Nitrogen

Nitrogen and Soil

The most limiting essential element in the environment

Surface soil range: 0.02 to 0.5%

0.15% is representative

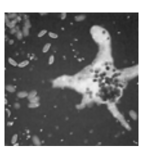
1 hectare = 3.3 Mg

Atmosphere = 300,000 Mg as N_2

Biological/Plant Nitrogen

Component of living systems

- Amino acids
- Proteins
- Enzymes
- Nucleic acids (DNA)
- Chlorophyll



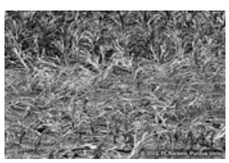
Strongly limiting in the Environment

Deficiency

Chlorosis – pale, yellow-green appearance primarily in older tissues.

Excess

Enhanced vegetative growth – lodging
Over production of foliage high in N
Delayed maturity
Degraded fruit quality



Distribution/Cycling

Atmosphere	N_2, NO, N_2O
Soil / soil O.M.	NH_4^+, NO_3^-, R – NH_2
Plants, animals	Proteins, amino acids

Organic Nitrogen (plant tissue, Soil Organic Matter): R – NH_2

During organic decomposition, R – NH_2 is usually broken down to NH_4^+

NH_4^+ is converted to NO_3^- by soil microorganisms

Forms: mineral and organic

Organic:	plant/tissue N	$R\text{-}NH_2$
Mineral:	soil N	NH_4^+, NO_3^-

Cycling in the Environment

Mineralization: Decomposition of organic forms releasing nitrogen into the soil, generally as NH_4^+

Immobilization: Plant uptake of mineral nitrogen, removing it from the soil and incorporating into plant tissue.

Ammonium

Mineralization

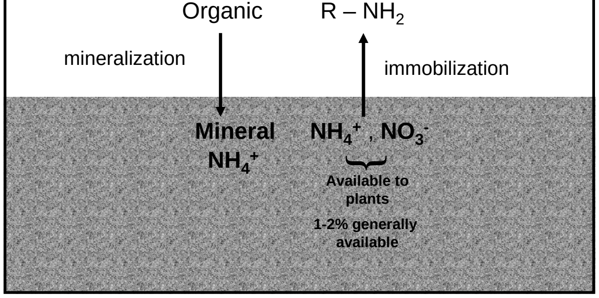
$$R - NH_2 \longrightarrow NH_4^+$$

organic → mineral

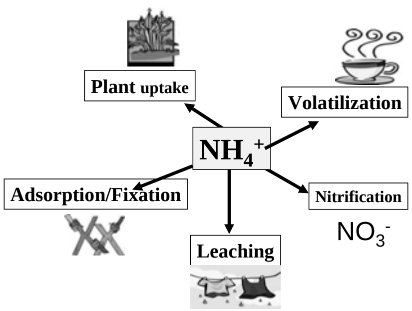
Immobilization

$$NH_4^+ \text{ or } NO_3^- \longrightarrow R - NH_2$$

Organic and Mineral Nitrogen



Nitrogen in the Soil

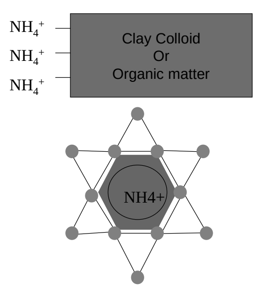


Adsorption and Fixation

NH_4^+

Exchange

Fixation



Nitrification

Aerobic (oxygen) →

$NH_4^+ \xrightarrow{\text{Nitrosomonas}} NO_2^- \xrightarrow{\text{nitrobacter}} NO_3^-$

← Anaerobic (low oxygen)

Nitrate

NH_4^+ —Nitrosomonas→ NO_2^- —nitrobacter→ NO_3^- (to plants)

NO_3^- ←

Leaching to groundwater, surface water
Loss of productivity
Environmental hazard

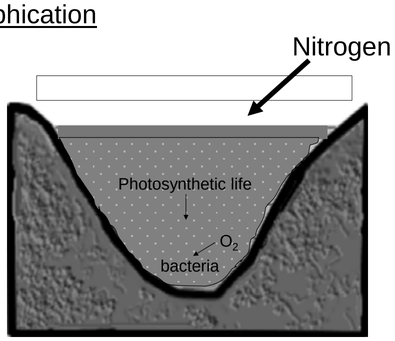
Environmental Impact

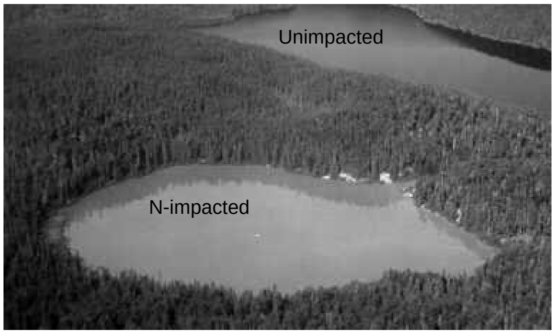
Methemoglobinemia – reduction by bacteria in ruminants and infants

$$NO_3^- \longrightarrow NO_2^-$$

Eutrophication – stimulation of algal growth, depletion of oxygen

Eutrophication





Control

Split applications
Nitrification inhibitors
Slow release fertilizers
Cover crops
Encourage natural N fixation

$NH_4^+ \xrightarrow{\text{Nitrosomonas}} NO_2^- \xrightarrow{\text{nitrobacter}} NO_3^-$

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Symbiotic Biological Nitrogen Fixation

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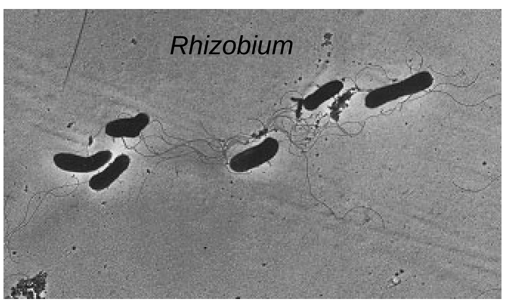
Symbiosis between plant roots and rhizobium bacteria



Atmospheric Nitrogen Fixation

- $N_2 + 6H_2 \longrightarrow 2NH_3$
- Fixing N_2 is “expensive”
- $N \equiv N \longleftarrow$ Triple bond
  - Must use energy to break these bonds

- Haber - Bosch Process - Artificial Fixation of Nitrogen Gas:
  - 200 atm
  - 400-500 ^{o}C yield of 10-20%
  - no oxygen

Produces 500 million tons of artificial N fertilizer per year.
1% of the world's energy supply is used for it
Sustains roughly 40% of the population

Symbiotic Biological Nitrogen Fixation

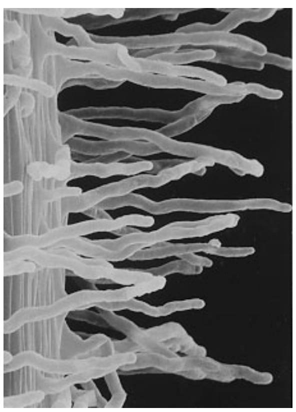
Initialization

Plant roots send out signals inviting rhizobia to colonize the root
Rhizobia signal plants to produce an area in which they can colonize
The root produces the area and the avenue to colonize

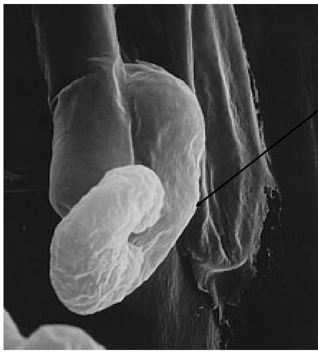
Area to colonize = meristem

Avenue of colonization = infection thread

- $N_2 + 6H_2 \longrightarrow 2NH_3$



Legume root hairs.
Chemical signals sent from
Root hairs to bacteria:
invitation to infect

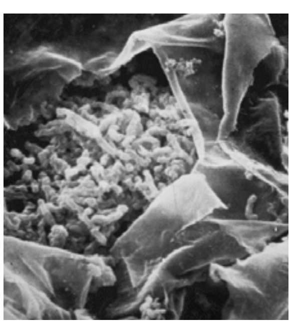


Root hair curls:
Traps bacteria

Nodules on legumes

Packed with N_2-fixing bacteria

Bacteroids in nodules



Bacteroids:
Rhizobium in
Nodules

Cells are
Fixing
atmospheric
Nitrogen

Residue from legume crops is usually high in N when compared with residue from other crops and can be a major source of N for crops that follow legumes in rotation.

Most of the N contained in crop residue is not available to plants until microbes decompose the plant material.

Residues from legume crops have low carbon to N (C:N) ratios and are easily decomposed by soil microbes. Residues from non-legume crops have a higher C:N ratio and are slower to decompose

N Contributions

alfalfa range from 100 to 150 lbN/acre

Soybeans range from 20-40 lb/acre