Nitrogen Cycle Game

An Introduction to the Nitrogen Cycle

Grade Level: 5-9

Activity Duration: 45 minutes

Overview:

I. Introduction to the nitrogen cycle
II. Nitrogen Cycle Game
III. Discussion

Literacy Connection

Leopold, Aldo. "Odyssey." From: A Sand County Almanac. Oxford University Press.

Summary: Students will explore the nitrogen cycle by creating a diagram with magnets and by taking on the role of a nitrogen atom traveling through the nitrogen cycle. A discussion at the end of the lesson will ask students to consider how humans impact the nitrogen cycle.

Topic: nutrients, cycles, nutrient cycles, nitrogen, ecosystem

Theme: Nutrients like nitrogen are important to sustain life and they continuously cycle through ecosystems. Humans can impact the amount of nitrogen in an ecosystem.

Goals: Students will understand the concept of nutrient cycling; in particular, students will understand the nitrogen cycle.

Objectives:

1. Students will define nutrient.
2. Students will enact the role of a nitrogen atom in a cycling game.
3. Students will identify the major reservoirs of nitrogen in an ecosystem.
4. Students will explain how the form of nitrogen matters in light of what organisms can use it.
5. Students will identify human impacts on the nitrogen cycle.

Lesson Suggested:

Gardiner, Lisa. (2005). "Traveling Nitrogen." Windows to the Universe. *National Earth Science Teachers Association.* Retrieved from http://www.windows2universe.org/teacher_resources/teach_nitroen.html

We Suggest Use in Correlation with:

MN DNR MinnAqua Program. (2010). Fishing: Get in the Habitat! Leader's Guide. "Lesson 3.2 – Function of Aquatic Plants."

Suggested MN Science Standards:

5.1.1.1.4 The Nature of Science and Engineering – The Practice of Science
Understand that different models can be used to represent natural phenomena and these models have limitations about what they can explain.

5.3.4.1.3 Earth and Space Science – Human Interaction with Earth Systems
Compare the impact of individual decisions on natural systems.

5.4.2.1.1 Life Science – Interdependence Among Living Systems
Describe a natural system in Minnesota, such as a wetland, prairie or garden, in terms of the relationships among its living and nonliving parts, as well as inputs and outputs.

5.4.4.1.1 Life Science – Human Interactions with Living Systems
Give examples of beneficial and harmful human interaction with natural systems.

6.1.3.1.1 The Nature of Science and Engineering – Interactions Among Science, Technology, Engineering, Mathematics, and Society
Describe a system in terms of its subsystems and parts, as well as its inputs, processes, and outputs.

7.2.1.1.1 Physical Science – Matter
Recognize that all substances are composed of one or more of approximately one hundred elements and that the periodic table organizes the elements into groups with similar properties.

8.3.4.1.2 Earth and Space Science – Human Interactions with Earth Systems
Recognize that land and water use practices can affect natural processes and that natural processes interfere and interact with human systems.

9.1.3.1.1 The Nature of Science and Engineering – Interactions Among Science, Technology, Engineering, Mathematics, and Society
Describe a system, including specifications of boundaries and other subsystems, relationships to other systems, and identification of inputs and expects outputs.

9.1.3.1.2 The Nature of Science and Engineering – Interactions Among Science, Technology, Engineering, Mathematics, and Society
Identify properties of a system that are different from those of its parts but appear because of the interaction of those parts.

Environmental Literacy Scope and Sequence

Benchmarks:

- Social and natural systems are made of parts. (K-2)
- In social systems that consist of many parts, the parts usually influence each one another. (3-5)
- Social and natural systems may not function as well if parts are missing, damaged, mismatched, or misconnected. (3-5)
- The output from a social or natural system can become the input to other parts of social and natural systems. (6-8)
- Social and natural systems are connected to each other and to other larger and smaller systems. (6-8)
- Interaction between social and natural systems is defined by their boundaries, relation to other systems, and expected inputs and outputs. (9-adult)

Concepts addressed in this lesson: abiotic factors, cause and effect, cycles, patterns, waste

For the full Environmental Literacy Scope and Sequence, see:
www.seek.state.mn.us/eemn_c.cfm

Great Lakes Literacy Principles

Please note, not all Great Lakes Literacy Principles are addressed in this lesson.

- Water makes the Earth habitable; fresh water sustains life on land.
- The Great Lakes support a diversity of life and ecosystems.
- The Great Lakes and humans in their watersheds are inextricably interconnected.
- Much remains to be learned about the Great Lakes.

For more information about the Great Lakes Literacy Principles, visit:
http://greatlakesliteracy.net/

Materials:

Introduction to nutrients:

- Magnetic boards like a dry erase board or a magnetic chalk board (not included in kit)
- Magnetic pieces of the nitrogen cycle
- Magnetic arrows to use in the nitrogen cycle

Nitrogen Cycle Game:

- 11 station signs
- 11 dice
- Student passports
- Stamps for each station
- Glue stick for each station
- Masking tape

Discussion:

- Additional magnetic pieces to add to the nitrogen cycle:
    - Water elements:
        - Surface water
        - Lake Superior (rather than the ocean)
        - Rain
        - Groundwater
    - Farm field
    - Waste water treatment facility
    - Roads on a hill that encourage runoff
    - Emissions

Background:

What is a Nutrient?[1, 2]

A nutrient is an "element or compound essential for animal and plant growth. Common nutrients include nitrogen, phosphorus, and potassium."[1] Without enough nutrients, plants and animals cannot sustain life. However, in high concentrations, nutrients can be harmful to plants and animals. Just like vitamins are good for people in the right amounts, nutrients are good for plants and animals in the right amounts.

Nutrients often make their way through an ecosystem by moving in a cycle. Much like the water cycle or the rock cycle, a nutrient cycle is a sequence of events that repeats itself.

Two nutrients that are important to the Lake Superior and St. Louis River systems are nitrogen and phosphorus.

The Nitrogen Cycle[2]

Nitrogen is an element that is found in both the living portion of our planet and the inorganic parts of the Earth system. Living things cannot exist without nitrogen. Atoms of nitrogen don't just stay in one place. They move slowly between living things, dead things, the air, soil and water. These movements are called the nitrogen cycle. The nitrogen cycle is one of the biogeochemical cycles and is very important for ecosystems. Nitrogen moves slowly through the cycle and is stored in reservoirs such as the atmosphere, living organisms, soils, and oceans along its way.

Most of the nitrogen on Earth is in the atmosphere. Approximately 80% of the molecules in Earth's atmosphere are made of two nitrogen atoms bonded together (N_2). All plants and animals need nitrogen to make amino acids, proteins and DNA, but the nitrogen in the atmosphere is not in a form that they can use. The molecules of nitrogen in the atmosphere can become usable for living things when they are broken apart during lightning strikes, volcanic activity, or fires, and by certain types of nitrogen-fixing bacteria (like those found in the root nodules of legumes). Other plants get the nitrogen they need from the soils or water in which they live mostly in the form of inorganic nitrate (NO_3-).

Nitrogen is one of the limiting factors for plant growth. Animals get the nitrogen they need by consuming plants or other animals that contain organic molecules composed partially of nitrogen. When organisms die, the decomposing organisms break down the nitrogen fixed in the animal's cells which releases the nitrogen into soil on land or

into the water. The decomposition process converts the nitrogen into inorganic forms such as ammonium salts (NH_4+) which is called mineralization or nitrification. The ammonium salts are absorbed onto clay in the soil and then chemically altered by bacteria into nitrite (NO_2-) and then nitrate (NO_3-). Nitrate is the form commonly used by plants. It is easily dissolved in water and leached from the soil system. Dissolved nitrate can be returned to the atmosphere by certain types of bacteria in a process called denitrification.

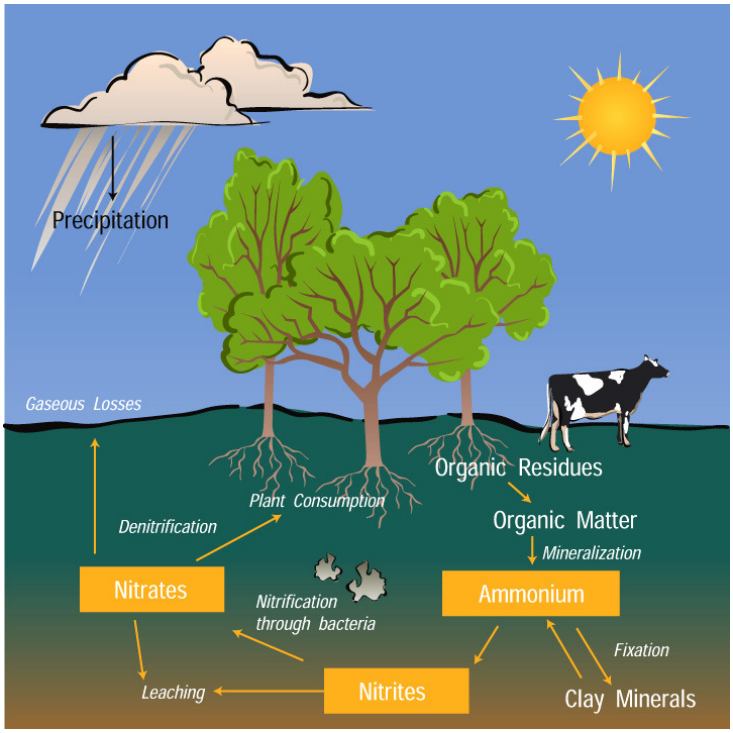


Figure 1. The Nitrogen Cycle[2]

Some human actions are causing changes to the nitrogen cycle and the amount of nitrogen that is stored in reservoirs. The use of nitrogen-rich fertilizers can cause nutrient leaching in nearby waterways as nitrates from the fertilizer wash into streams and ponds. The increased nitrate levels cause plants to grow rapidly until they use up the nitrate supply and die. The number of herbivores will increase when the plant supply increases and then the herbivores are left without a food source when the plants die. In this way, changes in nutrient supply will affect the entire food chain. Additionally, humans are altering the nitrogen cycle by burning fossil fuels and forests, which releases various solid forms of nitrogen. Farming also affects the nitrogen cycle. The waste associated with livestock farming releases a large amount of nitrogen into soil and water. In the same way, sewage waste adds nitrogen to soils and water.

Phosphorus, in addition to nitrogen, is and important nutrient to sustain life. While this lesson does not explore the phosphorus cycle, it is important to acknowledge that phosphorus too is important in ecosystems.

Phosphorus in the evironment[2]

Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a water body including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

There are many sources of phosphorus, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

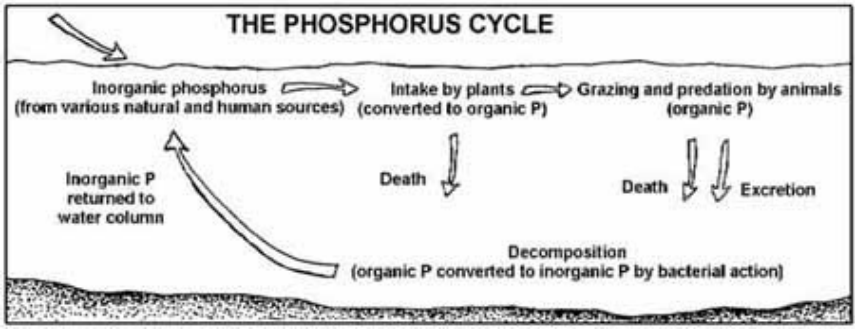


Figure 3. The Phosphorus Cycle[3]

Lake Eutrophication[4]

Excess nutrient runoff can cause eutrophication of lakes. Eutrophic lakes get their name from the Greek word, "eutrophus," which means "high nutritious," and eutrophic lakes are exactly that – they tend to have high nutrient loads, which support high "productivity" of plants and animals in the lake. The nutrient status of lakes varies naturally from very low nutrient levels to very high levels. This variation is caused by many natural factors, such as geologic "age" of the lake, soil type, size of the watershed relative to the size of the lake, lake depth, and temperature. Most lakes un-impacted by human activity will gradually accumulate organic matter and nutrients over geologic time (very slowly), but human activity can radically speed up this process. When our activities increase nutrient loads to a lake leading to rapid changes, we call it "cultural eutrophication" to distinguish it from the extremely slow

natural processes. Cultural eutrophication causes major changes in the lake ecosystem, which can negatively impact aquatic life, recreational activities, and water quality. The two primary nutrients responsible for eutrophication are nitrogen and phosphorus, found in fertilizer, pet and human waste, some detergents, and runoff from lands impacted by human activities. Both nitrogen and phosphorus are needed by algae and plants to grow, but in most Midwestern lakes, including Lake Superior, phosphorus is the nutrient in shortest supply and therefore the one that most readily triggers excessive, rapid growth. Algae reproduce rapidly when exposed to increased nutrients. Rapid algal reproduction, commonly referred to as algal "blooms," can cause unsightly green or blue-green water. Some algal blooms produce toxins that are harmful to pet and human health. Additionally, algae blooms decrease water clarity, which means sunlight cannot penetrate as deeply into the water. Aquatic plants important for fish and wildlife habitat that are dependent on sunlight can decline as a result. Algae and dead aquatic plants settle to the bottom and begin to decay. Bacteria that facilitate the decaying process require large amounts of oxygen, so oxygen is removed from the water, leaving less for fish and other animals. Fish die-offs and changes in the food web can be a result of cultural eutrophication. The moral of the story? If you want a beautiful green lawn, be prepared for a green lake as well!

Additional resources:
http://www.seagrant.umn.edu/newsletter/2006/10/unsolved_mystery_lake_superiors_missing_carbon.html
http://www.epa.gov/climatestudents/basics/today/carbon-dioxide.html

Vocabulary[3]:

Ammonia (NH_3)/Ammonium (NH_4^+) – compounds of nitrogen and hydrogen that readily dissolve in water. In oxygen-rich water, ammonium is easily transformed to nitrate and in oxygen-poor water to molecular nitrogen. Ammonium and nitrate comprise most of the inorganic nitrogen in precipitation.

Denitrification – bacteria that use nitrates as an alternative to oxygen in respiration reduce nitrates to nitrogen gas, thus replenishing the atmosphere.

Eutrophication – a process in which nutrients degrade water quality due to excessive growth of microscopic plants and animals. As this matter dies and decays, it sometimes removes so much dissolved oxygen from the water that fish and other organisms cannot survive.

Nitrate (NO_3^-)– a compound of nitrogen and oxygen that is highly soluble in water. Nitrate is stable over a wide range of environmental conditions and is readily transported in surface and ground water.

Nitrification – bacteria convert the ammonia produced by decay into nitrates that are used by plants.

Nitrogen – an element that is essential for life. Molecular nitrogen (N2), is an extremely stable gas that comprises 78% of the atmosphere. Plants and animals use nitrogen compounds to build proteins. Most organisms cannot use the nitrogen gas in the atmosphere; nitrogen fixing plants and bacteria are necessary to change nitrogen into forms that can be used by plants.

Nitrogen decay – nitrogen leaves plants and animals when they rot and decomposers break down dead organic matter

Nitrogen fixation – the process by which lightening, bacteria in the root nodules of legumes, and bacteria in the soil convert nitrogen into useable compounds. Plants take up these soluble nitrates through their roots and use them to build proteins that can be taken by animals.

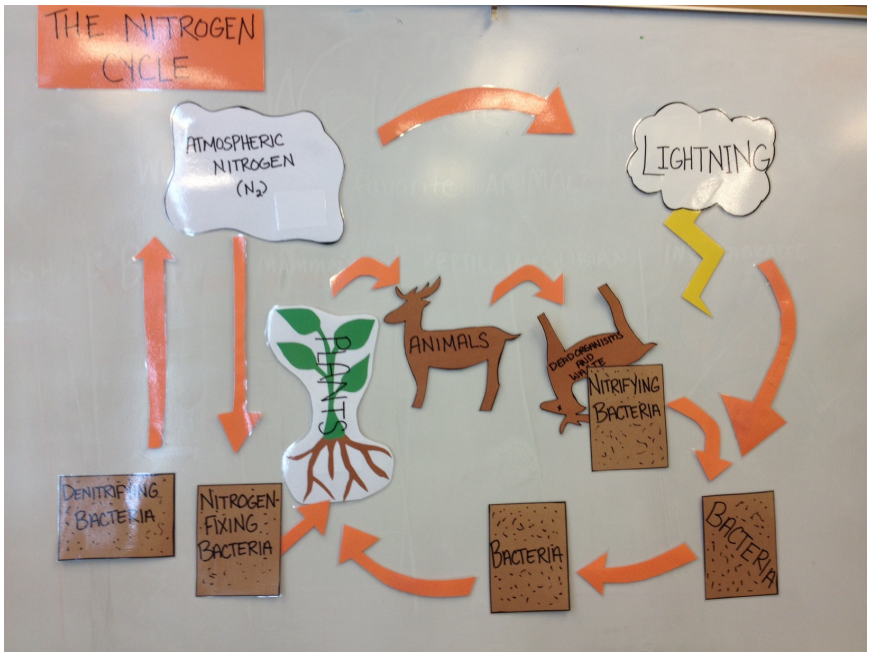
Nutrient – according to the U.S. Geological Survey of 2007, a nutrient is an "element or compound essential for animal and plant growth. Common nutrients include nitrogen, phosphorus, and potassium."

Phosphorus – an element that is a key nutrient that fuels biological productivity. Phosphorus is rapidly recycled by bacterial decomposition.

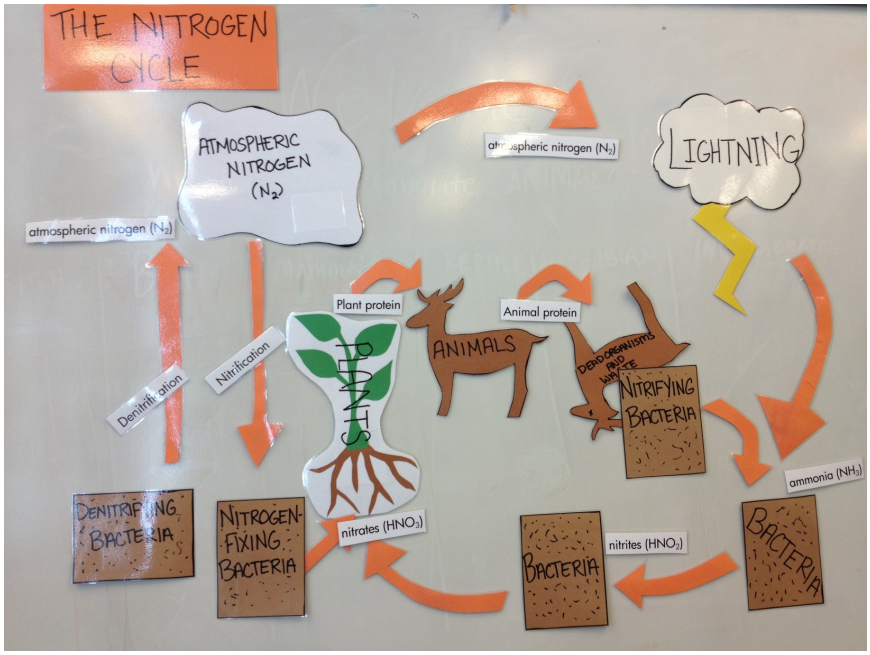
Procedure:

Introduction to the Nitrogen Cycle

1. Ask students if they've ever heard someone say "Drink milk to get the calcium you need." Ask students if they take, or know anyone who takes, vitamins.
    a. Have students explain why we need calcium or vitamins.
2. Vitamins are full of the nutrients we need to be healthy – to build healthy bodies. Calcium is just one of those nutrients. Plants and animals need nutrients also.
3. Three nutrients that are really important to plants and animals are nitrogen, carbon, and phosphorus.
4. Just like the water cycle and the rock cycle, these nutrients travel through an ecosystem in a cycle being used by different parts of the ecosystem along the way.
5. Today, we're going to get familiar with the nitrogen cycle to see how plants and animals use and transfer nitrogen.
6. First, we'll put the cycle together on the board – then, we'll become nitrogen atoms in the cycle!
7. Hand out the numbered images of the nitrogen cycle.
8. Invite students up based on the numbers to place their image in the appropriate place in the cycle and read the description. Place arrows as new pieces are put on the board.
    a. Sky: N_2 is the nitrogen gas in the atmosphere.
    b. Lightning: turns the N_2 into Ammonia, NH_3
    c. Bacteria: turn the NH_3 into Nitrites, HNO_2
    d. Other bacteria: turn the Nitrites into Nitrates, HNO_3
    e. Plants: turn the Nitrates into proteins
    f. Animals: eat the plants and turn plant protein into animal protein
    g. Fungi and bacteria: turn animal waste, dead animals, and dead plants into Ammonia, NH_3
    h. Denitrifying bacteria: turn Nitrates, HNO3, into atmospheric nitrogen, N2
    i. Nitrogen-fixing bacteria: turn N_2 into HNO_3
9. The whole process might be a little confusing, but it will make more sense after the students actually become a molecule of nitrogen.



The above image shows the basic configuration of the nitrogen cycle with the magnet diagram.



The above image shows the configuration of the nitrogen cycle with the magnet diagram – including the chemical outputs of each part of the cycle.

The Nitrogen Cycle Game[2]

See included lesson plan or visit the following source:

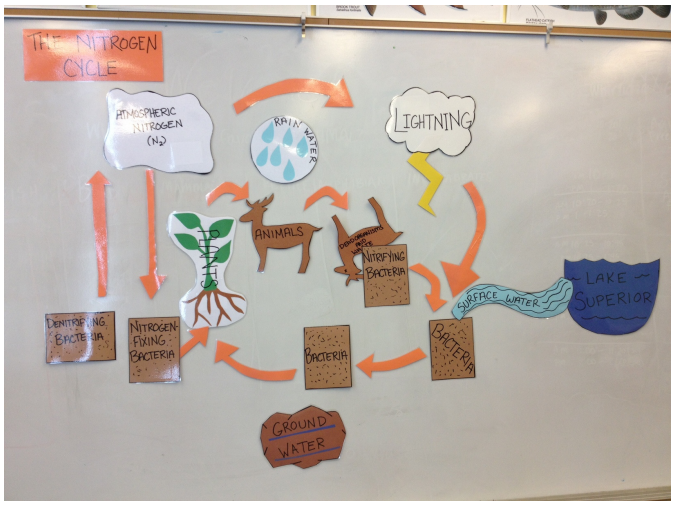
Gardiner, Lisa. (2005). "Traveling Nitrogen." Windows to the Universe. *National Earth Science Teachers Association.* Retrieved from http://www.windows2universe.org/teacher_resources/teach_nitrogen.html

EXTENSION:

Have students use their passports to draw a picture of their nitrogen cycle journey. Be sure to have them use arrows to show the direction of travel that their nitrogen atoms took. For older students, have them include the chemical composition of the nitrogen compounds as the atoms move through the cycle. This extension is good preparation for a group discussion using the questions in the wrap-up.

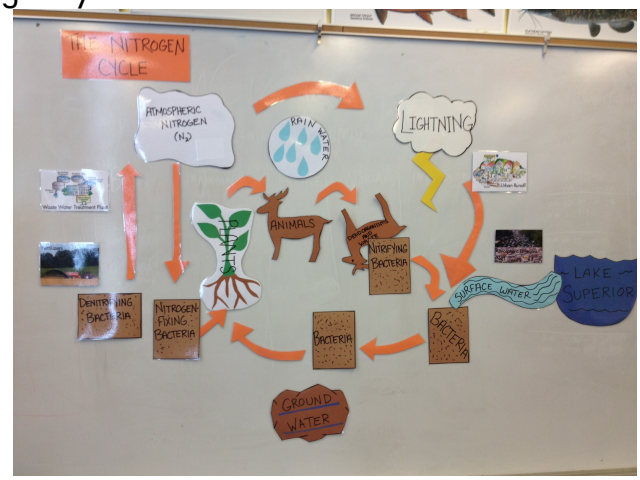
Wrap-up – Discussion Question Suggestions:

1. Have students share their nitrogen journeys.
    a. Did your journeys take you in a perfect circle? *Acknowledge that, while nitrogen keeps moving through the different reservoirs, there is no one set pattern of movement.*
    b. Are all of the journeys of the class the same? *Nitrogen can move through ecosystems in many different pathways.*
    c. How long did you stay at each station? *One roll.* How is this different than the length of time you might actually spend in a plant or in groundwater as a nitrogen atom or compound? *If you were built into the protein of an animal, you could potentially stay in an animal for a very long time. Have students come up with reasons that a nitrogen atom may stay in other reservoirs for a long time. Have students come up with reasons that a nitrogen atom may move very quickly from one reservoir to the next.*
2. What can we add to our diagram based on the nitrogen game we just played? (rain, surface water, ground water)
    a. Add the magnets for rain, surface water, ground water, and Lake Superior (Lake Superior will take the place of the ocean from the game)



The above image shows the addition of water sources to the basic nitrogen cycle magnetic diagram.

3. What is missing from our diagram? *(significant human impact)* What are ways humans can impact the nitrogen cycle?
    a. Add an image of a farm field and lots of fertilizer.
    b. Add an image of paved roads that promote runoff.
    c. Add an image of the waste water treatment plant.
    d. Ask what other influences people might have on something like a nitrogen cycle.



The above image shows the addition of four human activities to the nitrogen cycle diagram.

4. Ask students how they think nitrogen works in water. (**Extension:** use as introduction to a unit on water quality and nutrient cycling in aquatic systems)
5. Explain to students that we have just begun to scratch the surface of the complexities of the nitrogen cycle – and this is only one of multiple nutrient cycles that are always happening! Ecosystems are very complex.

References:

1. US Geological Survey, 2007
2. Gardiner, Lisa. (2005). "Traveling Nitrogen." Windows to the Universe. *National Earth Science Teachers Association.* Retrieved from http://www.windows2universe.org/teacher_resources/teach_nitrogen.html
3. "Nitrogen in the Nation's Rain." (2000). Illinois State Water Survey and the National Atmospheric Desposition Program. Retrieved from http://nadp.isws.illinois.edu/lib/brochures/nitrogen.pdf
4. Bronmark, C. & Hansson, Lars-Anders. (2008). *The Biology of Lakes and Ponds.* New York: Oxford University Press.

Brought to you by Great Lakes Aquarium, Minnesota DNR MinnAqua Program, Minnesota Sea Grant, and Wolf Ridge ELC. This project is funded in part by the Coastal Zone Management Act, by NOAA's Office of Ocean and Coastal Resource Management, in conjunction with Minnesota's Lake Superior Coastal Program.