Soil Science and Practices for Sustainable Landscapes

Ciencia y Prácticas del Suelo para Paisajes Sostenibles

Learning Objectives:

- Understand soil physical, chemical & biological processes, in order to
- Adopt sustainable landscape practices that protect and restore soil functions, for cost-effective, efficient landscape installation and maintenance.

GREEN GARDENING PROGRAM | Seattle Public Utilities | Local Hazardous Waste Management Program in King County

Green Gardening Program 2015

Creado por / created by:
David McDonald, Seattle Public Utilities
Incluyendo / including slides de / from:
James Urban FASLA, Urban Tree + Soils
Howard Stenn, Stenn Design
Traducción por / translation by:
Gonzalo Yepes, Colombian Gardens LLC
Program: Cascadia Consulting Group

Why build healthy soils?

- Keep soil loose and fertile for healthy plant growth
- Help prevent plant disease
- Store water and nutrients in plant root zone
- Save time and money (less water, fertilizer & pesticide needs)

Soils without compost

Soils with compost amendment

Compost improves all soil types.

Healthy soils are good for the environment too!

Protect streams, wildlife, & our climate:

- Allow rainwater to soak into soil, slow runoff that erodes streams
- Reduce need for fertilizers & pesticides
- Reduce irrigation needs
- Filter out urban pollutants
- Store carbon from atmosphere into soil
- Grow trees & other "green infrastructure"

Class Outline

Soil Science:

- Washington soil types, and urban soil challenges
- soil physical, chemical & biological processes
- water and nutrient management

Sustainable Soil Practices:

- protection, restoration & amendment,
- plant selection & placement
- fertilization, mulching & watering

Activities:

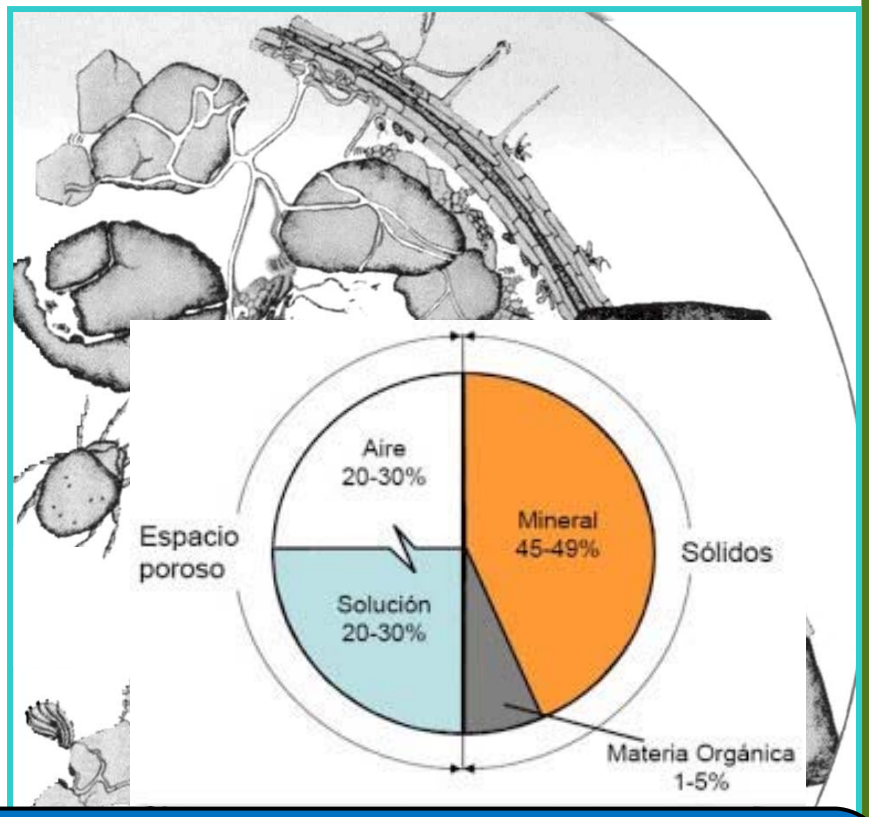
- determining soil texture by feel
- reading soil lab test reports
- reading fertilizer bag
- soil-in-water shake-&-settle test
- mulch, compost, & soil sample examination

Best practices =
key points for successful, sustainable landscapes

Understanding soil: texture, structure, organics, & pore space (provides infiltration and water capacity)

Soil components:

- "The Dirt" (mineral particles)
  - sand, silt, clay, rock
- Air and Water in pore spaces
- Organic Matter and Soil Life
  - plant debris, bugs, fungi, bacteria
  - create essential soil functions



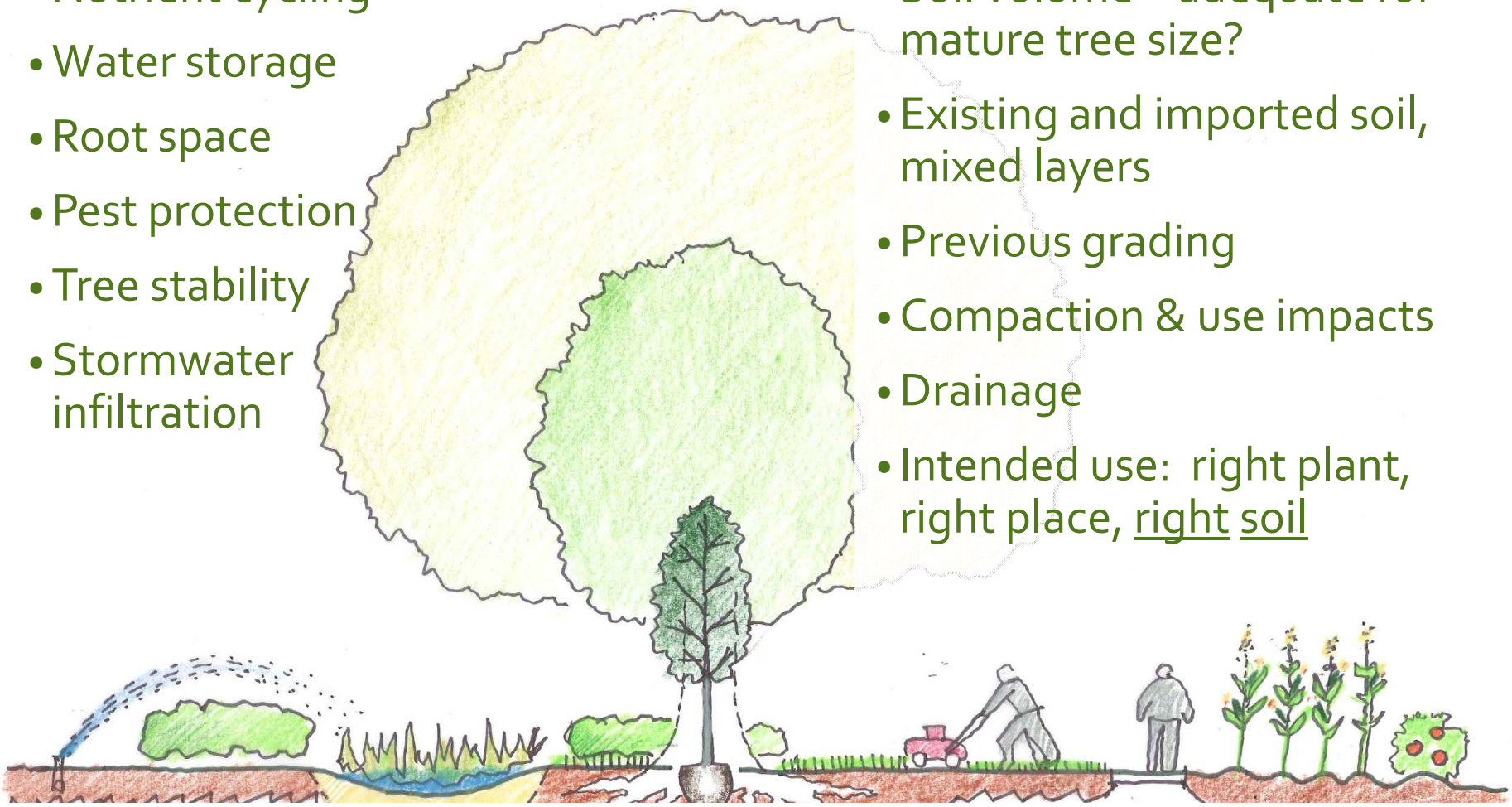
Healthy soil is

- half mineral (sand, silt, clay, rocks)
- half pore space (air & water)
- plus a small but essential amount of organic matter and soil life

Soil Functions and Soil Challenges

- Nutrient cycling
- Water storage
- Root space
- Pest protection
- Tree stability
- Stormwater infiltration

- Soil volume – adequate for mature tree size?
- Existing and imported soil, mixed layers
- Previous grading
- Compaction & use impacts
- Drainage
- Intended use: right plant, right place, right soil



Sub-Soils in the Washington: Leftovers from glaciers & volcanoes

Glacial till: unsorted, un-stratified mixtures of clay, silt, sand, gravel, and boulders; deposited in moraines, and under ice

Hardpan: till compacted under glacier

Outwash soils: layers sorted by particle size by water
- sand / gravel / rocks

Water deposited soils

Lake/marine bed soils: clay or silt that settled out in lakes & estuaries

River bottom (alluvial) soils: deposited by flooding

Volcanic soils

Volcanic ash: light, fertile, holds moisture – mostly blown east of mountains

Mudflows: mixed size, compact - like till

Learn about Washington soils at:
http://puyallup.wsu.edu/soils/soils/

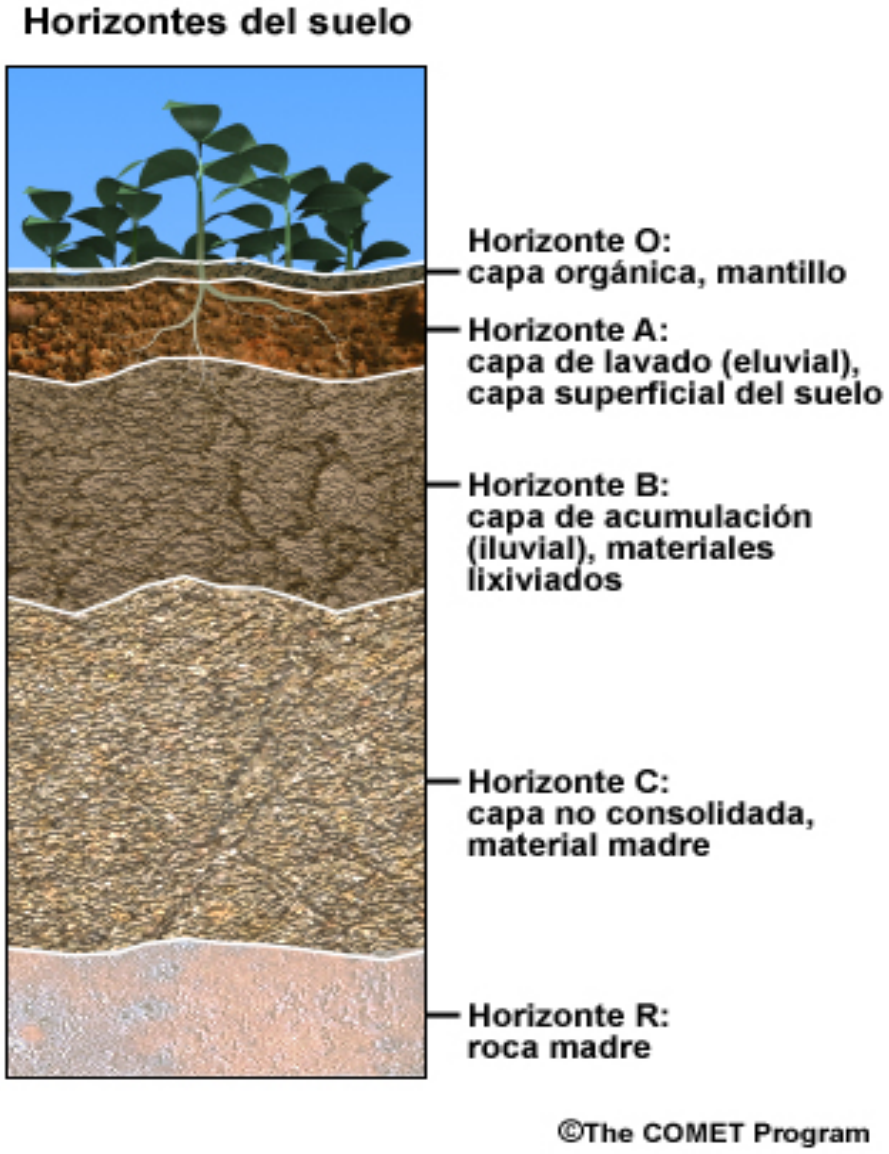
Disturbed soils in urban areas

- Topsoil layer removed
- Compaction
- Subsoil or fill layers
- Debris or toxins?

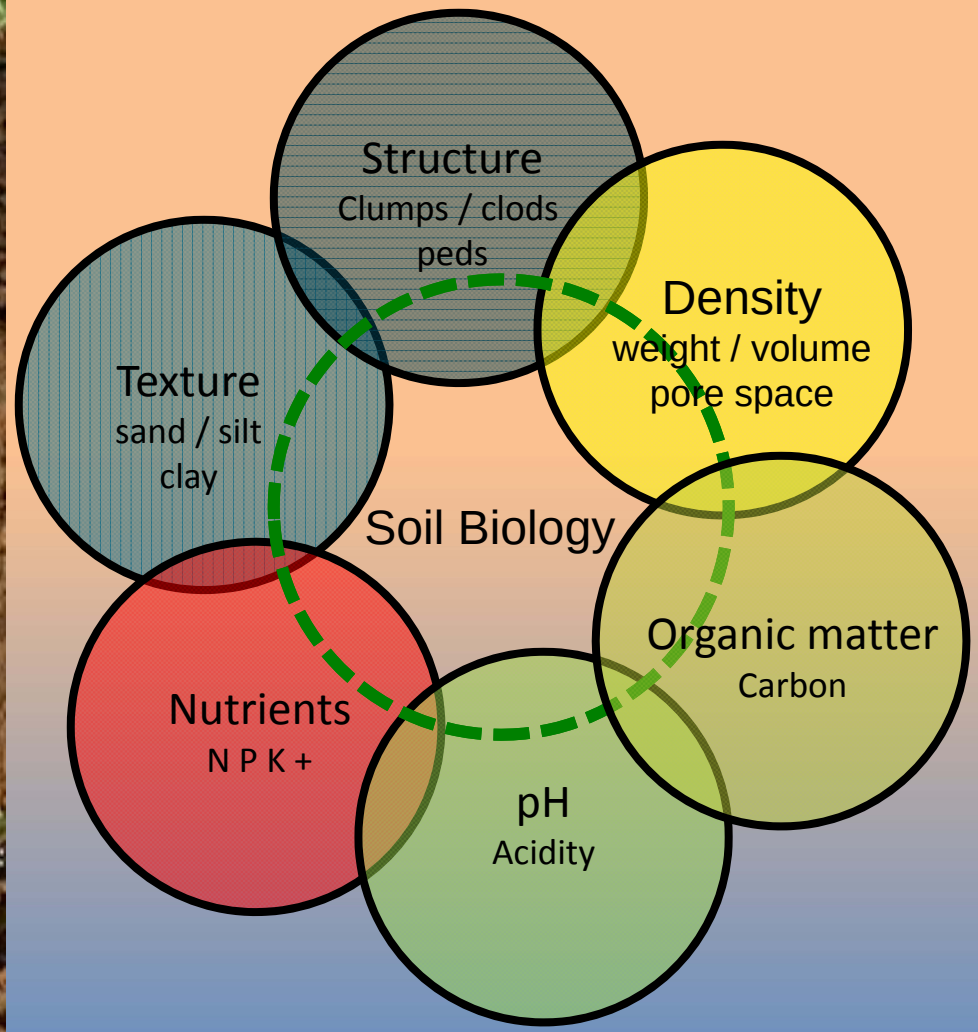
Soil horizons ("soil profile"): develop from mineral "dirt" & rock

- Organic duff (O) and Topsoil (A) horizons created by biological processes
- Subsoil (B) created by physical and chemical processes from Substratum (C) or Bedrock (R)

http://soils.usda.gov

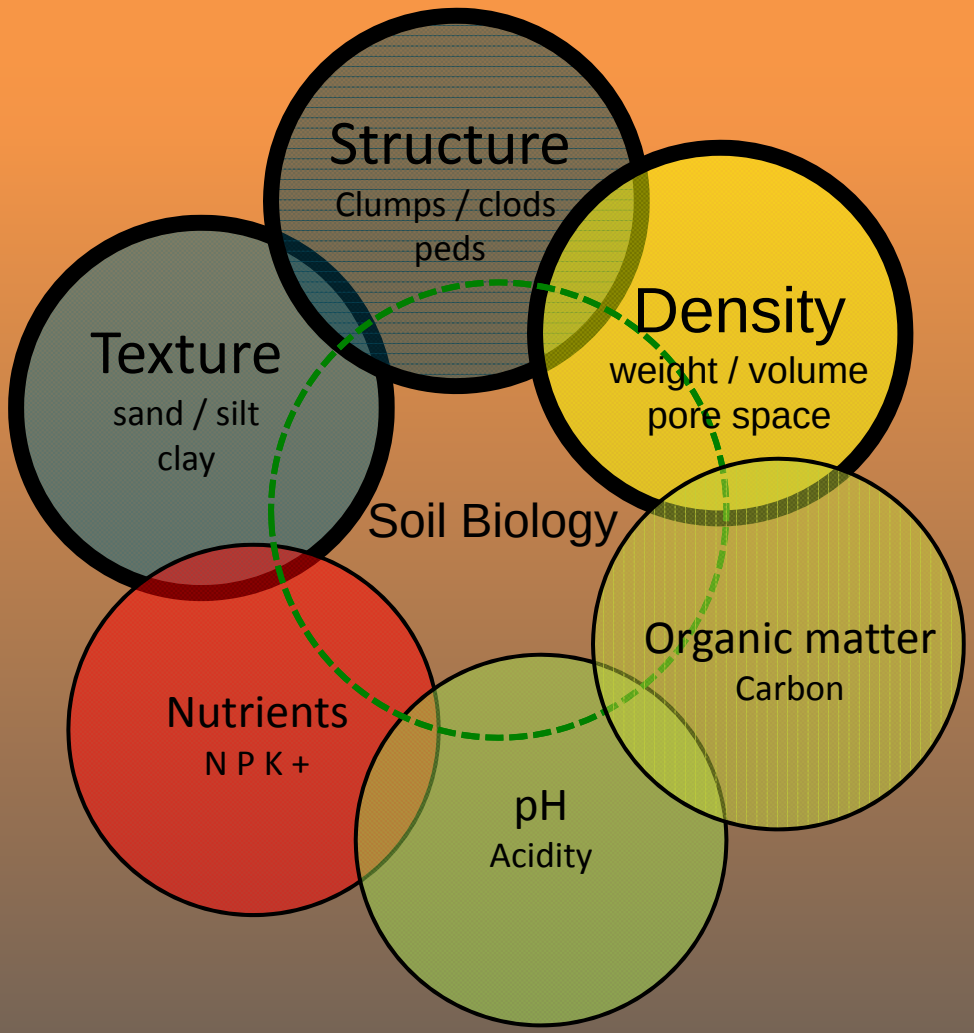


Soil properties & processes



Air and water movement / soil profile

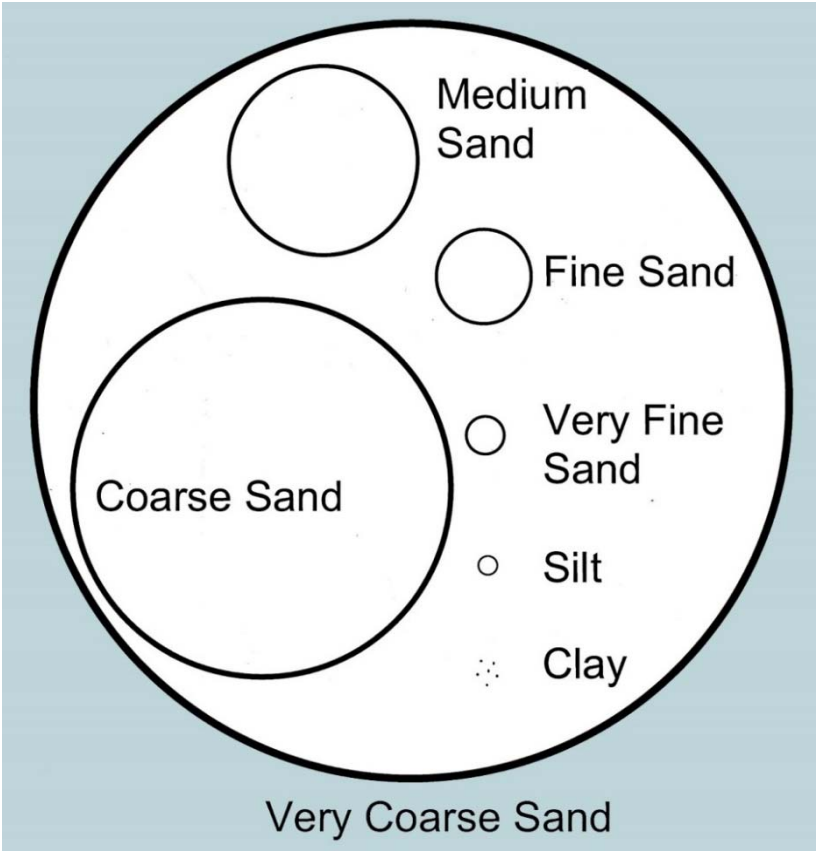
Physical properties of soil

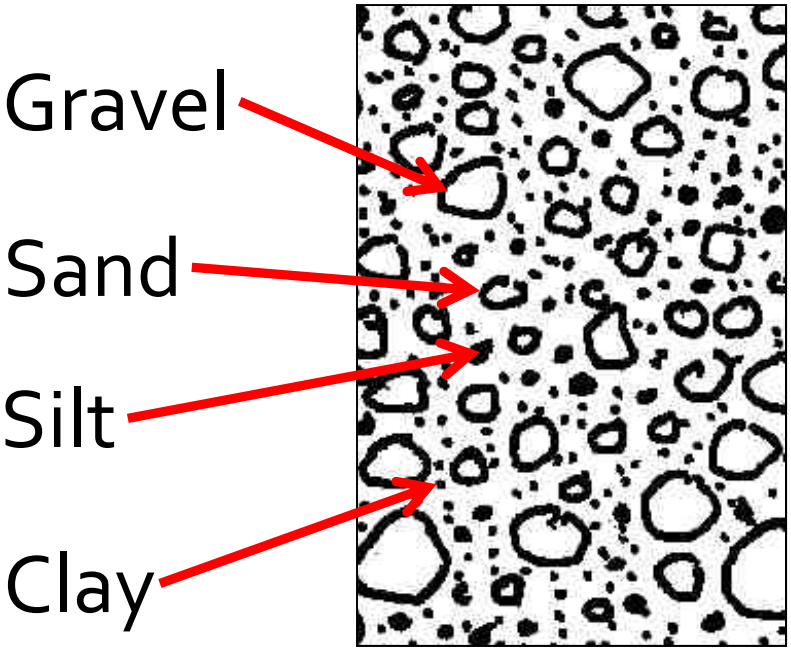


Air and water movement / **Soil Profile**

Soil Texture = particle size

- **Sandy soils** absorb water quickly, but hold less water and nutrients.
- **Clay soils** absorb water slowly, but hold more water and nutrients.





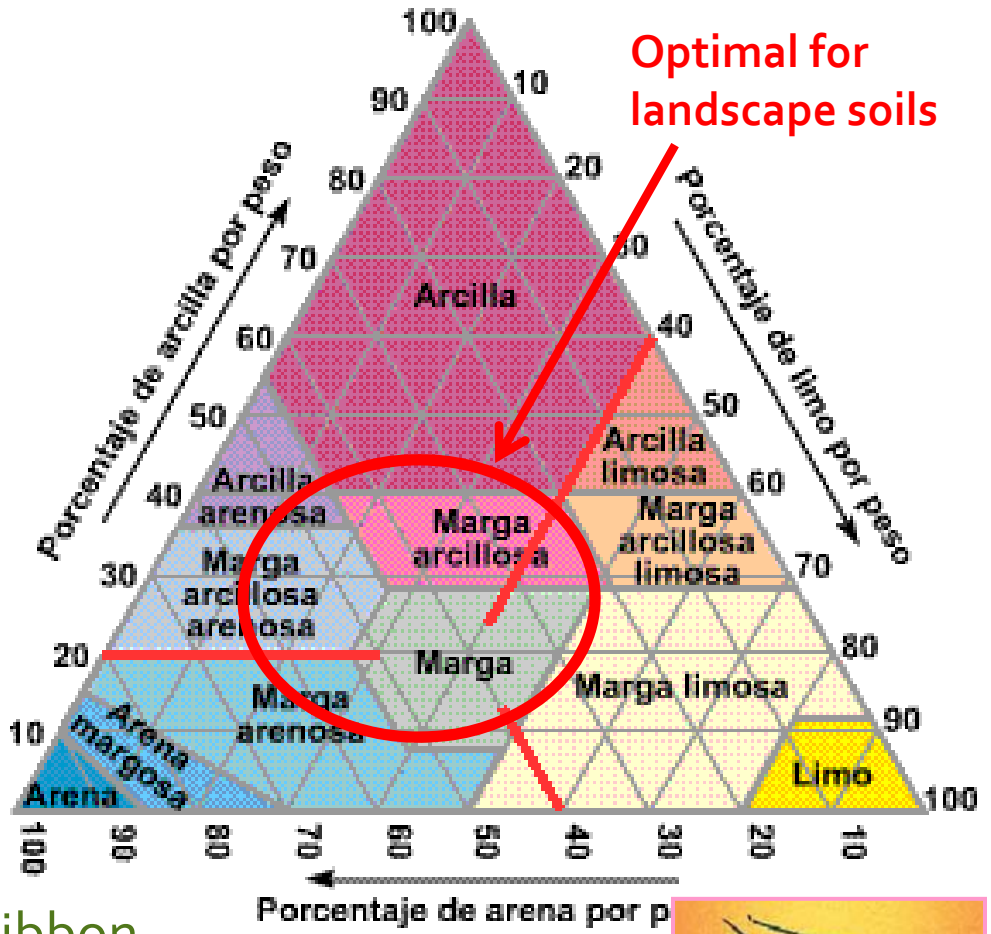
Compost helps all soil types absorb and store more water and nutrients in plant-available forms.

Soil Texture Test

Ribbon + feel test:

Moisten soil, roll between hands, then squeeze out with thumb:

- Sand: no ribbon, grainy
- Sandy loam: ½ inch ribbon
- Loam: thick 1 inch ribbon
- Silt: makes flakes rather than ribbon
- Silty clay loam: thin, breaks easily, has floury feel
- Sandy clay loam: stronger, has grainy feel
- Clay: long (3 inch) ribbon, has smooth feel



See video at http://puyallup.wsu.edu/soils/soils/

Soil Structure = strength, clods & pore spaces

- Soil life, roots, and clay stick smaller particles together into larger aggregates, clods or "peds"
- Soil life creates pore spaces, for air, water and root movement.

Peds = Clods

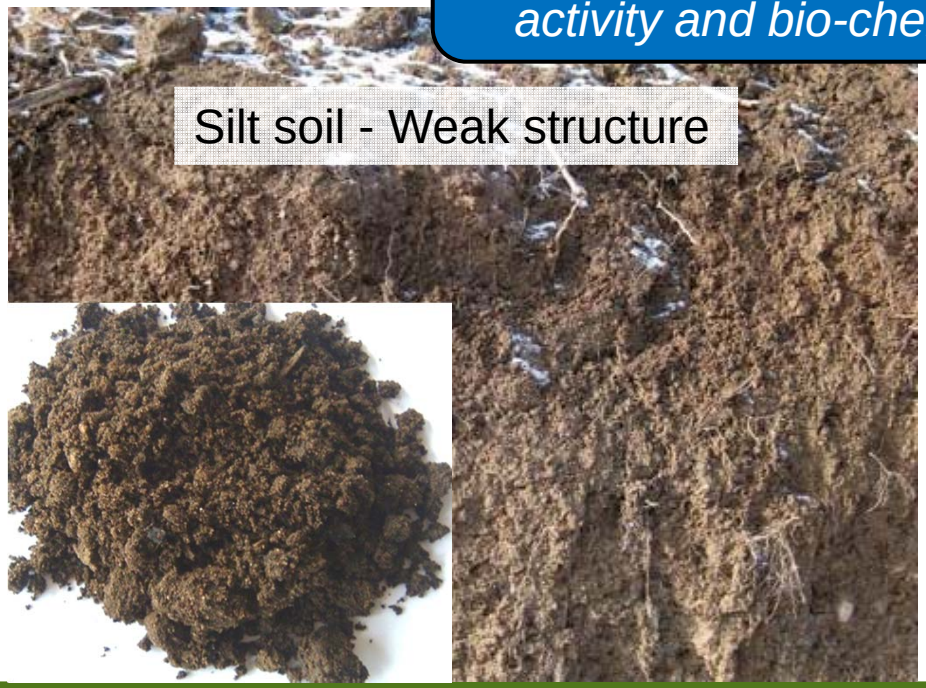
Macro-Pores

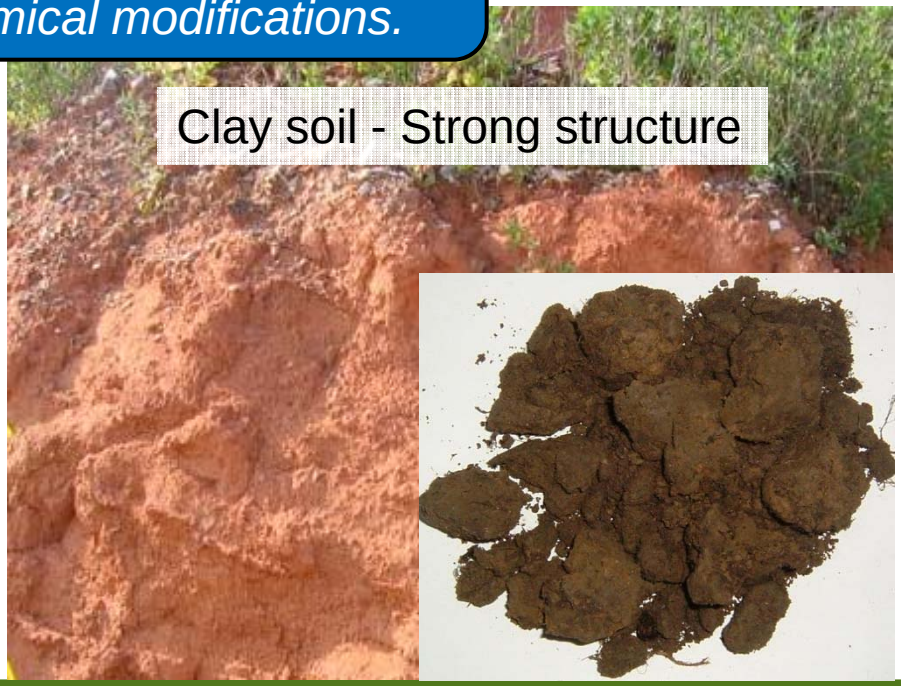
Micro-Pores

Don't grind up your soil! Mix loosely to preserve the peds & pore spaces.

Don't till wet soil – it compacts the pores.

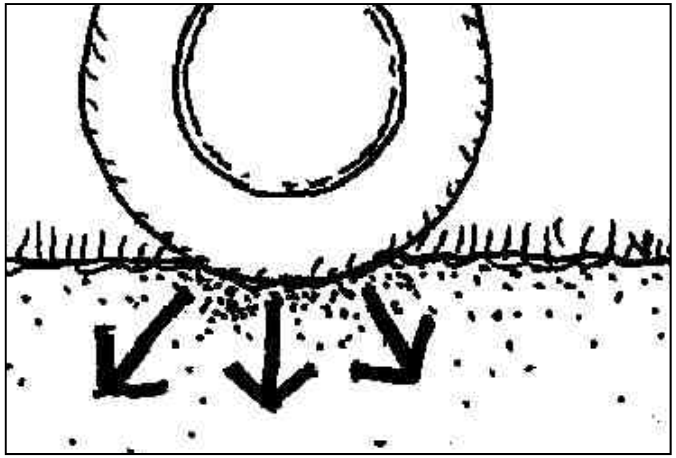
Organic amendments (compost) improve structure in all soil types, through biological activity and bio-chemical modifications.



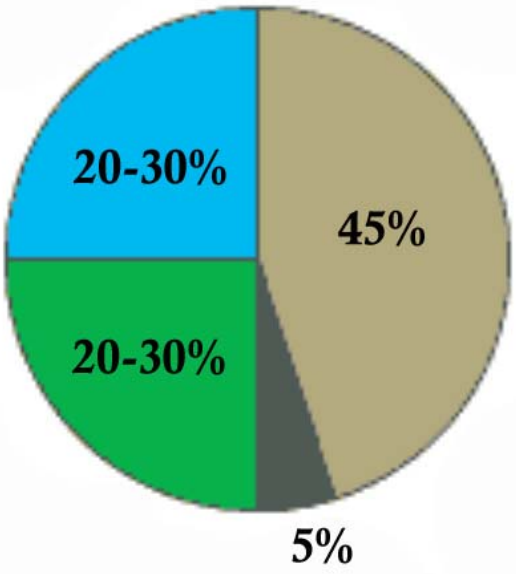


Density or Compaction

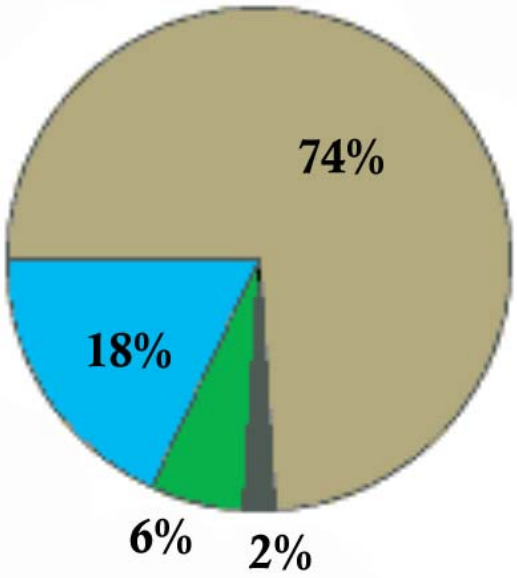
As compaction increases, pore space for water, air, and roots decreases.



Healthy soils



Compacted urban soils



Soil solid matter

Mineral

Organic

Soil pore spaces

Water

Air

Nutrients move by air and water, and roots need space, so compaction can cause nutrient deficiencies.

Compaction & grading impacts

- Tree root damage = breaking hazard & early death
- Reduced air & water penetration
- Reduced resistance to disease
- Less beneficial soil life
- Less nutrient availability
- Less root space
- Poor plant growth!

Roseville Urban Forest foundation, www.rosevilletree.org

Causes of soil compaction

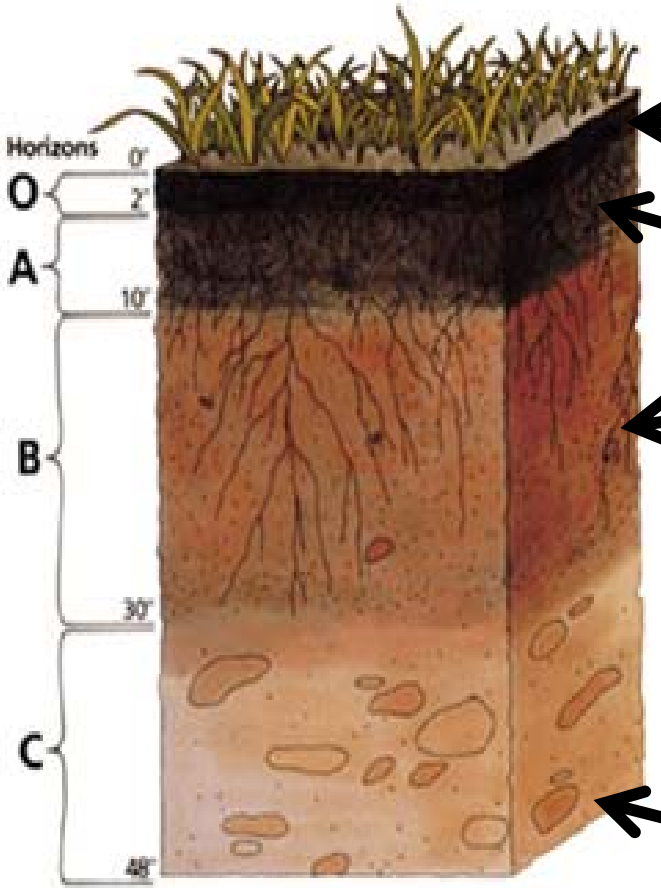
- Topsoil removal
- Loss of organic matter
- Vehicle and foot traffic
- Excessive tilling, especially wet soils
- Overuse of soluble fertilizers and pesticides, which damage soil life.

Restoring compacted soils:

- Rip or loosely till to incorporate compost, but leave clods intact
- Maintain mulch layers on beds, and mulch mow lawns, leaving clippings to feed soil life
- Reduce use of soluble fertilizers and pesticides.

Soil profile

Adding fill layers can create "interfaces" = sharp changes in soil texture that limit air, water, and root movement.



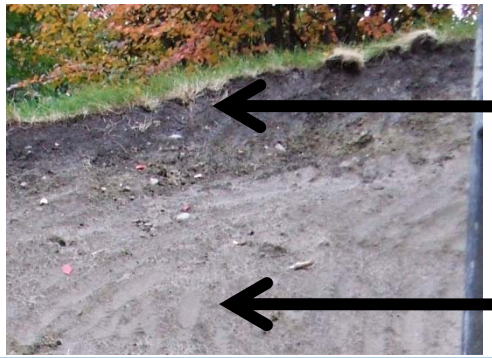
Organic duff (natural mulch)

Topsoil

Subsoil

Rock, native mineral soil

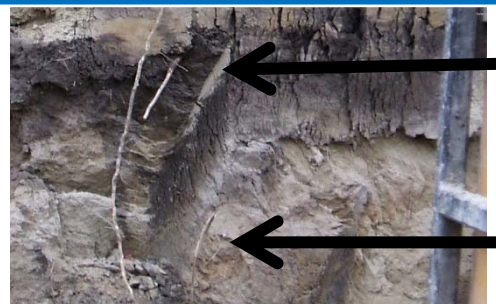
Natural soil profile



Imported topsoil

Fill soil

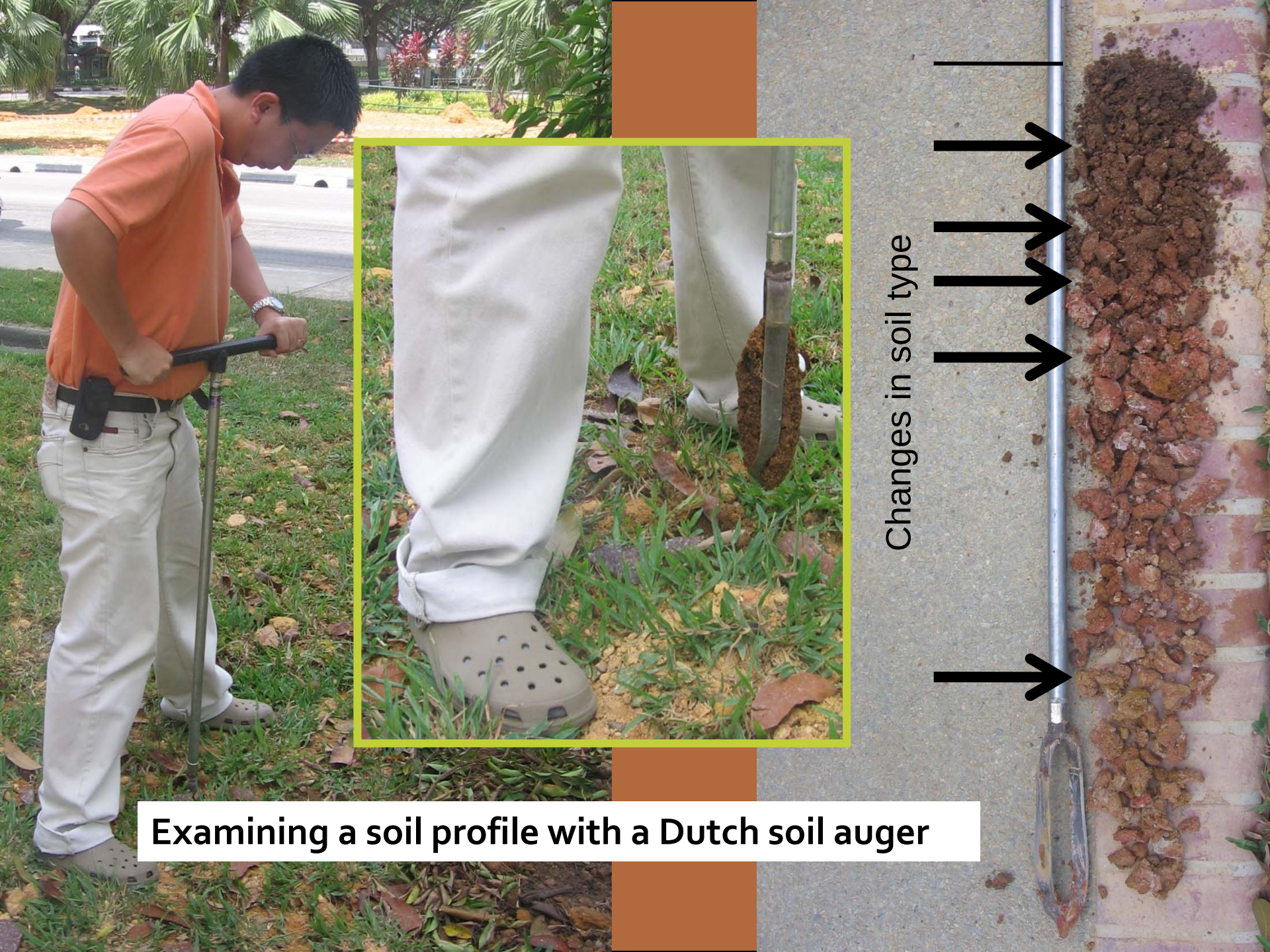
When adding fill is necessary, always rip or till new layer into several inches of lower layer, to avoid interface problems.



Remnant topsoil

Remnant subsoil

Disturbed urban soil



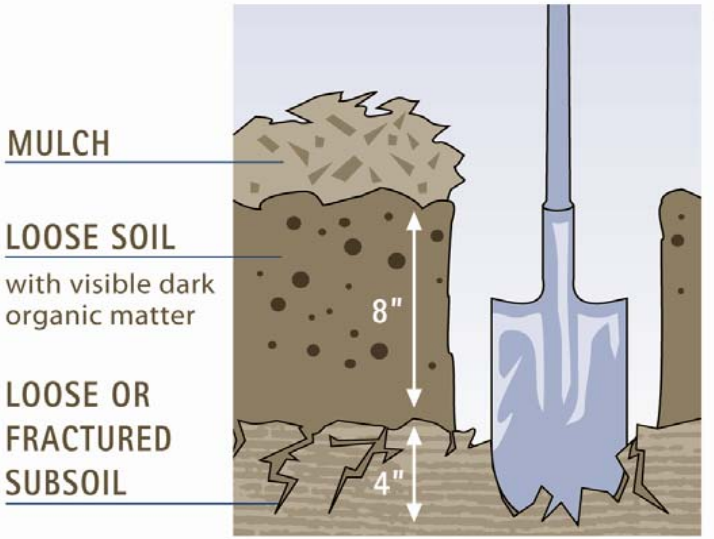
Examining a soil profile with a Dutch soil auger

Examining a soil profile with a soil probe / core sampler

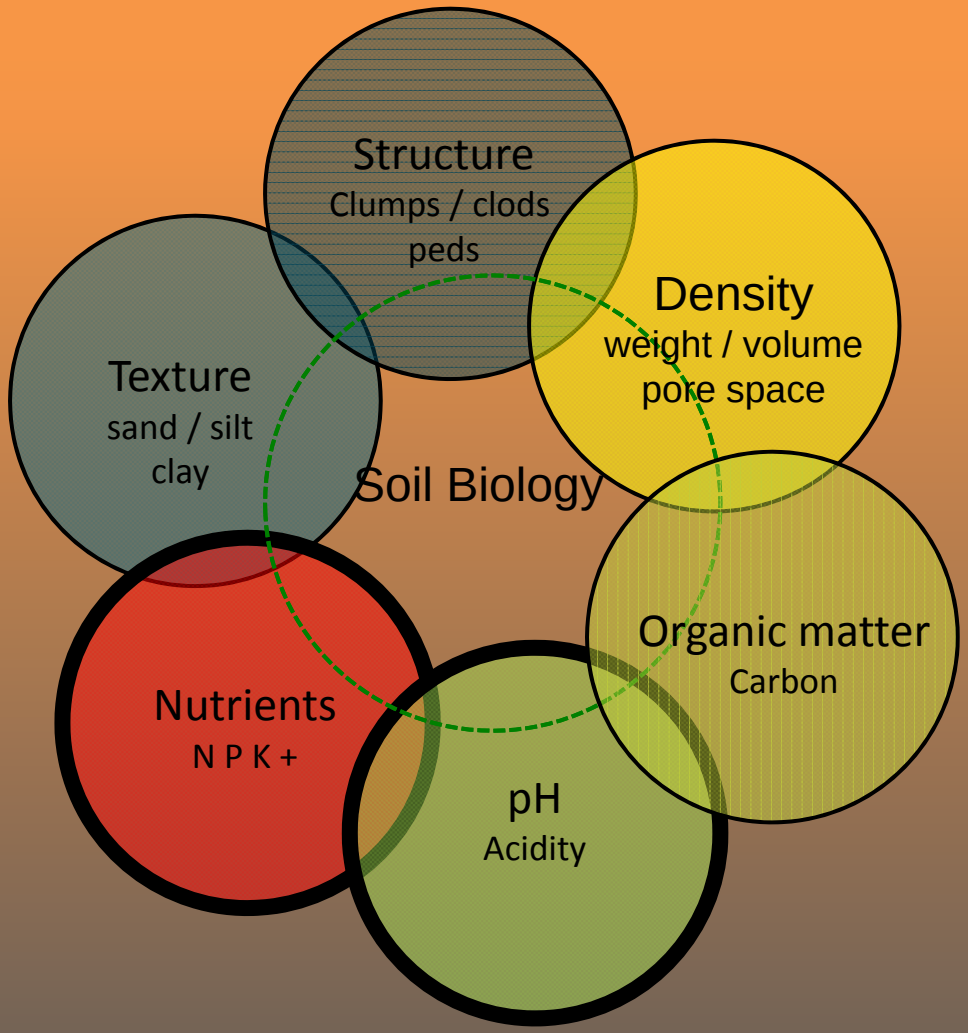
Only works 6 -12" deep, so better for lawns than trees.

Compacted vs. Amended

Examining soil profile with shovel

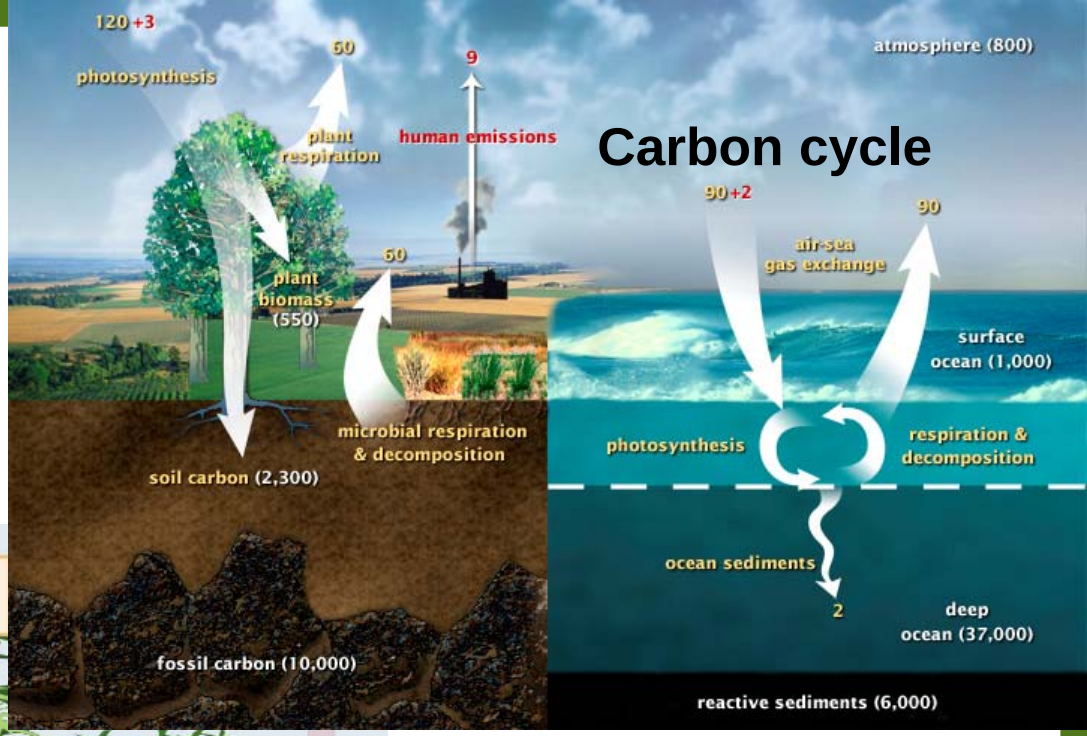


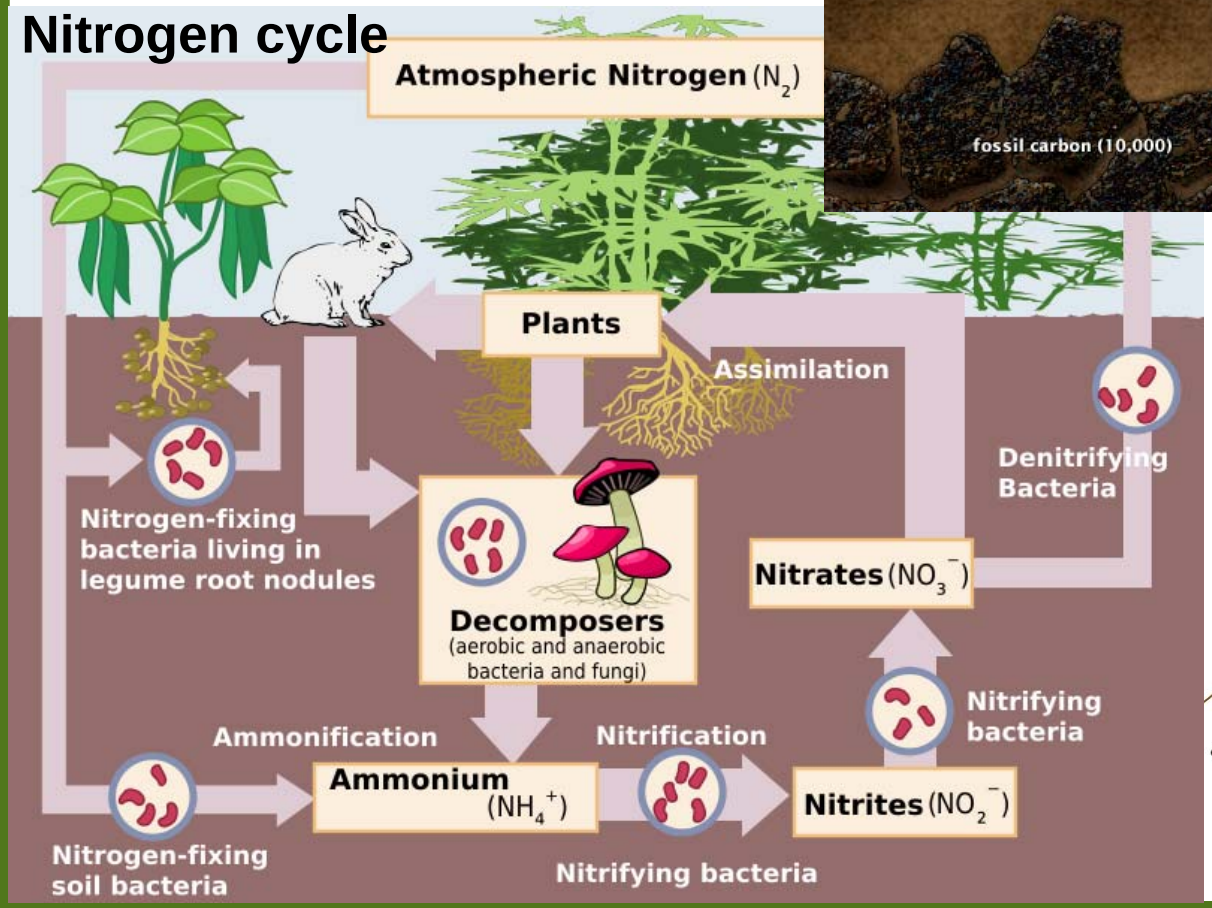
Chemical properties of soil

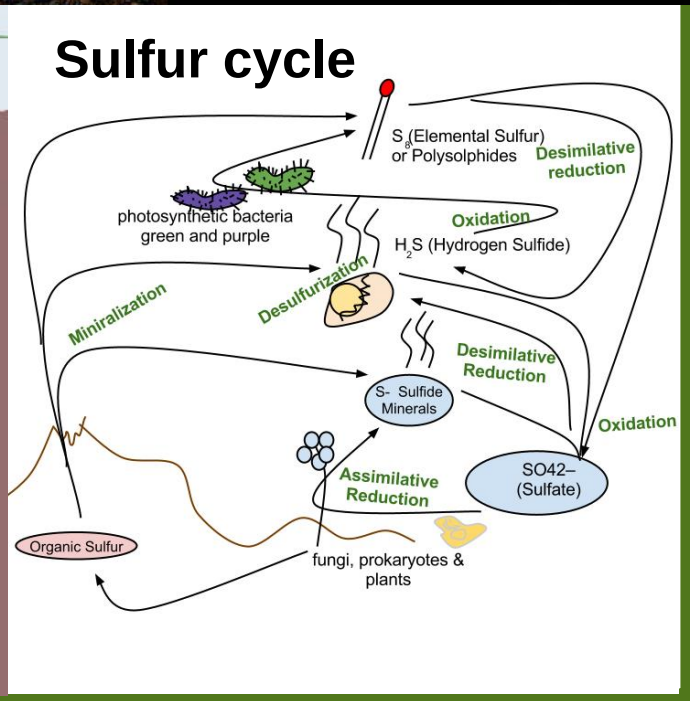


Air and water movement / soil profile

Chemical properties of soil = *endless cycles*







Elements (nutrients) required by plants

air & water

Base elements

Oxygen (O)

Hydrogen (H)

Carbon (C)

soil (bacteria fix N from air)

Macronutrients

Nitrogen (N)

Phosphorus (P)

Potassium (K)

Calcium (Ca)

Magnesium (Mg)

Sulfur (S)

Micronutrients

Boron (B)

Chlorine (Cl)

Cobalt (Co)

Copper (Cu)

Iron (Fe)

Manganese (Mn)

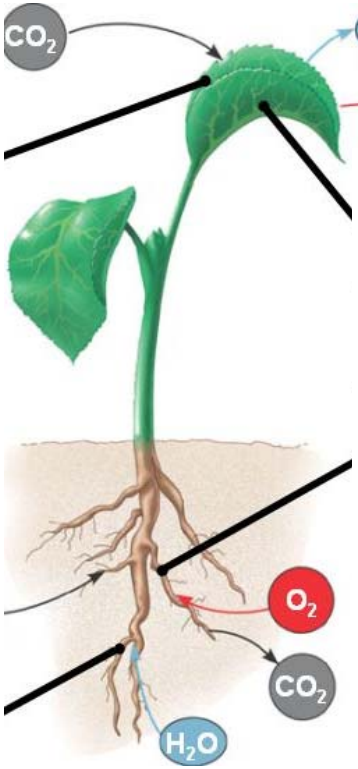
Molybdenum (Mo)

Zinc (Zn)

How plants get nutrients

Sunlight provides energy for **photosynthesis**:

Plants use carbon dioxide and water to make sugar and starch, for energy and structures.



Leaf pores absorb carbon dioxide, and expel oxygen and water.

Beneficial fungi & bacteria help plants get nutrients and water. Roots also "breathe": exchange oxygen and carbon dioxide.

Roots absorb mineral nutrients and water from soil.

image: extension.missouri.edu

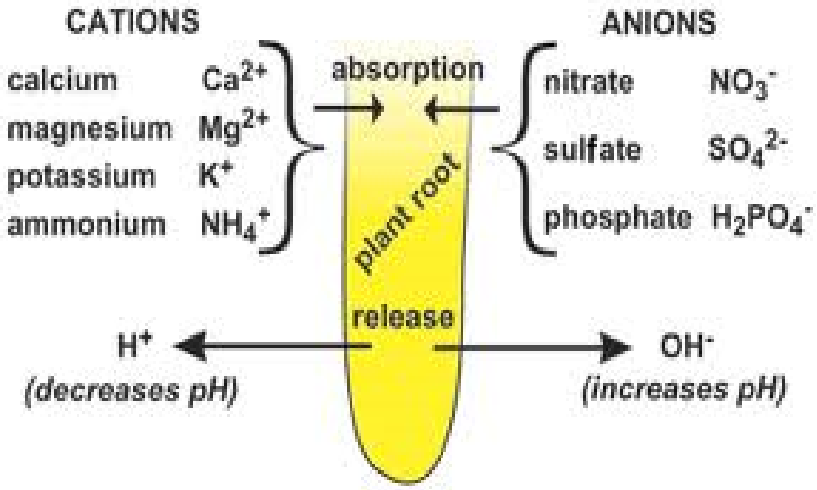
Plants get their essential nutrients from the soil. Fertilizers supplement, but don't replace soil fertility.

Cation Exchange Capacity (CEC)

Cations = positively charged nutrients, dissolved in water in soil

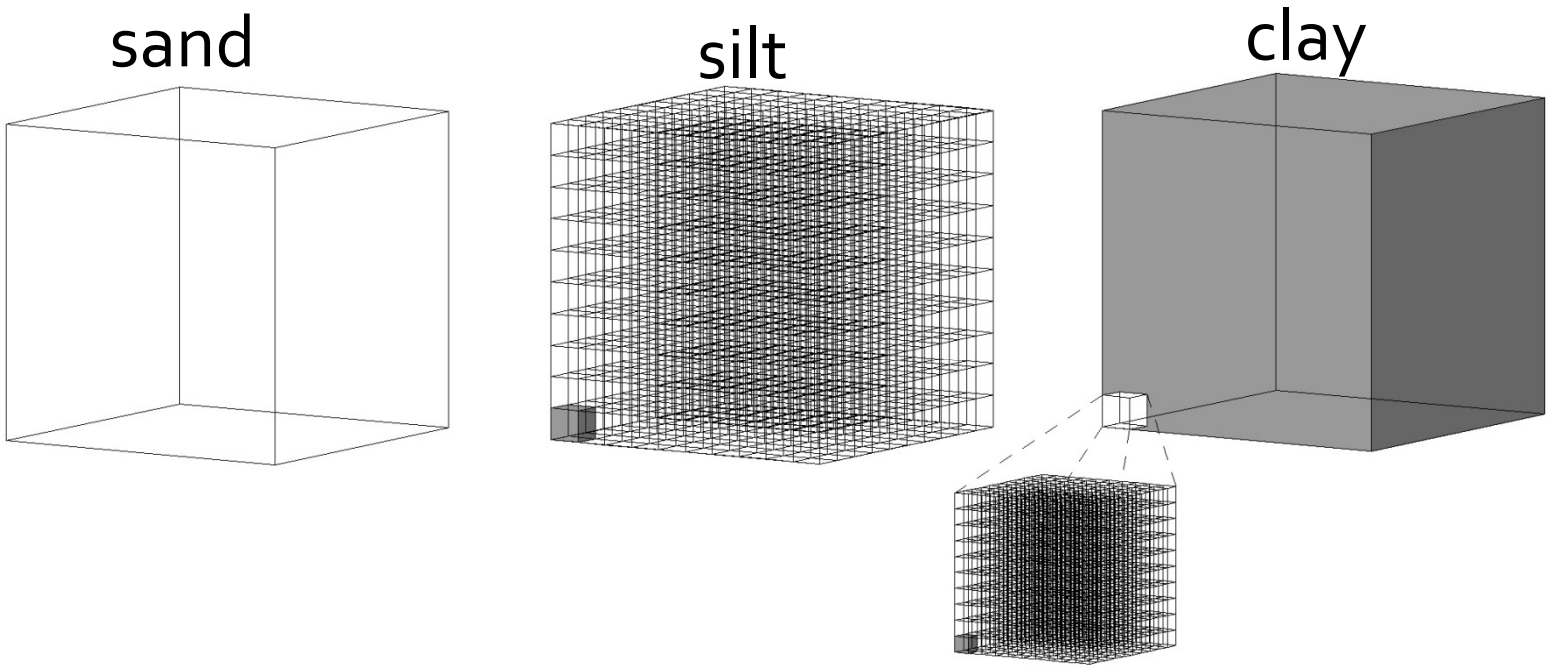
Cation Exchange Capacity (CEC) is the ability of soil particles to hold and release nutrients for use by plants and micro-organisms.

CEC determines which nutrients are available for uptake by plant roots and which nutrients remain in soil and are not available to plants.



Clay and organic-rich soils provide more nutrients

Clay or silt soils have more surface area than sand, so have more Cation Exchange Capacity = more nutrient availability



Compost and soil organic matter (“humus”) increase CEC nutrient-holding capacity, from a CEC of 5 in sandy soils up to 200!

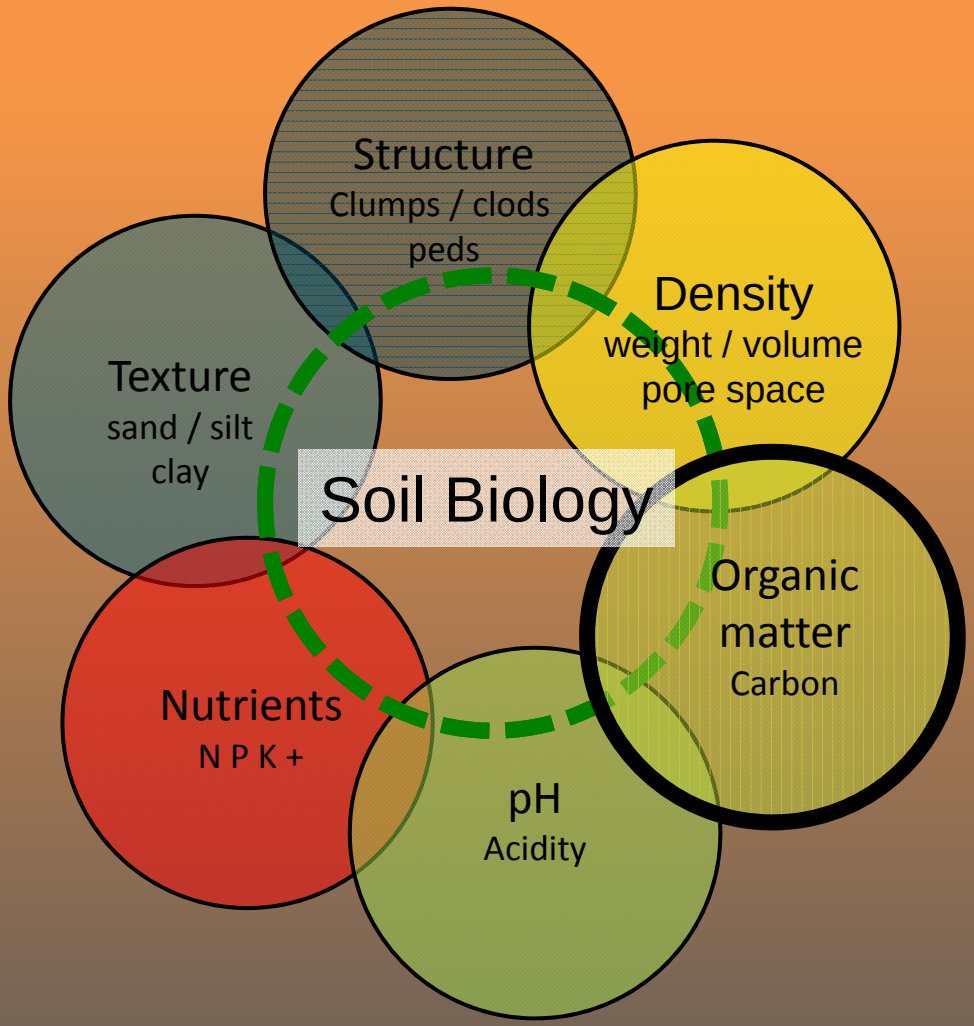
pH = Acidity ↔ Alkalinity

Lowering pH (increasing acidity) increases availability of cations, but decreases availability of anions

Humus (compost) buffers soil pH towards 6.3 to 6.8, which is optimal for nutrient availability.

Acid	**pH range**	
Ultra acid	1.8 - 3.4	Toxic to most plants
Extremely acid	3.5 - 4.4	Restrictive to most plants
Very strong acid	4.5 - 5.0	
Strongly acid	5.1 - 5.5	Acid-tolerant plants
Moderately acid	5.6 - 6.0	
Slightly acid	6.1 - 6.5	Best nutrient availability for most plants
Neutral = 7	6.6 - 7.3	
Slightly alkaline	7.4 - 7.8	Alkaline-tolerant plants
Moderately alkaline	7.9 - 8.4	
Strongly alkaline	8.5 - 9.0	Restrictive to most plants
Very strongly alkaline	9.1 - 11.0	Toxic to most plants
Alkaline		

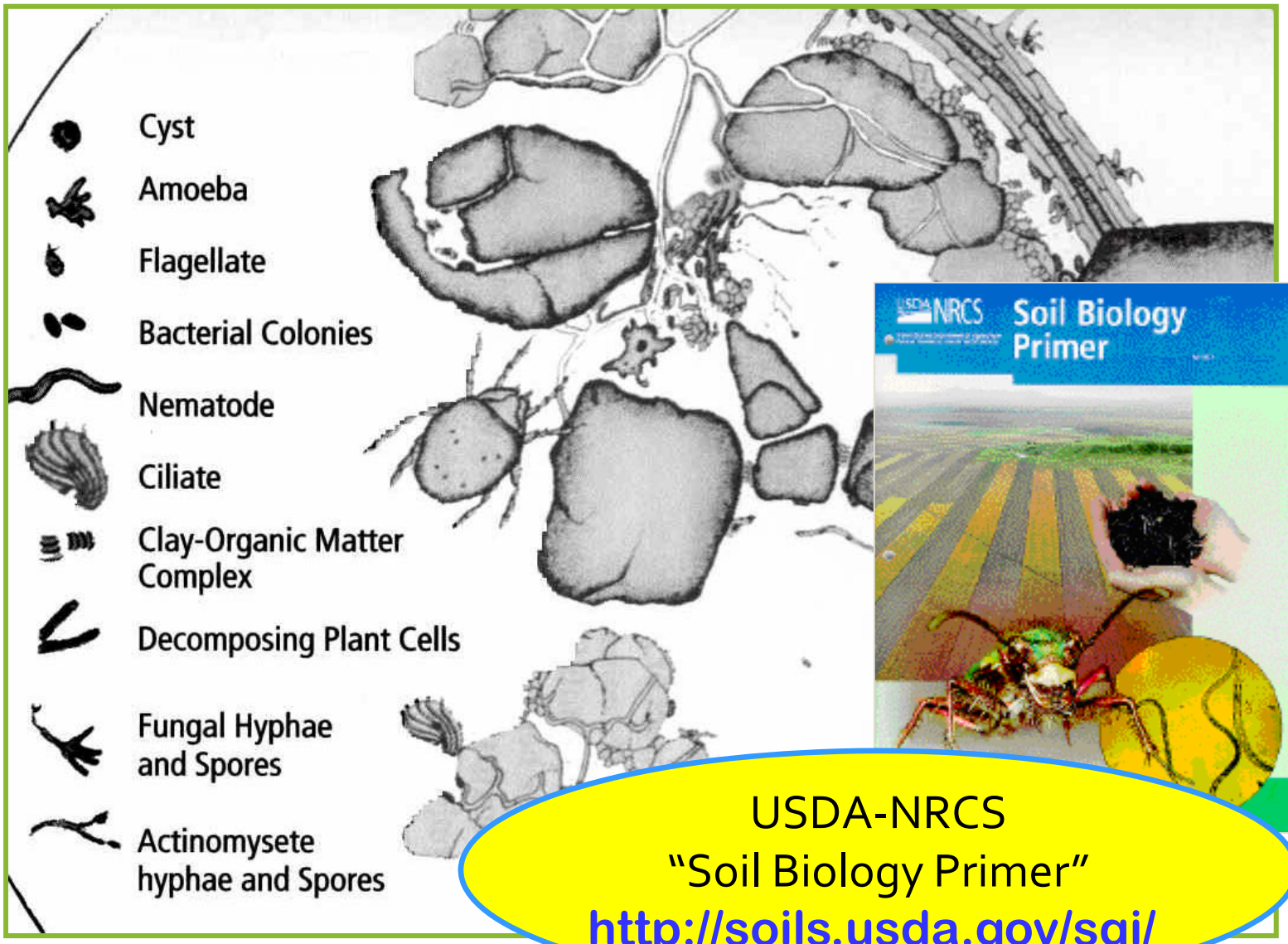
Organic & Biological properties of soil



Air and water movement / soil profile

Soil life provides essential functions

Soil is alive!

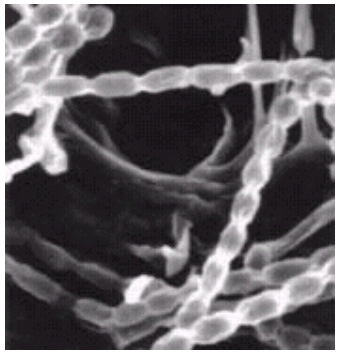


USDA-NRCS
"Soil Biology Primer"
http://soils.usda.gov/sqi/

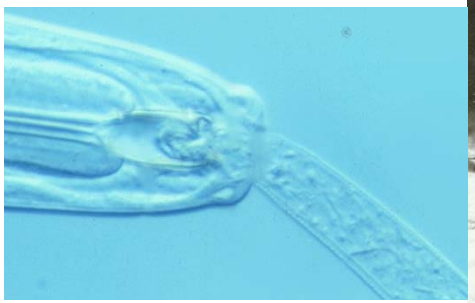
S. Rose & E.T. Elliott

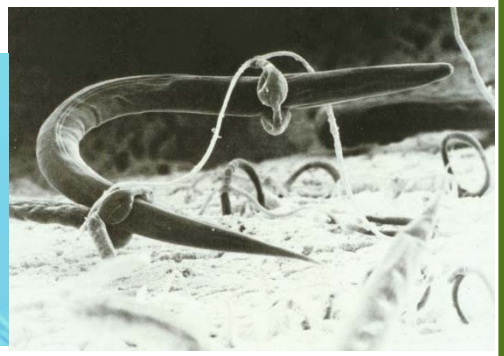
Common organisms in the soil ecosystem

Bacteria

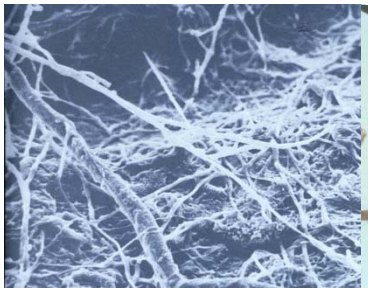


Nematodes



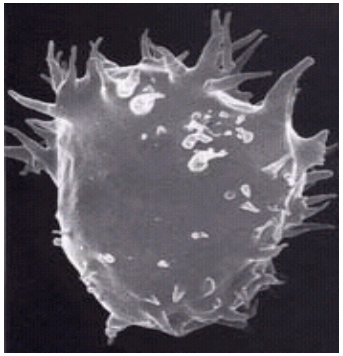


Fungi

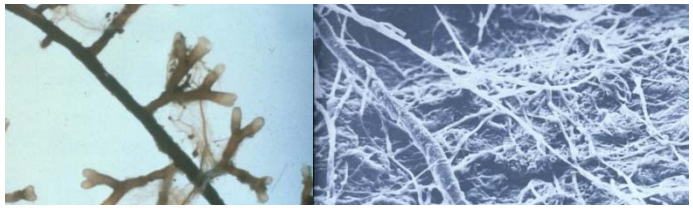


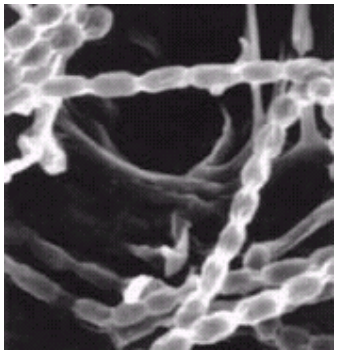
Arthropods

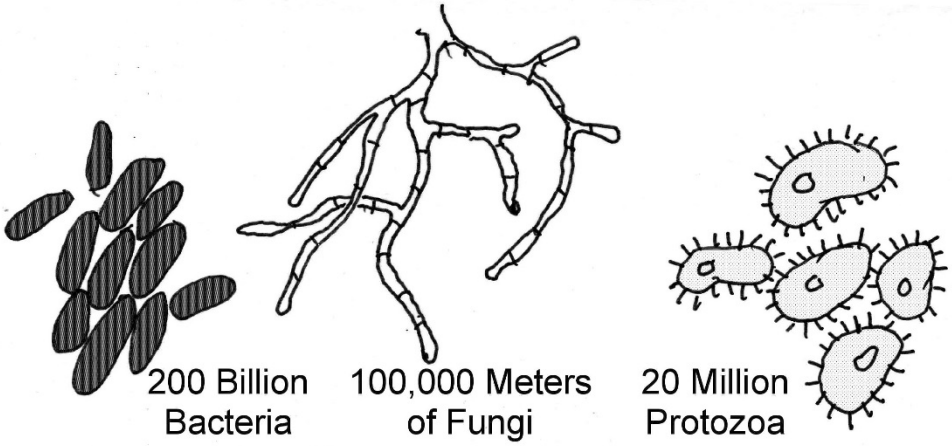
Protozoa

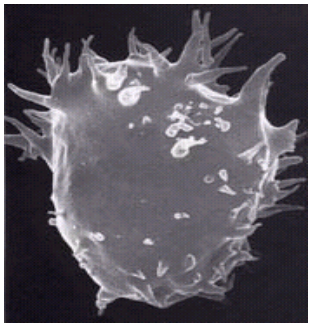


Earthworms



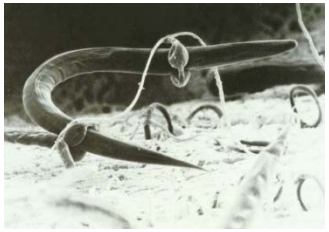


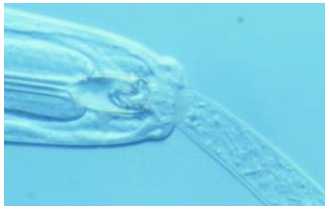




One cup of healthy soil can contain…

Avoid broadcast use of herbicides, insecticides, and fungicides, to protect beneficial soil life.





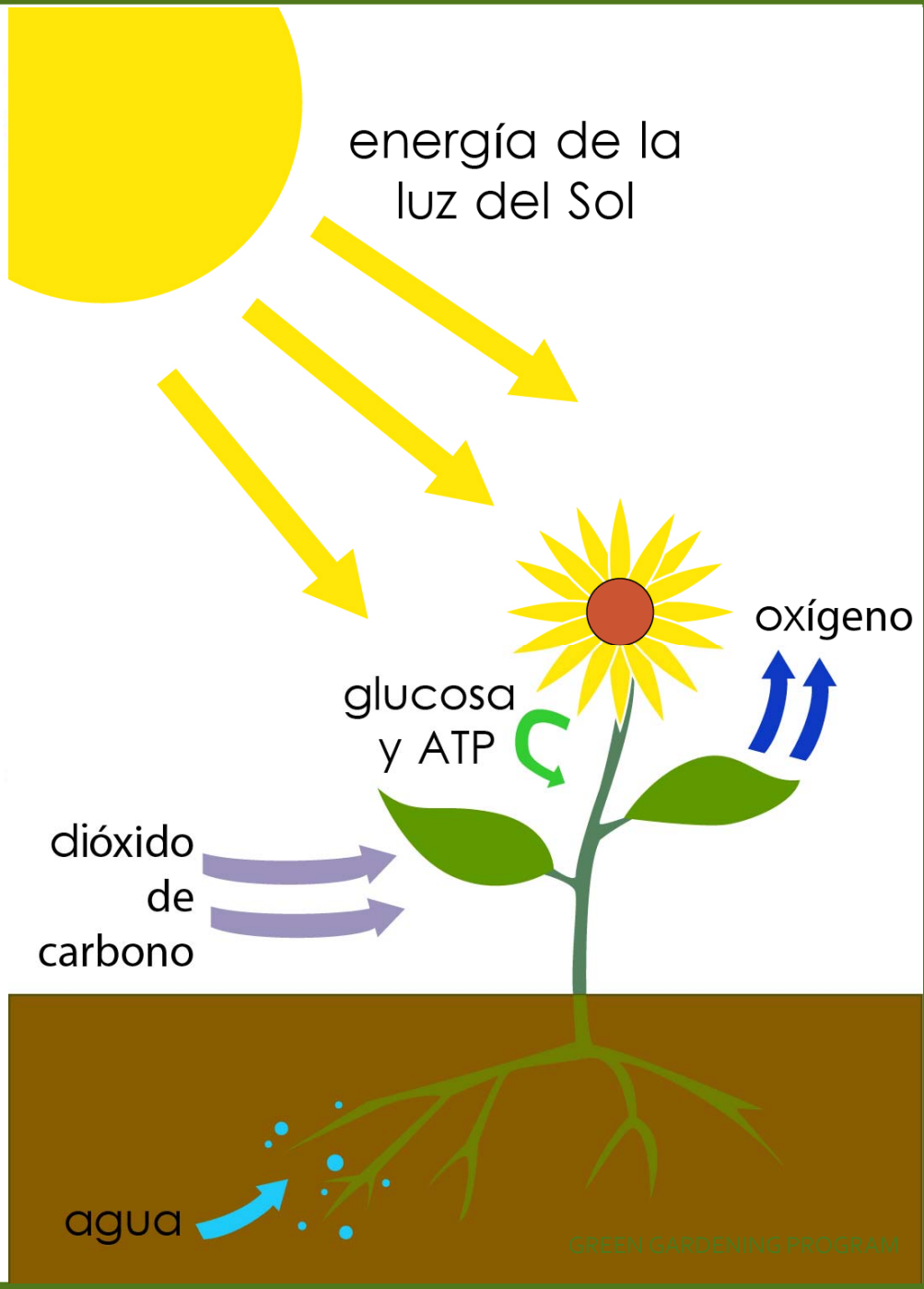
What fuels the soil ecosystem?

Plant **photosynthesis**:

Sunlight + CO_2 + water → carbohydrates (sugars)+ energy

Plants release 20-30% of their carbohydrates into their root zone to feed beneficial soil organisms (bacteria & fungi).

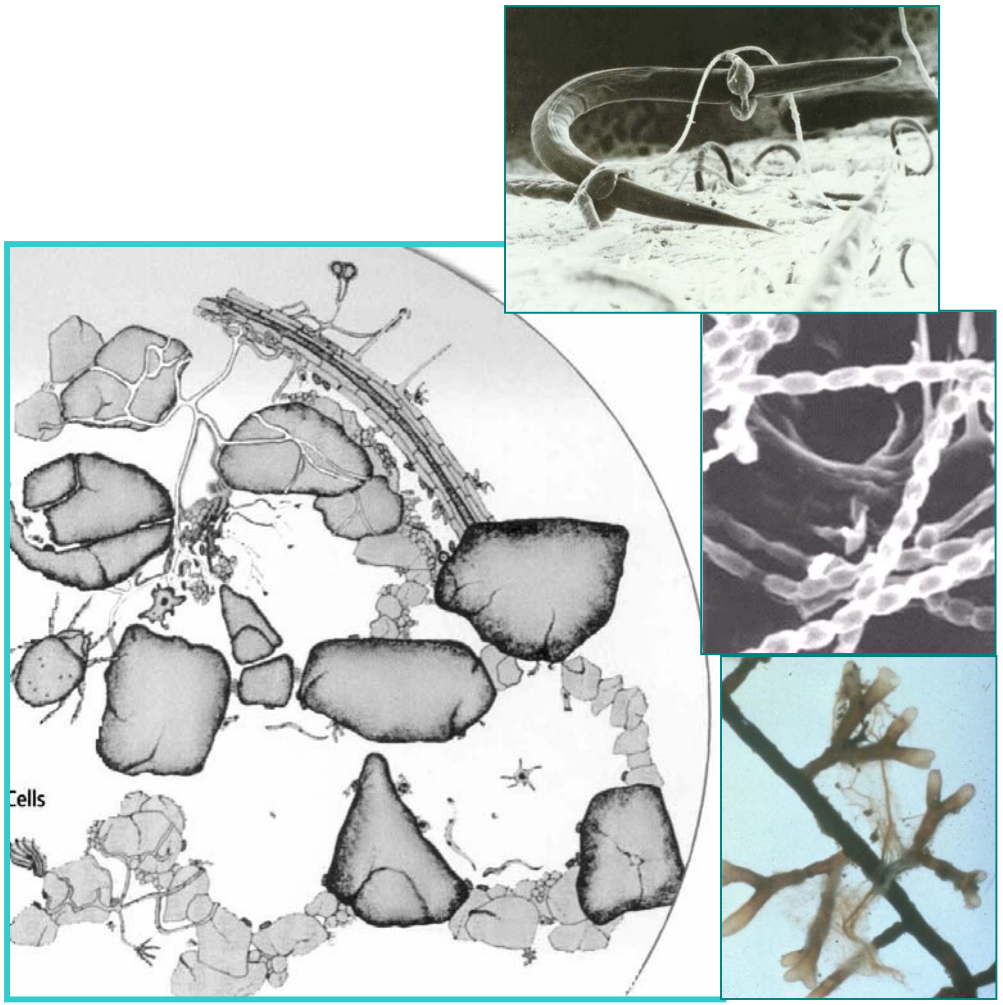
Dead plants, leaves & roots also feed soil life.



Restore soil life, to restore soil functions

Soil organisms create:

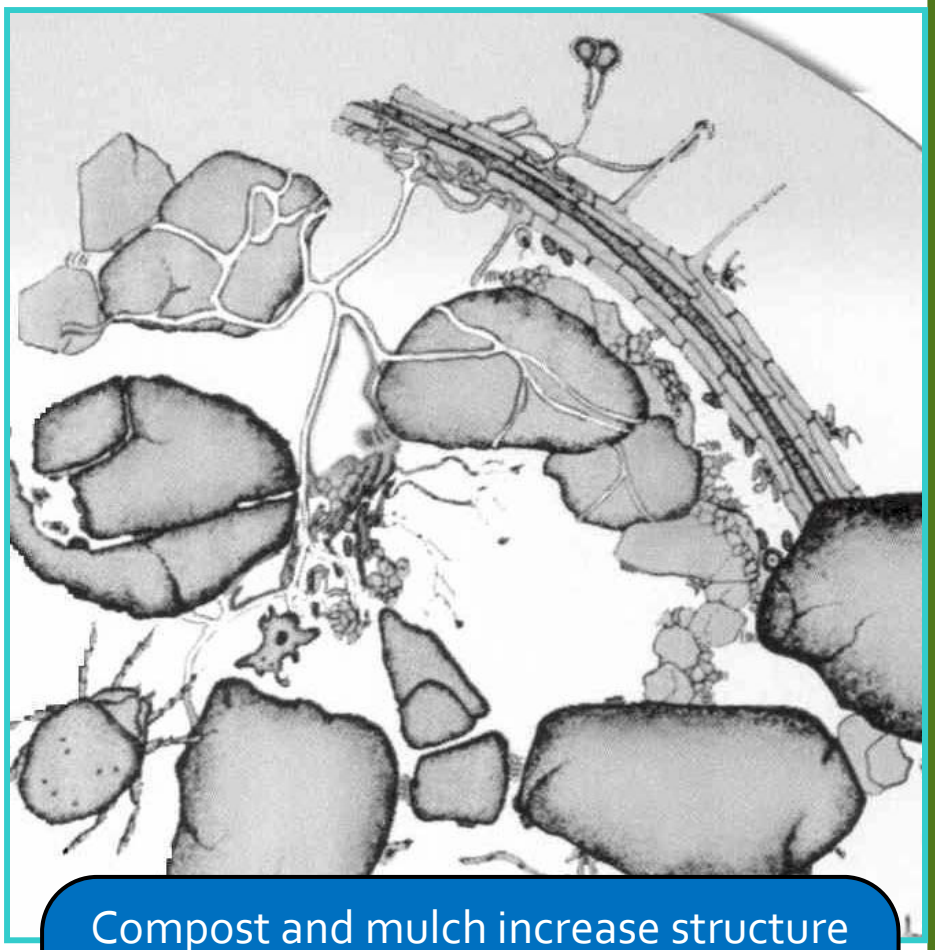
- Soil structure
- Fertility = nutrient cycling
- Plant disease protection
- Bio-filtration of pollutants
- Erosion control
- Storm water detention & moisture capacity



Compost helps restore healthy soil function, by feeding and providing homes for the beneficial soil organisms.

How does soil life create soil structure?

- Bacteria secretions glue clays, silts and sands together into micro-aggregates.
- Micro-aggregates are bound together by fungi and roots.
- Spaces are made by moving arthropods & earthworms, and decaying roots.
- Only when all organisms are present can roots and water move into the soil easily.



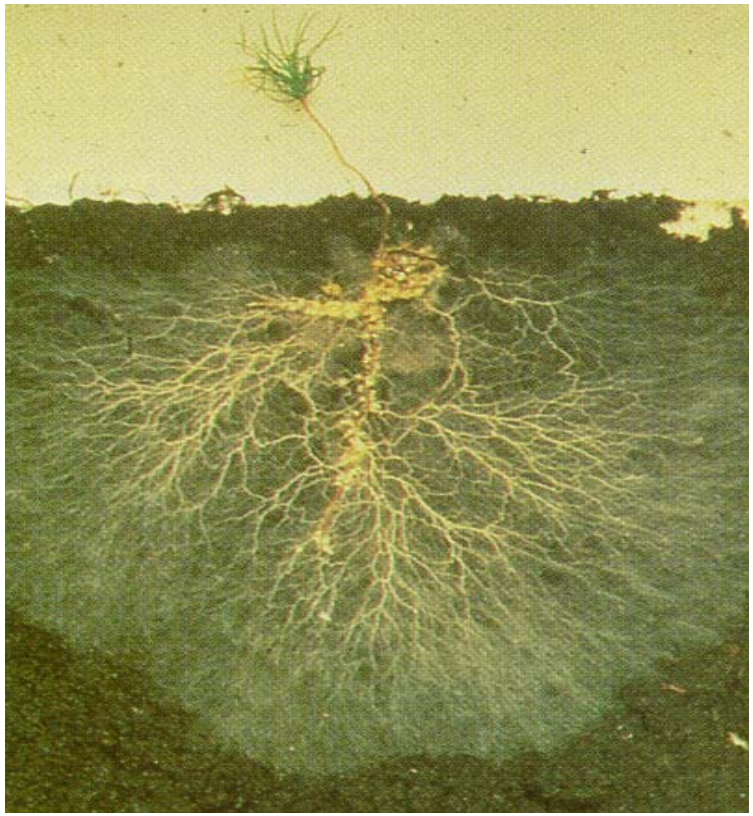
Compost and mulch increase structure and pore space.
That increases soil water holding capacity, helping protect plants from summer drought.

How does soil life provide fertility (nutrient cycling)?

- Soil ecosystem stores nutrients in living & dead organic matter
- Nutrients are released in root zone as organisms eat and excrete "waste" (nitrogen, etc.)
- Mycorrhizal fungi* bring nutrients and water to roots of plants

*"Mycorrhizal" means "root fungus". Most plants have these beneficial fungi in their roots. They grow out into the soil to bring water and nutrients to the plant, and protect the plant from disease.

The plant provides carbohydrates (sugar) to the fungus.

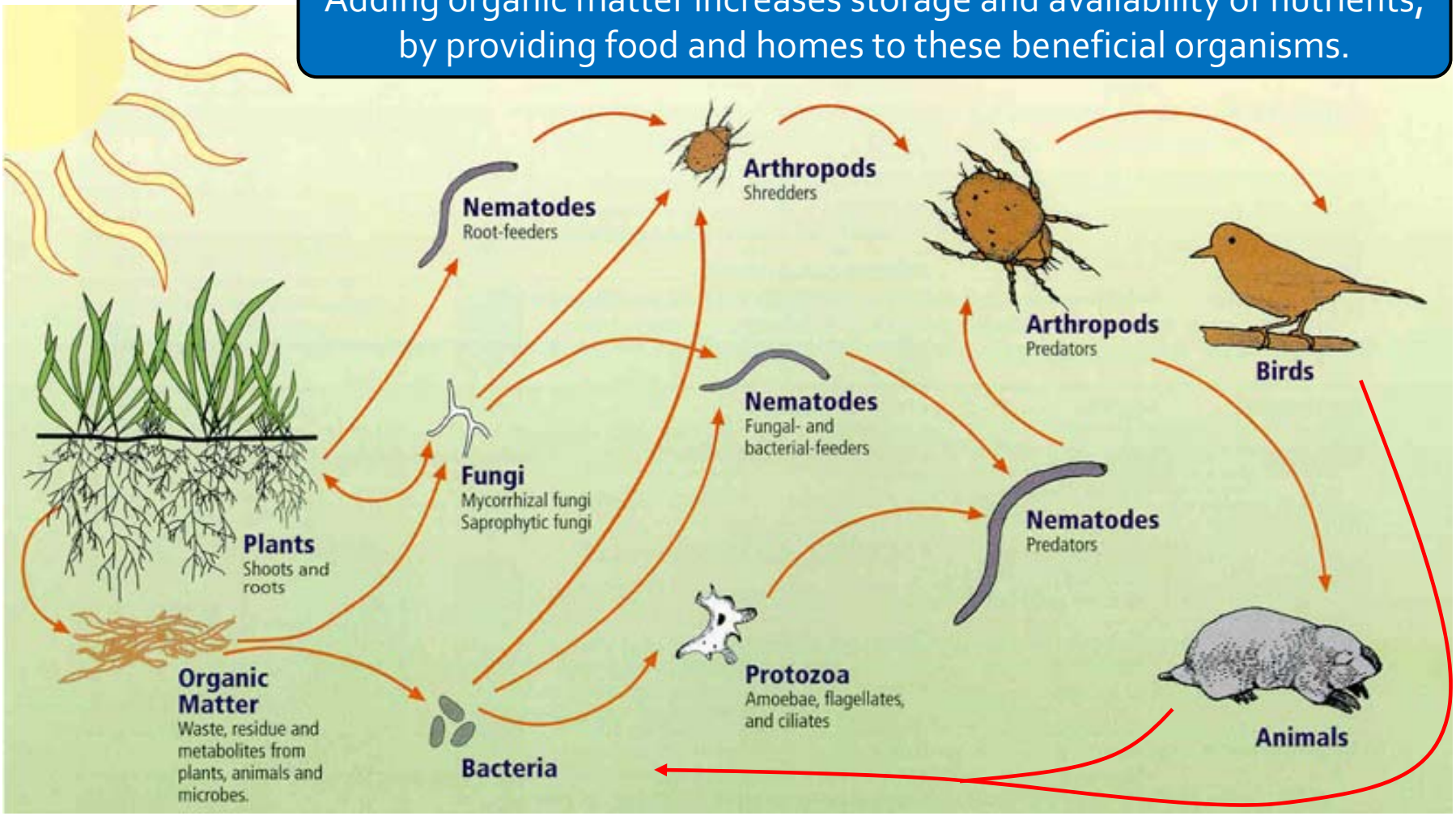


Dr. Michael P. Amaranthus, Mycorrhizal Applications Inc.

The soil food web

Nutrients are stored when organisms eat & grow, and released to plants when organisms excrete excess nutrients, or die and decay.

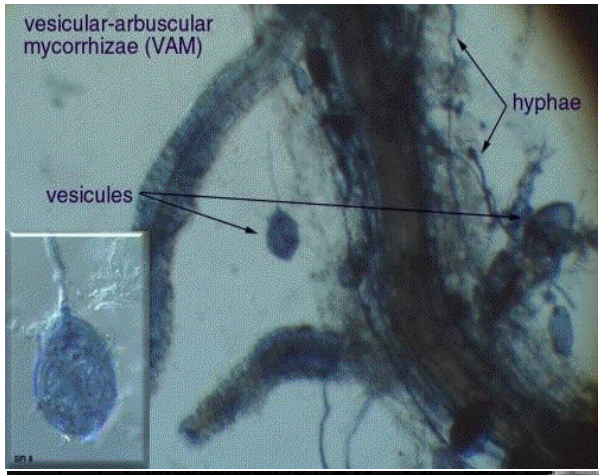
Adding organic matter increases storage and availability of nutrients, by providing food and homes to these beneficial organisms.

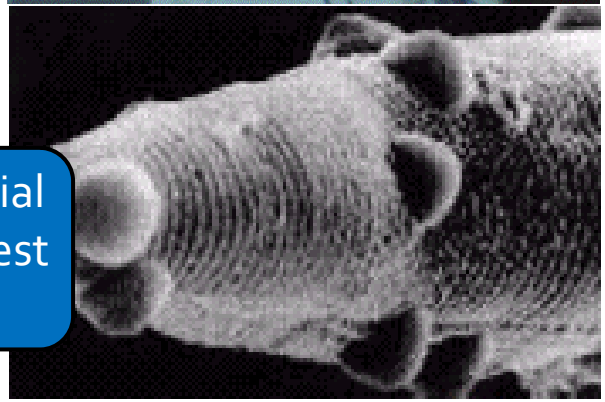


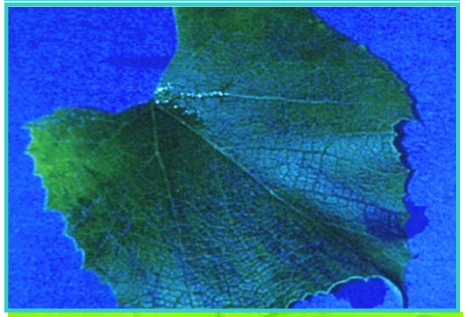
How does soil life provide plant disease protection?

Diversity ⇒ predation, parasitization & competition with the few disease-causing organisms

- Bacteria cover leaf surfaces, block infection
- Mycorrhizae prevent root infection
- Many organisms prey on the few disease-causing organisms







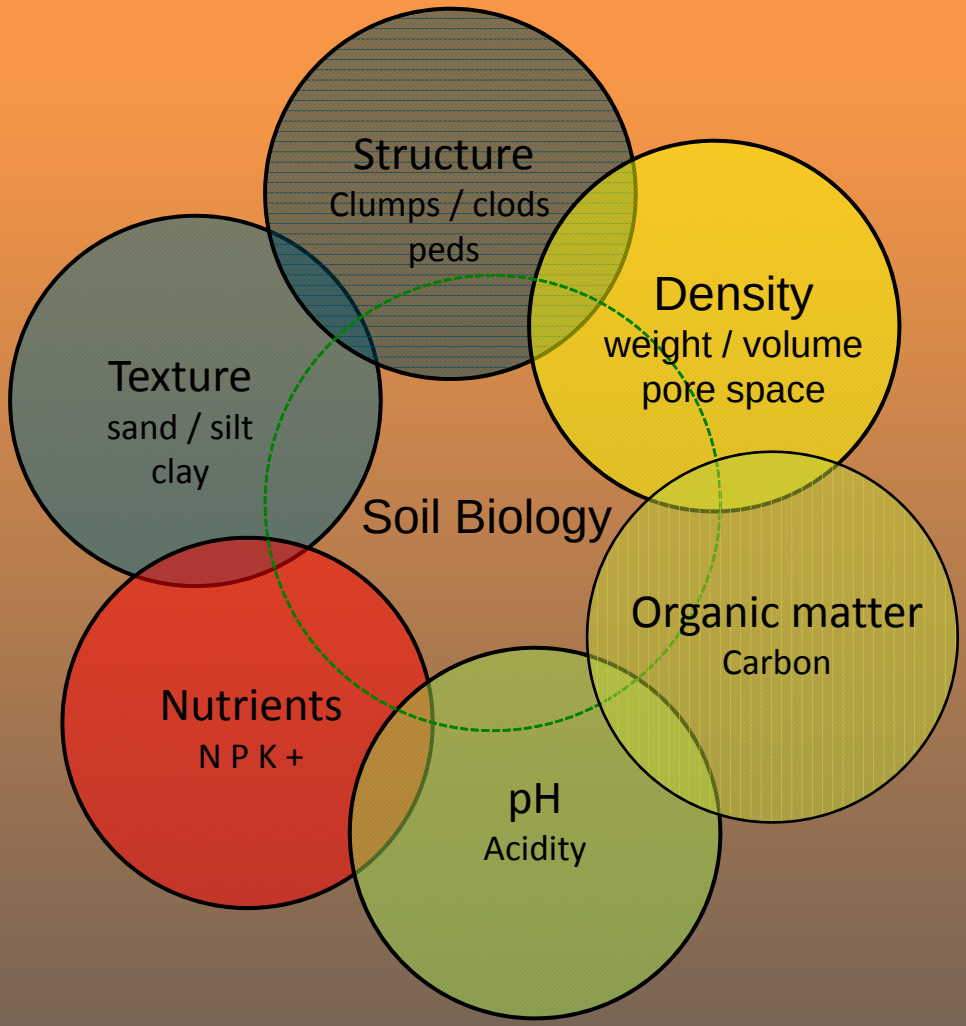
Pesticides often disrupt beneficial organisms, causing increased pest problems over time.

How can we restore soil organisms, to improve soil moisture & nutrient capacity, and plant growth?

- Prevent /reduce compaction (keep heavy machinery off)
- Reduce intensive use of pesticides & soluble fertilizers
- Incorporate compost into soil, leave grass clippings & leaf litter, and mulch regularly, to feed soil life

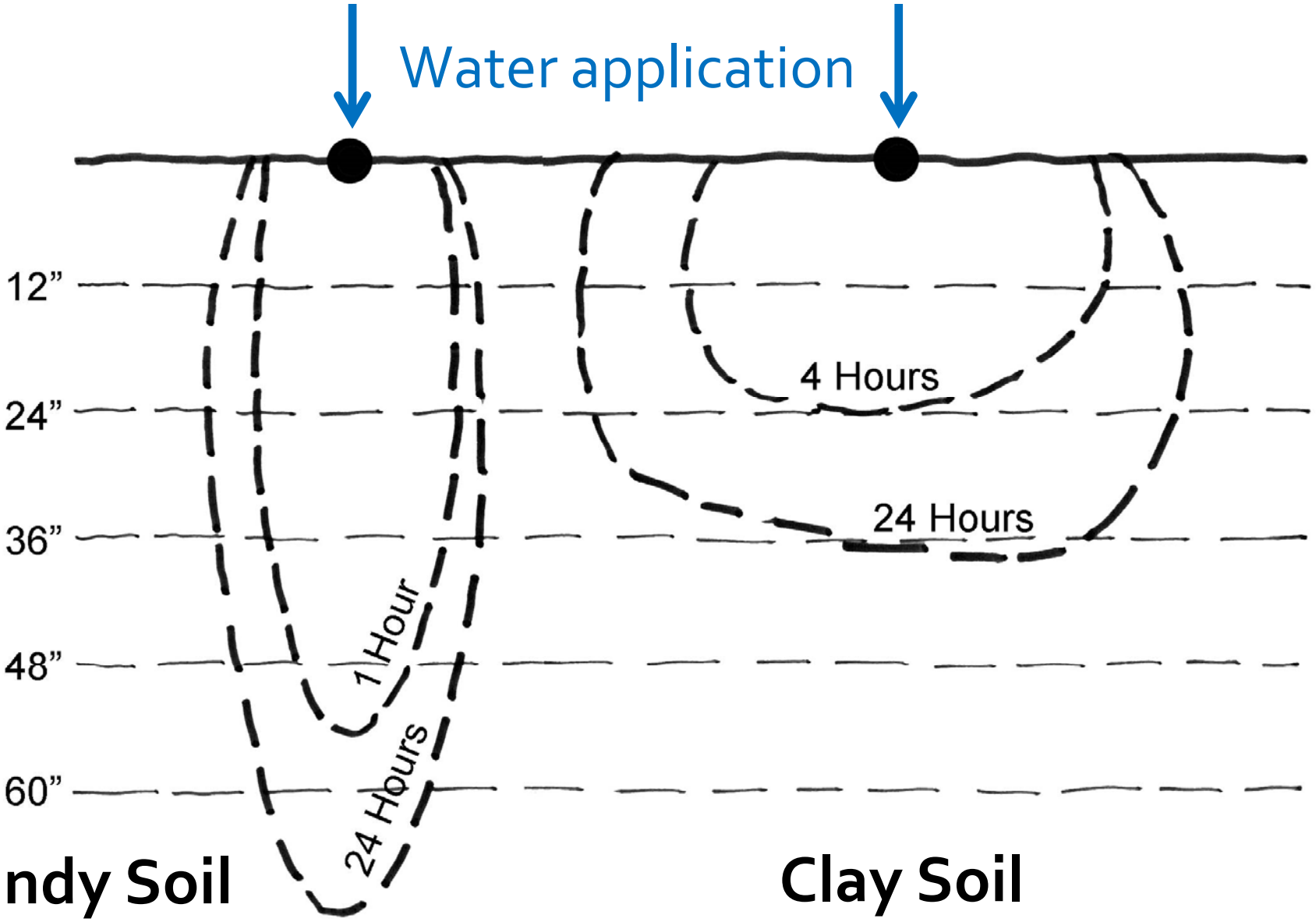
organic matter + soil organisms + time
creates ⇒
soil structure, fertility, disease prevention, & water capacity

Air and Water movement in soil



Air and water movement / soil profile

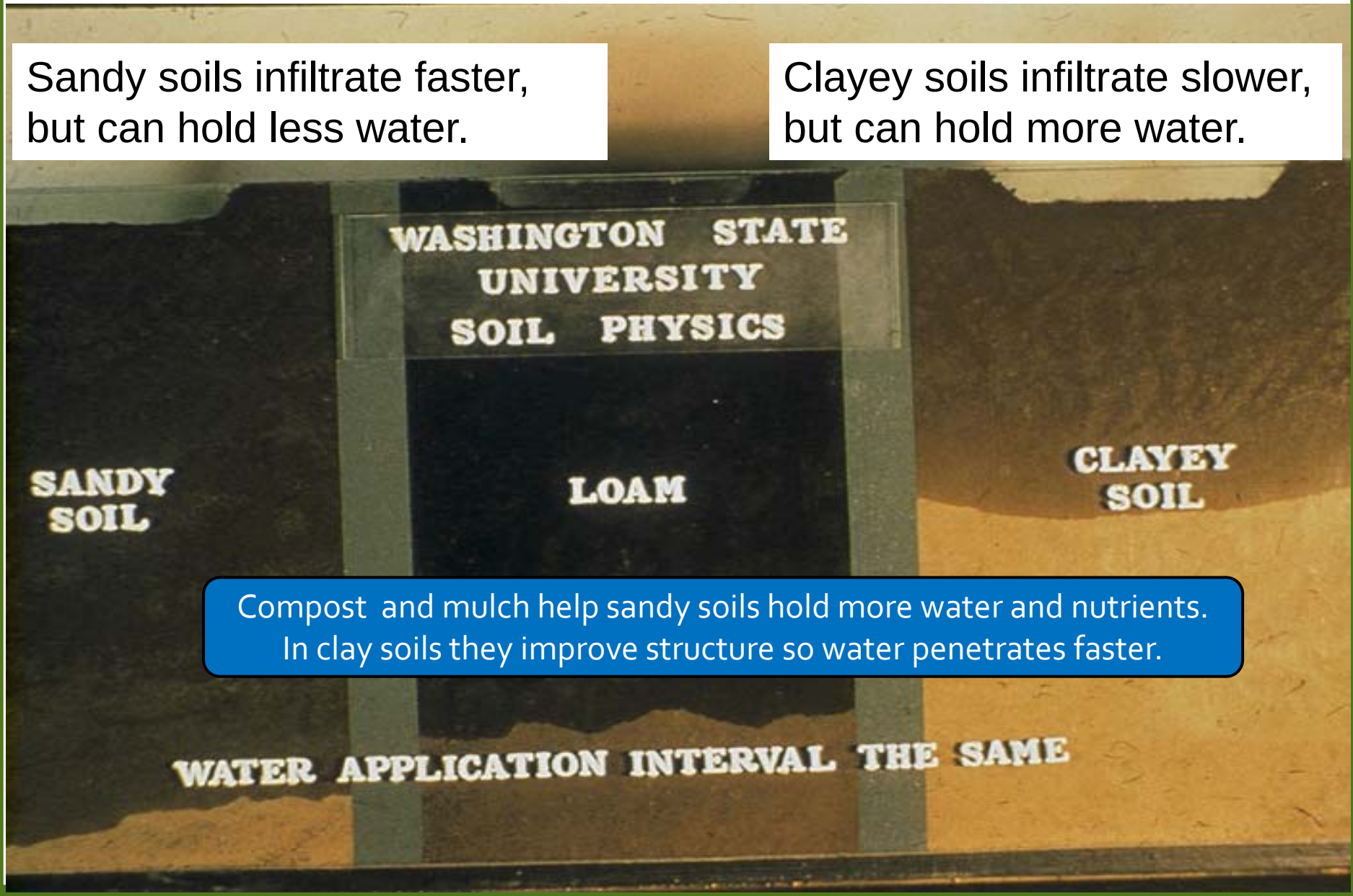
Water penetration & spread in different soils



Water penetration rate & capacity

Sandy soils infiltrate faster, but can hold less water.

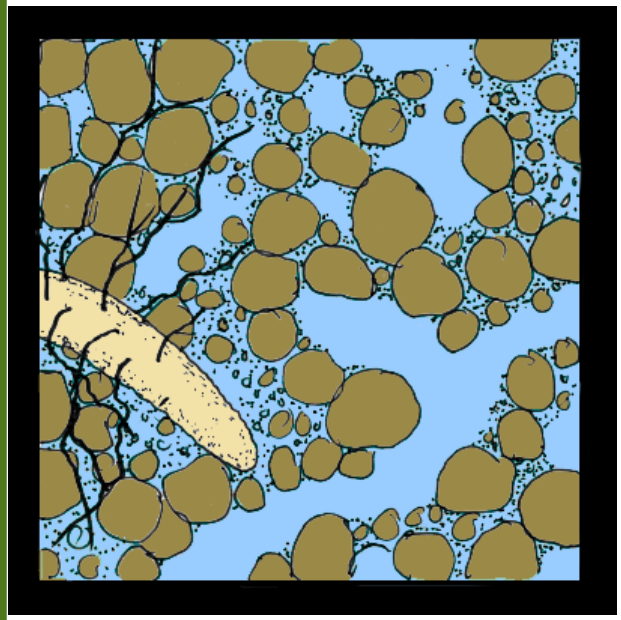
Clayey soils infiltrate slower, but can hold more water.



Compost and mulch help sandy soils hold more water and nutrients. In clay soils they improve structure so water penetrates faster.

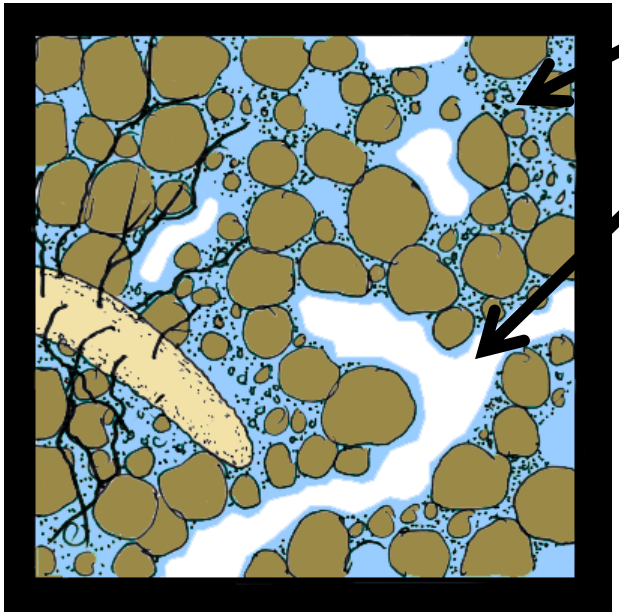
Plant available water

= field capacity minus wilt point.



Saturation Point

all pores full

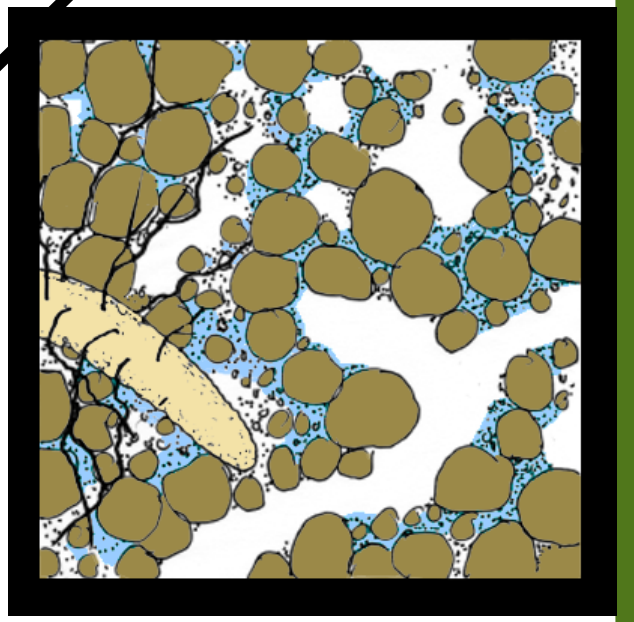


Micro-pores

Macro-pores

Field Capacity

gravitational water has drained out



Wilt Point

remaining water held in micro-pores too tightly for plants to suck it out

Soil organic matter and compost increase plant-available water storage in all soil types.

Plants breathe through leaves and roots

- Soil pore spaces allow water and air to enter, and roots to grow
- Plant roots and beneficial soil organisms exchange gases into soil pores and atmosphere
- Compact or saturated soil reduces gas and water exchange, damaging plants

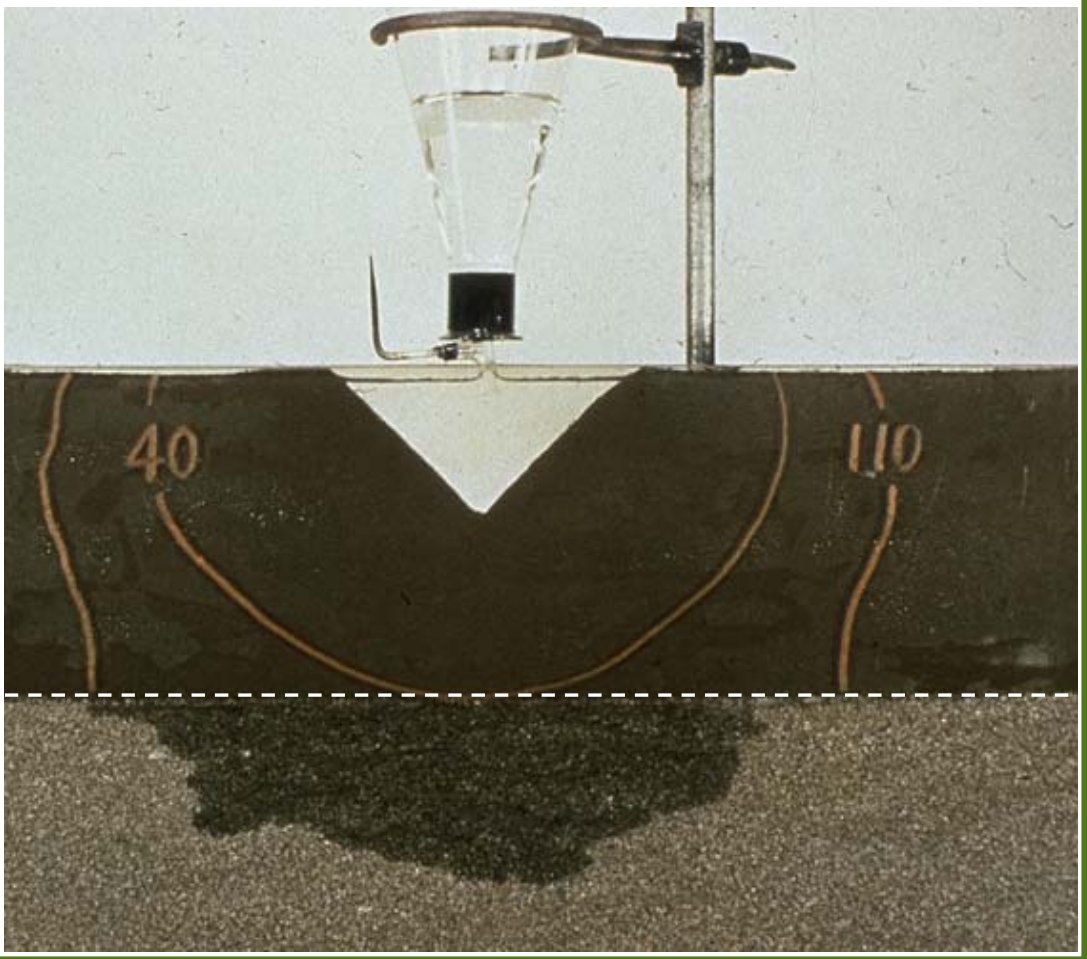
Smell your soil:
Stinky (ammonia) smell and gray or yellow color indicate anaerobic conditions from compaction or poor drainage.

Common mistakes that damage soil and plants

Layering different soil types. "Interfaces" limit air and water movement.

Better to:

- Amend site soil
- If importing soil, till or mix a few inches to reduce interface problems



Common mistakes that damage soil and plants

Adding sand to heavy clay reduces structure and pore space.

– better to amend clay with 10-15% compost

using soil science

Soil Best Practices for Landscaping – design, installation, and maintenance

- Efficient
- Cost effective
- Healthy for people and wildlife
- Sustainable
- Successful: beautiful landscapes year 'round

Site & soil assessment

Look, smell, feel:

- Core sample or dig holes
- Soil texture-by-feel
- Smell: earthy or stinky?
- Color, particle size, organic matter
- Root penetration, structure
- Compacted layers? Drainage?

Lab tests:

- Organic matter: 3-6% optimum
- NPK and micro-nutrients
- Lab's recommendations

Plant conditions:

- Leaf color
- Compare growth
- Persistent plant problems?

Collecting samples for lab tests

- Use clean core sampler or trowel, and plastic bucket, to avoid contamination
- Collect samples at rooting depth
- Remove upper 1-2 inches with leaf litter, or sod & thatch from lawns
- Collect 10-12 samples, then mix in plastic bucket, then take 1-cup sample
- Spread sample to dry overnight
- Then plastic bag sample for lab
- Fill in lab form with location, and intended use (lawn, vegetables, trees etc.)

Learn how to collect samples, and how to interpret results (in English or Spanish) at :
http://puyallup.wsu.edu/soils/soils/

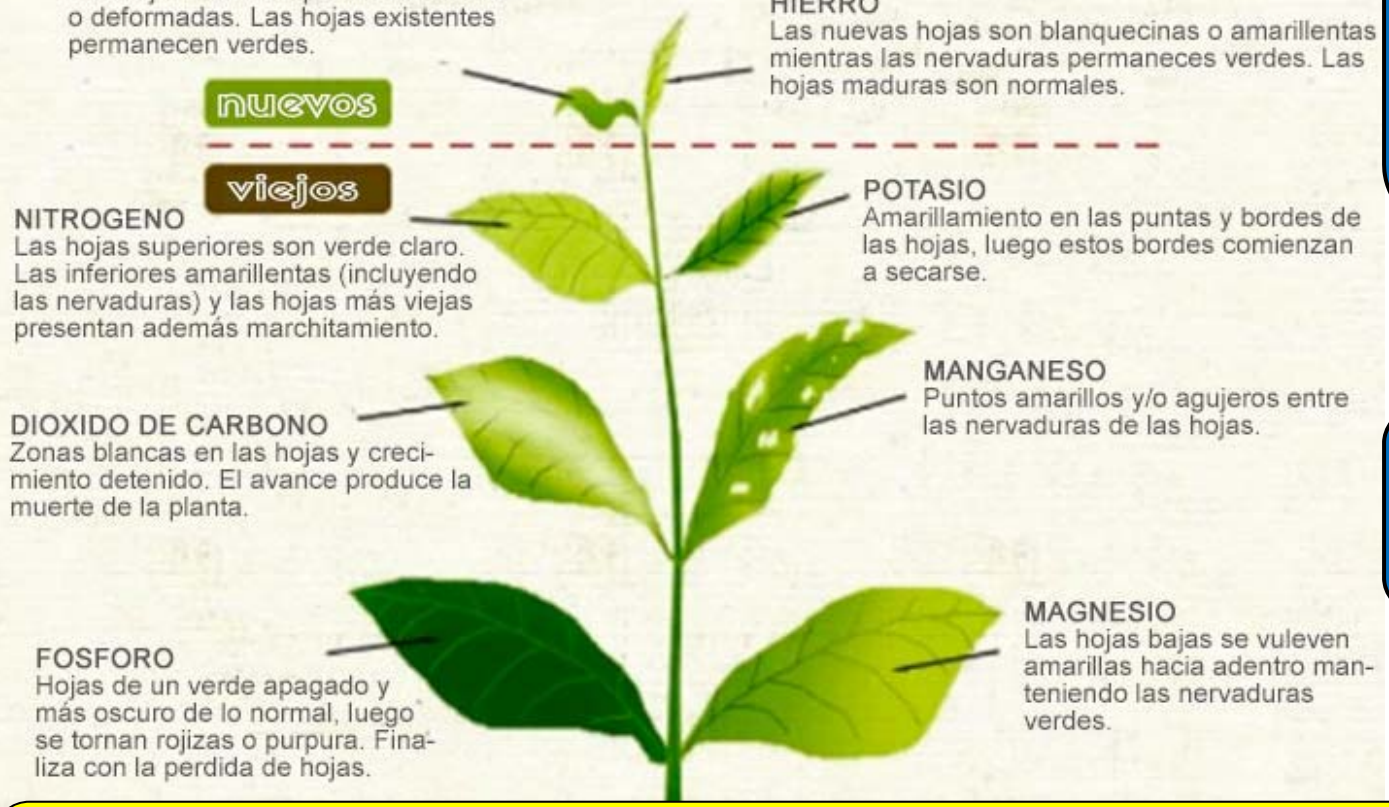
Plants as indicators of soil differences and problems

Examples:

- Early fall color indicates stress

- Trees planted at same time, but show different growth

Falta de Nutrientes
guía rápida



Deficiencies may be caused by low organic, poor drainage, compaction, or incorrect pH.

Get a soil test to verify nutrient deficiencies.

Learn signs of nutrient deficiencies and other plant problems at :
http://hortsense.cahnrs.wsu.edu *en español "Suelos, fertilizantes y nutrición de plantas"*
http://smallfarms.wsu.edu/espanol/suelo-composta/index.html

Protecting soil & vegetation during construction

- Fence soil protection zones – especially tree roots
- Inform all contractors: no stockpiles, equipment, or storage in protection zones

Protecting soil & vegetation during construction

- If temporary vehicle access is required, place steel plates, plywood, or 6” coarse wood chips or rock

Restoring construction-damaged soils

- Rip or scarify to 12 inch depth to correct compaction
- Till in 2-3 inches of compost to 8-12 inch depth
- Or spread compost-amended stockpiled or imported topsoil
- Mulch after planting

Learn more at :
www.BuildingSoil.org

Compost erosion control methods during construction

Learn more at :
www.BuildingSoil.org

- WA State approved compost blankets and socks
- "2 for 1" value – use compost for erosion control, then till in to restore soil
- No disposal costs
- Faster planting, better growth

Improving soil function in existing landscapes

Key steps:

1) Amend soil with compost when re-landscaping
2) Mulch beds annually with leaves, chips, compost, etc.
3) Mulch-mow lawns (leave clippings)
4) Top dress lawns with compost
5) Choose "natural organic" fertilizers
6) Base fertilizer use on soil tests and plant needs

Amend soil before planting

WHEN Before planting lawns, annuals, perennials, trees and shrubs.

HOW Use shovel or fork, or rototiller or excavator for large areas. Amend the whole bed, not just small planting holes,
to promote root growth.

HOW MUCH

- Lawns: 1-2" of compost, tilled in 6" deep
- Gardens: 2-4" compost, tilled in 10-12" deep

☑Use more compost on sandy soils, less on heavy clay

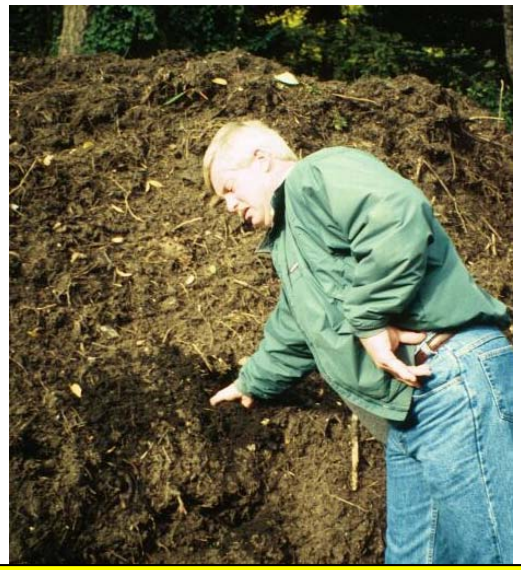
Amend soil before planting

WHAT Best materials: yard debris compost, or composted biosolids or manure. Leaves or fresh manure O.K. if tilled in 1-2 months before planting.

- Other materials: aged bark or sawdust, peat moss, coconut coir – OK if adding nitrogen source
- "Topsoil" mixes O.K. if bought from reputable supplier.

GOOD COMPOST?

- Earthy smell
- Brown to black
- No weeds
- Purchase from WA-permitted composter



WA-permitted compost facilities listed at:
www.ecy.wa.gov/programs/swfa/organics/soil.htm

Mulch plantings regularly

WHEN At least once a year:

- Spring on trees and shrubs to prevent weeds.
- Early summer on gardens to hold moisture, stop weeds, and feed plants. (Let soil warm up first.)
- Fall on beds to prevent erosion and winter weeds.

WHERE Whole beds, paths, 3 ft. or larger ring around trees & shrubs in lawns.

HOW

- Remove weeds & grass before spreading mulch.
- Keep mulch away from plant stems.
- Use weed barriers like cardboard to control aggressive weeds.

Mulch plantings regularly

HOW MUCH

- 1-2" Compost, leaves, sawdust, fine bark, grass clippings
- 2-4" Wood chips or coarse bark

WHAT

- Woody mulches (arborist chips, bark) for woody plants (trees, shrubs).
- Non woody mulches (compost, leaves grass clippings, composted manure or biosolids) for non-woody plants (annuals, perennials, berries, roses).

TIP: Place weed barriers (cardboard, newspaper) under mulch to help control aggressive weeds. Avoid using plastic or fabric weed barriers.

Mulch-mow lawns (leave clippings)

- Mulch-mowing doesn't cause thatch (build-up of roots and stems)
- Returns free fertilizer, cuts fertilizer needs by ¼ to ½
- Feeds soil life, improves soil structure, water-holding capacity; helps lawns resist drought damage

Learn about sustainable lawn care (in English & Spanish) at:
www.seattle.gov/util/LandscapeProfessionals

Top dress lawns with compost

- Aerate spring or fall
- Spread ¼ to ½ inch compost, rake in
- Over-seed with site-appropriate grass

Fertilizing

WHAT choose "natural organic" or "slow-release" fertilizers

- Too much fertilizer produces excess growth and sets plants up for pest and drought damage.
- Overuse also damages essential soil life.
- Soluble "quick-release" fertilizers may easily wash off into streams and lakes.

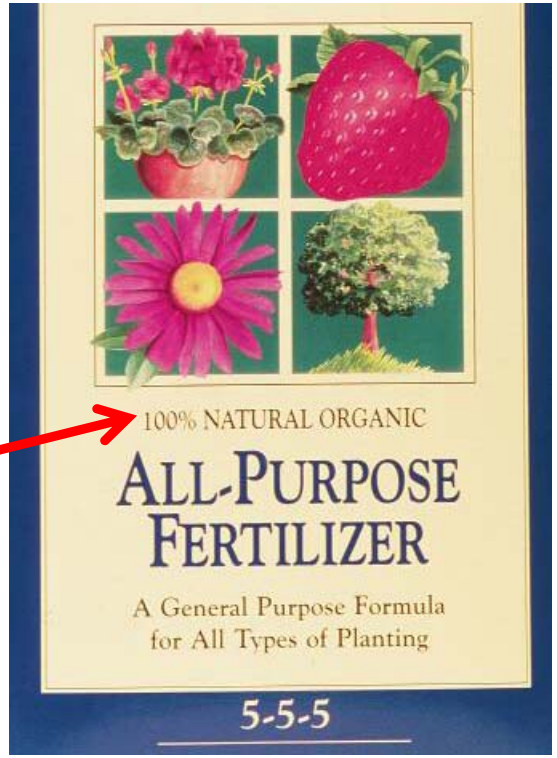
WHERE

- Most trees and shrubs get all the nutrients they need from regular mulching.
- Lawns and gardens (annuals and perennials) often need additional nutrients = fertilizer or compost.

TIP: Feed the soil, not the plant

TYPES of FERTILIZERS

- **AVOID** Soluble synthetic or "quick-release" – washes off quickly
- **USE** "Slow-release" synthetic or
- **USE** "Natural organic"
- **TIP:** Look for "natural organic" or "slow-release" on the bag



WHEN to fertilize

- Lawns: May and Sept., plus lime every few years.
- Annuals/gardens & perennials: Mix into soil when planting and mid-season. Base on plant signs or soil test. Lime may be needed every few years.
- Trees & shrubs: only if plants show need, or soil test

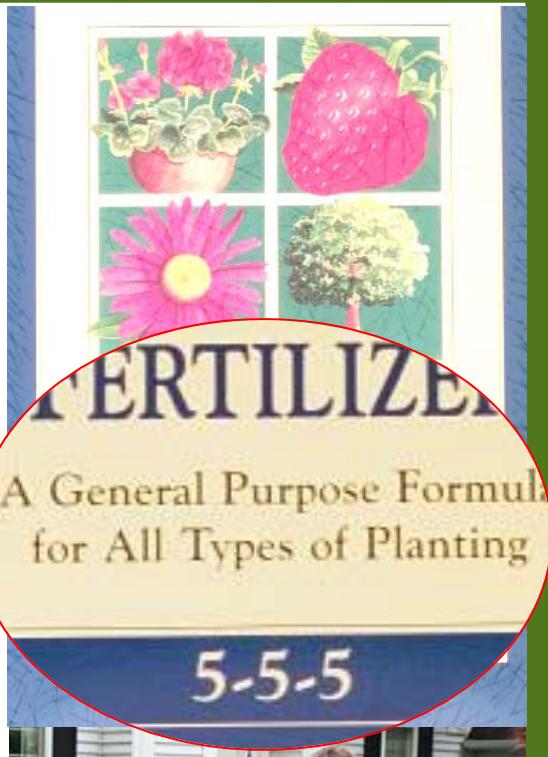
FERTILIZER NUTRIENTS

Nitrogen (N) – Phosphorus (P) – Potassium (K)

- Numbers are percent by weight:
  5% x 20 lb. bag = 1 lb. N, 1 lb. P, 1 lb. K
- Use fertilizer recommendations from soil test to multiply with area, to compute how much fertilizer to use.

FERTILIZING TIPS:

- Look for higher non-soluble N on label = slower release
- No/low phosphorus, to protect streams
- Look for micronutrient content
- More is not better – follow recommendations
- Apply twice, in two directions, using ½ of total each time

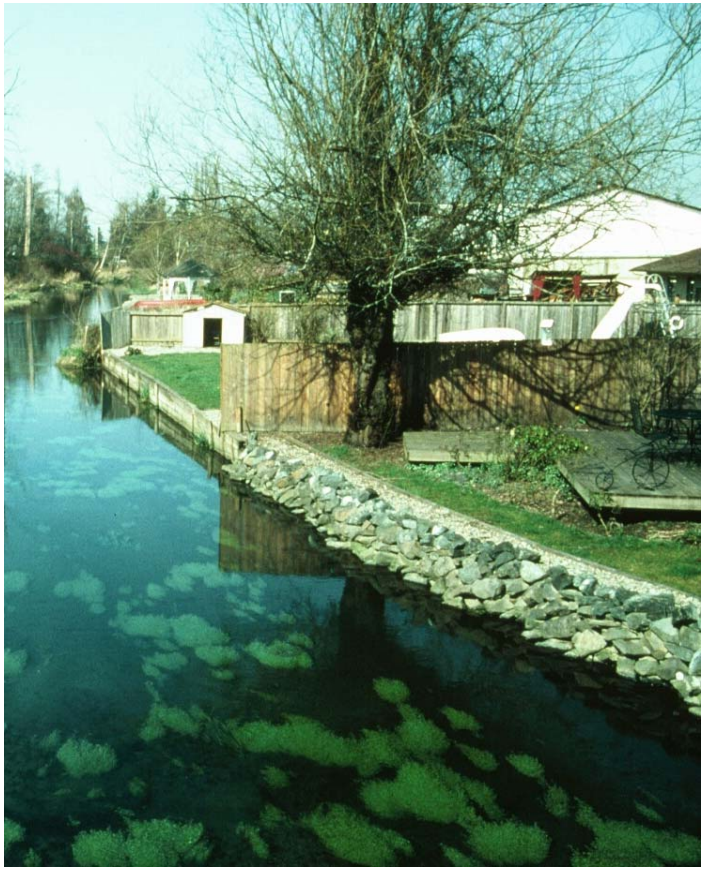


Base fertilizer use on plant needs & soil test

Observe plants' needs, and get a soil test to diagnose problems, and determine needs for lime or other amendments.

PROTECTING WATERWAYS

- Natural organic fertilizers are less likely to wash off.
- Never apply any fertilizer (especially soluble synthetics) or pesticide near ditches, streams, lakes, or storm drains.
- Sweep excess off pavement
- Don't apply just before heavy rain



Watering: Match soil conditions & plant needs

SANDY SOILS

- Water more frequently but less each time

CLAY SOILS

- Water less frequently, but slowly, or start-and-stop so water has time to penetrate

WATERING TIPS:

- Observe plants – water when lawns dull or leaves droop
- Water early morning or late in day to reduce evaporation waste
- Over-watering promotes plant diseases

Compost helps all soil types absorb and store more water and nutrients in plant-available forms.

Plant selection: right plant, right place, right soil

Choose plants that fit your site's conditions:

- Soil type:
  - Sand
  - Silt
  - Clay
- Organic content
- Drainage
- Soil volume – room to grow

Select plants that grow well in your soil type and drainage.

Select trees that will grow to mature size in the available soil volume.

Healthy plants grow in healthy soil

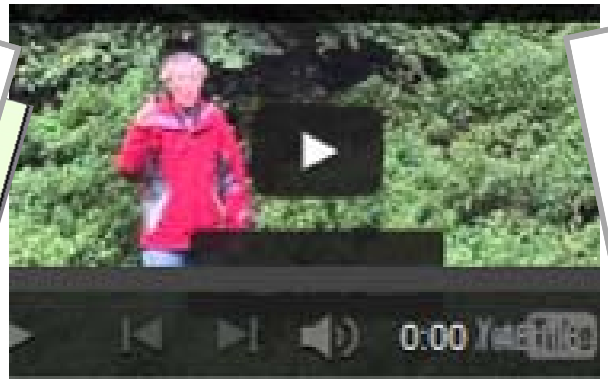
Learn more at: www.seattle.gov/util/LandscapeProfessionals

this presentation is on "Training" page

publicaciones en español en pagina "Training/Translations"

Questions? Garden Hotline 206-633-0224 www.gardenhotline.org

(language interpretation available)



GREEN GARDENING PROGRAM | Seattle Public Utilities

Local Hazardous Waste Management Program in King County

Actividades: videos y guías / Activities: videos and guides

- "Determining Soil Texture by Hand" http://puyallup.wsu.edu/soils/soils/
  "Estimando la Textura del Suelo"
  http://smallfarms.wsu.edu/espanol/suelo-composta/index.html

- Reading soil lab test reports http://puyallup.wsu.edu/soils/soils/
  "La Composición y Análisis de Suelos "
  https://puyallup.wsu.edu/soils/wp-content/uploads/sites/411/2014/12/SS_Composicion_Analisis_de_Suelo.pdf

- "Suelos, fertilizantes y nutrición de plantas" (presentación con audio)
  http://smallfarms.wsu.edu/espanol/suelo-composta/index.html

- Reading fertilizer bag, and fertilizer calculations
  https://www.youtube.com/watch?v=a5RVGqu6ACE https://www.youtube.com/watch?v=gXLYS27JEEg
  "Cómo Leer una Etiqueta", y "Cómo Calcular Uso de Fertilizante"
  https://www.youtube.com/watch?v=muj4dj1E6Bk https://www.youtube.com/watch?v=rhoDkJ71T7k

- Prueba de agitación en agua y asentamiento de suelo (para determinar contenido arena, limo & arcilla) / Soil-in-water shake-&-settle test (to determine sand, silt & clay content) https://www.youtube.com/watch?v=iZvgRMjYpVM

- Examinacion deacolchado, composta & muestra de suelo / Mulch, compost, & soil samples www.seattle.gov/util/ForBusinesses/Landscapes/TrainingCertification