Life in the Soil

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What is soil?

As defined by Hans Jenny, the Father of Soil Science:

1. Mineral: Sand, silt, clay
All minerals properly balanced

2. Organic matter

3. Organisms

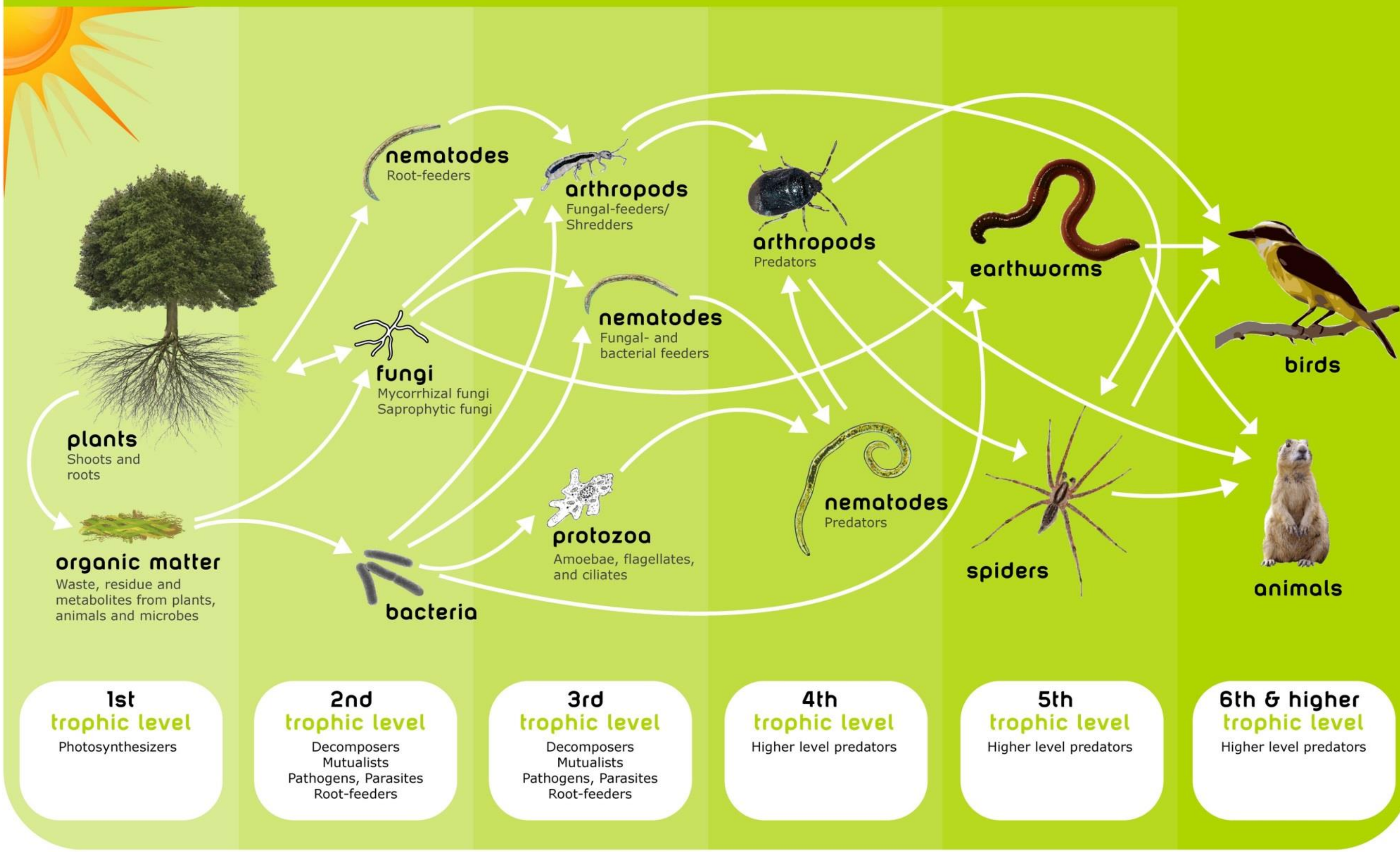
4. Abiotic factors

A Healthy Food Web Will:

- **Suppress Disease (competition, inhibition, consumption; no more pesticides!)**
- **Retain Nutrients (stop run-off, leaching)**
- **Nutrients Available at rates plants require (eliminate fertilizer) leading to flavor and nutrition for animals and humans**
- **Decompose Toxins**
- **Build Soil Structure –(reduce water use, increase water holding capacity, increase rooting depth)**

the soil food web

soilsymbiotics
www.soilsymbiotics.com



Appearance
Function

To make sure everyone has an idea of what each organism group looks like: Morphology

Function:
What each group does

Bacteria, Aggregates, Roots, Ciliate (Protozoan)

Numbers: Species or Individuals

We need to understand both species and individuals, but……

A high number of species means all the functions of that group could be done; a low number means missing functions.

ALSO need lots of individuals of each species active, doing their jobs to get the work performed.

BOTH have to happen.

Bacteria, fungi, humus, aggregates: 400X total magnification

Numbers versus Biomass

One elephant versus one mouse?
One fungus versus one bacterium?
Which is more important?

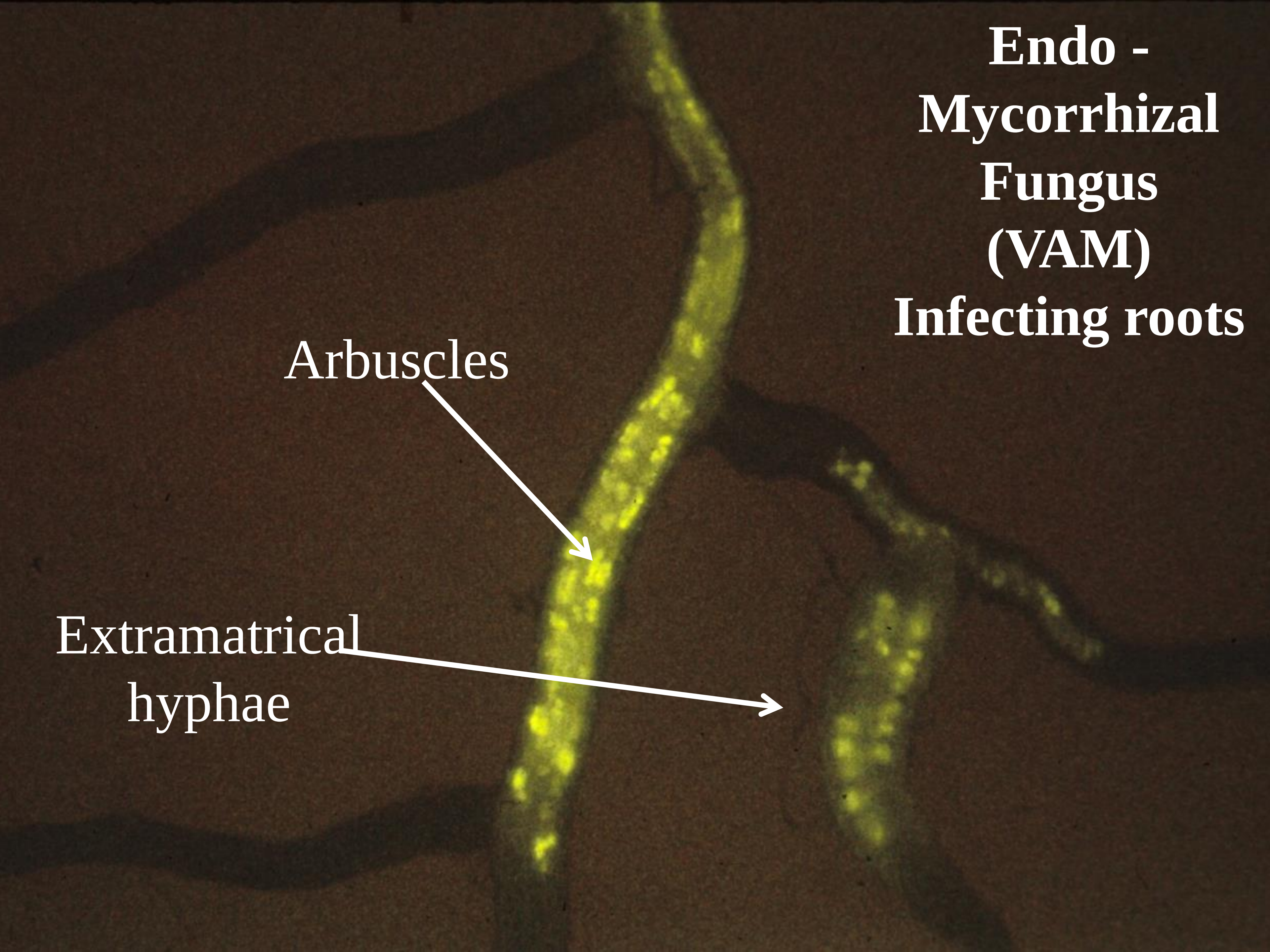
The largest organism on this planet is a fungus.
Bacteria are much smaller

How do you compare function of a single fungus with a single bacterium?

Biomass, not numbers

Josh Webber: Portmore Golf Course North Devon, UK

Endo - Mycorrhizal Fungus (VAM) Infecting roots



David Reid

Ecto-Mycorrhizal fungi on pine seedling

How much more of the soil can the plant get nutrients from?

Structure in soil;
Holding nutrients

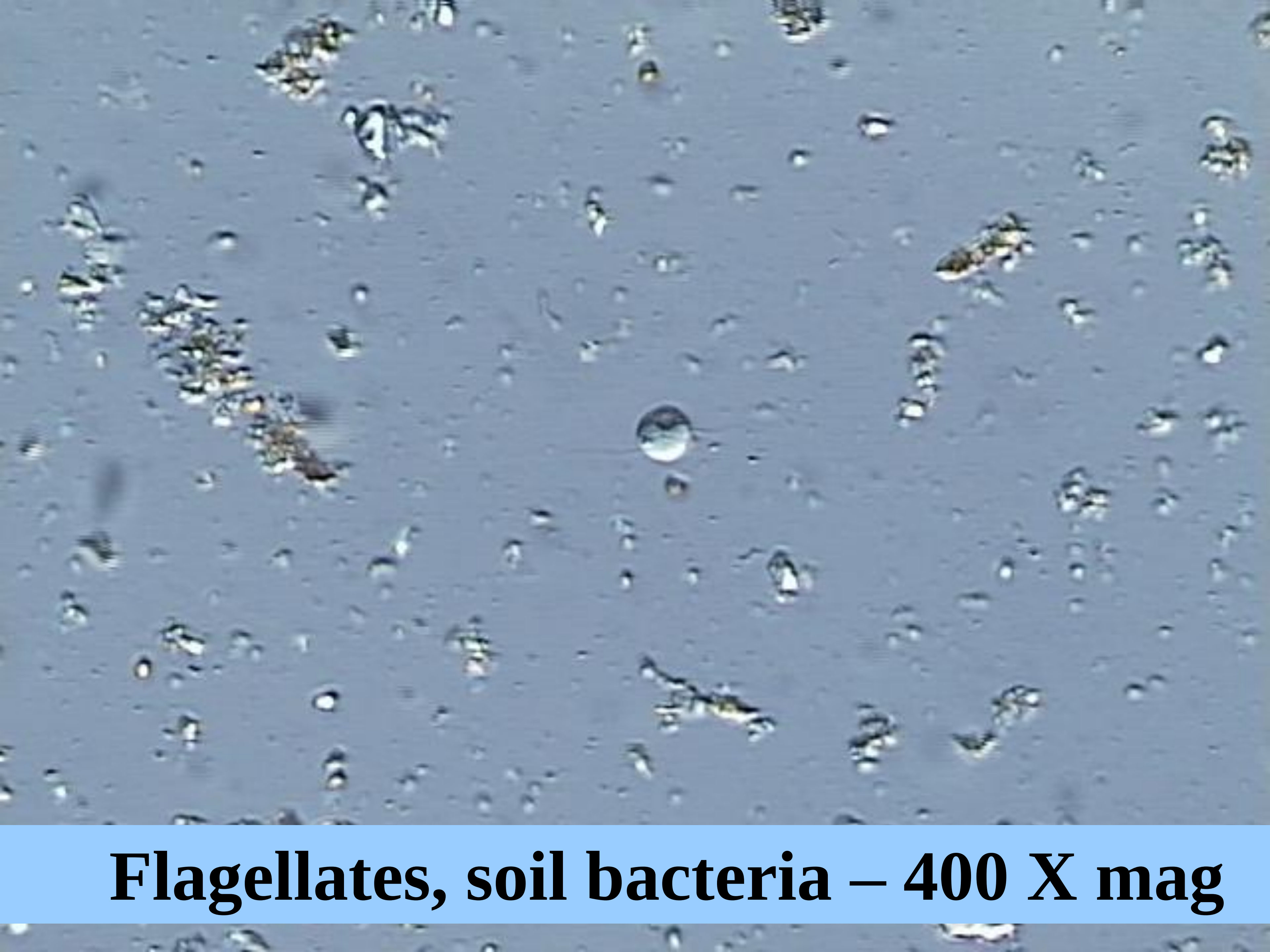
Bacteria make glue that hold small particles together, build "bricks"

Fungi mortar the bacterial bricks together to build walls, floors, ceilings and doors.

Fungi condense the simple compounds in soil into ever more complex forms, and thus are most responsible for making humus

Predator Morphology

Protozoa, Nematodes



Flagellates, soil bacteria – 400 X mag

Beneficial Nematodes

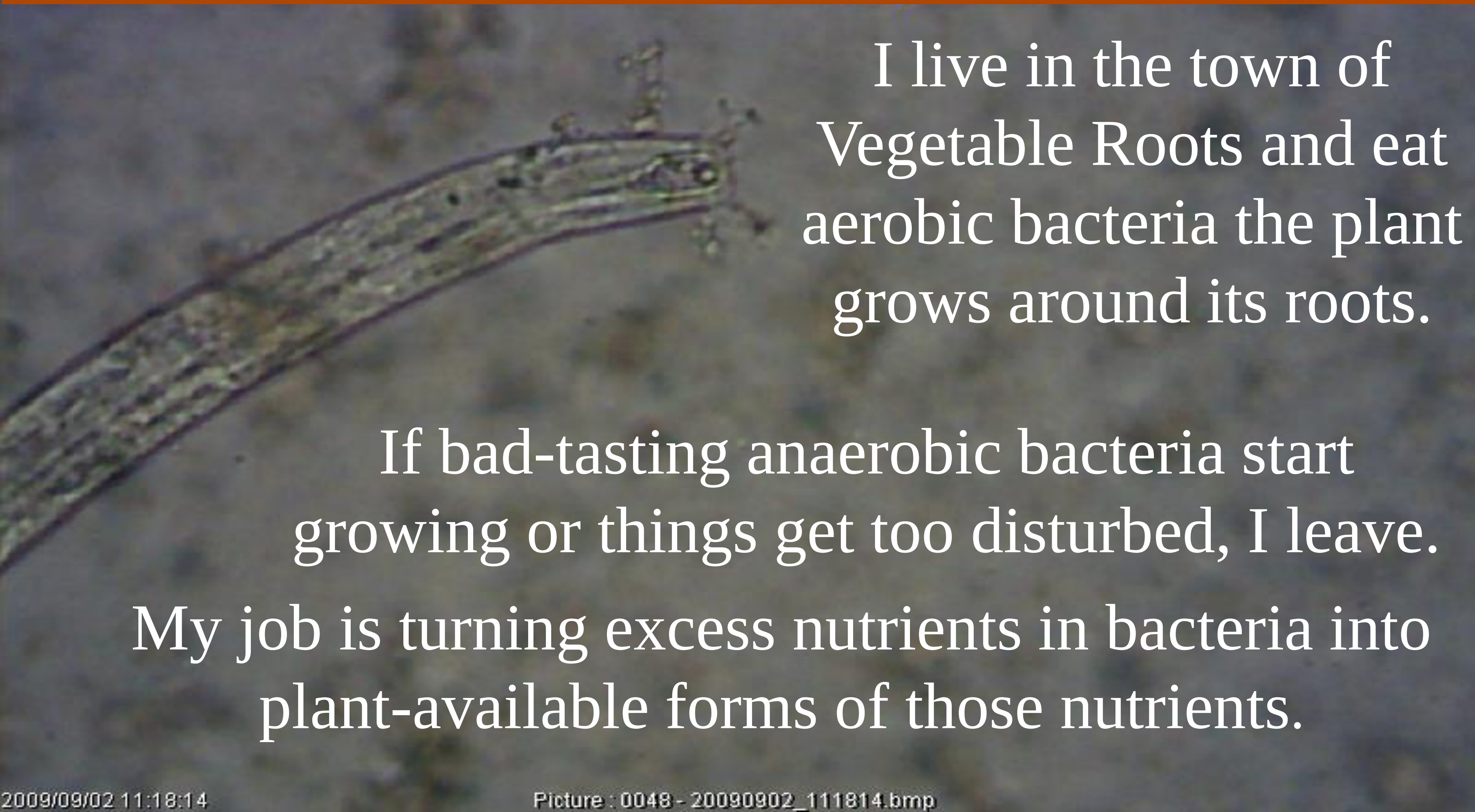
Hi! I'm Alaimus!

My mouth and lip hairs let you know who I am.

I live in the town of Vegetable Roots and eat aerobic bacteria the plant grows around its roots.

If bad-tasting anaerobic bacteria start growing or things get too disturbed, I leave.

My job is turning excess nutrients in bacteria into plant-available forms of those nutrients.



Nutrient Retention

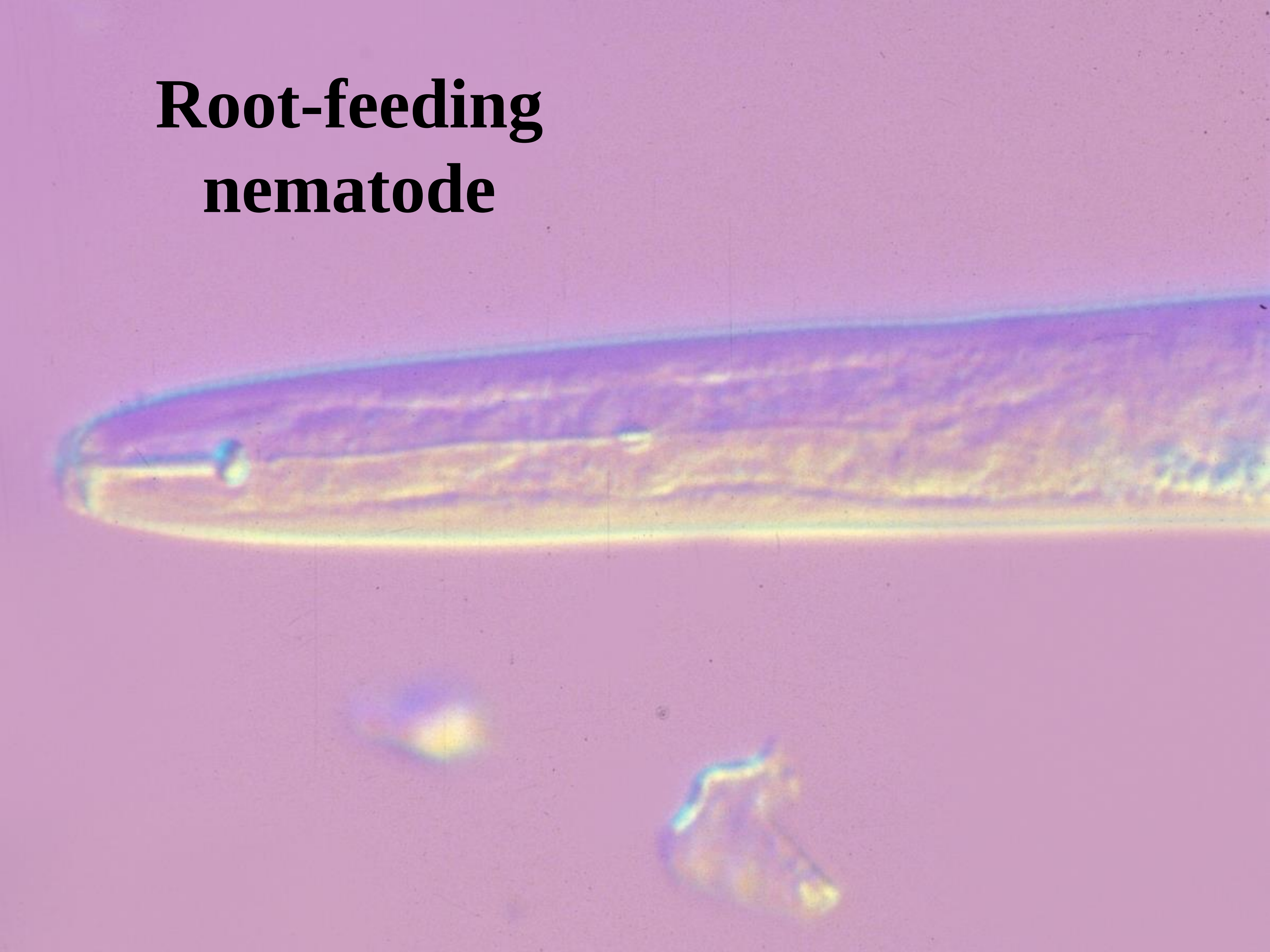
Bacteria and fungi form a massive wall around roots, because plants feed them

Protozoa and nematodes are attracted to the large number of their prey

Because nutrients are so much higher in bacteria and fungi than in their predators, excess nutrients are released, but in plant available forms


Fungal-feeding
nematode

Predatory Nematode


Root-feeding
nematode

Videos of Life in the Soil

Critter Movies!

Why be concerned with soil life?

Healthy plants

- Don't need toxic chemicals to grow
- Have the proper balance of nutrients
- So they taste good and satisfy hunger

Flavor depends on the balance of ALL nutrients

Where do plants get their nutrients?

All but two nutrients come from the soil.

So, human nutrition comes from soil.

Minerals in soil (Sparks 2003)

Element	Soils (mg/kg) Median	Range	In the Earth's crust (mean)	In Sediments (mean)
O	490,000	-	474,000	486,000
Si	330,000	250,000-410,000	277,000	245,000
Al	71,000	10,000-300,000	82,000	72,000
Fe	40,000	2,000-550,000	41,000	41,000
C (total)	20,000	7,000-500,000	480	29,400
Ca	15,000	700-500,000	41,000	66,000
Mg	5,000	400-9,000	23,000	14,000
K	14,000	80-37,000	21,000	20,000
Na	5,000	150-25,000	23,000	5,700
Mn	1,000	20-10,000	950	770
Zn	90	1-900	75	95
Mo	1.2	0.1-40	1.5	2
Ni	50	2-750	80	52
Cu	30	2-250	50	33
N	2,000	200-5,000	25	470
P	800	35-5,300	1,000	670
S (total)	700	30-1,600	260	2,200

All the mineral nutrients plants need are already in your soil

- You do not need to add more!
- BUT ---- Mineral nutrients need to be converted to SOLUBLE forms for plants to be able to take them up
- What converts minerals to soluble forms?
- SOIL LIFE

Definitions for the coming discussion:

- **Organic**: many say “contains carbon”, but this is not correct. Organic materials are compounds that contain **CHAINS** of carbon produced through photosynthesis.

- **Soluble**: can dissolve in water, typically either organic compound or a salt because there has to be a positive and negative charge on the compound so water will bind and allow it to dissolve.

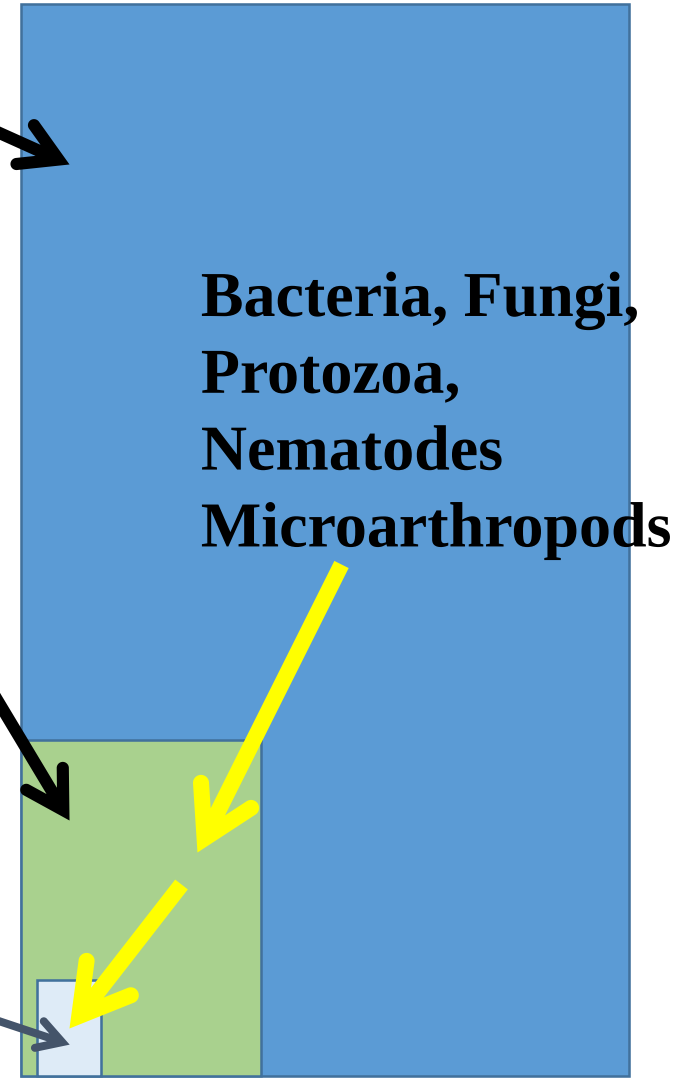
- **Mineral**: Not organic, typically forms a salt.
- **Mineralized**: converted from organic to mineral.
- **Immobilized**: Does not move with water; bound to something organic (organism, organic matter).

Nutrient Pools in Soil

Total – everything

Exchangeable - easily pulled off surfaces; easy to make soluble

Soluble – dissolved in soil solution; potentially available to plants



Without organisms to retain the soluble nutrients that a plant does not take up, or to change plant-not-available forms in plant-available forms, no new soluble nutrients will occur.   Plants will suffer.

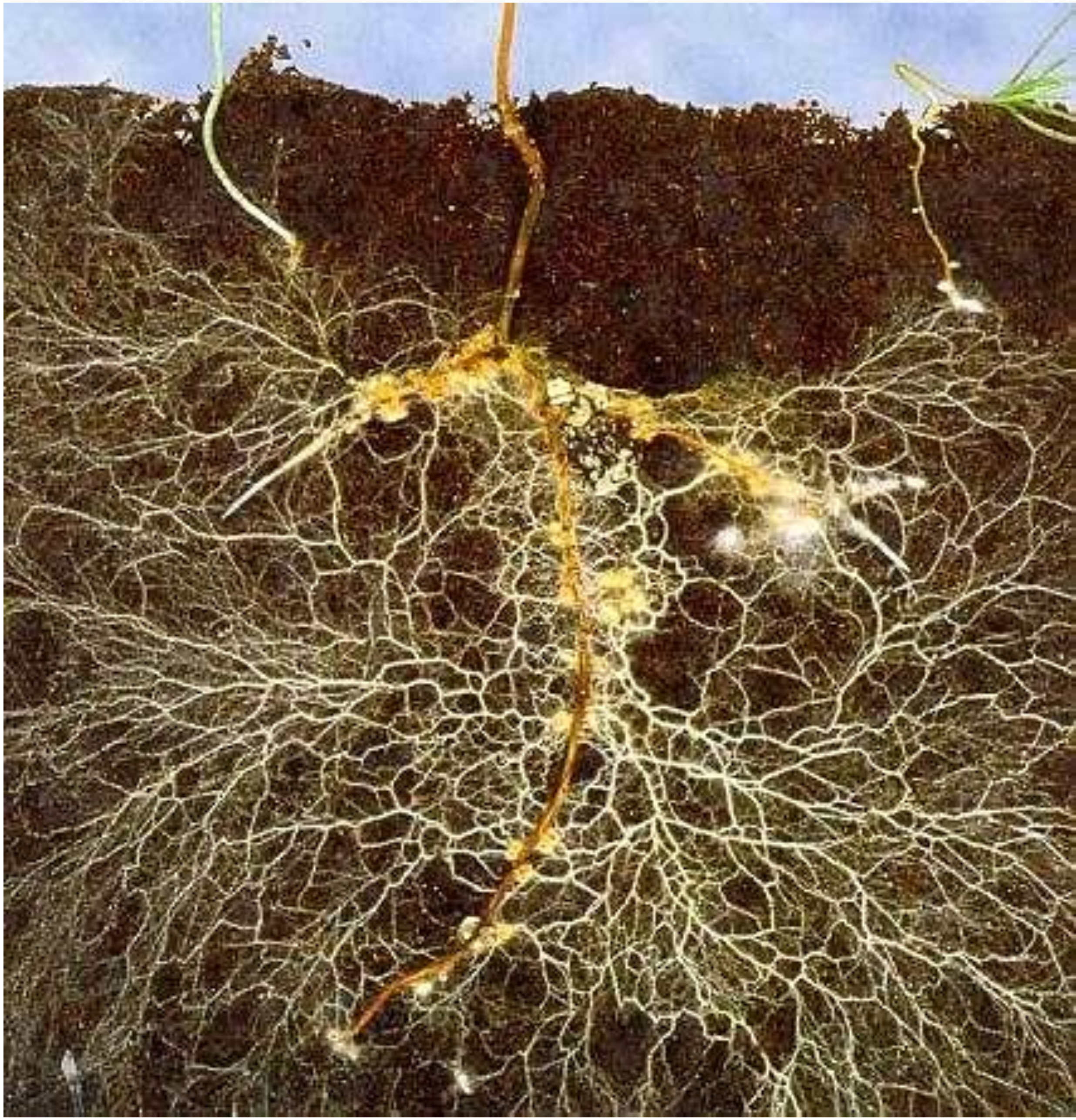
What biomass of each organism is needed so the plant gets the nutrients it needs?

Balance is everything, but who controls the balancing act?

Plants: Exudates

Bacteria/Fungi

Protozoa, nematodes, microarthropods earthworms



Pine seedlings and mycorrhizal fungi (David Reid)

Not just bacteria, not just fungi, the WHOLE FOODWEB is required

What happens if all or part of those beneficial organisms are killed by:

- Tilling or disturbing the soil too often or too much?

- Pesticides,

- Inorganic fertilizers, i.e. salts?

How do you get soil life back?

Organisms do all the work in soil.

- They perform all the processes of:
  - making nutrients plant available;
  - building soil structure;
  - suppressing diseases and pests
- Plants feed bacteria and fungi through root exudates, and dead plant material.
- Highest numbers of bacteria and fungi are around the roots.
- Bacteria and fungi solubilize mineral nutrients from rocks, sand, silt and clay.
- Bacteria and fungi are eaten by protozoa, nematodes, microarthropods, and earthworms (predators).
- Plant-available, soluble nutrients are released

Consequences of organisms doing their jobs

- Soil structure improved; roots go deeper
- Water holding increased; don't need to irrigate
- No need to rotate crops;
- Balanced nutrients in plant material, healthy plants, not susceptible to diseases
- Healthy people

A Healthy Food Web Will:

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How do you keep soil life at maximum activity when it is most important to the plant?

- Maximum diversity of everything
- The right balance of organisms the plant needs
- But they need to be constantly fed small amounts
  - too much, soil goes anaerobic
  - too little, not enough nutrient cycling, soil structure isn't maintained,
  - rhizosphere disease-patrol isn't maintained
- How do you keep soil life constantly fed?

Examples of results of getting the biology “right”:

Boston Tree Preservation; SafeLawns

Monitoring

Date	**F:B**	**P:N**	**Notes**
Soil before starting: October	5: 300 Want: 300:300	0 : 4 Rf Want: 10,000 Prot	No difference b/t grass; flowers; veg: trees areas
Compost Autumn	250:300 plus humic acids (fungi)	Protozoa 20,000; No nematodes	Mulch under trees, shrubs. VAM spores
Soil March 15	150:400	F: 10,000 A: 5,000 C: none	Bf nemas only

Date	F:B	P:N	Notes
Compost for Tea, March (needed help)	225: 1050	F: 8,000 A: 1,000 C: none	Bf and Ff: 15/g
Compost tea, April	150: 900	No protozoa. No nemas	Fungal foods add protozoan infusion
Soil, April (2 wks later)	300:750	F: 10,000 A: 15,000 C: 25	Bf nemas only

Date	F:B	P:N	Notes
Compost for Tea, May	200: 2050	F: 10,000 A: 1,000 C: none	Bf and Ff: 15/g
Compost pre-treated with fungal foods	750:450	F: 15,000 A: 25,000 C: 25	No nemas detected (disturbance)
Compost tea, May	350: 550 Humic acids added	Protozoan infusion added.	No nemas.
Soil, May	550: 900	F: 30,000 A: 5,000 C: 25	Bf nemas

Date	**F:B**	**P:N**	**Notes**
Compost pre-treated with fungal foods	1050:500	F: 10,000 A: 5,000 C: 25	Bf nemas
Compost tea, June	500: 300 Humic acids trees, shrubs	F: 20,000 A: 15,000 C: 25	Bf nemas.
Soil June 15	450:450 grass 450:225 shrubs 700: 300 trees	F: 30,000 A: 25,000 C: 100	Bf, Ff and Pred

Monitoring needed for a project

1. A BEFORE picture

a. Organisms in the soil BEFORE starting;

b. Organisms in the compost, extract or tea

c. Compaction, diseases, fertility….etc

2. On-going

a. Organisms in the soil after applying compost /extract / tea or any amendment

b. Pictures through the course of the project and especially when the biology is fixed

c. Yields

Assessing Soil

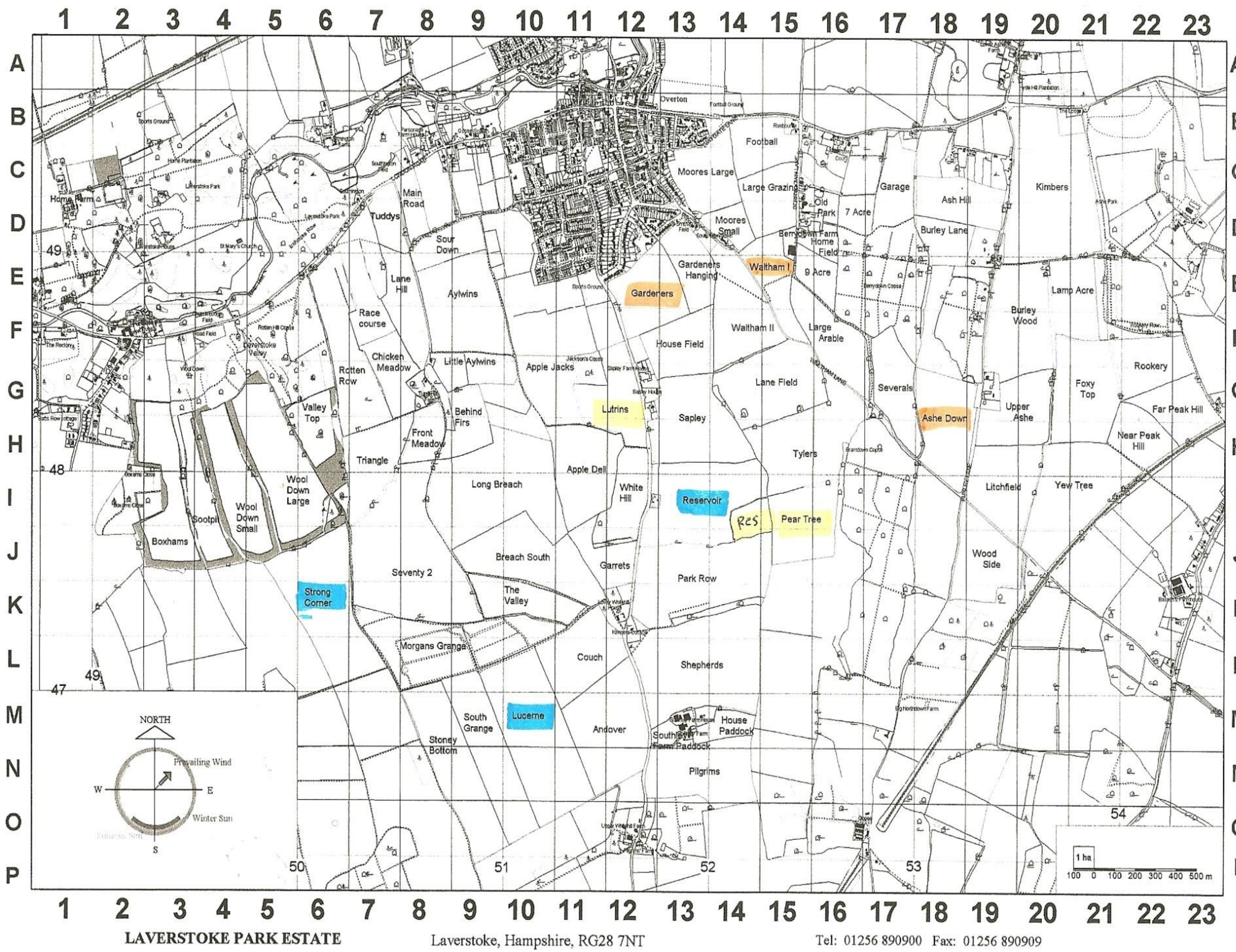
What organisms are in my soil?
What problems are present
Soil Detective School

Starting out………

Examine the property:

a. Map of property, what plants where ?
b. What problems in the past? Diseases, insects, poor fertility, compaction? Pesticides, herbicides, inorganic fertilizers used in the past?
c. Best and worst growth areas?
d. Compaction problems? What caused compaction – penetrometer readings
e. Erosion issues? Nutrients leached?

Choose what you want to know about

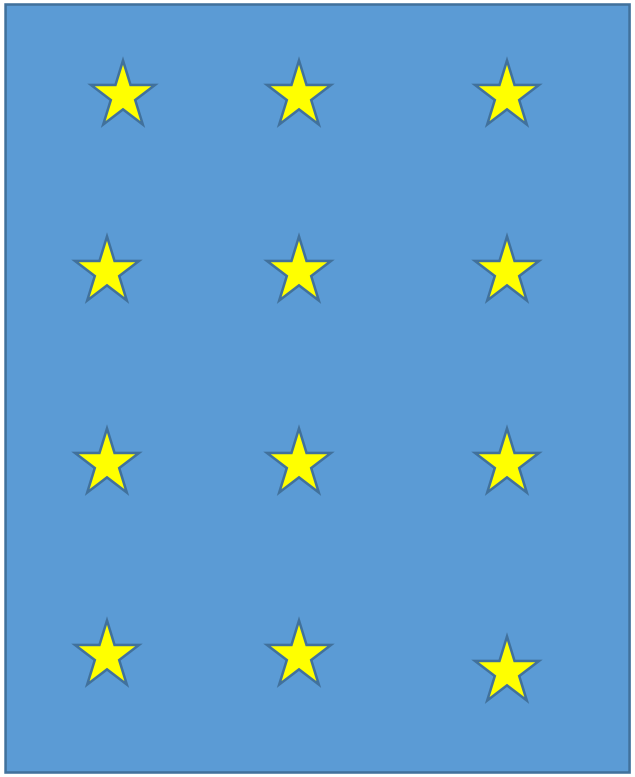


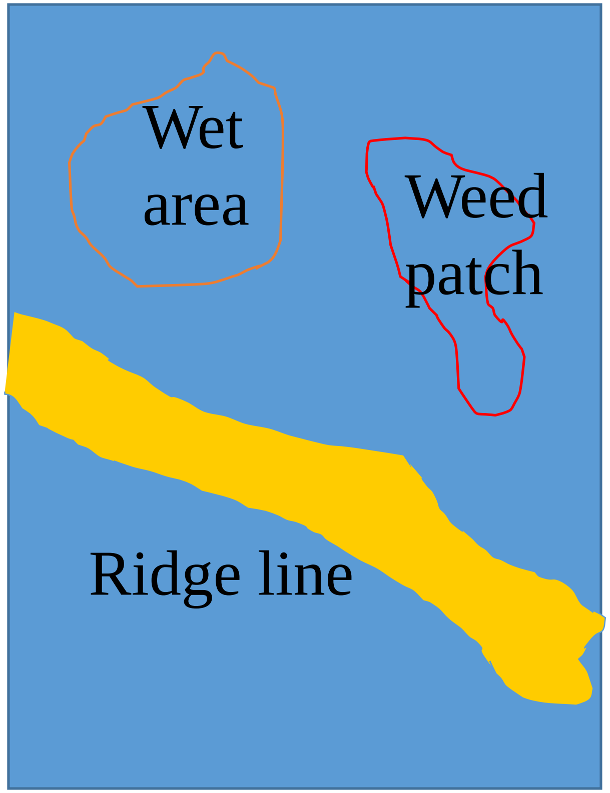
PASTURE

ARABLE

VINES/HOPS

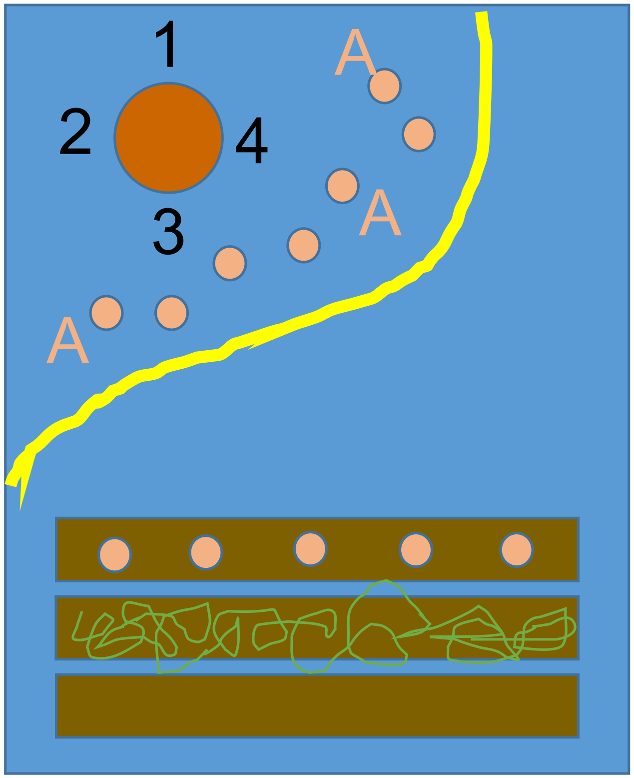
Consider topography



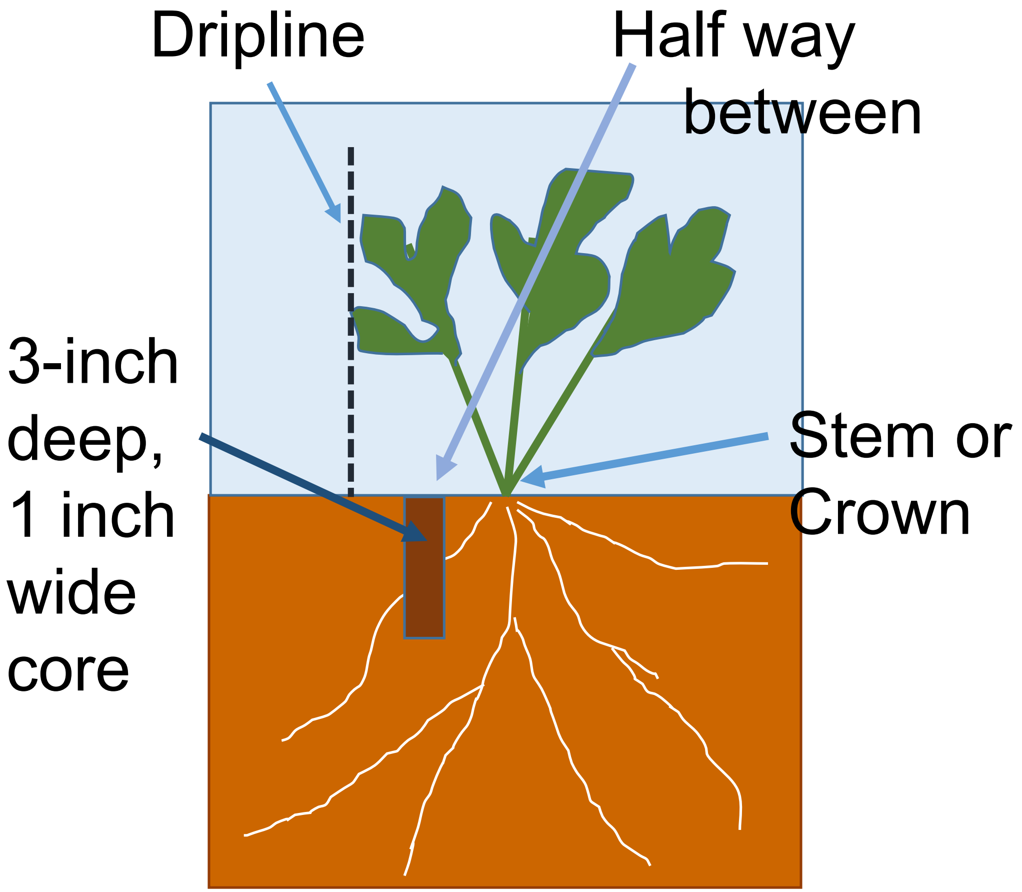


Number the points, randomly draw numbers out of a hat, sample from those points

Split field into habitat areas. Grid each area, number each grid section, pick numbers, sample from each point



The bigger the area or the larger the plant, the more points should be sampled. Choose within an area randomly.



Sample from half way between the drip line and the stem or crown of the plants you care about

How to Sample Soil

Pick representative fields or areas to sample; AT LEAST 3 of each

Randomly choose from all the possible places

Half-way between stem and dripline using a coring tool such as an apple corer

Sealable SANDWICH or SNACK size plastic bags; label and send to lab or examine yourself

Dealing with Biology

- Determine what is missing: Microscope Tests
- What biology and balance is needed for different plants?
    - Check for factors that affect soil biology
    - Compaction, disturbances, water
- Add organisms using compost, extracts, tea
- Consider if inoculants, bio-control agents might be needed short term.
- Add foods to help beneficial organisms
- Monitor to make sure improvements have occurred, that organisms are performing their functions

A Biological Plan

- Autumn –
  - Apply organisms to soil, especially to residues, to prevent disease growth, improve soil structure all through the winter
  - Monitor to determine what survived, what might need to still be added
- Pre-Plant –
  - Apply organisms to soil and foods based on monitoring from fall
- Seed –
  - Apply organisms, foods, mycorrhizal fungi to the seed, or to soil below the seed
- Foliar applications through spring
  - protect leaves from diseases, foliar feed nutrients

Figure out what is missing….

- What life selects for the plant you want need?
  - Succession and Soil Life
- Why aren't the organisms there?
  - Is there a compaction problem? Toxic chemicals? Disturbance?
- Chemistry is a consequence of what organisms do
  - Removing "excess" minerals isn't the right approach. Leaching does not remove just one chemical, everything is likely leached
  - Toxic chemicals will need to be remediated by getting organisms to decompose

Sample the compost, tea, extract… Is it really compost?

Sample when mature (cooled to ambient temperature)

Three to five sub-samples; more if large piles

Choose a consistent depth to sample from

Sample just before use to make sure life is maintained in pile

How much compost, tea or extract?

That all depends on the organisms in the compost!

- 1 to 10 tons per acre per application of solid compost depending on the organisms in the soil and in the compost
- If foliar disease observed, then ACT: 10 to 15 lb of compost in 500 gal applied at 1 to 5 to 20 gal per acre.
- Seed dressing: coat the seed
- Extract: 1 to 5 to 20 gal per acre per application depending on organisms (spring, fall).

Test to Determine Success

- Monitor to make sure beneficial soil organisms increase to correct levels, correct balance, and maintain those levels and balances.

- Monitor measures of health
  - Compaction, puddling
  - Watering requirements
  - Yields, tillers, plant color, brix
  - Disease, pests
  - Fertility

Background

Lessons I learned along the way

Elaine Ingham, B.A., M.S., Ph.D.

Soil Microbiologist

St. Olaf College, Double Major in Biology and Chemistry
Master's, Texas A&M, Marine Microbiology

Ph.D., Colorado State University, Soil Microbiology
Research Fellow, University of Georgia

Assistant, Associate Professor, Oregon State University (1986 – 2001)

Rodale Institute, Chief Scientist 2011 - 2013

President, Soil Foodweb Inc., 1996 – present
Labs in many places around the world

Oyster Research

Master's Degree, Texas A&M, Marine Microbiology

Oysters in Galveston Bay were not growing

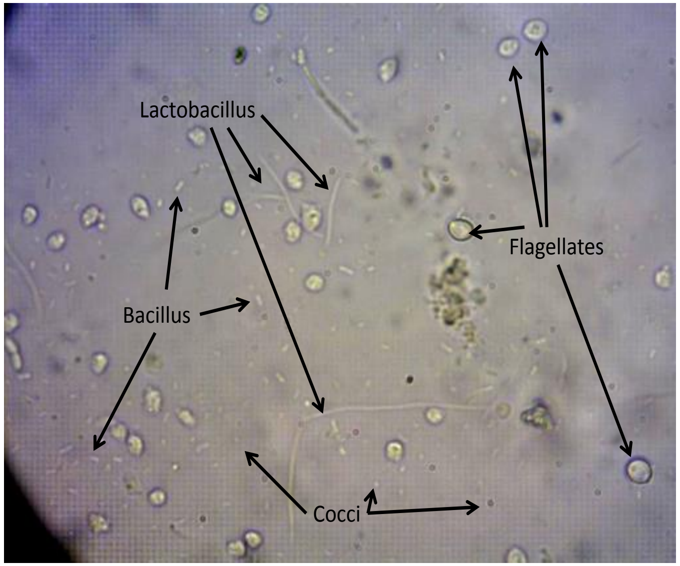
Every chemical known to man had been added to the beds, nothing worked

Maybe biology problem?
Used classical methods to assess what was in oyster digestive system, but……

My Dad had taught me to use microscopes, so I looked at the material using a microscope, and because I was taking an electron microscopy course, looked using electron microscopy

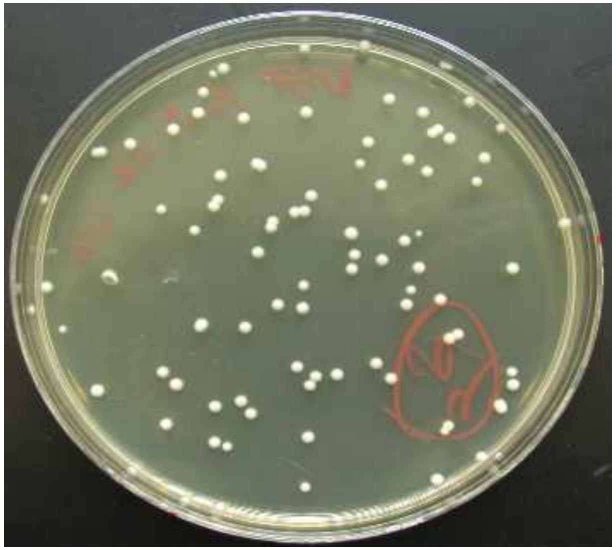
Began to understand that plate count severely under-estimate total bacteria or fungi numbers or species

Direct Microscopy
in a part of a drop (microliter)



1000 bacteria, 12 species; protozoa

Plate Count using TSA
in a teaspoon or ml



100 Bacteria CFU; 2 species

Plate Counts: Classic Method in Pathogenic Bacteriology

- Specific mix of foods in layer on bottom of dish
  - Potato dextrose agar (PDA) for "total fungi"
  - Tryptone soy agar (TSA) for "total bacteria"
- Spread sample on surface of medium
- Cover dish with lid
- Incubate at constant temperature, humidity, moisture.

If organisms can grow, they will reproduce rapidly from 1 to a million individuals overnight (a colony), using up most the oxygen in the limited atmosphere, which selects for pathogen growth.

Why use Plate Counts?

- If we know the exact conditions to grow specific species of bacteria, then we can assess the numbers of those individuals of that species that can or will grow

- Perfect to assess how many human pathogens are present and can grow

- Consider why and who developed plate counts as a method.
  - Doctors looking to understand human and animal pathogens…..

More Methods to Assess Microbes

- Enzyme assays:
  - Substrate use, e.g., cellulose, sugar (glucose, amylose), electron acceptor like TTC into formazan, quite often detected by pH change
- CO_2 evolution:
  - CO_2 is released when food is used
  - Problem: bacterial efficiency, fungal efficiency
- Chloroform Fumigation:
  - Kill "all" organisms, measure CO2 evolved from the dead biomass….. But if all the organisms were killed? Doesn't the biomass of the not-killed organisms count?

Lessons Learned

Plate Counts vs Microscopy: Texas A&M

Active versus Total Biomass

Organism Balances through Succession

Nutrient Cycling:

Colorado State University

Properly Testing GMO's

Starting Soil Foodweb:

Oregon State University

Ecological Monograph

- Ingham et al. 1986
- Established nutrient cycling is performed by the beneficial organisms in the soil
- Requires bacteria, fungi, protozoa and nematodes; and microarthropods when in perennial systems
- David Coleman and the Soil Ecology Society continue this type of nutrient cycling work

Colorado State University

Soil Microbiology

An across ecosystem comparison of:
Irrigated wheat
Dryland wheat,
Shortgrass priarie,
Tallgrass prairie,
Meadows, and
Lodgepole pine forest

From very bacterial to very fungal
The organisms in soil set the stage for different plants to grow
Exclude weeds when biology shifts
Most rapid rates of decomposition under a blanket of snow

Assistant, Associate Professor,
Oregon State University

IPGA at the USEPA in Corvallis

Worked on genetically engineered *E. coli* species

E. coli does not survive in healthy soil

Addition of antibiotic markers means this organisms has to use energy the parent does not, so there is no environmental gain and the GMO dies faster than the parent

Testing of GMO's was the same as for FIFRA and TOSCA:

What effect would GEMs have on ducks, fish, or shrimp-like water creatures when put in their food?

USDA – APHIS established regulatory language, based on these few bacterial species tests:

"GEO are of no greater risk than the parent"

Therefore, testing is not needed…… but…...

Klebsiella planticola

1. Decomposes green plant material and exudates and exists in the root systems of ALL PLANTS
2. Engineer alcohol production into the bacteria, then you can make alcohol from all plant residues.
3. Instead of field burning, remove residues to container on-farm, add this GEM, produce alcohol, sell it
4. Remaining material in the container could be spread on field as fertilizer

What possible harm?

Ph.D. Graduate student: Michael Holmes

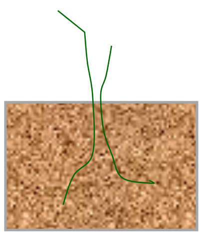
Genetic material coding for alcohol production taken from *Xymomonas*, a bacterium, and inserted into genome of *K. p*.

Test to see if this GEM could cause any environmental effects.

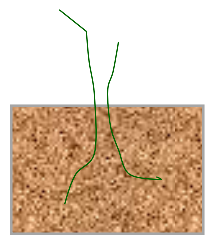
What is the effect of the anaerobic waste compounds, alcohols, on roots?

<u>Experiment done by Mike Holmes:</u>

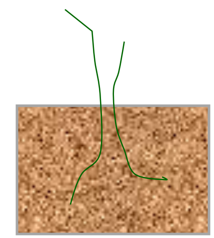
Sieved, mixed soil added to soil microcosms



Just water



Parent *Kp*



GEM *Kp*

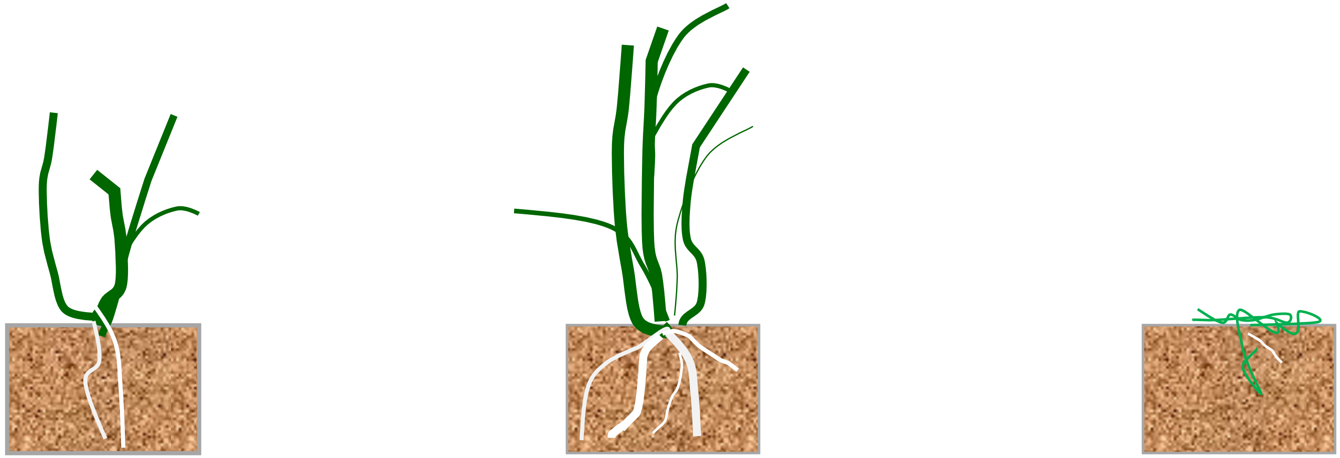
in the same amount of water as control

Wheat seedling planted in each microcosm

Placed in incubator, moved daily to make certain no incubator bias

Published: M. Holmes et al. (Applied Soil Ecol., 1999):

A week later:



Just water — Parent *Kp* — GEM *Kp*

Alcohol is one of the most plant toxic materials known

Presented Dr. Holmes' data to the United Nations Biosafety Protocol meetings in Madrid in 1995 and prevented the US delegation from deleting the Biosafety protocol.

On returning to Oregon State University, the "quality", "validity" and "repeatability" of my science was questioned.

Until that point, none of my publications, none of my scientific methods were never questioned or held "suspect".

When I had the audacity to suggest GMO's could be dangerous, and showed that was exactly the case, then my science became suspect.

When my research might require bio-tech companies to actually test their products, then I was suspect.

Because of the attack on my reputation and the harrassment from Oregon State University

I started Soil Foodweb Inc. in 1996

Work with growers all over the world
Experience with all types of ecosystems
Tropical to Polar
Experience with all agricultural and landscape situations

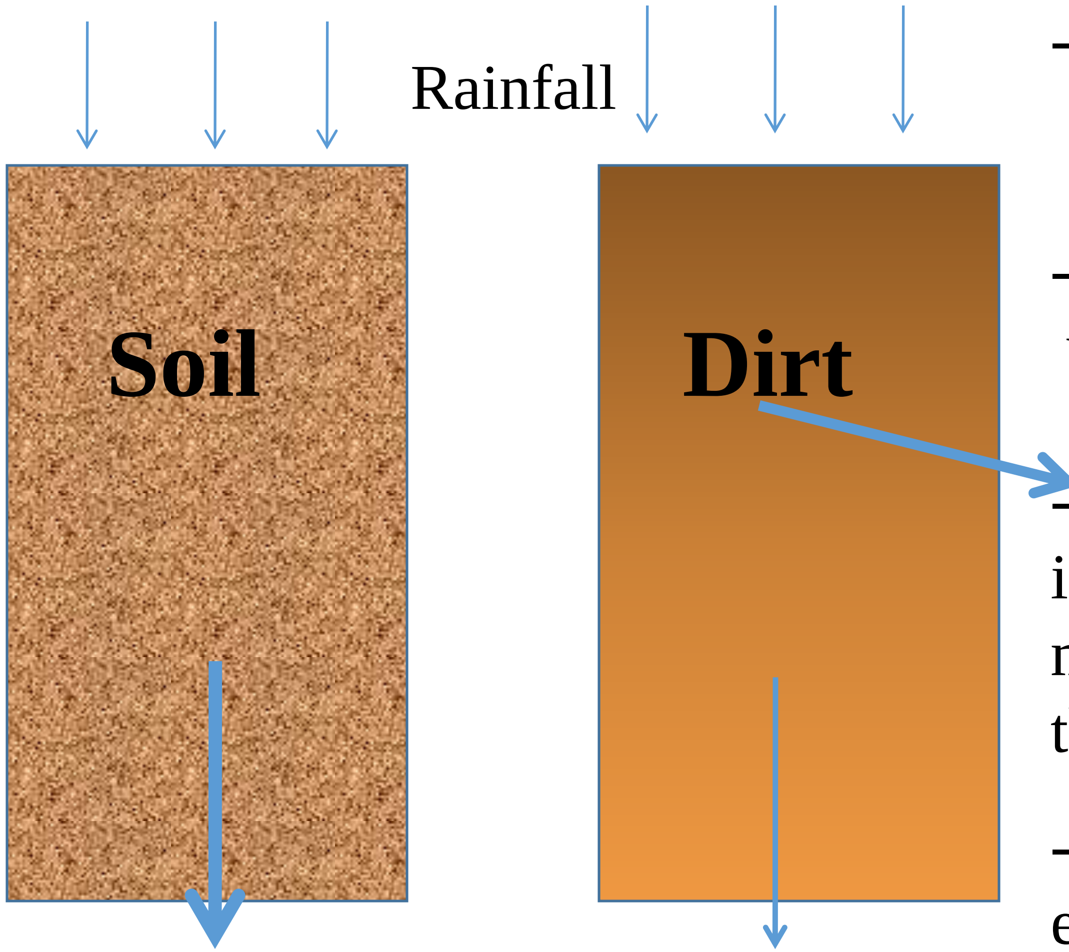
We will go over examples of some of these systems, from small to large scale, natural landscape to agriculture and everything in-between

Soil vs Dirt: Clean water?

-Organisms build structure

-Nutrients held

-Water is retained and moves slowly thru the soil



Clean Water

-no organisms, no structure

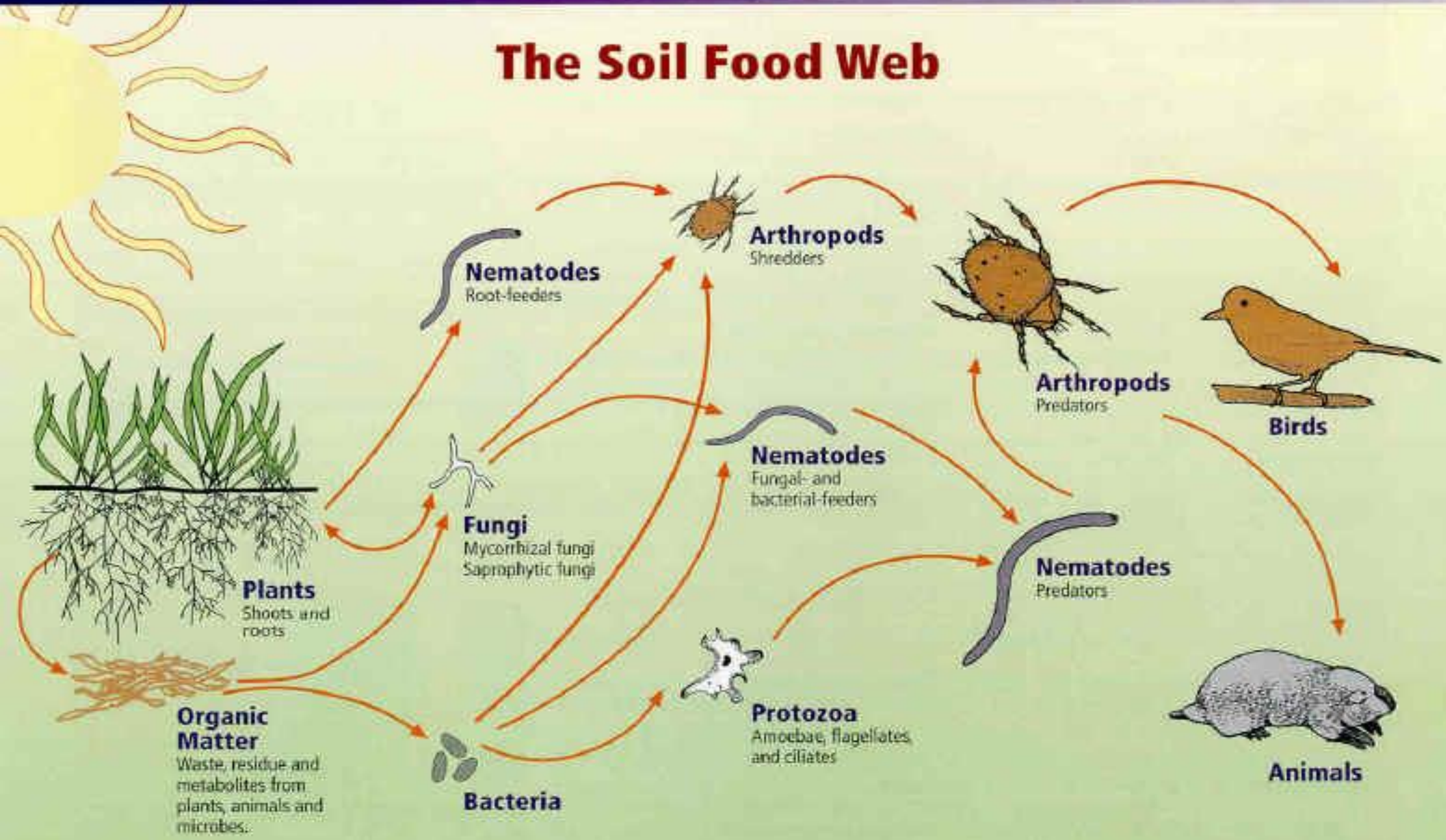
-Nutrients move with the water

-Water not held in soil pores, moves rapidly thru soil

-Leaching, erosion and run-off are problems

Water moves clay, silt and inorganic chemicals so no “cleaning” process

The Soil Food Web



First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators

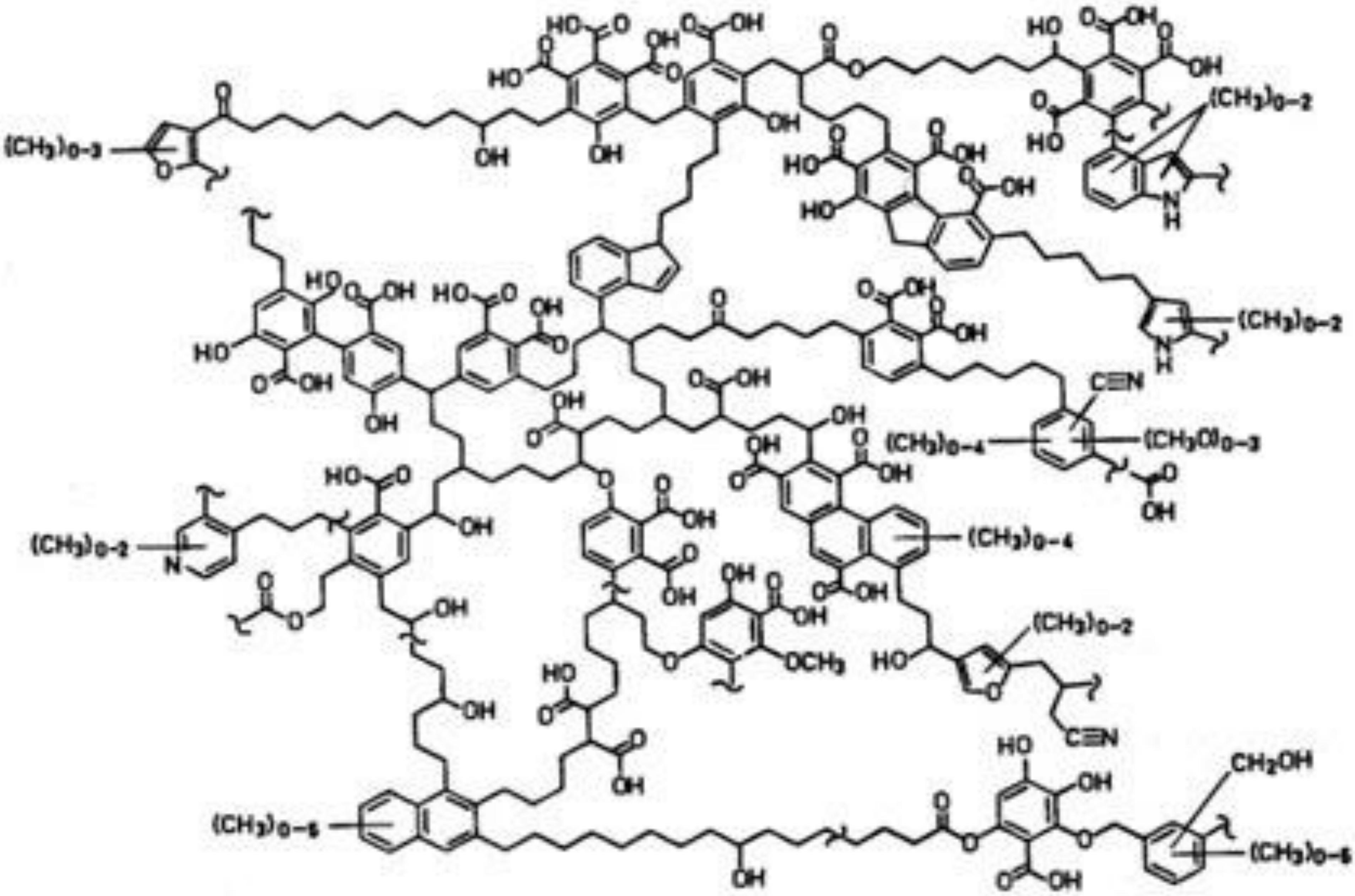
Organism Group	C:N
• Bacteria	5:1
• Fungi	20:1
• People	30:1
• Green Leaves	30:1
• Protozoa	30:1
• Nematodes	100:1
• Brown plant material	150 – 200:1
• Deciduous wood	300:1
• Conifer wood	500:1

Simple to Complex Organic Matter

- Sugar Unbranched carbon chains
- Amino Acids Unbranched sugars with N (NH_2)
- Protein 1 – 10,000 amino acids, branched, plus other nutrients
- Lipo-polysaccharides Branched, PO_4
- Hormones Long protein chains, cyclical
- Olmic acids Highly branched, rings,
- Fulvic acids More highly branched

- Humic acids Extremely branched, complex

A small part of a humic acid molecule



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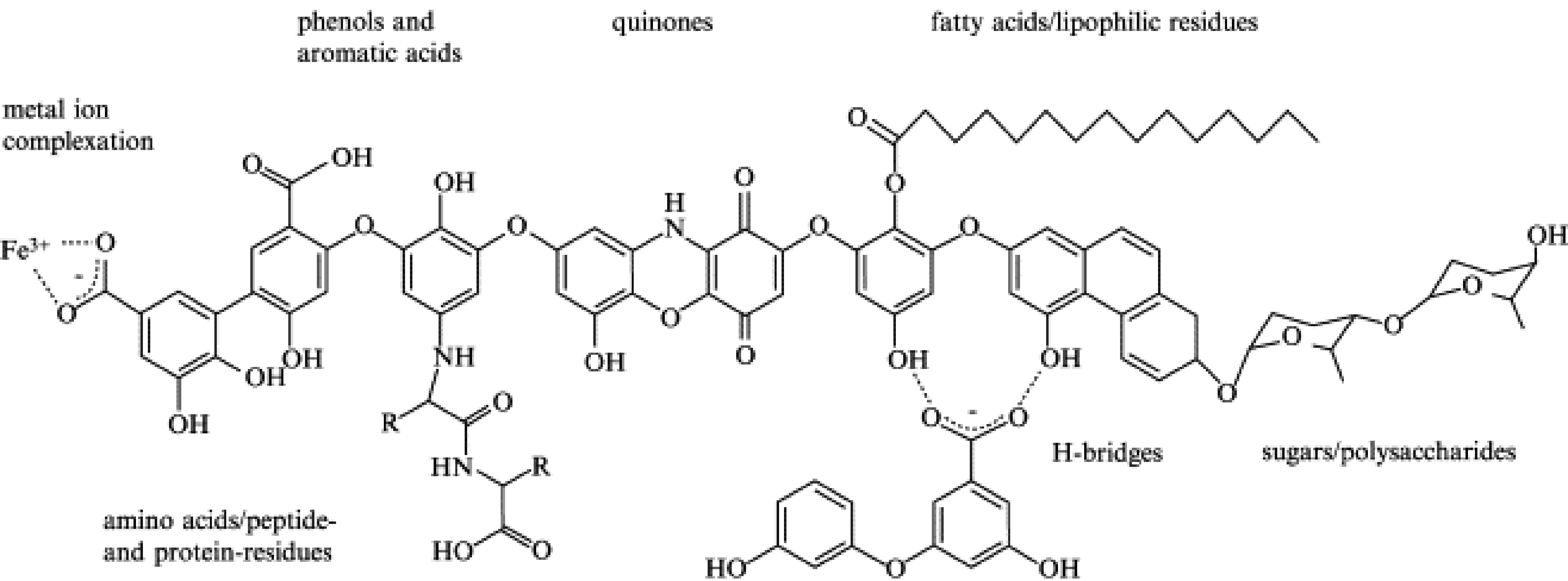
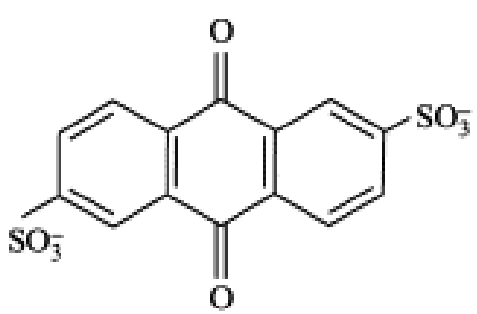


phenols and
aromatic acids
quinones
fatty acids/lipophilic residues
metal ion
complexation
H-bridges
sugars/polysaccharides
amino acids/peptide-
and protein-residues

B



AQDS

Why does soil need organic matter?

- To feed bacteria, fungi, which feed predators and thus cycle nutrients
- Together these organisms build soil structure (keep soil aerobic)
- Hold nutrients so they don’t wash away
- Turn nutrients into plant-available forms
- Compete with, inhibit and consume diseases and pests
- Hold water

Interactions

How do minerals, organic matter and organisms interact?

Soil Mineral Particles

Classified by **Size:**

Sand = 0.05 to 2.0 mm (visible to the eye)

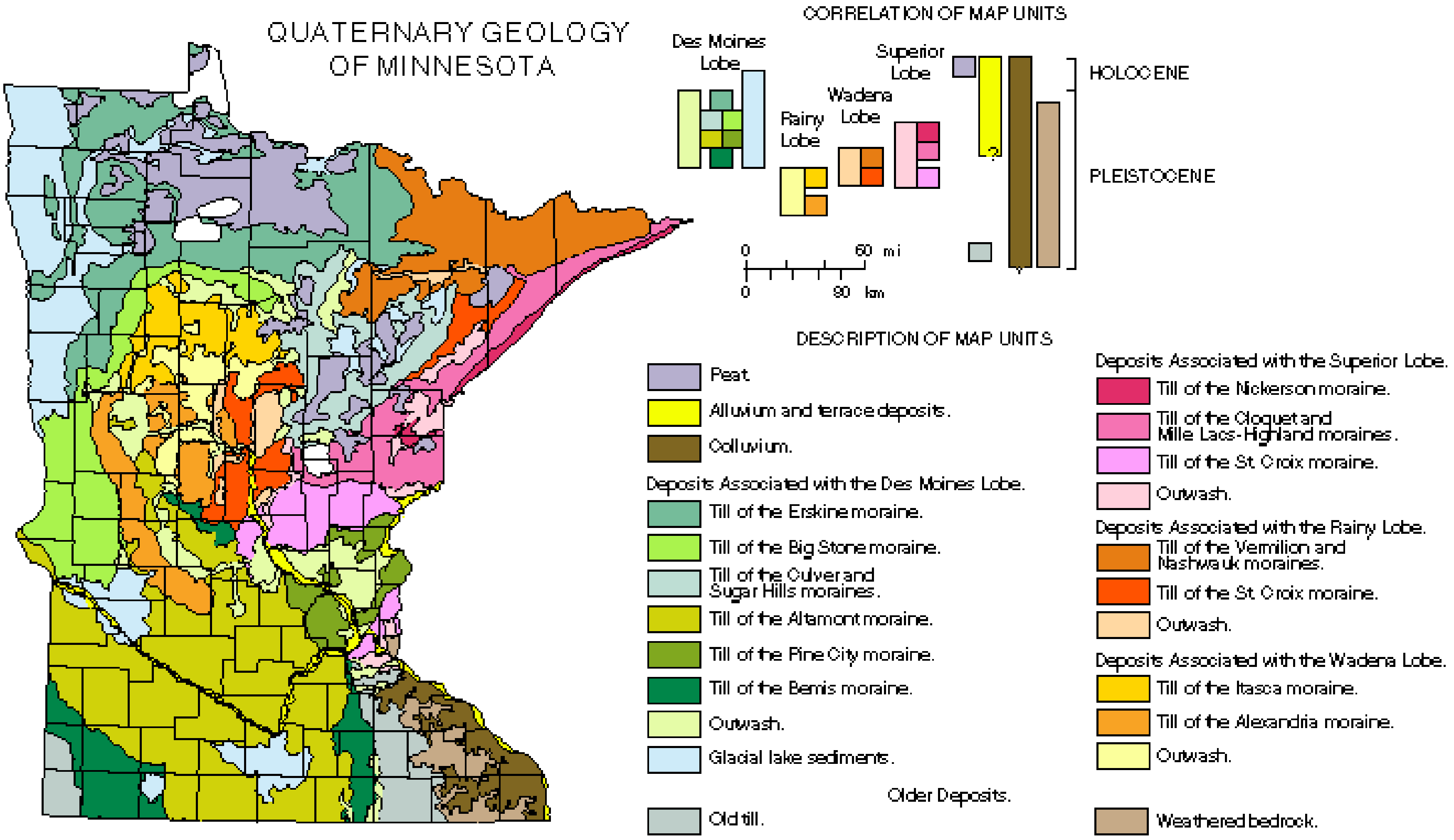
Silt = 0.002 to 0.05 mm (the size of a blood cell)

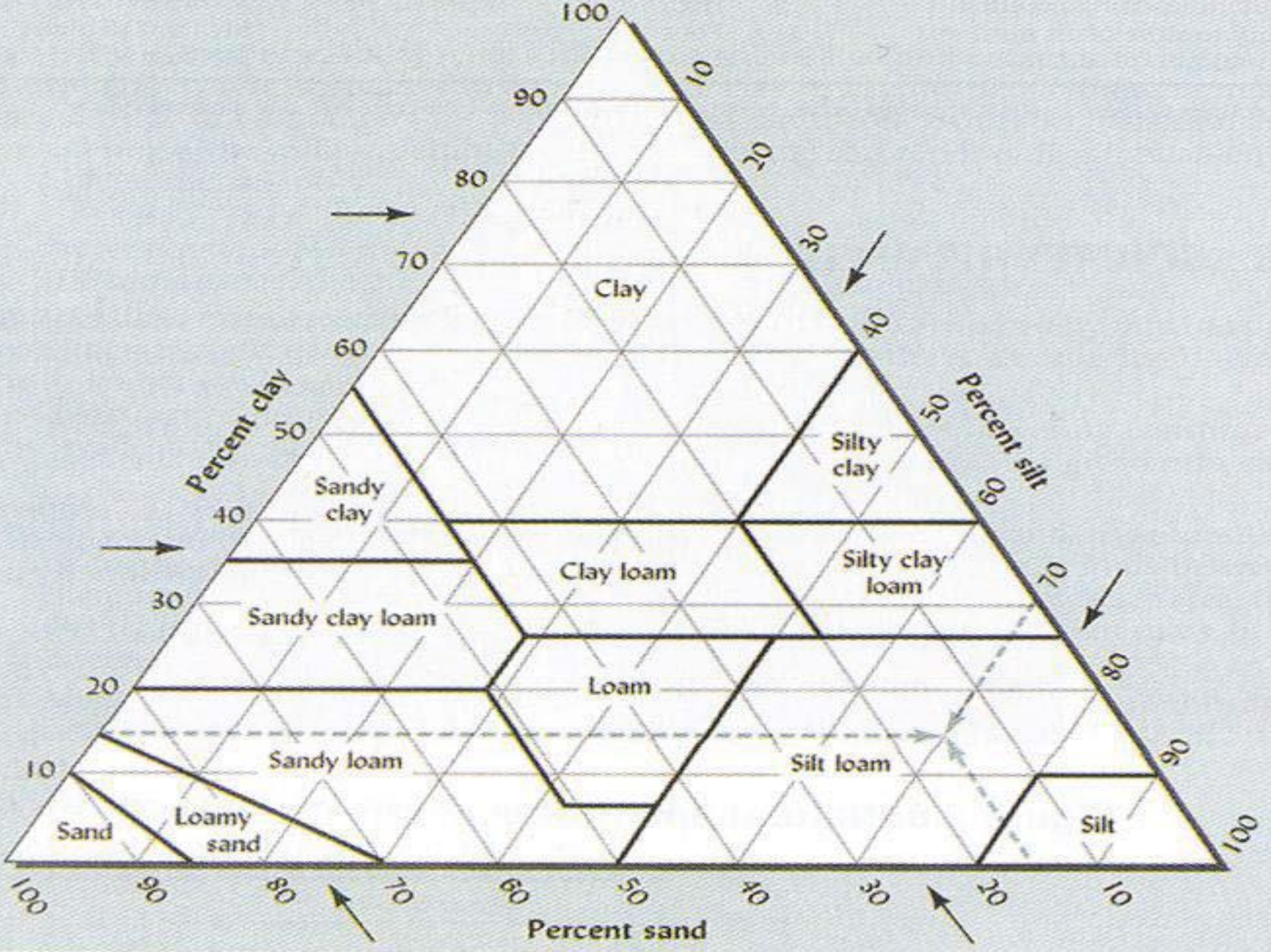
Clay = < 0.002 mm or 2 µm

----

cm = centimeter 10^{-2} meter
mm = millimeter 10^{-3} meter
µm = micrometer 10^{-6} meter

Mineral particles come from… Parent material / Bedrock





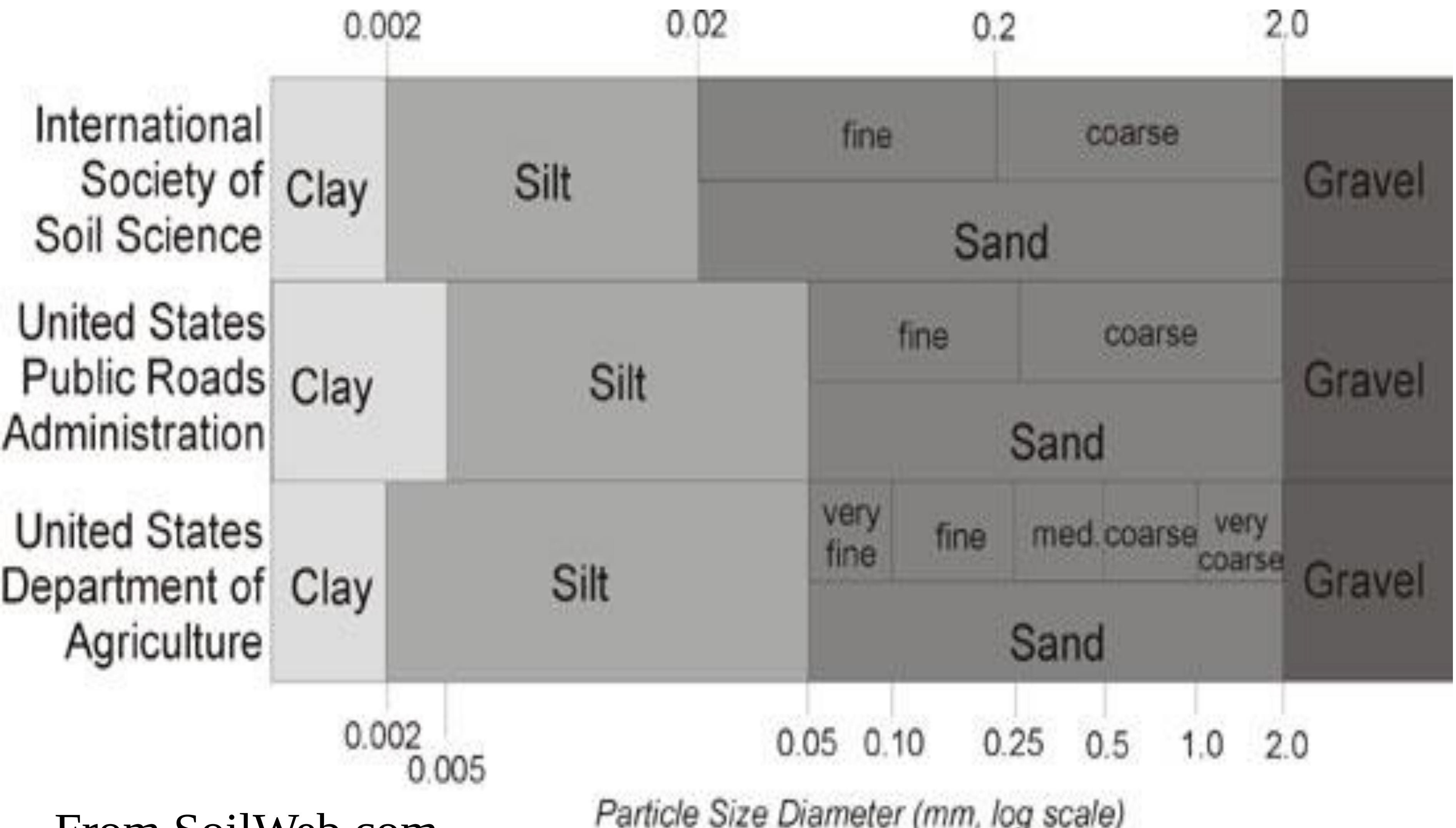
100
90
80
70
60
50
40
30
20
10
Percent clay
10
20
30
40
50
60
70
80
90
100
Percent silt
100
90
80
70
60
50
40
30
20
10
Percent sand
Clay
Silty clay
Sandy clay
Clay loam
Silty clay loam
Sandy clay loam
Loam
Sandy loam
Silt loam
Loamy sand
Sand
Silt

Silicate Clay Mineral Groups:

Adapted from Sposito1989. The Chemistry of Soils. Oxford University Press.

Group	Layer Type	Layer Charge	Type of Chemical Formula
Kaolinite	1:1	<0.01	$[Si_4]Al_4O_{10}(OH)_8.nH_2O$ (n= 0 or 4)
Illite	2:1	1.4-2.0	$M_x[Si_{6.8}Al_{1.2}]Al_3Fe.025Mg_{0.7}5O20$ $(OH)_4$
Vermiculite	2:1	1.2-1.8	$M_x[Si_7Al]AlFe.05Mg0.5O_{2}0(OH)_4$
Smectite Montmorillinite	2:1	0.5-1.2	$M_x[Si_8]Al_{3.2}Fe_{0.2}Mg_{0.6}O_{2}0(OH)_4$
Chlorite	2:1:1	Variable	$(Al(OH)_{2.55})4[Si_{6.8}Al0_{1.2}\}Al_{3.4}Mg_{0.6}$ $)20(OH)_4$

Soil Mineral Particles



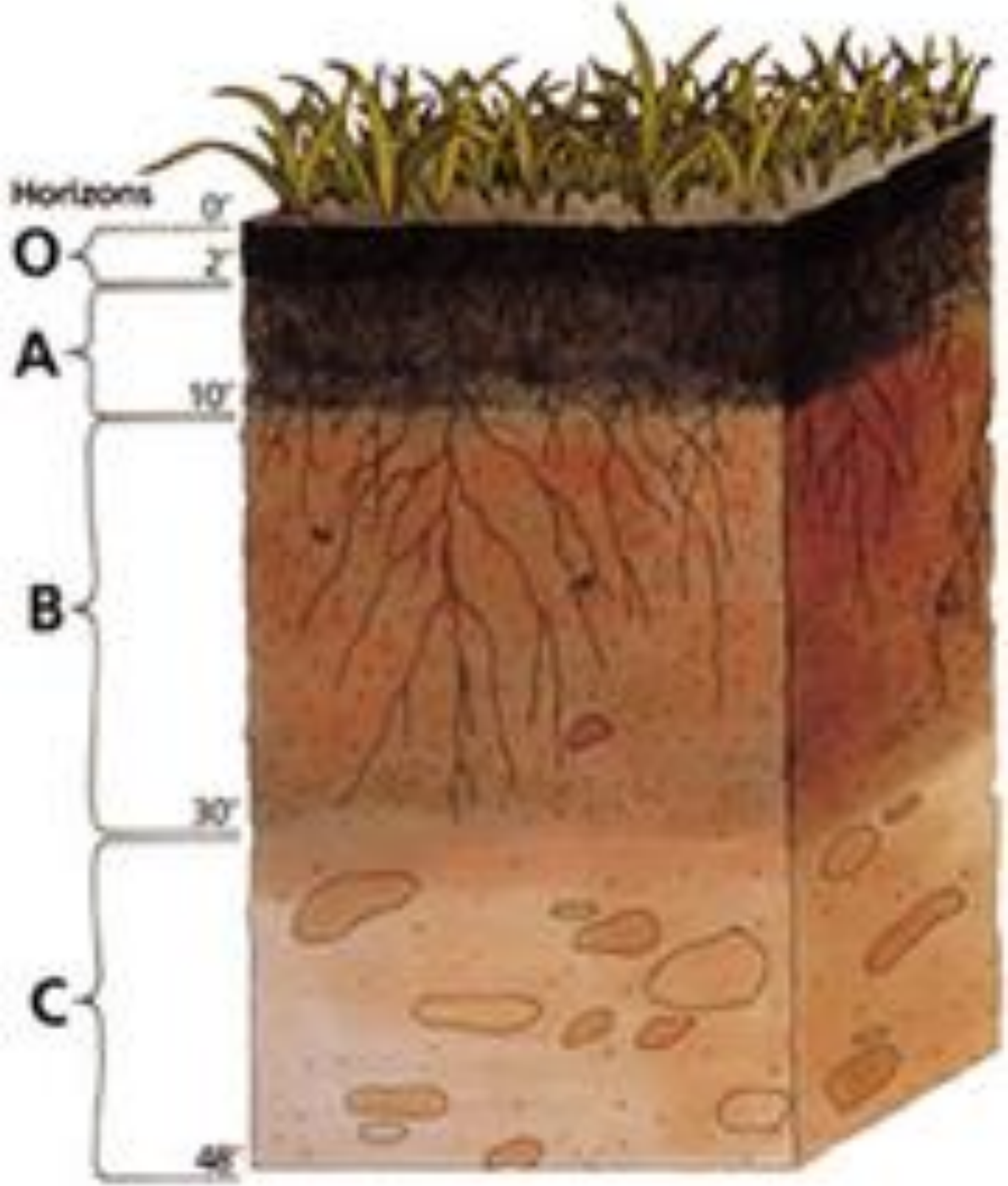
From SoilWeb.com

Elaine's thought: Not til its ground up does it get reactive

Minerals in soil (Sparks 2003)

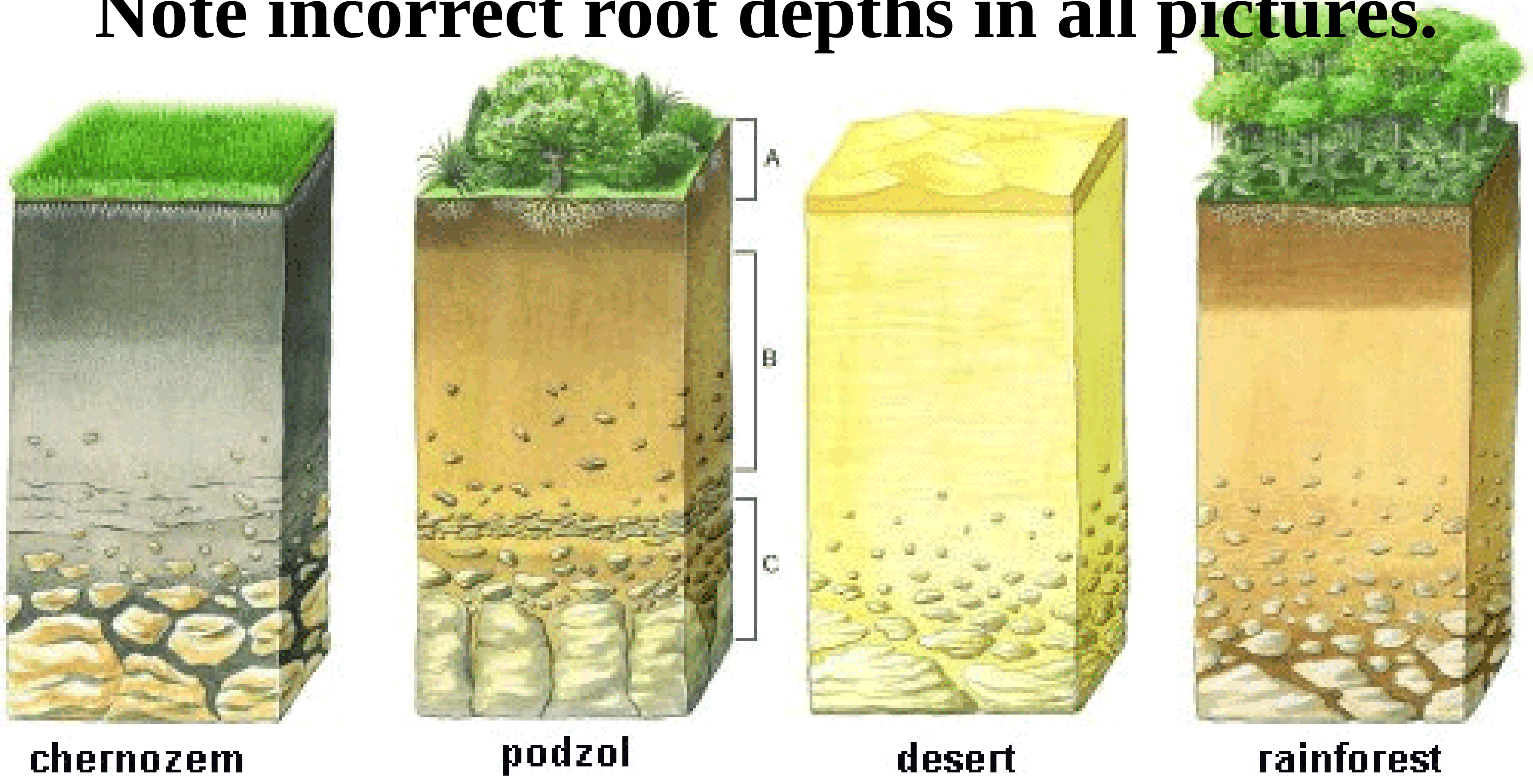
Element	Soils (mg/kg) Median	Range	In the Earth's crust (mean)	In Sediments (mean)
O	490,000	-	474,000	486,000
Si	330,000	250,000-410,000	277,000	245,000
Al	71,000	10,000-300,000	82,000	72,000
Fe	40,000	2,000-550,000	41,000	41,000
C (total)	20,000	7,000-500,000	480	29,400
Ca	15,000	700-500,000	41,000	66,000
Mg	5,000	400-9,000	23,000	14,000
K	14,000	80-37,000	21,000	20,000
Na	5,000	150-25,000	23,000	5,700
Mn	1,000	20-10,000	950	770
Zn	90	1-900	75	95
Mo	1.2	0.1-40	1.5	2
Ni	50	2-750	80	52
Cu	30	2-250	50	33
N	2,000	200-5,000	25	470
P	800	35-5,300	1,000	670
S (total)	700	30-1,600	260	2,200

Undisturbed soil
- Horizons



Soil profiles, or horizons (O, A, B, C) are slightly different in different climates, but all require soil life to develop.

Note incorrect root depths in all pictures.



Soil Chemistry: Nutrient Pools

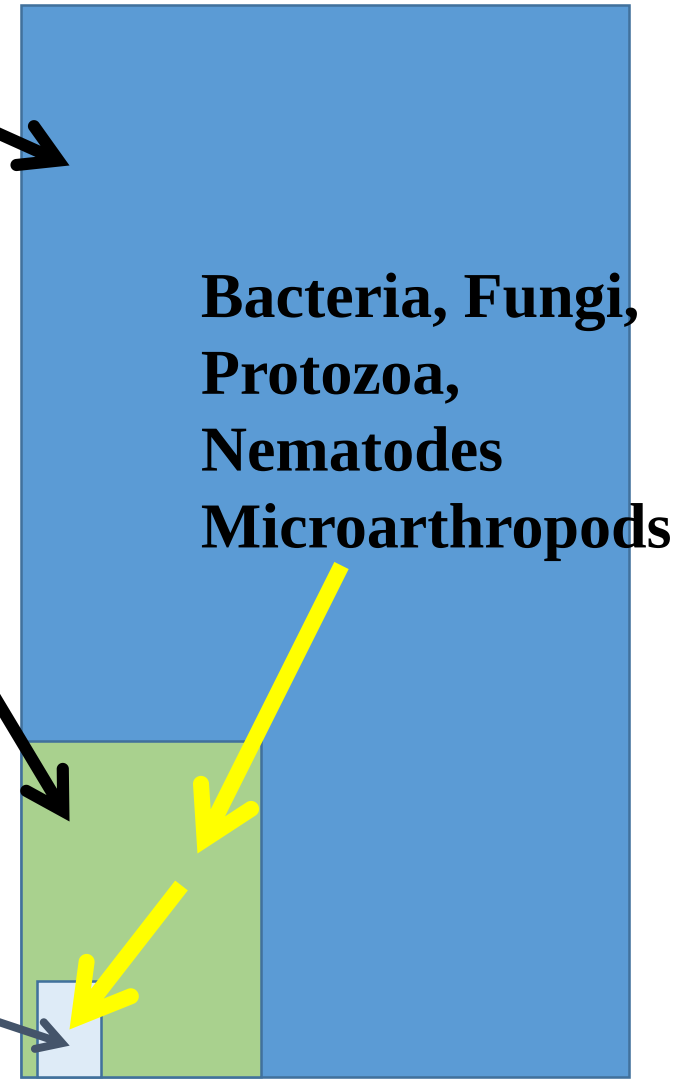
- **Total Nutrients** – not normally reported
  - Grind, complete digestion and combustion
- **Exchangeable Nutrients** (Melick 3, Ammonium Acetate 1N)
  - Strong extracting agents, but not ALL nutrients
- **Soluble Nutrients**
  - Extracts soil solution or water soluble nutrients
  - Available nutrients – made available how?
- **Plant Tissue Tests**
  - Total chemical components….. Balanced?

Nutrient Pools in Soil

Total – everything

Exchangeable - easily pulled off surfaces; easy to make soluble

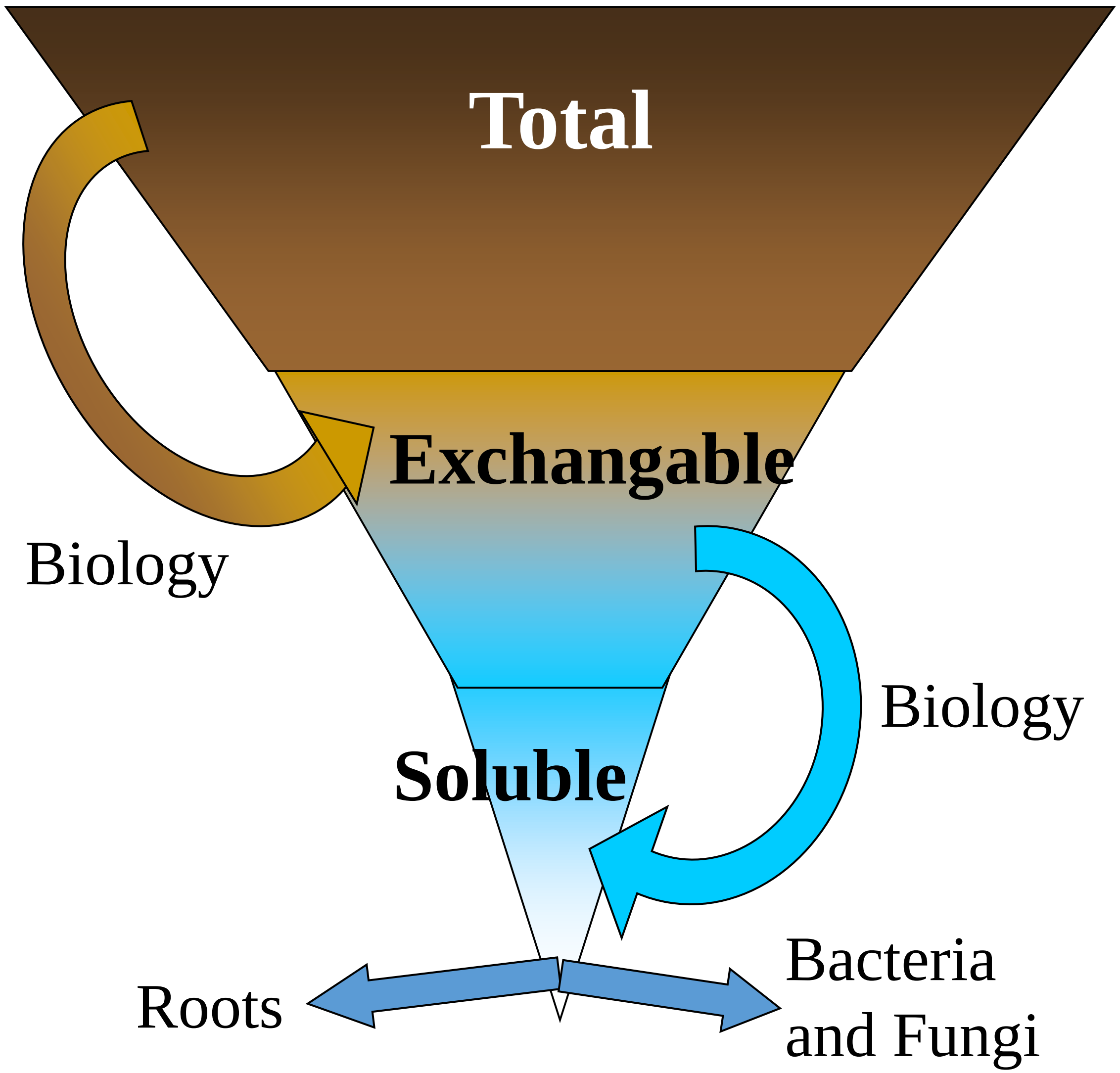
Soluble – dissolved in soil solution; potentially available to plants



Without organisms to retain the soluble nutrients that a plant does not take up, or to change plant-not-available forms in plant-available forms, no new soluble nutrients will occur. Plants will suffer.

What biomass of each organism is needed so the plant gets the nutrients it needs?

Soil Nutrient Pools



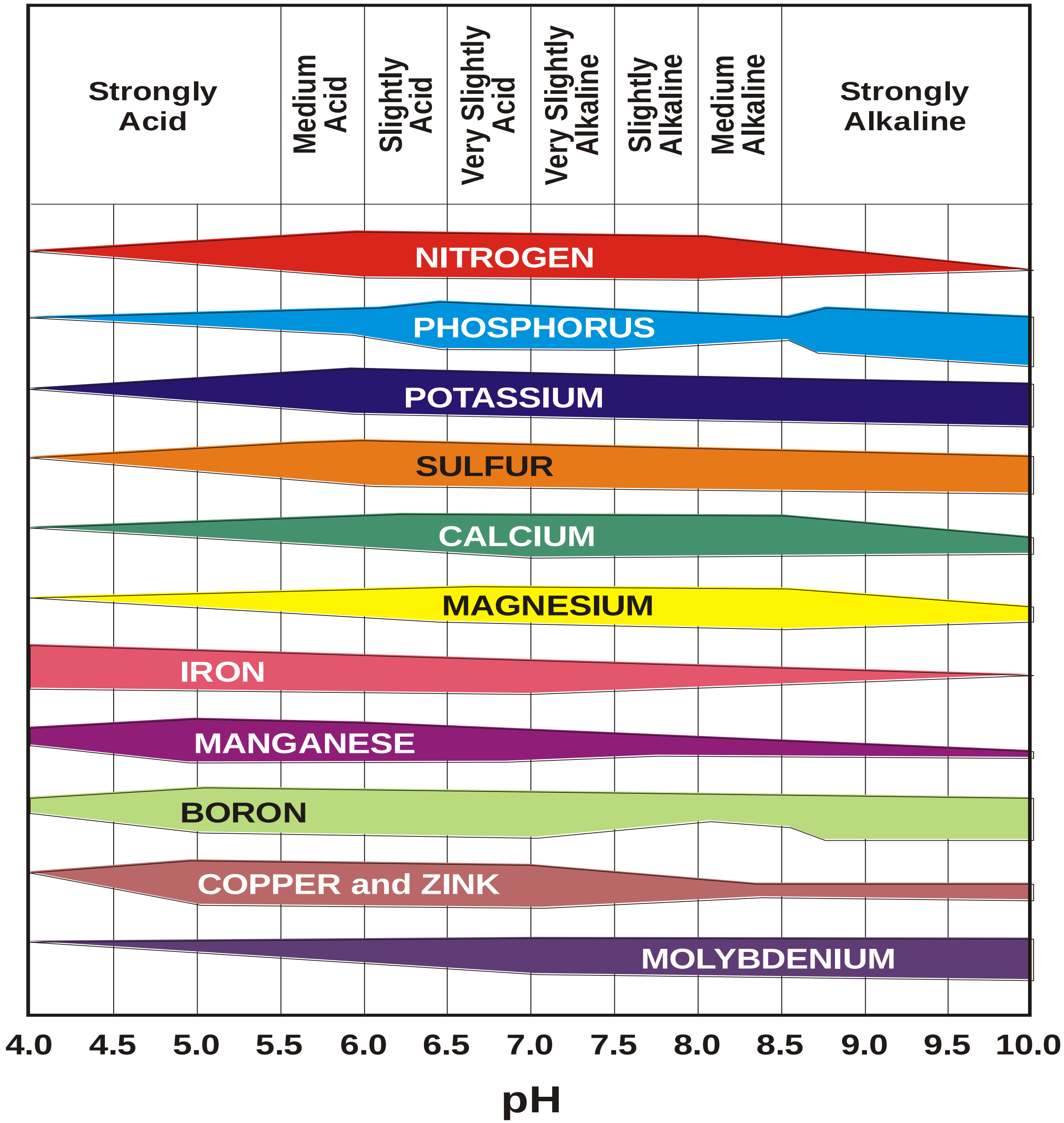
Tests used for the different pools

Grind; Conc. Nitric acid, combustion
10% HCl, H_2NO_3

Melich III
Bray 2
Amm. Cl / BaCl

Colwell
Olsen, Bray 1
Melich I
Morgan (Reams)
1 M KCl, Universal

Availability of Minerals Relative to pH



Without biology, you are stuck with pH as the sole arbiter of what is available to plant roots, as indicated to the left. But add organisms, and plant nutrition is no longer ruled by chemistry alone.

Soil Chemistry

Albrecht and Ca:Mg

What are the nutrients in this soil?

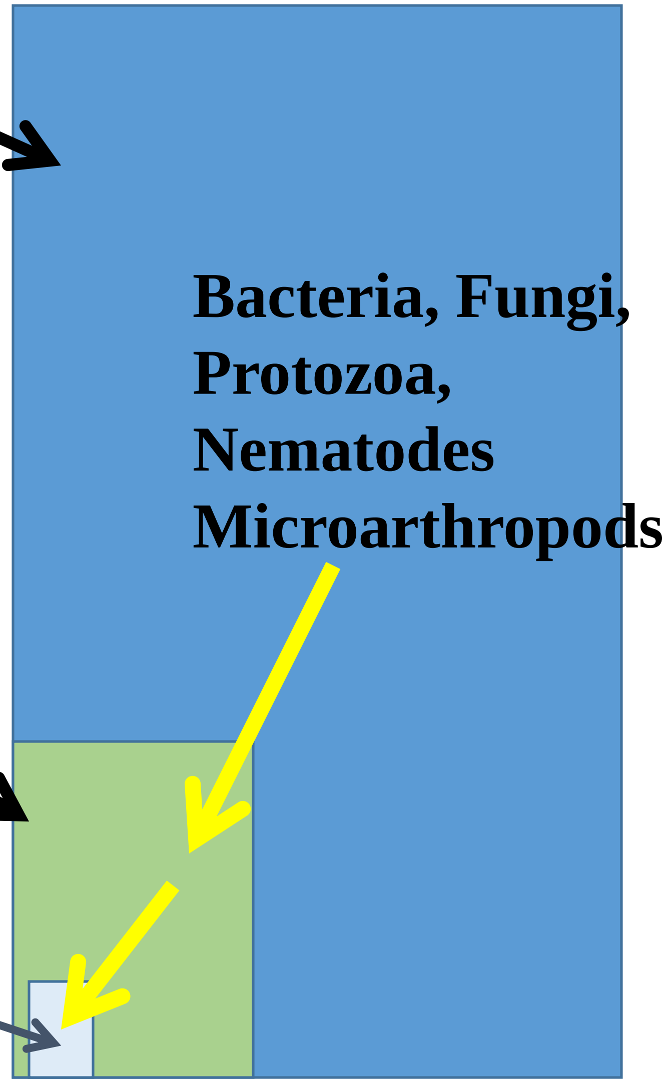
What is the “right” form of N? P? K? S? Mg?

Nutrient Pools in Soil

Total Extractable – not available to the plant

Exchangeable - easily pulled off surfaces; easy to make soluble

Soluble – dissolved in soil solution; potentially available to plants



Without organisms to retain the soluble nutrients that a plant does not take up, or to change plant-not-available forms in plant-available forms, no new soluble nutrients will occur.   Plants will suffer.

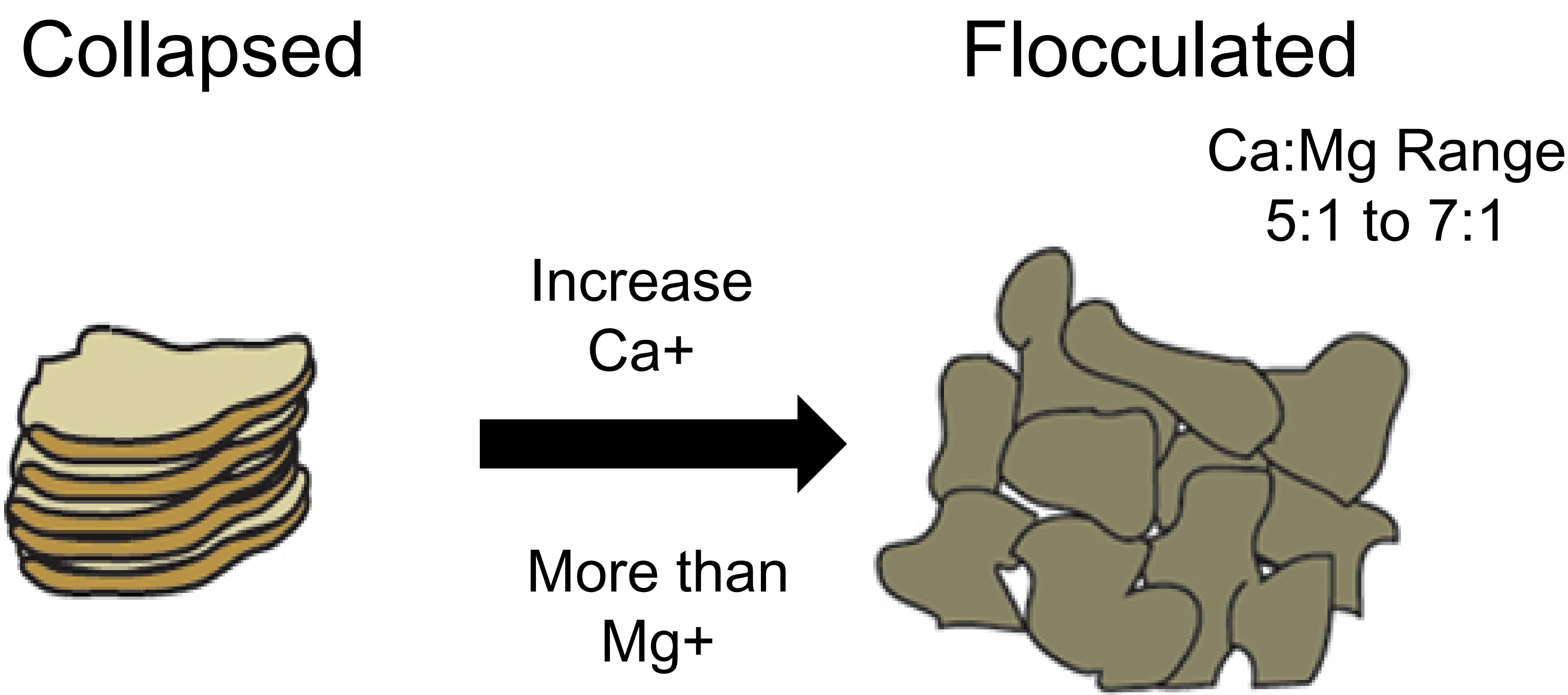
What biomass of each organism is needed so the plant gets the nutrients it needs?

Why do we care about Exchangeable Nutrients?

1. Much of the chemical basis of soil structure lies in how the clays bind to each other in the soil
2. To get air and water to move into the soil, and then be held in the soil structure, clays must be floculated.
3. To floculate the clays, the exchangebable Ca:Mg ratio must be correct, given the type of clay.

Collapsed vs well-structured clays

Adapted from. J. Walworth. Soil Structure: The Roles of Sodium and Salts. University of AZ



Victorian Resources Online: Soil Structure

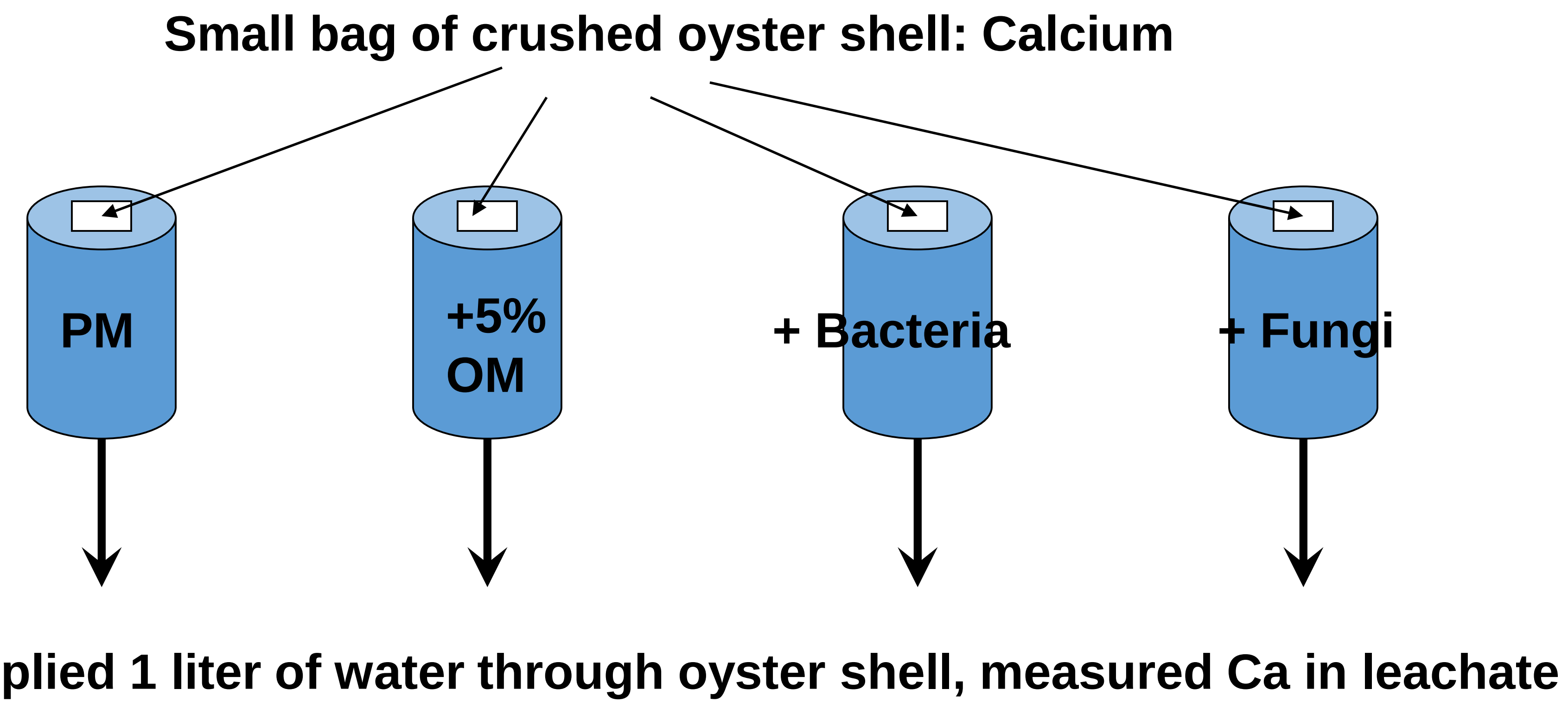
What holds Ca in soil?

- Discussed N, what about other nutrients?

- Calcium as an example

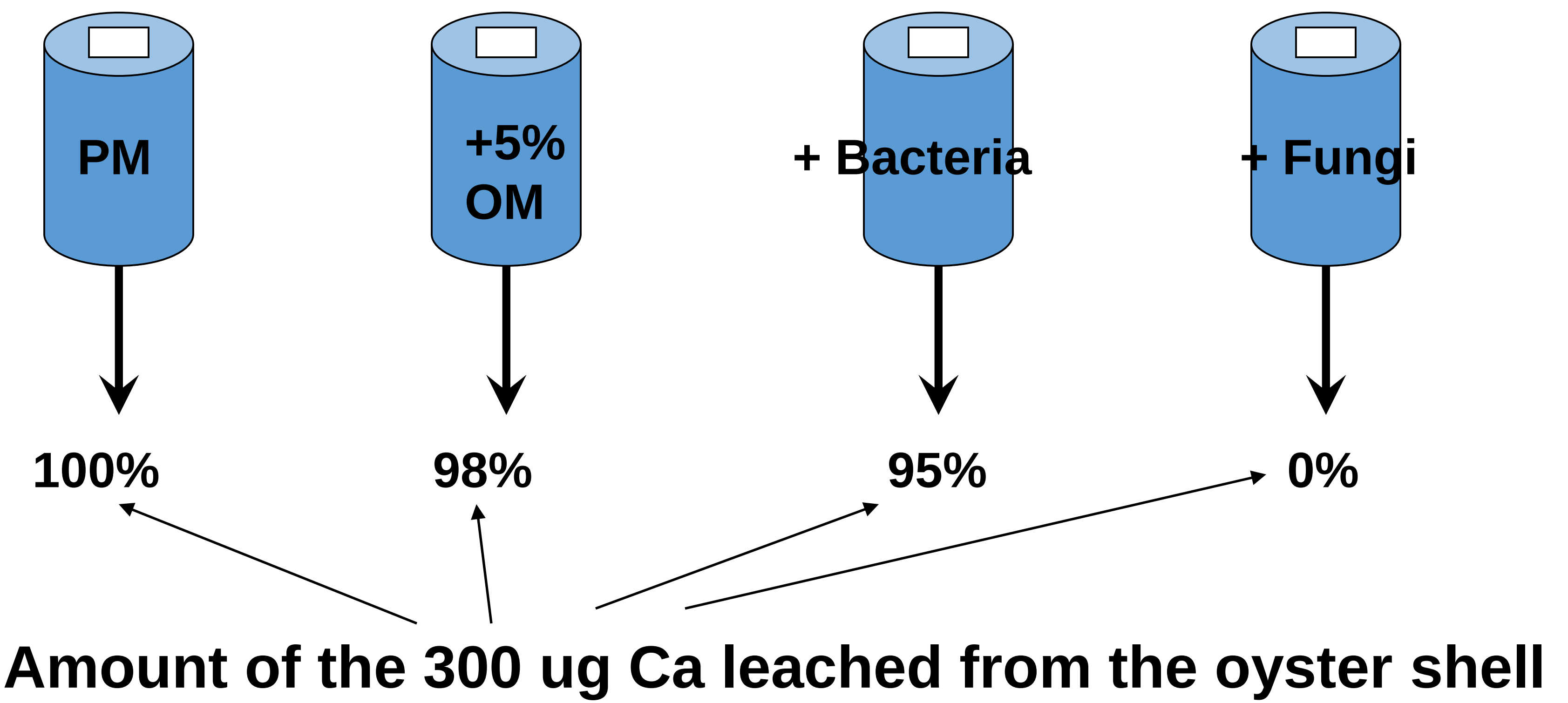
Sandy loam soil, no OM, sterile, re-packed to same bulk density

- Bag with oyster shell on surface of each replicate of the following treatments; 1 L water passed through, 300 micrograms of Ca leached into soil



Sandy loam soil, no OM, sterile, re-packed to same bulk density

- Parent material held no Ca. Sterile OM held only 2% of the leachable Ca, bacteria and OM held 5% of Ca, when fungi present, ALL CALCIUM held.



Biology and chemistry working together properly build soil physical structure

What comes first?

1. Clays must be flocculated. What makes Ca soluble in soil?
2. Microaggregates must be built
3. Macroaggregates must be built
4. Air passageways and hallways must be present

Example Systems

Examples of Success:
Weeds in large ag types of systems
Plant Succession

Adding Biology

Swiss Chard in Petaluma, California

- Front area sprayed with one tea application
- Back area, normal organic practices
- From Daniel and Caitlin McLeod

One of the biggest problems….

- Weeds…
- In the 1990's, herbicide companies talked to growers to find out what people considered weeds.
- Basically, they came up with "any plant out of place" is a weed.
- At sometime or another, therefore, all plants will be weeds.
- This is not a useful definition.

- What is the real definition of a weed?

Ecologically, what is a weed?

- Only occur early in succession
- Disturbed soil, i.e., food web lacks one or more groups
- Pulses of nitrates: high concentrations for short times, no nitrate for short times
- Lack of soluble nutrients at certain times
- High acid or base; extremes of pH
- Habitat that helps “r” selected plants; plant is geared to seed production, not roots

Ian Smith, Mooreville, Tasmania

- Three compost teas have been applied to date. 2 x prior to seeding and 1 x post seeding.
- Reduced herbicide rate used prior to germination greatly reduced weed pressure on paddock 12, when compared with conventional paddock 7
- I am very excited about the progress to date and very impressed with the dedication that the SFI crew show towards their client.

Paddock 7 Onions with Conventional fertiliser and herbicide applications, planted same date as paddock

Close-up showing clean seedbed. Paddock 12

Overall view of paddock 12 low weed pressure

Overall view of paddock 12 low weed pressure

Paddock 7 Onion root system on coventional program. Poorer than Paddock 12.

Well established root system on onion plant. Paddock 12.

Paddock 12 one spray run not treated with compost tea.(Can you spot the difference?)

Flowerfield Enterprises, Kalamazoo, MI

www.wormwoman.com

Summer, 2008:

Can't find the crop where herbicides were used

No weeds with tea

Example 2 - 4: More large scale ag

Claims are made that “going sustainable” means lower yield, more weeds, poor nutrition

In fact if attention is paid to soil life:
- Soil structure improves; roots go deeper
- Weeds do not germinate, do not compete with the crop
- Water holding increases; don’t irrigate
- No need to rotate crops; diseases not an issue
- Balanced nutrients in plant material

Permaculture, Organic agriculture and Natural Agriculture are in fact able to feed the world…..

Keyline design involves usually three years of cutting slits several inches to more than a foot deep into the land parallel to a contour line — called the keyline — where the land's slope levels off. SUBMITTED

New plowing method may help fight drought

'Keylining' slices ground so it holds rain, compost

By Anne Paine
The Tennessean

Howard Switzer, known for building straw bale buildings, is helping bring another eco-friendly technique to the state.

It's called keylining — farming to hold moisture where the land needs it and to enrich the land. The practice is paired with a compost "tea" to help build topsoil to nurture plants, versus chemically feeding crops.

"The future is soil," said Switzer, a silver-haired innovator with Ecoville ArchiTechs.

He was assisting Brian Bankston, dubbed the Keyline Cowboy, last week as he plowed property along the Big East Fork near Leiper's Fork in Williamson County.

The unusual plow, a tool for a technique developed in the 1950s in Australia by P.A. Yeomans, cut deep through grass roots and compacted subsoil. Knife-like prongs sliced into the earth, and a liquid compost "tea" dribbled down small tubes into the land.

The cuts fell along a "keyline" where the landscape's slope levels out. The design is meant to stop rainwater, absorbing and diverting it to adjacent ridges.

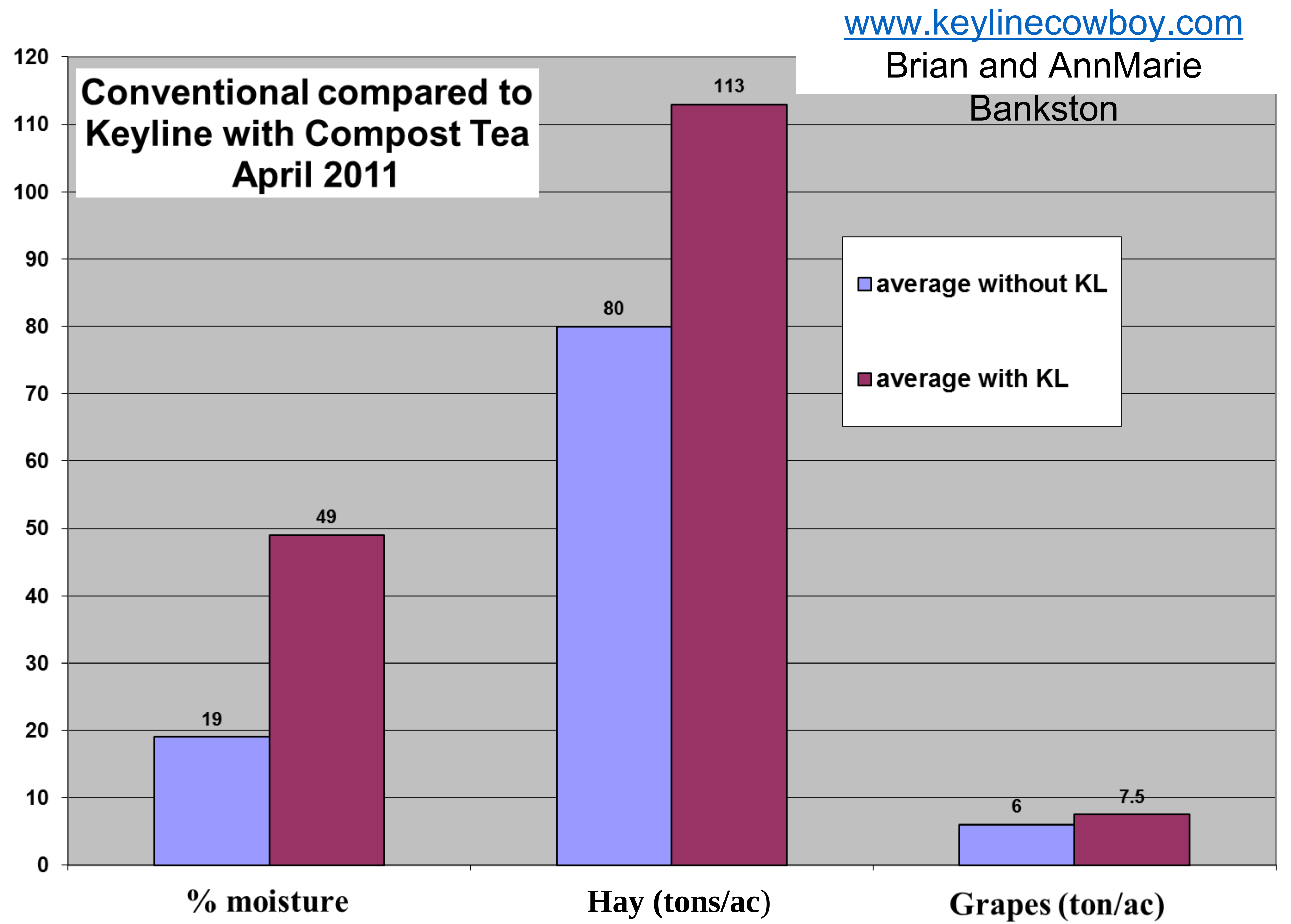
The land belonging to Dr. Jonathan Oppenheimer wasn't being turned over, but the subsoil was opened to beneficial fungi and bacteria and water.

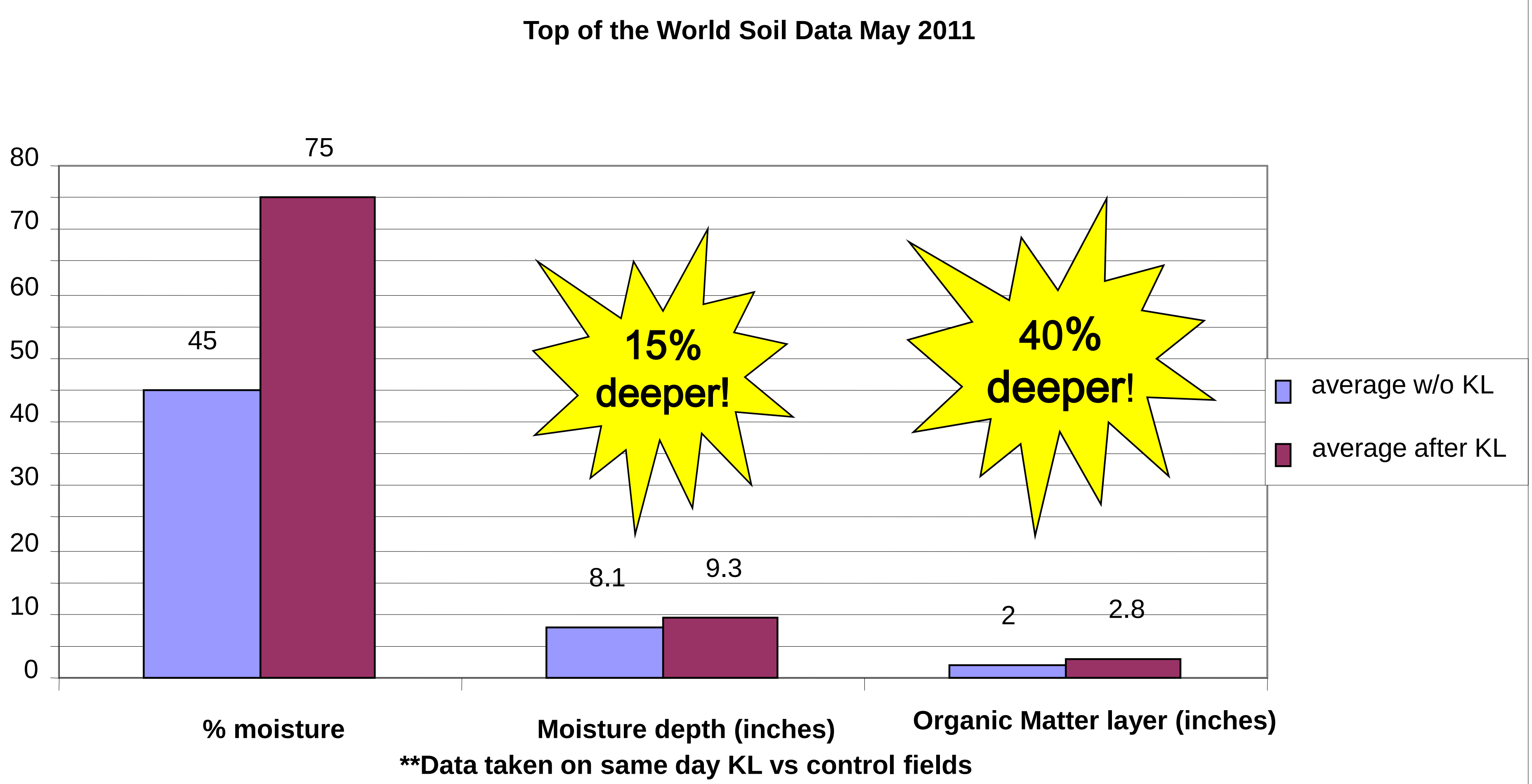
Brian Bankston, the Keyline Cowboy, talks with architect and eco-innovator Howard Switzer beside a vat of compost "tea" on Jonathan Oppenheimer's land in Williamson County. The tea is dripped into the ground cuts. SUBMITTED

"We've learned that our current agricultural practices destroy soil," Switzer said. "We're learning to re-grow it."

The idea that soil is harmed by current farming techniques or that the subsoil needs to be cut isn't something that one University of Tennessee-Knoxville agriculture expert agrees with.

» FARMING, 6B


www.keylinecowboy.com
Brian and AnnMarie Bankston
Conventional compared to Keyline with Compost Tea April 2011
120
110
100
90
80
70
60
50
40
30
20
10
0
19
49
80
113
6
7.5
average without KL
average with KL
% moisture
Hay (tons/ac)
Grapes (ton/ac)



www.keylinecowboy.com Brian and AnnMarie Bankston

Success stories demonstrate disease suppression abilities and impressive financial benefits of technology

Example, 5,000 HA tomato farm (other crops too) in Africa

Conventional Chemical Agriculture

- 1-2 years of production followed by 10 years of fallow due to huge pest & disease issues
- Only 18% was first grade quality
- Yield of 80 tons/ha

Better land use

Better quality

Higher yields

After implementation of new approach

- Worst lands: 3 years of tomato followed by 1 year of fallow
- Best: Continuous tomato without fallow period or crop rotation
- 50% first grade quality
- Currently 100-110 tons/ha, expected to go up to 120 tons/ha

Source: expert interviews; team analysis

Disease suppression; reduction in water

Grape Exchange Australia (table grapes):

- **2006: one non-productive farm achieved normal yields in 1 year**
- **2007: 34 farms converted; weathered severe drought, produced 75% normal yields (vs. 30-50% for conventional farms)**
- **16% reduction in operating expenditure**
- **Improved fruit quality, 8% increase in marketable yields**
- **Reduced average water consumption by 50% to 70%**

Sultanas grown on Australian grape farm

MVOA Ukraine Barley 2009

Control	Extract
# Weeds/m2	
40 – 44	12 – 15
# Tillers/plant	
1.6	2.8
#seeds / seed head	
30	36
Height of plant	
1 m	1.25 m
150 psi Compaction Depth	
4.5 cm	15 – 24 cm
Root length at heading	
3 cm	6 – 10 cm

Brant J. Bordsen bordsen@yubasutterlaw.com

Three years ago we went "no till" and in consultation with Matt Slaughter we started to shift the biology in the right direction for our crop. The results were beyond expectations. Last year we grew the California/West Coast record 1645.5 pound pumpkin (largest ever grown west of the Rockies and 13th largest of all time). Attached is a picture of the pumpkin just before loading for the weigh off. There is no doubt that the soil food web fed the plant. Thank you for your work that gave the knowledge to assess and correct the biology.

Examples 7 - 28: Pasture systems

- Pasture is a crop just like any other green plant

- Grow your own local, indigenous sets of good biology

- Check biology in the soil

- How much compost, extract or tea needed to bring back life to good balance?

CAMPERDOWN COMPOST COMPANY

Biological Farming Products

Tony Evans and Nick Routson

Andrew and Linda Whiting's Farm

Reggie and Geoff Davis

Featured on Landline last month 3/7/2011

Tim and Sally McGlade

Issues

- Fertiliser costs out of control but fertility not good enough
- Insect pressure on lucerne; Insecticides used regularly
- Grass being pulled out by the roots, had to re-sow many paddocks each Autumn ($20,000/field)
- Clover long gone: no nitrogen fixation, dependence on chemical fertilizers
- Profit margins not good, animals sick, disillusioned with results of farming
- No waste management plan

Making compost Graeme Clay 24/12/2010

Program

- Make compost ON-FARM; applied at 3 tonne hectare (1.5 tons to the acre). Shared equipment over 74 farms

- In the first year, added calcium nitrate liquid and in the second year, just pond water

- If fertility issues seen, the plan was to apply fish and tea sprays to pasture. This was never required.


Andrew Whiting & clover 20/12/2010


STOCKFEEDS
intervet

Nodules on N-fixing plants


December (spring) 2010
The left side is the neighbors farm;
Right side of fence is the Whiting's farm.
Whiting's farm looked like neighbours farm 3 years ago.


Same paddock in April, 2011
Whiting’s on left
Neighbours on right
Grazed 5 times
Grazed once
since the season started


May 2011
Whiting's: Grazed 7 times
times since season started
Neighbours grass
still not grazed

May 2011

No N has been applied since compost addition. Pasture is ready to be grazed ten days after last grazing

Results

- Deeper and larger root system; Cows not pulling grass out by roots
- Re-sowing costs decreased by 90% ($20,000 reduced cost per field per year)
- Nitrogen use reduced by over half each year (dropped costs by $100,000 in first year, $50,000 more in second year, no N applications in this year). Saved growers over $200,000/yr
- Converted wastes into benefit
- No disease or insect pressure
- Cow fertility improved significantly (need to validate).
- Stocking rate increased over last two years by 15%
- Mycorrhizal fungi increase from 4% to 87% in three years

Results

- Tissue tests balanced
- Farm different colour
- No response to gibberelic acid or N fertiliser
- Much higher brix from 1-2 up now to 11-13
- No cockchafer damage, neighbours still do
- No red legs or lucerne flea damage
- Clovers coming back
- Deeper roots
- Good growth in wet conditions
- Lots of worm activity and good numbers

Why has 25 years of organic agriculture not fixed fixed the problem? Weeds; Compaction; Urine patches, Poor animal health. Not paying attention to organisms.

Example Systems

Success stories:
Zoos, Landscape

Komodo Dragons at Woodland Park Zoo, Seattle

Extremely high *E.coli* in the soil was remediated by applying compost tea

Date	*E. Coli* #	Foodweb	
March 5, 2009 Before tea spray	4300	Bacteria alone	Three samples taken
Ap 1, 2009	0	Bacteria, fungi, protozoa	Three samples taken
April 15, 2009	0	Bacteria, fungi, protozoa	Two samples taken
Sept 15, 2009	0, 1050	Bacteria	Two samples taken

Brooklyn Bridge Park, NYC Compost tea user –
Client of James Sottilo ElmWise.com

After weeks of hot weather and after 8,000 people watched a movie on the lawn the previous night!

Brooklyn Bridge Park, planted April 2010

Picture taken by Tom Pew (U of Az) Aug 17, 2010 during drought

Work by James Sottilo, elmsave.com

Brooklyn Bridge Park

Planted April 2010

Picture taken by Tom Pew (U of Arizona)

Aug 17, 2010 during drought period

Work by James Sottilo

www.elmsave.com

Battery Park understory planted April 2010
Picture taken by Tom Pew (U of Arizona) Aug 17, 2010 during drought period
Work by James Sottilo, elmsave.com

Battery Park Ball Field maintained with biological approach only

(T. Fleischer, Park Conservancy)

Picture taken by Tom Pew (U of Arizona) Aug 17, 2010 during drought period

Work by James Sottilo

www.elmsave.com

Sod installed around new pond just after installation and one compost tea spray

6 weeks after sod was laid with compost tea below and on the sod.

Roots were less than ½ inch, now 6 inches deep into the soil.

No erosion, no weeds, no disease

Sustainable Growth Texas:
Before – “Sugar Sand” Soils; Hearne, TX, 5/20/02

Before – “Sugar Sand” Soils
Hearne, Texas 5/20/02

Six weeks – “Sugar Sand” Soils
Hearne, Texas, 7/2/02


Bob Long, Jeffries Compost, Adelaide, Australia


Bob Long, Jeffries Compost, Adelaide, Australia

Bob Long, Jeffries Compost, Adelaide, Australia

CASE STUDY
Twin Buttes Reservoir
San Angelo, TX

Twin Buttes Reservoir

- Completed 1963,
  - 8.34 miles long X 134' high
  - Covers over 37 sq. miles
  - Storage capacity of 640,000 acre-feet
- Average rainfall, 18-20 in/yr
- Dam face - silt-clay growing medium

Twin Buttes Dam
San Angelo, TX

Alternative Treatments

- Erosion identified, $\leq$ 6 foot gullies, 1997
- Three test treatments performed, 1999
  - Three 75' X 125' plots
  - Hydroseed, straw blankets, vegetative barriers
  - Material cost range, $2,277-$27,807
- Compost application with seed
  - 105 CY at 2-3" deep
  - Total cost, $3,550

1999 test areas


1999 test area
APR 4 2002

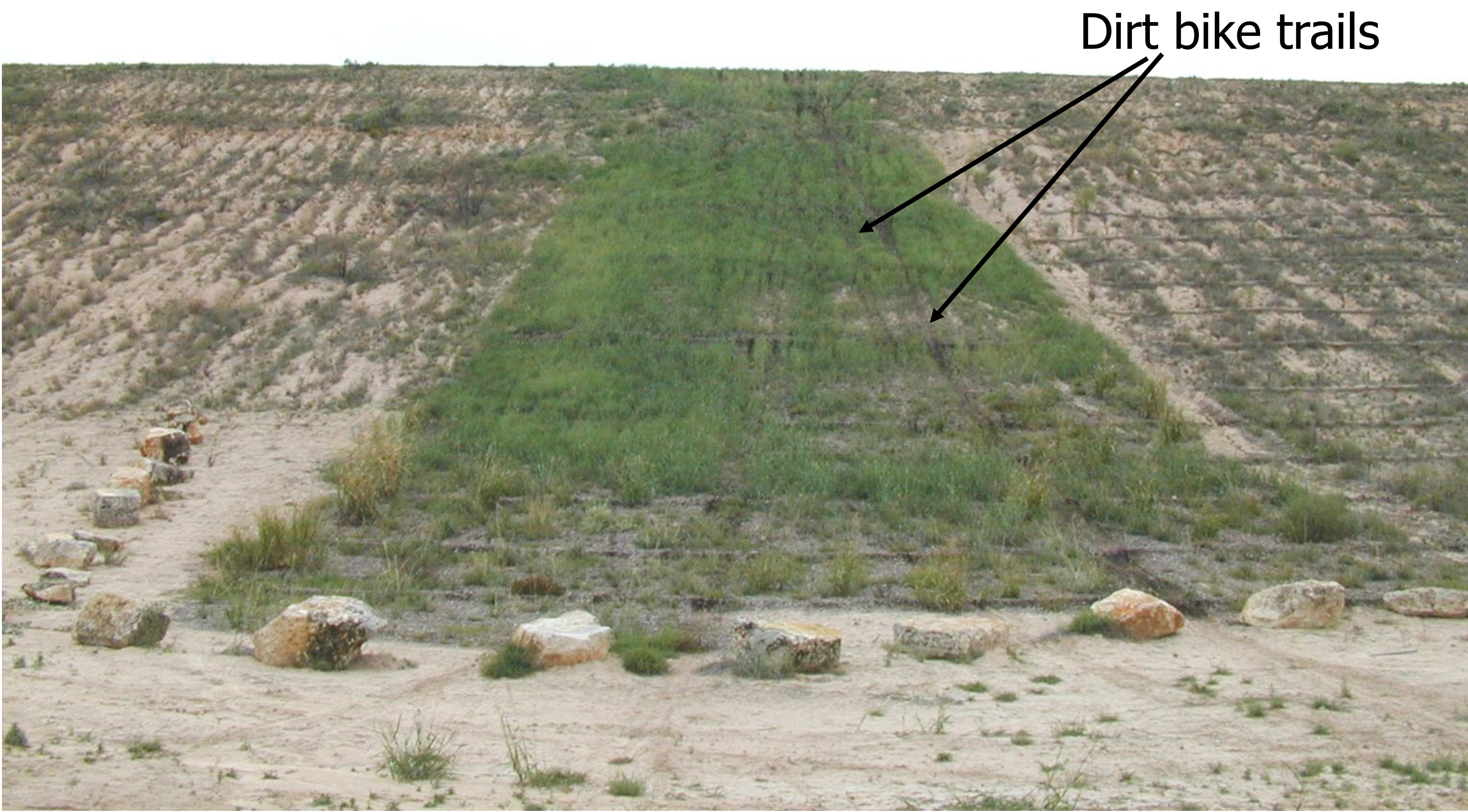
Record high temperature day, 104°F!!

Completed application with berms


Thirteen weeks.
Last rain: 0.5 inches on 7/13/02
Daily temp. 85-95° F
JUL 24 2002


Thirteen weeks .
JUL 24 2002

Six months October 2002



One year May 2003

Two yearsMay 2004

Perennials

Injecting liquid compost into the soil down to 4 to 5 feet to break compaction around roots

Why would the soil be compacted?

Shredded bark benefits what set of organisms?


Lotusland, Santa Barbara, CA

Succession

How Nature Causes Succession to Occur

Succession

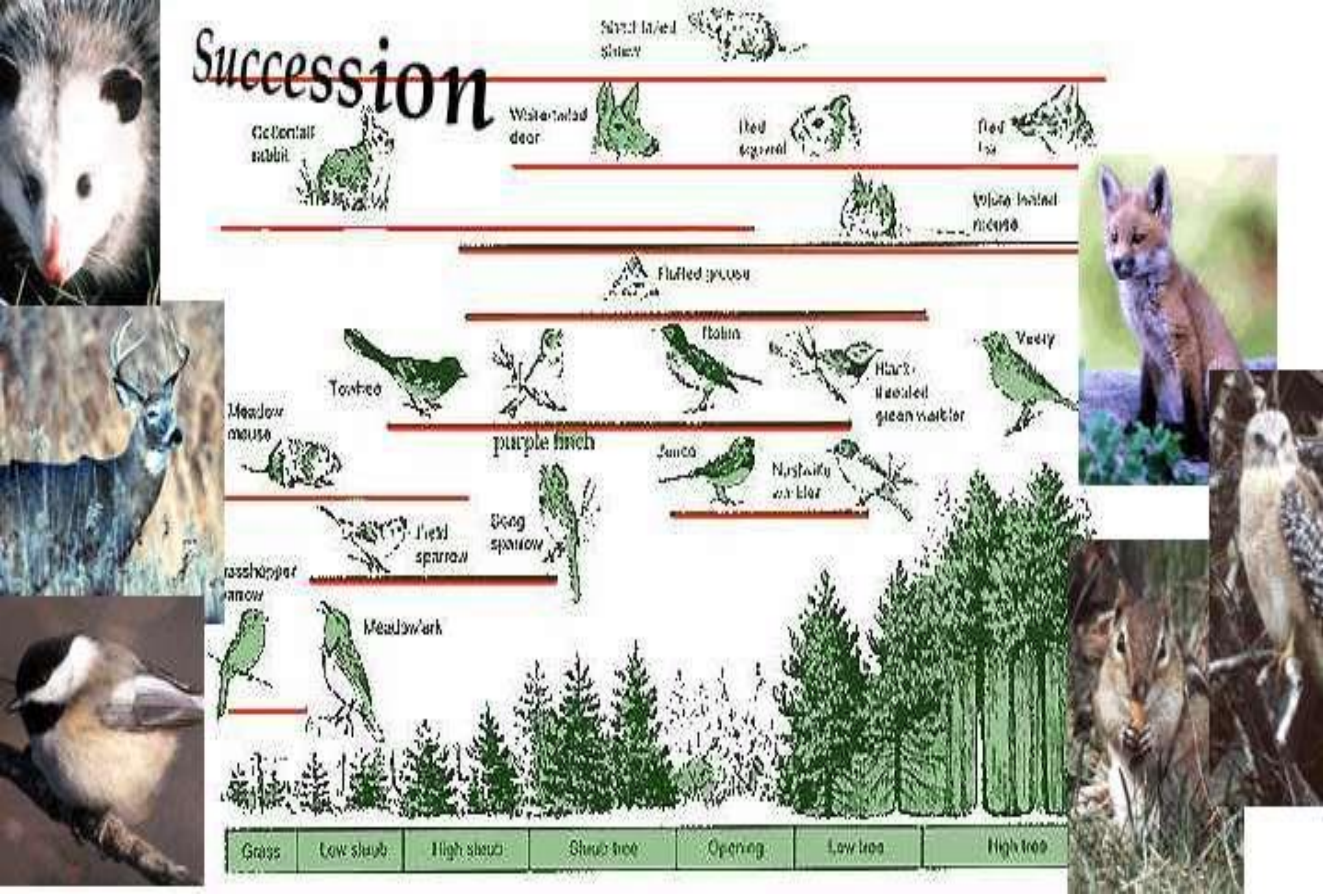
- What is it exactly?

- What stage of succession do you want to have?

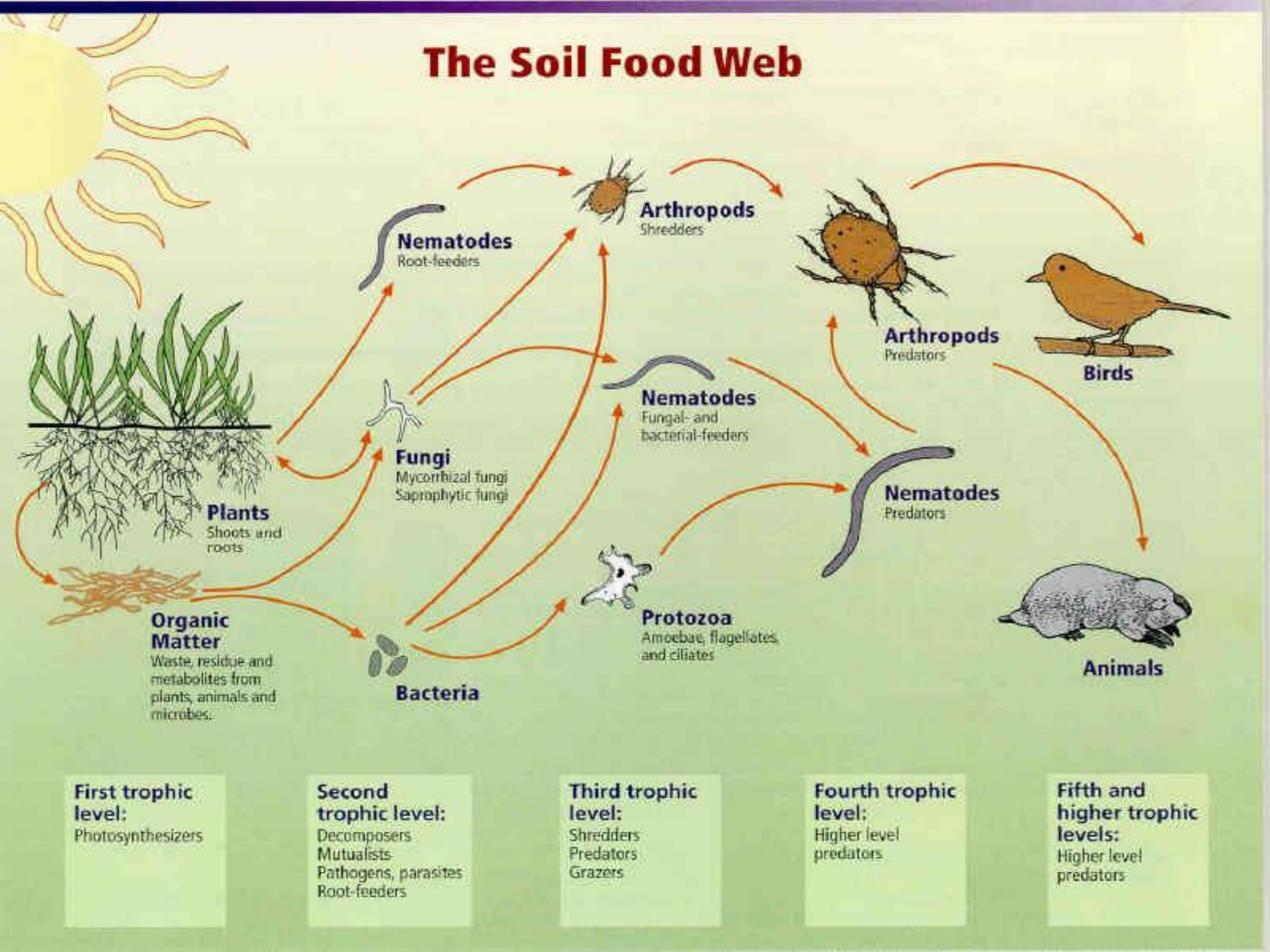
What is the correct stage of succession for tomato? Where does tomato grow in the natural world?

If we select for huge size peppers, does that change the pepper plant’s physiology?

Does that change its place in succession?



McDaniel College


The Soil Food Web
Nematodes
Root-feeders
Arthropods
Shredders
Arthropods
Predators
Birds
Nematodes
Fungal- and bacterial-feeders
Fungi
Mycorrhizal fungi
Saprophytic fungi
Plants
Shoots and roots
Nematodes
Predators
Organic Matter
Waste, residue and metabolites from plants, animals and microbes.
Bacteria
Protozoa
Amoebae, flagellates, and ciliates
Animals
First trophic level:
Photosynthesizers
Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders
Third trophic level:
Shredders
Predators
Grazers
Fourth trophic level:
Higher level predators
Fifth and higher trophic levels:
Higher level predators

DISCOVERY: Ph.D., Colorado State University, Soil Microbiology

An across ecosystem comparison of:

Irrigated wheat

Dryland wheat,

Shortgrass priarie,

Tallgrass prairie,

Meadows, and

Lodgepole pine forest

From very bacterial to very fungal

The organisms in the soil are what sets the stage for the plants to grow

Exclude the weeds when biology shifts

Most rapid rates of decomposition under a blanket of snow

SFI Data: Based on Ecosystem Studies

Arid/ Semiarid Grassland, Crop & Pasture

Texas A&M, Colorado State, Wyoming, Nebraska, Kansas, Washington State, Mexico, Utah, New Mexico,

Alpine, Tundra, Conifer Forests

Rocky Mts, Maine, New Hampshire, Canada, Alaska

Deciduous Forest, Wetlands,

Oregon State, University of Georgia, North Carolina, Canada, Florida,

Tropical Fruits and Vegetables

Hawaii, Mexico

ALL have data published about foodweb

Examples

- **Tomato -** Territorial Seed, Sunbow Farms, Tanimura and Antle, Earthbound Farms, Dennison Farms, Hono Ho'Aka
- **Strawberry -** NCSU, Pac Ag, Soil Rx, East Coast Compost, T&A
- **Orchards, Vineyards -** Columbia Gorge Organics, Ono Farms, HI, Marders, Dennison Farms, Watts Brothers, AlphaWolf, Clos du Bois, Gallo, Macari, BethShin, R&R, Wren, NY, Highlands, Salinas, CA
- **Potato -** Rustic Ag, Soil Logic, Nu-Vision Ag in Idaho, OSU, Kimm in Montana, Circle B, Utah, Monte Vista, CO
- **Wheat, Soybean –** Grant, NB, Hroncek, CO, Bio-Ag, Australia
- **Dairy –** Tulare County, CA, Natural Aeration, Spokane, WA
- **Landscaping -** HSLD, WA, Treewise, NY, Bainbridge, HI, Harrington, Koch, Creative Gardens, Boston Tree Preservation, Highlands, CA.
- **Turf -** SFI, Bandon Dunes, Creative Gardens, 6 NY, Woodbury, NJ, Philadelphia, CA: Olympic, Presidio, El Niguel, Coyote Hills, Uplands, Mirage, Bellagio, Las Vegas
- **Palm trees, cycads -** Mirage Hotel, Bellagio Hotel

Plate Counts versus Direct

System	Plate Index	ug B/g	ug F/g
Old Growth Forest	0	500	1200
Pasture			
2 lb weight gain	5	675	830
1 lb weight gain	6	230	50
Ag field			
180 bushels	7	450	400
100 bushels	12	210	75

Production Gradient	AB	TB	AF	TF	Diam-eter		Protozoan Numbers /g		Nema-todes	INDEX
		(µg/g)			(µm)	F	A	C	(#/g)	
Weeds	56	147	11	64	2	6,400	6,400	51	7	1
Garden	78	144	3	19	2	51280	55400	1001	7.0	4
Chem Pas	44	127	13	55	2.5	5475	4242	33	2	5
Pasture	84	117	23	83	2.5	16178	6715	417	5	8
Clearcut	17	124	16	73	3	1819	5325	7	1	15
OgGarden	81	180	30	47	2.5	5787	5356	73	16	17
O Potato	94	229	10	237	2.5	7309	21998	5665	11	19
Strawberry	340	531	22	702	2.5	27070	27070	1123	1	22
YoungFir	165	245	29	1275	2.5	18	7489	0	18	23
Oldgrowth	194	458	79	2946	3	126	77716	0	24	25
Variation	17%						20%		8%	

What does your plant need?

Bare Parent

Material

100%
bacterial

Cyanobacteria
True Bacteria
Protozoa
Fungi
Nematodes
Microarths
F:B = 0.01

"Weeds"
- high NO3
- lack of oxygen
F:B = 0.1

Early Grasses
Bromus, Bermuda
F:B = 0.3

Mid-grasses, vegetables
F:B = 0.75

Late successional
grasses, row crops
F:B = 1:1

Shrubs, vines,
Bushes
F:B = 2:1 to 5:1

Deciduous
Trees
F:B = 5:1 to 100:1

Conifer, old-
growth forests
F:B = 100:1 to
1000:1

Soil Foodweb Structure Through Succession, Increasing Productivity

Soil biological succession causes plant succession

Bacteria …A few Fungi……Balanced ……..More Fungi…… Fungi

Bacteria:	**10 µg**	**100 µg**	**500**	**600 µg**	**500 µg**	**700 µg**
Fungi:	**0 µg**	**10 µg**	**250**	**600 µg**	**800 µg**	**7000 µg**

Forms of nutrients: Critical to understand

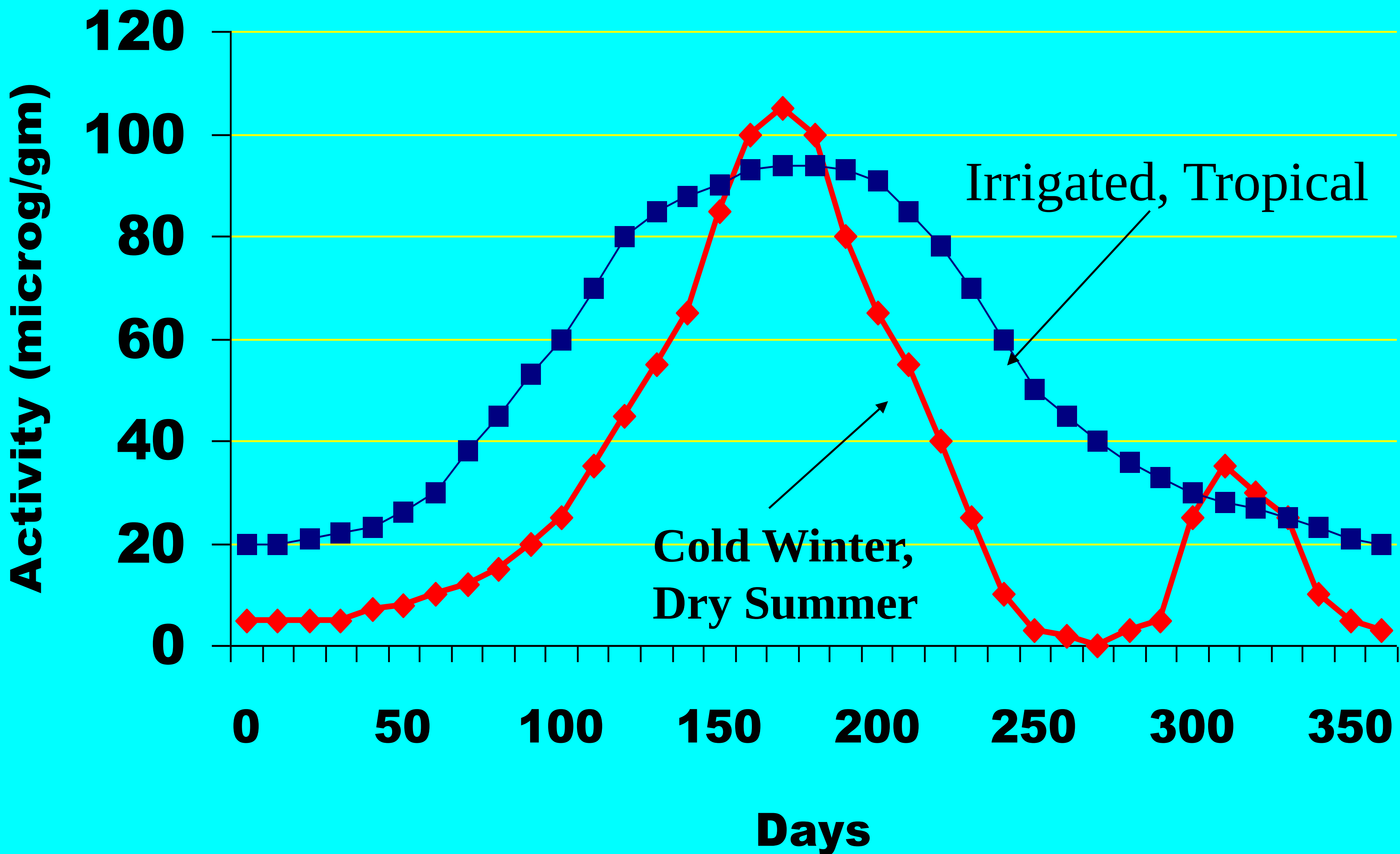
limited cycling **NO_3………… balanced …………………..NH_4**

NO_3 and NH_4

Protozoa.....B-f……..F-f……Predatory……Microarthropods

nematodes

Microbial Seasonal Activity



Disturbance

Intensity
Frequency

Why isn’t everything an old growth forest?

DISTURBANCES

GEMS

AIR POLLUTANTS

CLEARCUTTING, THINNING

COMPACTION

FERTILIZERS

PESTICIDES, HERBICIDES

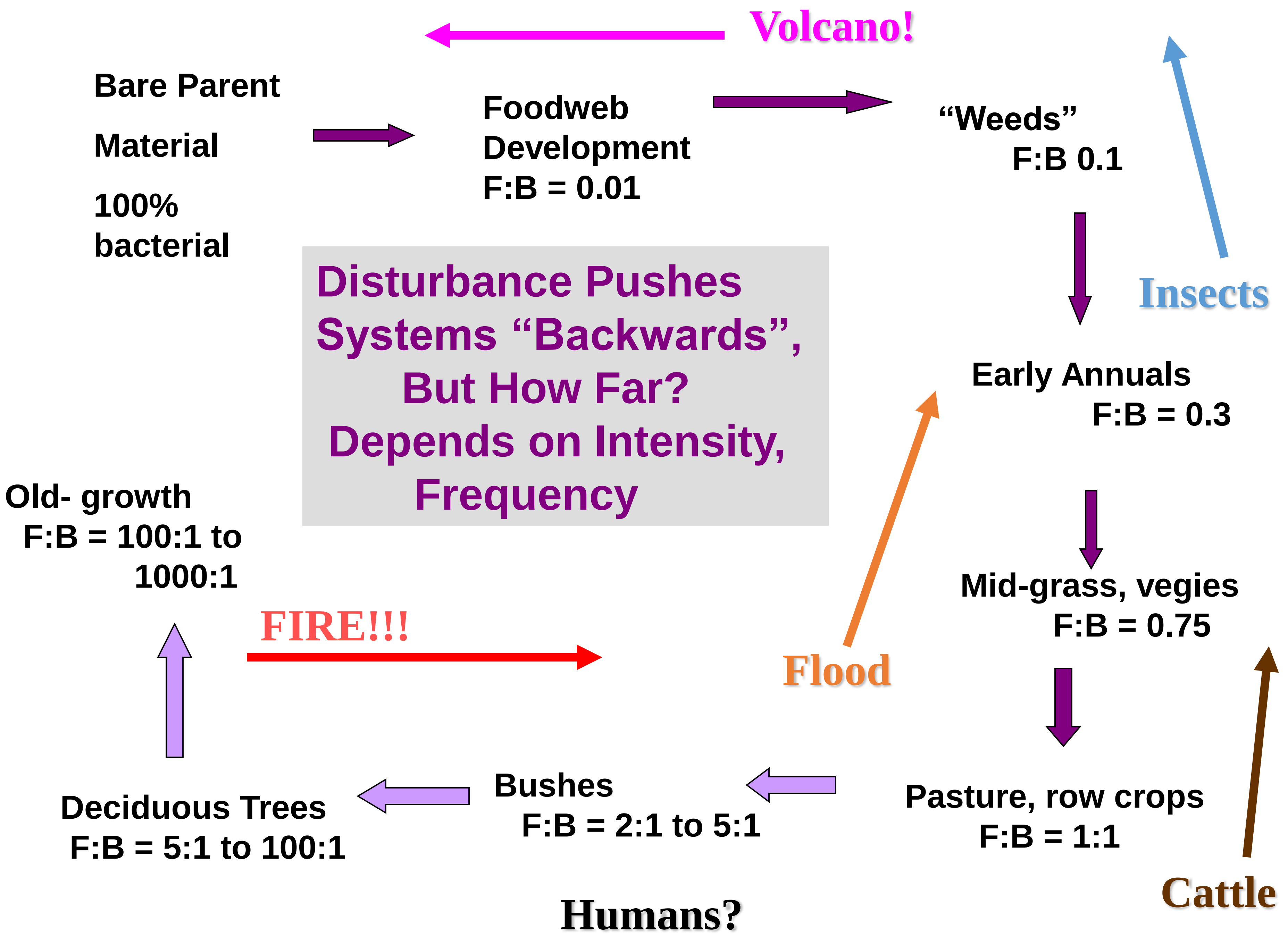
TEMPERATURE (Freeze / Thaw)

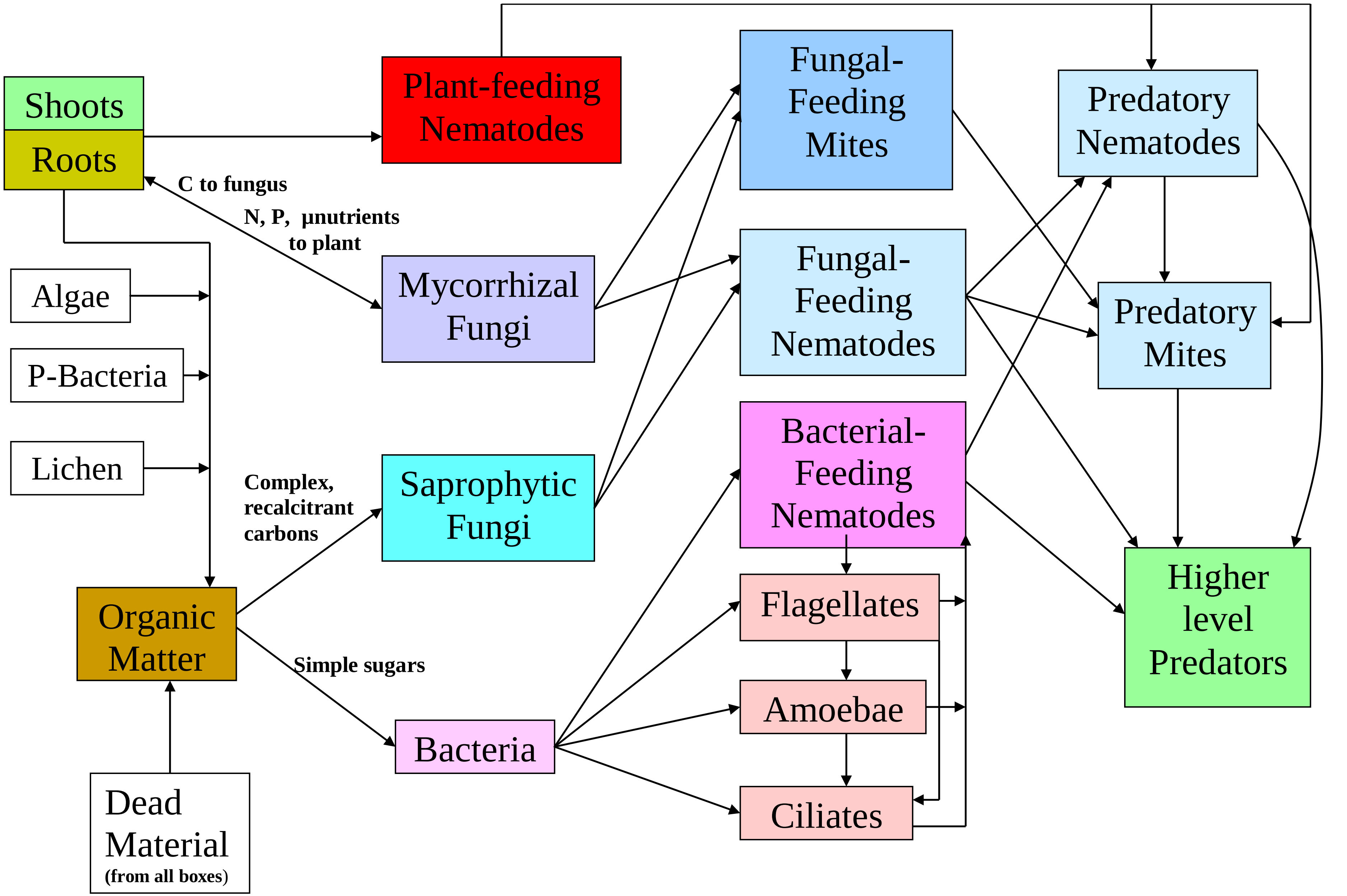
MOISTURE (Wet / Dry)

TILLAGE (Intensity, Repetition, Timing)

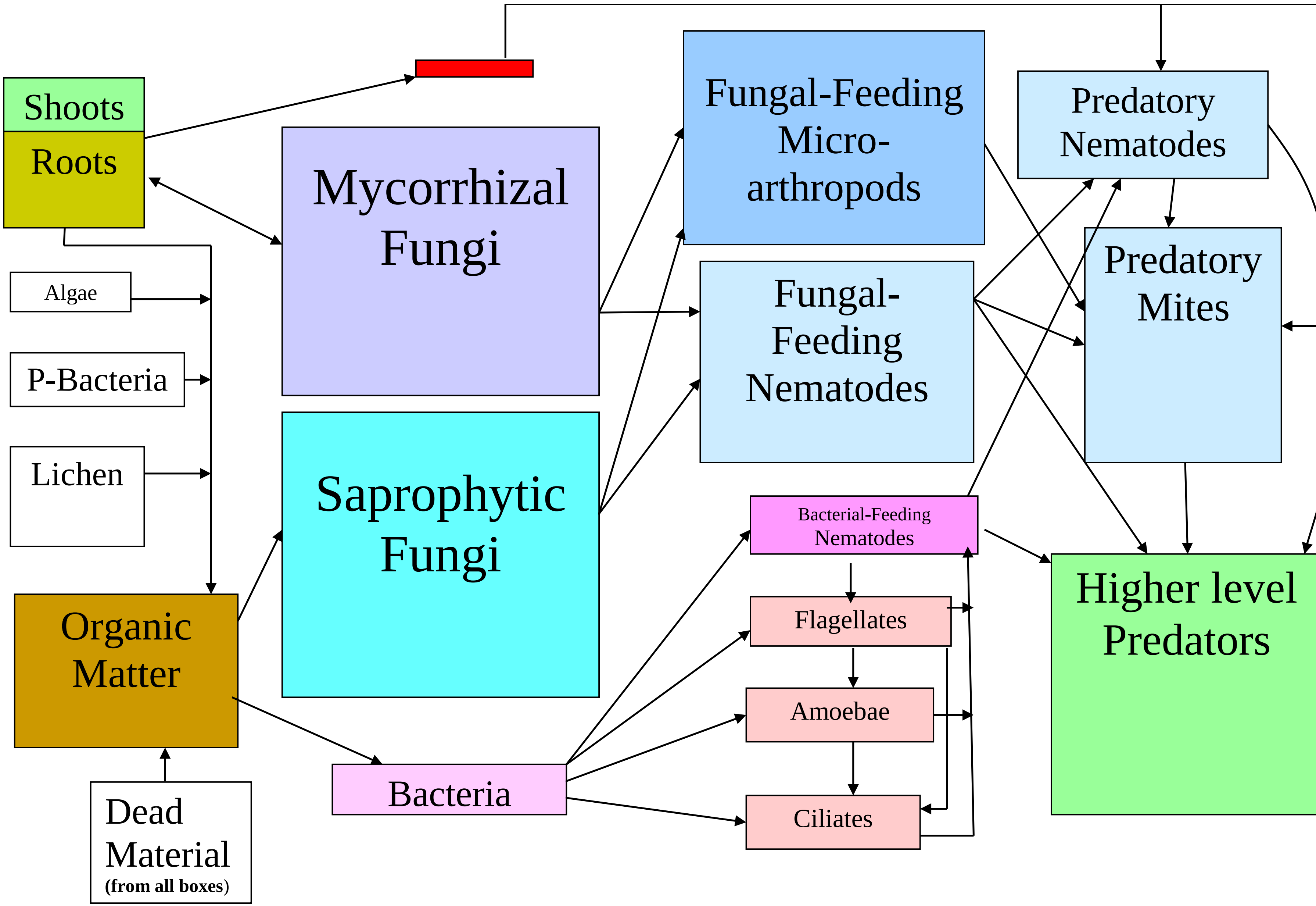
CROP (Monoculture, Intercropping)

ORGANIC MATTER (Timing, Type, Placement)

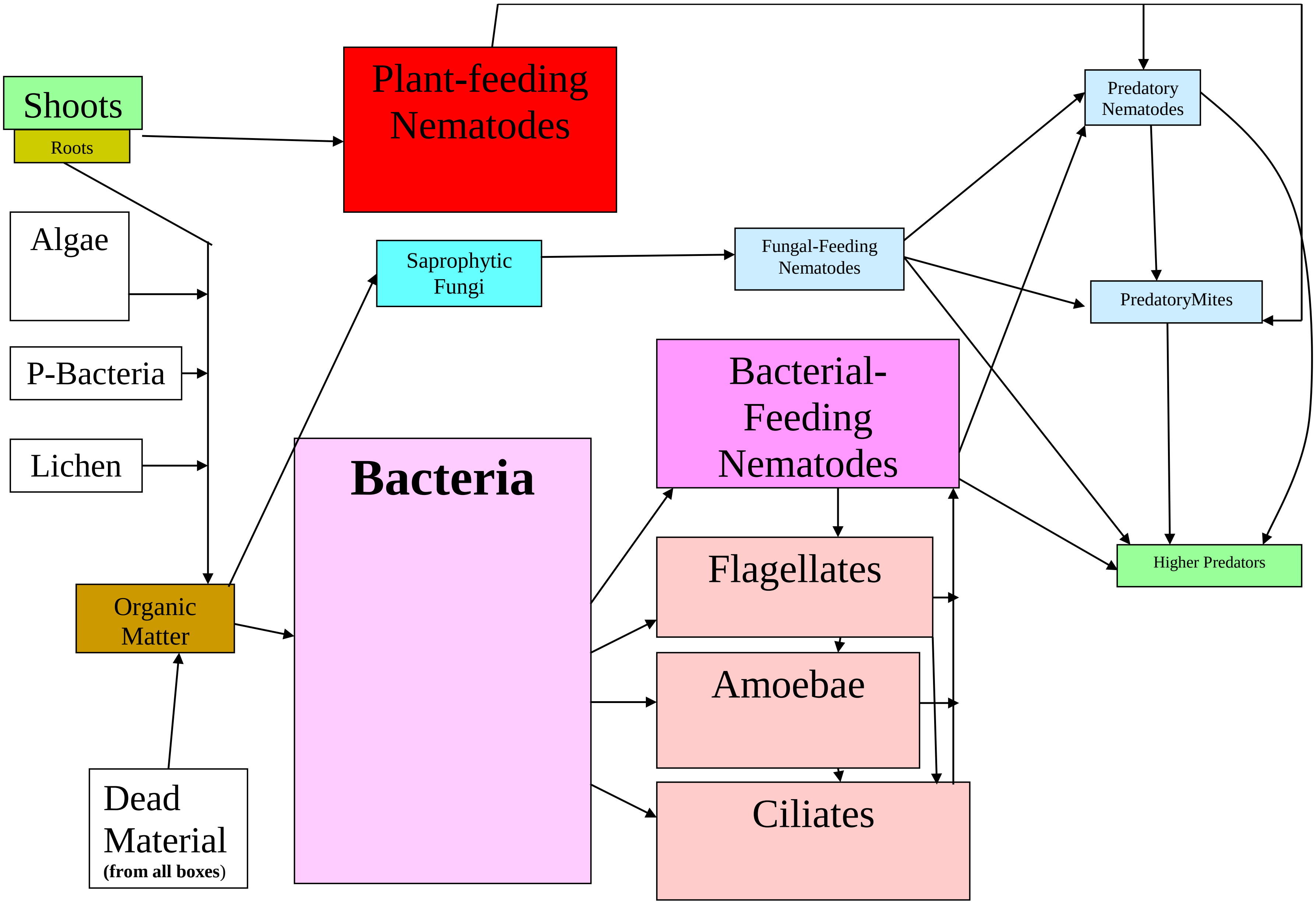

Volcano!
Bare Parent
Material
100%
bacterial
Foodweb
Development
F:B = 0.01
"Weeds"
F:B 0.1
Insects
Disturbance Pushes
Systems "Backwards",
But How Far?
Depends on Intensity,
Frequency
Early Annuals
F:B = 0.3
Old- growth
F:B = 100:1 to
1000:1
Mid-grass, vegies
F:B = 0.75
FIRE!!!
Flood
Bushes
F:B = 2:1 to 5:1
Pasture, row crops
F:B = 1:1
Deciduous Trees
F:B = 5:1 to 100:1
Cattle
Humans?



The Soil Foodweb in Lawns, Vegetable and Row Crops systems



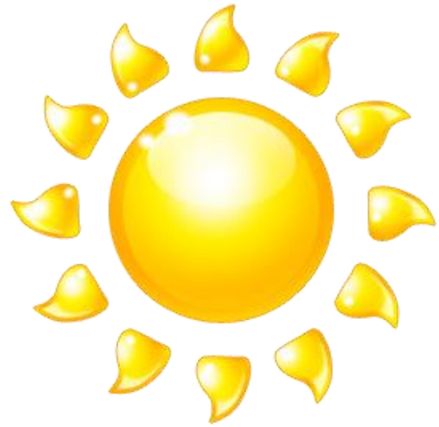
The Soil Foodweb in Healthy Orchard and Forest Systems



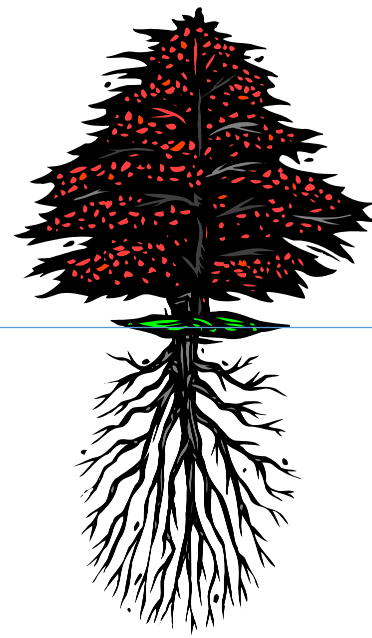
The Soil Foodweb in Weed Systems

How does biology affect soil chemistry?

Photosynthesis
Nutrient Uptake

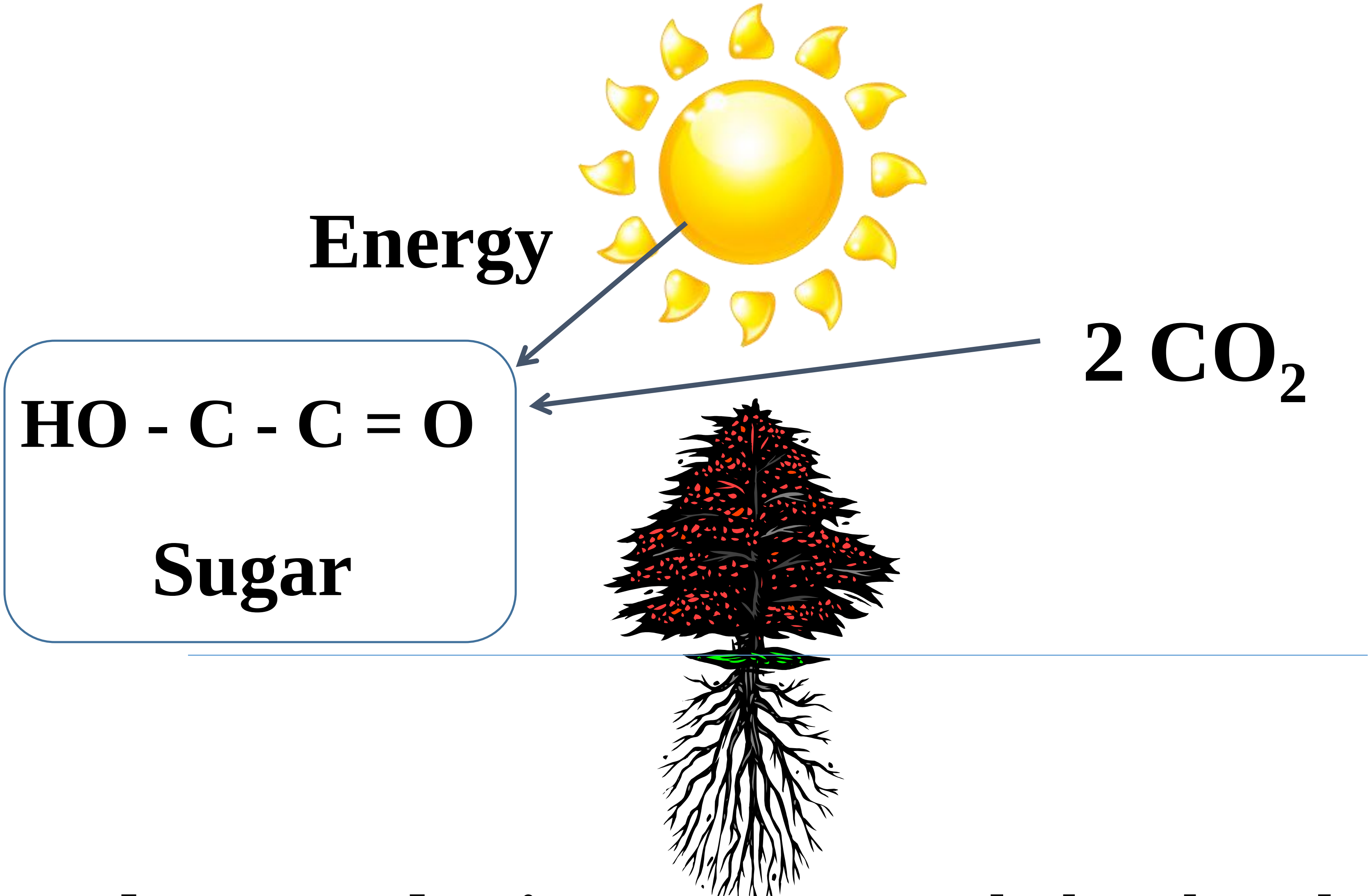


CO_2



Photosynthesis makes what compound?

Is CO_2 organic? Is the end product organic?



Photosynthesis: sugar is made by the plant.

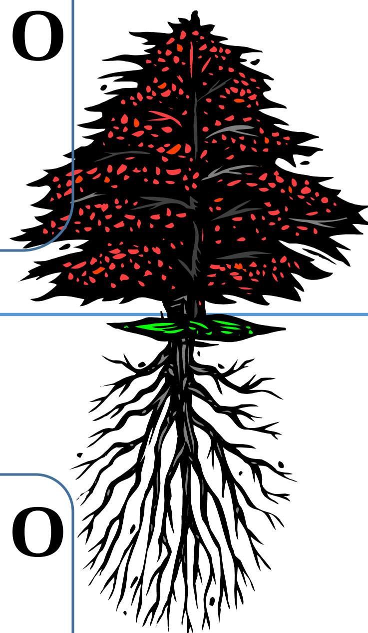
What does your plant do with sugar?

HO - C - C = O

Sugar

HO - C - C = O

Sugar



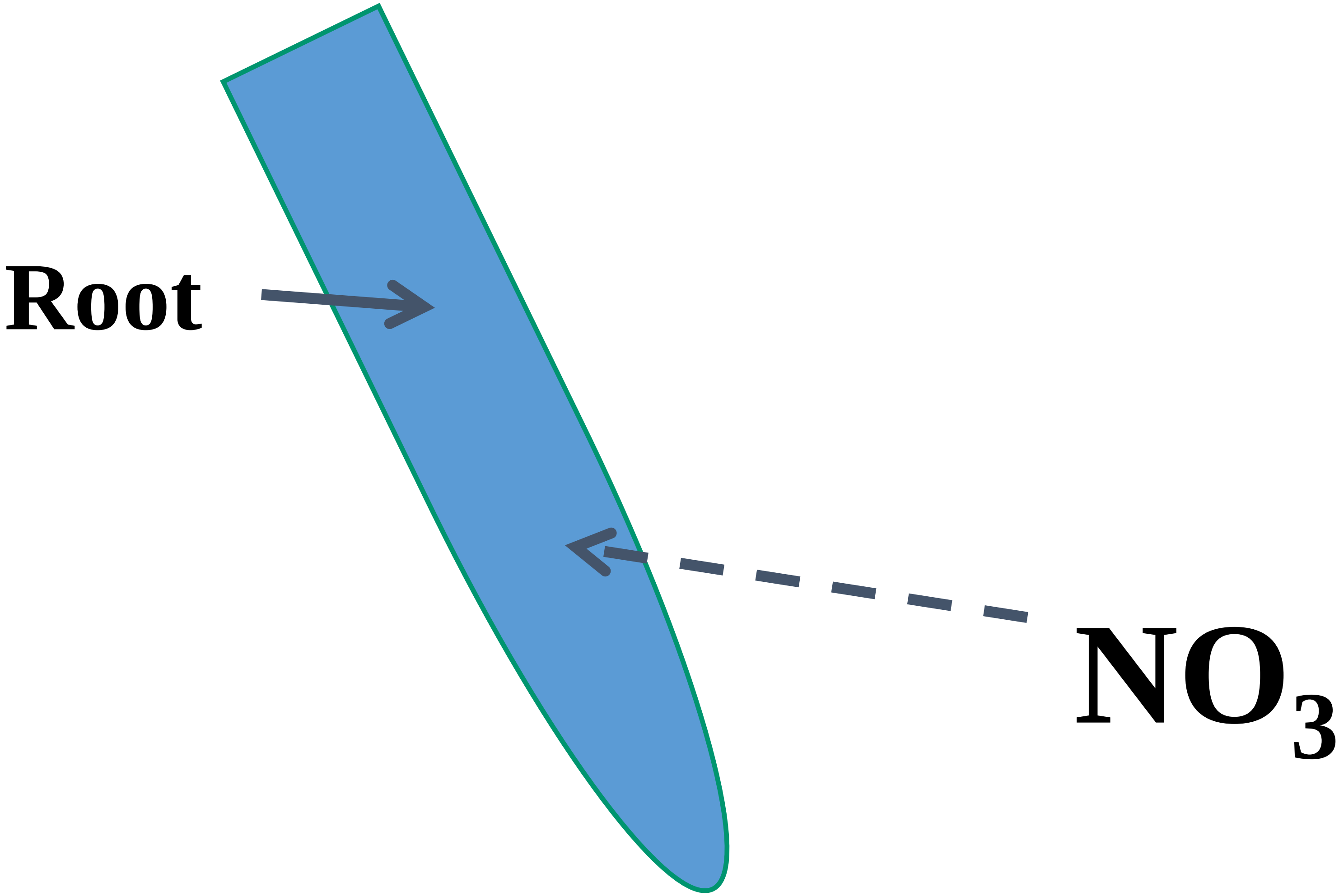
What is sugar? Just a simple carbon chain: it can be 2 C long, 3 C long, 10, 100, 1000, 1,000,000 carbons long….

Is it always just C in a chain? Add other things to it, what do you get?

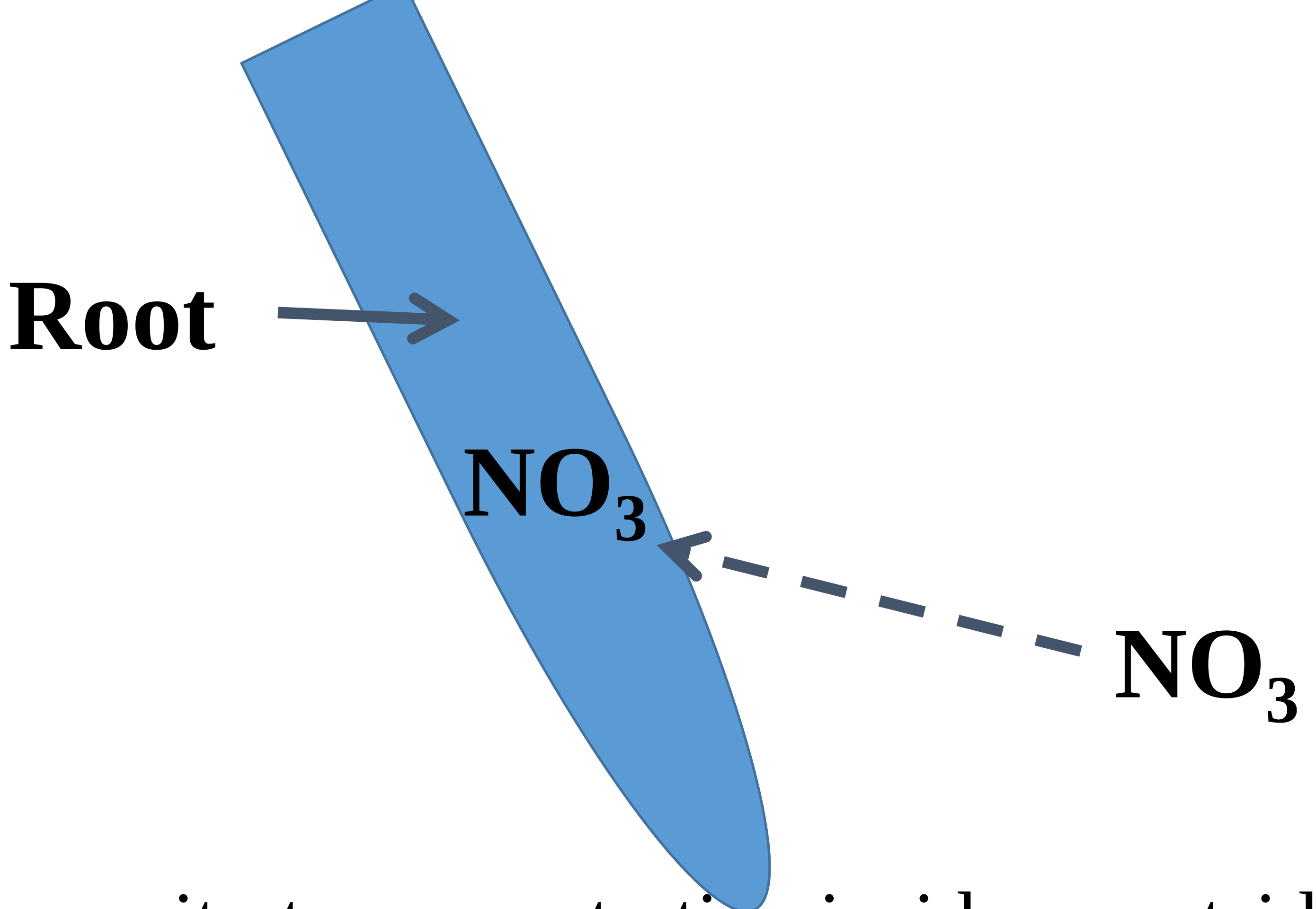
Sugar is pumped to the roots ….
Why?

Why does the plant do that?

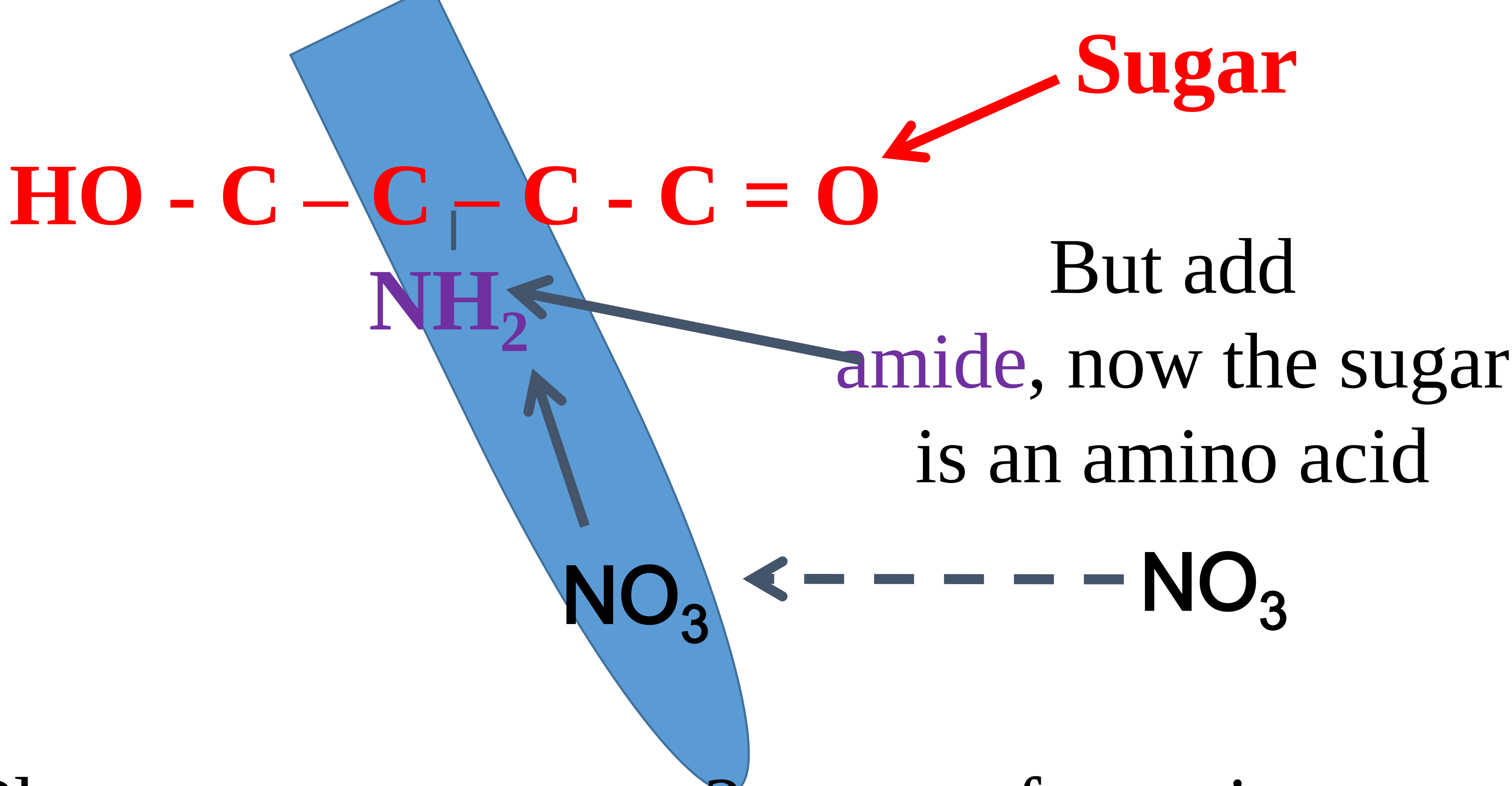
- Sugars made by the plant pumped into the roots, to pick up all the other nutrients the plant needs.
- How do nutrients get into roots? What form are they in?
- Soluble, INORGANIC nutrients which will harm the plant if in high concentration…..
- How do they get converted to non-harmful forms?
- What is a Protein? Enzyme? Carbohydrate? Phospholipid?



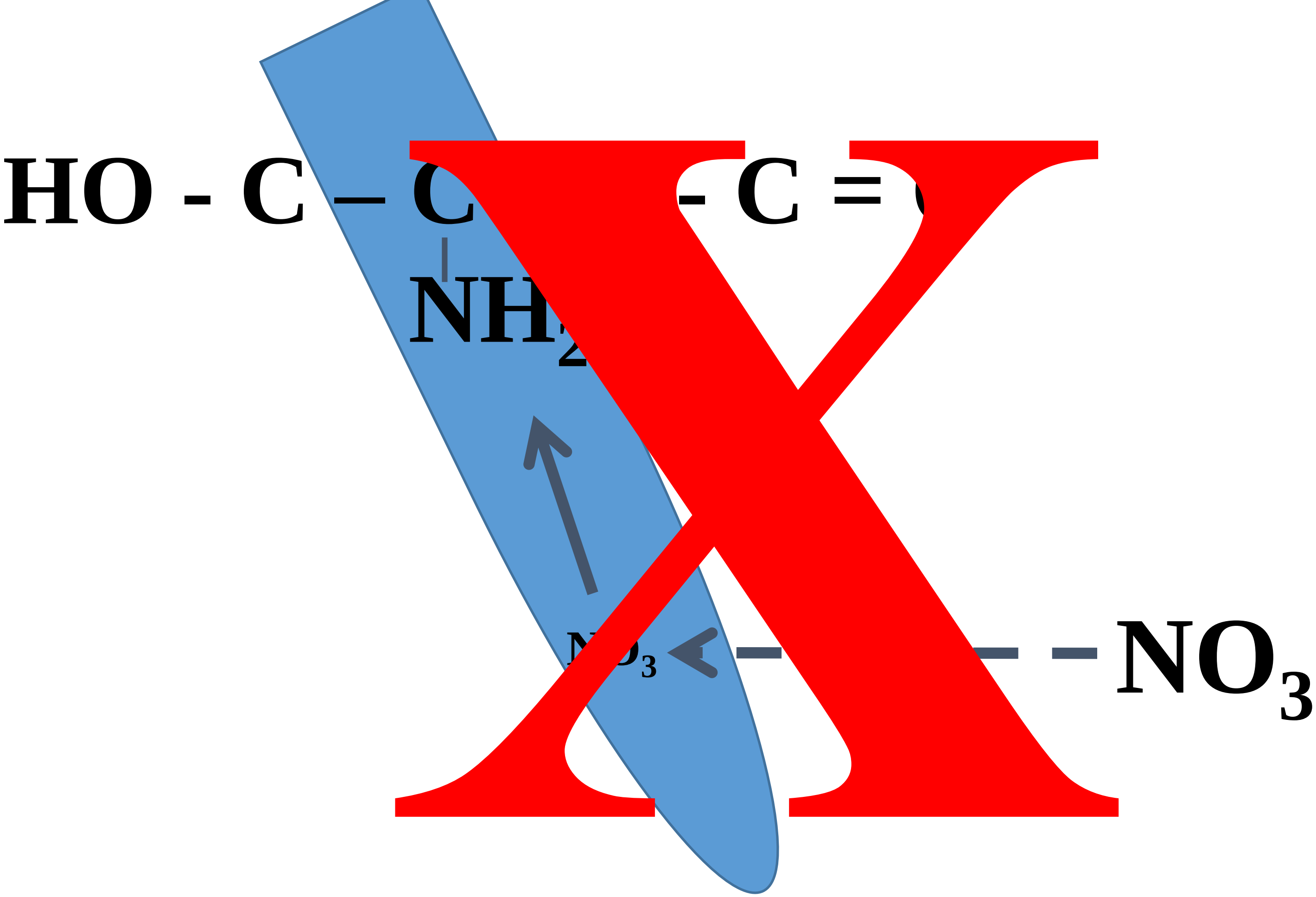
If there is no nitrate in the root, simple diffusion will pull the nutrients into the root so the concentration inside is the same as outside.



If same nitrate concentration inside as outside the root, then nothing more can be taken up……. unless……..? Nitrate in the root “goes away”. So, the plant changes nitrate into……. What?

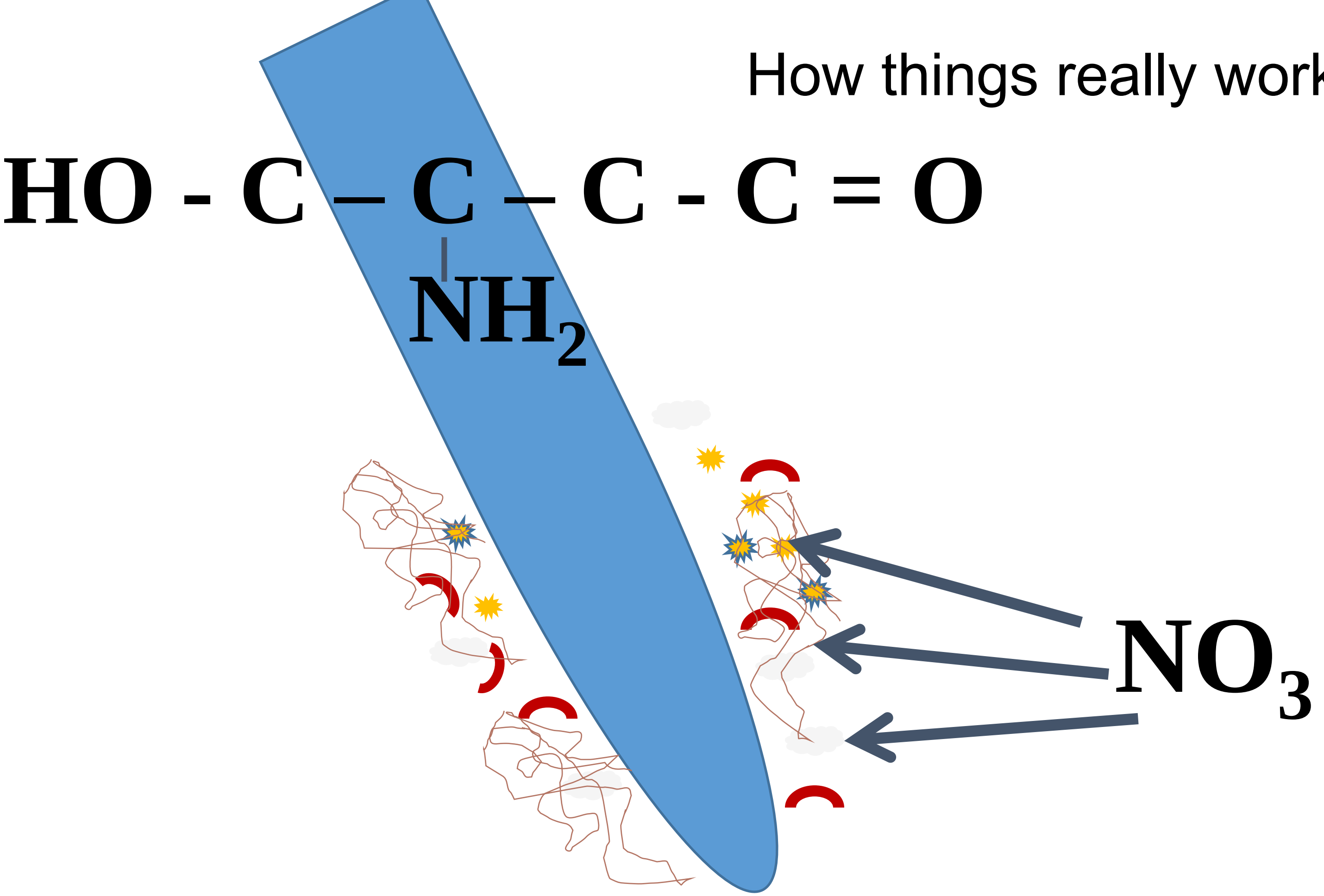


Plant enzymes remove 3 oxygen from nitrate, add hydrogen, bind the N to the C in sugar. Nitrate is now gone, so more nitrate can diffuse in. The plant continues to take up N…..



But.. .what about soil biology around the root? Won’t those organisms grab soluble inorganic nutrients long before they get to the root?

How things really work……..



The plant feeds bacteria and fungi growing around the root to protect the root. These microbes need N, P, K, S, etc, and grab soluble nutrients long before they get to the root.

So, there is more to the story…….

1. Plants release exudates into the root zone. Documented by many scientific publications e.g., The Rhizosphere, J. Lynch, 1971.
2. This feeds an enormous biomass of bacteria and fungi around the roots (E. Paul, Soil Ecology, 1990).
3. Bacteria and fungi need nutrients and intercept them before the roots will get them.
4. How can plants stay alive then? Mechanism?

Nutrient cycling

Bacteria, Fungi and Exudates

Ecological Monograph

- Ingham et al. 1986
- Established nutrient cycling is performed by the beneficial organisms in the soil
- Requires bacteria, fungi, protozoa and nematodes; and microarthropods when in perennial systems
- David Coleman and the Soil Ecology Society continue this type of nutrient cycling work
- Let’s go through an explanation of how this system works


Picture your
favorite plant

Did you remember the roots?

- How important are roots to plants?
- Weeds – only 20% of the energy fixed into roots
- Grasses 60% of their energy goes
- Vegetables up to 75% into the roots
- Shrubs, Trees 80% of their energy into roots

Energy going into roots is used to :

1. Build structural roots
   a. prevent the plant from falling over
   b. firm anchor in the soil
      - How deep do roots go?

2. Take up nutrients (lateral roots) only by diffusion, no enzymes to break down organic matter.

3. Make exudates - 50% of energy into roots is released as:

   Simple Sugars, Proteins, Carbohydrates

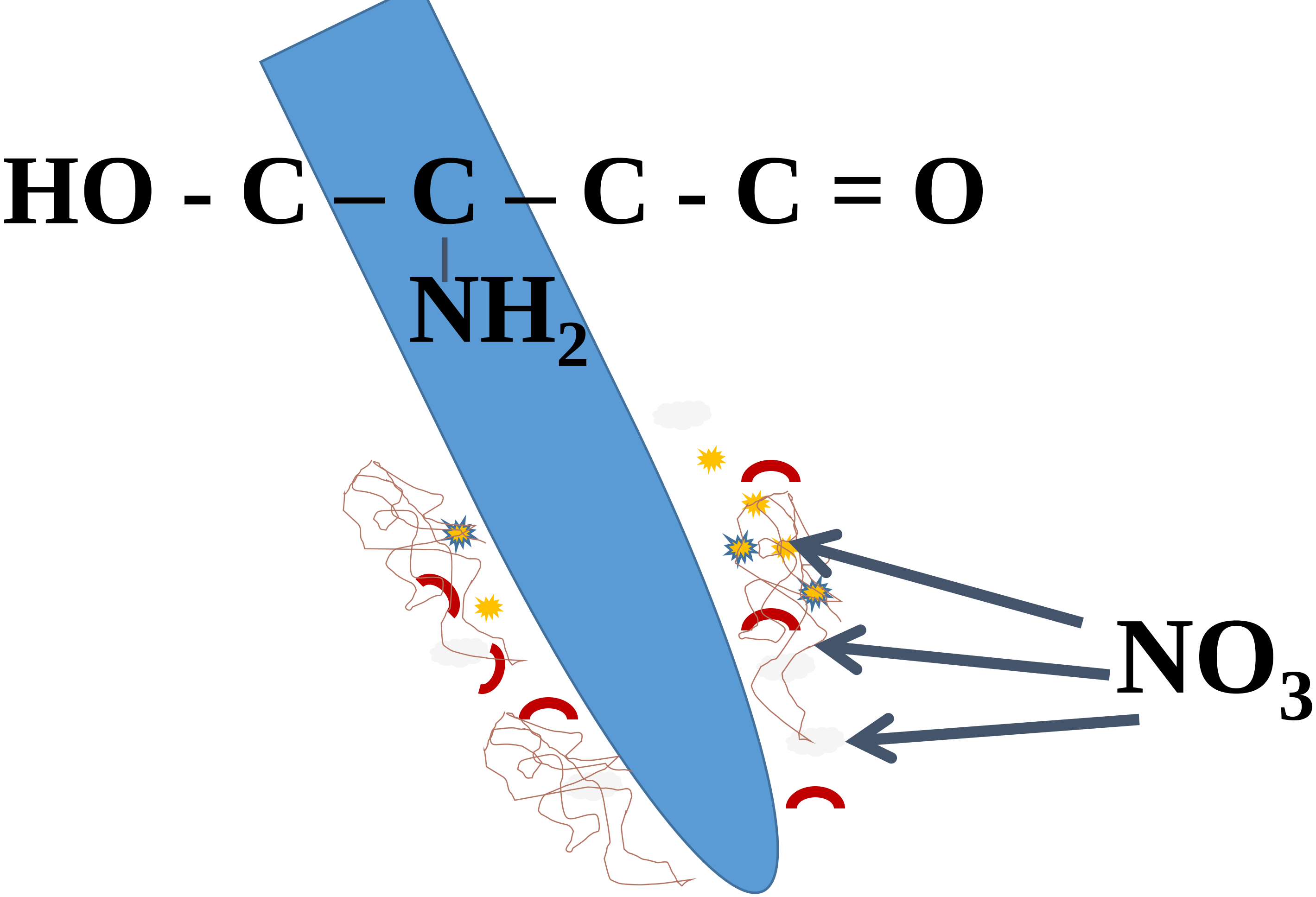
   Why would a plant release exudates?

Who do these cakes and cookies feed?

- Would these foods feed pathogens?
  - Plants would be dead if they did…..
- Would these foods feed organisms that are beneficial-to-the-plant?
- Consume the nutrients and foods that might feed any pathogen
- Convert N from nitrate to something that does not enhance disease-organism growth
- Occupy the space so pathogens can’t grow

Why Are Organisms Around Roots?

- **Disease Suppression Mechanisms**
  - Use exudates so no food left for pathogens
  - Produce antibiotics, inhibitory compounds, toxins to prevent pathogen or pest growth
  - Occupy infection sites on root surface by beneficial organisms so pathogen cannot bridge cell wall, infect cells
  - Occupy space so no room is left for undesirable organisms
  - Build structure to keep air and water moving



Plant exudates feed bacteria and fungi which grow in a thick layer on and around the root. These microbes need N, P, K, S, etc, and they grab soluble nutrients before those nutrients are pulled into the root. So…..how does your plant get those nutrients?

Organism numbers in soil vs roots

Organism Assays	Ag Soil	Ag-Rhizo-sphere	Healthy Soil	Healthy Rhizosphere
Total Bacteria (ug per g dry soil)	400	1000	350	1000
# of bacterial species/g soil	5,000	5,000	25,000	25,000 (75,000)
Total fungi (ug per g dry soil)	5	20	250	300 – 800
# of fungal species /g soil	500	500	8,000	8,000 (25,000)
VAM colonization	0	0	55%	55%

If you don't know that answer, then chemical agriculture appears to be logical.

1. By not understanding life in the soil, then the damage done by tillage, by compaction of soil, by manures high in salts, by application of high salt containing water is not understood.
2. Once life in the soil is destroyed, then agriculture is ultimately doomed.

Why did we think the Green Revolution worked?

Tillage
Toxic chemicals
Fertilizers

Why do we think toxic chemicals and inorganic fertilizers are necessary?

- Why did the Green Revolution work?
- Only “works” when soil has been turned into dirt
  - Define soil, define dirt
- How did we lose the life in soil?
  - Fertilizers: All inorganic fertilizers are salts.
  - Pesticides: All pesticides kill many more organisms than just their “target”
  - Tillage: Tillage equipment and compaction

Are inorganic fertilizers salts?

- **What is a salt?**
- Not just table salt (sodium chloride, or NaCl)
- A salt is any inorganic compound that dis-associates or dissolves in water
- Which means water is bound by any salt, and your plant cannot use that water
- The higher the salt level, the less water your plant - or soil life - has available to it

Are inorganic fertilizers salts?

Na^+ ------ Cl^-

OH^- ----- H^+

- Water is prevented from being available when it is bound by a salt.
- What other compounds are salts?

$Ca^+CO_3^-$ (lime) $Ca^+SO_4^-$ (gypsum)

$NH_4^+NO_3^-$ (ammonium nitrate)

$K_2^+PO_4^-$ (a typical phosphate fertilizer)

Inorganic fertilizers do not stay in soil

- Must convert soluble inorganic salts into something not-soluble so they do not wash away when water moves through the soil
- What grabs and holds soluble nutrients?
- Organisms: Plants and microbes. Plant roots only occupy between 1% and 20% of the soil, so if soil life has been killed by application of immense amounts of salts, what happens to the nutrients that do not contact a root system? LOST.
- What percent of soil is occupied by microbes? All of it!

Anyone been told that pesticides have been proven not to harm biology?

- Investigate the methods used in those studies very carefully
- What do they actually measure?
- Can those methods actually detect harm?
- Numbers decreased? Species or function lost?

Do pesticides harm beneficial organisms?

- **Set up the experiment**
- Same amount of the same soil put in each container. Many replicates of same soil, same containers, same water, same everything……
- If doing a field study, then each field has to be documented to be starting in the same condition.
- What will you use to determine they are all "the same"? What criteria?   No harm to any beneficial organism…. Active? Dormant? Sleeping?

Do pesticides harm beneficial organisms?

- Half of the units treated with water,
- Half treated with same amount of water but with pesticide in the water
- To assess no harm to any beneficial organisms, we would need to assess all the kinds of beneficial soil life = Bacteria, fungi, protozoa, nematodes, worms, arthropods…….

Do pesticides harm beneficial organisms?

- One week after adding pesticide to half the soil, plate both soils on PDA and TSA plates.

- Same number of colonies on all plates.
- Same number of colony types (species).

- Conclusion?
- Chemical industry: Pesticide did not harm beneficial organisms in soil
- Can this be concluded, given the method used?

Do pesticides harm beneficial organisms?

- Plate methods were developed to grow pathogenic organisms.
- Proper conclusion would be that the pesticide did not kill any pathogen.
- The pesticide did not kill the pest it is supposedly supposed to prevent.
- Methods must be understood, interpreted correctly.

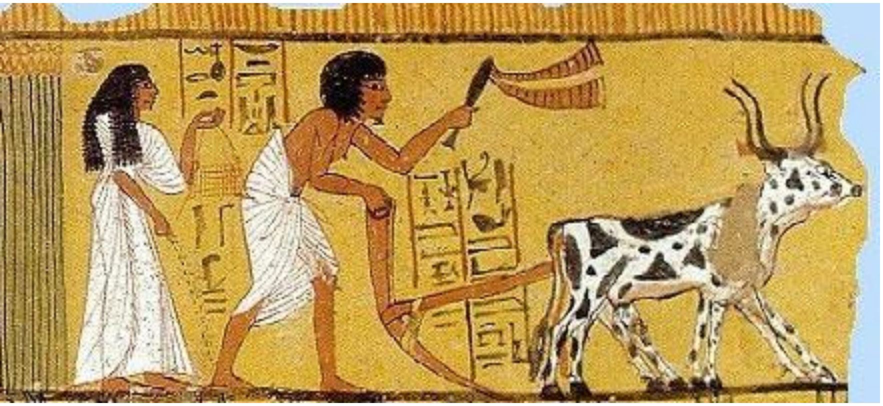
Direct Microscopy Required

- Numbers of bacteria vs numbers of fungi: Plate methods pick up mostly spores, only grow specific types of organisms
- Most fungi or bacteria cannot grow on plate media
- Direct counts do not rely on ability to grow the organisms. What if conditions on the plate media are not right to grow the organism?
- Direct methods are immediate, no time for selection or change to happen

The History of Agriculture

Tillage
Soil Horizons

Agriculture and tillage…….



How many times a year do you till the soil if you have to push the plow into the ground, keep the animals pulling the plow, and keep them going in a straight line?   Once a year!

How many acres can you plow a day by hand? Less than an acre?

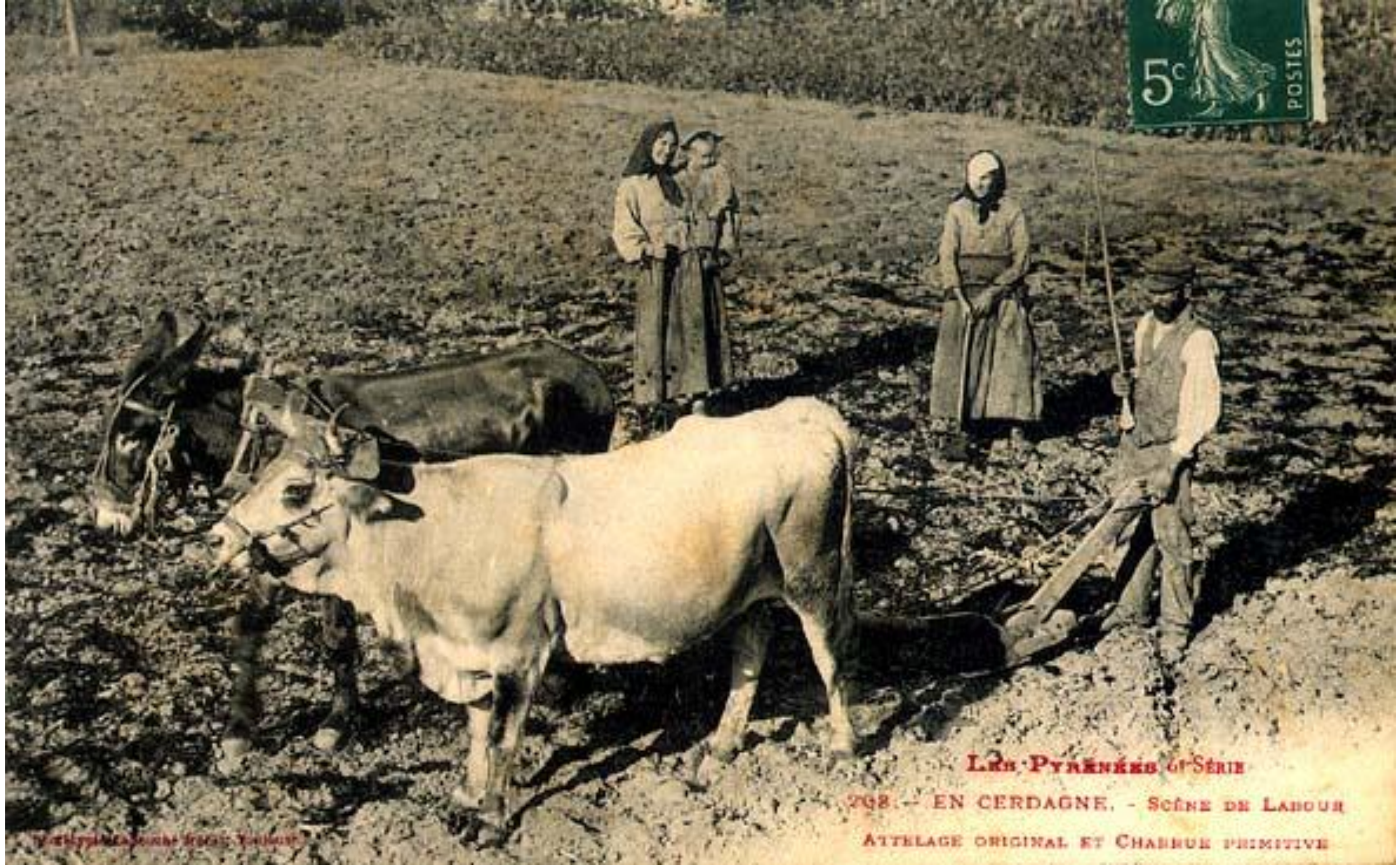
One tillage a year to make the seed bed……

Damage to the life in the soil is minimal with only one tillage a year. Recovery of the organisms killed by slicing and dicing happened.

But, other disturbances harm the organisms. Organic matter starts to be depleted (Cole et al, 1984) through tillage and inadequate return of organic matter to the soil.

As the food to feed the organisms is lost, soil life slowly decreases

Compaction becomes permanent. More tillage (hoeing) needed to take out weeds.



Manure applied to increase fertility. But salts build up from use of manure and poorly composted materials. Salts leached from the soil as life was killed, and crop production decreased. Every Ancient Civilization that failed was a result of loss of their agricultural base.

Mechanical tractors allow more acres to be tilled more often. Eight or more tillage events became common to remove weeds, till-in residues and to keep fields level.

Believing they were controlling weeds, they set the stage for worse weeds. Destroying soil life meant no plant available nutrients produced and inorganic fertilizers became necessary.

Without biology to suppress pests, pesticides become the only way to knock pests back.

Tillage, heavy equipment, and the loss of organisms that build soil structure, result in plow pan. Soil is "fluffed" above the tillage line, but compacted below. As a result, disease organisms had the perfect place to grow.

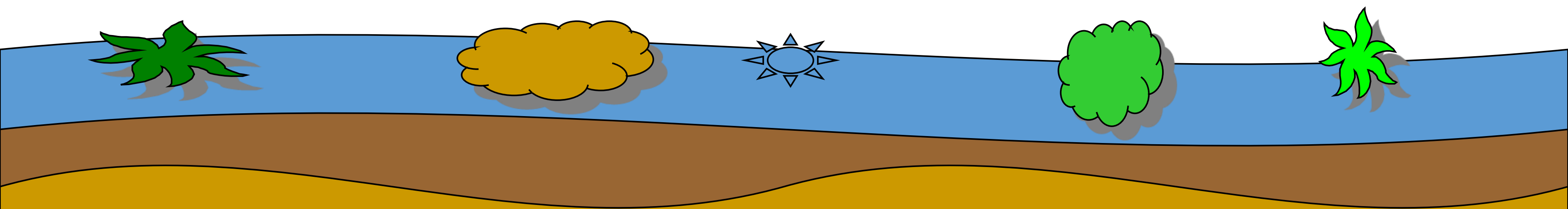
Disease organisms are kept in check by competition with aerobic organisms. Adequate oxygen is critical to disease suppression.

Plow pan shown by compacted layer. Poor structure in soil above plow pan because life has been lost

Soil Horizons

O horizon: O1 = recognizable plant debris

OH = dark brown humus (OM, organisms)



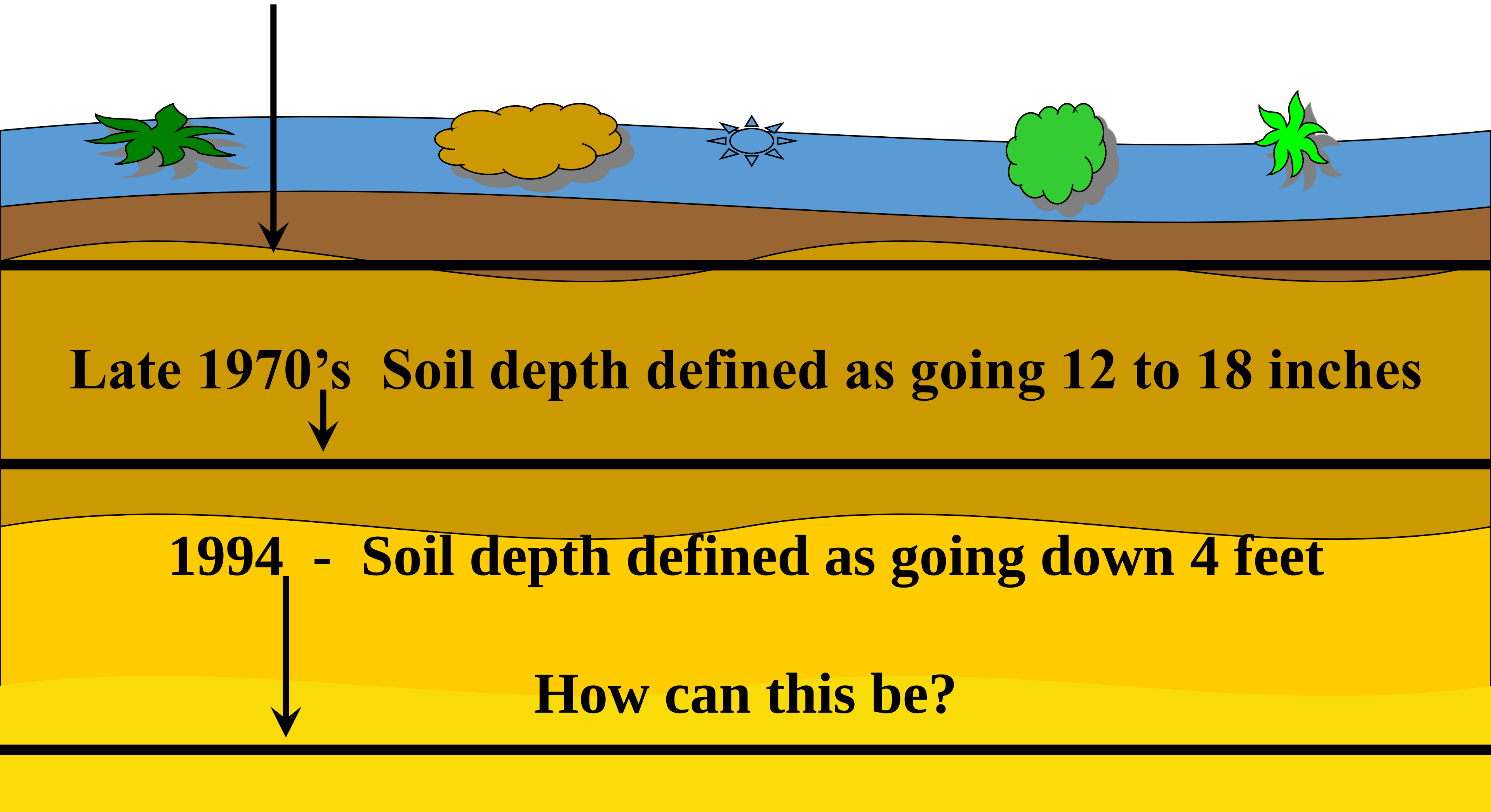
A Horizon: Add sand, silt clay to OM, organisms; color and depth depends on how much humus moves into top layer of soil

B Horizon: Less humus movement by water, fewer organisms, roots

C Horizon: Much less OM, but is this sterile?

Soil Depth

1940 – 1950 Soil depth defined as going to 4 to 6 inch depth



Since no one understood about life in the soil,

Since the methods available then missed 99.9999% or more of soil life,

It seemed a simple choice to turn to toxic chemicals to control diseases and pests.

And the chemical era began……

Compaction

Aerobic versus Anaerobic Effects on Roots

Collateral damage of destroying soil life is far-reaching. Erosion and run-off result. Compaction (big equipment) and burning (few foods left to feed the organisms), prevented soil life from holding nutrients and soil in place, so all systems downstream were harmed.

Unprotected soil surfaces means evaporation and salt accumulation which form crusts. Soil organisms work to immobilize those salts instead, incorporating them into OM, into biomass.

Extreme Lack of Oxygen in Soil

With aerobic life, nutrients are held, water is kept in the soil, diseases have no place to grow, insect pests are eaten (eggs and larval stages), nutrients are cycled at exactly the rates the plant needs, because the plant controls nutrient availability through exudate production. Weeds are not part of a properly balanced system.

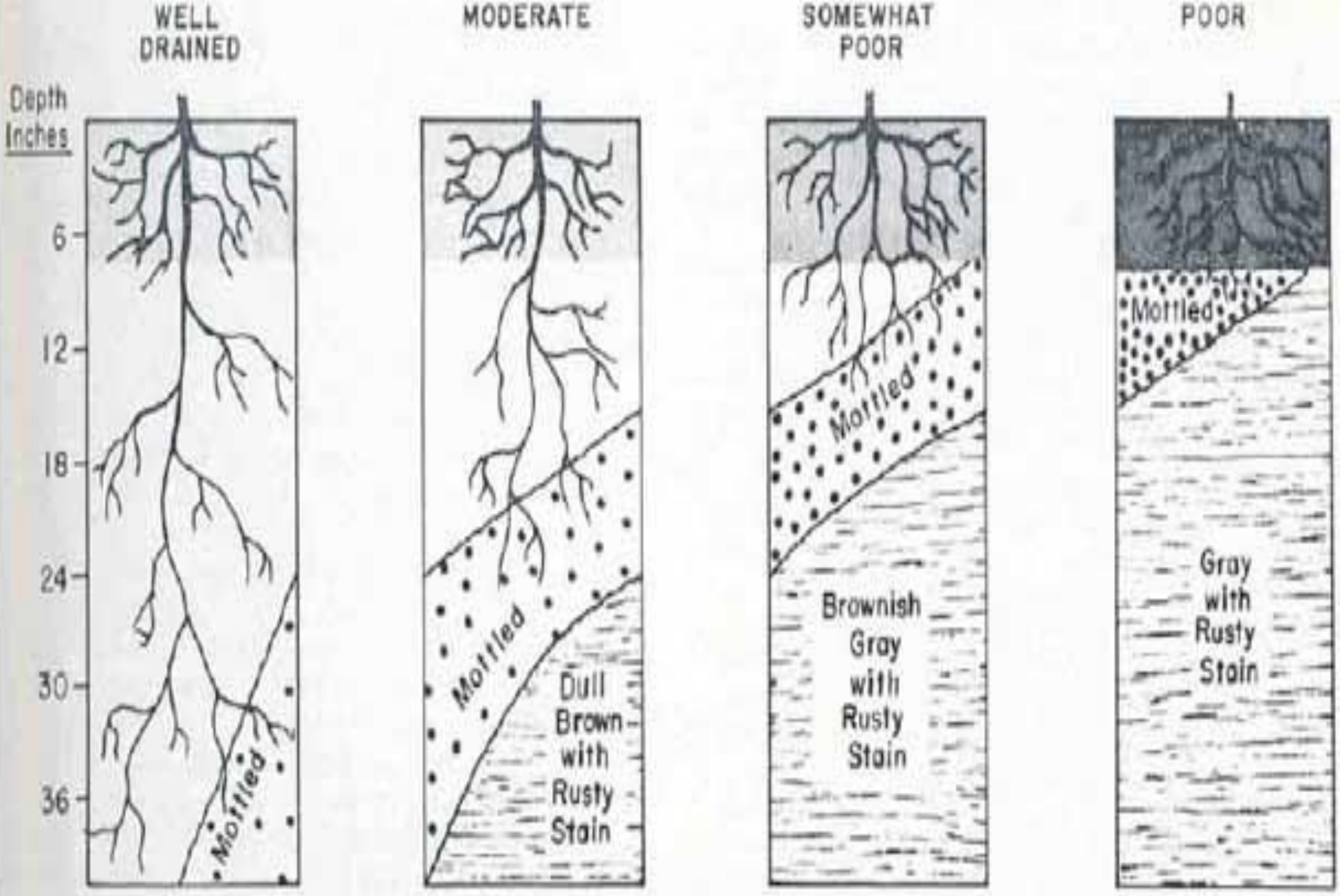


Figure 5.—Effect of soil drainage on root development.

Just because we see this in urban areas all the time, does it means this is how trees grow?

Peter M. Wild, Boston Tree Preservation

Compaction

- What causes compaction?
  - Heavy things - Lack of biology to re-build
  - Tillage - Toxic chemicals
- How does compaction affect plants?
  - Roots can’t grow deep – no structure
  - Lack of oxygen
  - Plant toxic compounds
- What happens to soil when compaction occurs?

Habitat!!!!

Aerobic .... Anaerobic

Predominant N form in soil

- OM, protein………………Remains as organisms

Inorganic forms

(leach, plant available?)

- NO_3 (nitrate)
- NO_2 (nitrite)
- NH_4 (ammonium)

NH_3

(ammonia)

Oxidized

Reduced

Aerobic ………………. Anaerobic

Predominant S form in soil

- OM, protein………………..Remains as organisms

Inorganic forms

(leach, plant available?)

- SO_4 (sulfate)
- SO_3 (sulfite) → H_2S (hydrogen sulfide)
- SO_2 (sulfur dioxide)
- S_2 (Elemental S)

Oxidized → Reduced

Aerobic ……………… Anaerobic

Predominant P form in soil

- OM, membranes………Remains as organisms and OM

Inorganic forms

(leach, plant available?)

- Rock P
- PO_4 (phosphate) → Phosphine gas

Oxidized → Reduced

Anaerobic organic acids

- Only produced under anaerobic conditions, smells indicate anaerobic conditions

- Acetic acid common name?
- Butryic acid
- Valeric acid pH of 2.0 or lower
- Putrescine

- Mix these with organic matter and what pH ?

Toxic materials only produced in anaerobic conditions

- Alcohol
  - 1 ppm alcohol solubilizes any plant cell wall
  - anaerobic soil/compost produces 25 ppm alcohol
- Formaldehyde
- Phenols

Lawns , trees, gardens or crops, the story is the same. Soil biology is being destroyed by human management. Roots are not going as deep as they should, and water, fertility and disease protection are lost.

How far down do roots go?

How do we get roots going down that far?

How far down do roots go?

- Visit some caves
- What is growing through the ceiling?
- How deep?
- Why would we have the attitude in agriculture that roots only go down a few inches?

If you cut the top, do the roots fall off?

Hendrikus Schraven holding ryegrass planted July 15, 2002

Harvested Nov 6, 2002
Mowed twice to ½ inch

70% Essential Soil,
30% Compost/organic fertilizer
Compost tea once

No weeds, no disease

www.soildynamics.com

The root of the matter is infiltration

Oxygen? Disease? Microbes?

Source: Conservation Research Institute

Size of Root System of a Rye Plant (*Secale cereale*)

Kind of Root	Number	Length	
		Meters	Feet
Main Roots	143	65	214
Secondary Roots	35,600	5,181	17,000
Tertiary Roots	2,300,000	174,947	574,000
Quarternary Roots	11,500,000	441.938	1,450,000
Total Root	14,000,000	609,570	2,041,214 (380 miles)

From Al Knauf

How do we fix damage that has been done to soils?

What do we do to stop the damage that occurs when a toxic chemical approach is followed?

Understand soil life.

Understand how to put that life back in the soil, nuture it, and provide the soil habitat that your plants require.

Why does permaculture work? Because of the life in your soil………

Soil Structure, Diversity and Nutrient Cycling

Who makes bricks, builds walls, puts the swimming pool in?

The right biology enhances :

- Disease protection (no more pesticides!)
- Nutrient retention, including C sequestration (stop leaching, volatilization)
- Nutrient availability (right forms in the right place at the right time)
- Decomposition of toxins (get rid of residues)
- **Build soil structure, improve root health, root depth, water holding, aerobic conditions, stop run-off, erosion.**


Cyst
Amoeba
Flagellate
Bacterial colonies
Nematode
Ciliate
Clay-organic matter complex
Decomposing plant cells
Water
Actinomycete hyphae and spores
Fungal hyphae and spores

Microbes make hallways and passageways in soil

Bacteria make glues that hold clays, silt, sand and organic matter together

Fungi are strands that make glue and threads that hold bacterial aggregates together

Nutrient cycling occurs because of predators

Protozoa control bacterial populations

Nematodes open up larger pore areas

Microarthropods engineer the larger pores

Roots engineer the freeways

Habitat Diversity Relates Directly to Species Diversity

- Diversity is increased by:
  - More amounts and diversity of foods,
  - Temperature fluctuation,
  - Oxygen variation,
  - Moisture variation,
  - carbon dioxide and other physical gradients,

August 3, 2005

Black layer in turf strongly evident

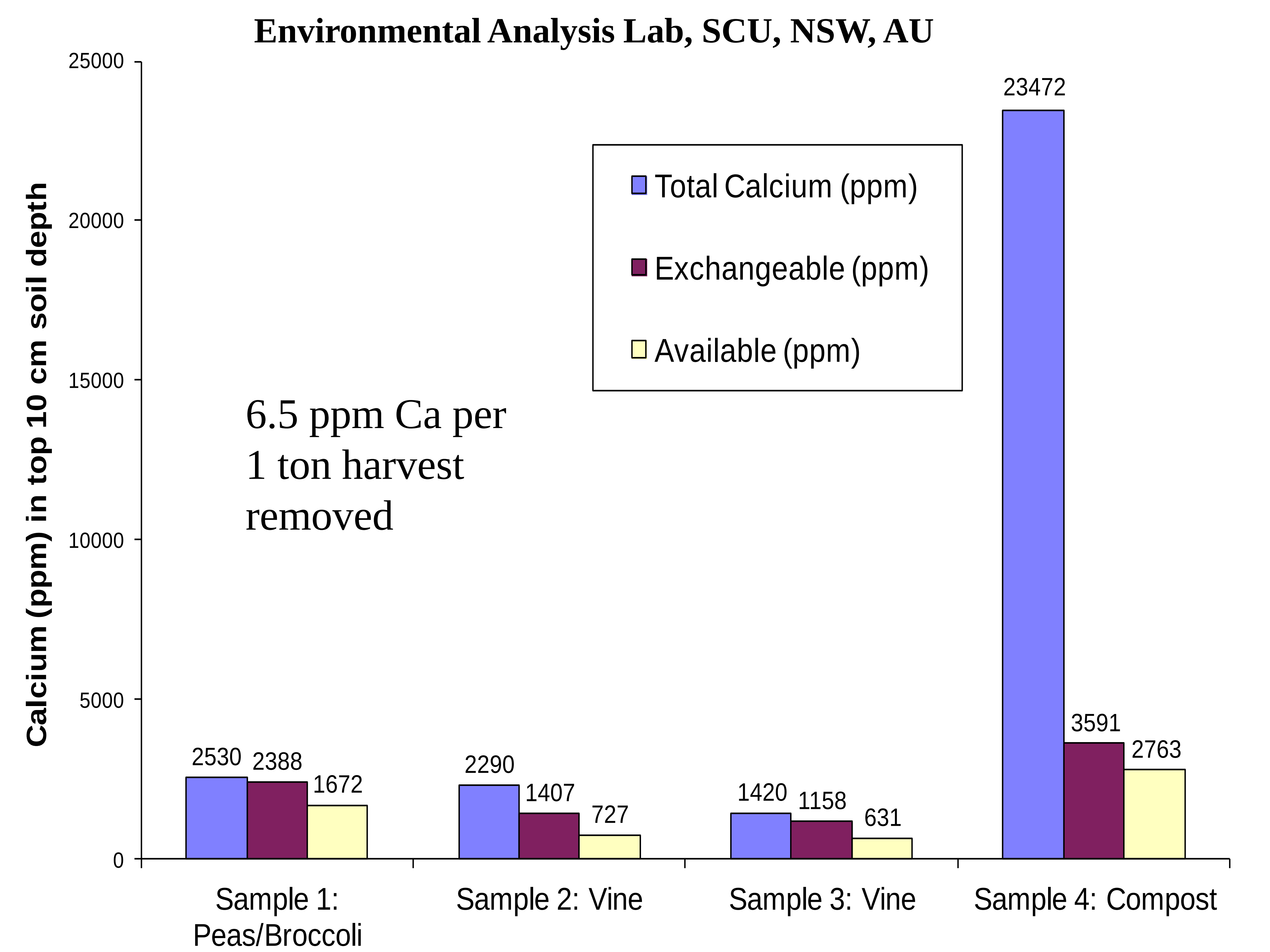
No roots growing through the black layer

100% pure sand green

September 26, 2005

Following third application of compost tea to turf

Note significant decrease in black layer


Environmental Analysis Lab, SCU, NSW, AU
Calcium (ppm) in top 10 cm soil depth
25000
20000
15000
10000
5000
0
Total Calcium (ppm)
Exchangeable (ppm)
Available (ppm)
6.5 ppm Ca per 1 ton harvest removed
23472
2530
2388
1672
2290
1407
727
1420
1158
631
3591
2763
Sample 1: Peas/Broccoli
Sample 2: Vine
Sample 3: Vine
Sample 4: Compost

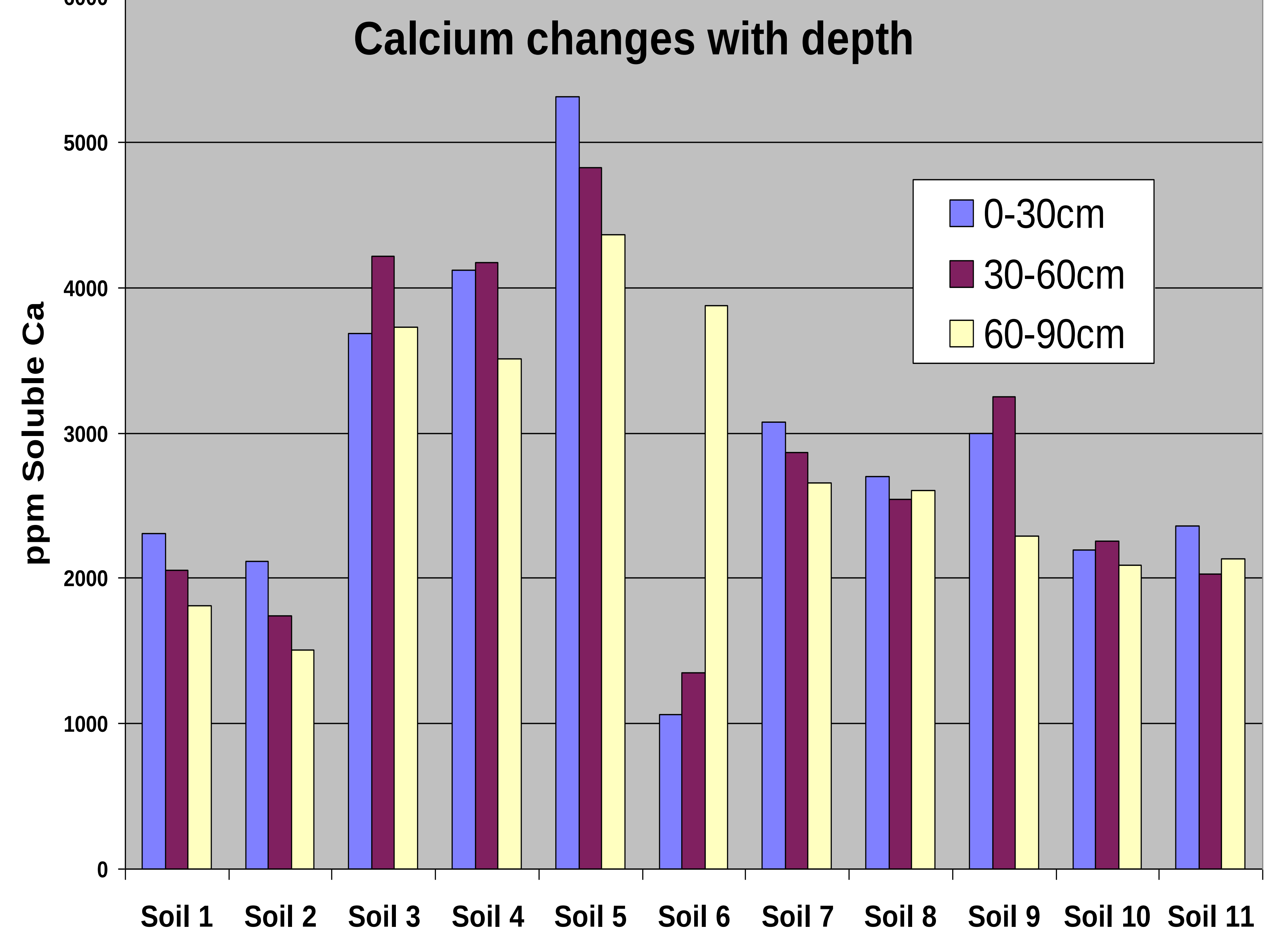
So roots CAN go deeper than the top 4 to 6 inches (10 cm)……

- The standard calculations for the amount of inorganic fertilizer needed, based on 4-6 inches, are nonsense……

- Compaction is critical to alleviate

- What are nutrient concentrations deeper in soil? Do nutrients disappear the deeper you go in soil?

- How deep is soil?


Calcium changes with depth
ppm Soluble Ca
0
1000
2000
3000
4000
5000
0-30cm
30-60cm
60-90cm
Soil 1
Soil 2
Soil 3
Soil 4
Soil 5
Soil 6
Soil 7
Soil 8
Soil 9
Soil 10
Soil 11

Coverage and Castle Walls

pH

Leaching

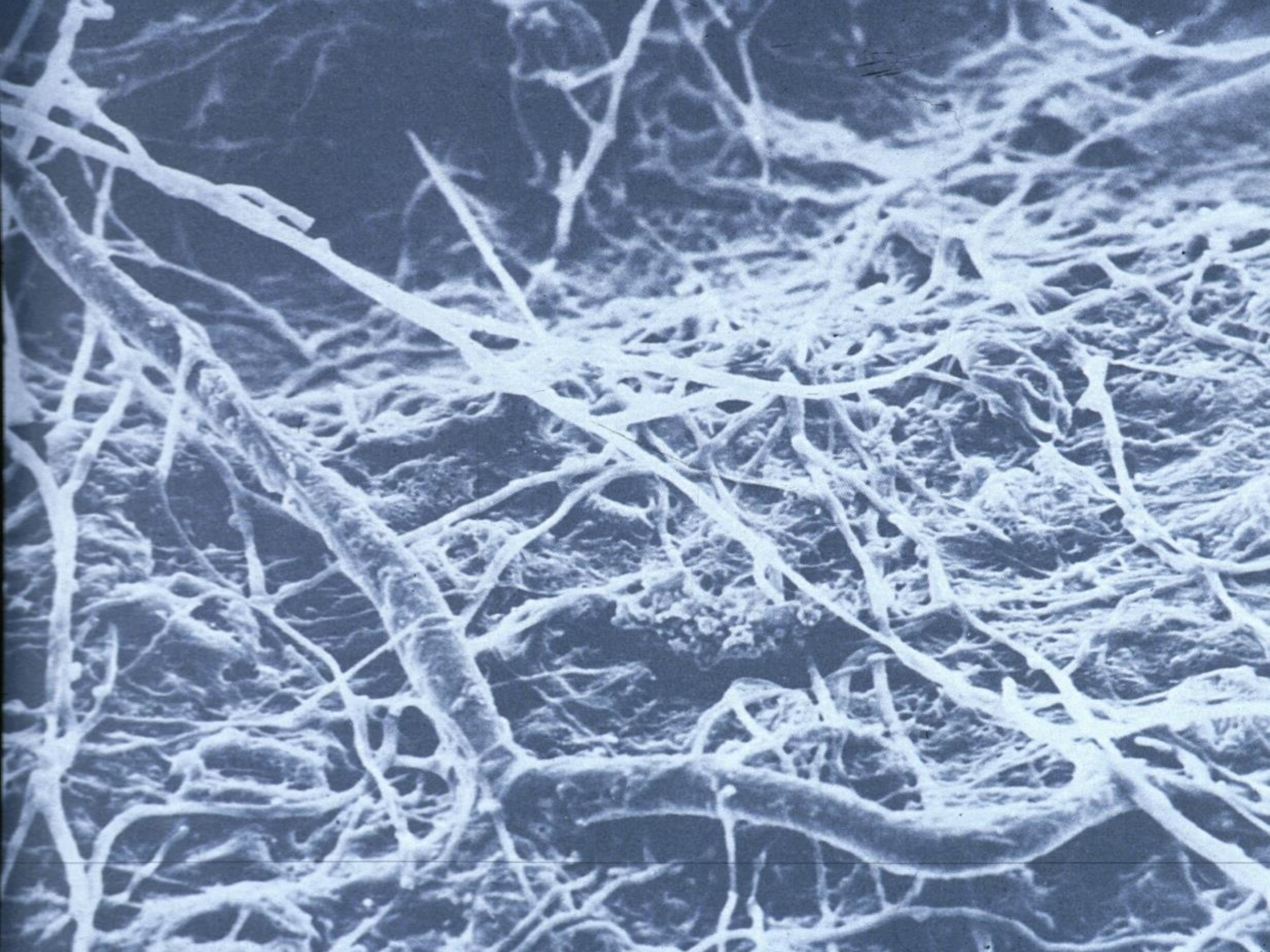
Nutrient Retention

The right biology enhances :

- Disease protection (no more pesticides!)
- **Nutrient retention, including C sequestration (stop leaching, volatilization)**
- Nutrient availability (right forms in the right place at the right time)
- Decomposition of toxins (get rid of residues)
- Build soil structure, improve root health, root depth, water holding, aerobic conditions, stop run-off, erosion.

Bacteria and fungi don’t wash away.

They need food,
and they stick to it!



AEROBIC bacteria and fungi stick to everything

- Bacterial glues
  - pH > 7
- Fungal threads
  - Organic acids whose pH is between 5.5 and 7.0
  - Glomulin

- R. Foster's book on Ultrastructure of the Rhizosphere

Bacteria and fungi don’t wash away

What is the concentration of nutrients

in Bacteria?

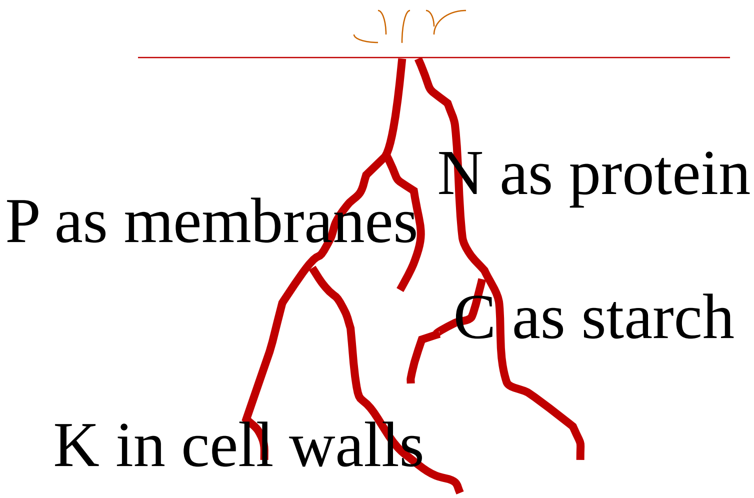
in Fungi?

Organism Group	C:N

- Bacteria
- Fungi
- People
- Green Leaves
- Protozoa
- Nematodes
- Deciduous trees
- Conifer trees

Organism Group	C:N
• Bacteria	5:1
• Fungi	20:1
• People	30:1
• Green Leaves	30:1
• Protozoa	30:1
• Nematodes	100:1
• Brown plant material	150 – 200:1
• Deciduous wood	300:1
• Conifer wood	500:1

C:N in Plants

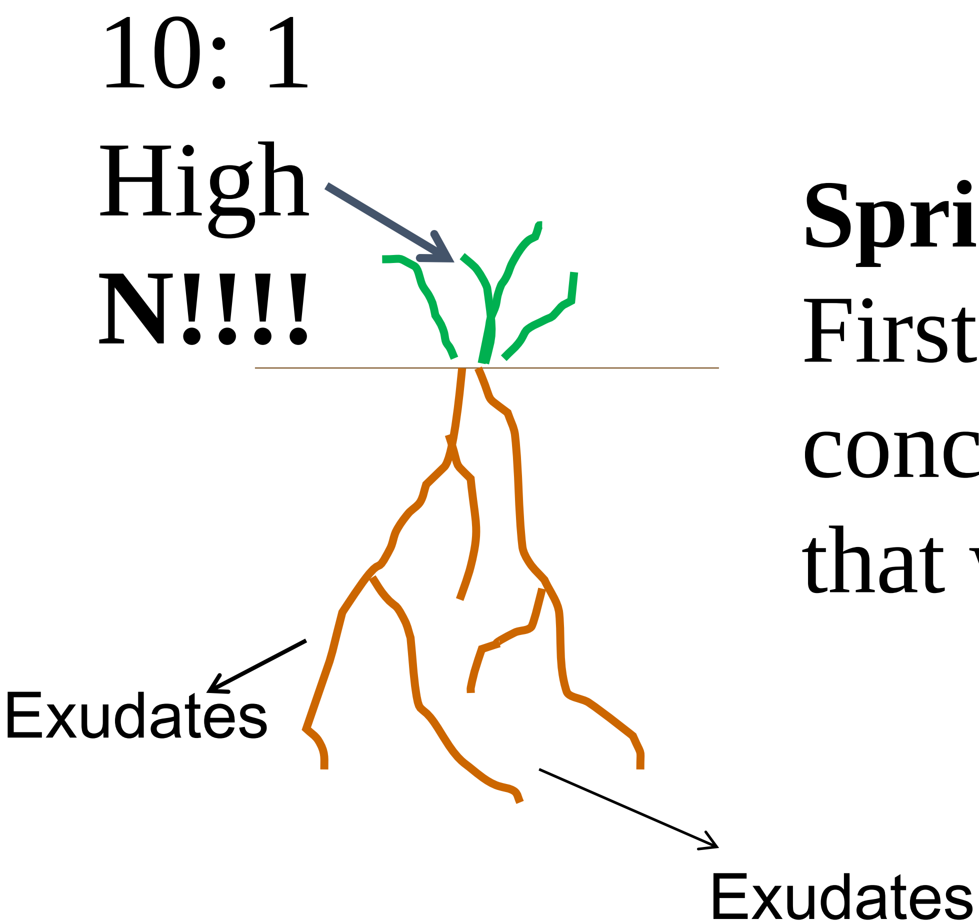


Winter:

All nutrients stored in roots.

As temperature, moisture become optimal, nutrients are mobilized into new growth

C:N in Plants

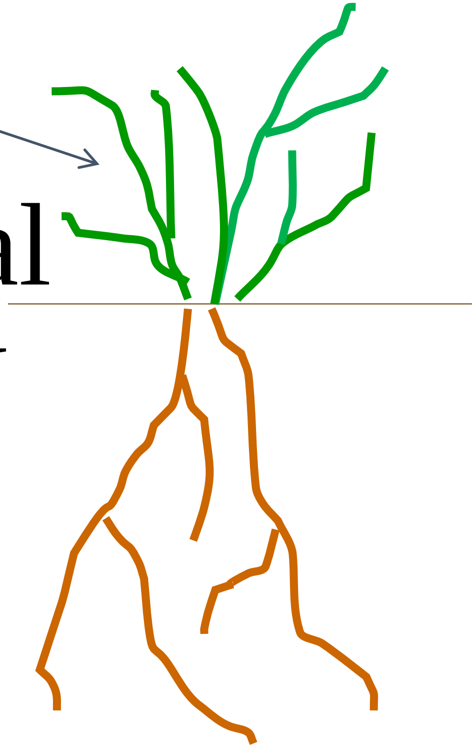


Spring:

First flush of new growth is concentrated with nutrients that were stored in roots.

C:N in Plants

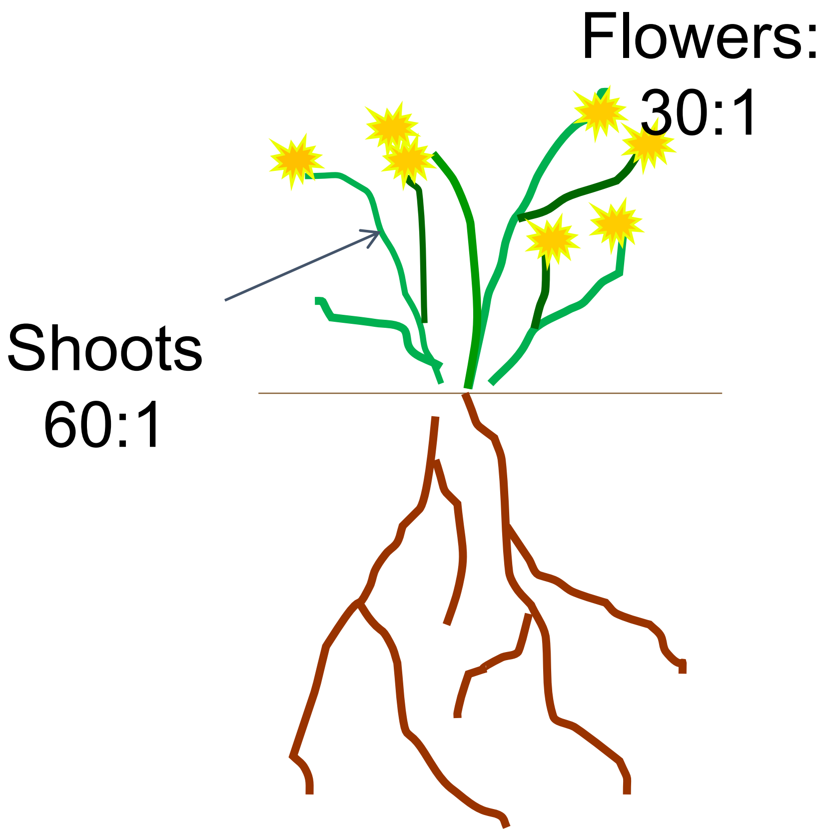
30: 1
normal
leaf N



Late Spring:
High initial nutrient concentration diluted as plant photosynthesizes

and adds carbon

C:N in Plants

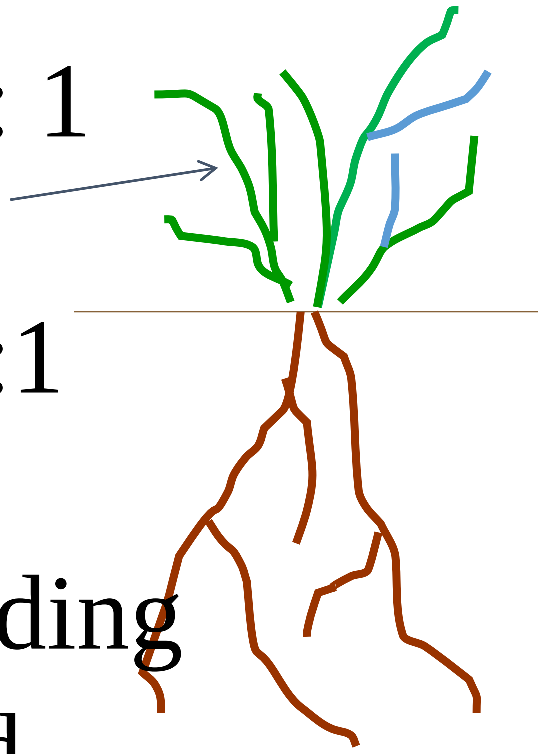


Flowering, seed set:
Seeds require high nutrient concentration.

Nutrients are taken from other plant parts to satisfy this need

C:N in Plants

150: 1
to
200:1
as
standing
dead



After seed produced: Plants get ready for dormant season, pull all nutrients possible back into roots

Bacteria and fungi are more concentrated in N than any other organism.

That means they hold (or retain) N

- Also true for P, S, K, etc.

- What is the C:N of bacterial or fungal food?

- Do bacteria or fungi release N?

Nutrient retention

- **Most leachable forms of N**
  - **NO_3^-**
  - **NO_2^-**
  - **NH_4^+**
  - **NH_3 (anaerobic and stinks!)**

The Inorganic Forms of N!!!

- Least leachable N

Nutrient retention

- Least leachable N (aerobic or anaerobic)
  - Bacteria
  - Fungi
  - Protozoa
  - Nematodes
  - Microarthropods
  - Roots
  - Organic matter

Why?

Least leachable

↓

More leachable

Nutrient Cycling

Predators and Prey

The right biology enhances:

- Disease protection (no more pesticides!)
- Nutrient retention, including C sequestration (stop leaching, volatilization)
- **Nutrient availability (right forms in the right place at the right time)**
- Decomposition of toxins (get rid of residues)
- Build soil structure, improve root health, root depth, water holding, aerobic conditions; “glue” soil together (stop run-off, erosion)

Nutrient Cycling (per unit biomass)

- Flagellates

need	30 C	1 N
• 1 bacterium	5 C	1 N
	-25 C	ok

More bacteria needed - how many?

Flagellates

need 30 C 1 N

- 6 bacteria 30 C 6 N

C ok but too much N!

- 5 N released for every 6 bacteria consumed.

- What form of N? NH_4

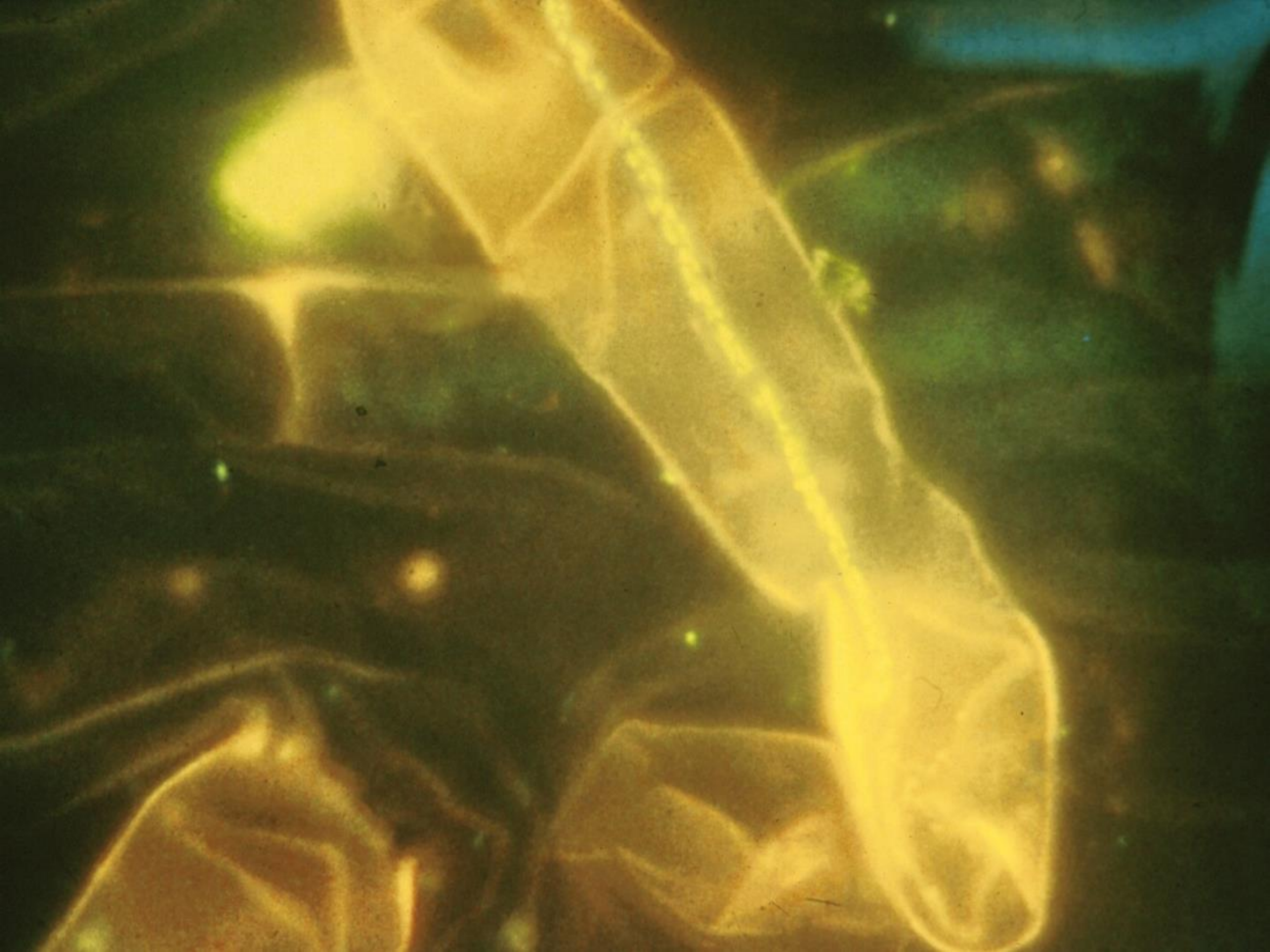
- Is this what plants need? Convert to Nitrate?

Is this enough N to grow plants?

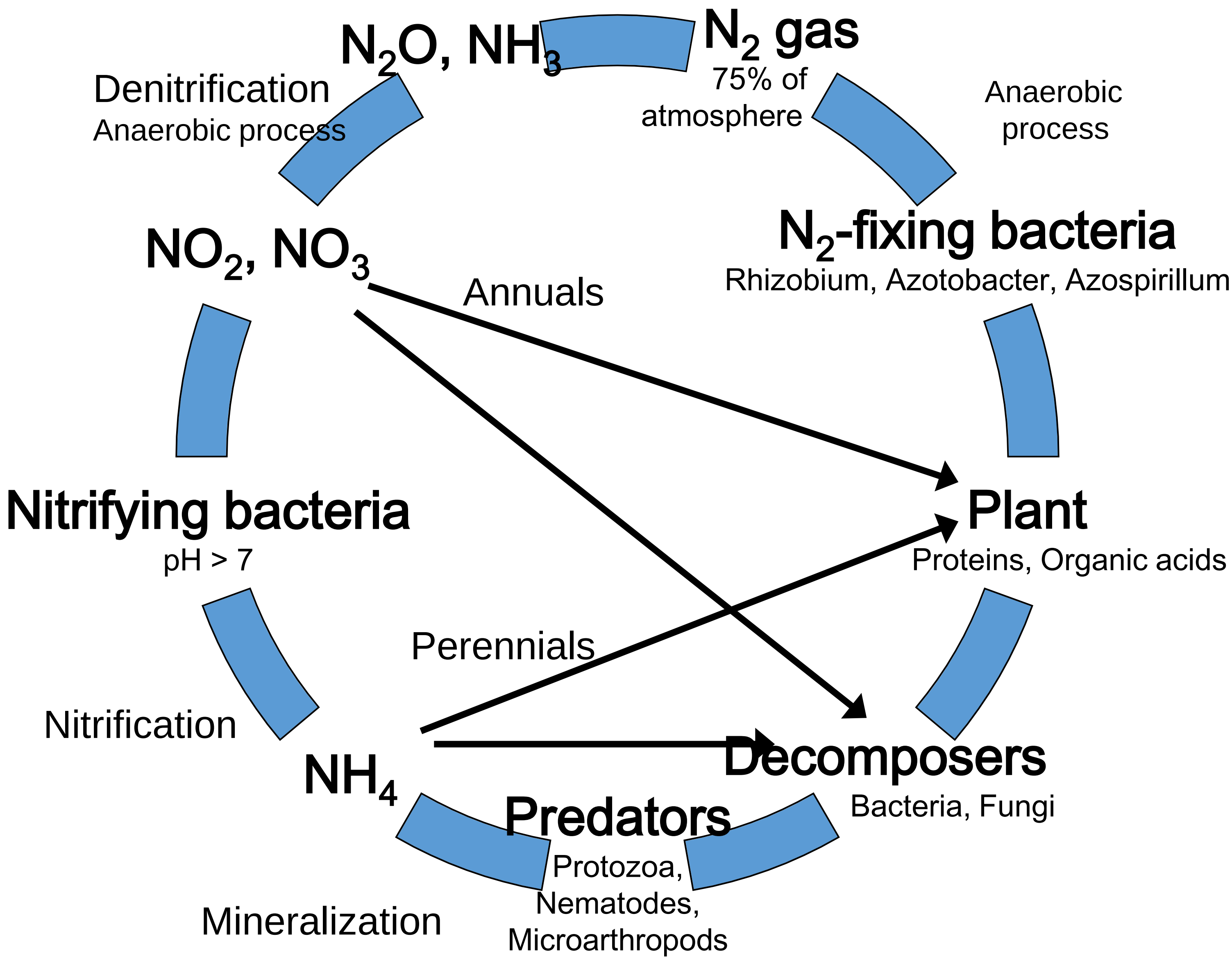
- 5 N released for every 6 bacteria consumed.
- Each protozoan eats 10,000 bacteria per day, so that’s 8,000 N molecules released per day per protozoan!
- Healthy soils contain 50,000 protozoa per g
- Protozoa eat 500,000,000 bacteria per g soil per day, which releases 400,000,000 molecules of N per g soil per day.
- This 7 ng of N per cm^2 surface of root soil per day, and Arabidopsis plants only require 0.2 ng per cm^2 root per day

N-fixing Nodules on Clover

Nodules on Roots of a Trefoil



N cycle


N_2 gas
75% of atmosphere
Anaerobic process
N_2-fixing bacteria
Rhizobium, Azotobacter, Azospirillum
Plant
Proteins, Organic acids
Decomposers
Bacteria, Fungi
Predators
Protozoa, Nematodes, Microarthropods
Mineralization
NH_4
Nitrification
Nitrifying bacteria
pH > 7
NO_2, NO_3
Denitrification
Anaerobic process
N_2O, NH_3
Annuals
Perennials

Soil Testing

- Walk your farm. Choose the best and worst places
- Check for compaction problems – penetrometer readings
- What do the plants say about the life in your soil?
- What stage are your soils at? Weeds? Diseases? Pests? Fertility?
- What needs to be fixed? Maybe a soil biology assessment would be a good idea if you are having trouble deciding.
- Look at the data: What is low? High? Out-of-balance?

	Block ID:		SFI#7623	Desirable Level Heavy Soil	Desirable Level Medium Soil
	Nutrient	Units			
Soluble Tests & Morgan 1 Extract	Calcium Ca	ppm	525	*1150*	*750*
	Magnesium Mg	ppm	593	*160*	*105*
	Potassium K	ppm	145	*113*	*75*
	Phosphorus (Morgan) P	ppm	0.5	*15*	*12*
	Phosphorus (Bray 1) P	ppm	4	*45 note 8*	*30 note 8*
Soluble Tests & Colwell + Bray 2 Phoshorus Extract	Phosphorus (Colwell) P	ppm	16	*80*	*50*
	Phosphorus (Bray 2) P	ppm	12	*90 note 8*	*60 note 8*
	Nitrate N	ppm	23.8	*15*	*13*
	Ammonium N	ppm	5.9	*20*	*18*
	Sulphate Sulphur S	ppm	12	*40*	*30*
	pH (1:5 water)	units	5.29	*6.5*	*6.5*
	Conductivity (1:5 water)	µS/cm	169	*200*	*150*
	Organic Matter	%	4.91	*5.5*	*4.5*
Ammonium Acetate Equiv. Extract	Calcium Ca	$cmol^+/Kg$	9.18	*15.6*	*10.8*
	Ca	kg/ha	4112	7000	4816
	Ca	ppm	1836	3125	2150
	Magnesium Mg	$cmol^+/Kg$	11.09	*2.4*	*1.7*
	Mg	kg/ha	2981	650	448
	Mg	ppm	1331	290	200
	Potassium K	$cmol^+/Kg$	1.28	*0.6*	*0.5*
	K	kg/ha	1117	526	426
	K	ppm	498	235	190
	Sodium Na	$cmol^+/Kg$	1.60	*0.30*	*0.26*
	Na	kg/ha	822	155	134
	Na	ppm	367	69	60
	Aluminium Al	$cmol^+/Kg$	0.13	*0.6*	*0.5*
	Al	kg/ha	26	108	90
	Al	ppm	12	54	45

	Aluminium	Al	$cmol^+/Kg$	0.13	*0.6*	*0.5*
		Al	kg/ha	26	108	90
		Al	ppm	12	54	45
Acidity Titration	Hydrogen	H^+	$cmol^+/Kg$	0.20	*0.6*	*0.5*
		H^+	kg/ha	4	12	10
		H^+	ppm	2	6	5
	Cation Exchange Capacity		$cmol^+/Kg$	23.47	*20.0*	*14.0*
Percent Base Saturation	Calcium	Ca	%	39.1	*77.0*	*76.0*
	Magnesium	Mg	%	47.3	*12.0*	*12.0*
	Potassium	K	%	5.4	*3.0*	*3.5*
	Sodium	Na	%	6.8	*1.5*	*2.0*
	Aluminium	Al	%	0.6	*6.5*	*6.5*
	Hydrogen	H+	%	0.8		
	Calcium/ Magnesium Ratio		ratio	0.83	*6.42*	*6.33*
SMP	BUFFER pH		units	6.60	*6.7*	*6.7*
Micronutrients- DTPA +Hot $CaCl_2$ Extracts	Zinc	Zn	ppm	0.7	*6.0*	*5.0*
	Manganese	Mn	ppm	19.4	*25*	*22*
	Iron	Fe	ppm	199.3	*25*	*22*
	Copper	Cu	ppm	2.8	*2.4*	*2.0*
	Boron	B	ppm	1.47	*2.0*	*1.7*
Total Nutrients	Total Carbon	C	%	2.81	*3.1*	*2.6*
	Total Nitrogen	N	%	0.22	*0.30*	*0.25*
	Carbon/ Nitrogen Ratio		ratio	12.8	*10 to 12*	*10 to 12*
	Texture	t		Clay	..	..
	Colour	c		Brown	..	..

Notes:

1: Cation Exchange Capacity = sum of the exchangeable Mg, Ca, Na, K, H and Al; Sodium % = ESP (Exchangeable Sodiu

1a: Soluble Salts included in exchangeable Cations - NO WASHING/ REMOVAL OF SOLUBLE SALTS

2: Albrecht Methods from Rayment and Higgins, 1992. Australian Laboratory Handbook of Soil and Water Chemical Methoc

3: Reams available nutrient testing adapted from 'Science in Agriculture' and 'Non-Toxic Farming' and Lamonte Soil Handbo

4. All results as dry weight; ppm = mg/Kg air dried @ 65°C and crushed to ensure homeogenity (ie. ring mill)

Soil Foodweb Inst Pty Lty.
Lismore, NSW 2480
Phone: 02 66225150
FAX 02 66225170

Soil Analysis
Client:
Sample Received: July 2009
Plant: Alfalfa

TRT	Dry Wt of 1 gram Fresh Material	Active Bacterial Biomass (µg/g)	Total Bacterial Biomass (µg/g)	Active Fungal Biomass (µg/g)	Total Fungal Biomass (µg/g)	Hyphal Diameter (µm)	Protozoa Numbers F	Protozoa Numbers A	Protozoa Numbers C	Total Nematode Numbers (#/g)
Fld 1	0.84	16	866	28	820	3	15,000	8,000	25	16
	OK	OK	Excel	Excel	Excel	Good		Good		Good
Desired Range	0.60 - 0.80	15- 30	300+	5 - 30	300+	2.5 or higher	10,000+	10,000+	20 - 100	5 - 24

TRT	TF to TB	AF to TF	AB to TB	AF to AB	Plant Available N Supply from Predators (lbs/ac)	Root-Feeding Nematode Presence
Fld 1	0.94	0.005	0.02	1.78	75 - 100	None detected
	Good	Low	Low	Bacterial	Good	

BACTERIAL-FEEDERS	**#/g**
ACROBELES	2
CEPHALOBUS	1
BURSILLA	1
RHABDITIDAE II (ST)	4
RHABDITIDAE II (LT)	2
PRISMATOLAIMUS	1
FUNGAL-FEEDERS	
MESODORYLAIMUS	2
EPIDORYLAIMUS	1
APORCELLAIMELLUS	1
FUNGAL/ROOT -FEEDERS	
QUINISULCIUS	1
PREDATORY	0
ROOT-FEEDERS	0

Soil Foodweb Inst Pty Lty.
Lismore, NSW 2480
Phone: 02 66225150
FAX 02 66225170

Client:
Sample Received:
Plant: Asparagus

Very Bacterial

TRT	Dry Wt of 1 gram Fresh Material	Active Bacterial Biomass (µg/g)	Total Bacterial Biomass (µg/g)	Active Fungal Biomass (µg/g)	Total Fungal Biomass (µg/g)	Hyphal Diameter (µm)	Protozoa Numbers F	A	C	Total Nematode Numbers (#/g)
Com-post	0.22	1.70	1932	0.00	0.31	2.5	0	230	2,667	3
	Wet	Low	High	Low	Low	OK		Anaerobic		Low
Desired Range	0.45 - 0.75	15-30	300+	2 - 10+	200 +	2.5 or higher	10,000+	10,000+	20 - 100	50 - 100

TRT	TF to TB	AF to TF	AB to TB	AF to AB	Plant Available N Supply from Predators (lbs/ac)	Root-Feeding Nematode Presence
Com-post	0.0002 Very Bact	None Too low	0.00 Too low	No fungi Bacterial	50 - 60 Too low	Lesion

Nematodes

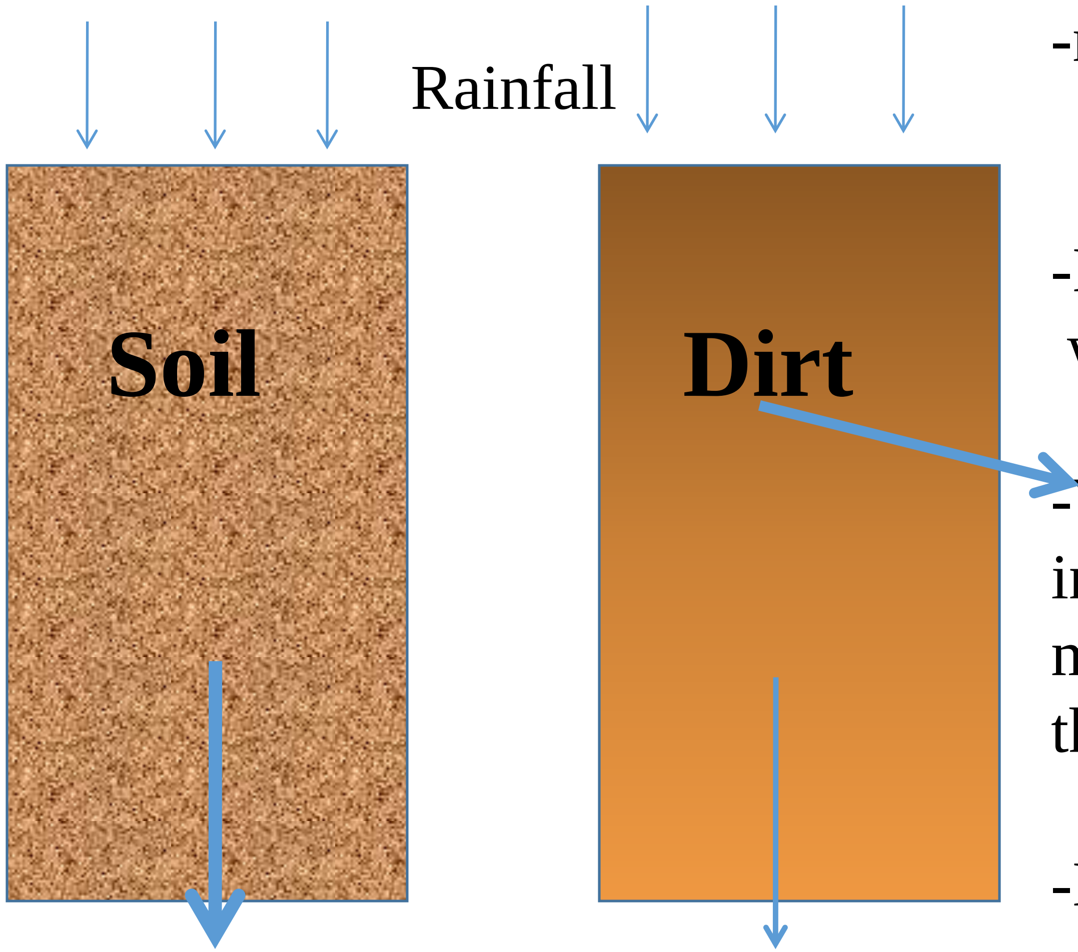
	#/g
BACTERIAL-FEEDERS	**None detected**
FUNGAL-FEEDERS	
	None detected
FUNGAL/ROOT -FEEDERS	
Malenchus	**1**
ROOT-FEEDERS	
Lesion	**2**

Soil results in clean water; dirt results in a bigger problem

-Organisms build structure

-Nutrients held

-Water is retained and moves slowly thru the soil



Clean Water

Water moves clay, silt and inorganic chemicals so no "cleaning" process

-no organisms, no structure

-Nutrients move with the water

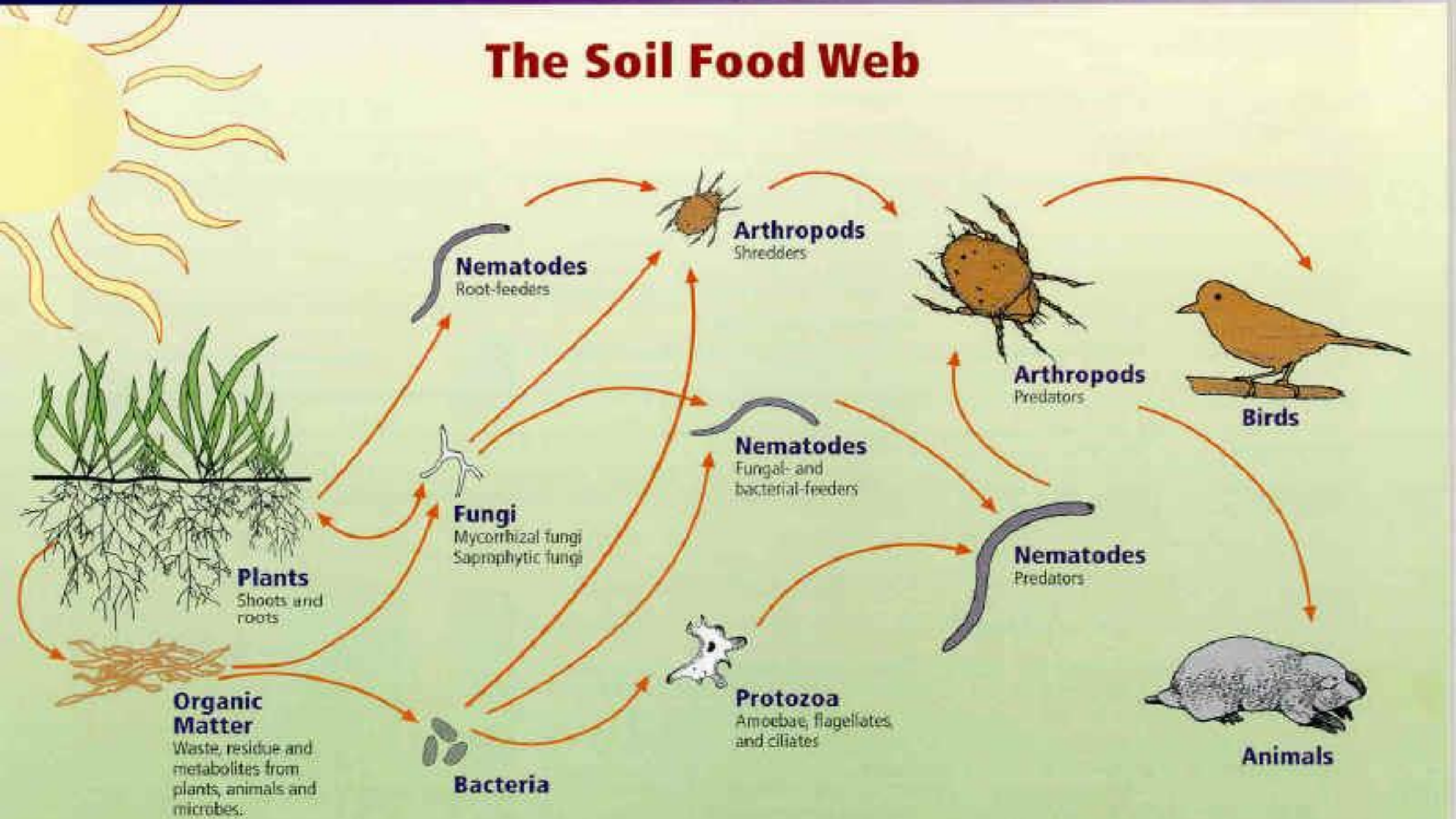
-Water not held in soil pores, moves rapidly thru soil

-Leaching, erosion and run-off are problems

ALL the biology must be present

- Which is “most important?”
- Holistic system, can’t forget any part
- No retention without bacteria and fungi
- No return to plant available forms without protozoa, beneficial nematodes and microarthropods
- Need to understand the **WHOLE** foodweb

The Soil Food Web



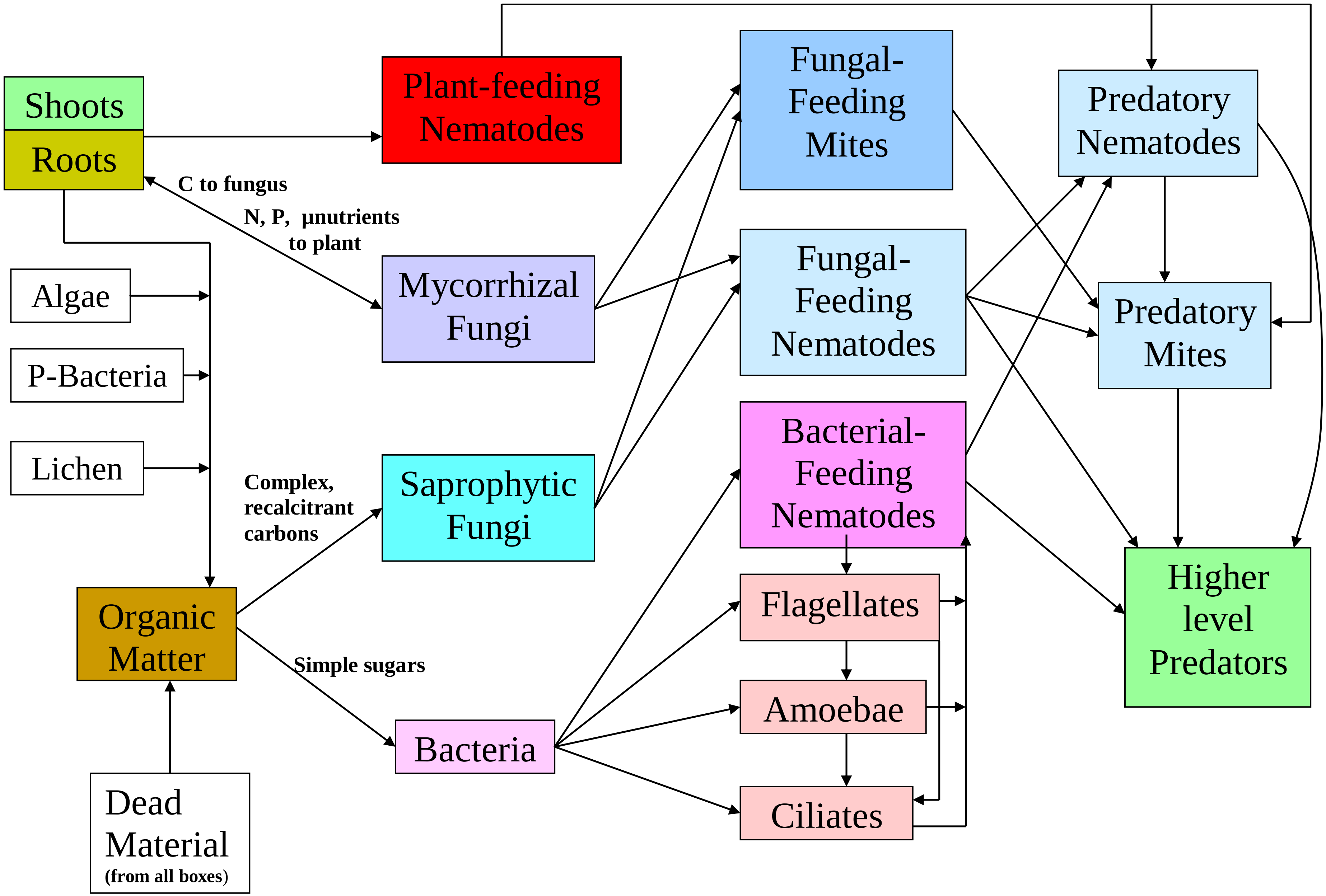
First trophic level:
Photosynthesizers

Second trophic level:
Decomposers
Mutualists
Pathogens, parasites
Root-feeders

Third trophic level:
Shredders
Predators
Grazers

Fourth trophic level:
Higher level predators

Fifth and higher trophic levels:
Higher level predators



The Soil Foodweb in Lawns, Vegetable and Row Crops systems

There is hope…..

- We can return the soil to health
- It will not cost billions, or even millions of dollars
- It will not take years
- Within one growing season, you can get the increased yields, decrease your costs and improve nutrition in the food you produce
- IF you get the biology right for your plant
- IF you get the WHOLE FOODWEB back
- And now…… it is up to you to go forth and help spread this knowledge

Contact Information…..

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- Books: info@nature-technologies.com