Lesson to Grow

Exploring the Nitrogen Cycle through Aquaponics

Description:

Students investigate the growing of food through an aquaponics system and the symbiotic relationship between plants and fish.

Grade Level: 9-12

Essential Skills:
5, 6

NGSS: HS-LS2-7

CCSS:
11-12.RST.3, 11-12.RST.5, 11-12.RST.7, 11-12.WHST.6

Time: 1 Week +

Materials:
- Aquaponics System which can either be purchased or made
- *What do plants need to grow?**
- *Understanding the Nitrogen Cycle**
- *Tracking changes**

** Worksheets provided in unit materials*

AITC Library Resources:

Videos:
Live, Local, Organic Virtual Field Trip

Books:
Science with Plants
Growing Food
Careers in Agriculture Packets

More Lessons:
Hungry Plants
Propagation & Regeneration in Plants

Background:

As the global population grows, simultaneously the amount of available farmland decreases. The challenge of feeding more individuals on less land becomes very real and relevant. Aquaponics presents one possible solution as it incorporates both plants and animals into one system and leaves little waste. There are two basic ideas coming together for aquaponics—growing plants without soil and raising fish. This differs from hydroponics which does not include fish. In an aquaponics system, fish are fed and then excrete solid waste that is converted to ammonia by bacteria in the system. Ammonia is toxic to fish and a build up in the tank may cause the fish to die. Beneficial nitrifying bacteria convert the ammonia to less toxic nitrate, which is readily absorbed by the plants growing in the grow tray. By cycling the ammonia and nitrate filled water to the plants, the plants remove these forms of the nitrogen from the water, and use them to grow. The water then filters down through the grow tray and returns to the tank, giving the fish fresh clean water to live in. Both the needs of the plants and fish work together in an aquaponics system, providing larger world applications of how this industry will only grow in the future. Aquaponics is one sustainable method of food production. Aquaponics systems are environmentally responsible with low water usage and relatively low power usage.

Directions:

Part I: Introduction to Aquaponics

1. Ask your students to imagine a farm. What things are on the farm? *Animals, plants, tractors/equipment, land.* Record responses on the board.
2. When space is a problem, then what can we do? *With a growing population, we have less and less land for growing food.*
3. What are some other ways we can grow food?
4. Provide students a couple minutes to research what it looks like to farm without using land. What methods exist? *Vertical Farming, Aeroponics, Hydroponics Aquaponics...*
5. Introduce the concept of aquaponics and ask students to define it.

The art of growing plants in nutrient rich water—those nutrients are provided by the fish. This method uses less water and land than traditional agriculture. This is a benefit because farmland is limited. Often the fish provide a protein source as well, which relieves pressure on ocean fisheries. Once established, a symbiotic relationship is developed and the only input is food for the fish!

5. Introduce students to aquaponics production by watching this tour of an aquaponics operation: bit.ly/3xpOiUm
6. After watching the video discuss the following questions with students:
    a) What purpose do the fish serve?
    b) Which species of fish do they use?
    c) Does water move around? Why or why not?

Part II: Looking Deeper at Water, Nitrogen Cycle and Fish Working Together
Section A: Plant needs

1. Explain to students no matter the size of the system there are needs to consider for every living creature. *In this section, we will look at the needs of plants. All plants are critical for sustaining life in humans and animals. This covers everything from fruits, nuts, leafy greens and herbs that we may grow in our aquaponics system.*
2. Provide each student with a copy of the *What Do Plants Need to Grow?* worksheet. Instruct students to cut out the plant needs cards. Then, have students place the cards in the chart on the *What Do Plants Need to Grow?* worksheet to describe which of the plant's needs the card is describing.
3. After, discuss the following questions:
    a) How does the aquaponics system meet the needs of plants?
    b) What, if any, adjustments need to be made to grow plants without soil?
    c) Are there any needs that are not provided by the naturally occurring aquaponics system?
    d) How does the care of plants change in an aquaponics system compared to growing plants in soil?

Section B: The Nitrogen Cycle

1. Explain to students that many of the world's resources are not available for use by plants or animals: only one percent of the Earth's water is drinkable. Two percent of the water on earth is glacier ice at the North and South Poles. Although 80 percent of the Earth's atmosphere is made of nitrogen—this form (N 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.
2. Have students brainstorm reasons why the other 99 percent might not be available for consumption. Record answers on the board. After some time, explain that 97 percent of water on Earth is salt water. Similar to the availability of water, some plant nutrients are not easily used by plants. Plants need nitrogen but a lot of the available nitrogen is used by them. How is it Used?
3. Students will discover more about the Nitrogen Cycle through filling in the missing pieces of the *Understanding the Nitrogen Cycle* Worksheet. In the worksheet students will read a description of how the cycle works and use context clues to identify where each portion fits into the cycle. Students can research the cycle further if they can not fill in everything.
4. Have students create a nitrogen cycle diagram for an aquaponics system using the aquaponics system (Resource Page). Ask key questions:
    a) Is this an improvement for the environment?
    b) There are four circles within this graphic, what reason are the three at the bottom different sizes?
    c) Bonus: What is the equation of the nitrogen cycle?

Testing Nitrogen Levels

Day 1

1) As you initially set up the system, use test strips to measure the levels of ammonia (NH_3), nitrite (NO_2) and nitrate (NO_3) in the tank and record the amounts in the Aquaponics Daily Log Table worksheet.
2)Add fish to the system. It's recommended to start with just one beta fish but you can experiment with this or try one round with beta and another with goldish. Once the initial cycle is stable, add more fish incrementally until you have an adequate bioload (generalized term for the amount of life existing in an aquarium) for the system.

Information on Bioload:
If the bioload is creating more waste than your system can handle, then the Nitrogen Cycle is out of balance, leading to problems in your aquarium. The bioload in your aquarium is too high when ammonia and nitrites are being produced faster than the bacteria in your filter can convert them to nitrates.

Fortunately, this is easy to test since ammonia and nitrite levels should be 0 ppm. Any indications of ammonia or nitrites –after your tank has cycled– could indicate the bioload is too large for your aquarium. If this is the case, you have two options:

a) Get a larger filter or
b) Decrease the size or quantity of fish

Measure NH_3, NO_2, NO_3, and pH levels of the water that the fish came in, record the data in the table on the worksheet.

For more information on setting up the Back to the *Roots Water Garden* visit this video: https://youtu.e/3c1cbBwill8

Day 2 +

1)Measure NH_3, NO_2, NO_3, and pH levels of the Back to the Roots aquarium water and record on your table.
2) Repeat the four tests 2-3 times a week for the next three or four weeks. Make sure to run the tests at the same time daily, before the fish are fed. The initial cycle will be completed when ammonia (NH_3) and nitrite (NO_2) levels are both at zero.
3)Record results using the worksheet provided in this lesson or have students create a spreadsheet.
4) After several days of data have been collected, have the students graph the results.

After testing is complete and you and your students feel comfortable with the system, use it to grow some herbs, leafy greens or sprouts.

Activity Page

What Do Plants Need to Grow?

Name_____

Directions: Place the cards in the correct row based on the label at the top of each card. Then, arrange the cards in each row based on which plant needs it's describing: water, air, nutrients or light.

Water	Air	Nutrients	Light

Resource Page

Plant Needs Cards

Directions: Cut out each of the cards below and attach them to the *What do Plants Need to Grow* worksheet.

Rarely Seen	Comprised of the elements $O + CO_2 + N$ Vapors and other gases	Comprised of the elements $H + O$	Often come from the breakdown of organic matter.
Over 70 percent of the earth is covered by _____.	Comes in 3 forms.	Holes in plant matter allow this to enter.	Used to irrigate farmland or plants in your aquaponic system.
Your body inhales this and exhales CO_2	Vitamins for plants.	Helps to make vision possible.	Found in soil.
Used with CO_2 and H_2O to perform Photosynthesis.	Capture this energy to make food.	Also referred to as fertilizer.	Energy

Activity Page

Understanding the Nitrogen Cycle

Name_____

Directions: Fill in the missing pieces of the Nitrogen Cycle below. When complete answer the questions on the following page. Use the information provided to help.

Nitrogen plays a significant role in a plant's growth and development. The atmosphere has a significant amount of nitrogen (approximately 75%) in the form of N_2. The process by which molecular nitrogen in the air is converted into ammonium (NH_3) is known as **Atmospheric Fixation.** Plants get their nitrogen in a fixed form such as nitrate ions, **ammonium**, or urea. Animals, which create **manure**, get their nitrogen from plants or from animals that have eaten plants, also known as **organic matter**. Through their roots, plants can take up some forms of nitrogen such as ammonia-nitrogen, but most plants get nitrogen that has been further processed by nitrifying bacteria. If this process is not balanced then nitrites or nitrate can be released into the air in a process known as **denitrification**.

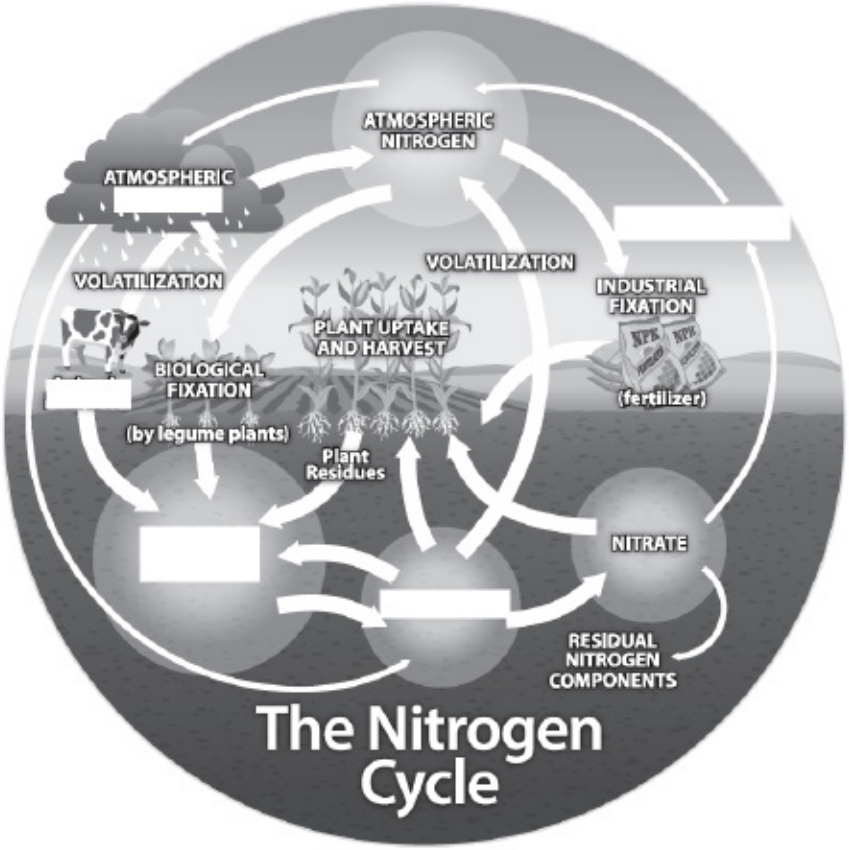


Image Source: Purdue University

Activity Page

Understanding the Nitrogen Cycle

Name_____

Directions: Reimagine this cycle using the aquaponics system. Work with a partner to create this cycle using an aquaponics system. Use the space below to make your diagram. Be sure to answer the questions at the bottom after.

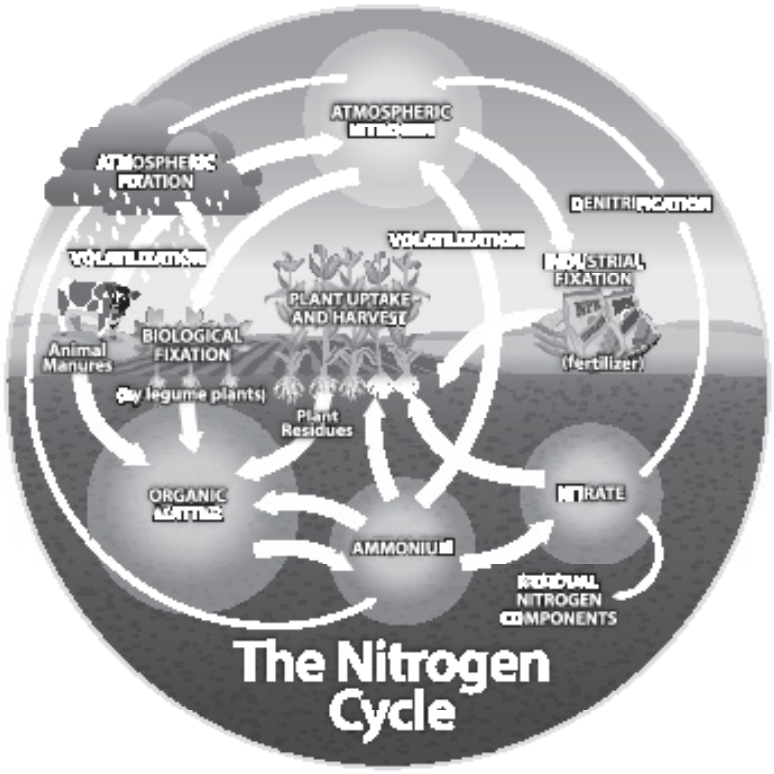
1) How does this system compare? What role do the fish play?

2)What are two major differences between the conventional Nitrogen Cycle and aquaponics?

Activity Page Answer Key

Understanding the Nitrogen Cycle

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.

Image Source: leaffin.com/cycle-new-aquaponics-system/

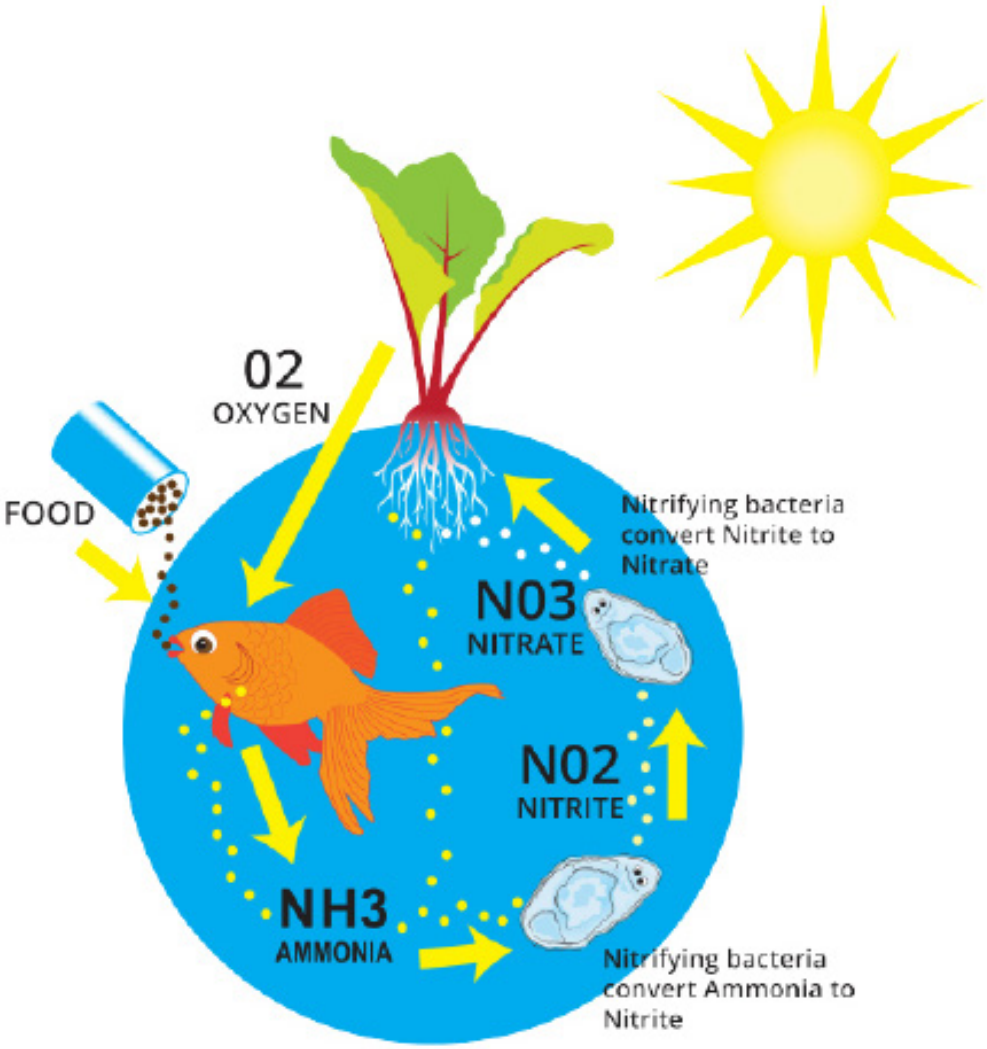
Aquaponics System Daily Log

Directions: Use a testing kit and record the daily levels withing your Aquaponics system. Make sure to test at the same time each day, before the fish are fed for consistent results

PH Level													
Nitrate Level													
Nitrite Level													
Ammonia Level													
Date Taken													
Time	Day 1												

Resource Page

Understanding the Nitrogen Cycle



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