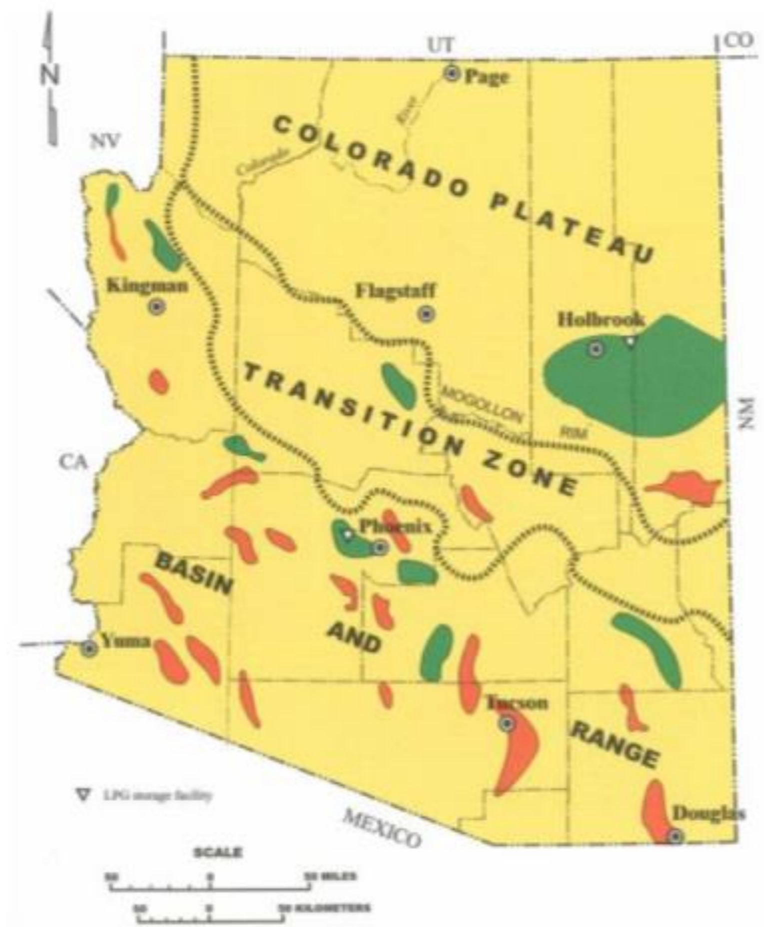
Classification	**pH**	**EC**	**ESP**
Normal soils	6.5-7.2	<4	<15
Acid soils	<6.5	<4	<15
Saline soils	<8.5	>4	<15
Sodic	>8.5	<4	>15
Saline-sodic	<8.5	>4	>15

Management of Saline or Sodic Soils

Naturally Salty Areas

AZGS Circular 30 has detailed descriptions of salt deposits in Arizona. The map below shows the location of Arizona's salt, known deposits in green, potential deposits in orange.

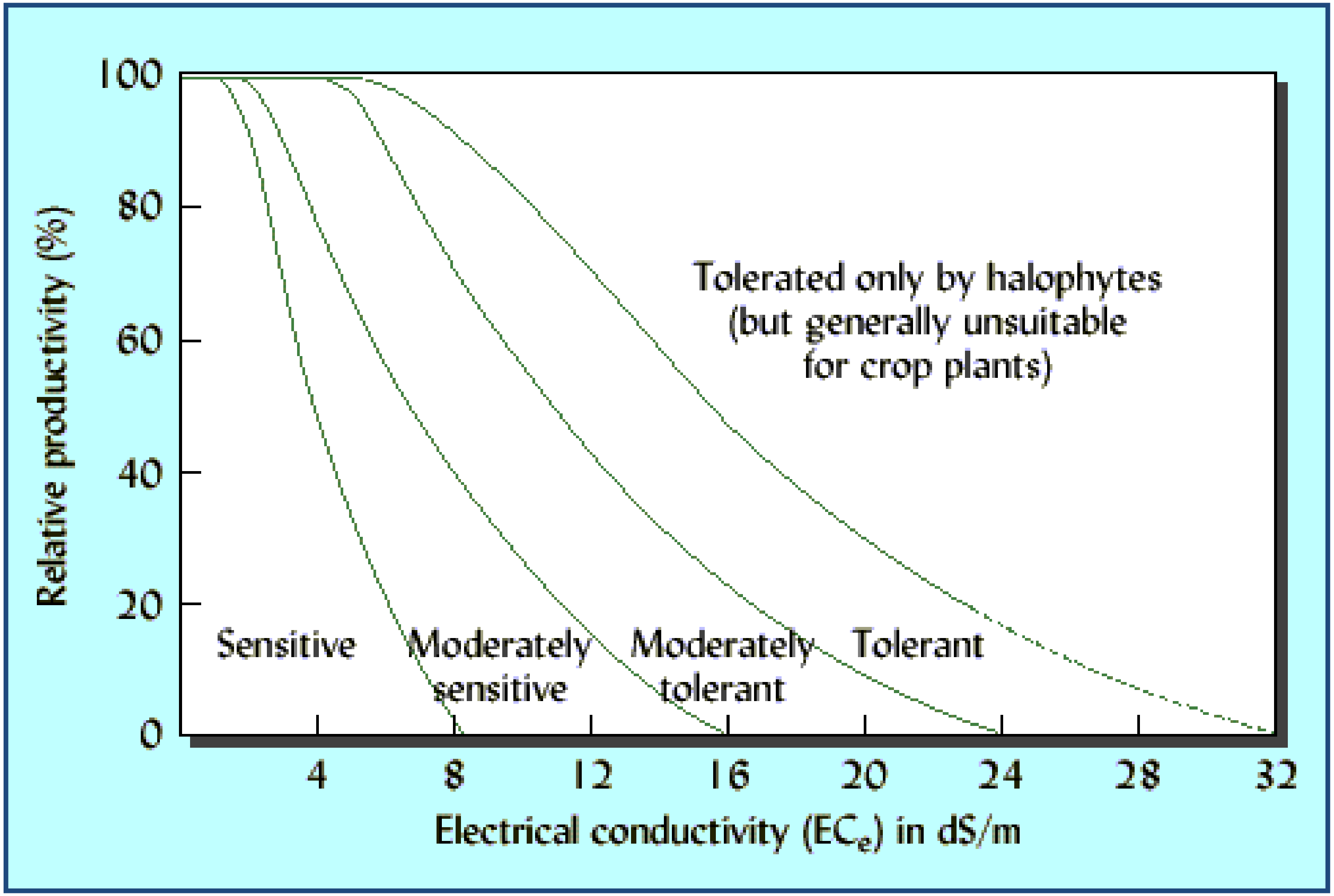
- Some areas of Arizona have natural salt deposits
- Green- known deposits of salt
- Orange- potential deposits of salt



Saline Soils

Class	Salinity (mmhos/cm)	Crop Response
Nonsaline	0-2	Salinity effects unimportant
Slightly saline	2-4	Yields of sensitive crops lowered
Moderately saline	4-8	Yields of many crops lowered
Strongly saline	8-16	Only tolerant crops yield well
Very strong saline	More than 16	Only most tolerant crops yield well

Plant Salinity Tolerance



Brady and Weil, Figure 9.27

Plant Salinity Tolerance

How to select salt-tolerant plants

« Return

Relative tolerances of trees to salinity — Two sources of data

		Source 1*		Source 2**	
Botanical name	**Common name**	Tolerance to salt spray	Tolerance to soil salinity	Tolerance to salt spray	Tolerance to soil salinity
Acacia baileyana	mimosa	sensitive	---	---	---
Acer pseudoplatanus L.	sycamore maple	---	---	sensitive	sensitive
Acer rubrum L.	red maple	---	---	sensitive	sensitive
>Albizia julibrissin Durazz.	mimosa silk tree	---	moderately sensitive	sensitive	sensitive
Araucaria heterophylla (Salisb.)	Norfolk Island pine	---	---	highly tolerant	tolerant
Atriplex canescens	four-wing saltbush	---	tolerant	---	---
Averrhoa carambola L.	carambola, starfruit	---	---	moderate	moderate
Baccharis salicifolia	seep willow	---	moderately sensitive	---	---
Bauhinia purpurea L.	orchid tree	---	---	sensitive	moderate
Bumelia lanuginosa	chittamwood	moderately sensitive	---	---	---
Callistemon citrinus Curtis.	lemon bottlebrush	---	---	tolerant	moderate
Carya illinoensis	pecan	highly sensitive	---	---	---
Carya illinoiensis Koch.	pecan	---	---	moderate	moderate
Cedrus deodara D. Don	deodar cedar	---	---	moderate	moderate
Celtis sinensis Pers.	Chinese hackberry	---	---	sensitive	sensitive
Cercis occidentalis	western red bud	---	sensitive	---	---
Chilopsis linearis	desert willow	moderately tolerant	sensitive	---	---
Chitalpa tashkentensis	chitalpa	---	sensitive	---	---
Citrus limon L.	lemon	---	---	sensitive	sensitive
Citrus paradisi Macf.	grapefruit	---	---	sensitive	sensitive
Citrus reticulata Blanco.	tangerine	---	---	sensitive	sensitive

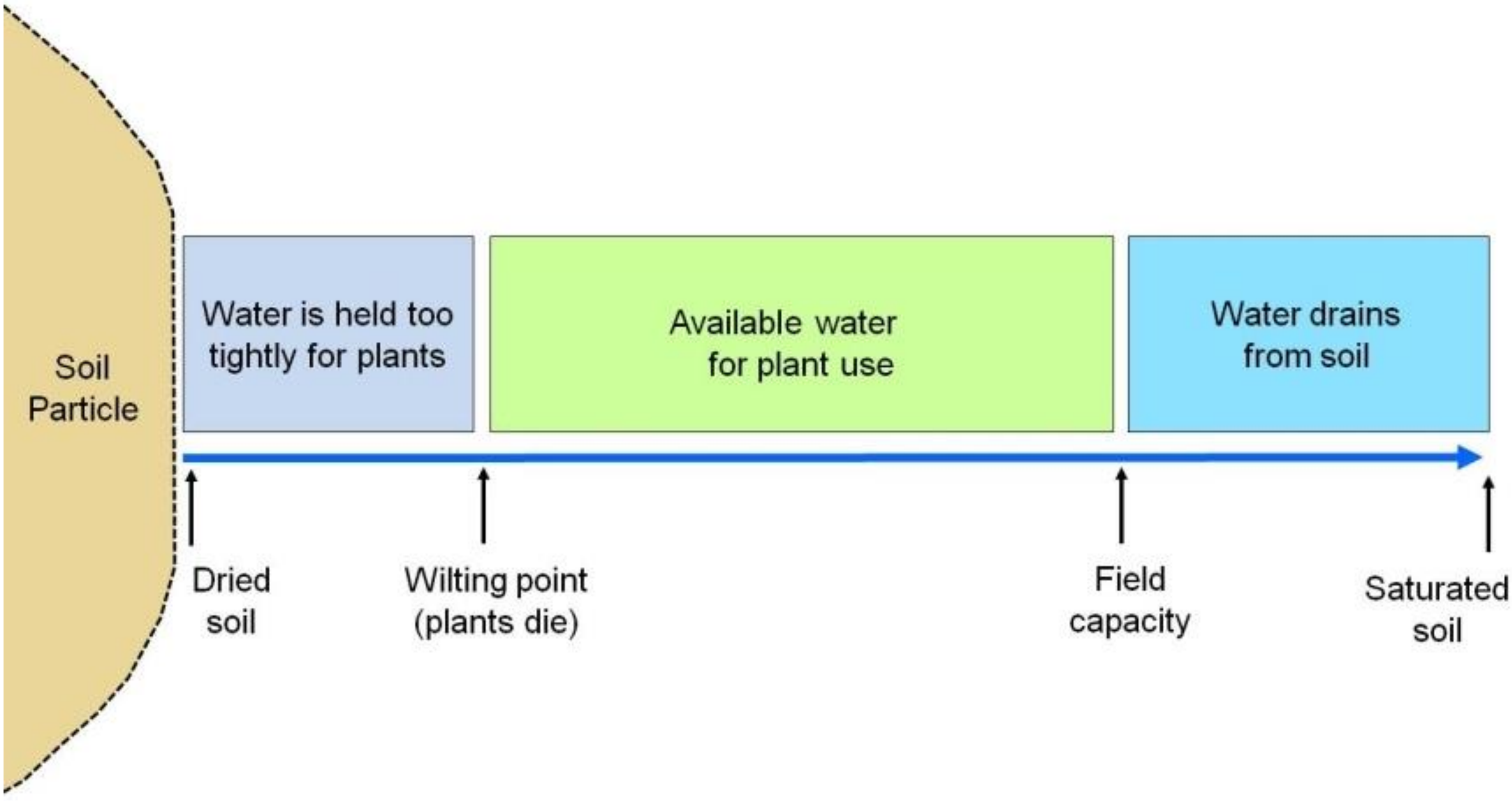
http://www.salinitymanagement.org/Salinity%20Management%20Guide/cp/cp_7_table-2.html

Soil Salinity Tolerance of Turfgrass

Turfgrass	EC <4	EC 4-8	EC 8-16	EC >16
Cool season	Kentucky bluegrass Solonial bentgrass creep red fescue Meadow fewscue Annual bluegrass Rough bluegrass	Tall fescue Perennial ryegrass	Creeping bentgrass Western wheatgrass	Alkaligrass
Warm season	Centipedegrass	Bluegrama	Bermudagrass Zoysiagrass St. Augustinegrass	Seashore paspalum

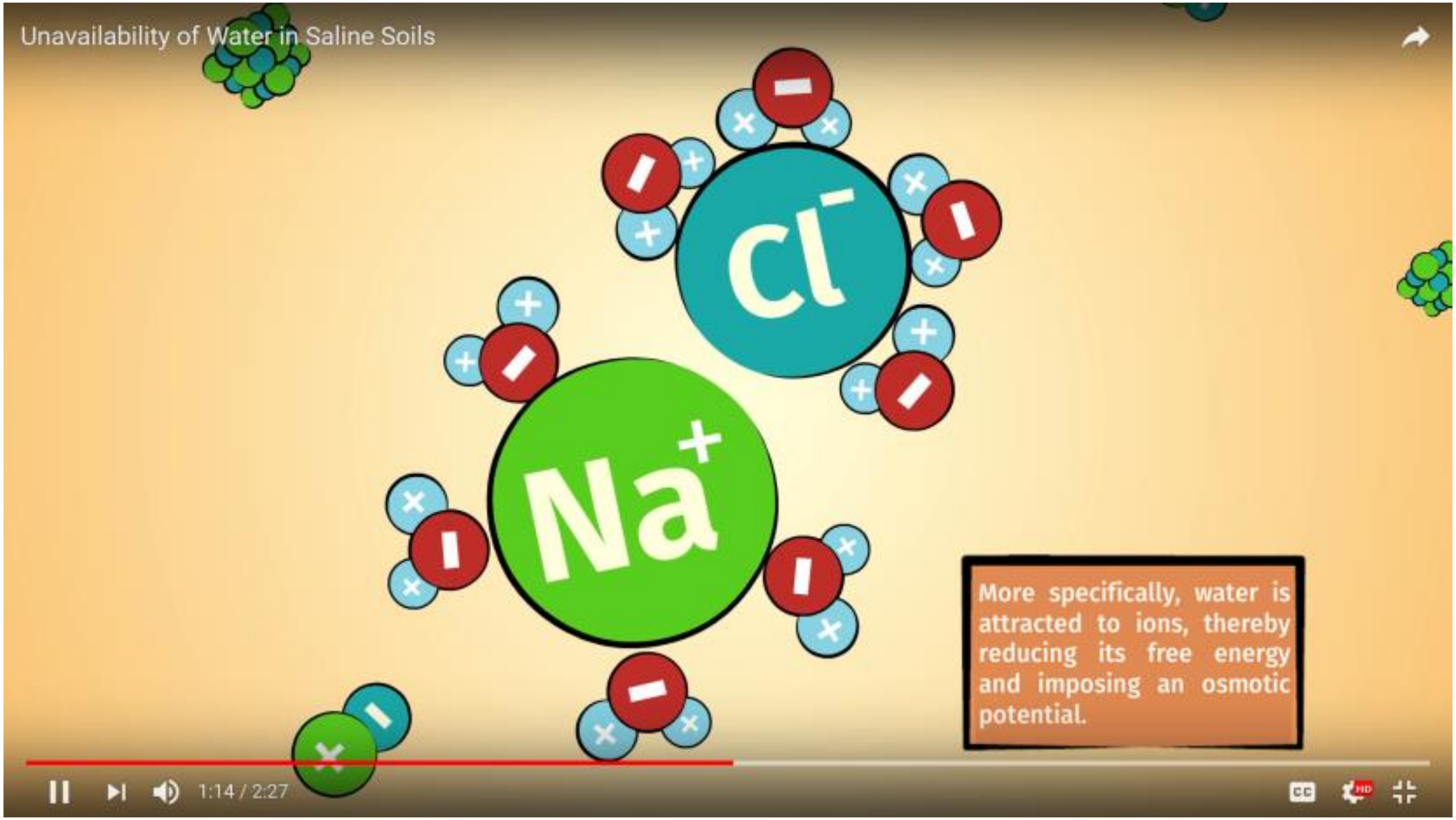
David M. Kopec, PhD, UofA

Available Water in Saline Soils



Available Water in Saline Soils

- https://www.youtube.com/watch?v=zJ_zi53UjF8



Water Quality

Where does our water come from?

Is it a potable city tap?

- Reclaimed?
- Lake or canal?

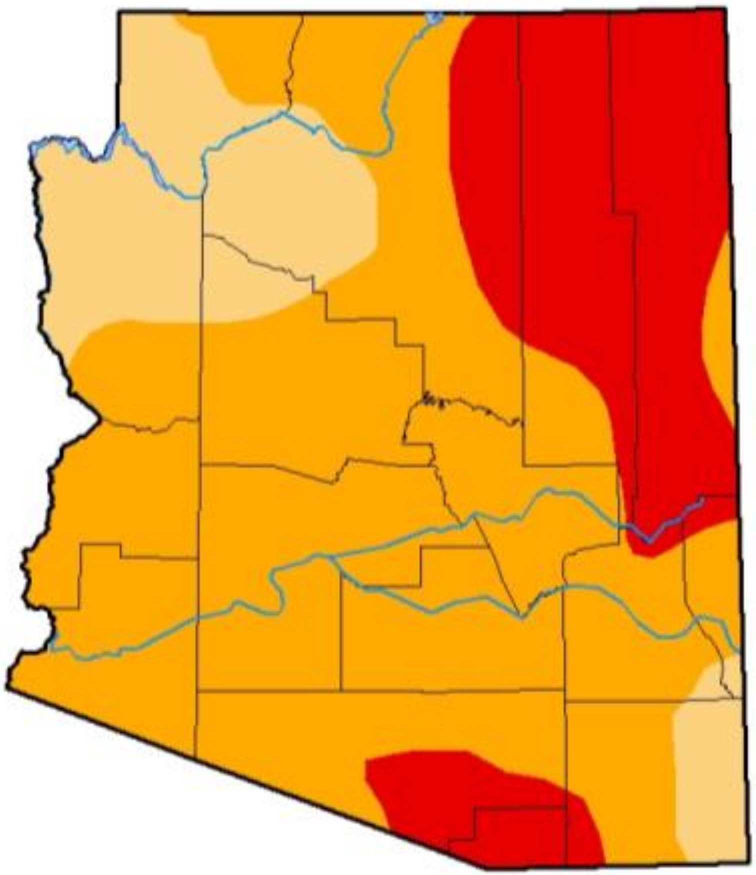
U.S. Drought Monitor

Arizona

March 6, 2018

(Released Thursday, Mar. 8, 2018)

Valid 7 a.m. EST



Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:

Richard Tinker
CPC/NOAA/NWS/NCEP

USDA

http://droughtmonitor.unl.edu/

SAR Hazard Levels from Water Test

Hazard	SAR Value	Concern
Low	10 meq/ 1 or less	Generally safe for all soils
Medium	10- 18 meq/l	OK for sandy, clay, silty soils, may accumulate sodium
High	18- 26 meq/l	May develop high soil sodium. Gypsum most likely required
Very High	Over 26 meq/l	Usually not acceptable for irrigation

Reclaimed Water Concerns

- High salinity
- Requires up to 25% more water as a leaching factor to remove salts from root zone
- Deterioration of soil structure
- Accumulation of specific ions
- Increase in sodium
- Decrease in permeability
- Decrease in water infiltration
- Damage to salt-sensitive plants

Reclaimed Water Quality

Class of Water	Concentration TDS
Class I, Excellent	250
Class 2, Good	250-700
Class 3, Permissible *	750-2000
Class 4, Doubtful **	2000-3000
Class 5, Unsuitable **	3000

*Leaching needed if used
**Good drainage needed and sensitive plants will have complications

Reclaimed Water Quality

Effect on plants	TDS
No problem with crop yield	<500 mg/L
Increasing problems with crop yield	500-2,000 mg/L
Severe problems with crop yield	>2,000 mg/ L

SRP's scale on levels reclaimed water impacts plants

Options for Desalinating Water

- Down the road technologies
  - Reverse osmosis
  - Nanofiltration
  - Advance membrane treatments
  - Thermal processes (distillation)
  - Electrodialysis/ Electrodialysis reversal
  - Blending water

Water Quality & Uses Triangle

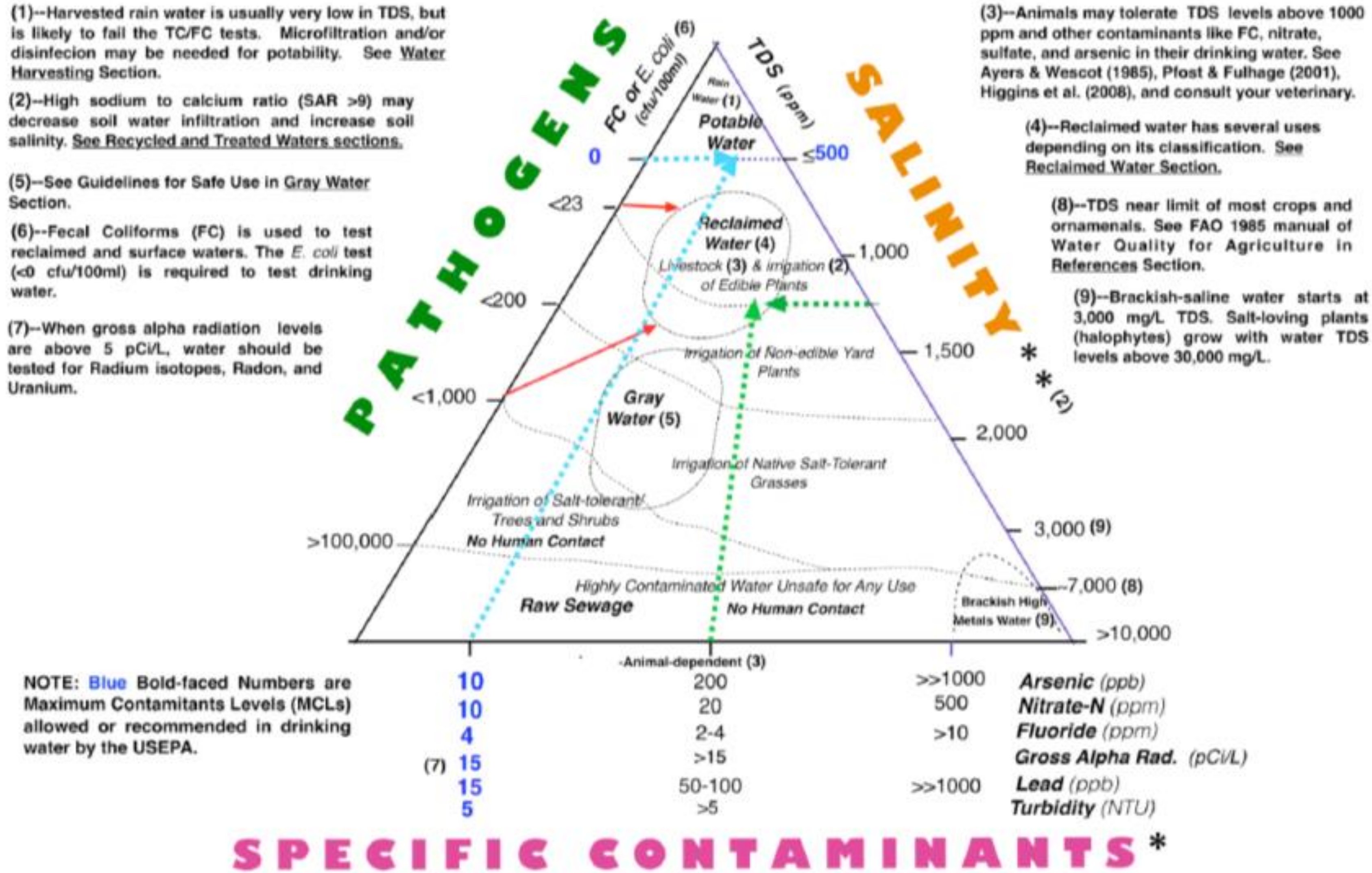


Figure 8. Water Quality and Uses Triangle[7].

Reclaiming Salted Soils

Salinity

- Saline
  - *Non-sodic soil containing sufficient soluble salt to adversely affect the growth of most crop plants with a lower limit of electrical conductivity of the saturated extract (ECe) being 4 deciSiemens / meter (dS/m), which is equivalent to a value of 4 mmhos/cm*
- Sodic
  - *Non-saline soil containing sufficient exchangeable sodium (Na) to adversely affect crop production and soil structure under most conditions of soil and plant type. The sodium adsorption ratio of the saturation extract (SARe) is at least 13*

Salinity

Sodium(Na)

Calcium (Ca)

Potassium (K)

and other salts

accumulate in soils

Peeling of the soil surface is a sign of poorly drained, salty soil and remediation is required for plants to grow

Managing Salt

- **Amendments**
  - Organic-based fertilizers
    - Low in salt
    - Enhance water infiltration
    - Provide food for the plant

- **Re-establish microbial population**
  - Breaking down nutrients in the soil for the plant to take up
  - Create a healthier soil for the pant to survive

Managing Salt

- **Calcium**
  - Gypsum/ lime depending on pH
    - decades to see real results
  - Chicken
  - Liquid sprays
    - Not very cost effective

Managing Salt

- **Soil Treatment**
  - Aeration
    - 2-3 times per summer to help alleviate compaction of tight soils
    - Top dressing with sand to keep areas open, allowing air and water to penetrate
  - Top dressing
    - Sand to create a new medium for plant to 'live'
    - Done over time by adding ½" or 33 tons/A or 1000 sq ft per aerification
    - At least 5 seasons of applications to establish new root zone for turfgrass
    - Sand keeps compaction to a minimum
    - Creates warmer soil temperature
  - Gypsum
    - Adding calcium to soil takes some time before results can be seen
    - Depending on salt levels, enormous amount of calcium may be required to have impact on soil

Managing Salts with Organic Matter

- Stimulate soil chemistry
- Help break down salts
- Improve soil structure to aid in flushing salts
- Helps reduce soil pH, which releases salts from being bound by soil

Managing Salt

- Apply extra water to prevent excessive salt buildup
  - The amount of extra water needed is called the ***leaching requirement*** **(LR)**
    - LR is higher when using salty irrigation water
    - LR is higher when growing salt-sensitive plants
- You can save water and prevent salt buildup by using adapted plant species

Leaching Fraction (LF)

- LF = (EC) water x 100
  (EC) soil
- (EC) water = EC from water test for effluent water
- (EC) soil = EC from soil salt tolerance table

- Example: Perennial ryegrass
- Effluent water EC of 1.5dSm-1
- Current soil EC 6 dS/m
- (ryegrass max soil EC is 8.0)

% LF= (1.5 dSm^)

(6.0 dSm

LF=0.25

The LF is used to adjust the actual amount of water applied to meet the ET or water use of the turf & prevent the buildup of salts in the soil.

How much actual water will be needed to maintain adequate leaching given the LF of 0.25?

Actual water= ET of grass

(1 – LR value)

AW= 0.35 inches

(1-.025)

AW= 0.35 = .046 inches

0.75

AW= 0.46 inches

0.46 inches of water are needed to irrigate perennial ryegrass with a 0.25 LF value to prevent unsuitable salt buildup AND meet the turf water use of 0.35 inches

Managing Salt- Water Treatments

- **Wetting agents** make water 'wetter'
    1. Agents that condition the water
    2. Agents that rewet the hydrophobic soils
    3. Agents that leach the soil
    4. Granular- typically rewet the soil

- **Acids**
    - Sulfuric acid
        - Very dangerous to handle
        - Only modifies the water
    - N-pHuric
        - Safe to handle
        - Only modifies the water
    - N-Control
        - Safe to handle
        - Modifies water and soil
        - Adds air to soil

What is the difference between removing the 'hardness' vs. the 'alkalinity'

Managing Salty Water

1. Apply leaching fraction to area
2. Blend water sources to dilute saltiness
3. Promote drainage with aeration
   - Areate frequently and deeply

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Breakout Sessions

1. Soil and Water Interactions
2. Salt Management