Activity 3-7

Understanding Nutrients: Nitrates

Adapted BTNEP/LSU AgCenter: *Nonpoint Source Water Pollution*

Focus/Overview

Understanding the roles of phosphorus and nitrogen in aquatic plant growth and the routes these nutrients take to become components of nonpoint source pollution is an important step toward learning how to control the impact of these nutrients on our ecosystems.

Learning Objectives

The learner will…

- understand that nutrients like nitrates are essential to life.
- participate in a skit to understand the nitrogen cycle.

Louisiana Grade Level Expectations (Science)

4: GLE-50	Explain how some organisms in a given habitat compete for the same resources (LS-E-C1)
4:GLE-72	Predict and describe consequences of the removal of one component in a balanced ecosystem (e.g. consumer, herbivores, nonliving component) (SE-E-A2)
7: GLE-36	Distinguish the essential roles played by biotic and abiotic components in various ecosystems (SE-M-A1).
7: GLE-37	Identify and describe the effects of limiting factors on a given population (SE-M-A2).
HS Biol: GLE-26	Analyze the dynamics of a population with and without limiting factors (LS-H-D3).

Materials List

- construction paper for two sets of labels (below)
- string or tape
- paperclips

Advance Preparation

1. Prepare enough of the following **role labels** from construction paper for all your students to participate. You can use a hole punch and string so that the students can hand them around their necks.
   - 1 – thunderstorm
   - 1 – bacteria and fungi (ammonification)
   - 2 – leguminous plant (nitrogen fixers)
   - 4 – nitrifying bacteria
   - 2 – denitrifying bacteria
   - 1 – artificial fertilizers
   - 1 – plant residues
   - 1 – animal waste
   - plants using nitrogen (all remaining students)
2. Prepare the following cards from construction paper:
   - 40 – atmospheric nitrogen (N_2) - scatter these on the floor
   - 40 – oxygen (O_2) – scatter these on the floor
   - 5 – ammonia (NH_4) – give to animal waste, plant residues
   - 5 – nitrite (NO_2^-) – held by teacher and exchanged with students
   - 5 – denitrate (NO_3^-) – held by teacher and exchanged with students

BTNEP Connection
Water Quality

Grade Level
4, 7, HS Biology

Duration
1 class period

Subject Area
science

Setting
classroom

Vocabulary
nitrogen fixation, hypoxia, nitrification, dead zone, ammonification, limiting factor, denitrification, algae blooms, eutrophication

Original Source
"Is Nitrogen Recyclable?" in BTNEP/LSU AgCenter: *Nonpoint Source Water Pollution*, Activity 7

BTNEP BARATARIA-TERREBONNE NATIONAL ESTUARY PROGRAM
www.btnep.org

Background

Nitrogen and phosphorus are essential to life and are cycled through the natural ecological systems in an orderly, balanced way. Both are building blocks for amino acids, proteins and DNA for both plants and animals. Without nitrogen and phosphorus, there would be no food chain.

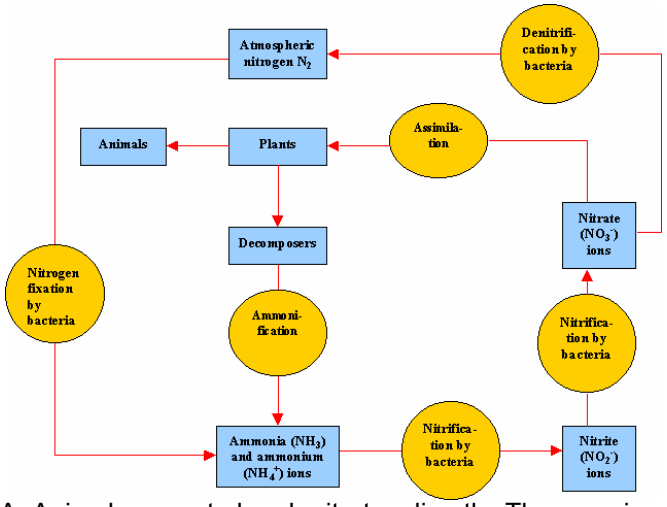
Nitrogen makes up about 78 percent of the atmosphere, yet most organisms can not use this nitrogen. If this is the case, we need to have a source for usable nitrogen. All consumers get nitrogen-bearing compounds in the things they eat. All food, as you know, can be traced back in a food web to a producer. Producers get their nitrogen-bearing compounds from the soil or water in which they grow. Producers are organisms that make their own food, such as algae and plants. Thus, nitrogen is recycled in nature in a series of chemical and biological processes involving a range of living organisms including bacteria, plants and animals and natural phenomena such as lightning. **Blackline Master #1 – The Nitrogen Cycle** outlines the steps in the nitrogen cycle.

Two processes allow nitrogen to be transformed into a useful form (nitrate) for plants to use. First, atmospheric nitrogen can be changed to ammonia through nitrogen-fixing process by bacteria in the roots of certain legumes (plants). Second, decomposing bacteria will first convert nitrogen into ammonia and ammonium, during the nitrogen fixation process. Plants can use ammonia as a source of nitrogen.

Nitrogen fixation is carried out according to the following reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

After ammonium fixation, the ammonia and ammonium that is formed will be further transformed during the nitrification process. Two different types of aerobic bacteria use oxygen to convert ammonia and ammonium ions.



Nitrification takes place according to the following reactions:

$$2NH_3 + 3O_2 \rightarrow 2NO_2 + 2H^+ + 2H_2O$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

Plants absorb ammonium and nitrate during the assimilation process, after which they are converted into nitrogen-containing organic molecules, such as amino acids, proteins and DNA. Animals cannot absorb nitrates directly. They receive their nutrient supplies by consuming plants or plant-consuming animals.

When nitrogen nutrients have served their purpose in plants and animals, specialized decomposing bacteria will start a process called **ammonification**, to convert them back into ammonia and water-soluble ammonium salts. After the nutrients are converted back into ammonia, anaerobic bacteria will convert them back into nitrogen gas, during a process called **denitrification**. Denitrification takes place according to the following reaction:

$$NO_3^- + CH_2O + H^+ \rightarrow \tfrac{1}{2} N_2O + CO_2 + 1\tfrac{1}{2} H_2O$$

The nitrogen will than be released into the atmosphere again. The whole process will start over after release.

Nitrate is considered a **limiting factor** in soil, because plants need nitrogen in order to grow and make amino acids, proteins and DNA. When there is little nitrogen available to them, the slow or stop their growth. Two things cause nitrogen's position as a limiting factor to be problematic in ecosystems:

1. Nitrate has a high solubility in water so is easily leached out of the soil.
2. Farmers often apply nitrate fertilizers to the soil.

Problems arise when too much nitrogen is present in the soil or water. In particular, this can upset the natural balance in aquatic ecosystems and cause accelerated aquatic plant growth, which can lead to oxygen depletion and death of aquatic organisms. If we pay attention to the news, we may hear about **algae blooms** and fish kills, especially in the summer. Algae blooms are often caused by putting too many nutrients, such as nitrogen (nitrates) and phosphorus (phosphates) into an aquatic ecosystem.

Perhaps you have heard about the "**dead zone**" or "**hypoxia**" in the Gulf of Mexico. This is an example of nutrient overload that results in a zone of oxygen depletion in the Gulf along the coast of Louisiana in the summer. Runoff from agricultural land, forests and cities throughout the Mississippi River watershed enters the Gulf from Mississippi River water and makes its way west along the coast on the shallow continental shelf. The water forms layers, with the fresh river water floating above the heavier salt water. This stratification, or layering, adds to the problem by preventing mixing and oxygenation of the lower, saltier waters.

Another problem, **eutrophication** occurs where the water contains high levels of nutrients and aquatic plant life (including algae) and low levels of oxygen. It is literally premature old are in a waterway! It is not a healthy situation, especially in an area where people make a living from the water.

Procedure

1. We learned that nutrients are important to life, but, when there are too many nutrients in an ecosystem, there can be serious problems. Nature has a way of recycling materials so nothing builds up and becomes a problem. Human activities can upset nature's system, leading to problems like algae blooms and fish kills. We'll learn about the way nitrogen is recycled in nature. This is called the nitrogen cycle.
2. The nitrogen cycle involves several steps and chemical changes. We will simulate the steps using these labels. *Distribute the role labels to the students. Tell them to pin them on their shirts or hang the labels around their necks. Distribute the construction labels showing the various forms of nitrogen and oxygen on the floor.*
3. We start with the nitrogen of the atmosphere. The air is made of 78% nitrogen. In this form it is not very useful to living things in the soil, so it must changed to a form that plants and animals can use. One way this can happen is during a thunderstorm. Lightning causes the nitrogen and oxygen gases to combine to make NO_2 (nitrous oxide).
   THUNDERSTORM: Pick up as many N_2 and O_2 molecules as you can. Paper clip them together to make nitrous oxide and put them on the ground. *Give thunderstorm about 30 seconds to pick up N_2 and O_2 molecules from the floor.*
   LEGUMINOUS PLANTS: Pick up as many N_2 and O_2 molecules as you can. Paper clip them together to make nitrous oxide and put them on the ground. *Give leguminous plants about 30 seconds to pick up N_2 and O_2 molecules from the floor. Leave the paper clipped molecules together on the floor.*
   ANIMAL WASTE AND PLANT RESIDUES: Drop your ammonia labels onto the ground. You have decayed and added ammonia, a nitrogen compound.
   NITRIFYING BACTERIA (two of the four students) – pick up the ammonia and exchange ammonia labels for nitrite labels I have here. *The two students representing nitrifying bacteria pick up the ammonia labels and take them to the teacher, exchanging them for nitrite labels.* Now the other two nitrifying bacteria, take the nitrite labels and exchange them for nitrate labels. *The other two nitrifying bacteria take the nitrite labels from the first bacteria and take them to the teacher to exchange for nitrate labels.*
   FERTILIZER: Throw in all of the nitrate labels. *Students representing artificial fertilizer throw in several nitrate labels.*
   PLANTS: Take only two nitrate labels each and use them for growth. If there are any ammonia or nitrite labels still out, you may each pick up one of those. *Students representing plants collect two nitrate labels as well as any uncollected ammonia or nitrite labels.*
   DENITRIFYING BACTERIA: Pick up two remaining nitrates, bring them to me and exchange them for nitrogen and oxygen. *Denitrifying bacteria exchange nitrates for nitrogen and oxygen. This represents the release of nitrogen and oxygen back into the atmosphere.*
4. What's left in the soil? *Students observe that there are no more labels, indicating no nutrients are available.* What if fertilizer had thrown in more nitrate labels than the plants could pick up? *Then the excess nitrates from the fertilizer would be left in the soil.*
5. Using the knowledge of the nitrogen cycle gained from acting out the skit, we are going to make a diagram of the nitrogen cycle. We need one of each of our labels to create the diagram. Let's begin with nitrogen in the atmosphere. *Orally, go through the same steps as in the skit until the nitrogen cycle is complete. Place arrows between the labels to show the direction of the cycle.*

Blackline Masters

1. **The Nitrogen Cycle**
2. **Forms of Nitrogen in the Nitrogen Cycle**

Assessment

- none

Resources

BTNEP Resources:

Portrait of an Estuary, publication by LSU AG and BTNEP

Websites:

Deacon, Jim, Institute of Cell and Molecular Biology, The University of Edinburgh, n.d., **The Microbial World: The Nitrogen Cycle and Nitrogen Fixation**, accessed January 9, 2006, at http://helios.bto.ed.ac.uk/bto/microbes/nitrogen.htm.

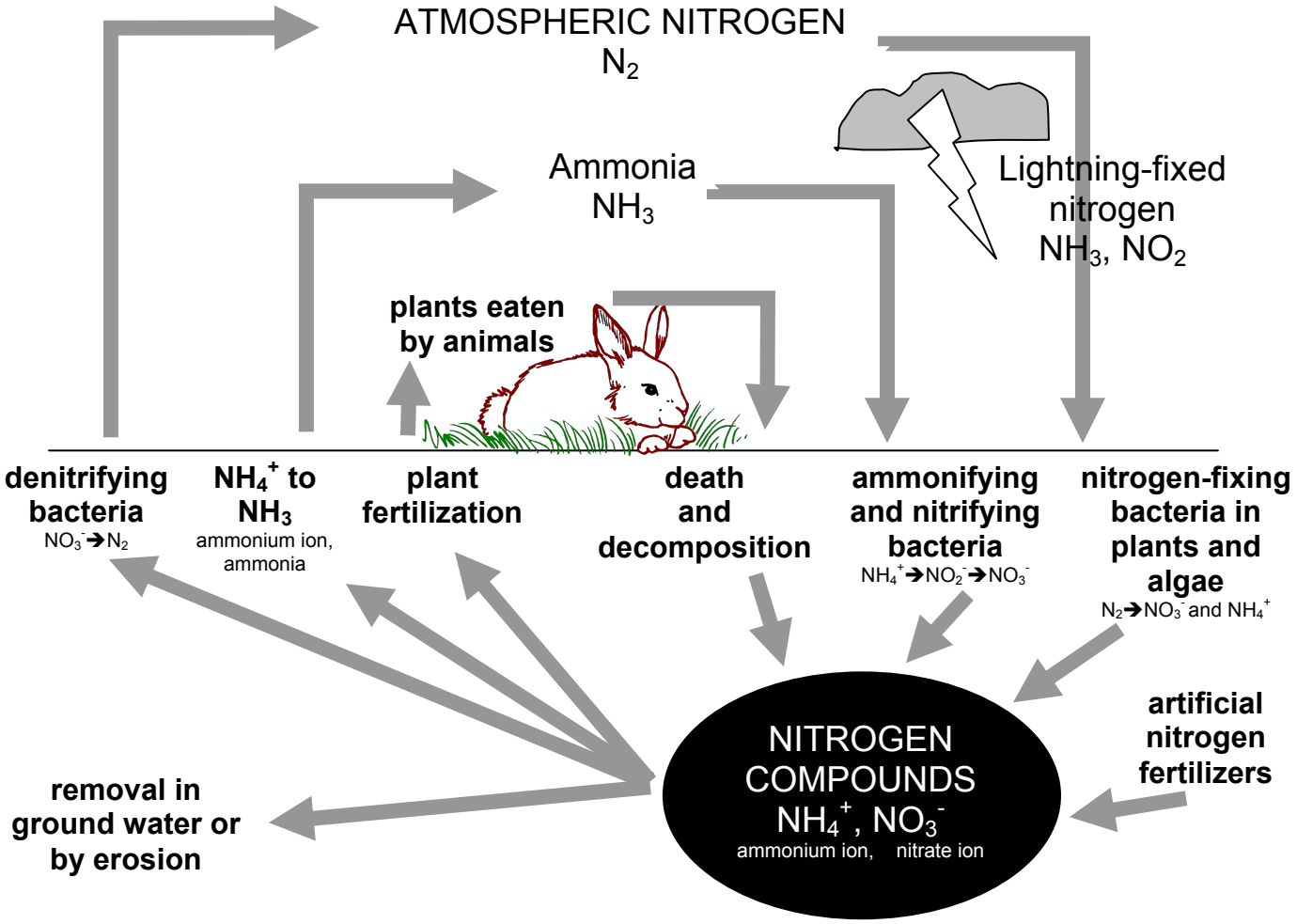
Thorough explanation of the nitrogen cycle.

The Nitrogen Cycle, accessed January 9, 2006, at http://www.neuse.ncsu.edu/nitrogen/.

An interactive diagram of the nitrogen cycle.

Blackline Master #1

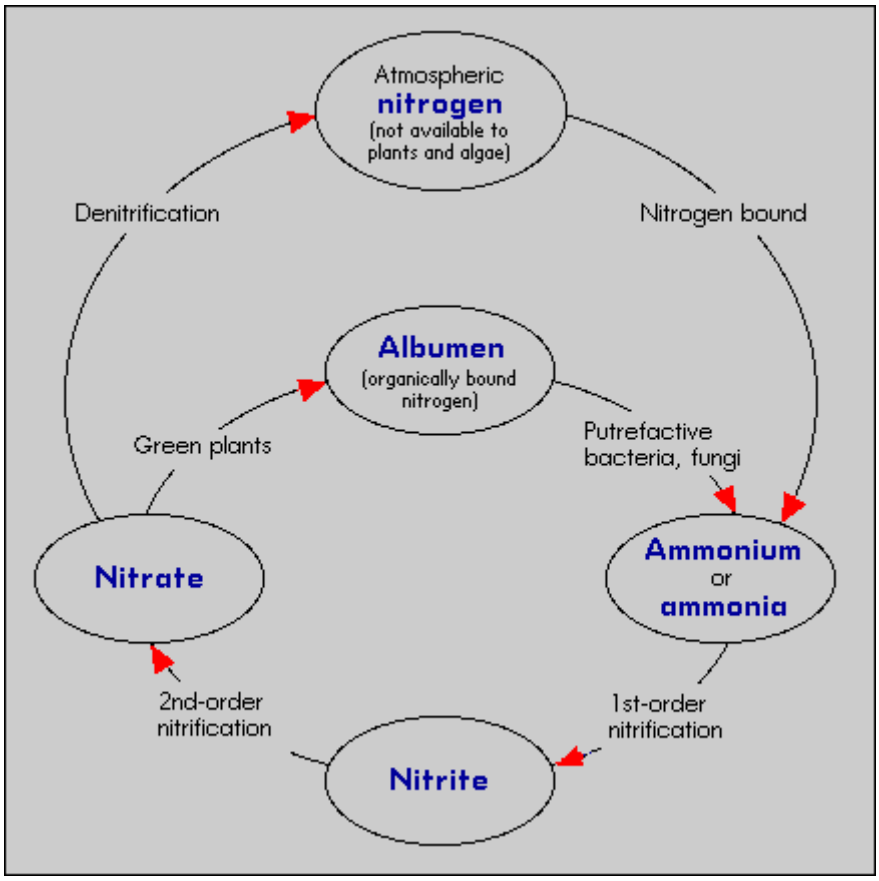
The Nitrogen Cycle



The Nitrogen Cycle

Since animals cannot absorb nitrogen from the air or the soil, they must obtain nitrogen by eating plants or other animals. When these animals die, their bodies are broken down through the action of decomposers. Animal waste and decaying plant materials also contain nitrogen and these materials are also broken down by decomposers. Some bacteria that live in the soil or in the roots of plants called legumes, can convert nitrogen gas into ammonia through a process known as nitrogen fixation. Other bacteria in the soil are able to take ammonium ions and convert them into nitrates, which is a form of nitrogen that plants can absorb and use to make protein. Consumers then eat the producers and reuse the nitrogen to make their own proteins. Some bacteria (denitrifying bacteria) are able to absorb nitrogen compounds from the soil and convert them back to nitrogen gas, thereby completing the nitrogen cycle.

Forms of Nitrogen in the Nitrogen Cycle



Accessed July 20, 2005, at http://www.water-garden.co.uk/expert/nahrstoff.html