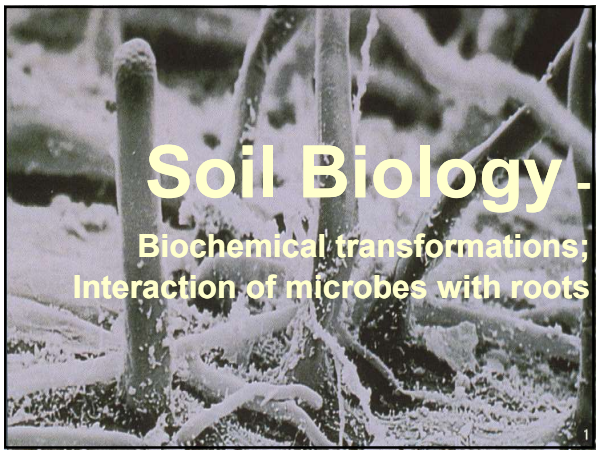

Lecture outline

- Biochemical transformations
  - Example #1: Biological N fixation
  - Example #2: Mineralization / Immobilization
  - Example #3: Denitrification
- Microbe interactions with plant roots
- Plant nutrients

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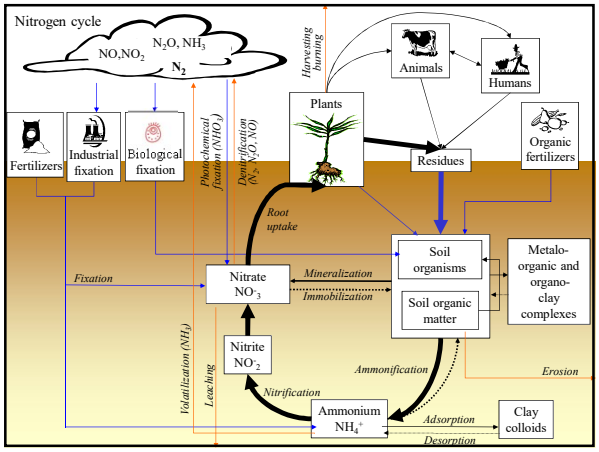

The sources of soil N are:

- Biological fixation of N_2
- Deposition of N (NO_3^- and NH_4^+) compounds from the atmosphere by precipitation
- Fertilizers
- Plant residues
- Manure

Addition of organic matter

Processes that are mediated by soil organisms

4

The losses of soil N occur through:

- Plant removal
- Leaching
- Gaseous losses (denitrification and NH_3 volatilization)
- Erosion (wind and water)
- Ammonium fixation (clay complexes)

Processes that are mediated by soil organisms

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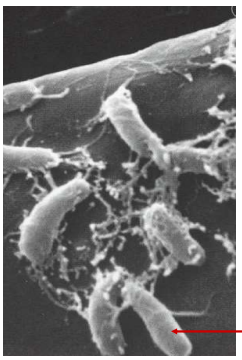
Example #1 - Biological fixation of N



Biological conversion of N_2 to ammonia (NH_3) done by some bacteria, cyanobacteria, and actinomycetes

N fixing bacteria generate cellulose as they attach to the root hair

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Example #1 – cont.

Biological N fixation

$$\overset{0}{N_2} + 8H^+ + 8e^- \xrightarrow[(Fe,Mo)]{Nitrogenase} 2\overset{3-}{N}H_3 + H_2$$

Estimated amount of N fixation in terrestrial ecosystems is ~139 million t N per year

Example #1 – cont.

Typical levels of biological N fixation

Crop or plant	Associated organism	Typical level of N fixation (kgN/ha/yr)
Symbiotic		
Legumes (nodulated)		
Alfalfa	Bacteria (*Rhizobium*)	150 – 250
Clover	Bacteria (*Rhizobium*)	100 – 150
Vetch	Bacteria (*Rhizobium*)	50 –150
Non-legumes (nodulated)		
Alders (*Alnus sp.*)	Actinomycetes (*Frankia*)	50 – 150
Non-legumes (non-nodulated)		
Bahia grass	Bacteria (*Azotobacter*)	5 – 30
Non-symbiotic		
Not involved with plants	Bacteria (*Azotobacter, Clostridium*)	5 - 20

Example #1 – cont.

Symbiotic N fixers with legumes (nodulated)

Soybean nodules are spherical

Alfalfa nodules may grow multiple lobes

This newly emerged white clover root nodules will soon begin fixing N

Example #2

Mineralization / Immobilization

$$Organic\ N \underset{Immobilization}{\overset{Mineralization}{\rightleftharpoons}} Inorganic\ N$$

Example #2

Mineralization:

- Aminization

$$\text{Protein} \longrightarrow R - NH_2 + CO_2 + E\uparrow + other\ products$$

- Ammonification

$$R - NH_2 + H_2O \longrightarrow NH_3 + R - OH + E\uparrow$$

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

- Nitrification

$$2NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + 2H_2O + 4H^+ + E\uparrow$$ *Nitrosomonas sp.*

$$2NO_2^- + O_2 \longrightarrow 2NO_3^- + E\uparrow$$ *Nitrobacter sp.*

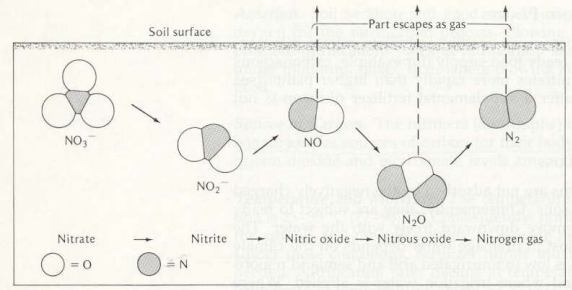
Example #2

Mineralization and microbes involved

- **Aminization** → heterotrophs (bacteria and fungi)
- **Ammonification** → heterotrophs (bacteria, actynomicetes, fungi)
- **Nitrification** → chemo-autotrophic bacteria

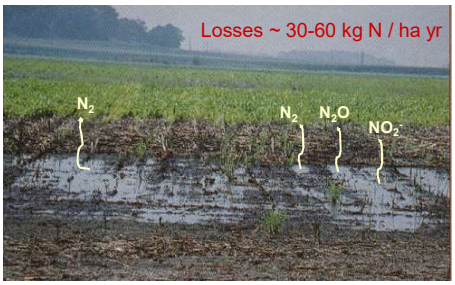
Example #3

Denitrification – biological reduction of NO_3^- to gaseous compounds



Example #3

Denitrification bacteria live under anaerobic conditions, such as those in saturated, compacted soils



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B. Interaction of microbes with plant roots

Mycorrhizae is a mutually beneficial, symbiotic association between plants and fungi, where fungus provides nutrients, while plant provides sugars from photosynthesis

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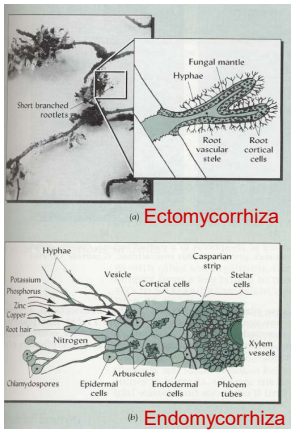

Types of mycorrhizae:

- Ectomycorrhiza with tree sp. except our 'cedars'
- Ericoid mycorrhiza with Ericaceae (blueberry, salal)
- Arbuscular mycorrhiza with most other plants

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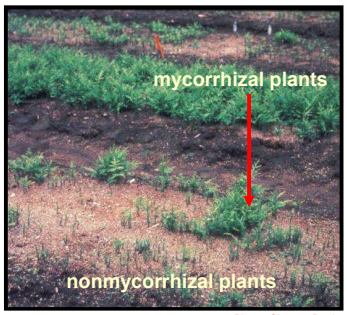
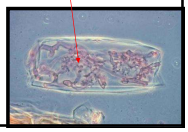
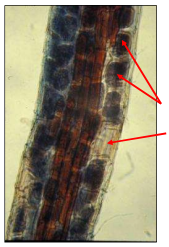


Photos: Shannon Berch

Arbuscular mycorrhiza

arbuscules





Ericoid mycorrhiza

colonized cells

uncolonized cell

Photos: Shannon Berch

salal on cutblock

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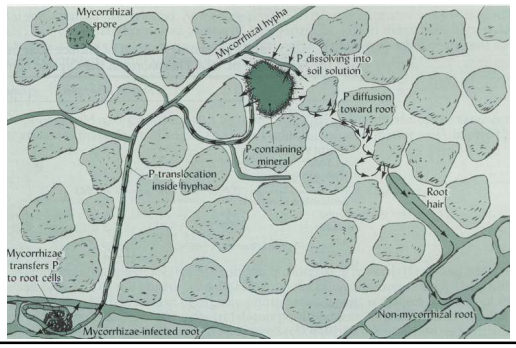
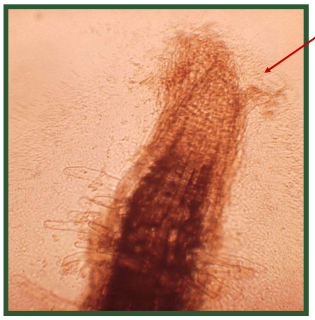
Role of mycorrhizal hyphae in the movement of phosphate ions to plant roots



Rhizosphere effects



Dead cells and exudates released from a corn root

Rhizosphere is the space near roots where microbes (e.g. bacteria) feed on dead root cells and exudates (sugars, proteins)

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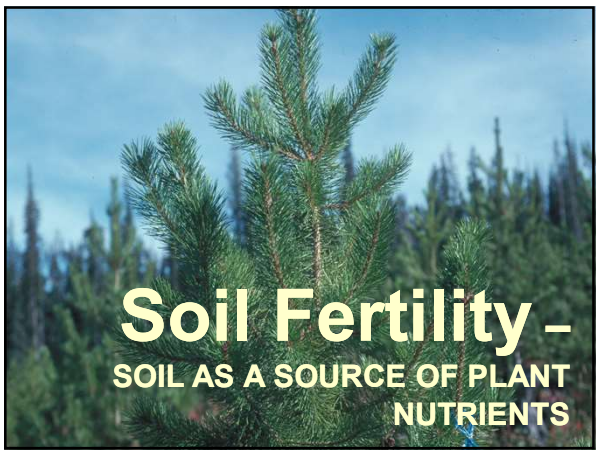

Soil fertility is study of soils' ability to supply nutrients needed for plant growth

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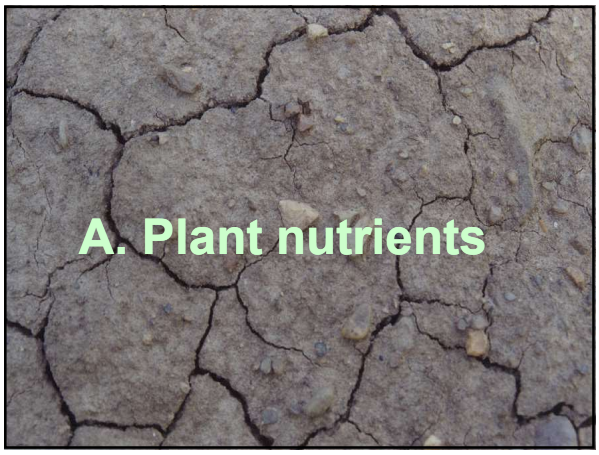
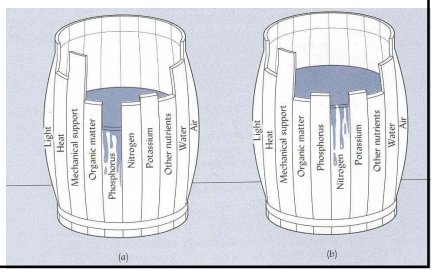


An element is considered as an <u>essential</u> if:

- A deficiency on an element makes it impossible for the plant to complete the vegetative or reproductive stage of its life cycle.
- Such deficiency is specific to the element in question and can be prevented or corrected only by supplying this element.
- The element is directly involved in the nutrition of the plant in a such way that it is a constituent of a necessary metabolite (e.g. S in amino acids methionine or cysteine).

The law of minimum and concept of the limiting factor

Plant production can be no greater than the level allowed by the growth factor present in the lowest amount relative to the optimum amount for that factor



The 17 elements considered as <u>essential</u> are:

- **Macronutrients**: C, H, O, N, P, K, Ca, Mg, S
- **Micronutrients**: Fe, Mn, Cu, Zn, Ni, B, Mo, Cl

C, H, and O account for 90-95% of plant dry weight. All organic compounds contain C and nearly all contain H and O.

N, P, and K are taken up by plants in large amounts. Their deficiencies are quite common and treated by fertilizer application.

Ca, Mg, and S are taken up by plants in moderate amounts. Their deficiencies are less common than for N, P, and K.

The 17 elements considered as essential are:

- **Macronutrients**: C, H, O, N, P, K, Ca, Mg, S
- **Micronutrients**: Fe, Mn, Cu, Zn, Ni, B, Mo, Cl

Beneficial elements (e.g. Co, Na, Si) are required by some plant species and their essentiality to plant growth has not yet been confirmed.

Some forms and functions of essential elements in plants

Element	*Forms and functions*
C, H, O	All plant organic components
N and S	Amino acids—constituents of proteins
	Proteins—enzymes, storage compounds, and membrane components
N and P	Nucleotides—energy transfer (e.g., ATP), electron transfer (e.g., NADP), genetic information (DNA and RNA)
P	Phospholipids—membranes
	Inorganic phosphate—synthesis of ATP
K	K ion—enzyme activator, osmotic regulator
Ca	Complexed as calmodulin—regulator of many cell processes
	Attached to cell membranes—stabilizer
Mg	Complexed as chlorophyll—photosynthesis
	Complexed with ATP—energy transfers
Fe	Complexed as cytochromes—electron transfers
Mo	Component of enzymes—N_2 fixation and nitrate reduction
Ca, Mg, Mn, Cu, Zn	Associated with enzymes—activators