California Foundation for Agriculture in the Classroom

Matter of Fact

Purpose

In this lesson, students will take on the role of a nitrogen molecule and experience how various forms of nitrogen cycle through the environment. Students will be able to identify and differentiate between atoms, molecules, and compounds.

Time

Teacher Preparation:
30 minutes

Student Activities:
Part I: 60 minutes
Part II: 60 minutes

Materials

For the teacher:

- Document projector
- Transparency film (optional)
- Tactile molecular models
- *Matter of Fact Notes* answer key
- *What Goes Around, Comes Around* answer key

For each station:

- Station instructions
- Die
- Twenty toothpicks
- Bowl

Background Information

All organisms require nitrogen to live and grow; it is a fundamental component of DNA and RNA, the building blocks of life. Approximately 78% of the Earth's atmosphere is made of nitrogen gas. This atmospheric form (N_2) is unusable by most plants. In order to be used by plants, nitrogen gas must be converted to ammonium, nitrate, or urea through a process called nitrogen fixation.

The nitrogen cycle is the process by which nitrogen is converted between its various chemical forms as it moves between the atmosphere, living organisms, and the Earth's crust. The cycle illustrates how nitrogen from the atmosphere interacts with microorganisms that can convert, or "fix," N_2 gas into forms of nitrogen that are usable by plants. Nitrogen can also enter the cycle from other sources besides the atmosphere including manure, decaying plant material, and commercial fertilizers. As nitrogen atoms move throughout the cycle, their chemical composition may change numerous times.

Forms of Nitrogen Highlighted in the Lesson

Chemical Formula	Name	State	Form
N_2	Nitrogen Gas	Gas	Molecule
NH_4^+	Ammonium	Solid	Compound
NO_3^-	Nitrate	Solid	Compound

Part I

1. Prior to the lesson, prepare several tactile molecular models to represent each of the following forms of nitrogen: N, N_2, NH_4^+, NO_3^-. Display for the class the *Matter of Fact Notes* handout and the Nitrogen Cycle diagram onto overhead transparencies (optional). Set up seven stations evenly spaced around the classroom. Place a bowl of gumdrops, toothpicks, and a die at each station. Post the station instructions above each station.
2. Explain to students that many of the world's resources are not available for use by plants or animals. For example, only one percent of the Earth's water is actually drinkable. Have students brainstorm reasons why the other 99 percent might not be available

- Twenty gumdrops *(various colors)*

For each student:

- *Matter of Fact Notes* handout
- *What Goes Around, Comes Around* activity handout
- *Nitrogen Cycle* handout

for consumption. Record answers on the board. After some time, explain that 97 percent of water on Earth is salt water. Two percent of the water on earth is glacier ice at the North and South Poles.

3. Similar to the availability of water, some plant nutrients are not easily used by plants. For example, although 78 percent of the Earth's atmosphere is made of nitrogen—this form (N_2 or nitrogen gas) is unusable by plants. Today we're going to experience how nitrogen changes its molecular form during the nitrogen cycle and learn what forms can be assimilated by plants.

4. Distribute the *Matter of Fact Notes* handout on page 38. Complete the handout with the class. As you review the different forms of nitrogen, show students examples using molecular models. Identify the type of atoms in each molecule.

5. Show students the Nitrogen Cycle diagram. Review each step of the nitrogen cycle.

6. Introduce the activity *What Goes Around, Comes Around*. Explain to students that there are seven different stations around the classroom. Each station represents a "reservoir" for nitrogen in the nitrogen cycle. Tell students that in this activity they will act as nitrogen atoms moving through the nitrogen cycle. They will start as a pure form of nitrogen. In this form, they are a single atom. Hold up a single gumdrop. At each station students will role a die to determine how they will transform. Students will create a model of the different forms of nitrogen using the toothpicks and gumdrops provided at their starting station. They will take this model with them as they transform into different forms of nitrogen at each station. Have extra gumdrops on hand for construction of the models. Each color gumdrop will represent a different element, the toothpicks will represent chemical bonds. Students should record the information from each station on their *What Goes Around, Comes Around* chart. Students may use the *Nitrogen Cycle* handout to identify each process in the cycle.

   Briefly review each station and tell students that you will give the signal to switch stations every five minutes and that they should rotate to different stations as determined by the roll of the die at each of their stations.

7. Instruct students to return to their desks and complete the *Think About It* section of the handout. Students may work in pairs. Answer any questions before releasing students to begin the activity.

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California Standards

Grade 8

Common Core English Language Arts

SL.8.1a
SL.8.1b
RST.8.3
RST.8 7
RST.8.9

Next Generation Science Standards

MS-PS1.A
MS-PS1.B
MS-LS2.A
MS-LS2.B
MS-LS2.C
MS-ESS3.C
MS-ETS1.B

Grades 9-12

Common Core English Language Arts

SL.9-12.1a
SL.9-12.1b
RST.9-12.3
RST.9-12.7

Next Generation Science Standards

HS-ESS2.E
HS-ESS3.A
HS-ESS3.C

8. As a class, review the *Think About It* section of the handout. Lead a class discussion to highlight the following "big picture" concepts:
   a. There is a limited amount of nitrogen in the environment. Nitrogen changes forms as it moves through different stages of the nitrogen cycle.
   b. Nitrogen does not move through the cycle as a single atom, but in stable compound and molecule forms.
   c. Bacteria play an important role in ammonification, denitrification, fixation, and nitrification. Without bacteria, the nitrogen cycle would cease to be a productive cycle.

Part II: Review

1. Prior to the review activity, divide the class into two equally sized groups based on an observable trait. For example, distribute paper streamers or divide the group by gender.
2. Introduce students to the review activity, *Molecular Shuffle*. Explain that in this activity, you will reveal different molecular formulas, including atoms, molecules, and compounds. After each chemical formula is revealed, students will scramble to create a group that accurately represents the atoms in the chemical formula.
3. For example, if the formula NO (nitric oxide) is revealed, a student with a green paper streamer will link arms with a student who has a blue paper streamer, to represent the two different elements bonded together. If the formula is H_2O (water) two green and one blue or two blue and one green will link together. If a student is unable to find a group they are "out" and can watch the activity from the sidelines. Any incomplete groups are also "out." If you announce a single atom, the students must stand at attention and yell "I'm an atom!"
4. Play the review activity, incorporating each form of nitrogen. Supporting presentation slides for the *Molecular Shuffle* may be downloaded from *www.LearnAboutAg.org/chemistry.*

Extensions

- Have students plan and construct a three-dimensional nitrogen cycle diagram using common household items or craft supplies.

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- Watch an educational video that illustrates the nitrogen cycle. Search YouTube using the term "Nitrogen Cycle."
- Have students create a "mind map" to visually organize information. Several online tools, such as *www.mindmeister.com* and *www.mindomo.com* offer real-time collaboration in order to have a concept map that the whole class can edit at the same time.

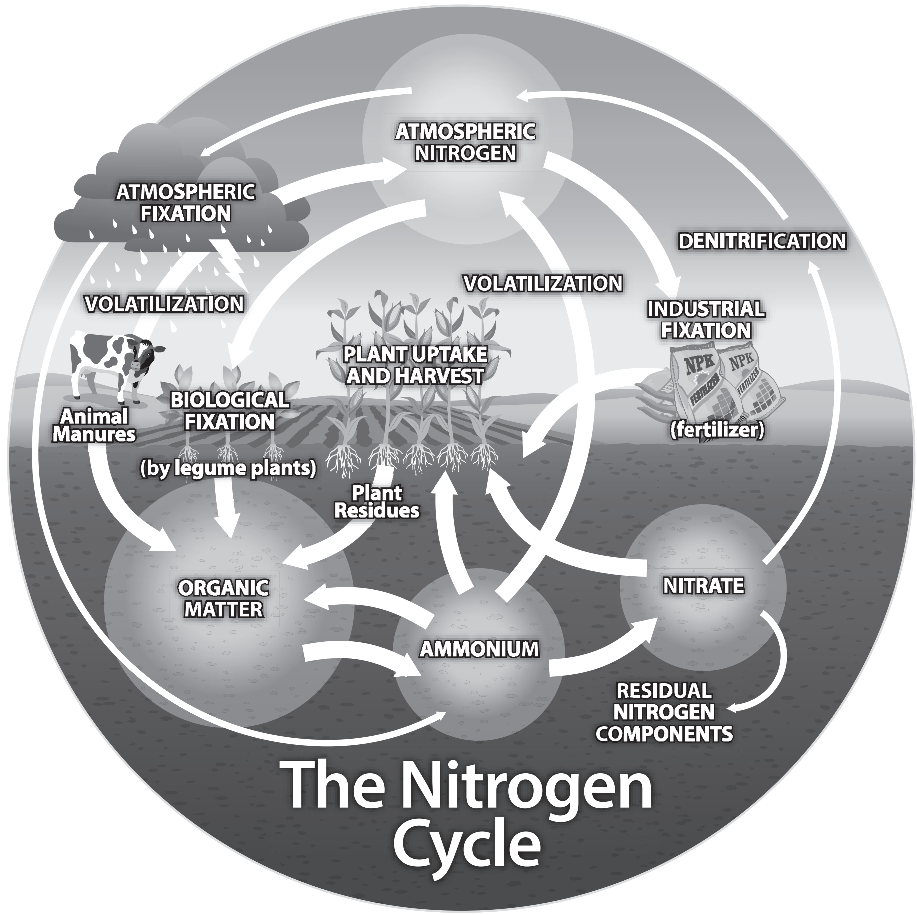
Variations

- Instruct students to use arrows and symbols to record their movement through the nitrogen cycle. Combine each student's unique path using different colors on a shared class diagram.
- Make the review activity, *Molecular Shuffle*, increasingly challenging. As students become familiar with the different forms of nitrogen, call out the name of the molecule only. Students must determine the chemical formula quickly before gathering into groups. Add oral responses for students to categorize elements as micro or macro nutrient, or increase the complexity of chemical formulas, using examples like calcium nitrate $Ca(NO_3)_2$.

ELL Adaptations

- The addition of the complex terms and science concepts can make learning even more difficult. Write down key terms so students can see them and connect them to the spoken word.
- Demonstrate activities in front of class to ensure that English language learners can see the procedures before engaging in an activity. Pair ELL students with partners who are English proficient and have a good understanding of topics being taught in class.

Nitrogen Cycle



- **Ammonification**: Bacteria or fungi convert organic forms of nitrogen (mostly from plant and animal waste) into ammonium NH_4^+, which can be used by plants.
- **Assimilation**: Living organisms take up nitrogen to be used for biological processes such as making chlorophyll, proteins, and enzymes.
- **Denitrification**: Under poor aeration, soil bacteria convert nitrate ions NO_3^- into nitrogen gas N_2, which cannot be used by plants and is lost to the atmosphere.
- **Fixation**: Bacteria convert nitrogen gas N_2 into ammonium NH_4^+ or nitrate NO_3^- that living organisms can assimilate. Rhizobium bacteria have the unique ability to fix nitrogen through metabolic processes. These bacteria form symbiotic relationships with plants in the legume family. Nitrogen gas can also be converted to forms that plants can use through the production of commercial fertilizers.
- **Nitrification**: Soil bacteria convert ammonium NH_4^+ into nitrate NO_3^- ions. Oxygen is needed for this process, therefore, nitrification takes place in the top layers of soil and flowing water. Nitrates can be used by plants.
- **Physical movement**: The physical movement of any form of nitrogen, which may include tilling (moving under the soil), leaching (moving through the soil), carrying (to transport via water), or runoff (the flow of water over land). No chemical process is involved in physical movement.

Matter of Fact Notes

Name: ____

1. ______________________ is anything that has ________________and takes up ________________________.
2. An ____________________________ is the smallest component of an element.

   Examples:

3. A ___________________ is the smallest particle of a pure ________________________ that has the properties of that substance. Also known as two or more atoms of the same type joined together by chemical bonds.

   Examples:

4. A _________________________ is a substance made up of atoms of ________________________ elements. There are relatively few chemical elements, but there are ___________________ of chemical compounds.

   Examples:

5. All compounds are molecules, but not all molecules are compounds. Explain why you think this statement is true or false.

   ____

   ____

   ____

6. A ___________________________ is a concise written description of the components of a chemical compound. It identifies the ________________________ in the compound by their symbols and describes the number of atoms of each element with _________________________. No subscript is used if one atom of an element is present.

   Example:

Matter of Fact Notes Answer Key

1. ______*Matter*________ is anything that has _____*mass*_____and takes up ______*space*_____.

2. An ______*atom*______ is the smallest component of an element.

Examples:

H *Hydrogen*	*N* *Nitrogen*	*Na* *Sodium*

3. A _____*molecule*_______ is the smallest particle of a pure _____*substance*__________ that has the properties of that substance. Also known as two or more atoms of the same type joined together by chemical bonds.

Examples:

N_2 *Nitrogen Gas*	H_2 *Hydrogen Gas*	O_2 *Oxygen Gas*

4. A _____*compound*____ is a substance made up of atoms of ____*at least two different*_______ elements. There are relatively few chemical elements, but there are ____*millions*______ of chemical compounds.

Examples:

H_2O *Water*	NH_4^+ *Ammonium*	NO_3^- *Nitrate*

5. All compounds are molecules, but not all molecules are compounds. Explain why you think this statement is true or false.
Answers may vary. Oxygen gas O_2 and Nitrogen gas N_2 are not considered compounds because they are each composed of the same element. Water H_2O is a compound because it is composed of more than one element.

6. A _____*chemical formula*____________ is a concise written description of the components of a chemical compound. It identifies the _______*elements*__________ in the compound by their symbols and describes the number of atoms of each element with ________*subscripts*__________. No subscript is used if one atom of an element is present.

Example:

$C_6H_{12}O_6$ Glucose

What Goes Around Comes Around

Name: ____________________

In this activity, you will take on the role of a nitrogen atom and experience how nitrogen cycles through the environment. Record each step of the journey in the chart below and assemble models out of gumdrops and toothpicks.

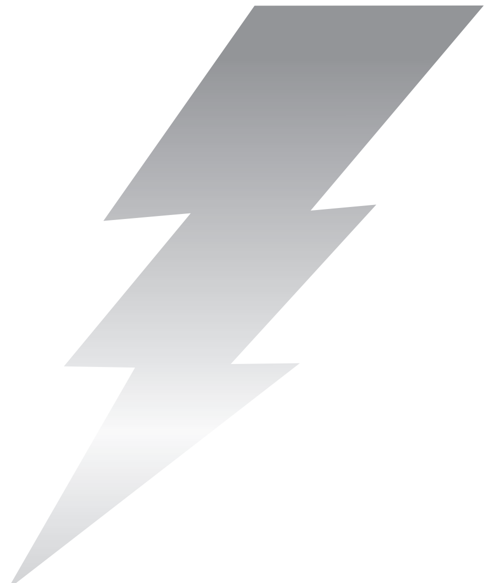
Station	Starting Location	Starting Form	Process	What Happened?	Ending Location	Ending Form	Atom, Compound, or Molecule?
Ex	Fertilizer	NO_3^-	Denitrification	Bacteria convert to nitrogen gas	Atmosphere	N_2	Molecule
1							
2							
3							
4							
5							
6							
7							

Think About It!

Complete all seven station rotations before answering the following questions.

1. How many different forms of nitrogen did you become in this cycle?
2. Explain how plants obtain nitrogen.
3. Explain how humans and animals obtain nitrogen.
4. Although you started as a single nitrogen atom (N) you never returned to a single nitrogen atom in this cycle. Why?
5. Explain the role of bacteria in the nitrogen cycle.
6. Predict what would happen if the bacteria population in an ecosystem decreased suddenly.
7. We know that matter cannot be destroyed. Hypothesize what happened to the atoms that were "lost" during some of the transformations.
8. How could human activity adversely or beneficially affect the natural cycling of nitrogen in the environment? Identify one realistic example and explain how the nitrogen cycle would be affected.

Atmosphere Station



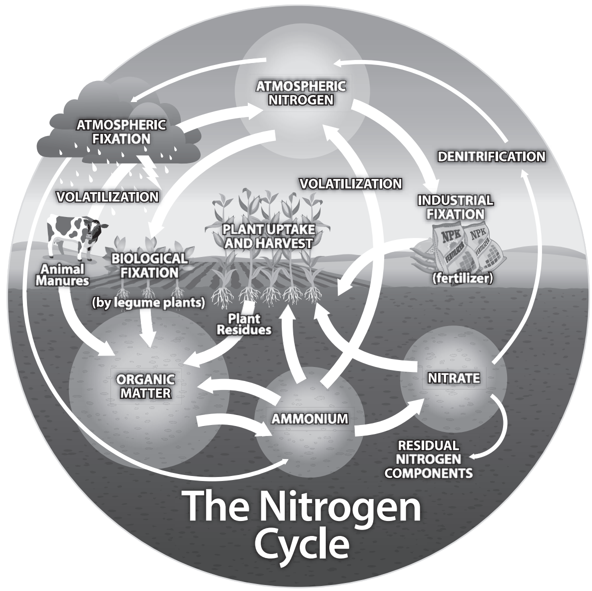
Starting Form: N_2

Dice Roll		Next Station
1 or 2	Lightning fixes atmospheric nitrogen N_2 in the atmosphere, which is carried by rain to a body of water NH_4^+.	Body of Water
3 or 4	Agriculture fixes millions of tons of atmospheric nitrogen N_2 for use as fertilizer NH_4^+.	Fertilizer
5 or 6	Bacteria in legumes convert nitrogen gas N_2 to a form plants can use NH_4^+, which is added to the soil.	Soil

Instructions

- Roll the die to select your path. Fill out your chart for that path.
- Use the toothpicks and gumdrops to make a model of the starting form of nitrogen and what it changed into. Take this model with you to your next station. You will use it to model the different forms of nitrogen throughout this lab.
- When time is up, move to the next station.

Soil Station



Starting Form: NH_4^+ or NO_3^-

Dice Roll		Next Station
1 or 2	Your neighbor doesn't follow the instructions when applying lawn fertilizer. Excessive watering after application leaches nitrate NO_3^- into the groundwater.	Groundwater
3 or 4	Bacteria in the soil convert ammonium NH_4^+ into nitrate NO_3^- and it remains in the soil.	Stay at soil
5 or 6	The nitrate in the soil NO_3^- is taken up by lettuce plants.	Plant

Instructions

- Roll the die to select your path. Fill out your chart for that path.
- Use the toothpicks and gumdrops to make a model of the starting form of nitrogen and what it changed into. Take this model with you to your next station. You will use it to model the different forms of nitrogen throughout this lab.
- When time is up, move to the next station.

Fertilizer Station

Starting Form: NH_4^+ or NO_3^-

Dice Roll		Next Station
1 or 2	The right amount of fertilizer is applied to the soil and taken up by plants NH_4^+ and NO_3^-.	Plant
3 or 4	High concentrations of pet waste in urban parks and neighborhoods may lead to nutrient movement into the groundwater (NO_3^-).	Groundwater
5 or 6	The fertilizer is consumed by soil bacteria, which, under anaerobic conditions, convert the nitrate into nitrogen gas N_2 which is released into the atmosphere.	Atmosphere

Instructions

- Roll the die to select your path. Fill out your chart for that path.
- Use the toothpicks and gumdrops to make a model of the starting form of nitrogen and what it changed into. Take this model with you to your next station. You will use it to model the different forms of nitrogen throughout this lab.
- When time is up, move to the next station.

Plant Station

Starting Form: Organic N

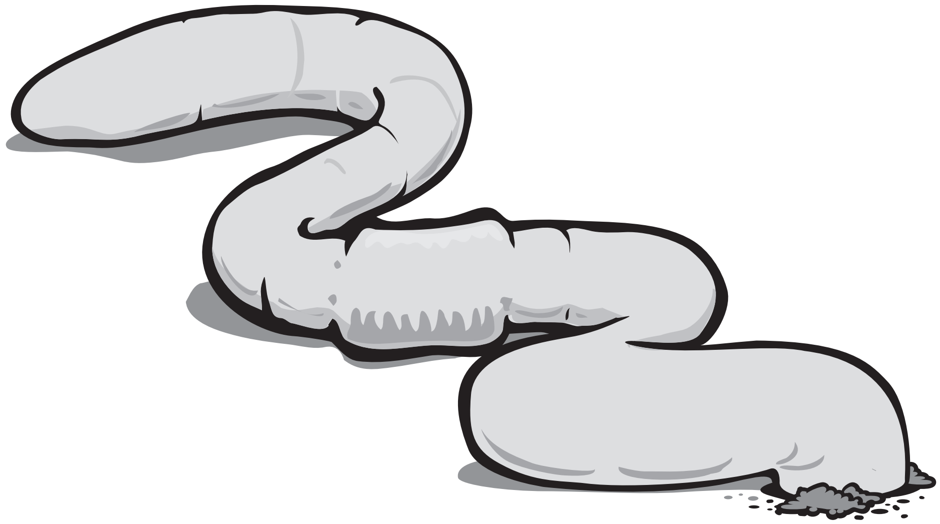
When NH_4^+ or NO_3^- is assimilated by a plant, we use the term "organic nitrogren" to describe the nitrogen compounds in the plant. These nitrogen compounds include many types of proteins, or by-products of protein digestion, such as urea and ammonium.

Dice Roll		Next Station
1 or 2	The inedible part of the plant is tilled into the ground, bacteria decompose the plant material NH_4^+.	Soil
3 or 4	A human eats the edible part of the plant, assimilates the nitrogen, and produces waste NH_4^+.	Waste/Decay
5 or 6	An animal eats the plant, assimilates the nitrogen, and produces waste NH_4^+.	Waste/Decay

Instructions

- Roll the die to select your path. Fill out your chart for that path.
- Use the toothpicks and gumdrops to make a model of the starting form of nitrogen and what it changed into. Take this model with you to your next station. You will use it to model the different forms of nitrogen throughout this lab.
- When time is up, move to the next station.

Waste/Decay Station



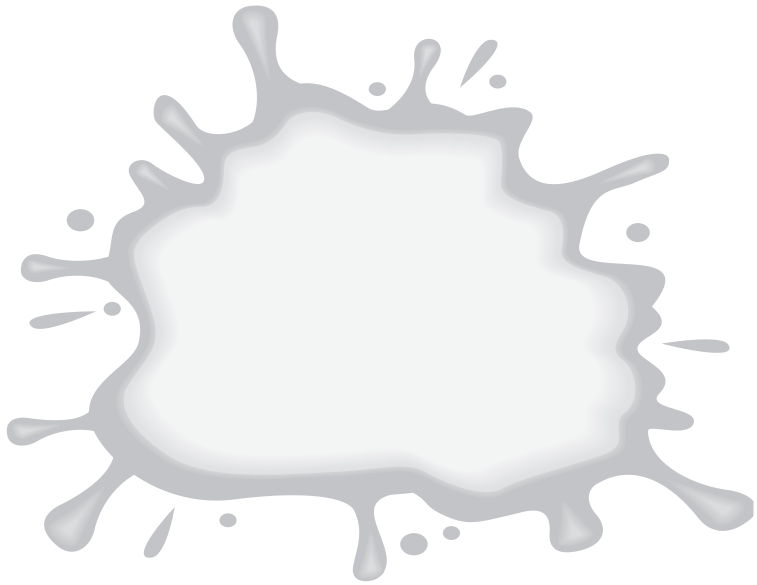
Starting Form: Organic N or NH_4^+

Dice Roll		Next Station
1 or 2	Waste and decaying materials (organic N) are composted by humans and used as fertilizer (NH_4^+)	Fertilizer
3 or 4	A malfunction at the city sewage treatment plant leads to run off into a body of water (NH_4^+).	Body of Water
5 or 6	Bacteria convert the nitrogen found in waste and decaying materials into ammonium, which remains in the soil (NH_4^+).	Soil

Instructions

- Roll the die to select your path. Fill out your chart for that path.
- Use the toothpicks and gumdrops to make a model of the starting form of nitrogen and what it changed into. Take this model with you to your next station. You will use it to model the different forms of nitrogen throughout this lab.
- When time is up, move to the next station.

Body of Water Station



Starting Form: NO_3^- or NH_4^+

Dice Roll		Next Station
1 or 2	Over time, nitrates NO_3^- from an old septic system may slowly leach into groundwater.	Groundwater
3 or 4	Nitrogen in the water is taken up by aquatic plants (NH_4^+).	Plant
5 or 6	Bacteria, in the process of denitrification under anaerobic conditions, convert nitrogen in a pond into atmospheric nitrogen N_2 which is released into the atmosphere.	Atmosphere

Instructions

- Roll the die to select your path. Fill out your chart for that path.
- Use the toothpicks and gumdrops to make a model of the starting form of nitrogen and what it changed into. Take this model with you to your next station. You will use it to model the different forms of nitrogen throughout this lab.
- When time is up, move to the next station.

Groundwater Station

Starting Form: NO_3^-

Dice Roll		Next Station
1 or 2	Underground aquifers carry the water underground until it reaches a body of water (NO_3^-)	Body of Water
3 or 4	Groundwater is pumped from underground through a well and applied to the soil (NO_3^-).	Soil
5 or 6	Bacteria, in the process of denitrification, convert nitrate NO_3^- in groundwater into atmospheric nitrogen N_2 which is released into the atmosphere.	Atmosphere

Instructions

- Roll the die to select your path. Fill out your chart for that path.
- Use the toothpicks and gumdrops to make a model of the starting form of nitrogen and what it changed into. Take this model with you to your next station. You will use it to model the different forms of nitrogen throughout this lab.
- When time is up, move to the next station.

What Goes Around Comes Around Answer Key

Station	Starting Location	Starting Form	Process	Ending Location	Ending Form	Atom, Molecule, or Compound
Atmosphere 1	Atmosphere	N_2	Fixation	Body of Water	NH_4^+	Molecule to Compound
Atmosphere 2	Atmosphere	N_2	Fixation	Fertilizer	NH_4^+	Molecule to Compound
Atmosphere 3	Atmosphere	N_2	Fixation	Soil	NH_4^+	Molecule to Compound
Soil 1	Soil	NO_3^-	Physical Movement	Groundwater	NO_3^-	Compound to Compound
Soil 2	Soil	NH_4^+	Nitrification	Soil	NO_3^-	Compound to Compound
Soil 3	Soil	NO_3^-	Assimilation	Plants	Organic N	Compound to Compound
Fertilizer 1	Fertilizer	NH_4^+	Assimilation	Plants	Organic N	Compound to Compound
Fertilizer 2	Fertilizer	NO_3^-	Physical Movement	Groundwater	NO_3^-	Compound to Compound
Fertilizer 3	Fertilizer	NO_3^-	Denitrification	Atmosphere	N_2	Compound to Molecule
Plants 1	Plants	Organic N	Physical Movement	Soil	NH_4^+	Compound to Compound
Plants 2	Plants	Organic N	Assimilation	Waste/Decay	NH_4^+	Compound to Compound
Plants 3	Plants	Organic N	Assimilation	Waste/Decay	NH_4^+	Compound to Compound
Waste/Decay 1	Waste/Decay	Organic N or NH_4^+	Ammonification	Fertilizer	NH_4^+	Compound to Compound
Waste/Decay 2	Waste/Decay	Organic N or NH_4^+	Physical Movement	Body of Water	NH_4^+	Compound to Compound
Waste/Decay 3	Waste/Decay	Organic N or NH_4^+	Ammonification	Soil	NH_4^+	Compound to Compound
Body of Water 1	Body of Water	NO_3^-	Physical Movement	Groundwater	NO_3^-	Compound to Compound
Body of Water 2	Body of Water	NO_3^-	Assimilation	Plants	Organic N or NH_4^+	Compound to Compound or Molecule
Body of Water 3	Body of Water	NO_3^-	Denitrification	Atmosphere	N_2	Compound to Molecule
Groundwater 1	Fertilizer	NO_3^-	Physical Movement	Body of Water	NO_3^-	Compound to Compound
Groundwater 2	Fertilizer	NO_3^-	Physical Movement	Soil	NO_3^-	Compound to Compound
Groundwater 3	Fertilizer	NO_3^-	Denitrification	Atmosphere	N_2	Compound to Molecule