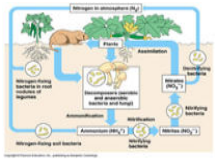


Activity: Nitrogen Cycling in Ecosystems – Game

In order to have a firm understanding of how nitrogen impacts our ecosystems, it is important that you fully understand how the various forms of nitrogen cycle through the environment. The following is a summary of the foundational knowledge you 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. You should eventually be able to describe in detail how the addition of fertilizer and the burning of fossil fuels would impact the nitrogen cycle.

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:

- 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.

- Biological fixation: Biological fixation is accomplished by a series of soil micro-organisms 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.

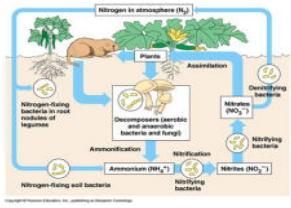
Nitrification:

Nitrification is the process by which ammonia is oxidized to nitrite ions (NO2-) and then to nitrate ions (NO3-), 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 (NH3) 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 (N2) 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.



Learning Activity: Nitrogen Cycle Review Game

Instructions:

1. Get in your assigned group of 3 students three students,

2. Each student needs to find a playing piece. (Eraser, coin, paperclip, etc…) This playing piece represents a nitrogen atom.

3. Each group needs:
   - Two coins
   - Playing board
   - Colored Pencils

   Each student needs:
   - Rules sheet (see Appendix A)
   - Copy of the playing board (see Appendix B)

4. Begin by placing game pieces on space #1.

5. At the start of a turn, flip both the coins as instructed in Appendix A, following the instructions as you go.
   - Make sure you do not simply follow the sequence of numbers but instead follow the chance moves that the coins present.
   - Two or more players can occupy the same place.
   - Reminder: when or if your nitrogen atom is returned to the atmosphere, you have completed one cycle.

6. Each person should continue to play the game until each student in your group has completed 5 cycles
   - Note: This means some of you might have more than 5 cycles completed.

7. On the individual game board, you should use the colored pencils to keep track of your own different cycles, with each color representing a single cycle.
   - Label the cycles "1st, 2nd," etc.

8. Have fun! Then answer the analysis questions on a separate sheet of paper…

Analysis Questions:

1. In the course of the nitrogen cycle, are nitrogen atoms themselves… Explain why or why not.
   a. Ever created?
   b. Ever destroyed?
   c. Ever changed into other kinds of atoms?
   d. Ever changed into other compounds?

2. Discuss what moves on the game board represented the following processes of the nitrogen cycle: Nitrogen Fixation, Nitrification, Ammonification, Assimilation, and Denitrification.

3. Identify what other gases, besides N_2, can be produced during denitrification. For each gas you identify, describe what human activities facilitate the production of these gases.

4. Discuss why a natural ecosystem (*assuming no anthropogenic interaction*) is not polluted by nitrogenous wastes from various organisms.

5. Draw & Label the Nitrogen Cycle