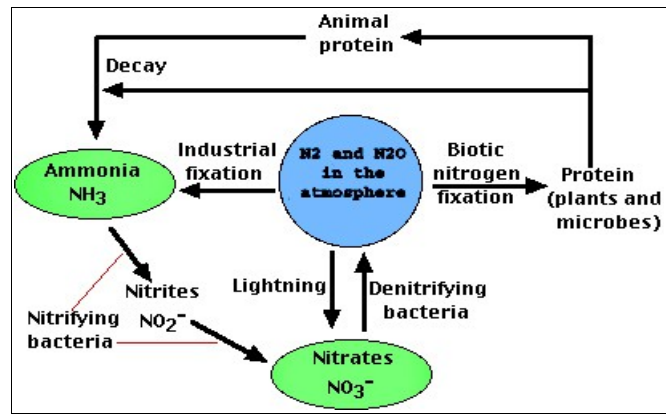


The Simplified Nitrogen Cycle

- All life requires nitrogen-compounds, e.g., proteins and nucleic acids.
- Air, which is 79% nitrogen gas (N_2), is the major reservoir of nitrogen.
- But most organisms cannot use nitrogen in this form.
- Plants must secure their nitrogen in "fixed" form, i.e., incorporated in compounds such as:
 - nitrate ions (NO_3^-)
 - ammonia (NH_3)
 - urea ($(NH_2)_2CO$)
- Animals secure their nitrogen (and all other) compounds from plants (or animals that have fed on plants).



Four processes participate in the cycling of nitrogen through the biosphere:

- nitrogen fixation
- decay
- nitrification
- denitrification

Microorganisms play major roles in all four of these.

Nitrogen Fixation

The nitrogen molecule (N_2) is quite inert. To break it apart so that its atoms can combine with other atoms requires the input of substantial amounts of energy.

Three processes are responsible for most of the nitrogen fixation in the biosphere:

- **atmospheric fixation** by lightning
- **biological fixation** by certain microbes — alone or in a symbiotic relationship with some plants and animals
- **industrial fixation**

Atmospheric Fixation

The enormous energy of lightning breaks nitrogen molecules and enables their atoms to combine with oxygen in the air forming nitrogen oxides. These dissolve in rain, forming nitrates, that are carried to the earth.

Atmospheric nitrogen fixation probably contributes some 5– 8% of the total nitrogen fixed.

Industrial Fixation

Under great pressure, at a temperature of 600°C, and with the use of a catalyst, atmospheric nitrogen and hydrogen (usually derived from natural gas or petroleum) can be combined to form ammonia (NH₃). Ammonia can be used directly as fertiliser, but most of it is further processed to urea and ammonium nitrate (NH₄NO₃).

Biological Fixation

The ability to fix nitrogen is found only in certain bacteria and a few other similar microbes. It is these microbes that we are interested in as microherders.

- Some of these bacteria form colonies in nodules on the roots of legumes. They are called rhizobia and legume seed inoculum can be purchased from rural seed stores or you can buy inoculated seed. Either way it is important to have the right bacteria on the seed to take full advantage of the nitrogen fixation of this symbiotic relationship.
- Some bacteria also establish symbiotic relationships with plants other than legumes and fix nitrogen by other pathways (e.g., carnivorous plants).
- Some establish symbiotic relationships with animals, e.g., termites and "shipworms" (wood-eating bivalves).
- Some nitrogen-fixing bacteria live free in the soil and it is these that are the easiest to introduce via biological preparations such as compost tea. They live in close proximity to the roots of plants and take Nitrogen directly from the air in the soil and combine it with the sugars from the root exudates to make protein. This nitrogen rich protein is the main source of Nitrogen in the soil foodweb.
- Nitrogen-fixing cyanobacteria, or blue/green algae, are essential to maintaining the fertility of semi-aquatic environments like rice paddies.

Biological nitrogen fixation requires a complex set of enzymes and a huge expenditure of ATP.

Although the first stable product of the process is ammonia, this is quickly incorporated into protein and other organic nitrogen compounds.

Decay

The proteins made by plants enter and pass through food webs just as carbohydrates do. At each trophic level, their metabolism produces organic nitrogen compounds that return to the environment, chiefly in excretions. The final beneficiaries of these materials are microorganisms of decay. They break down the molecules in excretions and dead organisms into **ammonia** (NH₃).

Nitrification

Ammonia can be taken up directly by plants — usually through their roots. However, most of the ammonia produced by decay is converted into **nitrites**. This is accomplished in two steps:

- Bacteria of the genus **Nitrosomonas** oxidize the ammonia to **nitrites** (NO₂⁻).
- Bacteria of the genus **Nitrobacter** oxidize the nitrites to **nitrites** (NO₃⁻).

These two groups of autotrophic bacteria are called nitrifying bacteria. Through their activities (which supply them with all their energy needs), nitrogen is made available to the roots of plants.

Many legumes, in addition to fixing atmospheric nitrogen, also perform nitrification — converting

some of their organic nitrogen to nitrites and nitrates. These reach the soil when they shed their leaves.

Denitrification

The three processes above, atmospheric, industrial and biological, remove nitrogen from the atmosphere and pass it through ecosystems.

Denitrification is the process that closes the nitrogen cycle by reducing nitrates to nitrogen gas and nitrous oxide.

Once again, bacteria are the agents. They live deep in soil and in aquatic sediments where conditions are anaerobic. They use nitrates as an alternative to oxygen for the final electron acceptor in their respiration.

It is when agricultural soils become anaerobic that the nitrogen, that is in plant-available mineral forms and the nitrogen that is in the organic compounds in the soil, decays and oxidises into gasses that transpire from the soil. The goal of microherders is to maximise the biological ability to bring ammonia, nitrite and nitrate into our soils and to minimise the losses by keeping our soils as aerobic as possible through sound management of stock, traffic and maximising biological populations.