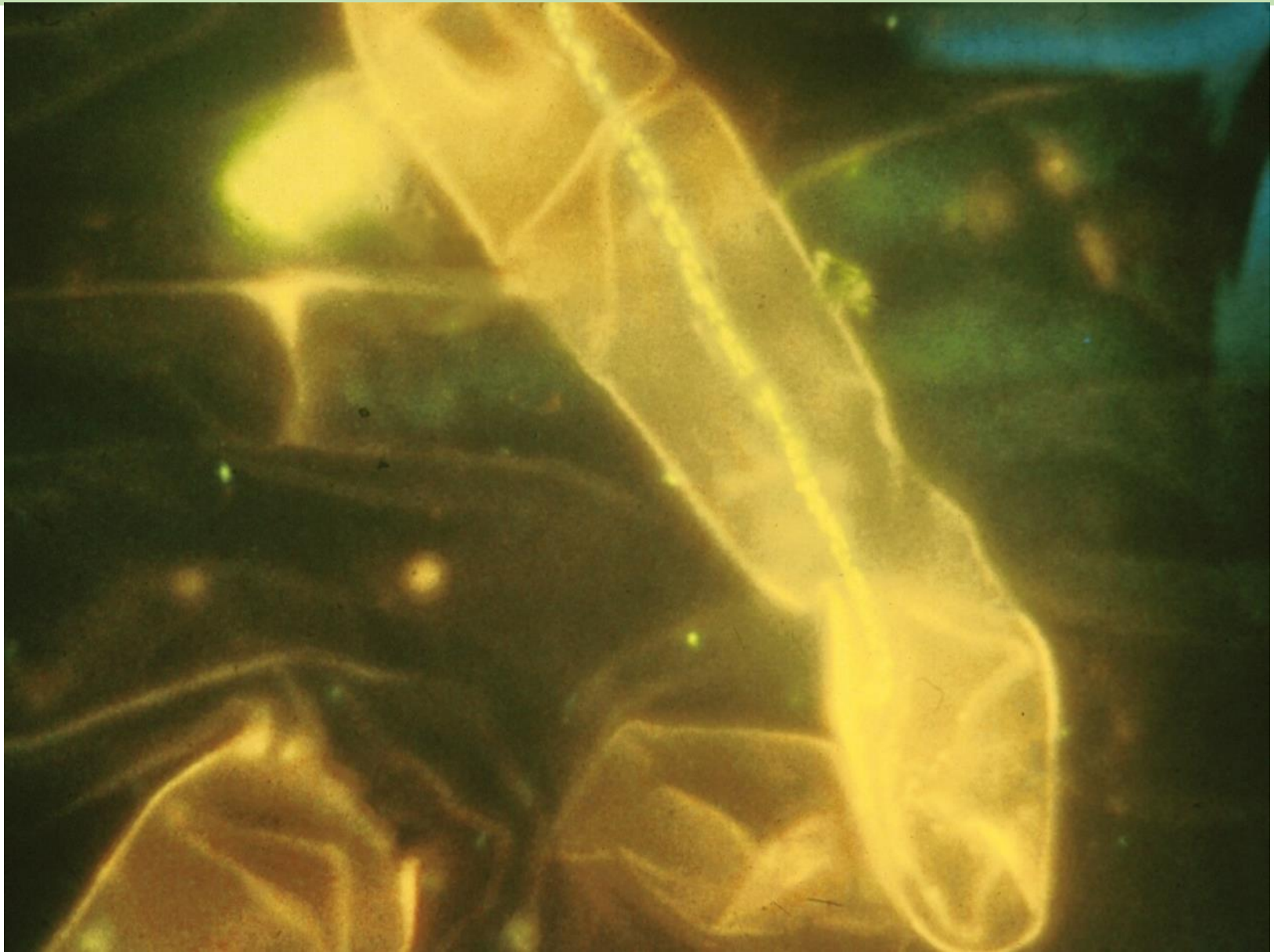
Chapter 2
The Benefits of the Soil Food Web

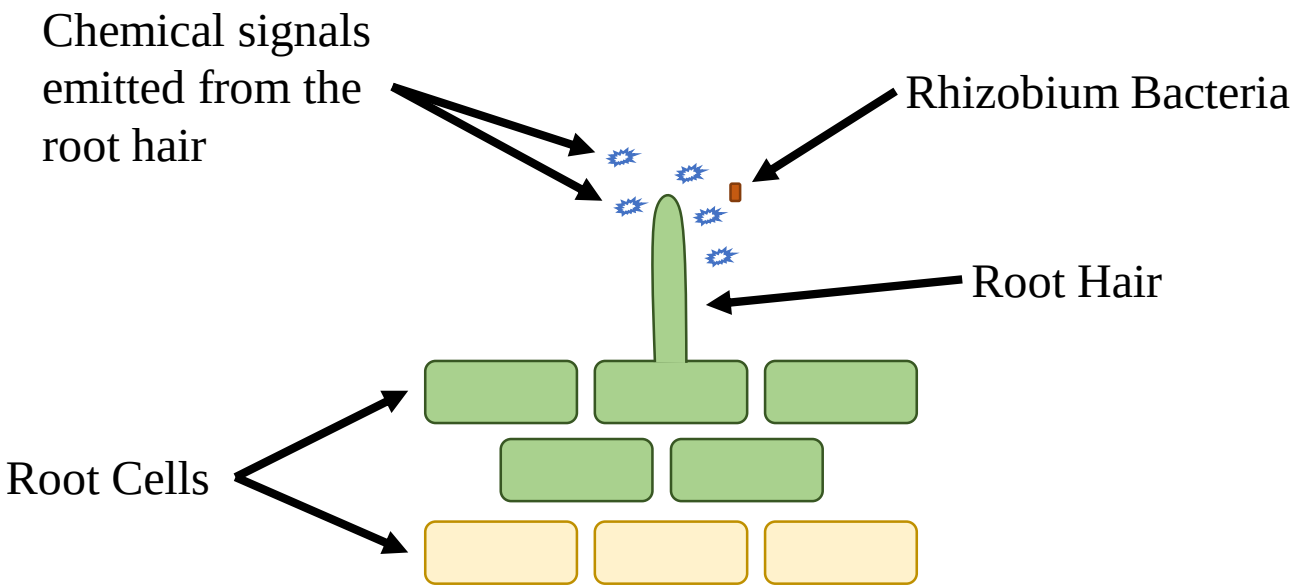
Lecture 13 - The Nitrogen Cycle

A Healthy Food Web Will:

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

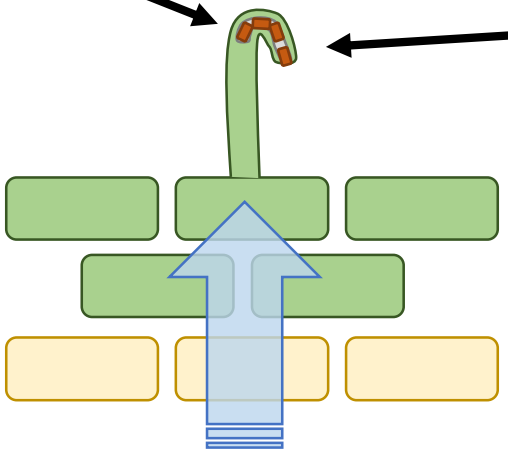
Root Hairs and Infection Sites




Chemical signals emitted from the root hair
Rhizobium Bacteria
Root Hair
Root Cells

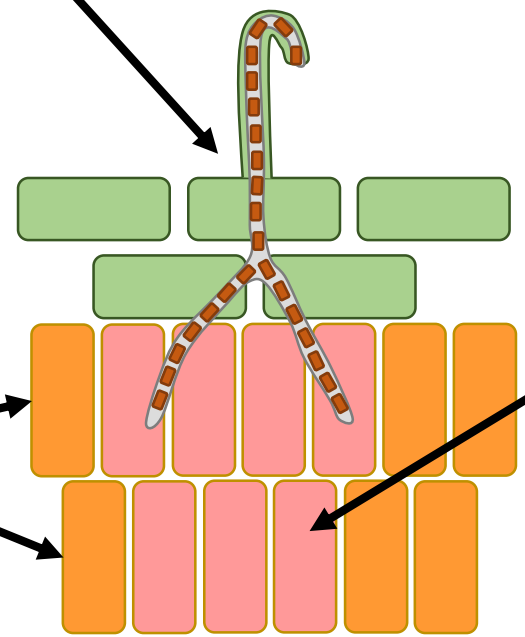
Infection thread is developed and bacteria starts to multiple

Root hair curls and Rhizobium bacteria infects the root



Sugars are sent to the root hair to feed Rhizobium bacteria

Infection thread moves to the interior of the root. Bacteria multiple

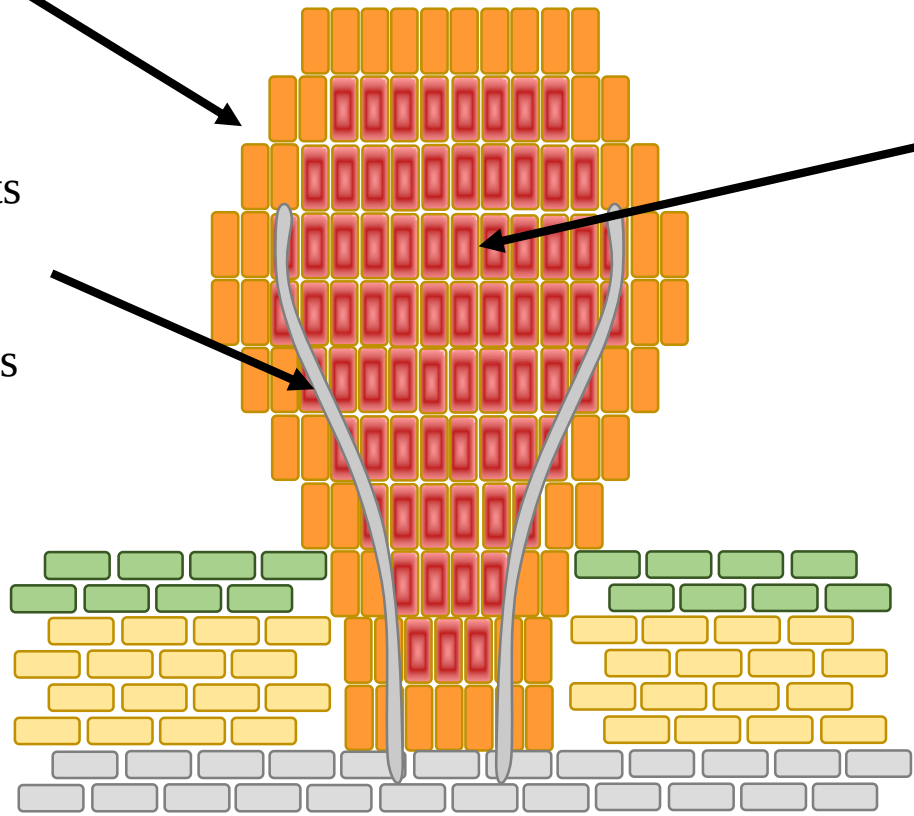


Infected cells fill up with Rhizobium bacteria. Cells transform into Bacteriodes

Root nodule cells form

Root nodule forms

Connection to the roots vascular system. Allows for transfer of sugars and amino acids



Infected cells turn anaerobic. Enzymes are released that allow for the breaking of atmospheric nitrogen bonds

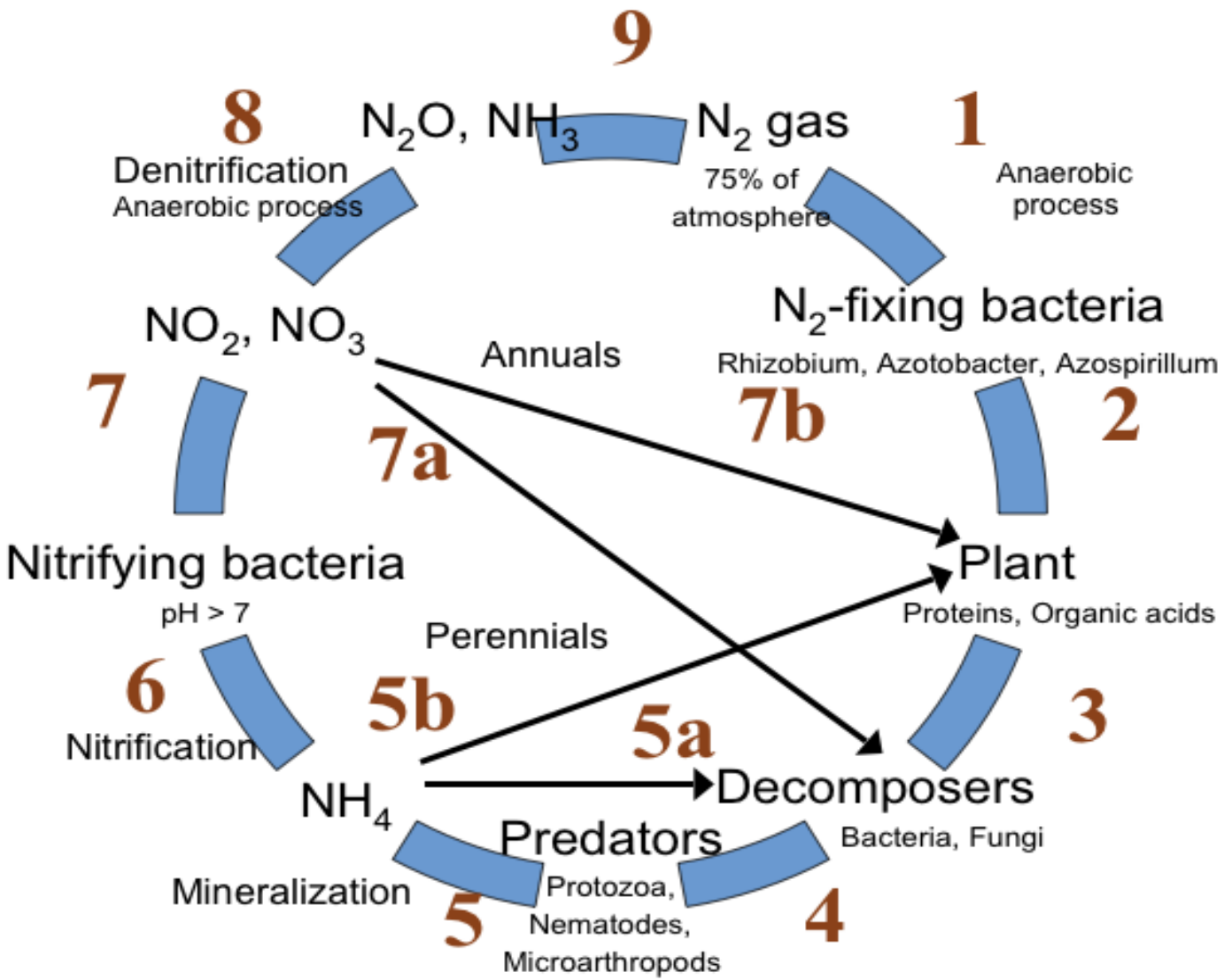
Root's vascular system

Nitrogen Fixing Nodules on Roots

Nitrogen Fixing Nodule on Clover Roots

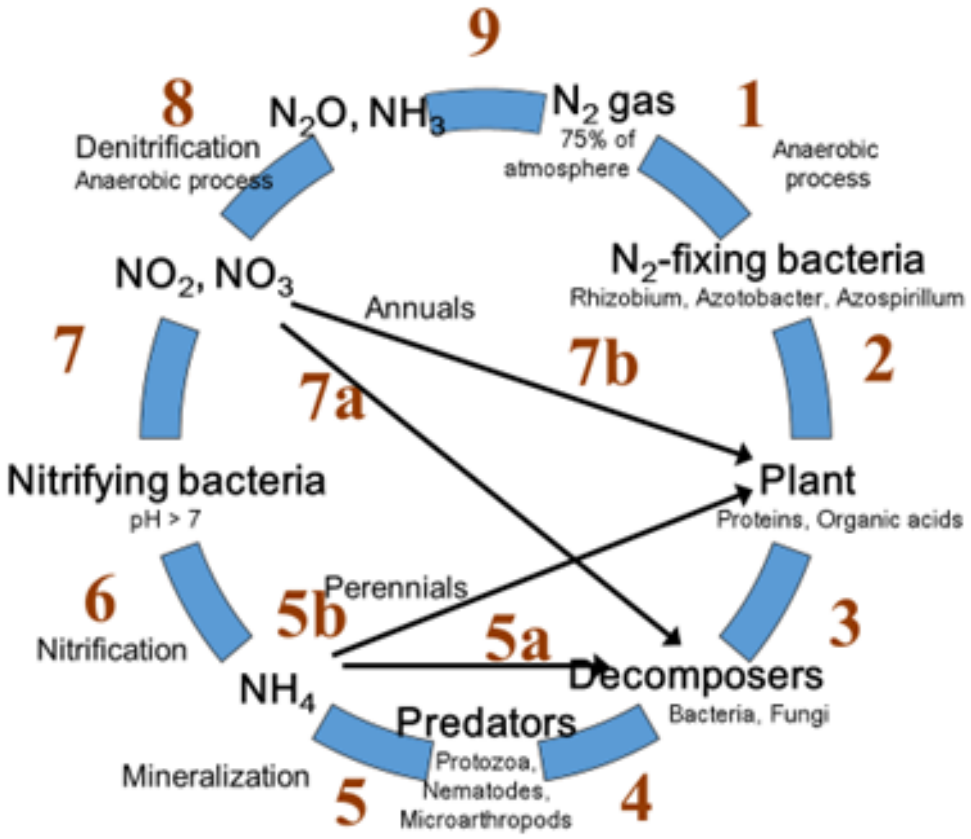
Good Sized Nodules on Roots

The Nitrogen Cycle



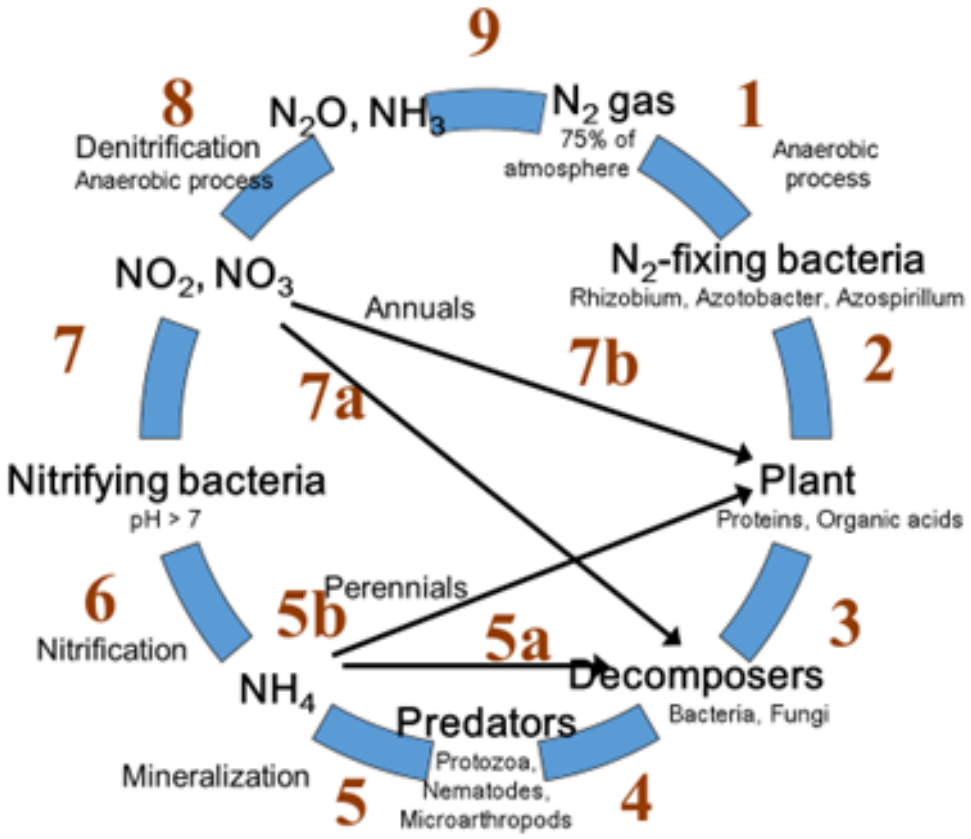
Step 1 in the N Cycle

- Nitrogen gas (N_2) diffuses into the nodule.
- All the oxygen is used up in the outer layers of the nodules by bacteria growing rapidly, allowing bacteria in the middle of the nodule to express the N-fixing gene.
- The correct enzymes are made to break the very stable triple-bond between the two N molecules in the N_2 gas.



Step 2 in the N Cycle

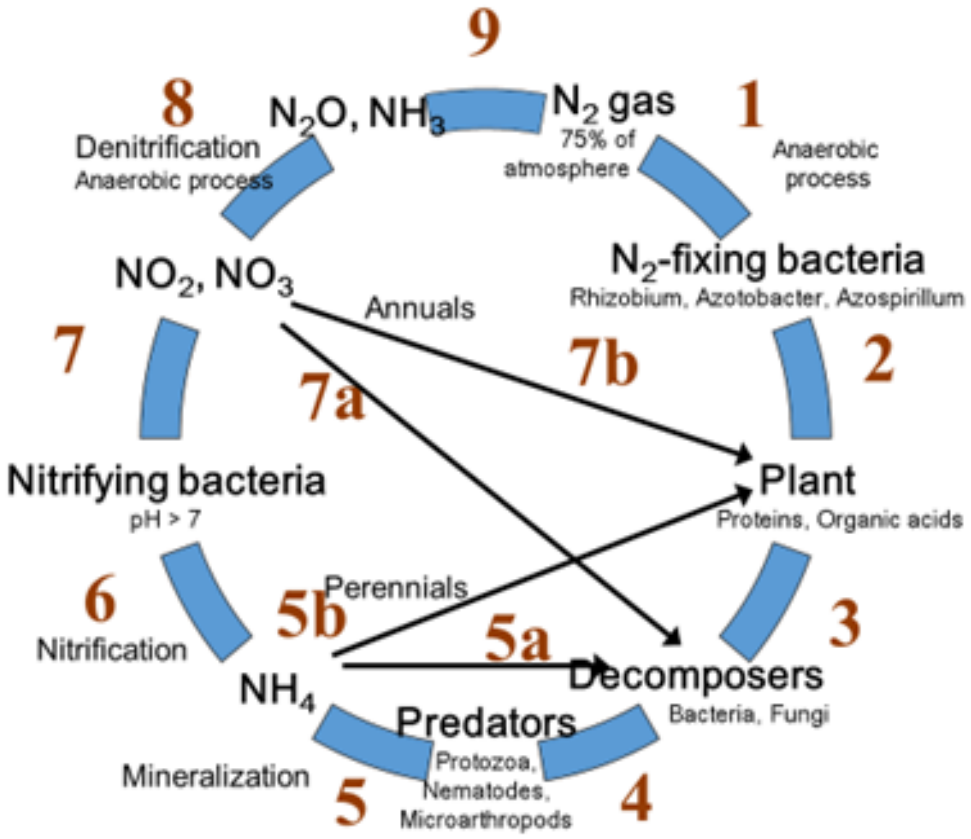
- The bacteria attach the N molecules to sugar carbon chains, making amino acids.
- The bacteria take what they need to grow, maintain the aerobic – anaerobic conditions in the nodules. But eventually the bacteria release amino acids and proteins to the plant so the plant grows better.



Step 3 in the N Cycle

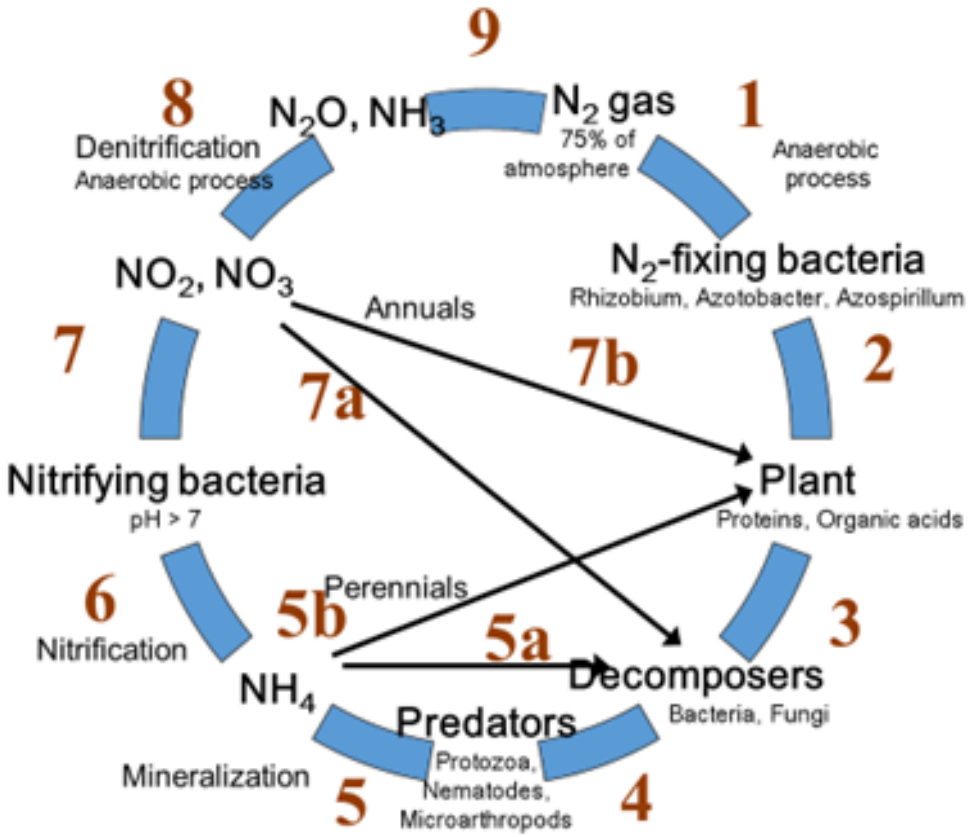
- The plant uses the extra N but releases very little of it into the soil around the plant. The plant spent way too much energy obtaining that N to give it away.

- When some parts, or all, of the plant dies, then bacteria and fungi decompose that plant material, concentrating the N in the biomass of the bacteria and fungi.



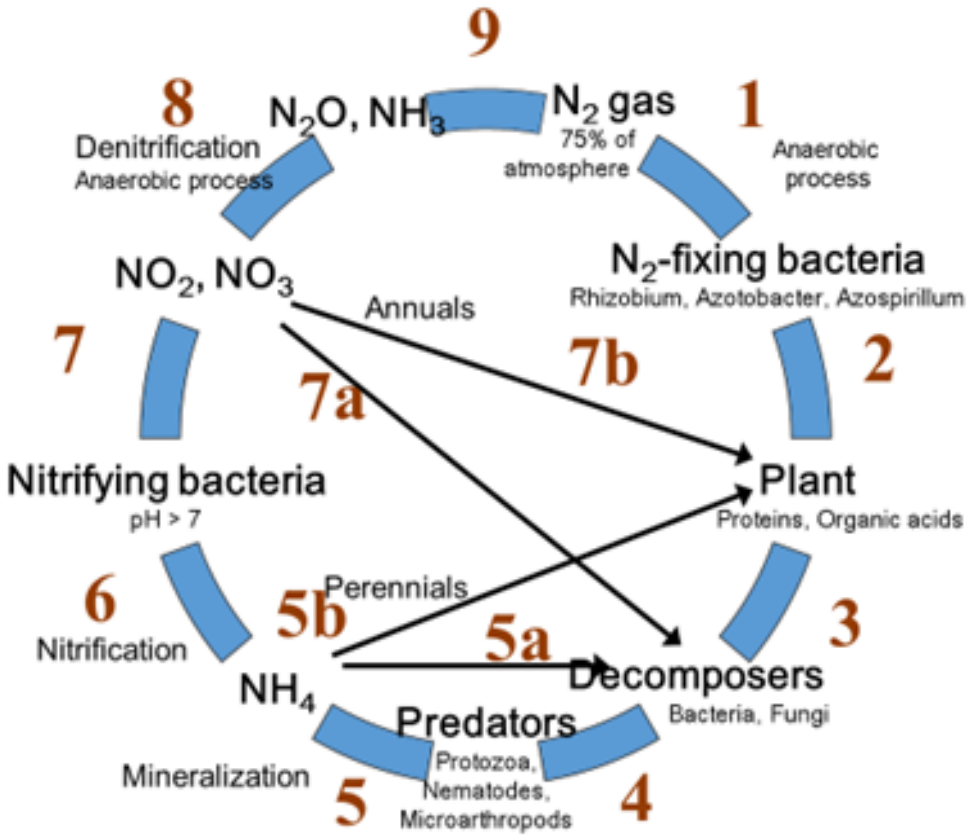
Step 4 in the N Cycle

The nitrogen that was in the plant when the bacteria and fungi consumed the plants residues stay in the bacterial and fungal biomass, until the bacteria and fungi are eaten by one of their predators, protozoa, nematodes, micro-arthropods, earthworm, etc.



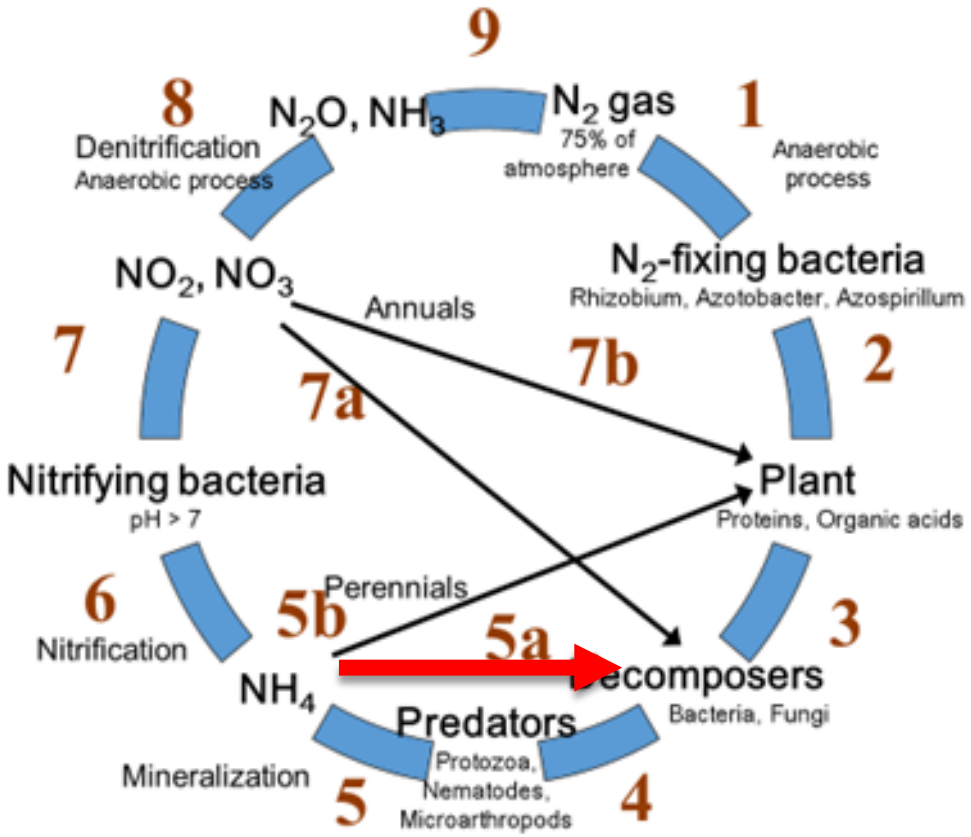
Step 5 in the N Cycle

- The Nitrogen Content of bacteria and fungi is much higher than their predators can tolerate.
- The excess nitrogen will be released by the predators as soluble, inorganic NH_4.



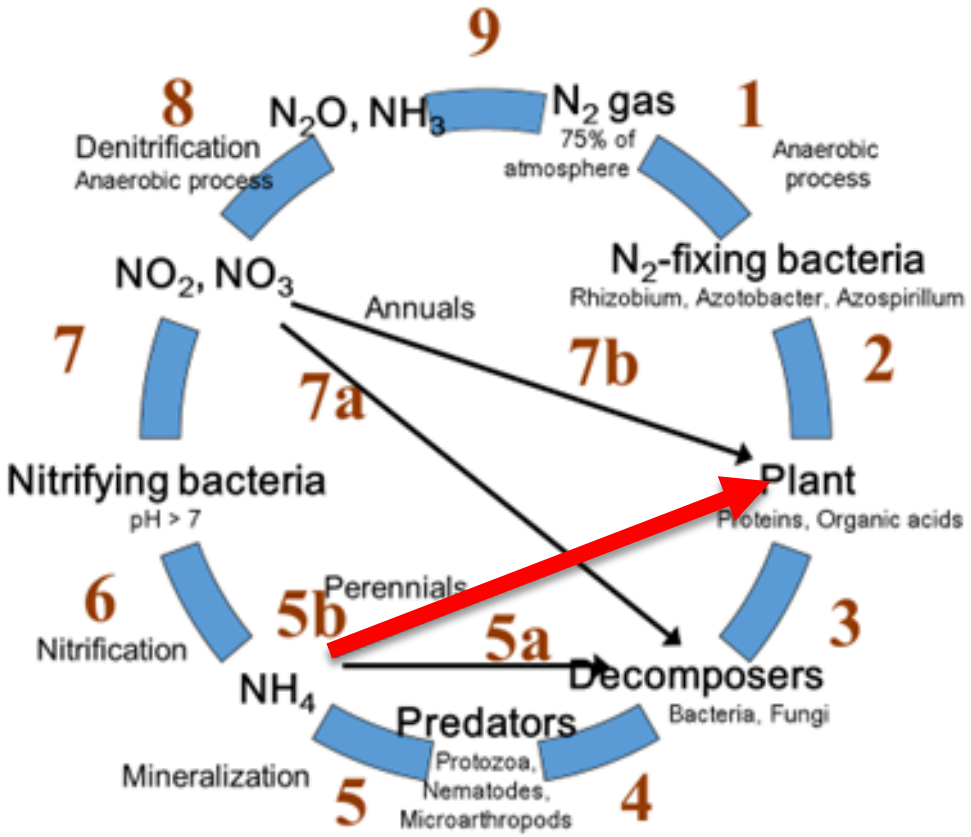
Step 5a in the N Cycle

- In a fungal-dominated soil, NH_4 will remain NH_4 because the soil is maintained in a slightly acidic condition by the large amounts of organic acids released from different fungal species.
- If the ammonium is not taken up by plants, then bacteria or fungi can take it up, and the N re-enters the Nitrogen cycle as bacteria or fungal biomass.



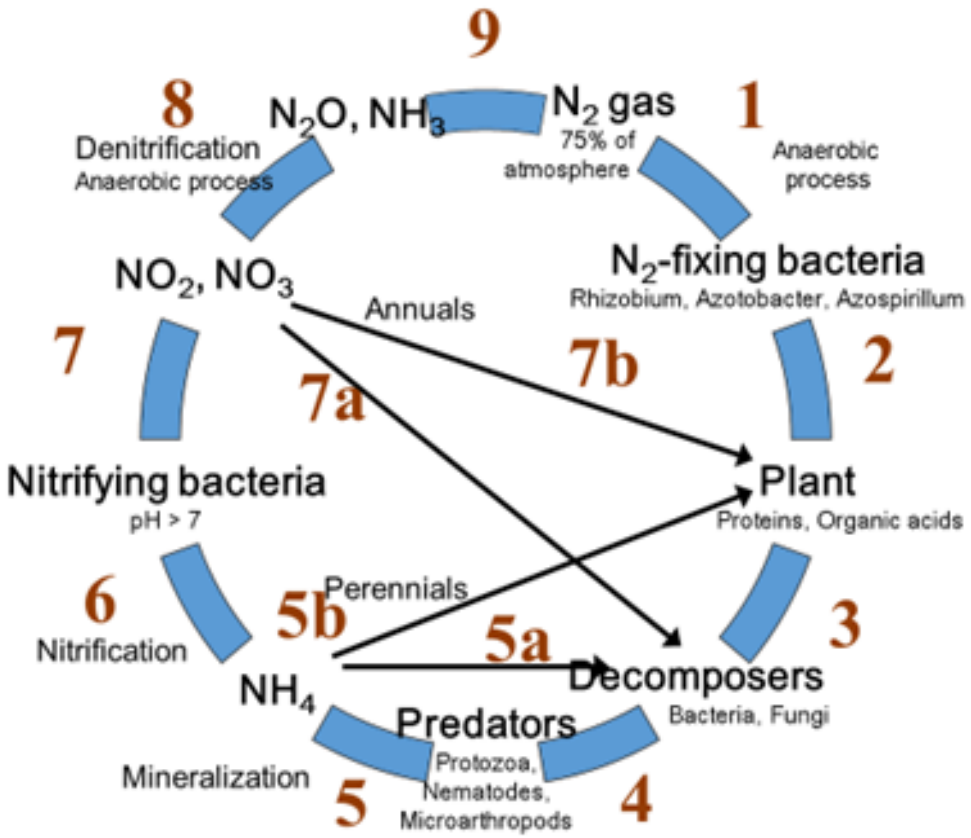
Step 5b in the N Cycle

- In a fungal-dominated soil, NH_4 will remain NH_4 because the soil is maintained in a slightly acidic condition by the large amounts of organic acids released from different fungal species.
- Ammonia can be taken up by the plant, and the N re-enters the Nitrogen cycle as plant residues.



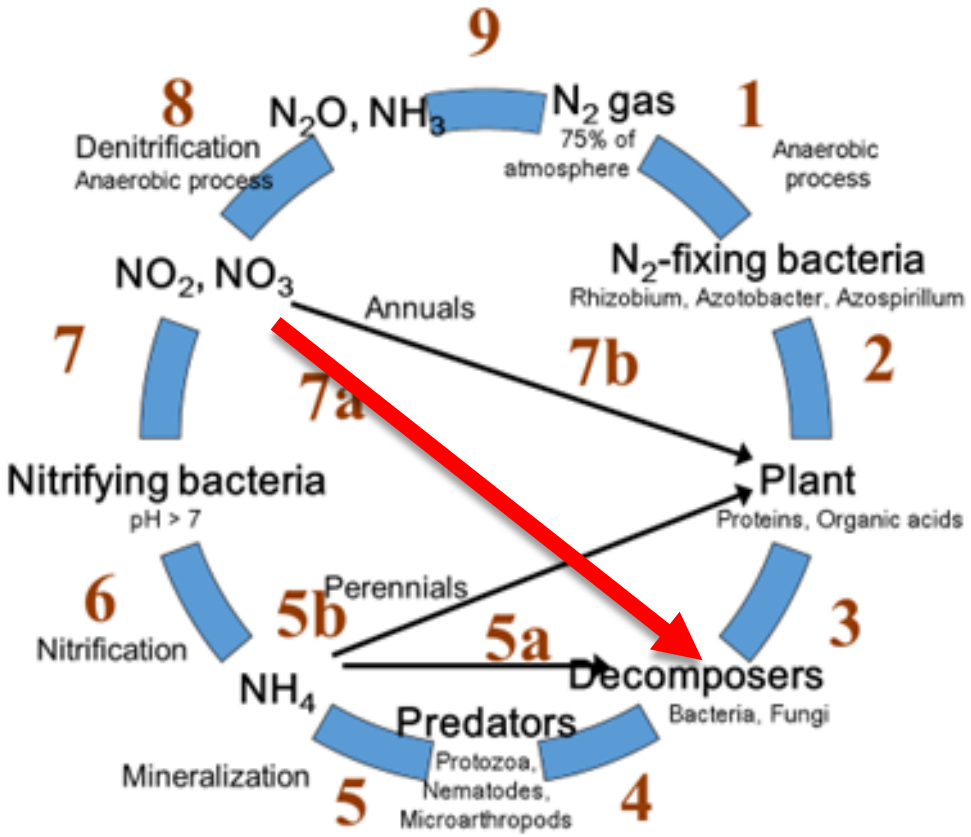
Step 6 & 7 in the N Cycle

- In a bacterial-dominated soil, NH_4 will be converted to first NO_2, and then NO_3 in the process of nitrification.
- Nitrification requires two different genera of nitrifying bacteria: Nitrobacter and Nitrosomonas.
- These bacteria need alkaline conditions to express their enzymes and convert NH_4 to NO_3.



Step 7a in the N Cycle

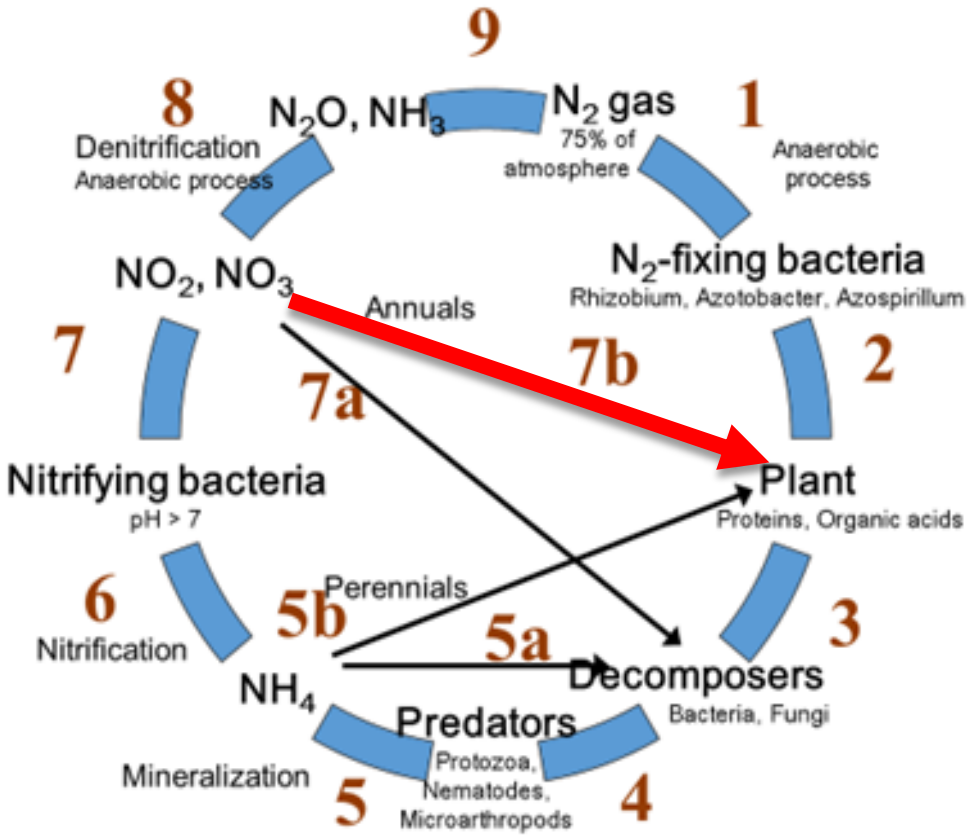
- In a bacterial-dominated soil, NO_3 will be produced.
- If plants don't take up the nitrate, then it will be taken up by bacteria and fungi.
- The N re-enters the Nitrogen cycle as either bacteria or fungi.



Step 7b in the N Cycle

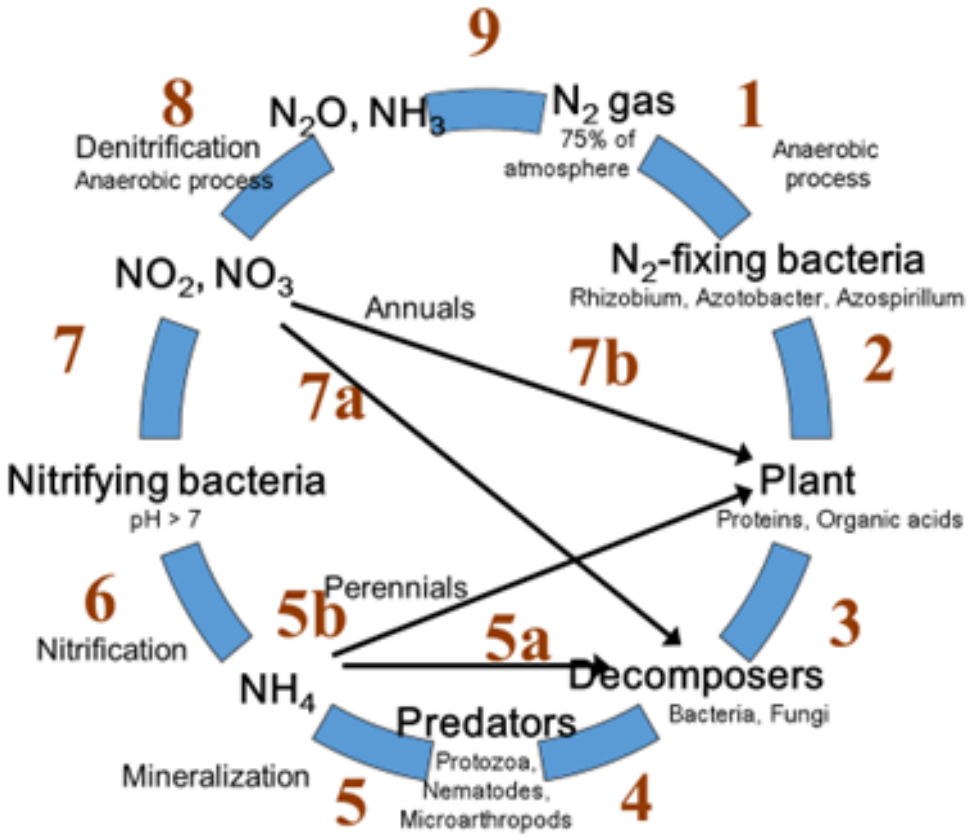
- In a bacterial-dominated soil, NO_3 will be produced. Plants can take up that nitrate.

- The N re-enters the Nitrogen cycle as when the plants dies and is decomposed by bacteria or fungi.



Step 8 in the N Cycle

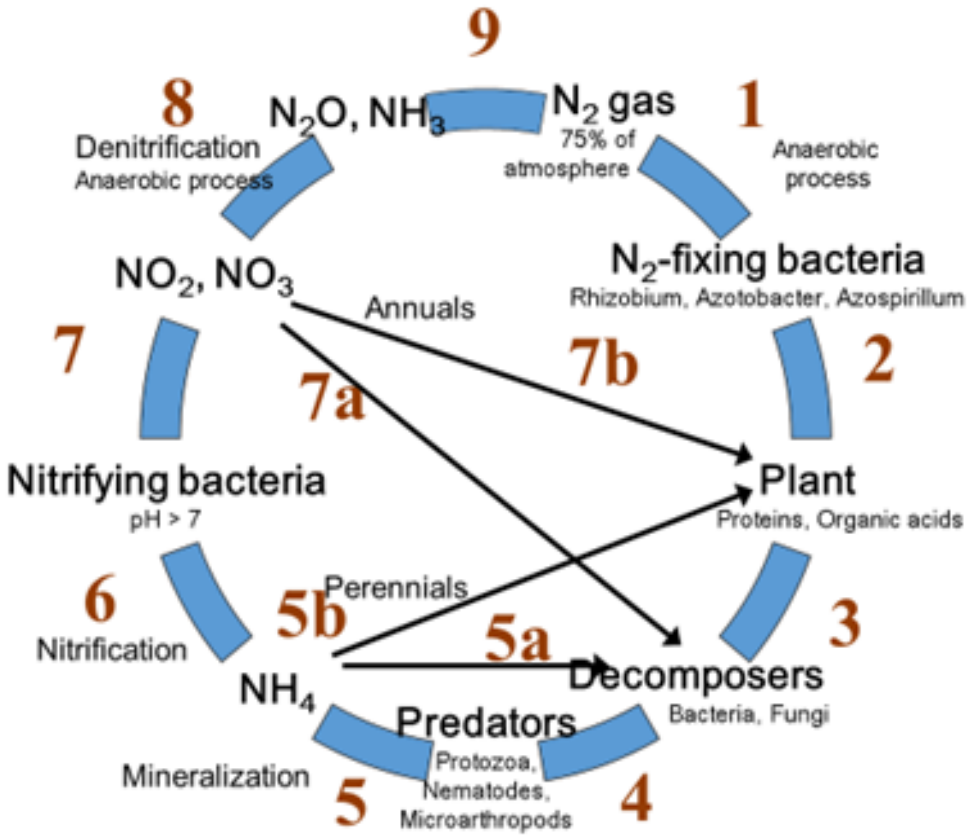
- Only if anaerobic conditions occur will anaerobic bacteria begin to grow.
- If the correct species of anaerobic bacteria, and perhaps some types of yeasts, are present NH_4, NO_2 and NO_3 will be converted to nitrous oxide (N_2O) or ammonia (NH_3). This processis called **denitrification**.



Step 9 in the N Cycle

- Nitrous oxide and ammonia released into the atmosphere will be converted to N_2 gas.

- This is the only process in the nitrogen cycle which does not require biology in order to happen. Otherwise, the entire rest of the Nitrogen Cycle is performed by living organisms.



How does this help us grow crops?

The Fungal-to-Bacterial biomass ratio (F:B) impacts:

1. The NH_4:NO_3 ratio and associated Weed Pressure
2. Disease and Pest problems
3. Crop Yields & Produce Quality Metrics (e.g. flavor) that are related to Nutrient Availability

If the F:B isn't correct for the desired crop, we can adjust it and greatly reduce these problems!