Soil and Fertilizer Management

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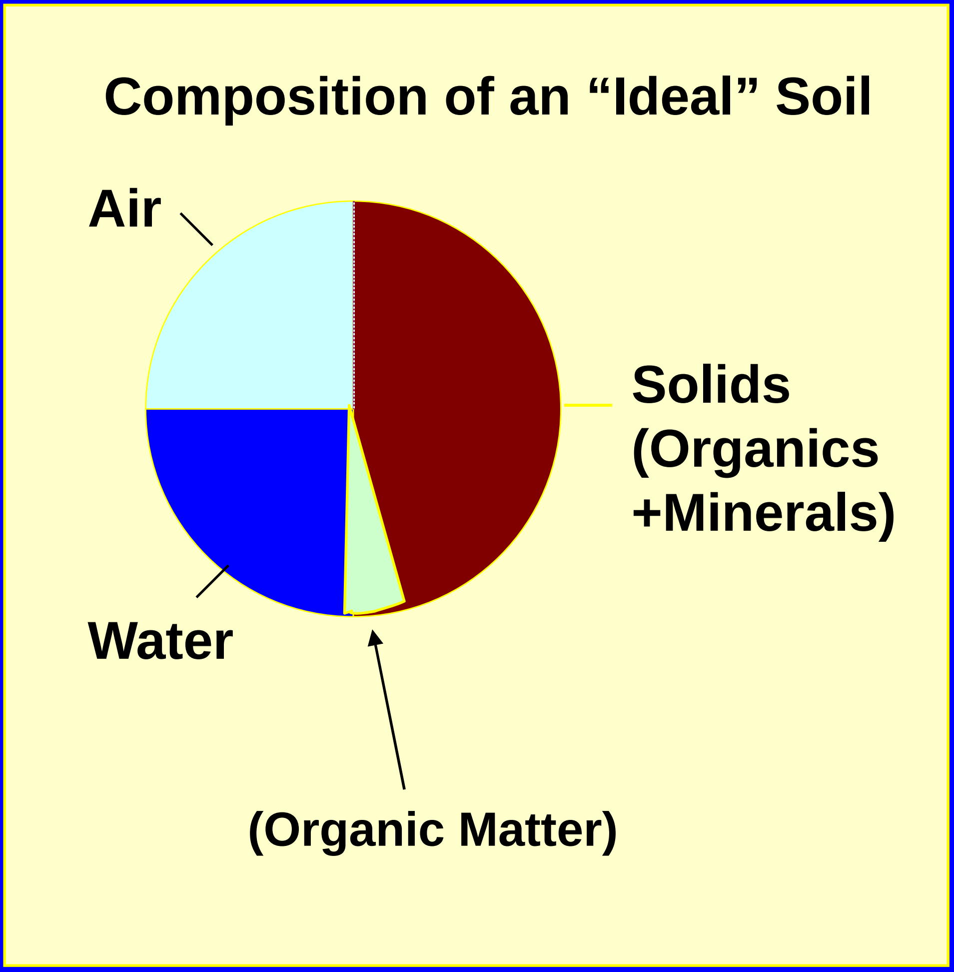
Outline for the Day

1. Lecture format
2. Break
3. Lecture format
4. Hands on Exercise
5. Lunch
6. Dig Hole
7. Lecture format

Soil Defined

- **"the upper layer of earth that may be plowed and in which plants grow"**
- **Soil is made of:**
  Minerals, Organic Matter, Air, Water



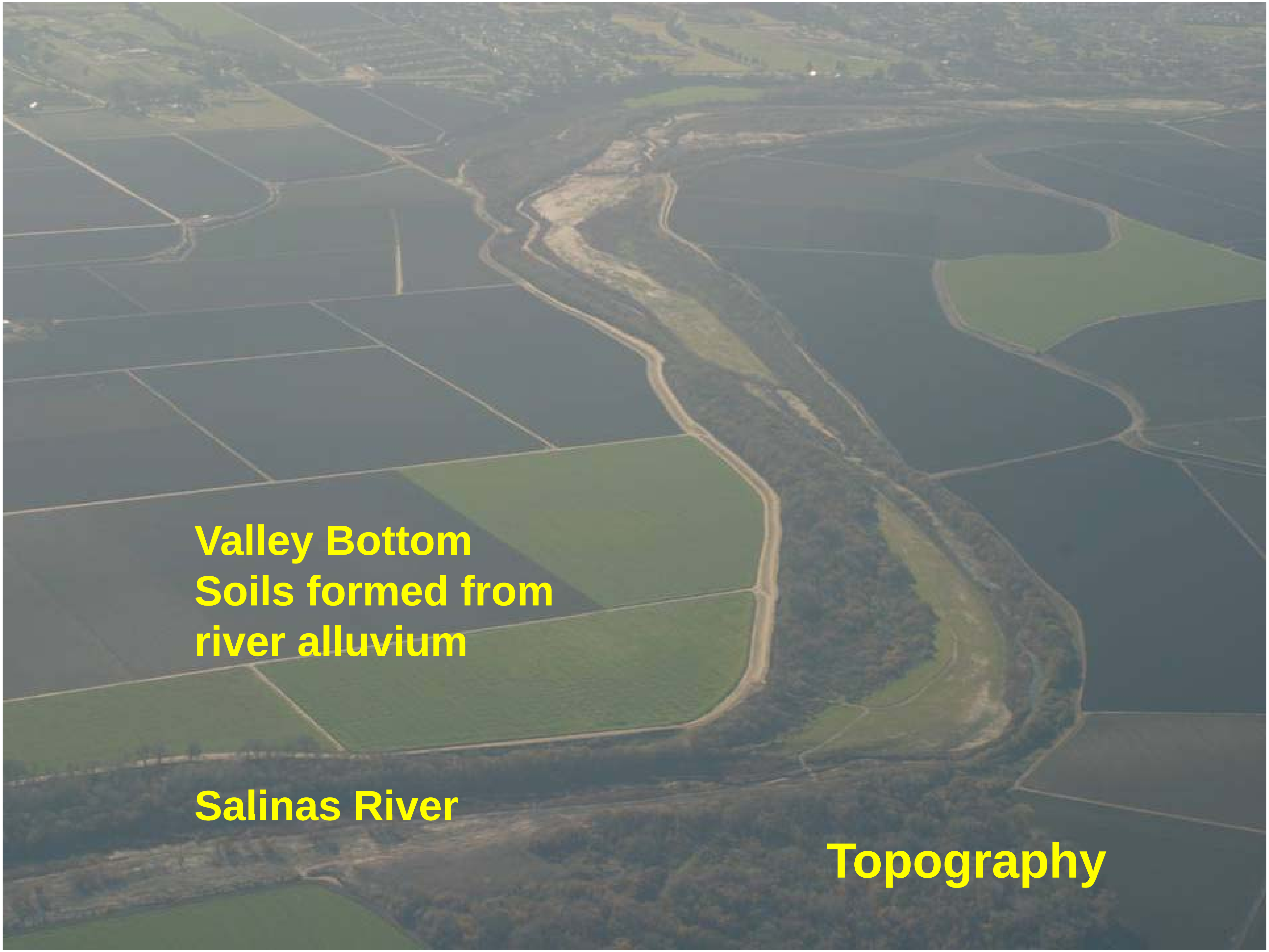
Soil Formation

- Soil is created over time from decomposing rocks and organic matter

- Variability in different types of soils arise from 5 dynamic factors:
  - Climate (temperature and rainfall)
  - Organisms (bacteria, plants, fungi)
  - Relief (topography, runoff, drainage)
  - Parent Material (bedrock, alluvium)
  - Time


Climate

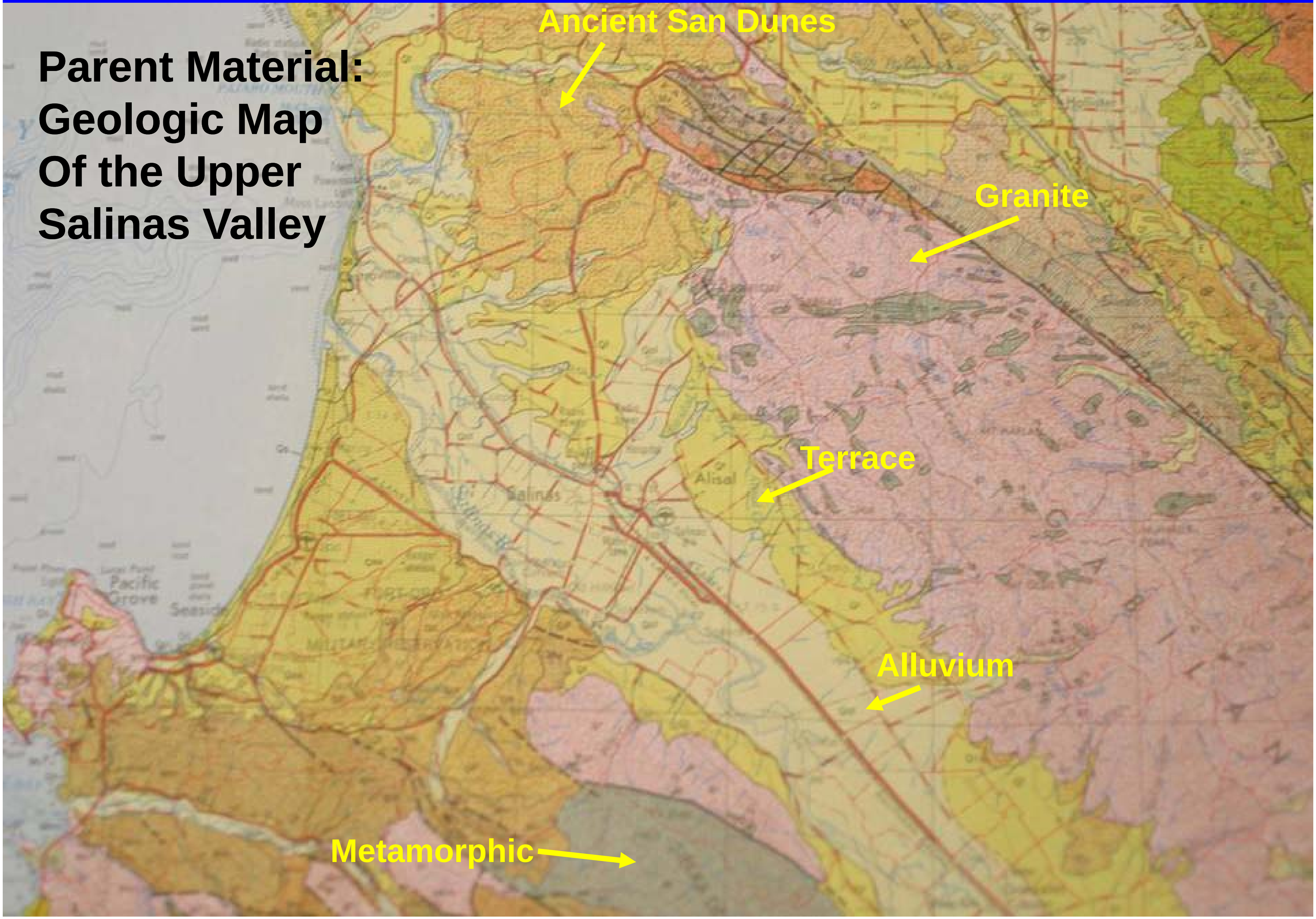

Climate


Valley Bottom
Soils formed from
river alluvium
Salinas River
Topography

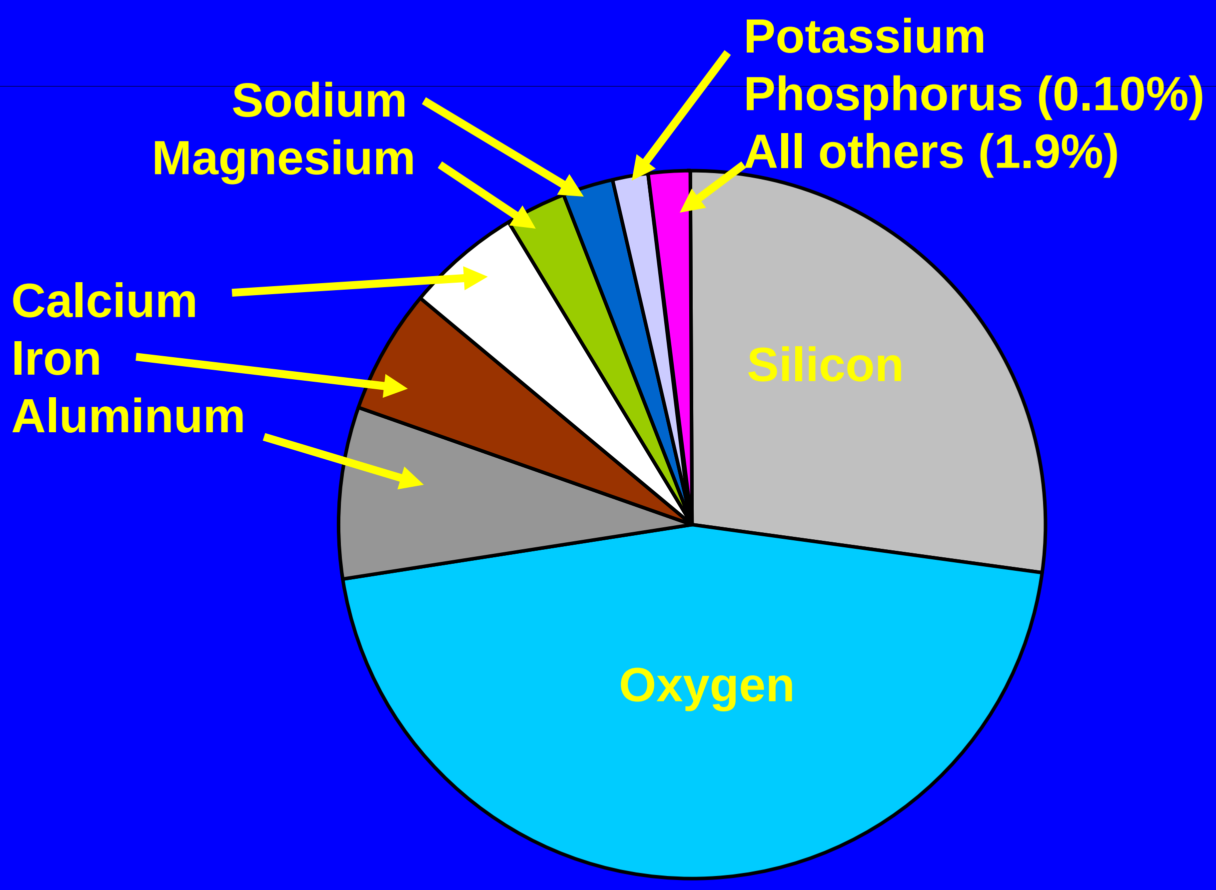

Topography

Parent Material
(Serpentine – high in Mg)

Parent Material: Geologic Map Of the Upper Salinas Valley



Elements of the Earth's Crust by Weight Percentage



Common Minerals in Rocks

- **Quartz**
  - **SiO2**
- **Feldspars**
  - **$(Na,Ca)(Si,Al)_3O_8$**
- **Micas**
  - **$K(Mg,Fe)_3(Si_3Al)O_{10}(OH)_2$**
- **Amphiboles**
  - **$(Ca,Na)_2(Mg,Fe,Al)_5Si_8O_{22}(OH_2)$**
- **Pyroxenes**
  - **$Ca((Mg,Fe,Al)(Si,Al)O_3)_2$**
- **Olivenes**
  - **$(Mg,Fe)_2SiO_4$**
- **Phosphates**
  - **$Ca_5(PO_4)_3(F,OH)$**
- **Carbonates**
  - **$CaCO_3$**

These minerals contain iron, magnesium, sodium, calcium and potassium but other elements such as copper, manganese and other essential elements are also contained in rock minerals.

Time


Older Soils on a Terrace
Recent Alluvium
Along River
Time

Soil Formation Terminology

- **Sedentary or residual soil : formed from bedrock weathering (formed in place)**

- **Transported soils are moved to a new location by natural forces:**

stream transported = alluvial

ocean transported = marine

wind-deposited = aolian

glacially transported = glacial

The Soil Profile Basics

- **As soils age, they differentiate into a profile of distinct layers, or horizons (A, B, and C)**

- **Note: Many profiles around urban areas have been disturbed and may not show distinct horizons**

A horizon

Mostly what we farm

B horizon (subsoil)

C horizon
(Weathered Parent Material)

The A Horizon - surface soil or topsoil

Depth: several inches to several feet

Characteristics:

- **Zone of greatest biologic activity and most microorganisms**
- **Typically the darkest horizon**
  This is the zone where nutrients are stored, leached and where salts accumulate

This is the zone that we place most of our efforts in terms of soil improvement

The B Horizon – subsoil

Characteristics:

- Fewer roots and microbes
- Usually lighter in color

- Accumulates minerals leaching from the A horizon

- Can be more compact
- This layer can accumulate clay and form pans

The B Horizon may not be present in very young soils (called A-C soils)

C Horizon:

- Little or no biologic activity
- Similar to parent material or bedrock
- Basically weathered rock

R Horizon:

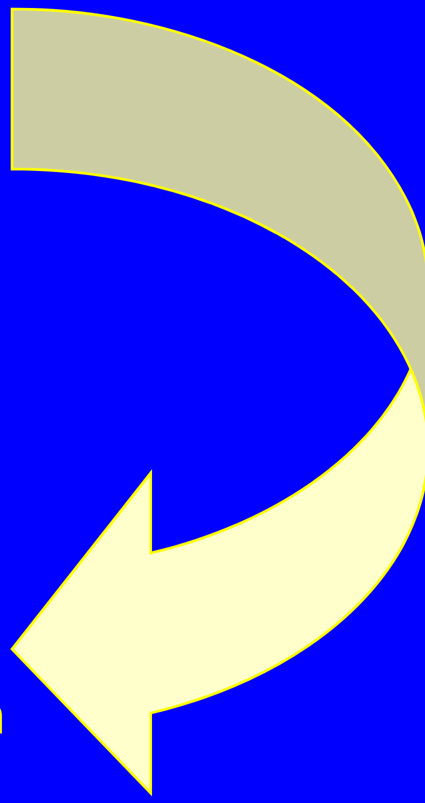
- Consolidated rock layer below A, B and C

Important Physical & Chemical Properties of Soil

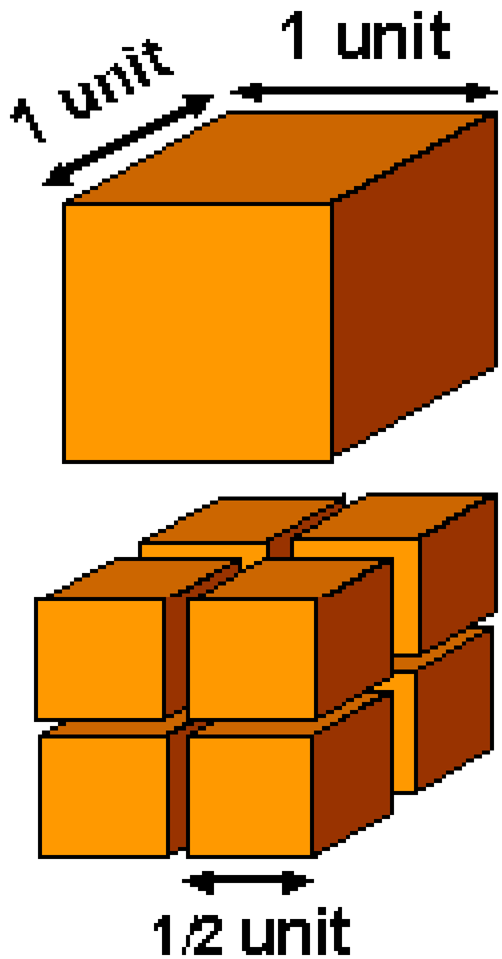
1. Soil Minerals
2. Soil Texture
3. Cation Exchange Capacity
4. Bulk Density
5. Soil Structure
6. Soil Porosity
7. Soil Color
8. Soil Depth
9. Soil Organic Matter
10. Soil Organisms

1. Soil Minerals

- **Sand**
  - Largest particle, least surface area
  - Ranges from 10 - 1000 times bigger than the largest clay particle
- **Silt**
  - Intermediate sized particles
- **Clay**
  - Smallest particle, greatest surface area
  - Thousands of times more surface area than silt, a million times more surface area than coarse sand



Clay forms as primary minerals weather and reform into silicate sheets



Total surface area of cube:
6 square units

Total surface area following disintegration:
12 square units

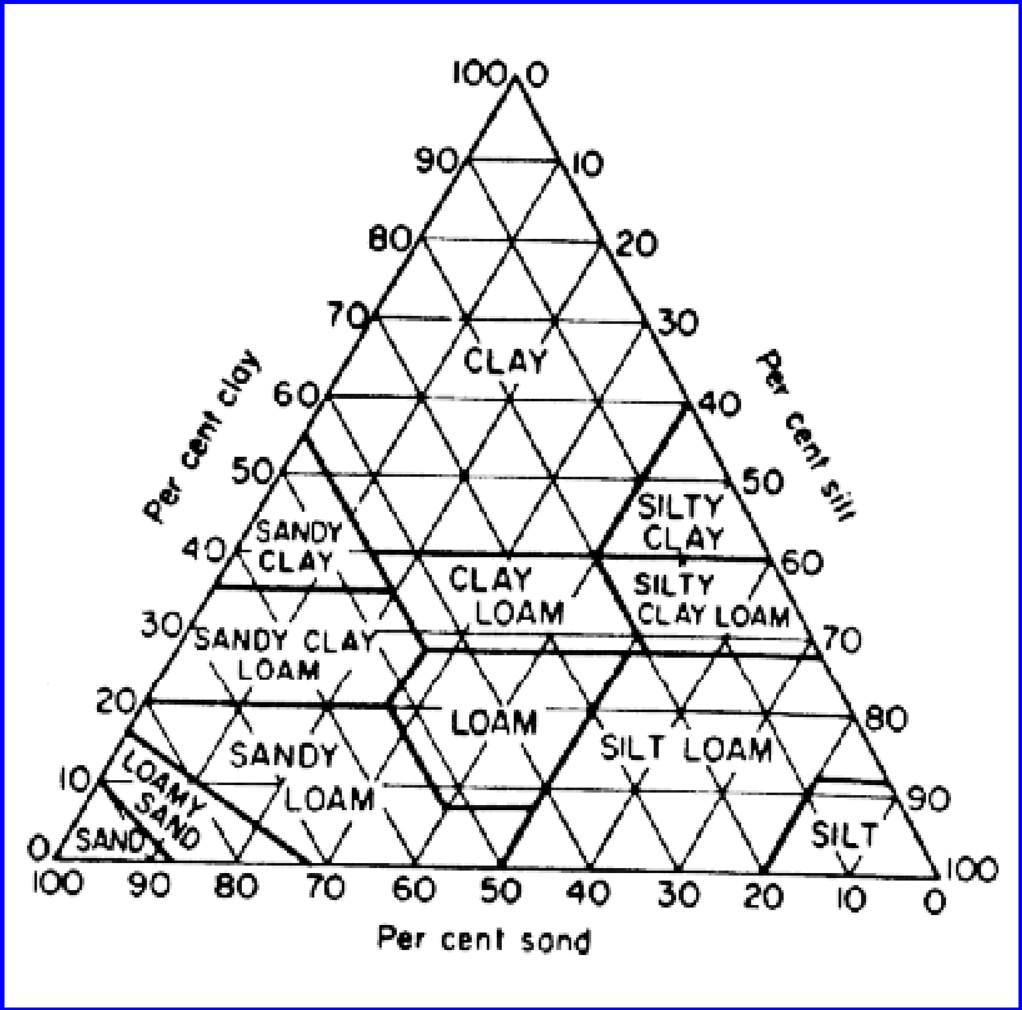
Impact of Soil Components on CEC and Surface Area

Soil Component	Surface Area ($meters^2/gram$)
• Organic Matter	500-800
• Montmorillonite clay	600-800
• Silt	0.045
• Sand	0.0045

2. Soil Texture

- Soil texture: relative proportions of sand, silt, and clay mineral particles in a given soil
  - Texture determines nutrient and water holding capacities
- General Categories of Soil Texture:
  - Course texture = “light soil”, sandy, coarse grained
  - Medium texture = loamy soil
  - Fine texture = “heavy soil”, clay
- Soil texture can be determined by feeling the soil….
  - Do the ribbon test on moist soil to determine texture

Soil Textural Classes

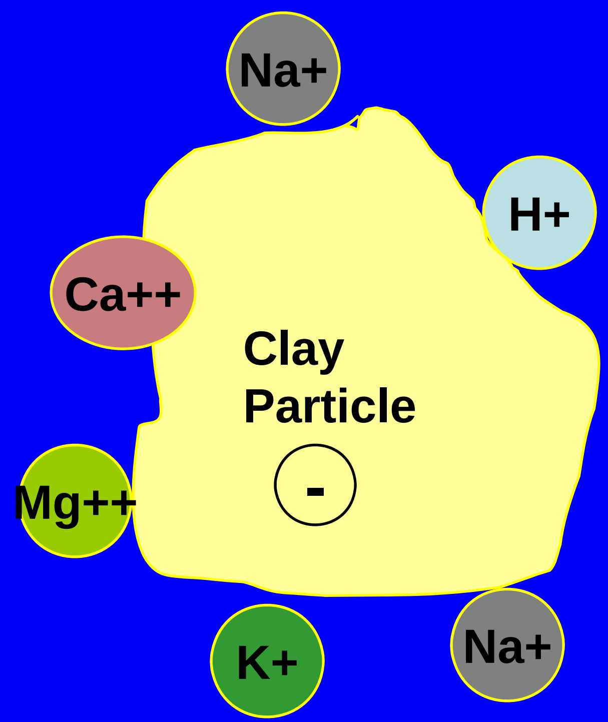


Effects of Soil Texture

- **Course textured soils**
  - **warm up faster in the spring**
  - **can have greater water infiltration**
  - **have less ability to hold nutrients and store water**
- **Fine textured soils**
  - **hold more water and nutrients**
  - **have less drainage potential, aeration and pore space**
- **Ideal Textures : sandy loam, loam and clay loams**
  - **This mix of particles holds sufficient water but still permits infiltration and percolation**

Clay is the most important soil particle because……

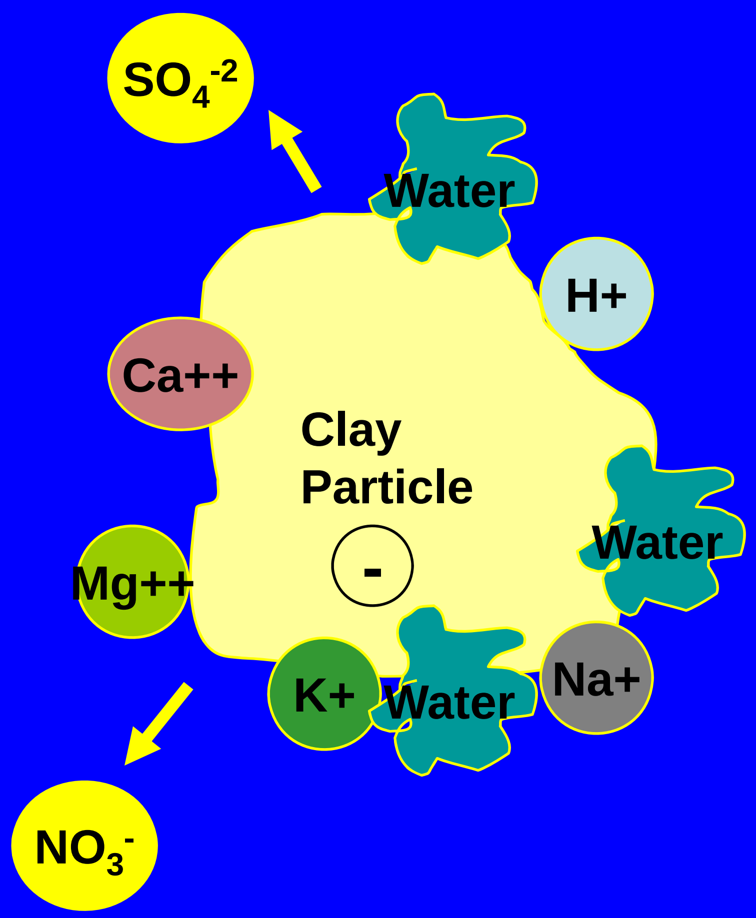
1. **Small clay particles have more surface area**
   - **Chemical reactions occur on the surface of mineral particles**
2. **Clay particles are negatively charged**
   - **Positively charged ions (cations) are essential plant nutrients and are attracted to the negative clay particles**
   - **Attraction of these cations to the surface of a solid is called adsorption**



Clay is the most important soil particle because……

3. **Clay has a high affinity for water**

4. **Clay particles repel negatively charged nutrients**



3. Cation Exchange Capacity

- Cation Exchange Capacity (CEC) = the amount of cations that can be absorbed or held by a soil
- Fertile soils have higher CEC: can hold more nutrients (greater reservoir)
- CEC is determined by
  – Amount and type of clay in soil
  – Organic Matter Content

Impact of Soil Components on CEC and Surface Area

Soil Component	CEC (meq/100 grams)
• Organic Matter	200-400
• Montmorillonite clay	80-150
• Kaolinite clay	3-15
• Silt	----
• Sand	----

4. Bulk Density

- **Bulk Density = Weight per Volume of a substance**
- **Materials with more pore space have a lower bulk density**
  - **Solid rock : 2.65 grams per cubic cm**
  - **Sandy soils : 1.6 grams per cubic cm**
  - **Clay soils : 1.2 grams per cubic cm**

5. Soil Structure

- Most soil particles exist in clumps known as aggregates (clods)
- Soil structure is the way in which aggregates are arranged
- Soil texture cannot be changed, but soil structure can be changed
- This is one of the most commonly asked questions – improving the soil structure of clays

Soil Structure : Aggregation

- Aggregation means soil structure development
- Deflocculation is the dispersal of aggregate particles (caused by sodium salts)
- Aggregate binding agents: clay, organic matter, microbial exudates, earthworms, tilling operations, root growth, climatic cycles (freezing and thawing), calcium salts
- Sandy soils support very little aggregation

Soil Structure:
Crusting vs Crumb Structure

Crusted, tight soil

Crumb structure
good water & air
infiltration

Maintaining Soil Structure

- Years of formation can be destroyed quickly with poor management
- Avoid working or walking on soil when wet
- Let soil drain 1-2 days before working, more drainage time is needed for clay soils

6. Soil Porosity

Pore space conveys oxygen, water, dissolved nutrients and gives roots space to grow

- Macropores: larger pores usually occupied by air (formed by rotting roots and earth worms)
- Micropores: smaller pores responsible for water storage

7. Soil Color

- **Color is a function of:**
  - **amount of organic matter**
  - **type of parent material**
  - **weathering forces and climate**
  - **type of salts present**
  - **aeration of the soil**

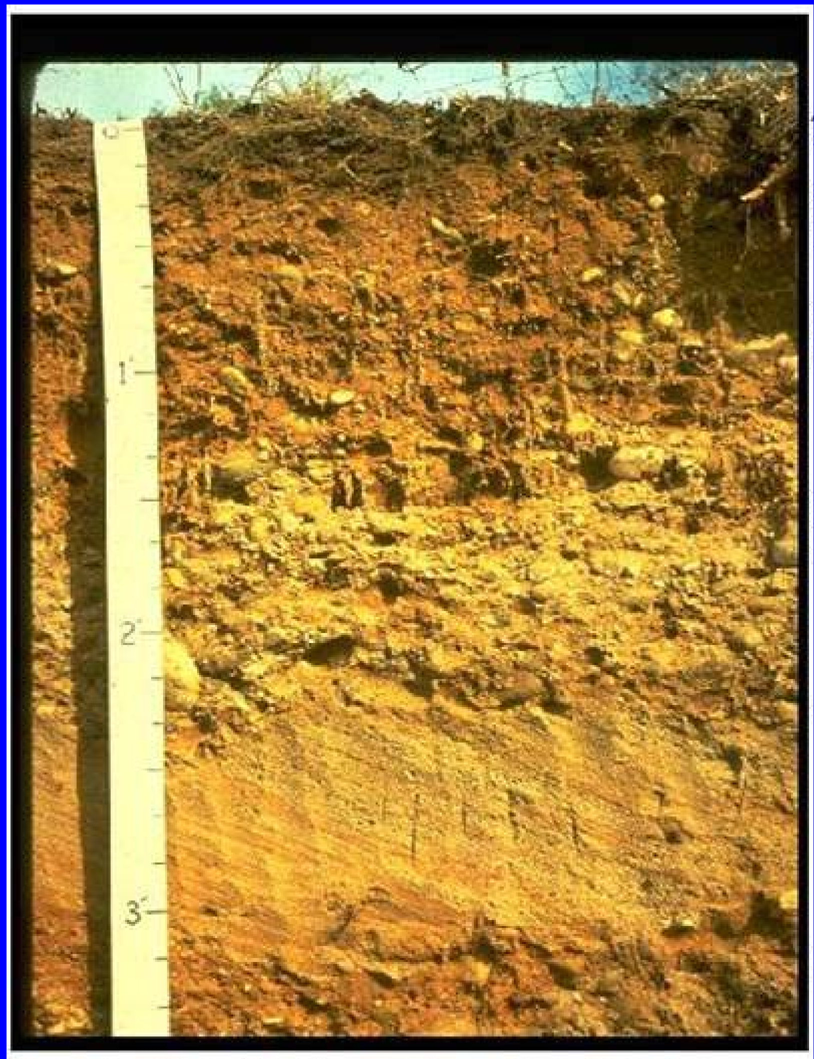
- **Can be a useful indication of the soil health and productivity**

Soil Color

Dark colored soils usually contain higher organic matter (1.5 – 2% in the Central Coast)

Soil Color

- Old soils are frequently red or yellow, indicating nutrient loss and build up of iron



Soil Color in California

- California soils are mostly grey and brown and low in organic matter
- Color can indicate origin:
  - Watsonville area, black soils on marine terraces
  - Brown to grayish soils develop along the river

8. Soil Depth

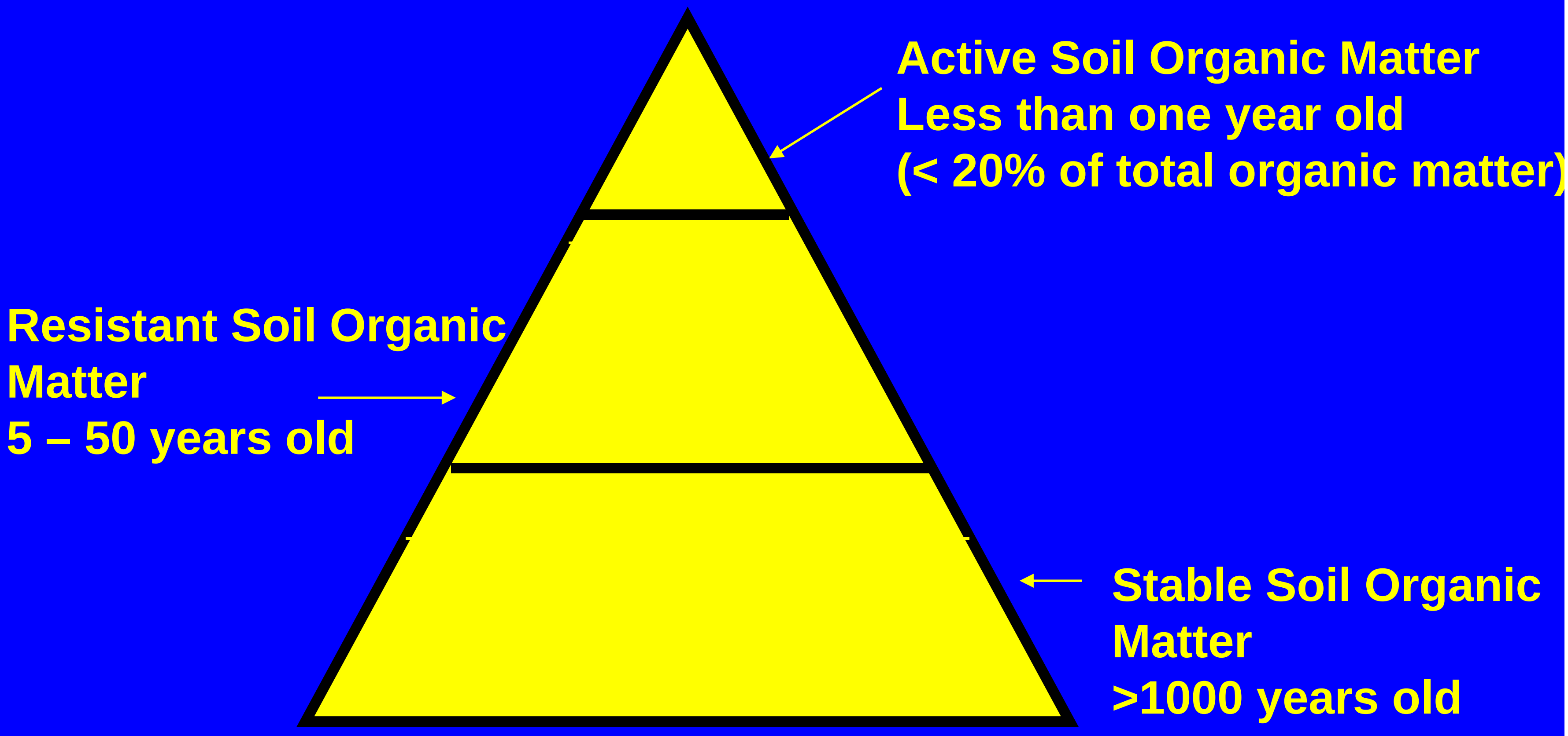
- **Soil Depth : Vertical distance between the soil surface and a layer that stops the downward growth or roots (i.e., bed rock, gravel, claypan or hardpan)**
- **Deeper soil means a greater total water and nutrient storage capacity**
- **Categories:**

<1 foot	= very shallow
1 – 2 feet	= shallow
2 – 3 feet	= moderately deep
3 – 4 feet	= deep
>4 feet	= very deep

9. Soil Organic Matter

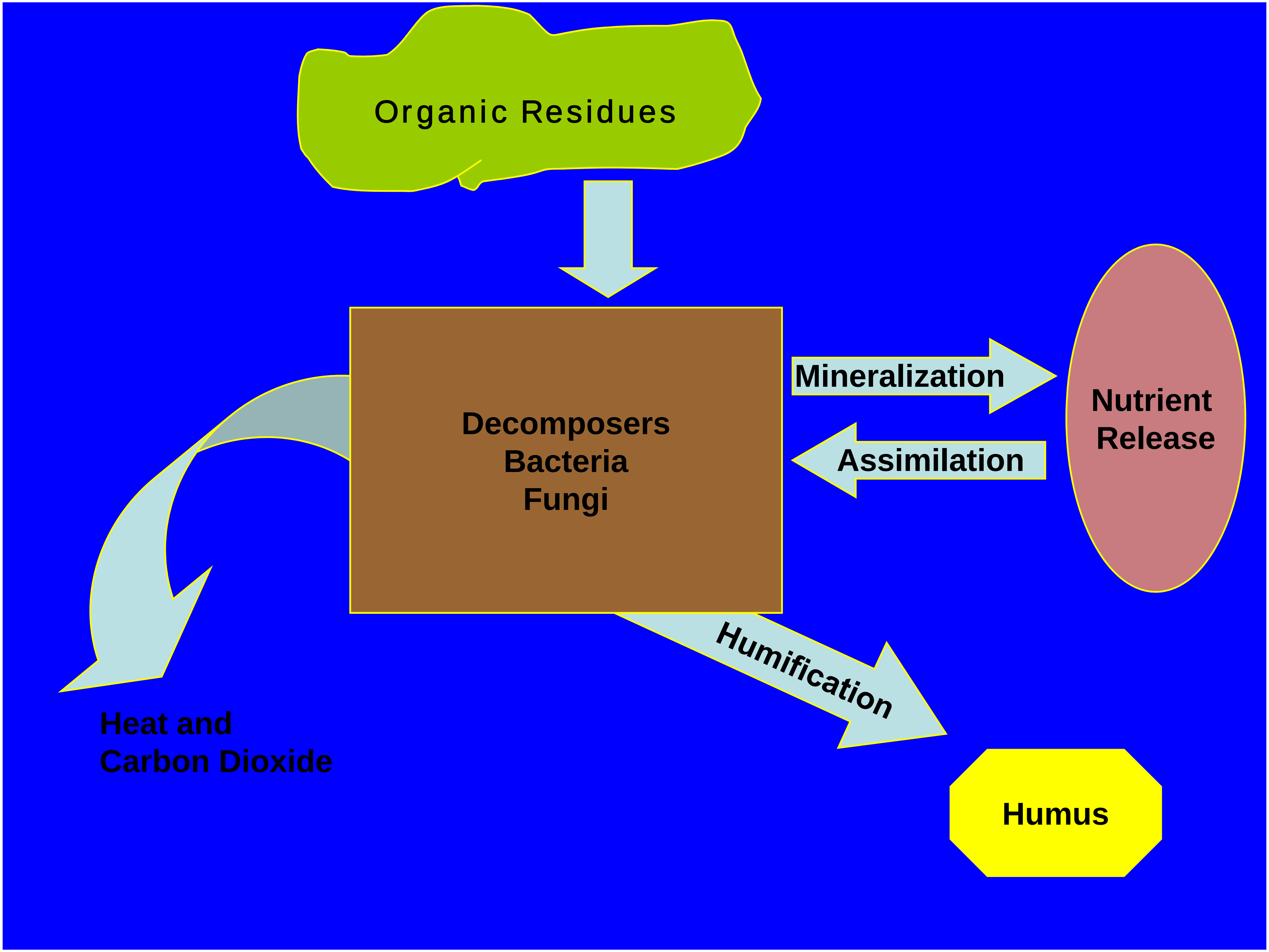
- Organic matter content depends on climate and soil type (1% in well-drained dry regions to 50% in poorly drained swamps)
- Frequent tillage and crop removal tend to decrease natural levels of organic matter

Make up of Soil Organic Matter



Soil Organic Matter : Humus

- Humus is organic matter that is resistant to further decomposition, composed mainly of humic and fulvic acids
- Like clay, humus is negatively charged and attracts plant nutrients and water
- Humus increases cation exchange capacity and serves as a reservoir of plant nutrients
- Humus aids in forming granular soil structure


Organic Residues
Decomposers
Bacteria
Fungi
Mineralization
Assimilation
Nutrient
Release
Humification
Heat and
Carbon Dioxide
Humus

C:N Ratio

- Microbes in soils in California are typically in a constant state of carbon starvation
- Additions of carbon rich materials help to build organic matter in the soil
- Microbes can temporarily "tie up" nitrogen while digesting large amounts of carbon rich residues

C:N Ratio of Common Organic Materials

Greens	
Alfalfa hay	12:1
Food wastes	15:1
Grass clippings	19:1
Rotted manures	20:1
Fruit wastes	35:1
Browns	
Cornstalks	60:1
Leaves	60:1
Straw	80:1
Sawdust	500:1
Wood	700:1

10. Beneficial Soil Organisms

- **Most live in the soil surface near roots**
- **One gram of soil may contain:**
  - **4 billion bacteria**
  - **1 million fungi**
  - **20 million actinomycetes**
  - **300,000 algae**
  - **One or two earthworms**

Earthworms

- **Earthworms are part of the soil macro fauna (visible organisms)**
- **Earthworms feed on plant residues and their movement stirs and aerates the soil**
- **Excreta is an excellent fertilizer high in phosphates, potassium, nitrogen, calcium, and magnesium**

Saprophytes (Bacteria and Fungi)

Saprophytes: Beneficial soil microorganisms which feed on decaying plant material

Functions of Saprophytes:

1. Enzymes are used to transform complex organic molecules into simple nutrients that become available to plants
2. Make humus
3. Make gummy substances that bind the soil particles

Symbiotic Micro Organisms

- **Mycorrhizae: Soil fungi which forms associations with plant roots (bacteria, fungi, actinomycetes)**

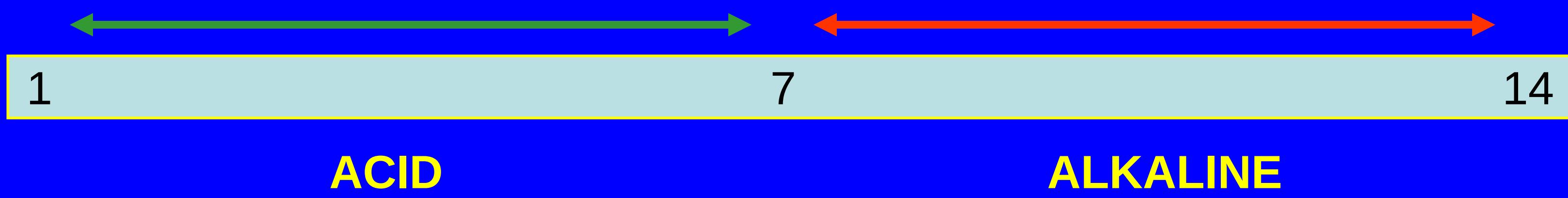
- **Rhizobia species: Soil bacteria that form symbiotic associations with roots of legumes**
  - **Fix atmospheric nitrogen to an available form that is available to plants**

Nodules on Bell Bean

Red interior of the nodule

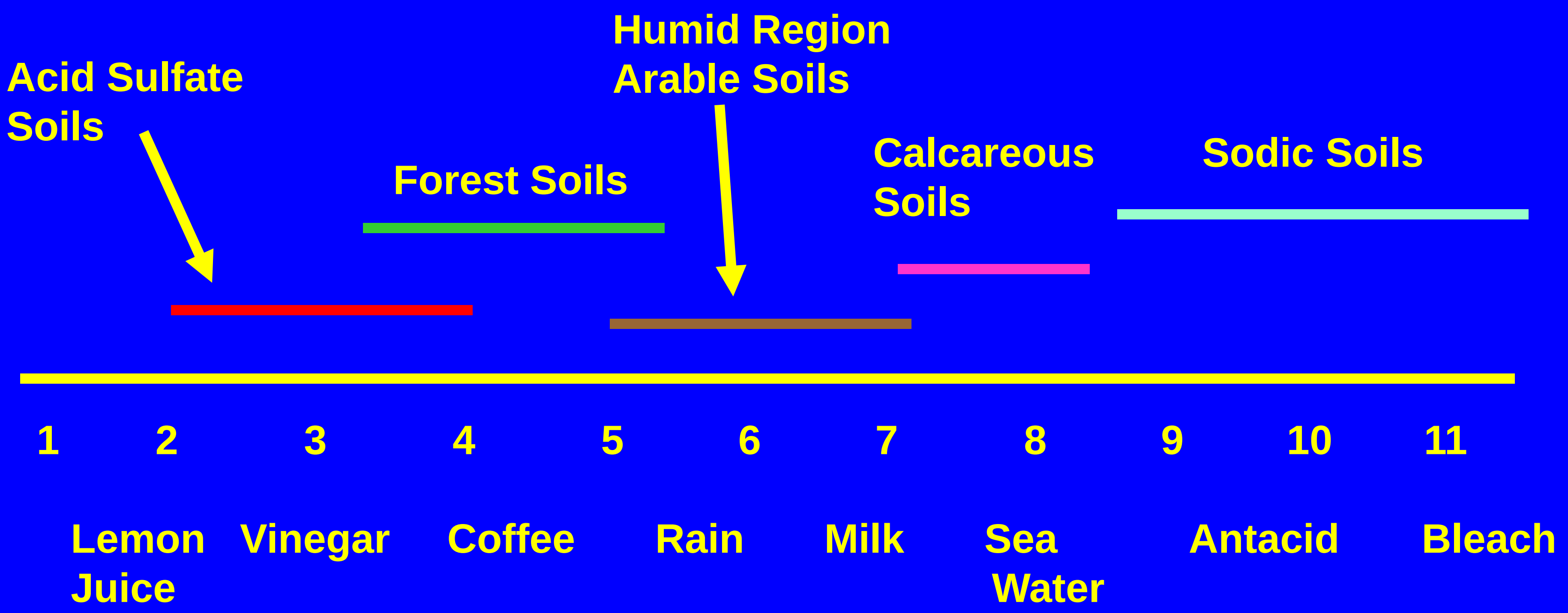
Soil pH

- Soil acidity or alkalinity effects nutrient availability
- pH scale



- Most California soils range from 5 to 8.5
- Crop plants do best in slightly acidic to neutral soils (pH 5.5 to 7.5)
- Note : azaleas, rhododendrons and blueberries prefer acid soils

pH Scale Examples



Soil pH and Nutrients

- At higher and lower pH, some important nutrients precipitate and cannot be absorbed by plants
- Soil pH also effects the amounts of toxic minerals
  - Acids soils may contain toxic levels of aluminum and manganese
  - Alkaline Soils may contain excessive amounts of toxic salts and sodium

Management of Soil pH

- **pH too low**
  - **Add lime (calcium carbonate, dolomite, etc) or wood ashes**
- **pH too high**
  - **Add sulfur (particle size effects speed of reaction)**
  - **May take several months to lower pH**
  - **Note: Gypsum (calcium sulfate) improves water filtration, does not lower pH**

Lime Requirement to Raise pH

In the top 6" of soil

Lbs limestone per 100 sq ft	Sand	Sandy Loam	Loam	Clay Loam
6.0 to 6.5	1.5	3.2	4.2	5.5

Sulfur Requirement to Lower pH

In the top 6” of soil

Lbs elemental sulfur per 100 sq ft	Sand	Loam	Clay
7.0 to 6.5	0.25	0.35	0.70

Hands On Exercise

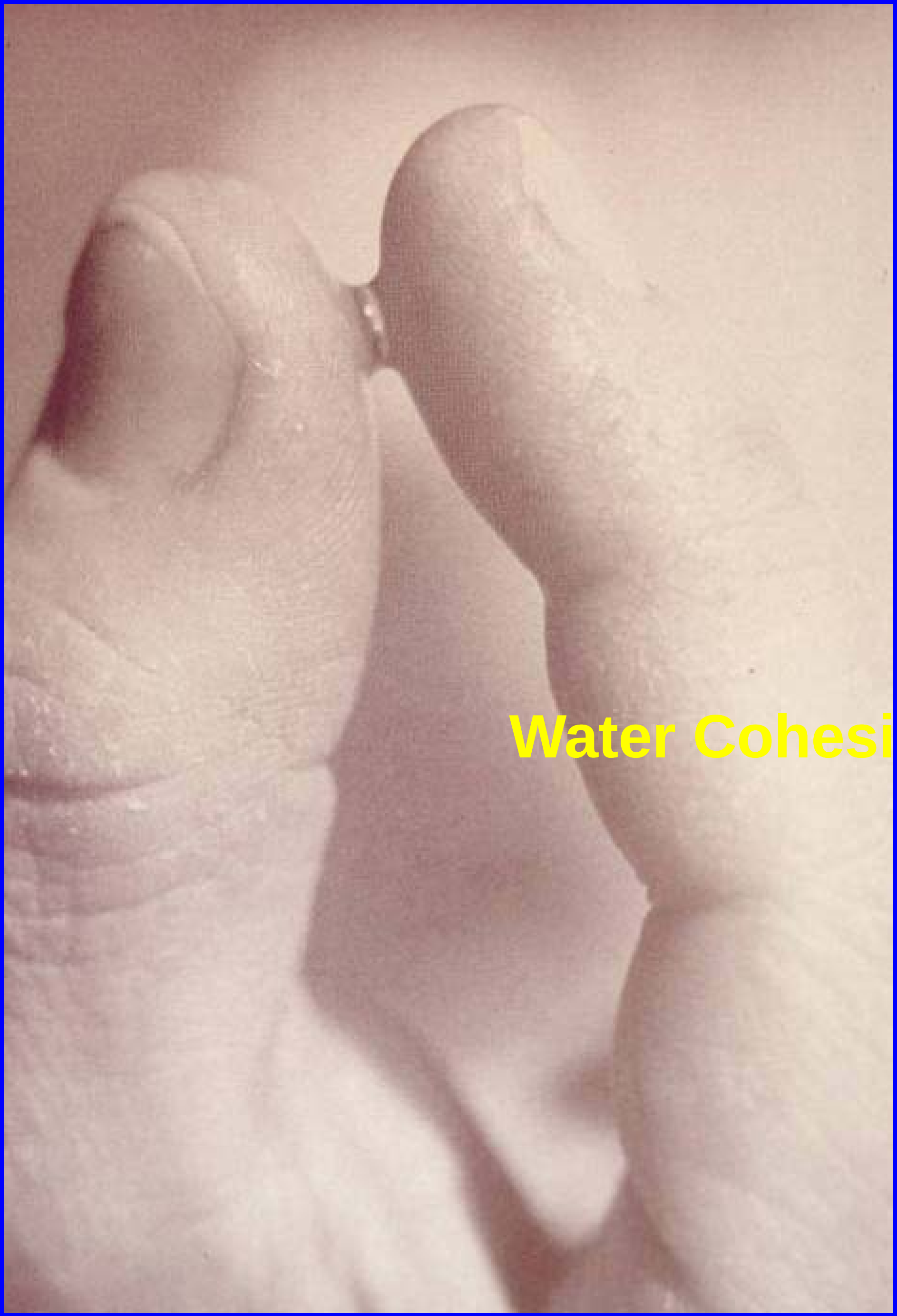
Soil Water Terms

- Water infiltrates and percolates in the soil
- Fate of water in soil:
  - Transpiration (water lost at leaf surfaces through stomata)
  - Evaporation (water lost as vapor at the soil surface)
- Collectively known as evapotranspiration

Soil Water

- Soil Water carries dissolved nutrients to plant roots
  - Interception of nutrients
  - Passive diffusion
- Plants compete with other forces for water
  - Cohesion is the tension between water molecules
  - Adhesion is the attraction of water to soil particles

Water Tension



Water Cohesion

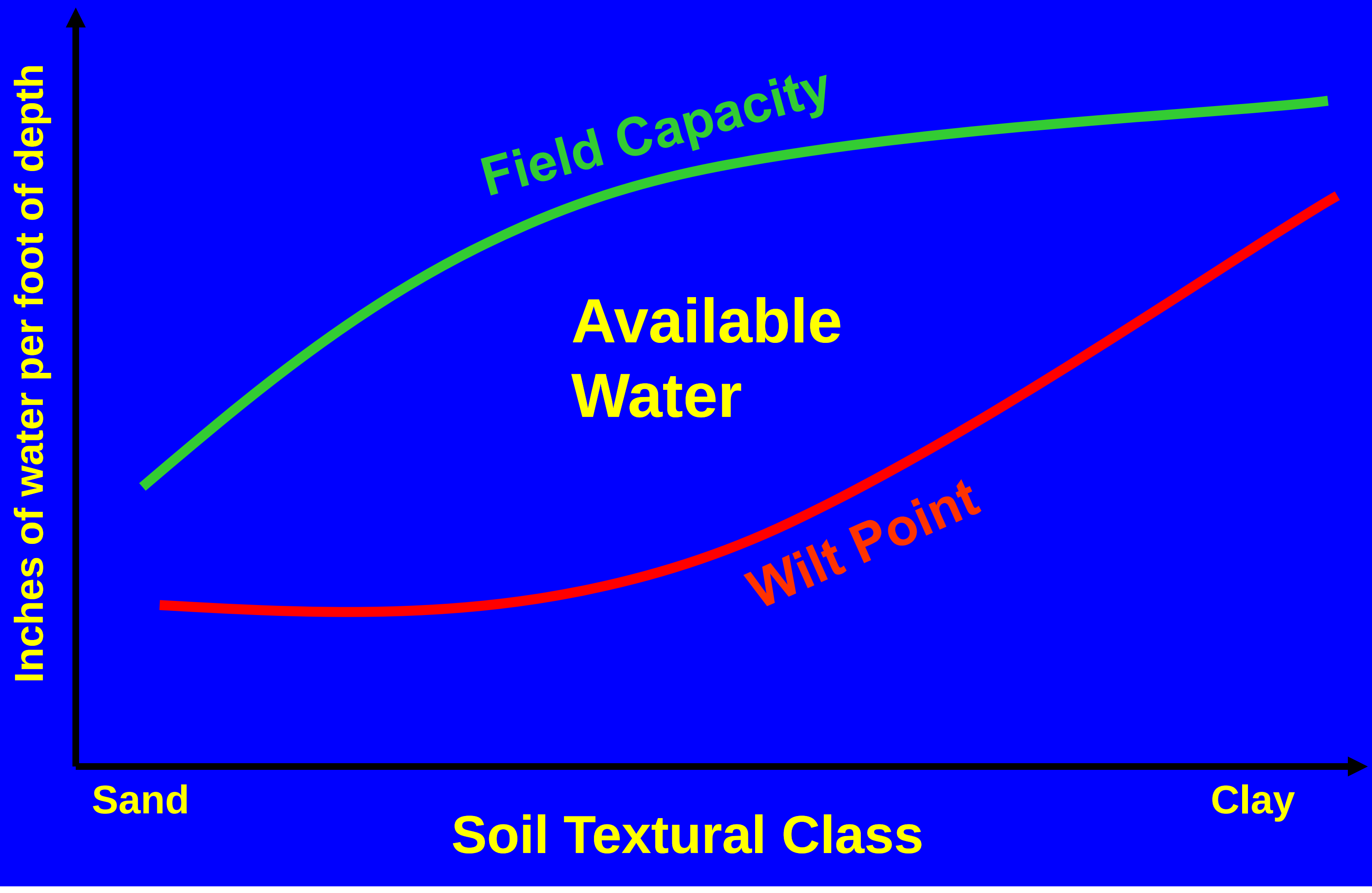
Soil Water Content

- **Saturated : When all the pore spaces are filled with water**
- **Gravitational Water: Water that drains freely because of gravity, remaining water is held by cohesion and adhesion**
- **Field Capacity : Maximum amount of water that can be held against the downward force of gravity when excess water is applied**
- **Permanent Wilting Percentage: The amount of water in soil from which plants are unable to extract any water for growth**

Soil Water

- The strength of cohesion and adhesion forces are influenced by total pore volume (porosity) of the soil
  - Clay soils hold water tightly because of smaller, negatively charged particles
  - Sands and coarse textured soils have less water-holding capacity
- Water furthest away from each soil particle is held loosely, and easier for plants to absorb
- Plants exert force to pull water away from the soil by transpiring through their leaves

Plant Available Water



Soil Fertility and Plant Nutrition

- A fertile soil contains 17 nutrient elements in optimal amounts and in a chemically absorbable form
- Of the 17 elements…..
  - 3 are taken from the air
  - 14 are absorbed by roots
    - Primary nutrients
    - Secondary Nutrients

→ Macronutrients : measured by percent

    - Micronutrients

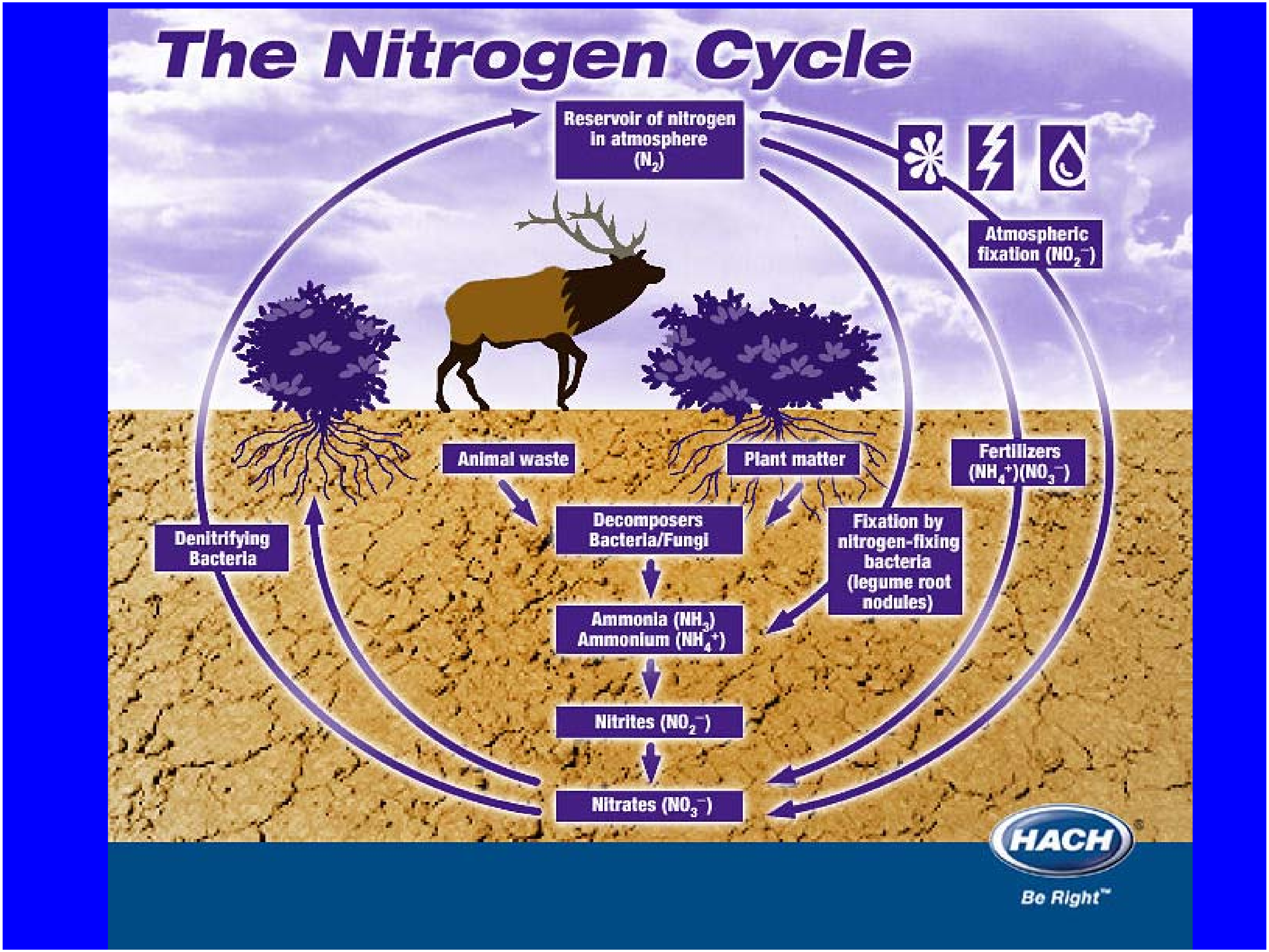
→ Measured as parts per million

Common Problems in CA

- **Common Deficiencies –**
  - **Nitrogen**
  - **Potassium**
  - **Phosporus**
  - **Zinc**
  - **Iron**
- **Common Toxicities –**
  - **Boron**
  - **Chlorine**
  - **Sodium**

Nitrogen (N)

- **Very important for many aspects of growth and development**
- **Taken up as NO_3^- (nitrate) and NH_4^+ (ammonium)**
- **Nitrogen in fertilizers converted to nitrate by microorganisms**
- **Deficiency: chlorosis (yellowing) of older leaves (nitrogen moves to younger tissue when limited)**
- **Excess: Dark green, excessive vegetation growth**


The Nitrogen Cycle
Reservoir of nitrogen in atmosphere (N_2)
Atmospheric fixation (NO_2^-)
Animal waste
Plant matter
Fertilizers (NH_4^+)(NO_3^-)
Decomposers Bacteria/Fungi
Fixation by nitrogen-fixing bacteria (legume root nodules)
Denitrifying Bacteria
Ammonia (NH_3)
Ammonium (NH_4^+)
Nitrites (NO_2^-)
Nitrates (NO_3^-)
HACH
Be Right™


Deficient Spinach

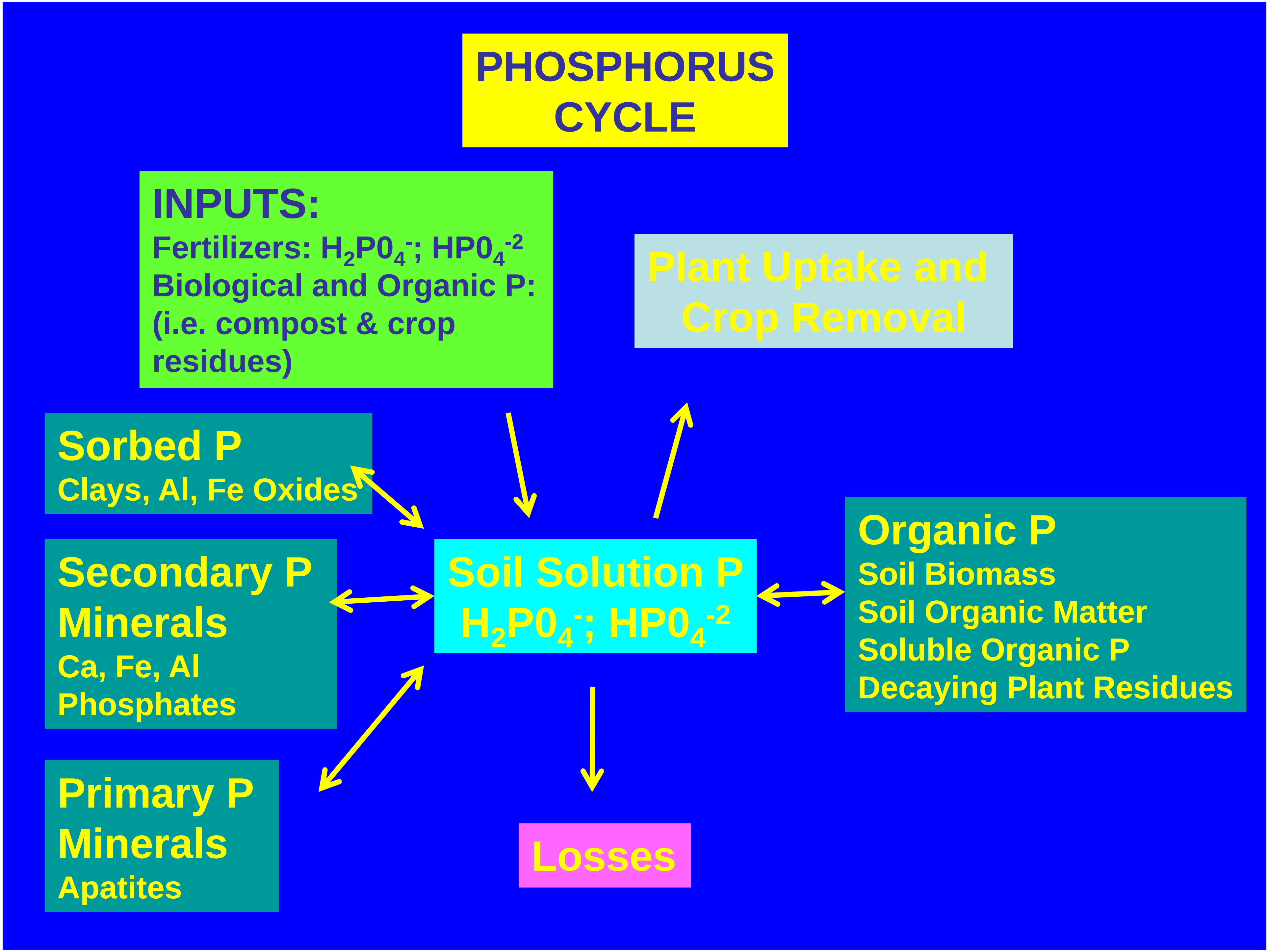

Older Leaves Turn Yellow

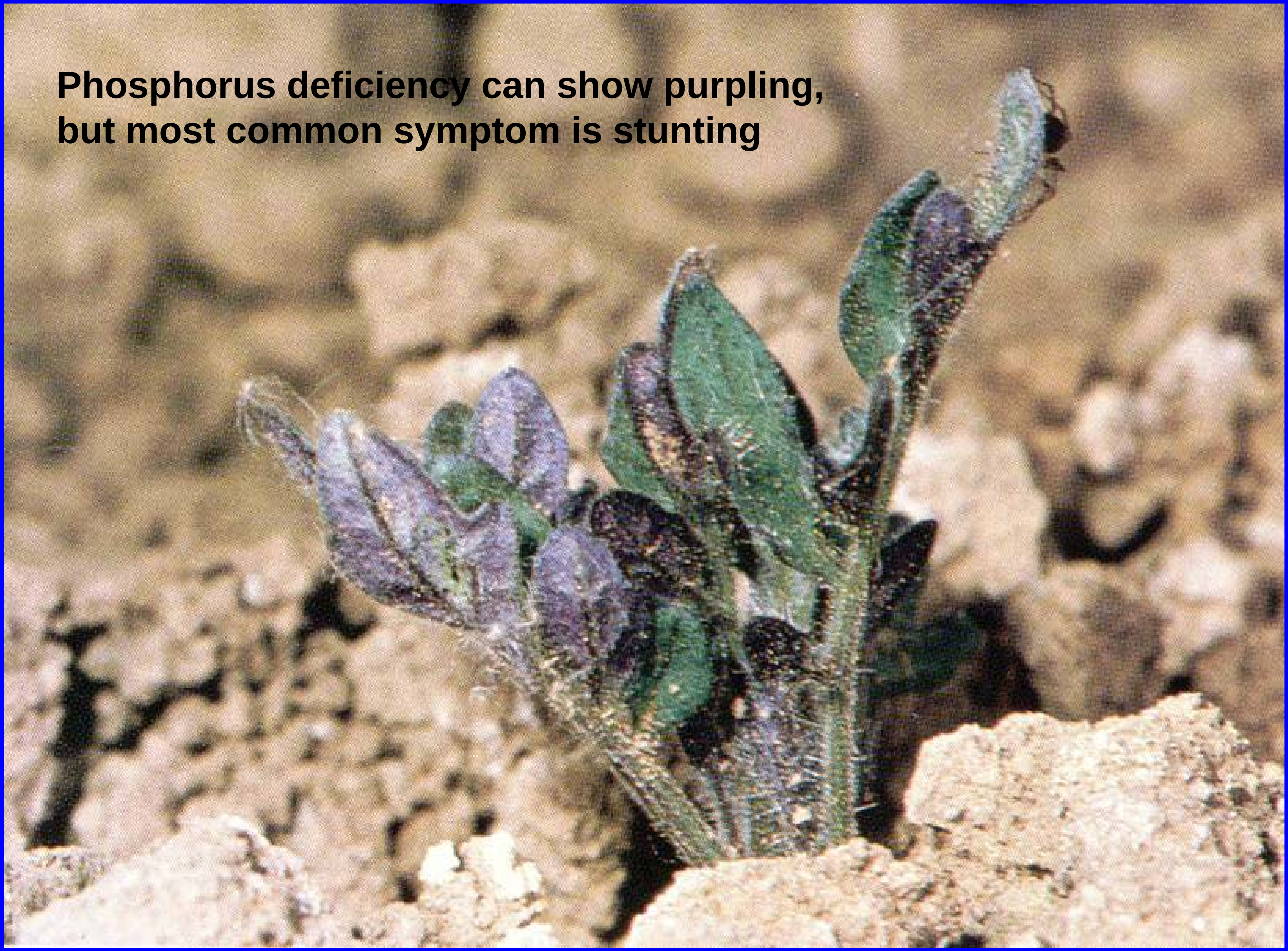

Virus infected


Nitrogen deficient broccoli turns purple

Phosporus (P)

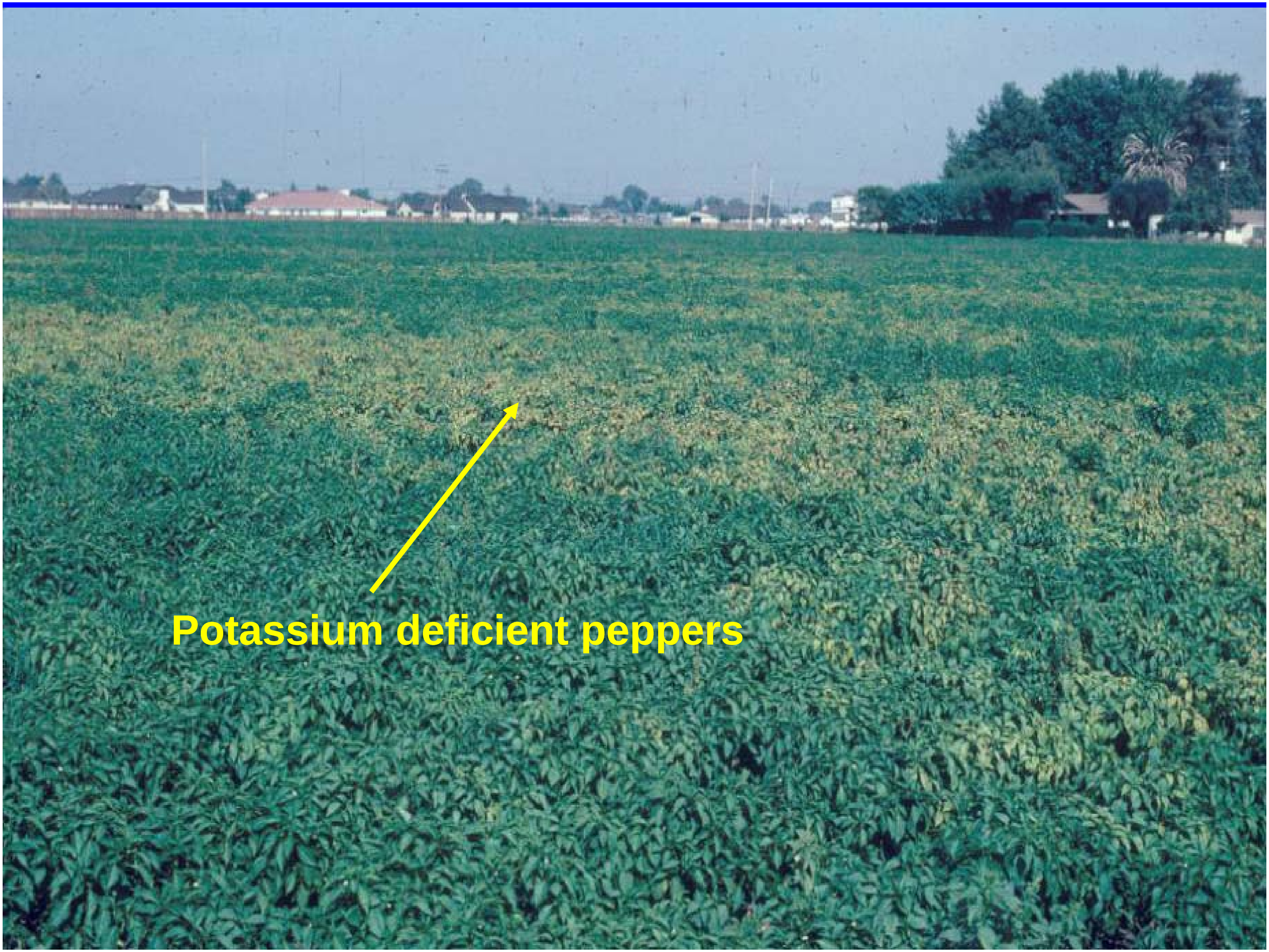
- Stimulates early growth and root formation, promotes seed formation, important in photosynthesis
- Deficiency:
  - Common in highly weathered soils with claypans or hardpans, or soils with long cropping history
  - Causes plant stunning and purplish casts on leaves


PHOSPHORUS CYCLE
INPUTS:
Fertilizers: $H_2P0_4^-$; $HP0_4^{-2}$
Biological and Organic P: (i.e. compost & crop residues)
Plant Uptake and Crop Removal
Sorbed P
Clays, Al, Fe Oxides
Secondary P Minerals
Ca, Fe, Al Phosphates
Primary P Minerals
Apatites
Soil Solution P
$H_2P0_4^-$; $HP0_4^{-2}$
Organic P
Soil Biomass
Soil Organic Matter
Soluble Organic P
Decaying Plant Residues
Losses


Phosphorus deficiency can show purpling,
but most common symptom is stunting

Potassium (K)

- Important for stomate opening/closing, cell division, starch and protein synthesis, size and quality of fruit and disease resistance
- Taken up as K^+
- Can be tied up in soil minerals
- Deficiency: Symptoms include scorching along leaf margins, slow growth, weak stems, poor roots


Potassium deficient peppers

Vigorous root system reduced K deficiency

Weak root system increased K deficiency

Nematodes causing potassium deficiency on peppers

Calcium (Ca)

- Essential component of plant cell walls and membranes
- Young tissues show deficiencies first
- Excess calcium lead to high pH
- Deficiency:
  - Reduced terminal growth of shoots
  - Blossom end rot of tomatoes
  - Tip burn on lettuce, cabbage


Strawberry


Spinach


Tipburn on
Romaine Lettuce


Blossom end rot on pepper

Magnesium (Mg)

- **Important part of chlorophyll molecule, aids in mobility of phosphorus**
- **Very mobile within plants**
- **Deficiency:**
  - **Marginal necrosis and intervenal chlorosis**

Magnesium toxicity

Sulfur (S)

- Taken up as SO_4^{-2}
- Deficiency: Not common, can occur in high rainfall areas and in rangeland

Zinc (Zn)

- An important component of enzymes including those involved with plant hormone synthesis
- Deficiency:
  - Can be easily measured with extractable zinc soil tests
  - Affects the growing point of plants
  - Plants can show interveinal chlorosis and stunting of terminal growth


Iron (Fe)

- Essential component of chlorophyll synthesis

- Deficiency:
  – Due to high pH,
  – Common when acid-loving plants are in alkaline soils

Blueberry with iron chlorosis

Manganese (Mn)

- Important component in enzyme catalysts for many reactions
- Excess: Only seen in highly acidic soils
- Deficiency:
  - Interveinal and marginal chlorosis of young leaves


Possible manganese excess on Romaine lettuce

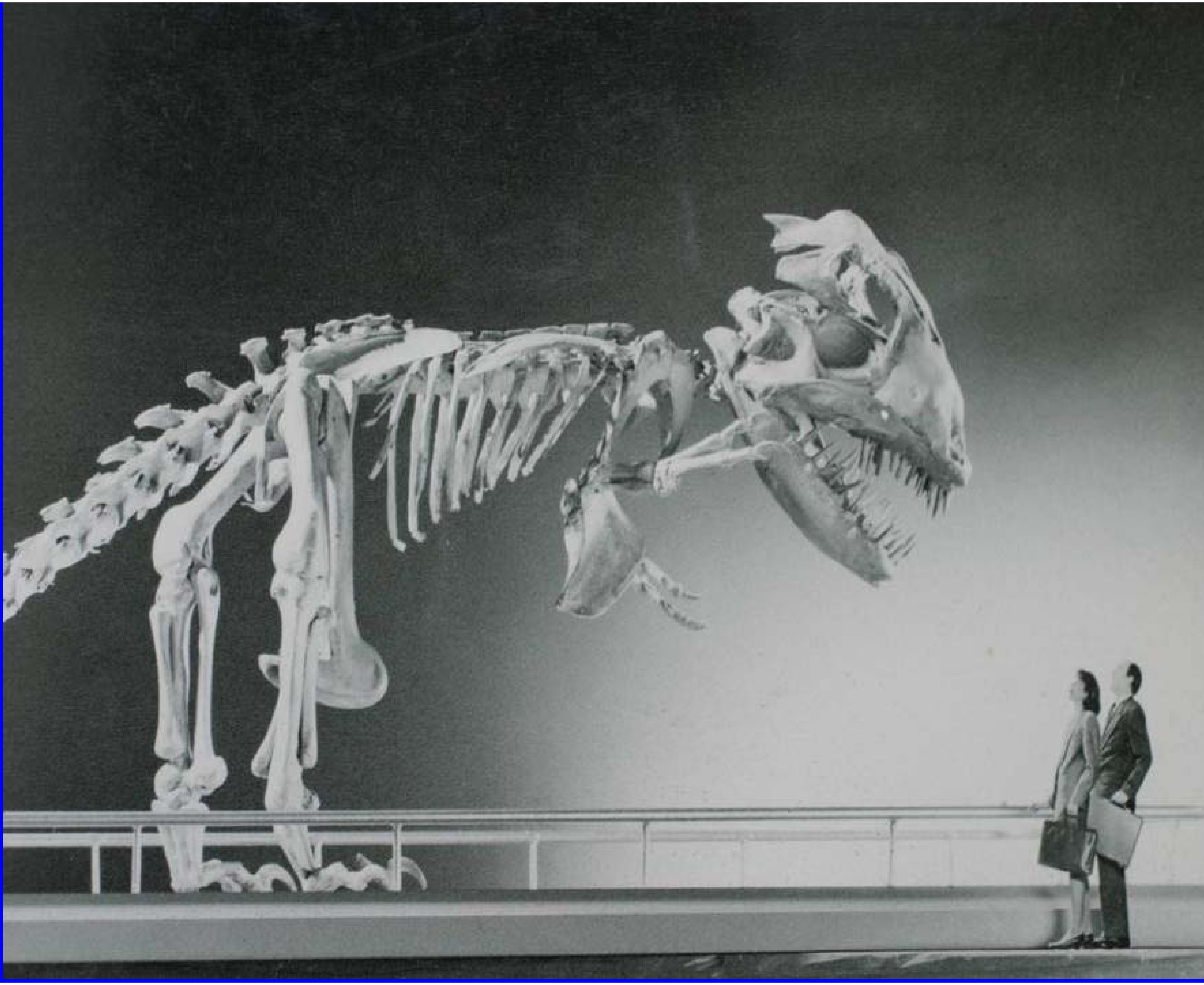
Boron (B)

- Important in meristem differentiation
- Toxicity is marginal burn on leaves
  - Very common in some parts of the State (i.e. Hollister area)
- Deficiencies common in intensive cropping systems
  - Occasionally applied to celery and strawberries

Boron deficiency on broccoli from Indiana

Hunger Signs in Plants : General Notes

- Master gardeners need to know signs of nutrient deficiency, toxicity, or imbalance!
- Sometimes plants do not show symptoms until severe stress has occurred
- Visual diagnoses are usually not enough -tissue and soil analysis are often needed to solve the problem



Fertilization of Garden Soils

- Nutrition management in gardens is relatively simple in California
- Most soils have sufficient levels of essential nutrients
- The use of composts and manures are excellent sources of fertility
- Mostly garden soils require small amounts of supplemental nitrogen fertilizer to achieve good growth

Nitrogen Fertilizers

- The air is 78% N
- Ammonia is formed by the reaction of nitrogen and hydrogen:

  $3H_2 + N_2$ (high temp & pressure) = $2NH_3$
- Anhydrous Ammonia: NH3 (82-0-0)

Nitrogen Fertilizers

- Ammonium nitrate: NH_4NO_3
  - (34-0-0)
- Ammonium sulfate: $(NH_4)_2SO_4$
  - (21-0-0-24)
- Calcium nitrate: $5Ca(N0_3)$
  - (15.5-0-0-19)
- Urea: $CO(NH_2)_2$
  - (46-0-0)

Nitrogen Inputs to Crops

- Soil mineralization
- Fertilizers
- Amendments (manure, compost, prior crop residues)
- Cover crops

Types of Inorganic Fertilizers

- Labels show percentage of: Nitrogen-Phosphorus-Potassium
- Example: A 100 lb bag of 12-12-12 contains 12 pounds of the following:
  - Nitrogen (N)
  - Phosphorus (P_2O_5)
  - Potassium (K_2O)

Organic Fertility Management of Gardens

- "Feed the Soil to Feed the Plant"
- This is the basic precept to organic soil management
- It is carried out by practices that increase soil organic matter, biological activity and nutrient availability

Building up Organic Matter

- Over time, adding materials such as green manures (cover crops), crop residues and compost builds up the levels of organic matter
- As soil organic matter increases, the ability of the soil to supply nutrients to the crop also increases

Common Dry Organic Fertilizers

Fertilizer	Nitrogen	Phosphorus	Potassium
Feather Meal	12	0	0
Blood Meal	13	0	0
Meat Meal	8	5	1
Chicken Manure	2-3	1.5	1.5
Fish Meal	10-11	6	2
Bone Meal	2	5	0
Alfalfa Meal	4	1	1
Kelp	<1	0	4

Commercial Organic Fertilizers

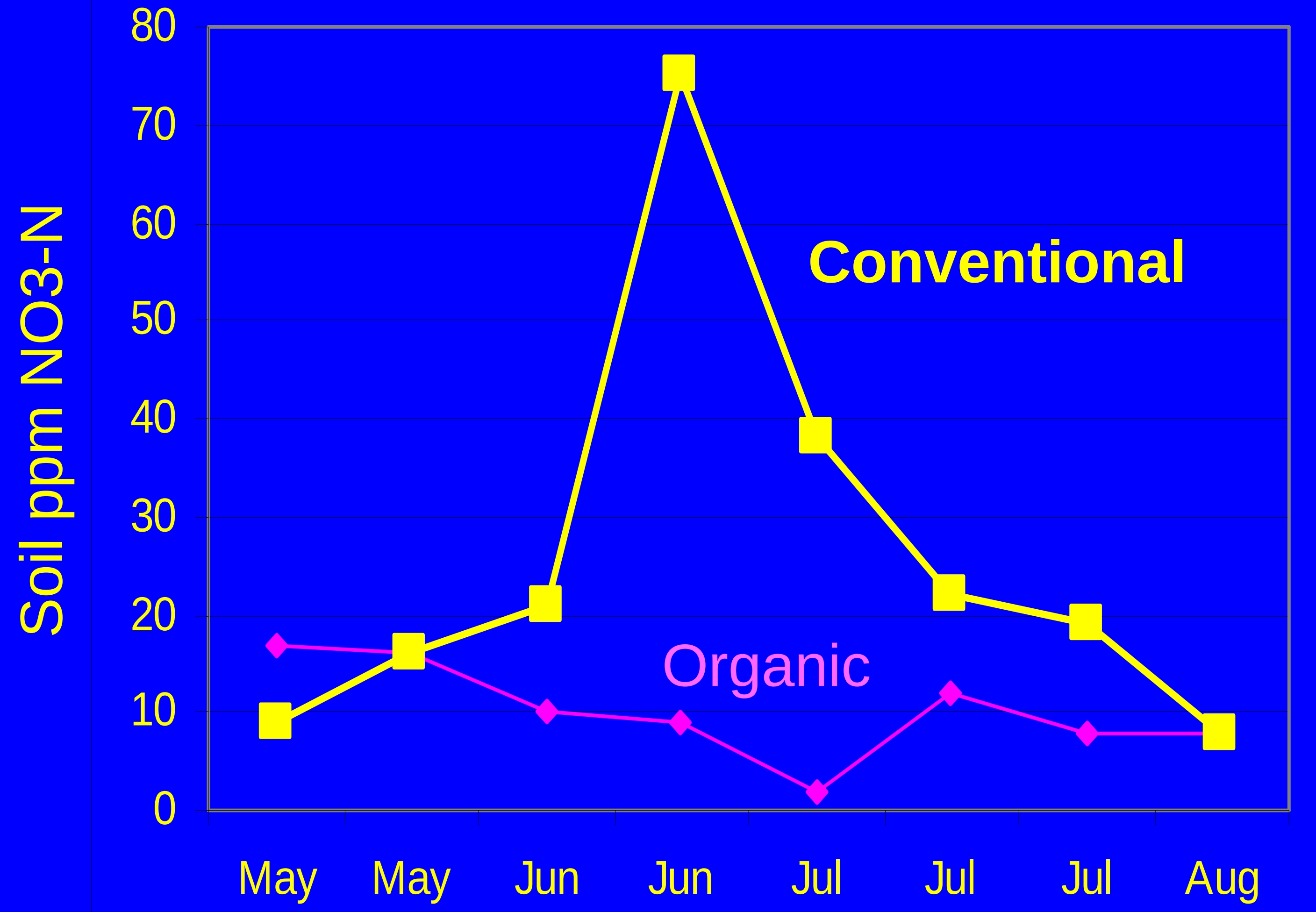
- They are expensive:
  - Dry materials are routinely more than $2.50 per pound of nitrogen
  - Liquid materials are 2-4 times this amount
- Their release of nitrogen depends upon the type of material and the size of the granules

Comparison of Organic vs Conventional Soils

Salinas, 2003

Management	Organic Matter Percent	Total Soil Nitrogen Percent	Stored Nitrogen Lbs/A
Organic	1.74	0.14	5,600
Conventional	1.37	0.11	4,400

Comparison of Organic and Conventional Onions, Hollister, 1996



For further information on organic fertility management

- http://anrcatalog.ucdavis.edu/
  - Go to free publications
    - Soil Fertility Management for Organic Crops
    - Publication Number: 7249


COVER CROPS

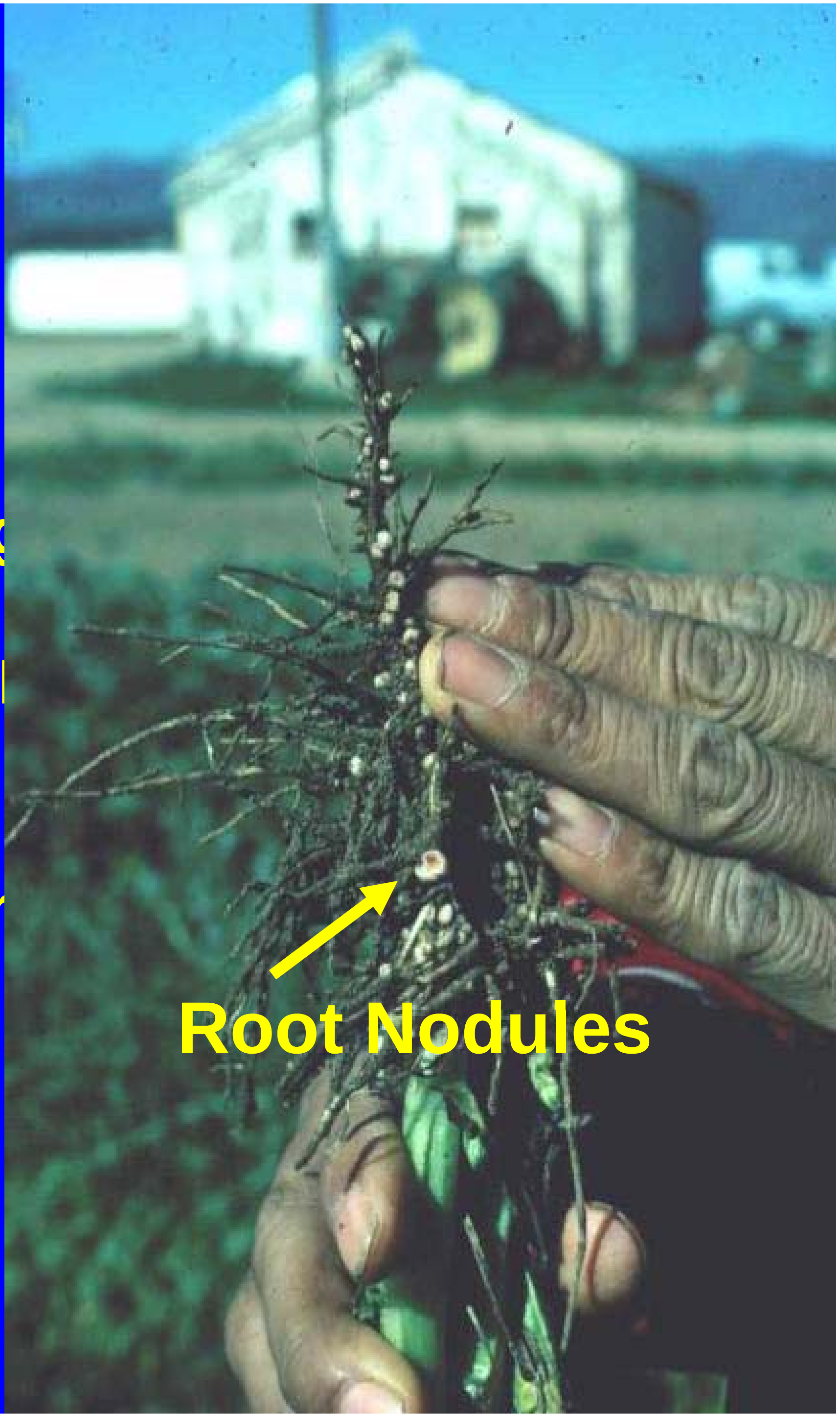
Legumes

•Bell beans, vetches and peas

•They provide a net input of nitrog
into the crop production system
by fixing atmospheric nitrogen (
into a form useable by crops

•Maximize N production by flower

•Not as good as scavenging as
cereals and mustards



Vetch

Peas

Bell Beans

Cereals

Mustards

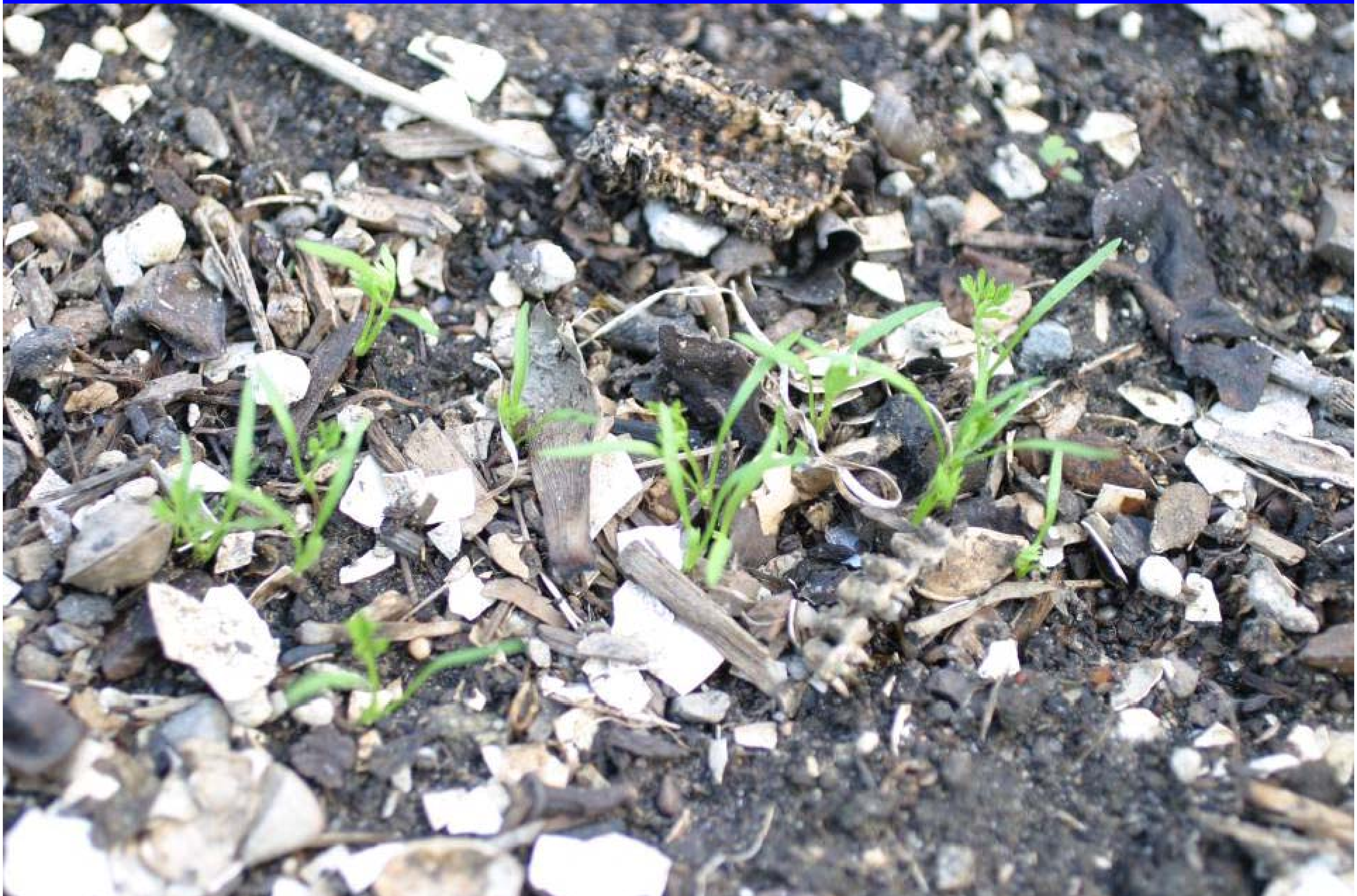
Cereal/legume Mix


FAMILY FLOUR
PYRAMID ORCHARDS APPLES

Tour of Richard’s Garden


Intensive Kitchen Garden
(with gopher wire underneath)


Composting Side
Building Side




More Extensive Area in the Back for
land intensive crops

Comparison of Soil Analyses
Garden and adjacent pasture

Soil Characteristic	Garden	Pasture
pH	5.2	4.8
CEC	8.3	4.4
Total Nitrogen (%)	0.09	0.06
N storage (lbs/A)	1,800	1,200
Organic Matter (%)	1.6	1.1
Nitrate-N (ppm)	70.9	12.1
Phosphorus (ppm)	47.0	32.8
Potassium (ppm)	139	114


Inputs:
Horse manure


Ground up sunflower stems
Spread back onto the garden area

Cover crops over the winter

Meat Meal 8-5-1

Partners in crime

Helpers


Fruit Trees


Beneath the mulch


Clovers between tre

Thank You For Your Attention