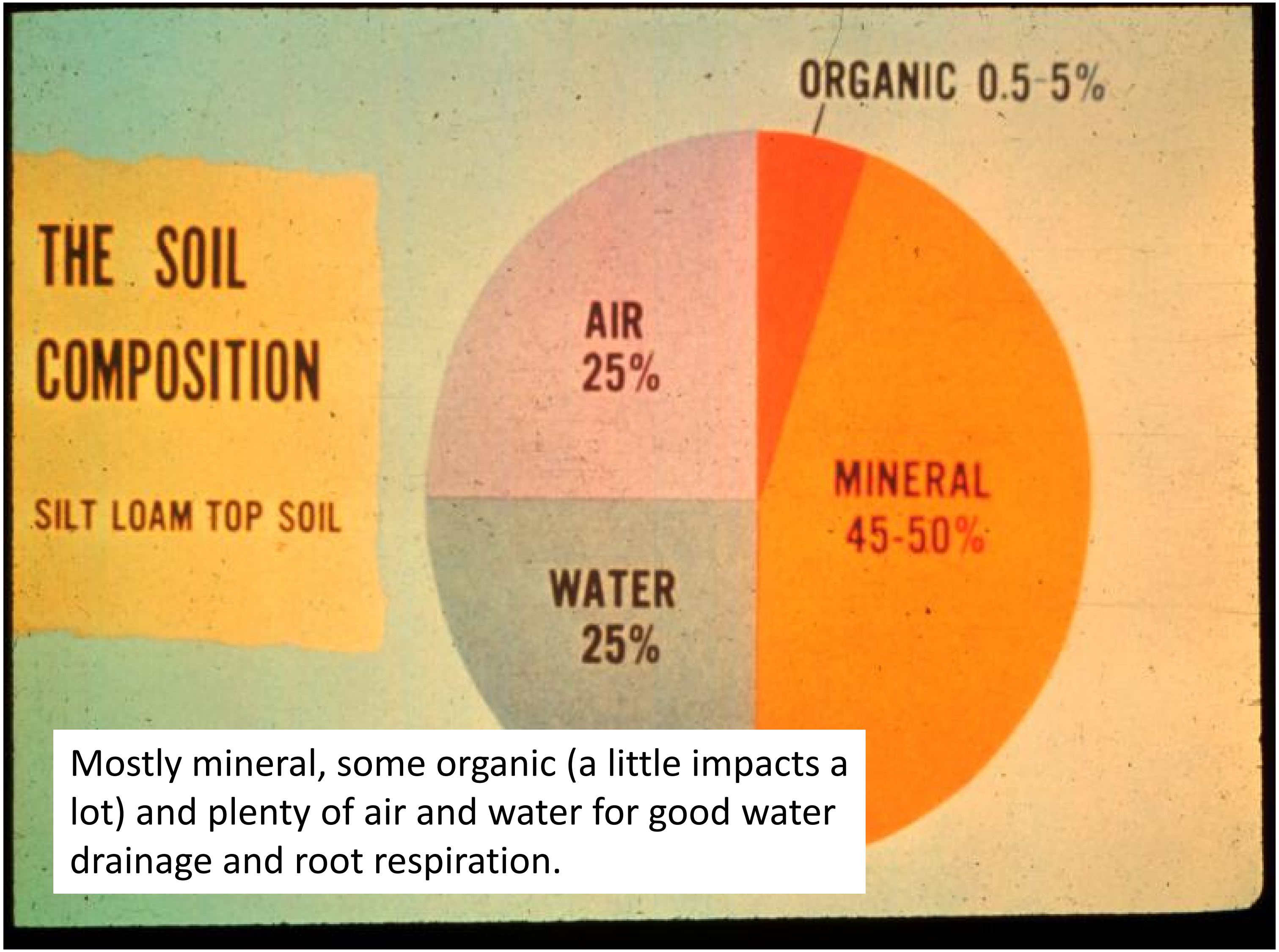
SOIL

Basics

Productive soil must be fertile

- physical fertility
  - texture, structure, drainage, tilth
- chemical fertility
  - nutrient supply
    - soil testing



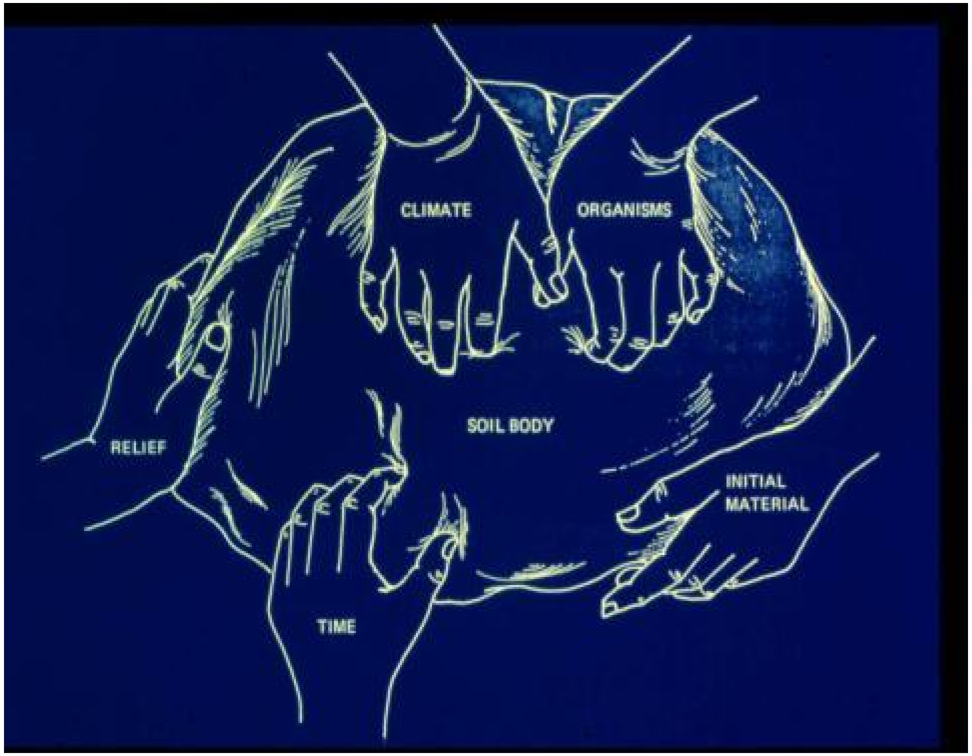
Mostly mineral, some organic (a little impacts a lot) and plenty of air and water for good water drainage and root respiration.

Soil formation-’weathering’

- physical
  - freezing, thawing, wetting, drying, organisms
- chemical
  - dissolved minerals moved in water
- soil horizons formed
- 25 mm. - 100 years

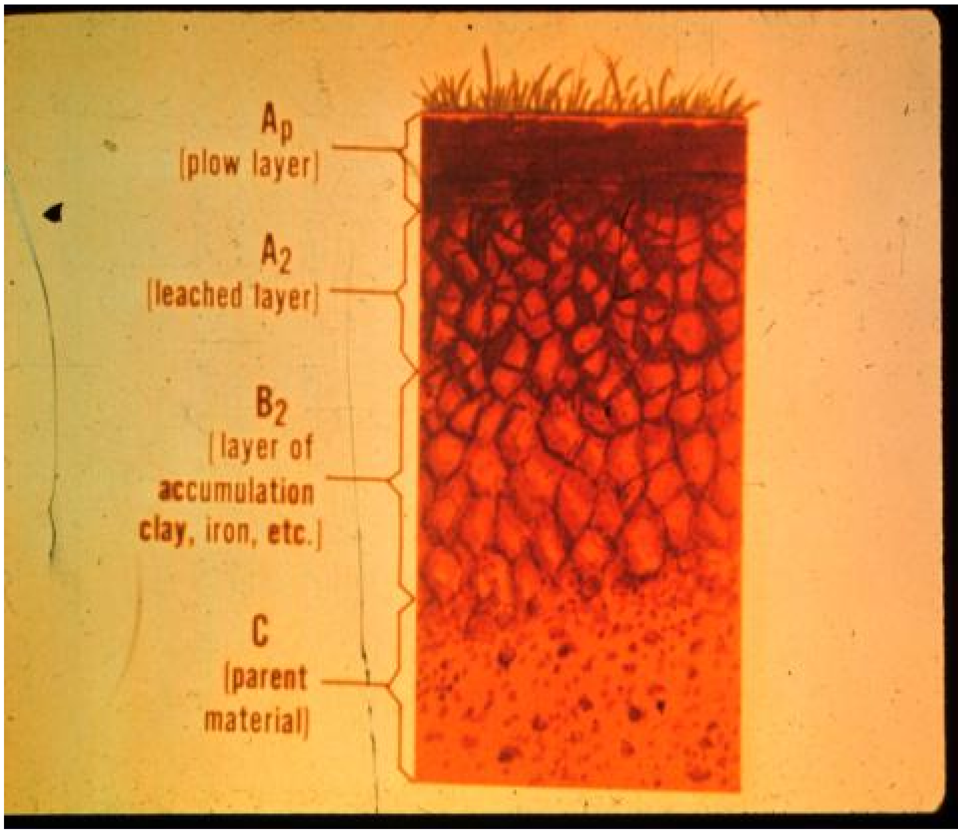
- Rocks are broken down by many different processes over many thousands of years.
- ‘old’ soils where intense weathering (rain, heat, plant growth year round) has left soils with low pH and very red from iron oxides in lower horizons

Why soils are different from each other



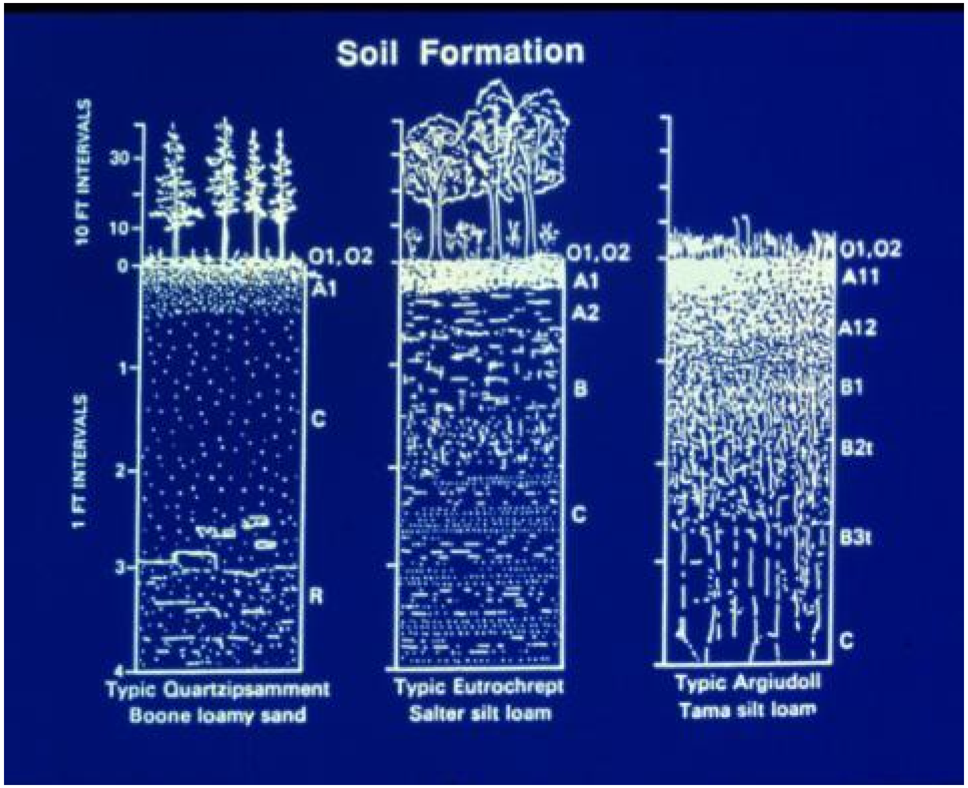
- What characteristics a soil has depends on how the processes of formation (climate, organisms, length of time, slope, and initial parent material) interact. Warmer climates have more intense weathering, soils 'age' faster than where cold stops/slows organisms. Soils on side slopes get less rain infiltrating, less leaching overall, than soils at bottom of slope so pH may be higher on slope than below. Types of rocks (parent material) determine the texture of the soil formed from it—very difficult to change inherent texture.

Horizons form from effect of rain infiltration



Water dissolves/carries elements, clays, organic matter to create depletion or leached layer and accumulates in a lower layer. Lower horizons tens to be reddish in color from presence of iron oxide coatings.

Plants and parent material affect how soils form



Different soils form at different locations because of how processes interact. Soil at left coarse-textured, thin upper horizon, not much structure.

Soil at right is highly developed 'prairie' soil—deep, very dark from high organic matter content, good structure .

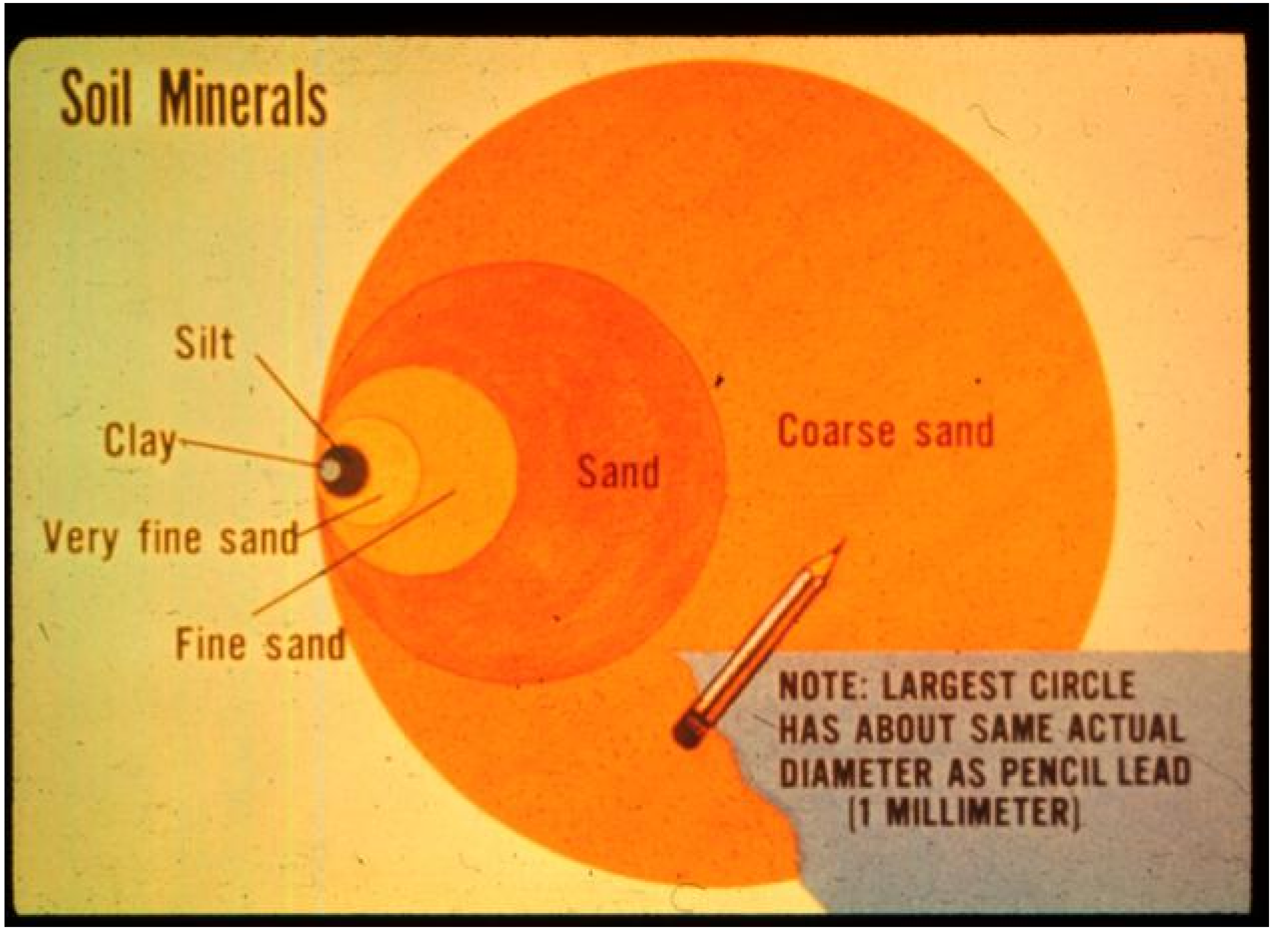
Middle soil is representative of where hardwood forest initially grew—soil characteristics in-between. The horizon depth is influenced by the dominant plant type—the fibrous root systems typical of prairie grasses influence soil structure at depth, whereas the limited, none fibrous roots of conifer trees offer little at depth.

Soil texture

classes - sand, silt, clay

- names based on proportions
  - loam, silty clay, loamy sand
  - changing proportions not recommended
- clay also group of minerals
  - montmorillinite, kaolinite....
- nutrient storehouse

- Back to 'ideal' soil—the mineral portion that makes up 45% of the solids.
- It is a mix of different-sized particles with definite sizes—sand, silt, clay.
- Analyzing the proportion of each size fraction allows naming soil accordingly.
- Changing inherent proportions to improve soil is not recommended, may create more problems



The diagram shows relative size of soil particles. All you can probably see is coarse sand. What you do see are not the individual particles but clumps of particles or aggregates. How these ‘clumps’ are put together determine many physical attributes of soil.

Soil organic matter

- plants, animals, microorganisms
  - living, dead, decay products
  - humus
    - complex, dark-colored, reactive
- soil acidity reservoir
- nutrient storehouse

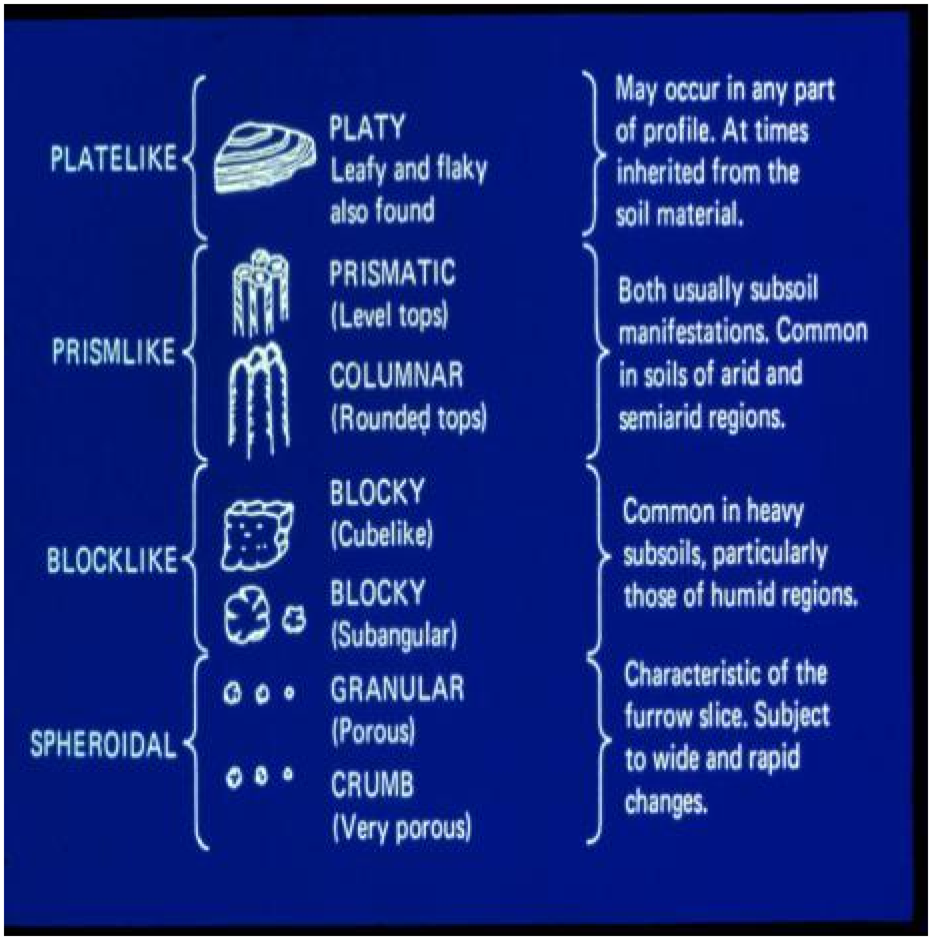
- The remaining 5% of solids in an ideal soil should be organic. Even though relatively small amount, packs a lot. Organic matter is mix of constituents. Have an active portion (fresh residues) and a stable fraction (humus). Goal for management is to supply fresh residues to stimulate microorganisms and degradation processes—will not increase stable quantity, but processes will improve soil.

Soil structure

- particles 'glued' into aggregates
  - organic matter, clay, bacterial secretions, Fe/Al oxide coatings
    - granular, platy, blocky
  - finer aggregates in 'topsoil', massive in subsoil
- improve by adding organic residues
  - decay: 90% CO_2 + H_2O

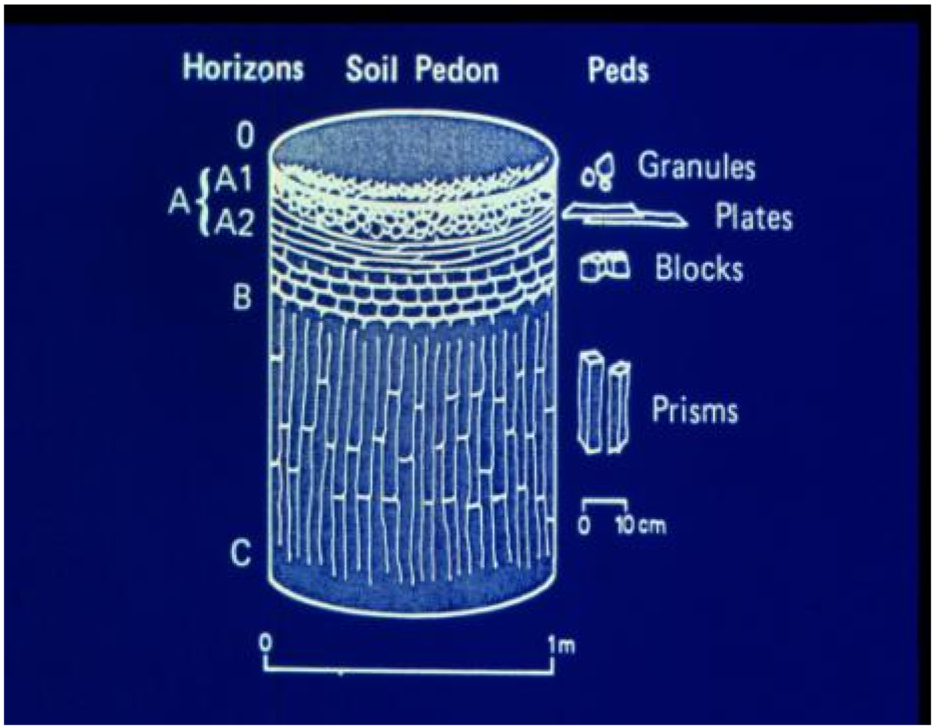
- Putting mineral plus organic fractions together gives soil structure.
- How soil particles get put together also determine how water and air move through them.
- Pore spaces, the size and quantity, determine how well water and air move.
- Do not expect to increase organic matter test level—90% of what is added becomes CO2+H20, but the process of microbial decomposition results in the improvement.
- Repeated additions, stimulating decomposition processes, will create more 'glue' and improve soil over time.

Structure



Structure type is one characteristic used to 'name' soils. Good structure can be destroyed by tilling when wet, compaction erosion. Platy structure or 'plow pan' is one type of structure caused by heavy equipment used when soils are wet.

Structure



Putting different structure together creates soil 'pedon' Granular or crumb is desired at the surface for good seed/soil contact.

Lower types depend on texture, parent material etc.

Thickness of upper horizon partially depends on management (erosion) and dominant plants (prairie/trees).

Problem: ‘heavy’ soil

- aggregates tightly packed
  - small pores
    - poor drainage, roots suffocate
  - ‘cloddy’ if tilled wet
    - compacts easily
- improve with organic residues
  - better crumb stability, larger pores
  - larger pores
    - sand + clay = cement

Problem with poor drainage?

Add organic residues to help create larger aggregates, therefore larger pores, to increase how fast water percolates through.

Problem: ‘light’ soil

- aggregates too big to pack tightly
  - large pore spaces
  - droughty
- improve with organic residues
  - ‘sponge’

- Problem with being too well drained?

- Same fix, add organic residues to create ‘sponge’ for holding water.

Organic residues

- compost, grass clippings, crop residues
  - annual gardens – 30 l. / 20 m^2
  - perennial gardens – 10 l./1 m^2
    - do not add to tree/shrub planting hole
- green manure, fall cover crops
  - green top growth tilled under
- extra N needed if high C residue
  - microorganisms ‘tie-up’ N
    - wood chips, sawdust, oat straw

- Organic residues to add—generally best in fall because will get some decomposition before freeze and again early in spring before planting.

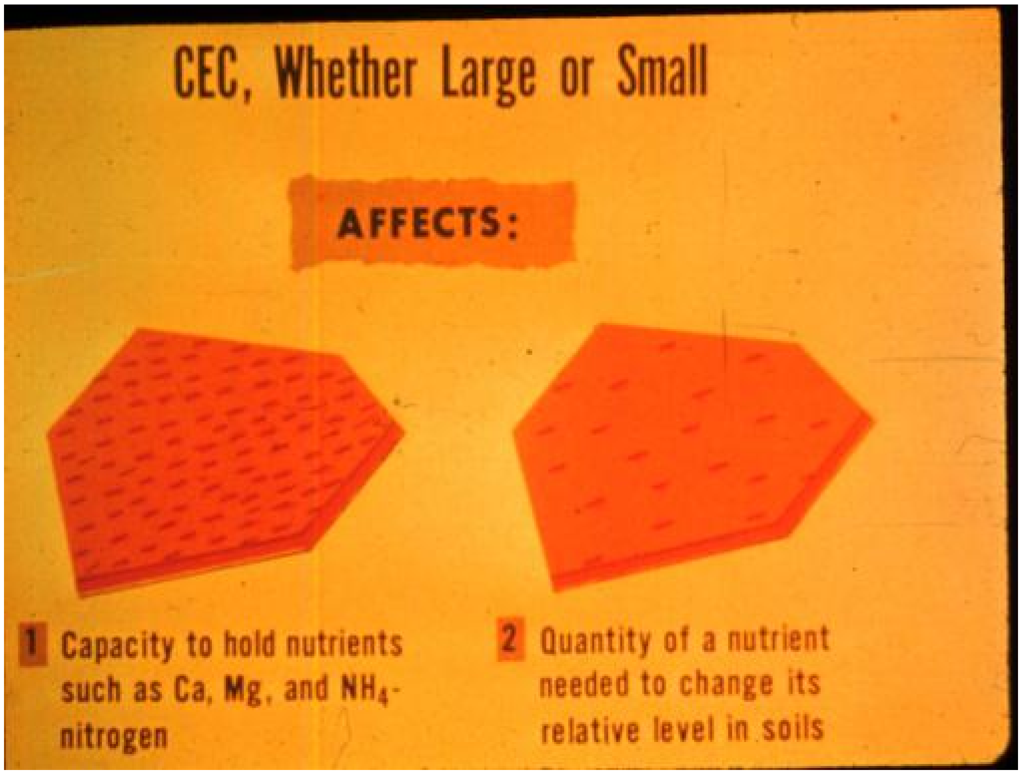
- Do not add a lot of organic materials to planting hole—creating a dramatic textural difference between the natural soil and the hole may restrict root growth to just the amended hole causing many growth problems.

Nutrient Availability

- clay main 'nutrient storehouse'
  - negative charge
  - attracts, holds positive ions
    - Ca^{++}, Mg^{++}, K^{+}, NH_4^{+}
- easily displaced, exchanged
  - plant uptake

- Chemical fertility—clay main storehouse.
- Has a negative charge created when soils were created from rocks—this charge attracts and holds nutrients plant need.
- Holds just tight enough to prevent loss by leaching—makes providing 'chemical' fertility easy.
- Goal should be to have enough on the 'exchange' sites so plants get what they need when they need it.
- Let soil do the 'work' of holding and releasing nutrients—very little reason to 'spoon' feed fertilizers.

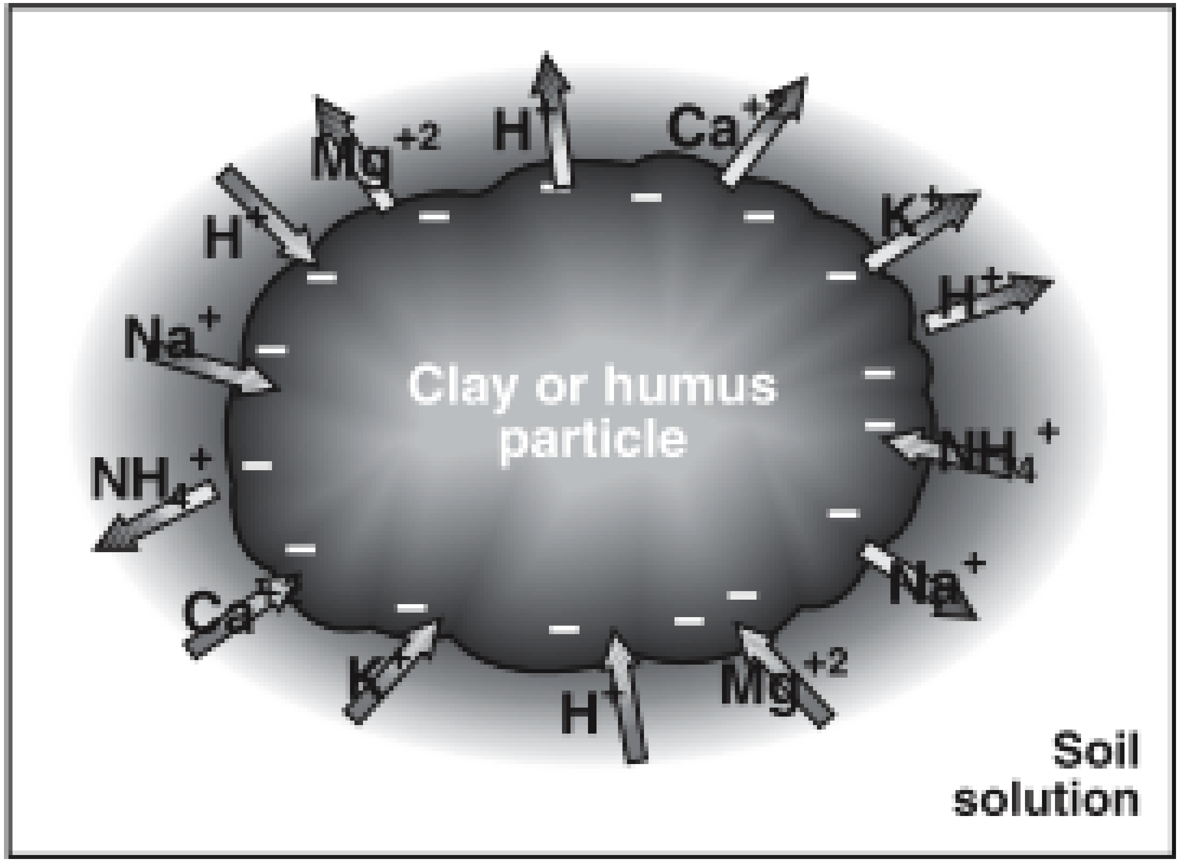
Cation Exchange Capacity



- Cation exchange---holds the positively charged nutrients until plants take up from solution.

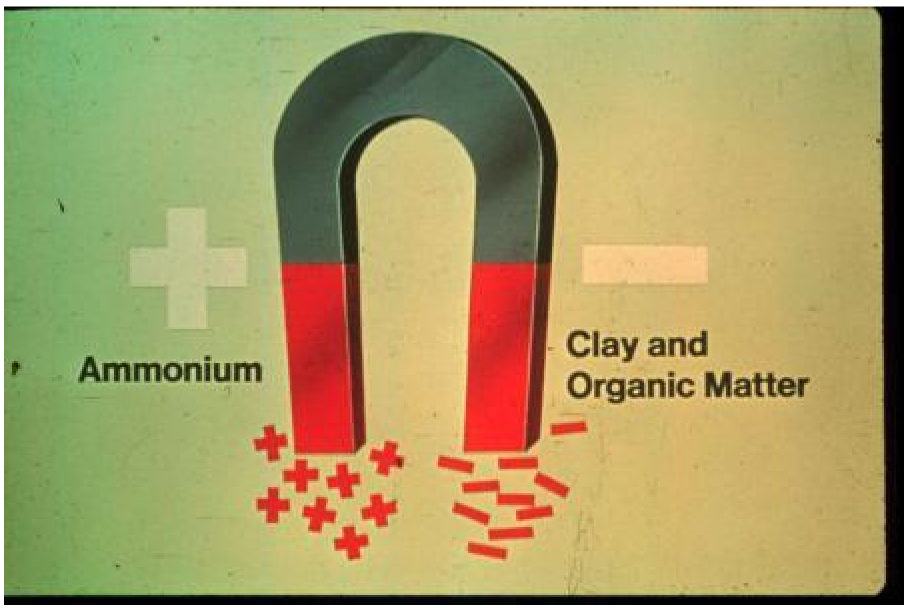
  Defines how much nutrients a soil can hold (can have K leaching on some highly fertilized sandy soils because of limited CEC) and how much fertilizer needed to change the soil test (buffer power)—therefore soils with same soil test will have different amounts of fertilizer needed.

CATIONS EXCHANGE CAPACITY



Exchangeable nutrient cations adsorbed on soil particles exist in equilibrium with cations in the soil solution. Cations from the particles replenish those taken up from the soil solution by plants.

Cation Exchange Capacity



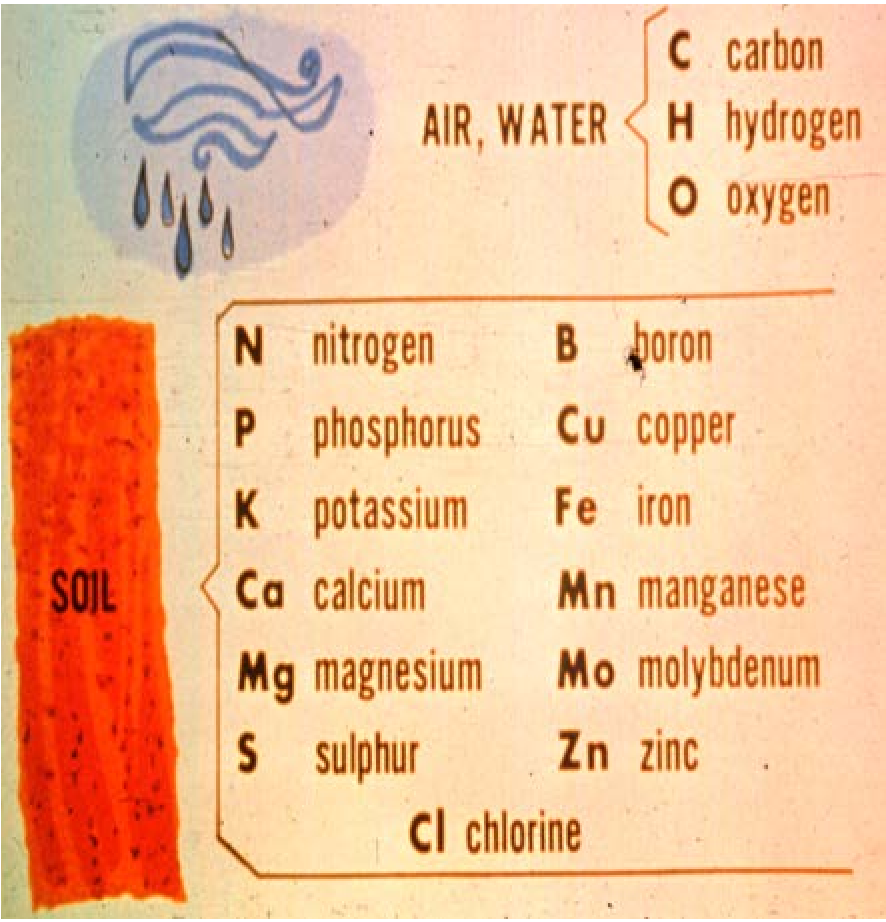
- Negative sites on clay surfaces act like magnet to attract, hold cations.
- Organic matter has some ability to hold cations but quantity changes with soil pH.

Nutrient supply: other sources

- Al, Fe and/or Ca compounds
  - phosphate fixed
  - recovery of fertilizer P < 30%
- organic matter
  - N, S, trace elements
- soil solution
  - NO_3^-, Cl^-, SO_4^{--}

- Nutrients for plant uptake also in other places besides CEC sites. Surface coatings of Fe or Al oxides/hydroxides 'fix' P2O5 very tightly. The more coatings, such as in highly weathered soil, the more P2O5 fixation.
- Organic matter supplies some nutrients—main source of N and S from organic decomposition. Also holds trace element such as Zn and Cu.
- Finally, the anions or negatively charged nutrients do not hold onto soil surfaces, but are generally part of soil solution.
- Trying to 'build' levels of N, regardless of source, will only result in too much for the plant to use in any one season and the excess, unused portion to leach below the root zone.

Essential Elements for Plants



- 16 essential elements (sometimes listed as 17 if consider Co, essential for N-fixing bacteria).
- Main ones of C, H, O from air, water sun—not to worry about.
- 13 soil supplied—macros (N, P, K) used in greatest quantity, secondary (Ca, Mg, S) used in lesser amounts and often supplied with macro fertilizers and 7 traces (B, Cu, Fe, Mn, Mo, Zn, Cl).
- Most always need N, sometimes P and K. Usually not Ca, Mg or S in SC WI.
- Of traces, usually only Fe and/or Mn needed by some sensitive ornamentals growing at high pH.
- Other traces need amending only if special crops growing in special, unique soil.

Soil Testing

- Soil testing only practical way to asses what may be lacking and needed for good plant growth.
- Popular press urges additions of many nutrients—macros and traces, and often times lime, at every planting because of trying to appeal to broad audience gardening on a variety of soils in extremes of climates.
- Because soil tests and interpretations are developed on a local basis to account for unique soil conditions and growing conditions, its best to use a local soil test info.

Soil Test

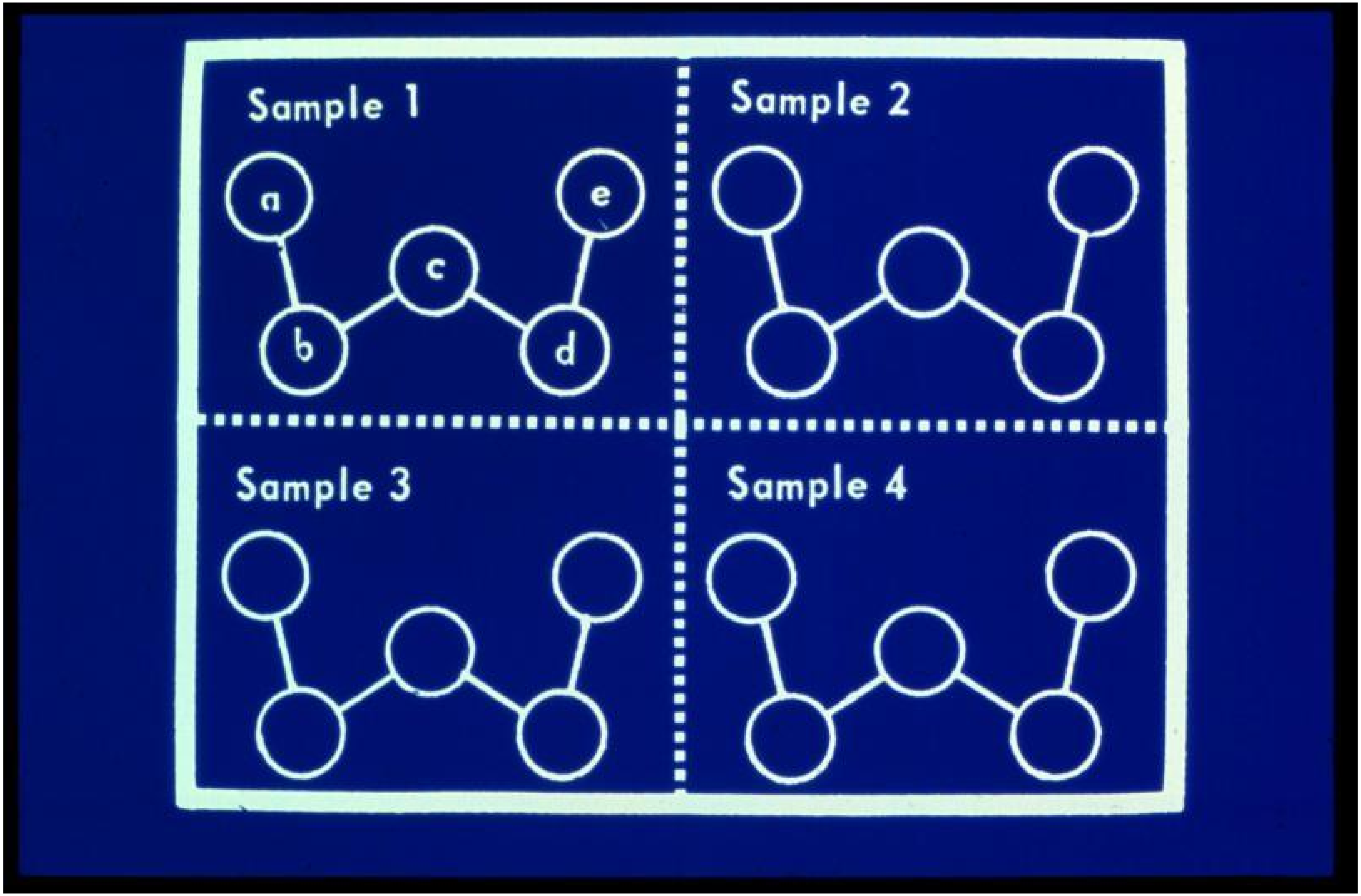
- rapid chemical analysis
- index of potential nutrient supply
  - deficiency
  - Excess
- sample to show ‘true’ variation

- Laboratory test gives index of relative nutrient supply and uses local research-based info to determine need for additional.
- Do-it-yourself tests do not have local research-based info to give appropriate interpretations.
- pH test kits can give good readings, but you only get part of the info needed in order to change soil pH in a predictable way.
- Lime, sulfur lab recs made based on soil pH and a ‘buffer pH’ combined with organic matter.

Sampling Soils

- sample depth
  - new turf, gardens – 15 cm. or tillage depth
  - Orchards: 30 cm.
  - raised beds - depth of bed
  - probe best, spade OK
- Combine at least 5 subsamples/jerib
- Sampling most important for good info. Lab tests only teaspoon or so—must sample at least 5 times for each area and combine into a 'composiate' in order to get average fertility of site.
- For recommendation to be useful, also must separate areas—lawns, veg gardens, flower gardens, fruit, etc.—because crop types grow best at different soil test levels and must be managed individually for best growth

This shows the suggested ‘random’ sampling pattern for each area—its not completely random because unusual areas such as backfill or wet spots should be avoided to not bias results. 5 individual soil cores mixed together make up each composiate.



Sampling Soils

- when
  - annual gardens, new turf
    - fall, spring before tillage
  - perennials, problems, established turf
    - anytime
  - suspected salt damage
    - very early spring
- sample each area separately
  - repeat every 2-3 yrs

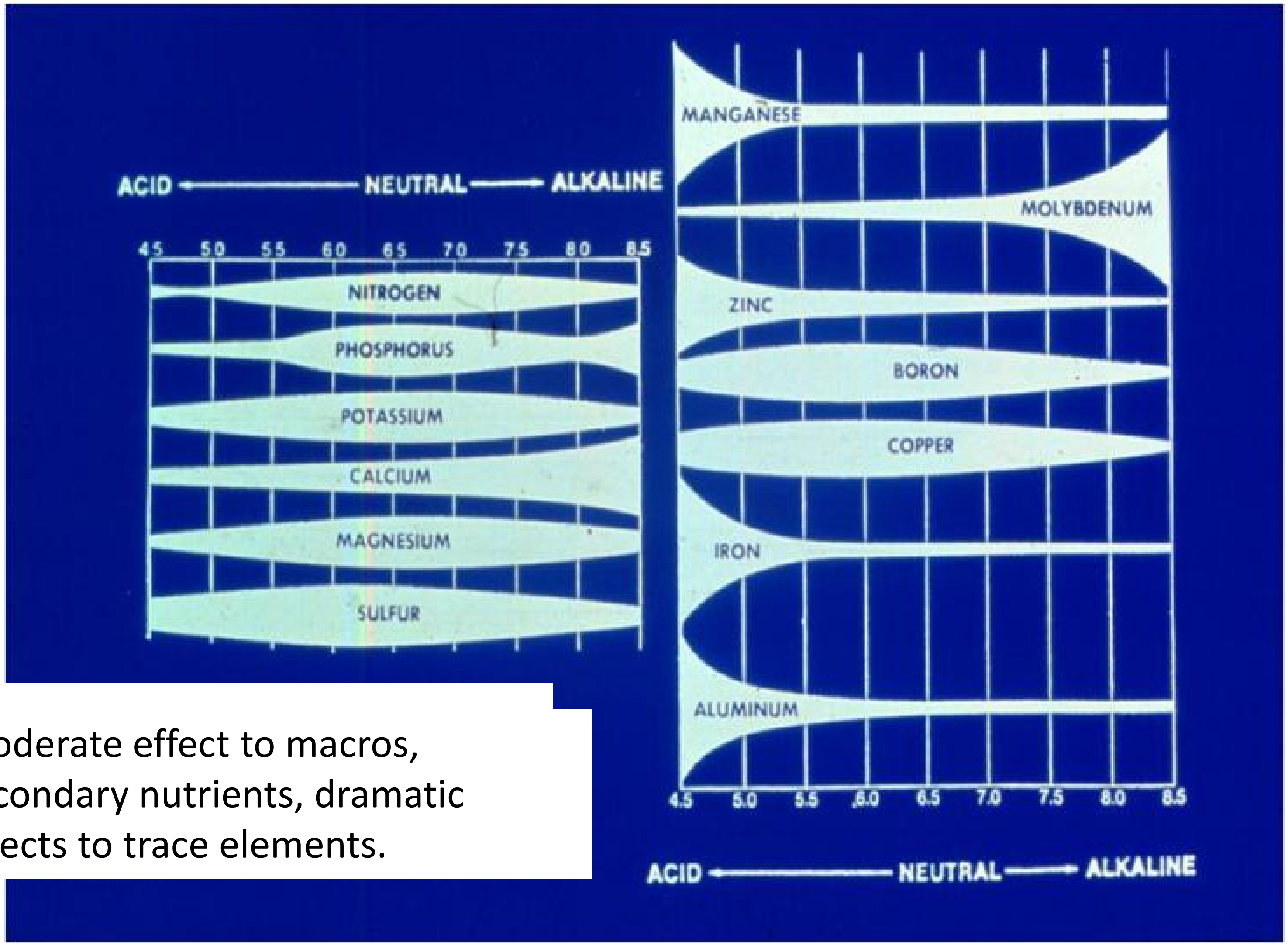
- Test soils every 2 or 3 years to confirm applications are appropriate.

Soil test report

- potential for deficiency
- which nutrient needed
- how much to apply fertilizer for nutrient need

when to apply
when to STOP!

Effect of soil pH on nutrient availability



Moderate effect to macros, secondary nutrients, dramatic effects to trace elements.

Soil test results - organic matter

- 2 - 4% most soils
  - impractical, difficult to change
- nutrient reservoir
- basis for N recommendation
- N recommendation formed from knowing what crop takes up and how much N is mineralized or released from organic matter each growing season—difference is N need.
- Application needed every year.
- On sandy soils, split applications may be best to avoid losses by leaching.
- C/N indicates the mineralization (10 is ideal)

Soil test results - N

- promotes leaf growth
- N recommendation based on crop need and organic matter level
- excess N
  - delays maturity
  - moves below root zone
- Do not try to ‘build’ soil N levels—excess will leach and plant will take up more than needed, quality/quantity of fruit compromised

Soil test results - P

- stimulates root growth and flowering
  - shallow rooted greater need
- optimum soil test P at planting
  - above 45 ppm

Soil test results - K

- promotes disease resistance, winter hardiness
- Fruit color and taste
- Flower bud formation
  - root crops require most
- Recommendation must pay attention to the level of the antagonist cations (Mg and Ca)

Inorganic fertilizer

- chemically simple
  - N in air plus water/fossil fuel
  - rock phosphate, potash mined, sized and cleaned
    - handling improved
      - clay, diatomaceous earth added
    - TSP from added acid

- Generally fertilizer materials in 2 categories—inorganic and organic. Each have merits and detriments to use. Some 'chemical' fertilizers may not really be as 'chemical' as you may think—for example, potash fertilizer is mined from earth deposits, washed and crushed and inert materials added to improve handling (minimize dust, water sorption) and bagged as 0-0-60.
- Phosphate is also mined from earth deposits, crushed and bagged as rock phosphate. If rock phosphate is treated with phosphoric acid, a highly soluble form called triple superphosphate is created.
- Without the acid treatment, rock phosphate is only soluble, therefore only useful for plants, if soil pH is less than 5.5

Inorganic fertilizer

Type	N	P_2O_5	K_2O
		Nutrient	
	------------%------------		
urea	46	0	0
ammonium nitrate	33	0	0
triple super P	0	46	0
ordinary super P	0	20	0
muriate of potash	0	0	60
potassium sulfate	0	0	50

Organic fertilizer

- chemically complex, contains C
  - naturally occurring
  - byproducts
- microorganisms must degrade
  - slow release, rate ???
- improve structure with long-term use

- Many organic fertilizers sold as by-products—tanning industry, fish processors, slaughterhouse etc. Because the nutrients are tied to C, microorganisms must degrade and break bonds to release nutrient for plant use. For many products, the rate of release in unknown. Long term use of low grade (minimal nutrient content) organic sources such as leaves, compost, grass clippings will improve soil physical characteristics.

Organic fertilizer

Type	N	P_2O_5	K_2O
	Nutrient		
	--------------%	-----------	
blood meal	13.0	1.5	0.6
bone meal, steam	2.2	27.0	0
seaweed	1.5	1.0	4.9
tree leaves	0.7	0.1	0.8
activated sewage s.	6.0	3.0	0.2

Because organic sources tend to be low grade, they in many countries do not fall under the law and are marketed as 'speciality' fertilizers.

Foliar sprays: fruits, sensitive ornamentals

- trace, secondary elements
    - soil Fe, Mn ‘fixed’ at high soil pH
    - supply by spraying leaves
    - temporary ‘fix’, requires repeating
- emergencies
    - no substitute for soil applied nutrients
        - leaf burn, expensive, extra work
        - most spray falls on soil

- OK for emergency deficiency because nutrient gets in plant almost immediately.
- But if trying to apply a lot, will cause leaf burn.
- Most spray falls on soil anyway and becomes available to roots anyway.

Lets try to critically read the fertilizers ads