



Nitrogen Cycling in Ecosystems

In order to have a firm understanding of how nitrogen impacts our ecosystems, it is important that students fully understand how the various forms of nitrogen cycle through the environment. The nitrogen cycle is most often introduced as a part of the biogeochemical cycles that are covered early in the year during units on ecosystem structure and dynamics. However, textbooks typically used in the AP Environmental Science course often vary with the level of depth and detail in which they cover the topic of the nitrogen cycle. The following is a summary of the foundational knowledge students should have regarding the nitrogen cycle in order to fully grasp its role in agricultural practices as well as its potential as an air and water pollutant, topics typically covered later in the course.

Nitrogen Fixation:

Nitrogen Fixation is the conversion of atmospheric nitrogen (N_2) into reactive compounds such as ammonia (NH_3) and nitrate (NO_3^-). The breaking of the bonds between the nitrogen atoms requires a great deal of energy and occurs naturally in two primary ways:

1. Abiotic Fixation: Nitrate is the result of high energy fixation in the atmosphere from lightning and cosmic radiation. In this process, N_2 is combined with oxygen to form nitrogen oxides such as NO and NO_2 , which are carried to the earth's surface in rainfall as nitric acid (HNO_3). This high energy fixation accounts for approximately 10% of the nitrate entering the nitrogen cycle.
2. Biological fixation: Biological fixation is accomplished by a series of soil microorganisms such as aerobic and anaerobic bacteria. Often, symbiotic bacteria such as Rhizobium are found in the roots of legumes and provide a direct source of ammonia to the plants. In root nodules of these legumes, the bacteria split molecular nitrogen into two free nitrogen atoms, which combine with hydrogen to form ammonia (NH_3). The following plants are common examples of legumes: clover, alfalfa, soy beans, and chick peas. The breakdown of these legumes by bacteria during ammonification actually returns excess nitrogen not utilized by the plant to the surrounding soil. Therefore, to promote sustainable soil fertility, it is beneficial to use these agricultural crops in rotation with other plants, such as corn, that are more profitable but deplete the available nitrogen in the soil. Some free-living aerobic bacteria, such as Azotobacter, and anaerobic bacteria, like Clostridium, freely fix nitrogen in the soil and in aquatic environments. Some members of the photosynthetic Cyanobacteria phylum fix nitrogen in aquatic environments as well.

Nitrification:

Nitrification is the process by which ammonia is oxidized to nitrite ions (NO_2^-) and then to nitrate ions (NO_3^-), which is the form most usable by plants. The two groups of micro-organisms involved in the process are Nitrosomas and Nitrobacter. Nitrosomas oxidize ammonia to nitrite and Nitrobacter oxidize nitrite to nitrate.

Assimilation:

Nitrates are the form of nitrogen most commonly assimilated by plants through root hairs. Since heterotrophic organisms cannot readily absorb nitrogen as plants do, they rely on acquiring nitrogen-based compounds through the food they eat. Since plants are the base of the food chain, the nitrogen-based compounds they have assimilated into their tissue will continue to pass from one organism to another (through consumption) as matter and energy transfers through the ecosystem's food web.

Ammonification:

In ammonification, a host of decomposing microorganisms, such as bacteria and fungi, break down nitrogenous wastes and organic matter found in animal waste and dead plants and animals and convert it to inorganic ammonia (NH_3) for absorption by plants as ammonium ions. Therefore, decomposition rates affect the level of nutrients available to primary producers.

Denitrification:

Denitrification is the process by which nitrates are reduced to gaseous nitrogen (N_2) and lost to the atmosphere. This process occurs by facultative anaerobes in anaerobic environments. Farmers with waterlogged fields and soils that have high clay content are especially vulnerable to nitrogen losses due to denitrification.