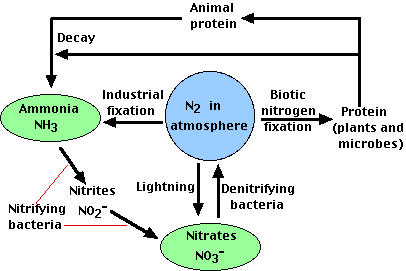
**Nitrogen Cycle**

* All life requires nitrogen-compounds, e.g., proteins and nucleic acids.
* Air, which is 79% nitrogen gas (N2), 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 (NO3−)
  + ammonia (NH3)
  + urea (NH2)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**](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/N/NitrogenCycle.html#Nitrogen_Fixation)
* [**decay**](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/N/NitrogenCycle.html#Decay)
* [**nitrification**](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/N/NitrogenCycle.html#Nitrification)
* [**denitrification**](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/N/NitrogenCycle.html#Denitrification)

Microorganisms play major roles in all four of these.

**Nitrogen Fixation**

The nitrogen molecule (N2) 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](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/S/Symbiosis.html) 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, which 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 fertilizer, 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](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/E/Eubacteria.html) and [archaea](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/A/Archaea.html).

* Some live in a symbiotic relationship with plants of the legume family (e.g., soybeans, alfalfa).
* Some establish symbiotic relationships with plants other than legumes (e.g., alders).
* Legume plants such as clover, alfalfa, and soybeans form nodules on the roots where nitrogen fixing bacteria take nitrogen from the air and convert it into ammonia, NH3. The ammonia is further converted by other bacteria first into nitrite ions, NO2-, and then into nitrate ions, NO3-. Plants utilize the nitrate ions as a nutrient or fertilizer for growth. Nitrogen is incorporate in many amino acids which are further reacted to make proteins.
* Some establish symbiotic relationships with animals, e.g., [termites](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/I/Insects.html) and "shipworms" (wood-eating [bivalves](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/I/Invertebrates.html#Mollusks)).
* Some nitrogen-fixing bacteria live free in the soil.
* Nitrogen-fixing [cyanobacteria](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/E/Eubacteria.html#Cyanobacteria) 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](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/A/ATP.html).

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](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/F/FoodChains.html#Food_Chains), 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.

**Nitrification**

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

* Bacteria of the genus **Nitrosomonas** oxidize NH3 to **nitrites** (NO2−).
* Bacteria of the genus **Nitrobacter** oxidize the nitrites to **nitrates** (NO3−).

These two groups of autotrophic bacteria are called [nitrifying bacteria](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/E/Eubacteria.html#Nitrifying_bacteria). Through their activities (which supply them with all their energy needs), nitrogen is made available to the roots of plants.

Both soil and the ocean contain archaeal microbes, assigned to the [Crenarchaeota](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/A/Archaea.html#Crenarchaeota), that convert ammonia to nitrites. They are more abundant than the nitrifying bacteria and may turn out to play an important role in the nitrogen cycle.

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 remove nitrogen from the atmosphere and pass it through ecosystems.

Denitrification reduces nitrates to nitrogen gas, thus replenishing the atmosphere.

Once again, bacteria are the agents. They live deep in soil and in aquatic sediments where conditions are [anaerobic](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/A/A.html#anaerobic). They use nitrates as an alternative to oxygen for the final electron acceptor in their [respiration](http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/C/CellularRespiration.html#respiratory_chain).

Thus they close the nitrogen cycle by converting nitrates back to nitrogen gas. A side product of this reaction is the production of a gas known as nitrous oxide, N2O. Nitrous oxide, also known as "laughing gas" - mild anesthetic, is also a greenhouse gas which contributes to global warming.

**Are the denitrifiers keeping up?**

Agriculture may now be responsible for one-half of the nitrogen fixation on earth through

* the use of fertilizers produced by industrial fixation
* the growing of legumes like soybeans and alfalfa.

This is a remarkable influence on a natural cycle.

Are the denitrifiers keeping up the nitrogen cycle in balance? Probably not. Certainly, there are examples of nitrogen enrichment in ecosystems. One troubling example: the "blooms" of algae in lakes and rivers as nitrogen fertilizers leach from the soil of adjacent farms (and lawns). The accumulation of dissolved nutrients in a body of water is called **eutrophication**.

**Effects of human interference in the nitrogen cycle**

When we cause nitrogen overloading in an ecosystem, there are many drastic effects. Dumping of raw sewage contains nitrogenous wastes, along with urban runoff. When large amounts of nitrogen collect in a water body, **eutrophication** can result. This is an accumulation of excess nutrients which causes **an algae bloom**. The algae **rapidly deplete** all of the **oxygen** in the water, making it **inhospitable** for fish and other aquatic organisms. Eutrophication also brings about the deadly red tides. When plant communities are **saturated with nitrogen**, the **soil** can become **acidified**. This makes the **soil inhospitable**. **Burning fossil fuels and wood** contributes to a large amount of **nitric oxide** in the atmosphere. Nitric oxide can combine with oxygen gas to for nitrogen dioxide, which reacts with water vapor to form a strong acid (nitric acid). This can **precipitate** out of the atmosphere in the **form of the deadly acid rain**. The acid can **damage trees and kill fish**. The use of inorganic fertilizers and depleting nitrogen resources by overharvesting legumes (which have nodules in their roots formed by a symbiotic bacteria that fix nitrogen) and **over mining nitrogen** also alter an ecosystem.