Chapter 5 : Chapter 5 : Nitrogen Nutrition

Nitrogen (N2) is an abundant and chemically inert gas making up almost 79-80% of the Earth's atmosphere. It is a vital component of many biomolecules such as: (1) proteins and (2) nucleic acids. However, the gaseous nitrogen molecules can't be used directly by animals or plants. Only a few species of bacteria and cyanobacteria (nitrogen-fixing organisms) can convert atmospheric nitrogen to biologically useful forms. Thus, despite its atmospheric abundance, biologically useful nitrogen is frequently in short supply and often may be the limiting factor (nutrient) in an ecosystem.

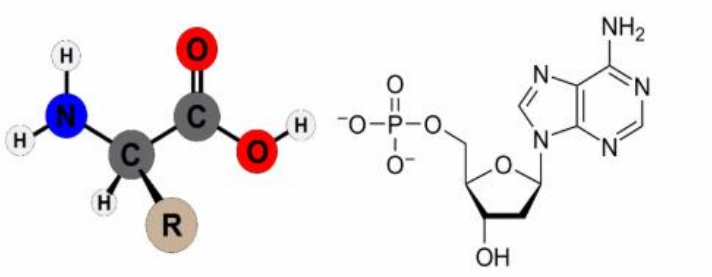


Figure 1: Left Amino group in amino acids (building blocks of proteins) contains nitrogen. Right - Nitrogenous base in nucleotides (building blocks of nucleic acids) contains nitrogen.

1. Forms of Nitrogen

a) organic nitrogen	b) inorganic nitrogen
Ammonium **(NH4+),** Nitrite **(NO_2),** Nitrate **(NO3),** Nitrous Oxide **(N_2O),** Nitric Oxide **(NO)**	Nitrogen gas **(N_2).**

2. Sources of Nitrogen to Plants:

- **Atmospheric Nitrogen (Molecular Nitrogen):** Although about 78% of the earth's atmosphere is composed of nitrogen, the majority of the plants cannot utilise from of nitrogen. Only some bacteria, some blue-green algae, leguminous plants (having root nodules) etc. can fix atmospheric nitrogen.
- **Nitrates, Nitrites, Ammonia in the Soil (Inorganic Nitrogen):** Among these, the nitrate is the chief form of nitrogen taken up by the plants from the soil.
- **Amino Acids (Organic Nitrogen) in the Soil:** Many soil micro-organisms make use of this form of nitrogen. Sometimes it may also be taken by higher plants.
- **Organic Nitrogenous Compounds in Bodies of the Insects:** Insectivorous plants fulfill their nitrogen requirement by catching the small insects and digesting them.

3. Nitrogen Cycle

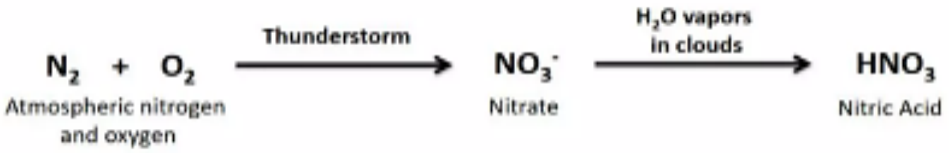
The nitrogen cycle is a biogeochemical cycle that involves the circulation of nitrogen in various forms (atmospheric nitrogen, nitrates, ammonium compounds, etc.) through the biotic and abiotic components of an ecosystem. There are five main steps in the cycling of nitrogen:

- **Nitrogen Fixation:** It is the conversion of atmospheric nitrogen to ammonia/ammonium compounds or nitrogen oxides such as nitrates, etc.
- **Nitrification:** It is the conversion of ammonia/ammonium compounds to nitrates.
- **Assimilation:** It is the uptake of nitrogen compounds by producers and its incorporation in proteins and nucleic acids.
- **Ammonification:** It is the decomposition of dead organisms or nitrogen- containing wastes into ammonia/ammonium compounds.
- **Denitrification:** It is the conversion of nitrates to unusable atmospheric nitrogen.

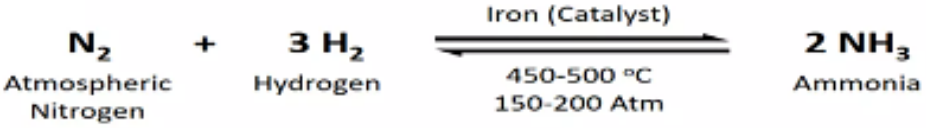
3.1. Nitrogen Fixation

It is the conversion of atmospheric nitrogen (N2) to ammonia (NH3) / ammonium compounds or nitrogen oxides such as nitrates, etc. It is of three types:

❖ **Non-Biological Natural Nitrogen Fixation:** Thunderstorms and lightning convert atmospheric gaseous nitrogen to nitrogen oxides. These oxides dissolve in water and form nitrous acid and nitric acid, which fall as rain. These acids in turn combine with other salts to produce nitrates.



❖ **Industrial Nitrogen Fixation:** Nitrogen fixation is also done in industries. In industrial nitrogen fixation, hydrogen is combined with atmospheric nitrogen under high pressure and temperature (iron is used as a catalyst). It produces ammonia (such as in Haber process) which is further converted into ammonium nitrate.



- **Biological Nitrogen Fixation:** Some bacteria and cyanobacteria transform atmospheric nitrogen into ammonia/ammonium compounds via an enzyme called nitrogenase, which only works in the absence of oxygen and requires large amounts of ATP.

- **Free Living Nitrogen Fixing Bacteria:** Many cyanobacteria such as Nostoc spp., Oscillatoria spp., Trichodesmium spp. and Cyanothece spp.; green sulfur bacteria; some anaerobes such as Clostridium spp., Bacillus spp., Enterobacter aerogenes, Azotobacter spp. and Escherichia coli; some methanogens, etc. can fix nitrogen.
- **Symbiotic Nitrogen Fixing Bacteria**: Rhizobium spp. are bacteria that grow as mutualists (exhibit mutualism) in the root nodules of leguminous plants (family Fabaceae - fruit is a leguminous pod). They fix nitrogen for the plants and in return, the plant provides them with food.

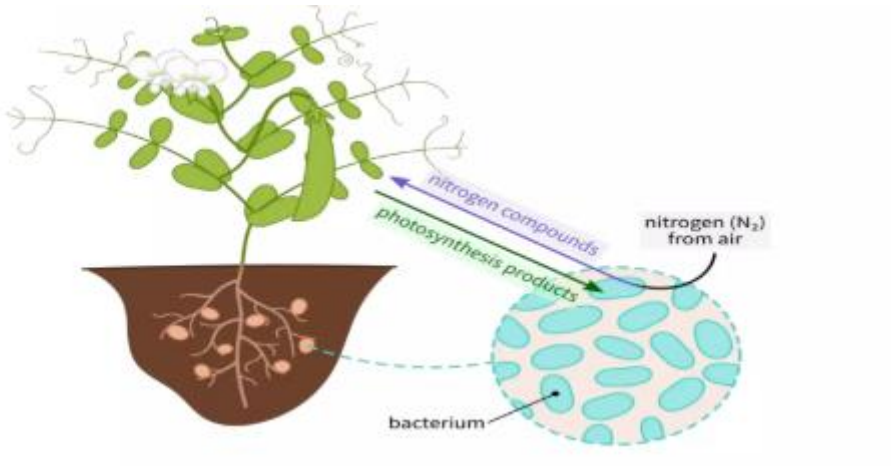


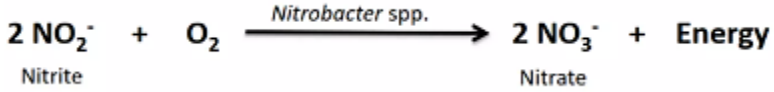
Figure 2: Relation between Rhizobium spp. and leguminous roots.

3.2. Nitrification

It is the conversion of ammonia to nitrate by soil bacteria, It occurs in two steps:

- **Step 1 Nitrite Formation:** Nitrosomonas spp. and Nitrococcus spp. convert ammonia/ammonium compounds to nitrite, energy is released:

- **Step 2 Nitrate Formation:** Nitrobacter spp. oxidizes nitrite to nitrate, releasing energy in the process:

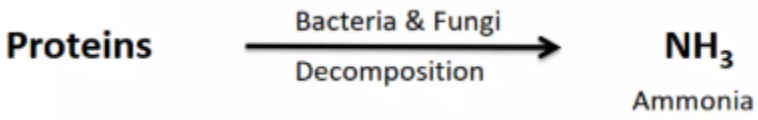


3.3. Assimilation

It is the uptake of nitrate and/or ammonia by primary producers and its incorporation into proteins and nucleic acids. These materials then pass along the food chain by ingestion, digestion, and further assimilation at each trophic level, i.e. primary consumers eat plants, secondary consumers eat primary consumers, etc.

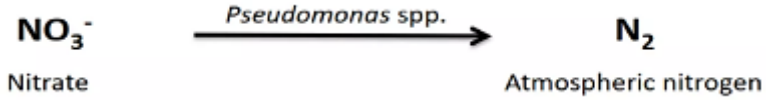
3.4. Ammonification

It is the decomposition of dead organisms or nitrogen-containing waste products of organisms to ammonia by ammonifying bacteria (such as Bacillus spp., Clostridium spp., Pseudomonas spp., etc.) and fungi in soil and aquatic environments. This process recycles ammonia and makes it available for nitrification and assimilation.



3.5. Denitrification

It is the reduction of nitrate to unusable atmospheric nitrogen. It is a steady drain from the biological component of the ecosystem (reduces the amount of biologically usable nitrogen). Anaerobic denitrifying bacteria such as Pseudomonas spp., Bacillus spp., Thiobacillus spp., Vibrio spp., etc. carry out this process that is not extensive but does cause a significant loss of biologically active nitrogen, i.e. in waterlogged soils.



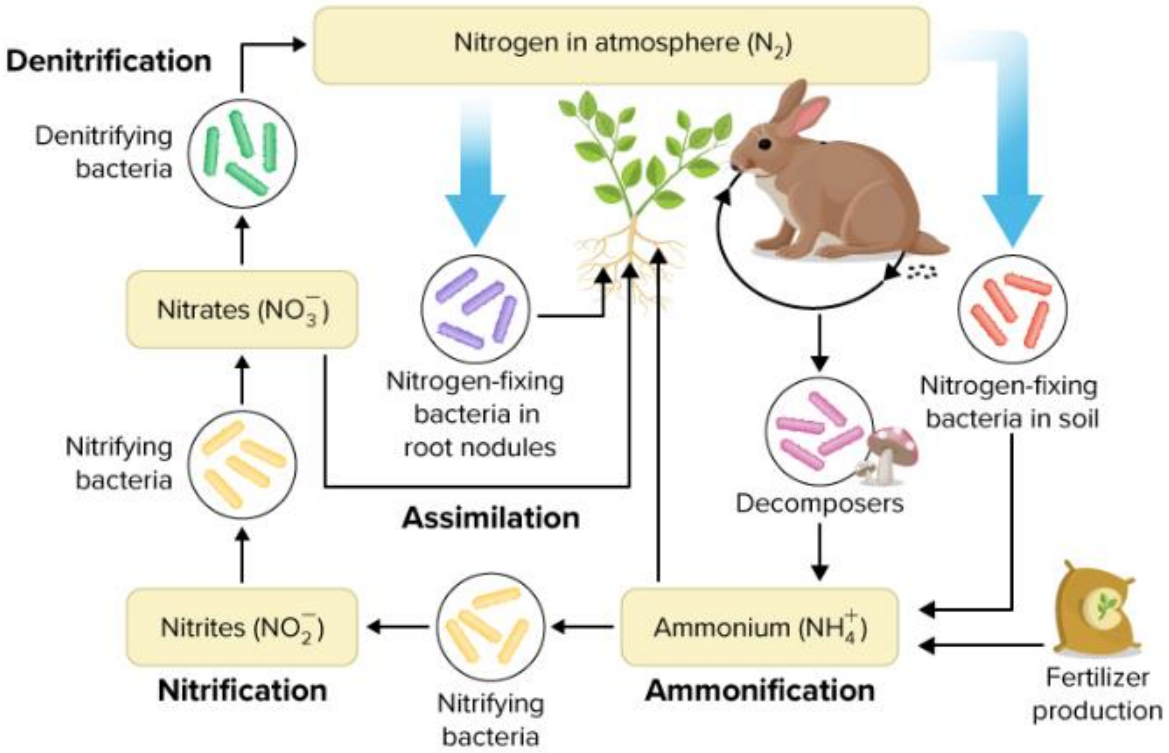


Figure 3 : Nitrogen cycle

4. Impact of human activities on nitrogen cycle

Human activities have a lot of adverse effects on the nitrogen cycle; some of them are discussed as follows:

- **Release of Nitrogen Compounds in the Atmosphere.**
- **Production of Fixed Nitrogen Compounds :** About 450 million metric tons of fixed nitrogen is prepared each year using the Haber process (in which N2 is reacted with H2 to make NH3). Most of this fixed nitrogen goes to make fertilizers that we use on our lawns, gardens, and agricultural fields. They increase soil nitrogen content, sometimes too much.
- **Nitrogen Depletion in Soils due to Human Activities.**
- **Eutrophication & Algal Blooms.**