Lesson Title: Nitrogen Cycle Game
Author: Ryan Lenz
Grade level: 5-8th

Date: February 1, 2008
Topic: Nitrogen Cycle
Lesson Length: 45 minutes

Overview: Students model the nitrogen cycle by following a nitrogen molecule as it is passed around the food chain. This lesson should be preceded or followed by "Testing Testing", which deals with measurement of nitrate concentration before and after a water change.

Objectives: Students will understand that:

- Animal waste is recycled by other organisms, often bacteria
- "Waste" is a relative term--some animals' waste is another's food.
- The sun is the driving force of the nitrogen cycle
- Aquariums, like the Earth, rely on biological organisms (plants and bacteria) to convert toxic animal waste into less-toxic compounds
- Unprocessed waste is toxic to the organism that produces it
- Molecules are changed by adding and removing atoms
- Aquariums are not a complete cycle--they lack powerful lights or a low-oxygen habitat for anaerobic bacteria to populate. Therefore, we have to remove built-up nitrogen (in the form of nitrate)

Prior Expectations from Learner: Conceptual understanding of a cycle (water cycle is most common). Basic understanding of the concepts of consumers, producers, decomposers. Understanding that producers use the sun's energy to build their bodies.

Assessment: Informal assessment--either an "exit pass" style question form or verbal quizzing.
Suggested questions:
Is nitrogen wasted in an ecosystem?
Why would something eat fish urine?
What form of nitrogen accumulates in the aquarium? Why?

Does nitrate accumulate in the ocean? Why or why not?

Materials	Teacher	Student	Notes
	Molecular modeling kit with approximately 6 nitrogens, 24 hydrogens, 18 oxygens, 18 "amino acids/proteins" (springs), and 36 bonds (sticks). Station instruction sheets (below) 6 tables, arranged in a circle (if possible) A small tub labeled "Aquatic Environment"		

Section/Time	Teacher Activity	Student Activity	Notes
Prep:			
	Start off by asking the question: What happens when a fish goes to the bathroom? (Usually gets disgusted faces) What happens to that fish pee (we call it "Ammonia")? What if I told you that something eats it? Does anyone know what kind of living organism eats fish waste?		
Engagement (5 min)	The goal of today's lesson is to understand that nutrients (such as nitrogen) move through an ecosystem in a cycle. It might seem disgusting to you, but fish waste is a very nutritious source of energy for tiny bacteria. Without these bacteria, their waste would accumulate and become poisonous to fish. We have to make sure that millions and millions of these bacteria are in the aquarium so that fish waste doesn't kill our fish!	Respond (possibly in small groups?).	
Introduction/Rules	Lay out the goals of the activity: the students will use molecular models to go through the nitrogen cycle. In other words, you are going to act as fish pee! We will divide into two groups: Nitrogen Forms and Nitrogen Processors. After the Nitrogen Forms have all gone through the entire cycle, we will switch and do it again. Show overhead of the nitrogen cycle. Instruct the students that they will be simulating this cycle in the activity. On board/overhead, indicate what each colored ball represents (i.e. oxygen is red, nitrogen is black, etc.)	Listen to instructions, ask clarifying questions.	

Main activity (20 min)	Divide the class into halves. Assign one half of the class as Nitrogen Forms and one half as Nitrogen Processors. Within groups, pair students together. Display overhead/draw on board a diagram of the nitrogen cycle (an example is included at the end of this document). Label the forms of nitrogen with their molecular formula (NH3 for ammonia, NO2 for nitrite, NO3 for nitrate, NC for protein). Make an overhead copy of one of the instruction sheets--show them how to find their nitrogen source and by-product. Demonstrate the building of molecules using balls and sticks. Then demonstrate moving from one station to another and completing the appropriate transformation (the "Molecular Manipulation) of nitrogen source, going to the Aquatic Environment to gather/get-rid-of atoms. When students understand the goal of the activity, hand out the appropriate molecule to each station. Begin activity. Instruct students to read the instructions at their station and perform the changes to their nitrogen form. As students complete the changes, ask them to hold their molecule up in the air for teacher approval. When all students have successfully been processed, move the nitrogen forms clockwise one station. Repeat the steps until they have completed rotation.	Students as Nitrogen Processors will quickly become 'experts' at their station and will be able to assist the nitrogen form in their change. Nitrogen forms will move around the inner circle, getting rid of and picking up pieces from the Aquatic Environment tub as necessary.
Closure (5 min)	When students return to seats, provide a general wrap-up: Nitrogen is added to the aquarium in the form of food. It is eaten by fish, which excrete ammonia (NH4). This ammonia is eaten by bacteria, which create nitrite (NO2). This nitrite is eaten by another type of bacteria, which create nitrate. Nitrate is plant food! If we had enough plant growth, we could complete the cycle. Unfortunately, we don't have bright enough lights on the aquarium to grow enough plants. So that means that this step isn't completed in the aquarium, so the nitrogen cycle is broken (indicate this on the overhead). If we continue to add food, but the cycle isn't completed, what will happen? (Nitrate builds up) Emphasize the cyclical nature and that "one man's trash is another's treasure". Nothing is wasted or "disgusting" in nature!	Students respond to questions
Assessment:	Informal assessment--either an "exit pass" style question form or verbal quizzing. Suggested questions: Is nitrogen wasted in an ecosystem? (No! Everything is used by something else.) Why would something eat fish urine? (it has lots of energy!) What form of nitrogen accumulates in the aquarium? Why? (Nitrate, because we don't have bright lights to grow plants, nor do we have anaerobic zones for denitrification--see TAG differentiation.)	

TAG Differentiation:	There is one other possible way for nitrogen to leave the aquarium that isn't mentioned in this activity. A certain type of anaerobic (not tolerant of oxygen) bacteria can take nitrate and reduce it to free nitrogen gas, which leaves the tank as bubbles. Ask students why these bacteria don't thrive in normal aquariums [because the aquarium is most highly aerobic--lots of oxygen is present. These bacteria require low-oxygen environments, such as the inside of porous materials (ceramics, porous rocks, dead coral skeletons, etc.). Can they design a filter that provides habitat for these types of bacteria?	Students attempt to answer challenge questions; potentially do library research on denitrifying filters (AKA "nitrate reactors" or "nitrate filters")
Possible extensions:	This game has a lot of potential to get really sophisticated! You could try adding carbon into the mix, with living organisms accumulating carbon until they die, then passing it on to decomposers. You could also try to simulate what actually happens in the aquarium, accumulation of nitrate, and then dilution by water change. You could model this by stopping students as they reach the Nitrobacter--->phytoplankton stage. There are many possibilities for expansion!	

Overall scheme of the game:

Copepod (eats phytoplankton)-----protein---> Sardine (eats copepod) ---------Ammonia, NH3-----> Nitrosonomas (eats Ammonia) ------nitrite, NO2----> Nitrobacter (eats nitrite) -------> Phytoplankton (uses nitrate) -----amino acid---->Copepod (eats phytoplankton) CYCLE COMPLETE.

Ecological function: Consumer

Type: Phytoplankton feeder (you eat microscopic plants)

Subtype: Copepod

Name: *Neocalanus* (say NEE-O-CAL-UH-NUSS)

Nitrogen form: Amino acids (from phytoplankton)

By-product: Protein

Microhabitat: Aerobic areas, probably swimming around in the open ocean.

Aquarium habitat: swimming around in the tank, the pump, everywhere!

<u>Molecular manipulation</u>: Take the amino acid and another amino acid to it, forming a protein.

The Long Story: You are a vegetarian consumer that swims around and filters out tiny plants (producers) like Anabaena out of the water. You build your body out of amino acids, which are the building blocks of protein. Then something like a fish eats you! Your proteins are passed up the food chain. You are part of the nitrogen cycle.

Ecological function: Consumer

Type: Zooplankton feeder (you eat animals)

Subtype: Sardine

Name: *Dussemeria* (say DOO-SUH-MARRY-UH)

Nitrogen form: Protein (from copepods)

By-product: Ammonia, NH_3

Microhabitat: Aerobic areas, probably swimming around in the open ocean.

Aquarium habitat: swimming around in the tank.

<u>Molecular manipulation:</u> Take the protein and remove the springs (you built muscles with the protein). Attach three hydrogens to create ammonia (fish urine).

The Long Story: You are a filter-feeding fish. You swim around and eat copepods and other zooplankton. You accumulate proteins in the process, but you excrete ammonia. This ammonia is very toxic to you, so it is important that many bacteria are nearby to eat your waste and turn it into something less toxic.

Ecological function: Decomposer

Type: Bacteria

Subtype: Nitrifying bacteria

Name: *Nitrosonomas* (say NI-TRO-SO-NO-MA's)

Nitrogen form: Ammonia, NH_3

By-product: Nitrite, NO_2

Microhabitat: Aerobic (Oxygen-rich) areas like the shallow layers of the ocean or the surface of a rock.

Aquarium habitat: In the filter, on rocks, on the glass, in the water.

<u>Molecular manipulation:</u> Remove 3 hydrogens and replace them with 2 oxygens.

The Long Story: You are a bacteria called *Nitrosonomas*. You eat fish waste (ammonia, NH3) and you excrete nitrite (NO2). This chemical process is called oxidation (you are adding oxygen). You live only in oxygen-rich environments, such as floating around in the open ocean or growing on the surface of a rock. Nitrite is highly toxic to fish, coral, starfish, and anemones. In the aquarium, you live in the filter and are usually present in extremely high numbers. Without you, all the cool creatures in the aquarium would die! But remember that it takes a few weeks before there are enough of you to process all the fish waste, so new fish tanks can't have fish in them.

Ecological function: Decomposer

Type: Bacteria

Subtype: Nitrifying bacteriaa

Name: *Nitrobacter* (say NI-TRO-BACK-TUR)

Nitrogen form: Nitrite, NO_2

By-product: Nitrate, NO_3

Microhabitat: Aerobic (Oxygen-rich)

Aquarium habitat: In the filter, on sand, on rock, on the glass, in the water.

<u>Molecular manipulation</u>: Add one oxygen to the nitrite molecule.

The Long Story: You are a bacteria called Nitrobacter. You use the by-product of another bacteria (*Nitrosonomas*) and you excrete nitrate, NO_3. This is a chemical process called oxidation (you are adding oxygen). Nitrate is slightly toxic to fish, coral, starfish, and anemones. A small amount is ok in the aquarium, but in high amounts it can be deadly. In the aquarium, you live in the filter and are usually present in extremely high numbers. Without you, all the wonderful creatures in the aquarium would die!

Ecological function: Producer

Type: Plankton

Subtype: Phytoplankton or algae

Name: *Anabaena* (say ANNA-BEAN-UH)

Nitrogen form: Nitrate, NO_3

By-product: Amino acids (the building blocks of protein)

Aquarium Habitat: Floating around in the water, maybe growing on the glass and rocks.

Micro-habitat: Open ocean, in the well-lit surface layer

<u>Molecular manipulation:</u> Take nitrate and remove 3 oxygens. Add a spring (amino acid).

The Long story: You are able to use the energy from the sun to create amino acids. Other animals will eat you and use your amino acids to create protein. You are at the very bottom of the food chain, but you are also very important! You are responsible for providing power for the entire nitrogen cycle! All of the other organisms in the nitrogen cycle (fish, humans, different types of bacteria) all rely on you to use energy from the sun to power the cycle.

Instructions:

In this role-playing game, you are going to act-out the nitrogen cycle. There will be two categories of players: Nitrogen Forms, and Nitrogen Processors. When a Nitrogen Form moves from one Nitrogen Processor to the next, the two groups must work together to change the Nitrogen Form. Each Nitrogen Processor table will have instructions on what changes must be made to the Nitrogen form. The goal of the game is to complete the nitrogen cycle.

What's what?

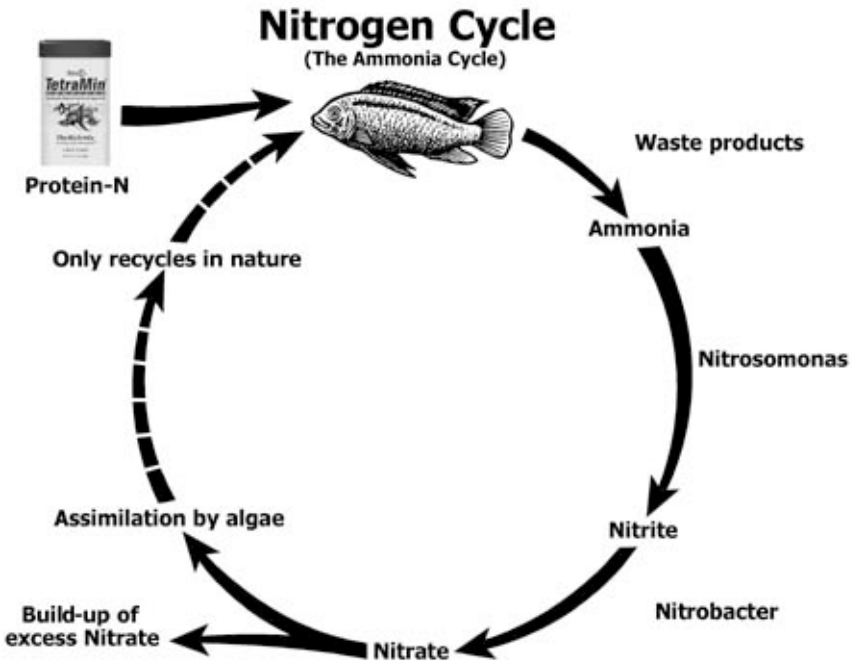
Black=Nitrogen, N

Yellow= Hydrogen, H

Red=Oxygen, O

1 Spring=Amino Acid

2 Springs=Protein



Used courtesy of National Aquarium in Baltimore