The Good Earth: Soil Science

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Outline

- Sustainable stewardship of the land
- Background – Why are there so many soil types?
- Turns garbage into food!
- Living organisms in the soil
- Soil organic matter: The living residue
- The soil matrix (texture and structure)
- Buffer capacity of soil for water, temperature and chemicals
- Waste and applied chemistry of soils
- Whither goes the soil we go?

Sustainable Stewardship of the Land

- Humans have a long history of poor land stewardship.
- Over exploitation has fueled cultural growth followed by societal collapse on depleted soils.

In contrast – mystical and spiritual traditions show great reverence for the soil.

Sustainable Stewardship of the Land

- "The God Yahweh formed man out of the soil of the earth." Genesis 2:7
  - Adam is formed from the Hebrew word "Adama"; meaning earth or soil
  - Eve comes from the Hebrew word "Hava"; meaning living
  - Together Adam and Eve signify soil and life!
  - The latin name for man is "homo", derived from "humus"; the stuff of life in the soil.

Hillel, 1991

Sustainable Stewardship of the Land

- Practical lessons from the past!
  - Salting and silting of Tigris-Euphrates river valley
  - Over time, dominant empires moved from lower to middle to upper Tigris-Euphrates river valley as soils were ruined: Sumer, Akkad, Babylonian, Assyrian empires. (fig. 6)
  - Indus River Valley extinction
  - Pattern: Clear native vegetation, raise crops, erosion of topsoil from poor management and overgrazing, nutrient depletion and destruction of soil organic matter, cultural decline with soil decline
- Many modern examples prove we have not learned our lesson!

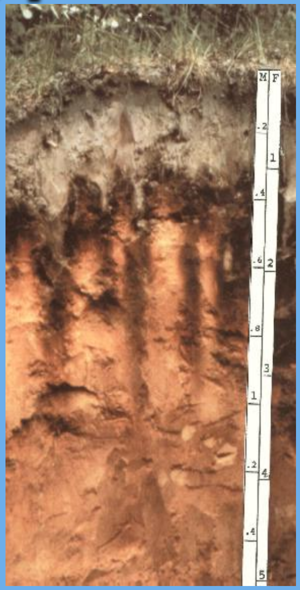
Hillel, 1991

Problems world wide related to soils

- Irrigation problems
- Salt seeps in Australia and North America
- Wind and water erosion
- Deforestation - Amazon
- Desertification
- Africa can no longer feed itself
- Disappearing wetlands
- Hazardous waste disposal

Background – Why are there so many soil types?

- **Soils are dynamic and have properties characteristic of the place where they are formed.**
- **Five soil-forming factors:**
  - **Vegetation**
  - **Climate**
  - **Topography**
  - **Parent material**
  - **Time (1”/500yrs)**



Forest Soils

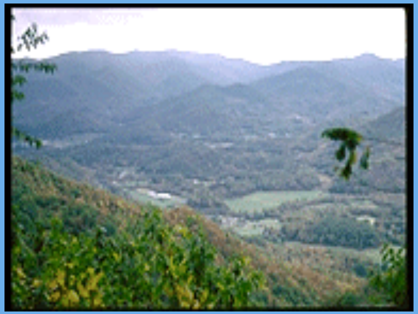
Prairie Soil

Iowa State USDA/NRCS

NRCS

Background – Why are there so many soil types?

- **Definition of a Soil:**
  Fragmented outer layer of earth's terrestrial surface that supports life.



Iowa State USDA/NRCS

Soil Turns Garbage Into Food

- Humanity discards most of its waste to soils, yet it is soil that sustains our food supply.
  - The soil does not magically convert waste into food, yet we behave as if it did. We try our best to eliminate soil from our lives as if we fear it;
    - Cities pave it over,
    - High tech gadgets keep it from our homes,
    - In English word associations with the soil are ALL negative ("dirty", "muddled", "underfoot", "soiled", "watered down", "humble", and of course "cleanliness is next to godliness")

Soil Turns Garbage Into Food

BAD NEWS - GOOD NEWS

Some things in the soil can make us sick, after all, anything that processes our waste is likely to have dangerous elements.

Without the soil we are worse than sick, we are dead! The soil is good news to us.

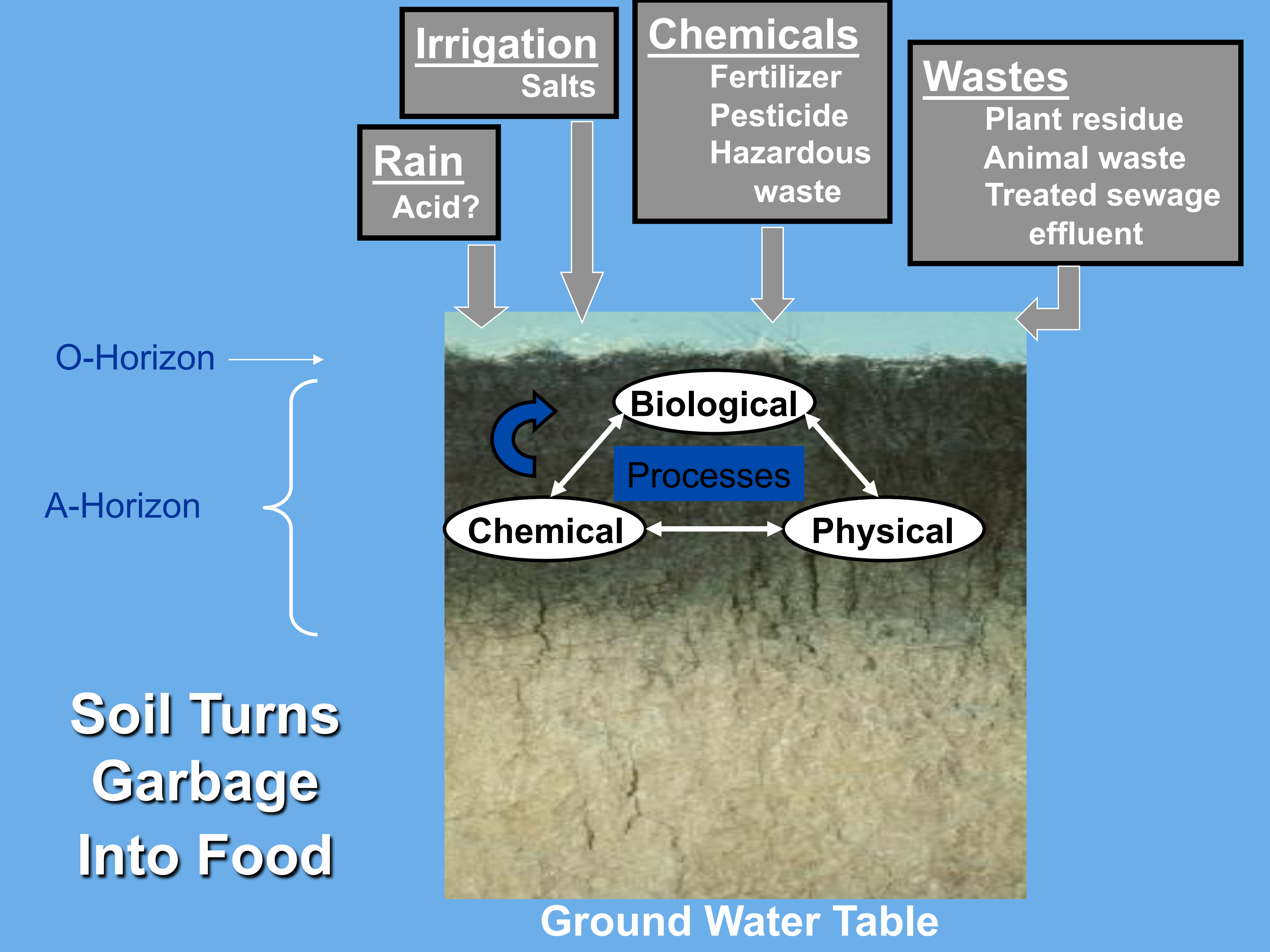
Perhaps associating soil with waste and not knowing what is dangerous causes us to choose ignorance and avoidance over stewardship.

NOT A WISE CHOICE

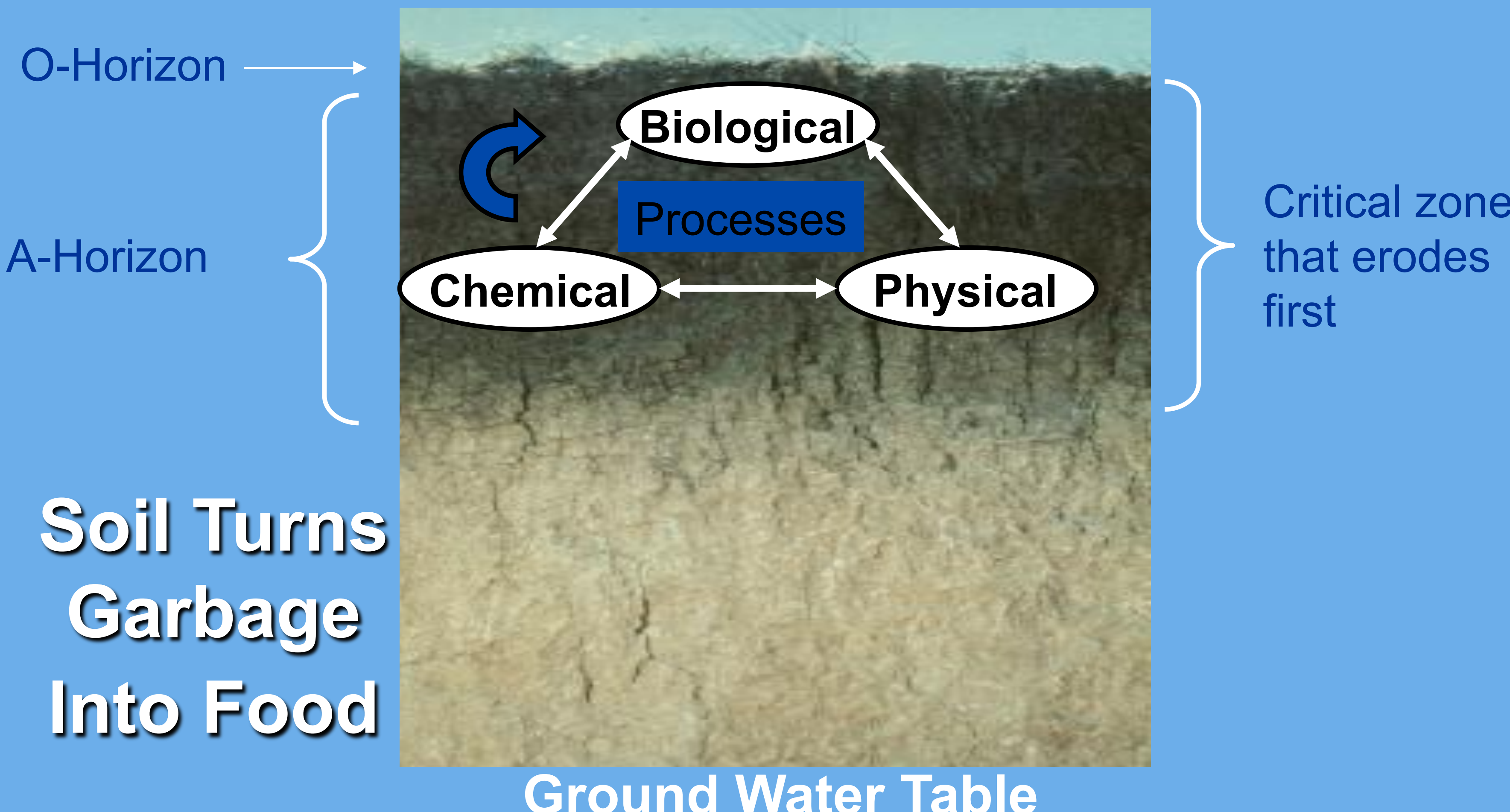
.

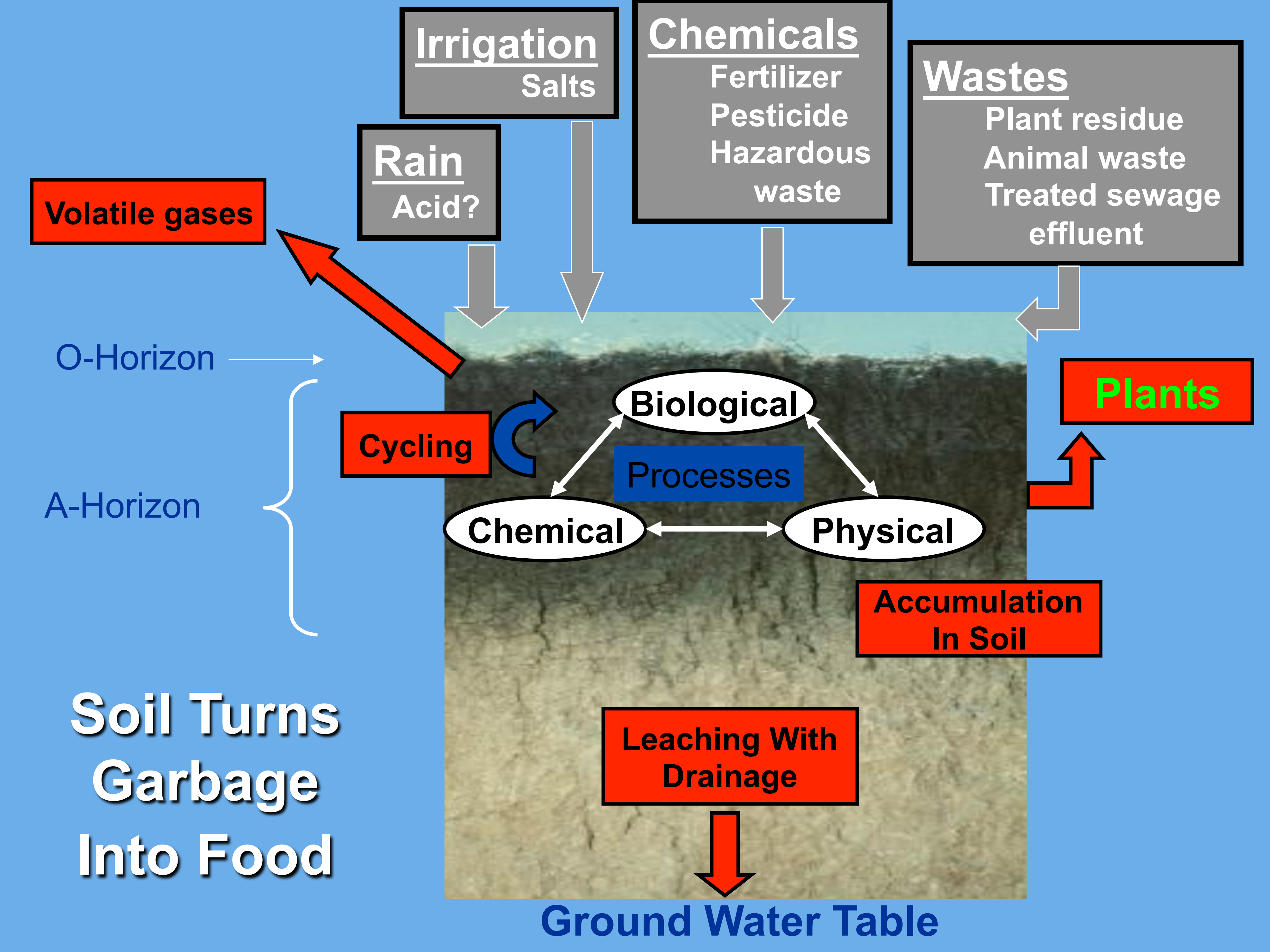
Soil Turns Garbage Into Food

- Can we respect, conserve and generally be good stewards of something we view as repulsive? NOT LIKELY! After all, we discard repulsive things!
- We must learn to respect the soil even though we do not understand much about how it sustains us – This requires humility, a word derived from humus, and education.


Irrigation
Salts
Chemicals
Fertilizer
Pesticide
Hazardous waste
Wastes
Plant residue
Animal waste
Treated sewage effluent
Rain
Acid?
O-Horizon
A-Horizon
Biological
Processes
Chemical
Physical
Soil Turns Garbage Into Food
Ground Water Table

At a time when intense technological and population pressures produce more waste, the A-horizon is disappearing from intense agricultural pressure to maximize economic yield!

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Physical
Plants
Accumulation In Soil
Leaching With Drainage
Ground Water Table
Soil Turns Garbage Into Food

Soil Turns Garbage Into Food

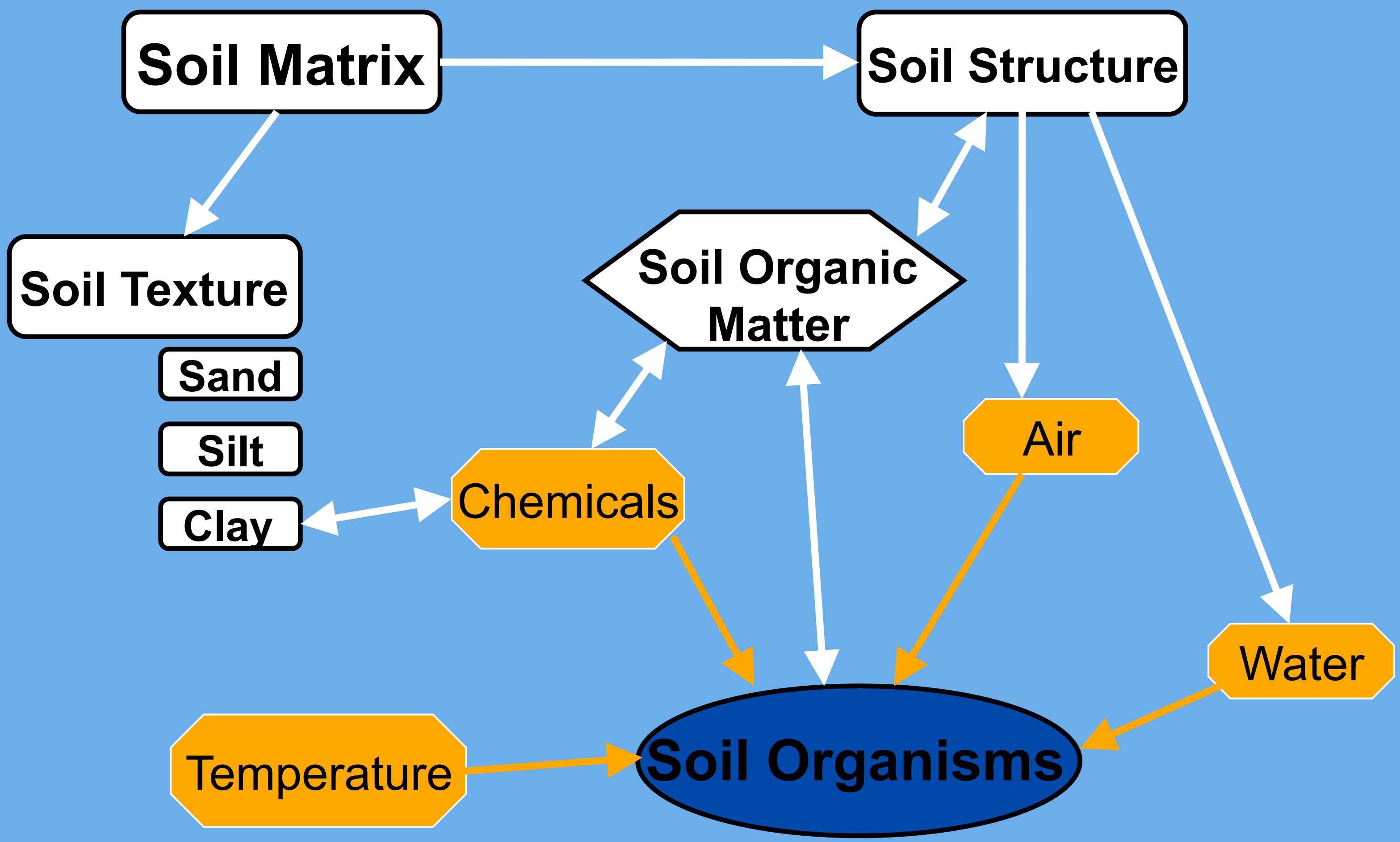
How does the soil turn garbage into food?

Soil Organisms are the key

<u>Animals</u>
Earthworms
Termites
Ants
Potworms
Snails
Nematodes
Millipedes
Springtails
Mites
…

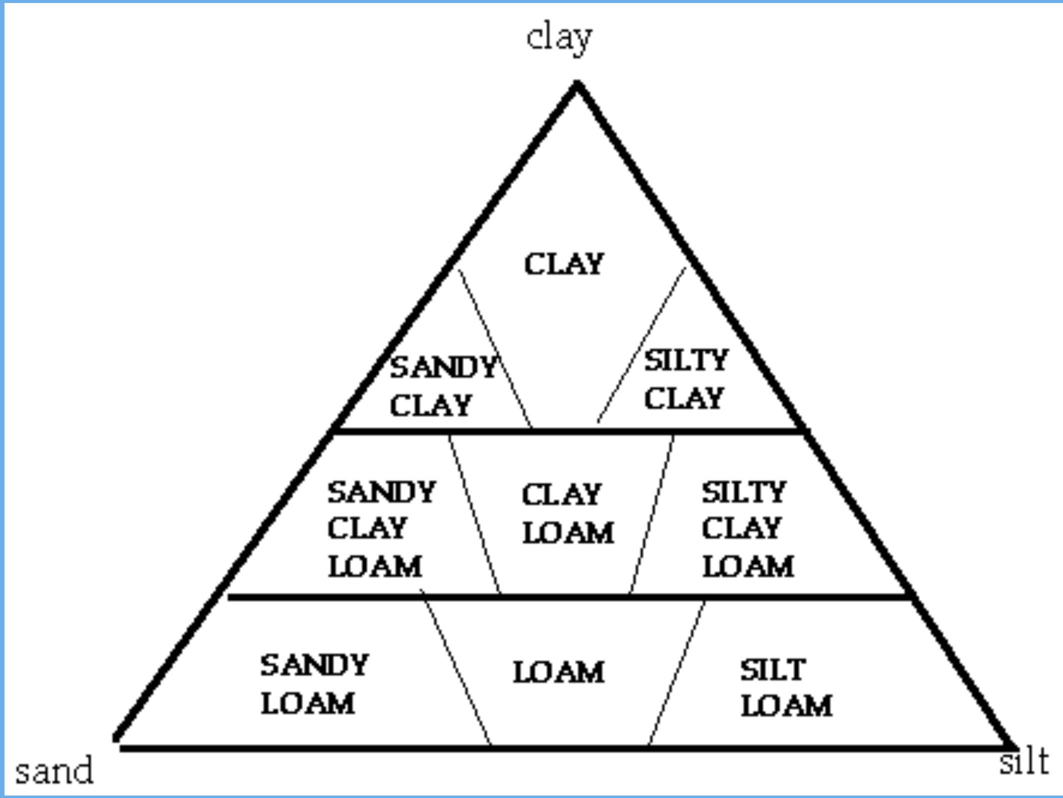
<u>Microorganisms</u>
Bacteria
Fungi

Living Organisms in the Soil and Their Interaction With the Physical Environment



Soil Texture

Proportion of sand (large), silt (medium) & clay (small) particles



GLOBE Teachers Guide

Soil Texture

Estimating Soil Texture

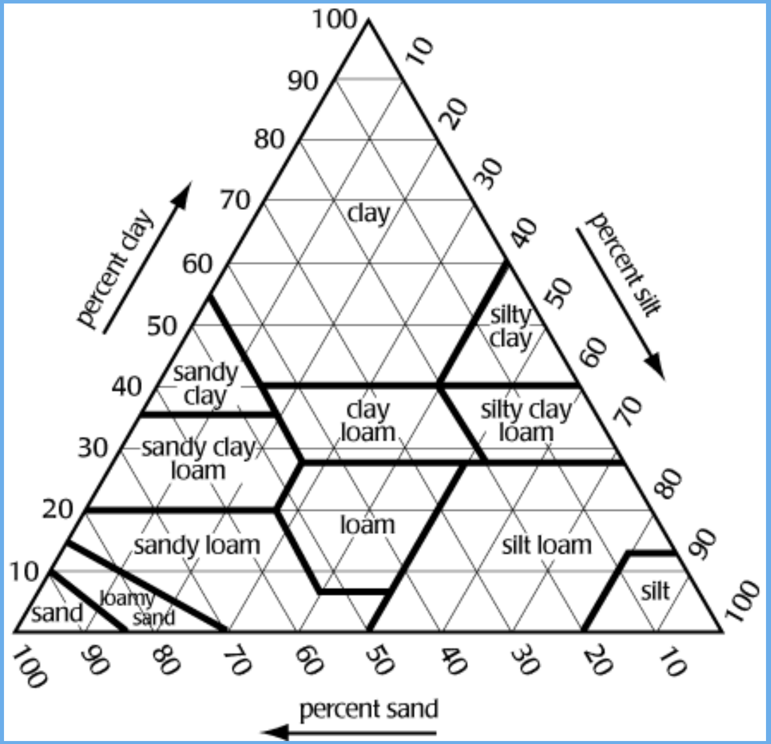
- Materials
  - 2, 1-liter (~1 quart) wide-mouth jars with lids
  - Scale with accuracy of at least 0.1 g
  - Sodium hexametaphosphate (or detergent with both sodium and phosphate in it) to disperse soil suspension
  - 50 g of soil that has been sieved through screen with ~2-mm holes
  - Mortar and pestle
- Procedure
  - Grind up any large soil particles with mortar and pestle
  - Add 5 g sodium hexametaphosphate to ~1 liter of distilled water
  - Add 50 g of dried, sieved, ground soil to solution and shake 5 minutes vigorously (Best to let suspension sit overnight)
  - Start timer and let solution/suspension sit for 2 minutes
  - Very gently decant or siphon water and suspension of silt/clay particles to another 1-quart, wide-mouth jar and oven dry sand at 104C from first jar. Weigh dried sand.
  - After 24 hours, very gently decant or siphon suspension, oven dry silt in bottom of second jar and weigh silt.

Soil Texture

Estimating Soil Texture

- Determining Sand, Silt & Clay Fractions
  - Two times the mass of dried sand in grams is equal to the percent sand in the sample.
  - Two times the mass of dried silt in grams is equal to the percent silt in the sample.
  - The percent clay is 100 - %silt - %sand
- Estimate texture from Textural Triangle →
- Sparta Loamy Sand Sample
  - 94% sand (47 g)
  - 4% silt (2 g)
  - 2% clay (1 g)

  (This particular sample had More sand than the typical Loamy sand – 93% vs 85%)



Soil Texture

Estimating Soil Texture

- The GLOBE (Global Learning and Observations to Benefit the Environment) project Teacher's Guide provides more detailed procedures for measuring soil texture as well as other quantities: pH, density, water content, temperature, soil color, fertility etc.

- The GLOBE home page is located at

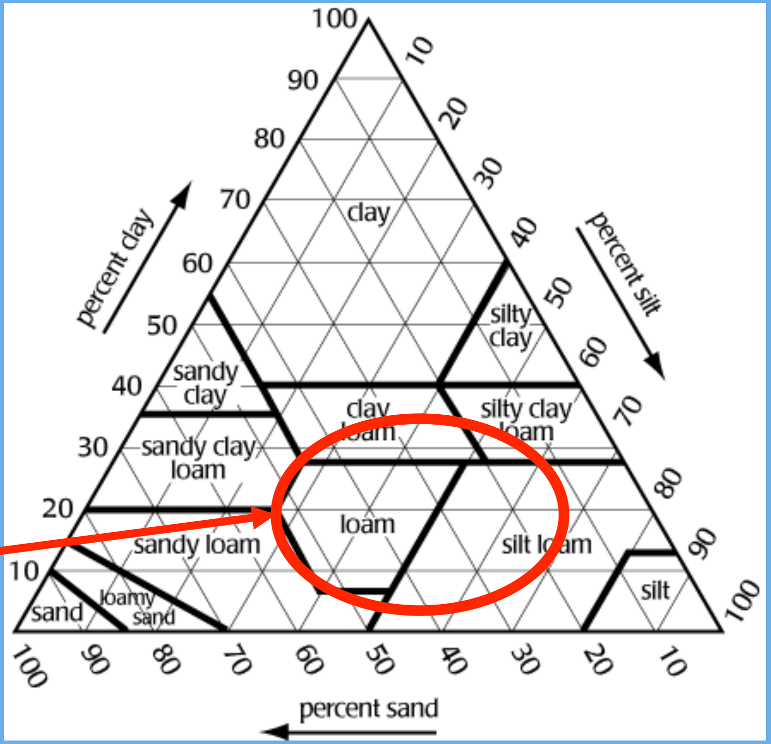
  http://www.globe.gov

Soil Texture

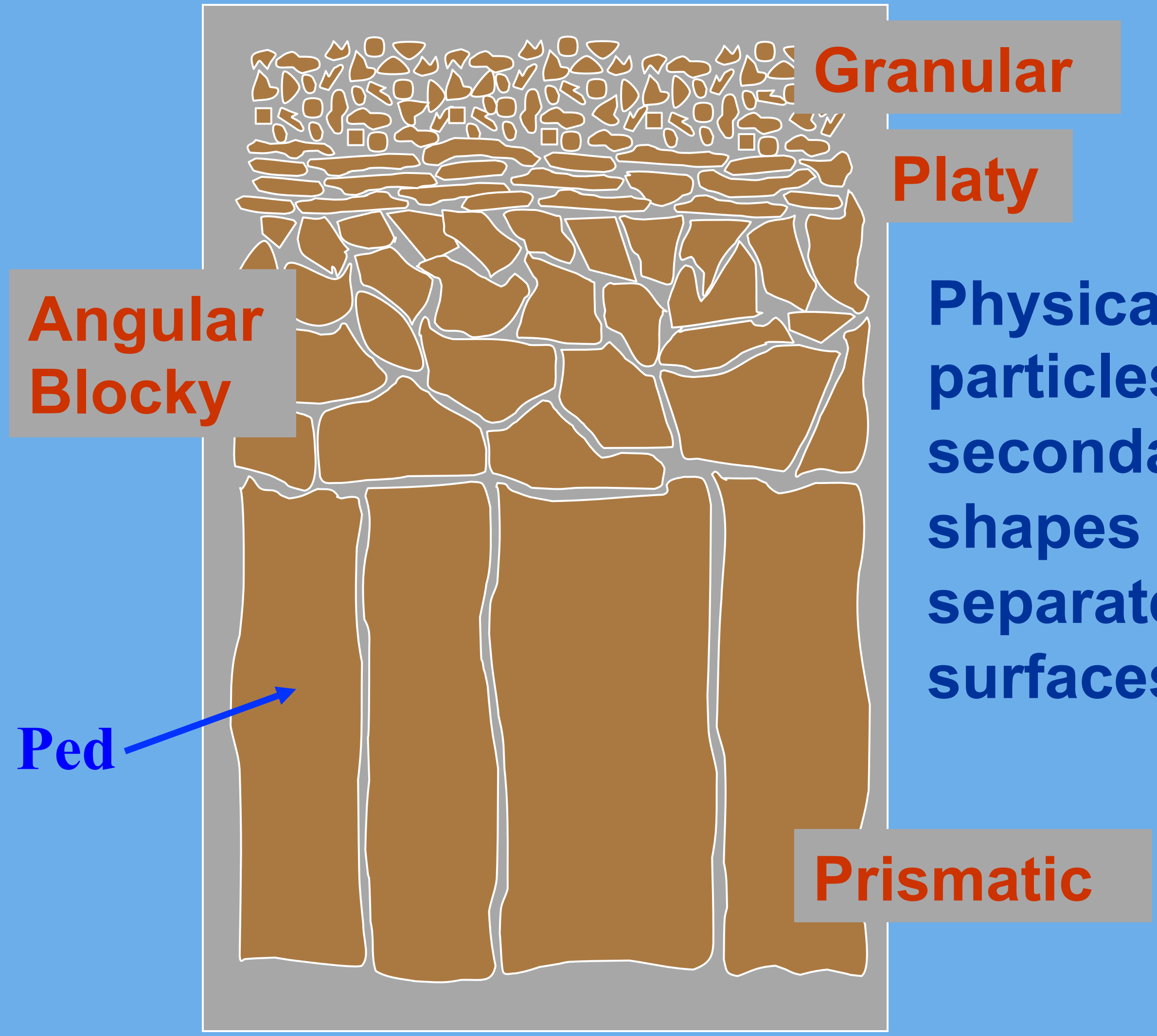
Soils near the center of the textural triangle are best for growing plants with just the right amount of air and water.

- **Sand soils have too much air and too little water storage capability**
- **Clay soils have too little air and too much water storage capability**

Best agricultural soils



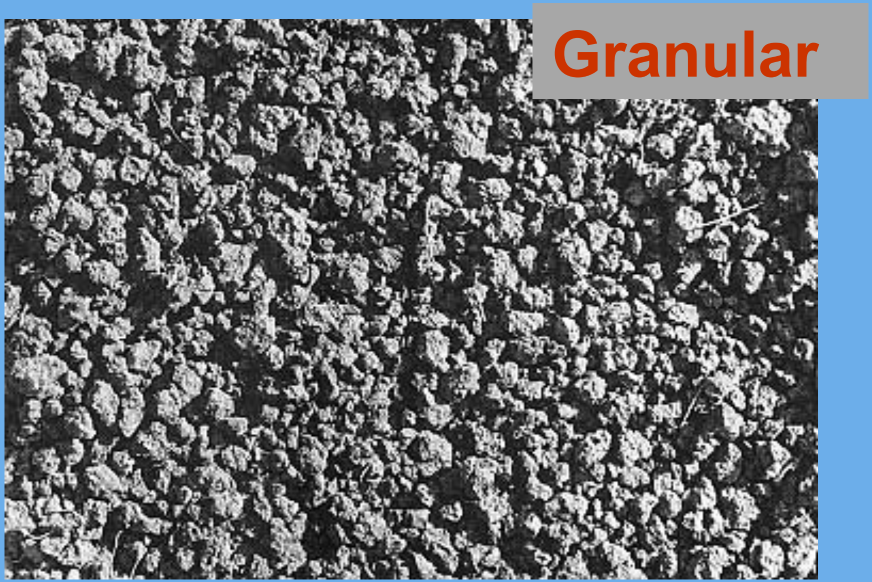
Soil Structure



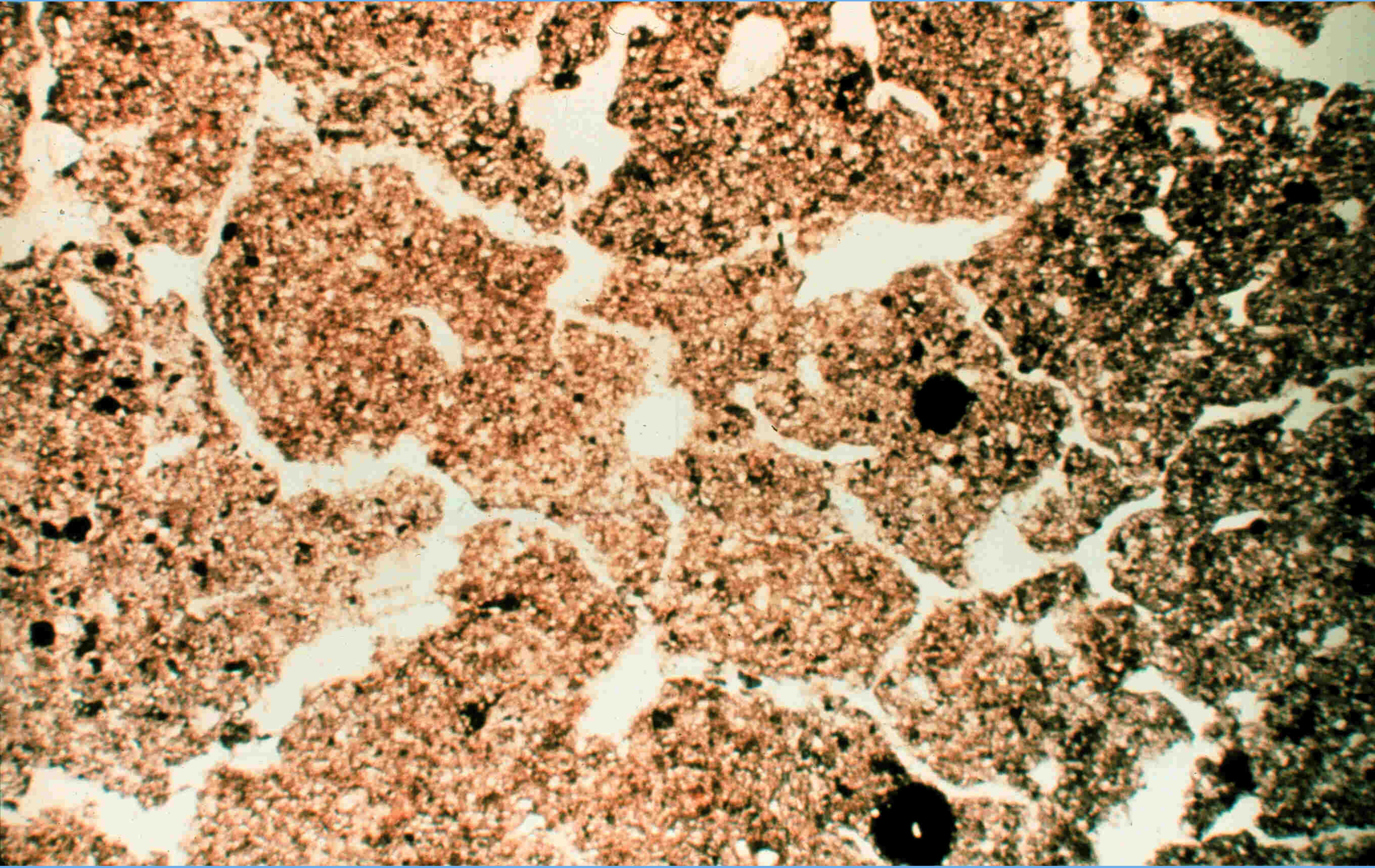
Physical constitution of solid particles and voids into secondary arrangements of shapes (peds) that are separated by natural surfaces of weakness.

Also
- Single Grain
- Massive

Soil Structure



Globe Teachers Guide

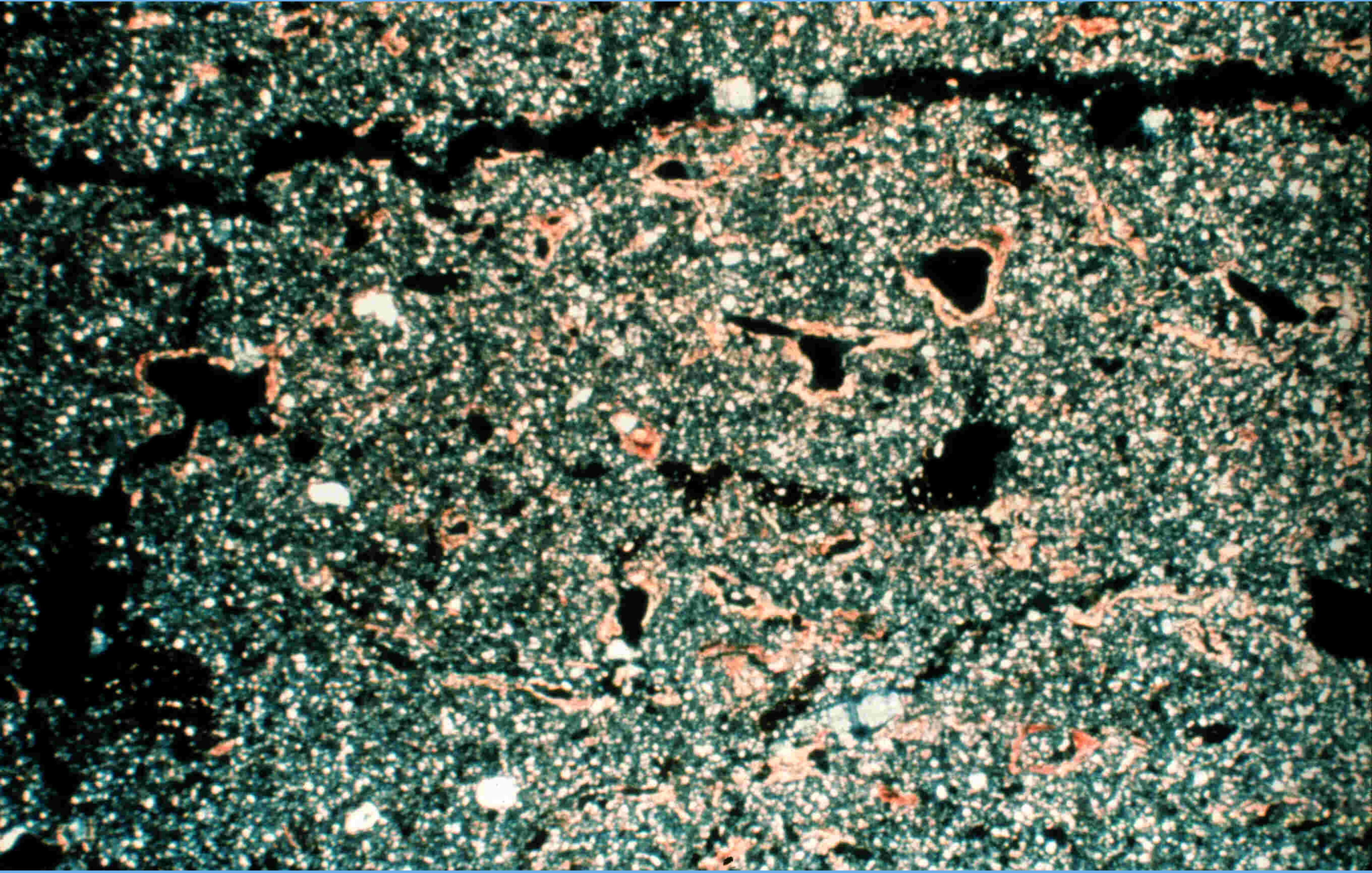


1 mm

Subangular blocky microstructure

Soil organic matter and clay skins stabilize structure by coating peds.

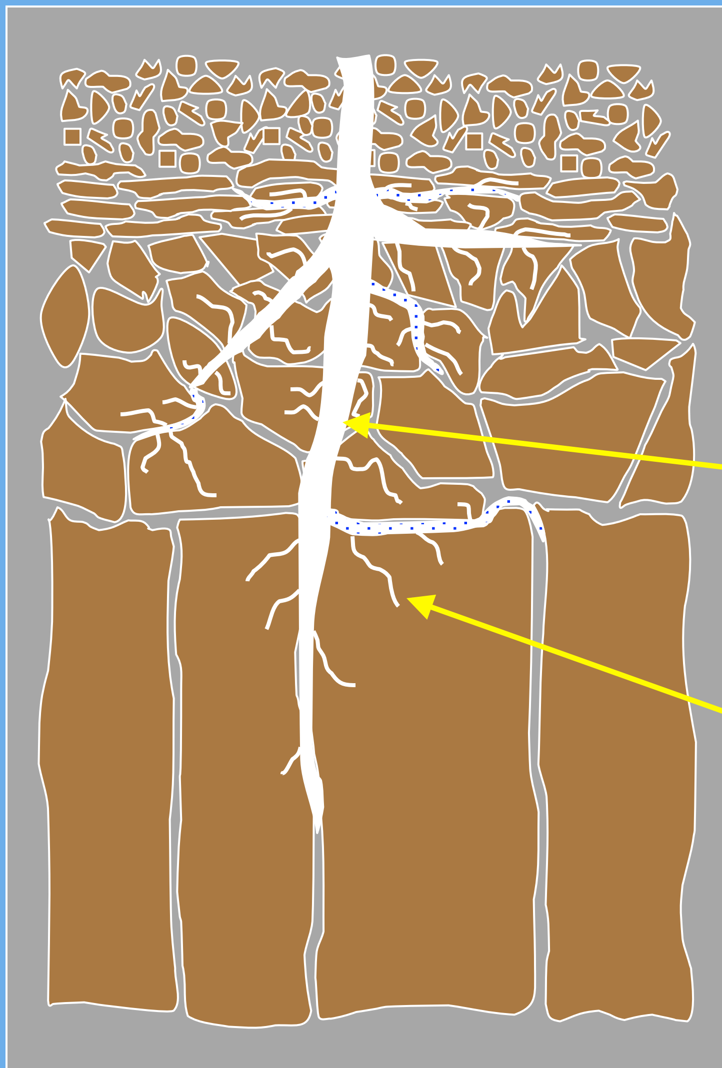
Microorganisms are concentrated near soil organic matter; fungi stabilize peds.



1 mm

Channel microstructure with clay coatings

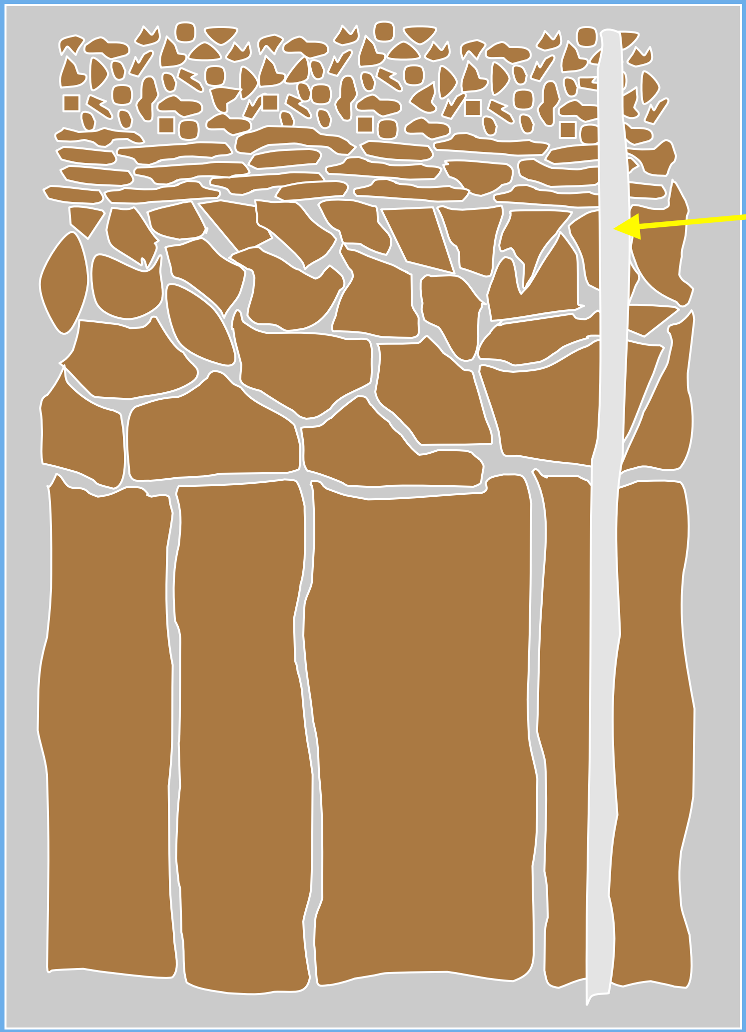
Roots help build and maintain structure by growing in weaker zones between peds



Primary roots in large pores

Secondary roots in peds

Fauna (Animals) create large pores



Earthworm Burrow

- Termites
- Ants
- Potworms
- Snails
- Nematodes
- Millipedes
- Springtails
- Mites
- ….

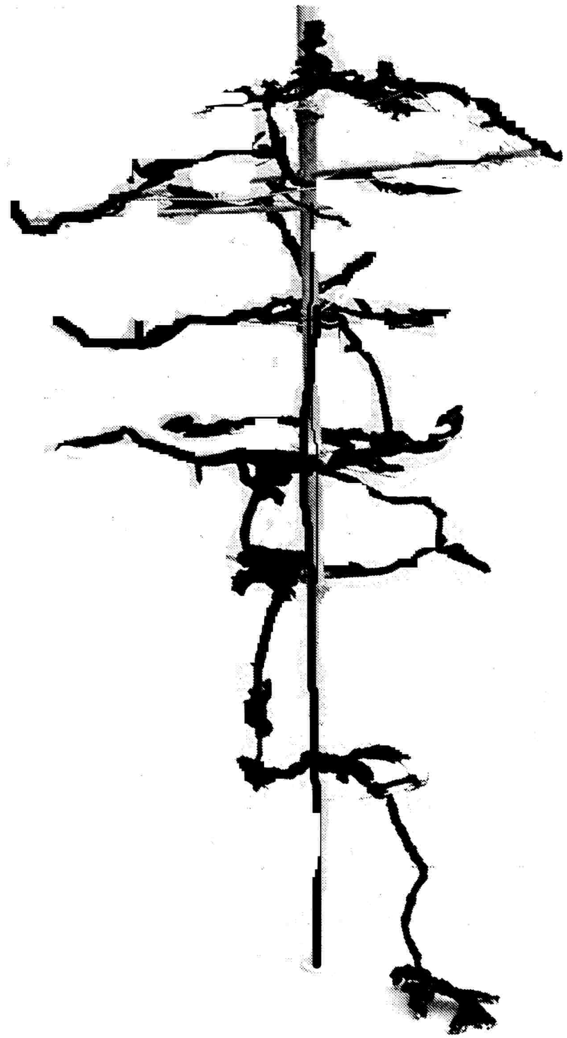
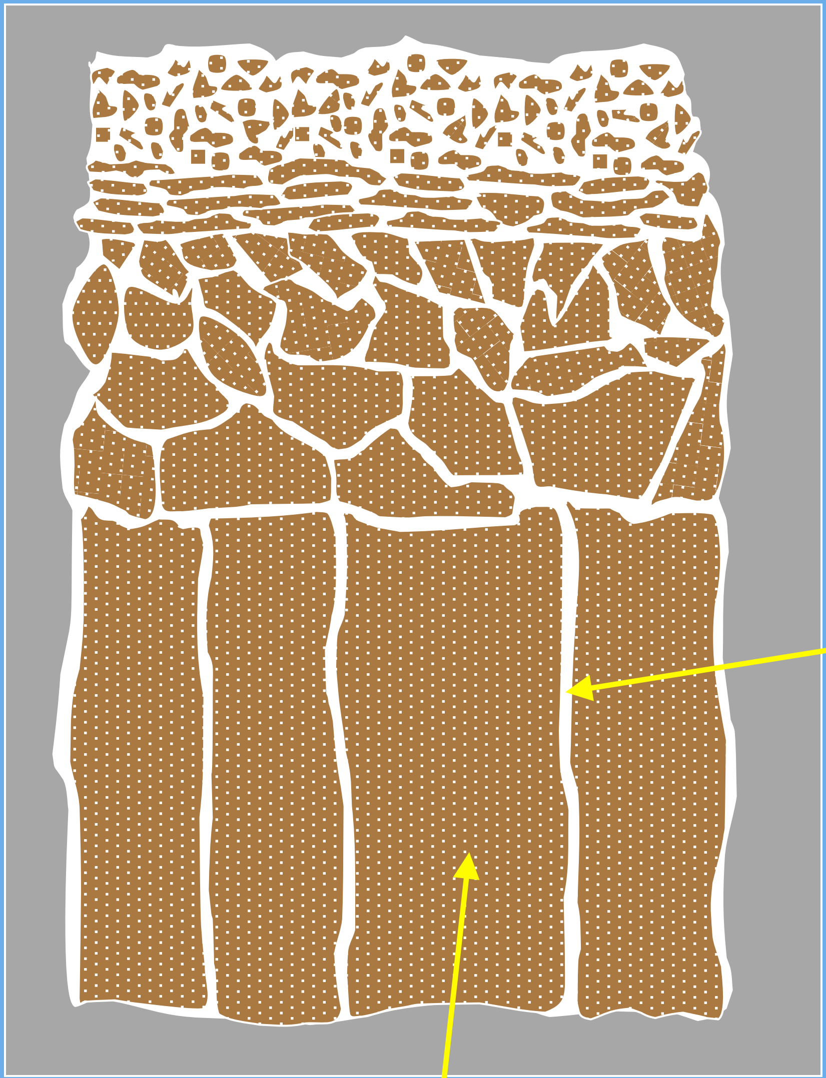


Fig. 1. Internal cast of an ant *Lasius neoniger* Emery nest (maximum depth of the nest: 70 cm).

Large pores & cracks in soil are called macropores.



Macropores drain excess water quickly and provide path for transport of air to organisms.

Water & nutrients stored in small pores in ped interior.

MACROPORES are channels of life in the soil.

Compaction can destroy them!

Soil: Natures Ultimate Buffer

- The soil buffer protects organisms by keeping water, chemicals and temperature from changing too fast
  - Life requires continuity and soil provides it by storing water, heat and chemicals and buffering harsh environmental changes
  - A good Wisconsin soil can store enough water for a crop to grow for a month without rain.
  - Chemicals are stored by being electrically attracted to clay and organic matter surfaces, by adsorption on particle surfaces, as precipitates, in organic forms in soil organic matter, and as rocks that are slowly weathered.
  - Temperature changes in soil are smaller than air

Waste and Applied Chemistry of Soils

- The soil is not a magical medium that turns anything we put in it to something desirable or harmless – The soil does have limits!
- Chemicals applied to soil may
  - move with the water
  - Become chemically bound to charged surfaces of clay or organic matter.
- Consider a simple chemistry experiment to illustrate how differently various chemicals can interact with the soil.

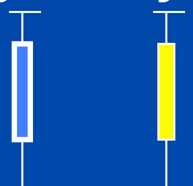
Waste and Applied Chemistry of Soils Experiment

- We can use two dyes and pass them through different soil columns.
  - Blue dye – Methylene blue (0.015 N)
  - Yellow dye – Potassium Chromate (0.25 M)
- Sparta Loamy Sand Soil
  - Pure soil packed in a column
  - Soil column with a macropore in it
- Silica Sand (beach sand)
  - Pure silica sand
  - Silica sand with a thin band of Sparta Loamy sand

Waste and Applied Chemistry of Soils Experiment

Materials & Supplies

1 ml blue dye | 1.5 ml yellow dye



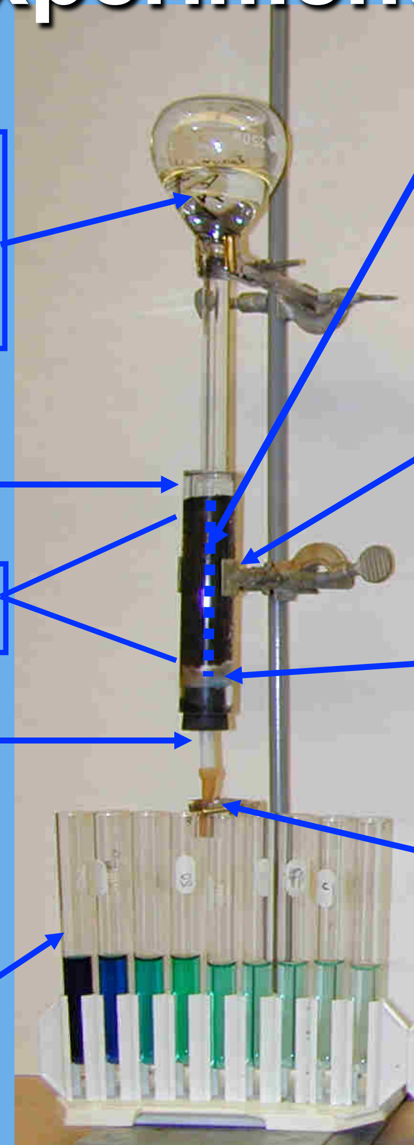
250 ml volumetric flask to supply water as soil drains

Water level ½ " above soil

Soil

Rubber stopper with rigid tube

Test tubes for spectrophotometer



Simulated macropore with 4" long glass tube ¼" O.D. pushed firmly into cotton

Plastic tube 1" I.D. 6" long clamped to ring stand

Cotton ball between soil and stopper

Latex flexible tube with clamp to control water flow

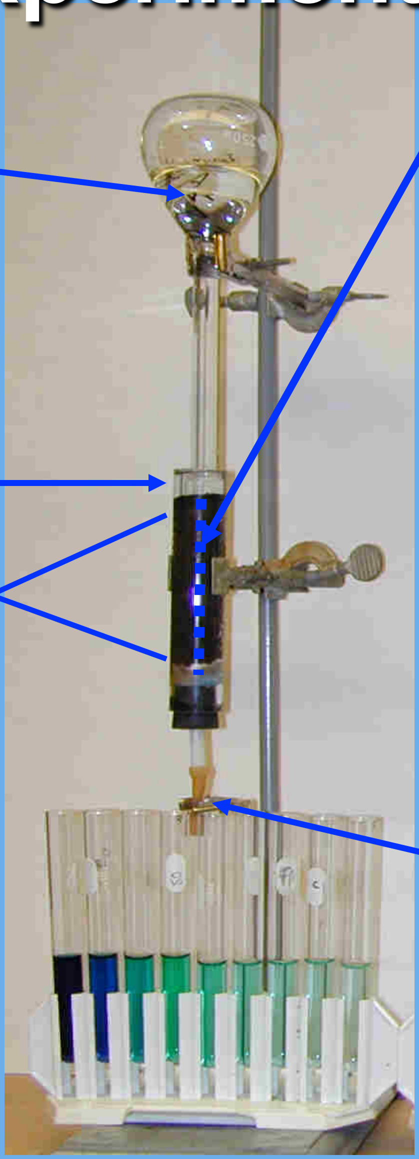
Waste and Applied Chemistry of Soils Experiment

Notes

Volumetric flask filled with tap water, blocked with finger, turned over with end placed in plastic soil tube at the same time finger removed

Water level ½ " above soil

Soil



For column with Macropore, soil filled around glass tube taking care to get NO soil inside tube– tube end extends 1/8 " above soil surface

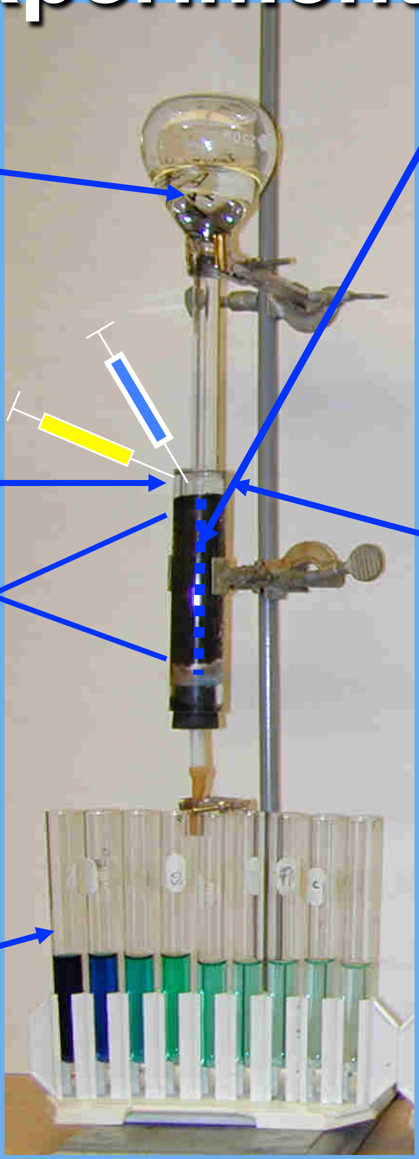
Allow about 50 ml of tap water to run through column and then close clamp

Waste and Applied Chemistry of Soils Experiment

Notes

When water level falls below volumetric flask opening, bubble will enter flask neck and water will maintain water level

For column with macropore, be sure all air bubbles are out of glass tube before injecting dye



Water level ½ " above soil

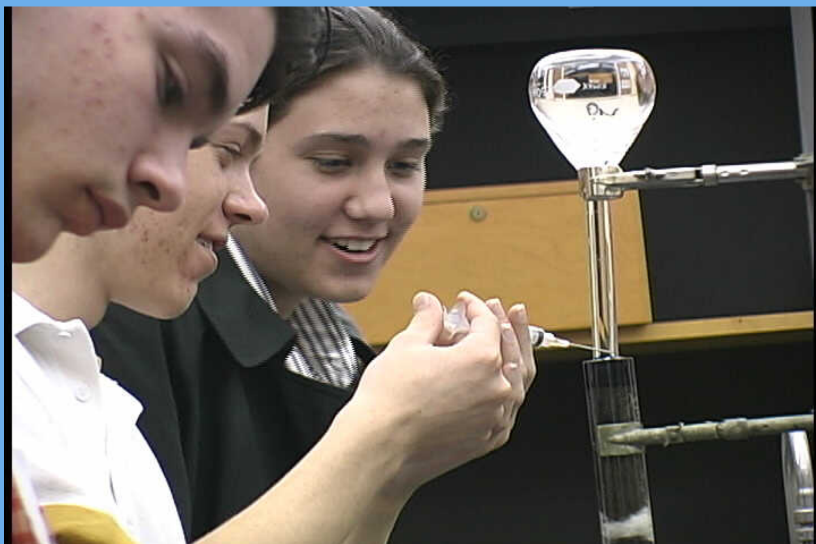
Soil

Inject dye in 5-ml syringe into water above soil VERY GENTLY

After injecting dye, open clamp and move test tubes under latex tube one at a time; fill test tubes about ½ full (about 15-20 ml)

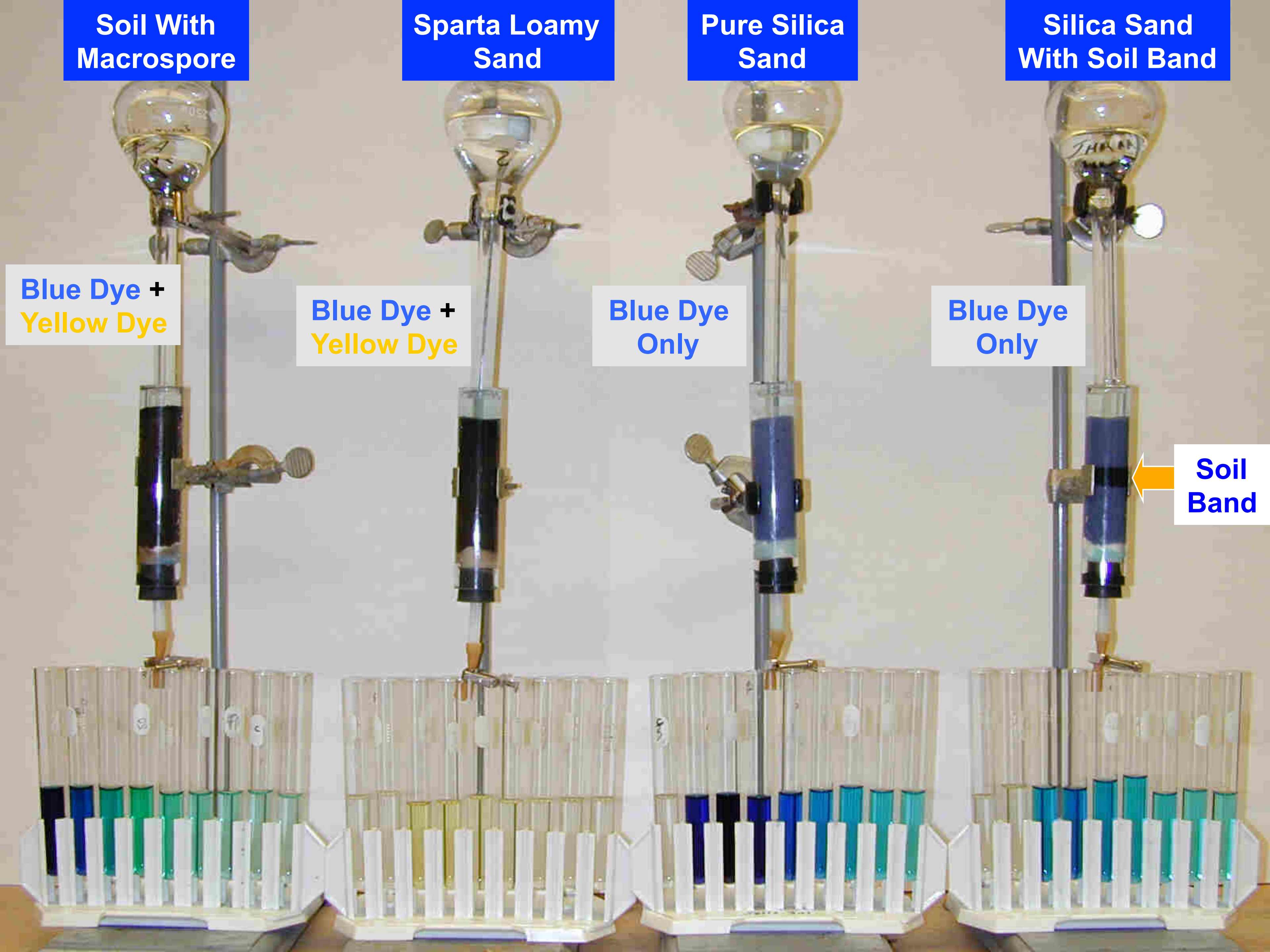
Class

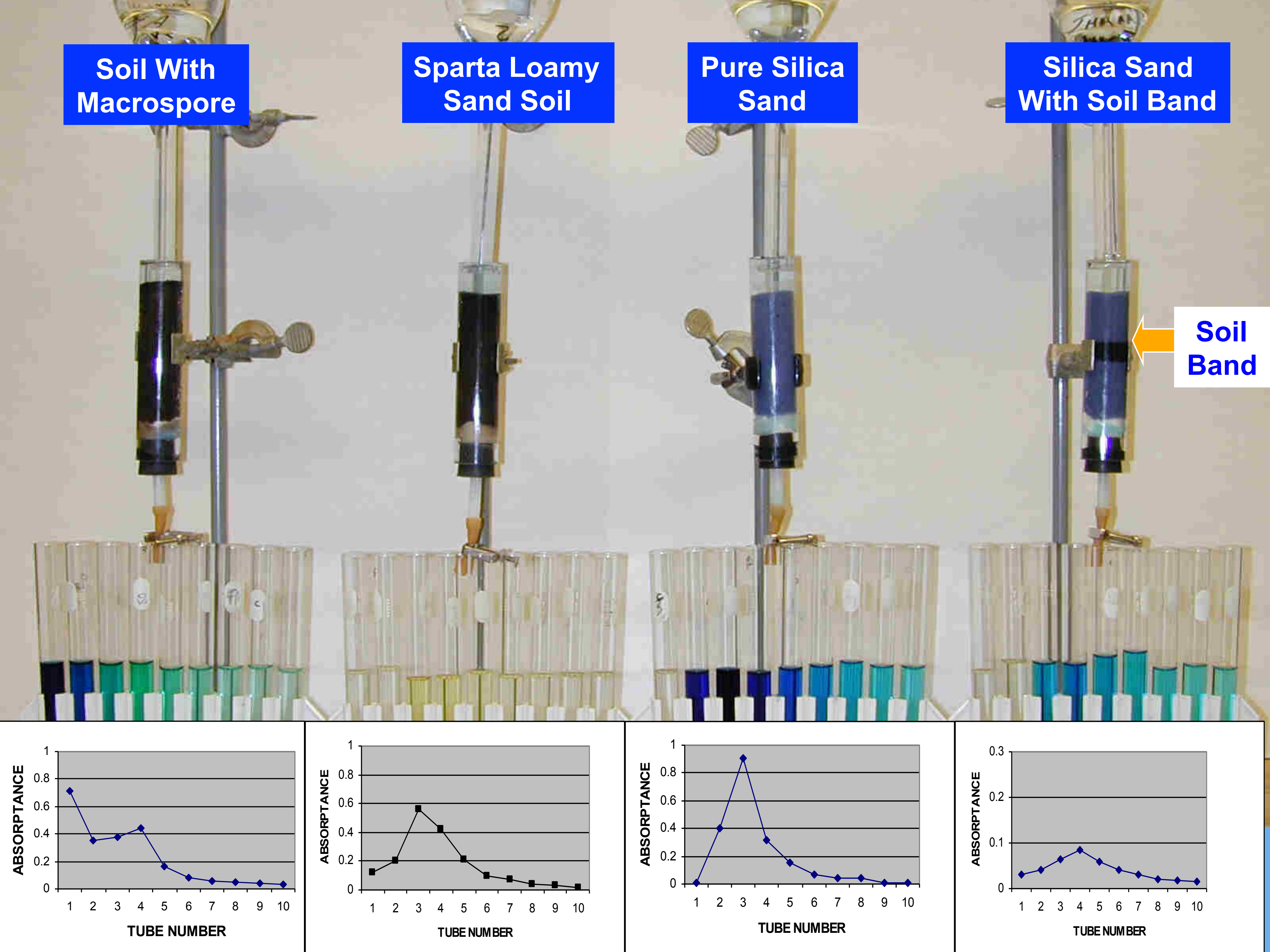
Waste and Applied Chemistry of Soils Experiment



Waste and Applied Chemistry of Soils Experiment

Class


Soil With Macrospore
Sparta Loamy Sand
Pure Silica Sand
Silica Sand With Soil Band
Blue Dye + Yellow Dye
Blue Dye + Yellow Dye
Blue Dye Only
Blue Dye Only
Soil Band



Soil With Macrospore
Sparta Loamy Sand Soil
Pure Silica Sand
Silica Sand With Soil Band
Soil Band
ABSORPTANCE
0 0.2 0.4 0.6 0.8 1
1 2 3 4 5 6 7 8 9 10
TUBE NUMBER
ABSORPTANCE
0 0.2 0.4 0.6 0.8 1
1 2 3 4 5 6 7 8 9 10
TUBE NUMBER
ABSORPTANCE
0 0.2 0.4 0.6 0.8 1
1 2 3 4 5 6 7 8 9 10
TUBE NUMBER
ABSORPTANCE
0 0.1 0.2 0.3
1 2 3 4 5 6 7 8 9 10
TUBE NUMBER

Waste and Applied Chemistry of Soils Experiment

Results

- Tube With Sparta Loamy Sand
  - Yellow dye goes through soil
  - Blue dye stays in soil
  - First 2 test tubes have no dye
- Tube With Simulated Macropore in Soil
  - First tube has both blue and yellow dye from macropore; only case where first tube has dye in it
  - Later tubes are green from mixture of blue and yellow
- Tube With Silica Sand Only
  - Blue dye stains sand but almost all comes through the sand
- Tube With Silica Sand and Band of Sparta Soil
  - Most of blue dye sticks in soil so less comes through

Waste and Applied Chemistry of Soils Experiment

Results

- Why Does Blue Dye Stay in Sparta Soil?
  - Blue dye has positive charge and is attracted to negative charge on clay and organic matter
- Why Does Blue Dye Pass Through Silica Sand?
  - No organic matter or clay
- Why Does Yellow Dye Pass Through Sparta Soil?
  - Yellow dye has negative charge and is not attracted to organic matter or clay
- Why is Tube With Simulated Macropore the Only Tube With Dye in first Test Tube?
  - Macropore conducts water with both dyes in it so they bypass the small soil pores and come out quickly
  - With other tubes, water with dye must displace clear water in small soil pores before dye can come out

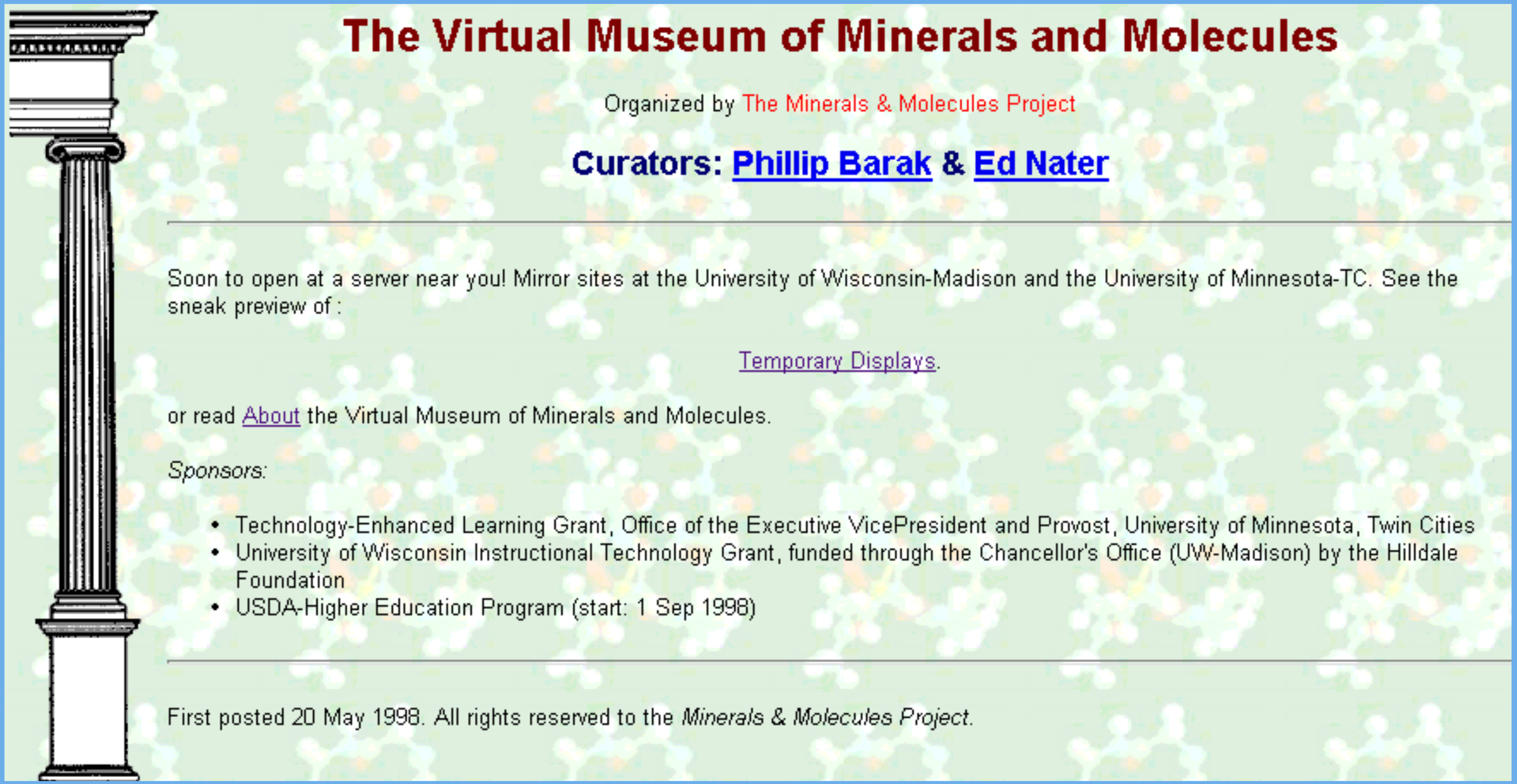
Waste and Applied Chemistry of Soils Experiment

Conclusion

- Some chemicals are bound to the soil and other chemicals may pass through the soil with the water. Nitrate fertilizer is a chemical that passes through the soil with the water.
- Even though some chemicals may bind to soil particles, they may still pass through the soil if
  - The soil has little clay and soil organic matter
  - The soil has macropores that permit rapid movement of water following very heavy rains
- Ability of soil to attract cations (+ charged) is called the cation exchange capacity & varies among soils a lot
- The soil is an interesting medium for applying chemistry

Waste and Applied Chemistry of Soils

- **More interesting information on the application of chemistry to soil science is available on the Virtual Museum home page:**
  - **http://www.soils.wisc.edu/virtual_museum**



The Virtual Museum of Minerals and Molecules

Organized by The Minerals & Molecules Project

Curators: Phillip Barak & Ed Nater

Soon to open at a server near you! Mirror sites at the University of Wisconsin-Madison and the University of Minnesota-TC. See the sneak preview of :

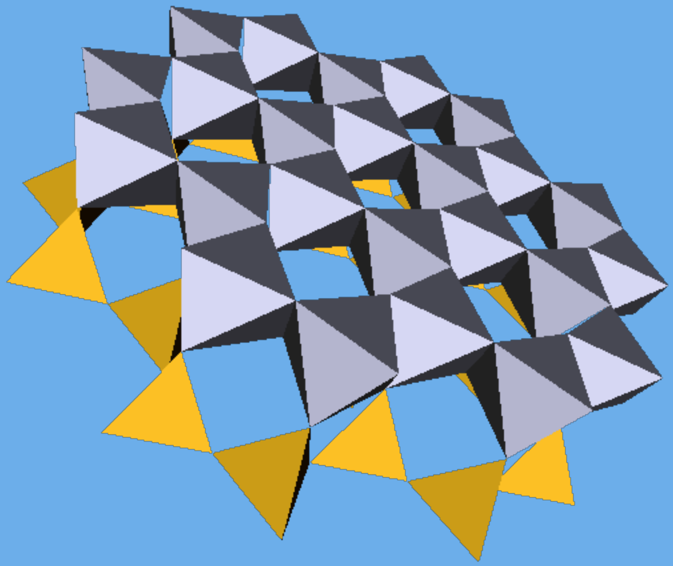
Temporary Displays.

or read About the Virtual Museum of Minerals and Molecules.

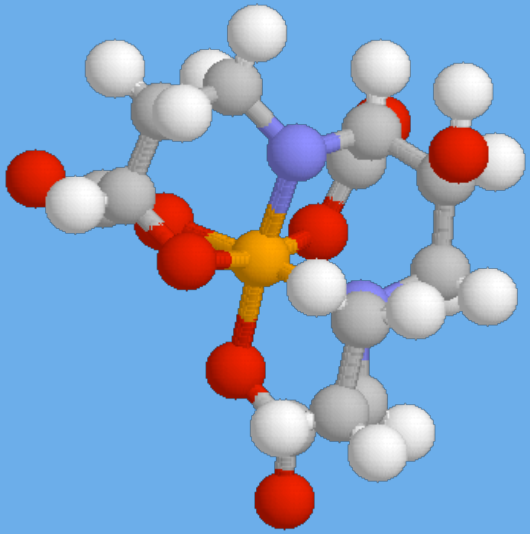
Sponsors:

- Technology-Enhanced Learning Grant, Office of the Executive VicePresident and Provost, University of Minnesota, Twin Cities
- University of Wisconsin Instructional Technology Grant, funded through the Chancellor's Office (UW-Madison) by the Hilldale Foundation
- USDA-Higher Education Program (start: 1 Sep 1998)

- The function of soil components–both organic and inorganic–is largely determined by their 3-dimensional structure



kaolinite

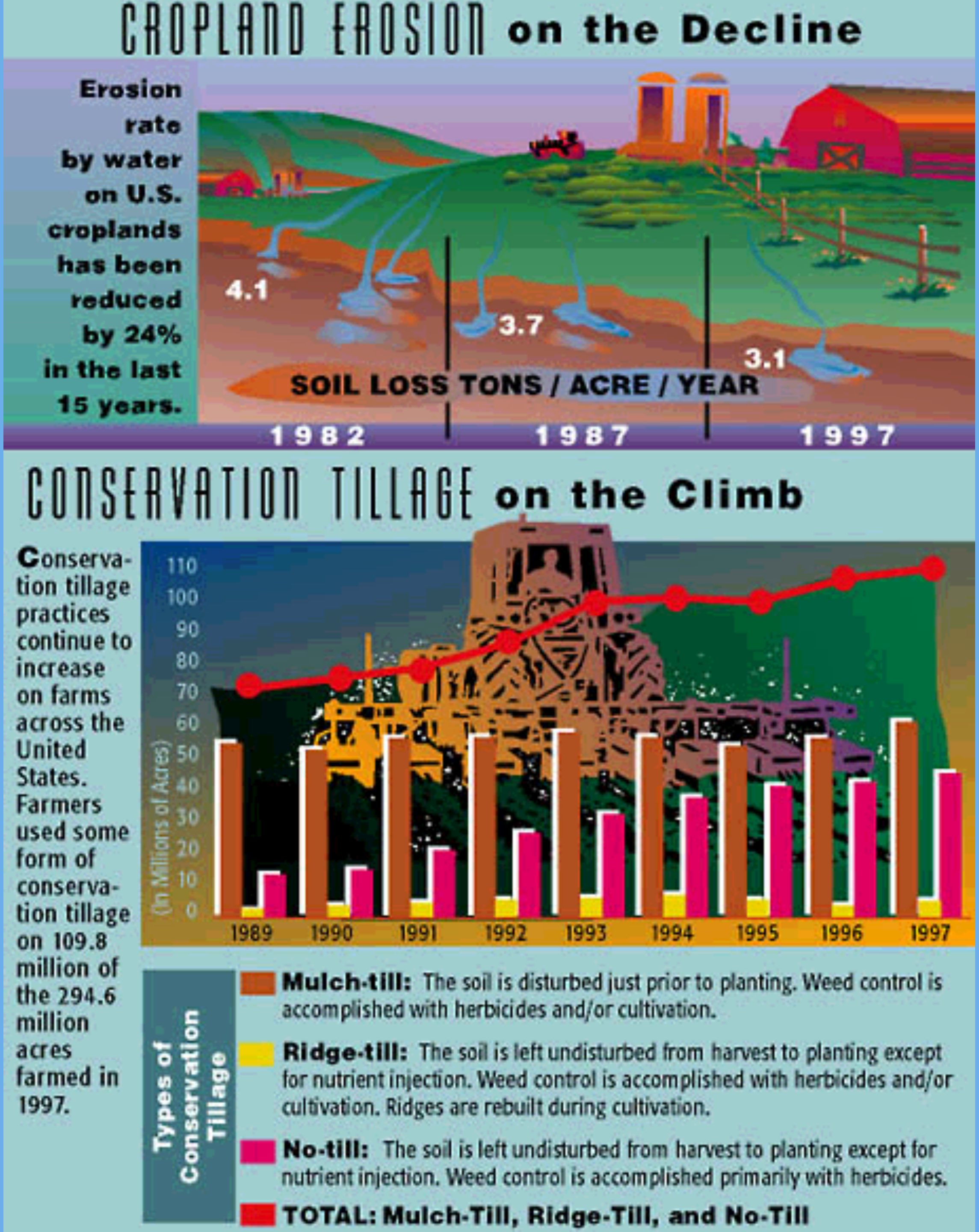


mugineic acid

From the Virtual Museum

Whither goes The Soil We Go

- We must care for the soil if our civilization is to survive – Applying industrial economics to soils is perilous because humans do not create soils like we create buildings, steel, roads, etc.
- For this generation soils are an irreplaceable natural resource
- Conservation of soils is critical and having lost 1/3 to 2/3 of the top soil of the most productive soils in the world (in midwest of U.S.), we are getting more serious about conserving this asset.



Source: Conservation Technology Information Center National Crop Residue Management Survey