Lesson 7: The Nitrogen Cycle

California Education Standards:

Kindergarten, Earth Sciences
3. Earth is composed of land, air, and water. As a basis for understanding this concept:
   c. Students know how to identify resources from Earth that are used in everyday life and understand that many resources can be conserved.

Grade 1, Physical Sciences
1. Materials come in different forms (states), including solids, liquids, and gases. As a basis for understanding this concept:
   a. Students know solids, liquids, and gases have different properties.
   b. Students know the properties of substances can change when the substances are mixed, cooled, or heated.

Grade 2, Investigation and Experimentation
4. Scientific process is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:
   d. Write or draw descriptions of a sequence of steps, events, and observations.

Grade 3, Physical Sciences
   e. Students know matter has three forms: solid, liquid, and gas.

Grade 4, Life Sciences
2. All organisms need energy and matter to live and grow. As a basis for understanding this concept:

   b. Students know producers and consumers (herbivores, carnivores, omnivores, and decomposers) are related in food chains and food webs and may compete with each other for resources in an ecosystem.
   c. Students know decomposers, including many fungi, insects, and microorganisms, recycle matter from dead plants and animals.

**Grade 5, Physical Sciences**
1. Elements and their combinations account for all the varied types of matter in the world. As a basis for understanding this concept:

   a. Students know that during chemical reactions the atoms in the reactants rearrange to form products with different properties.

**Grade 6, Ecology (Life Sciences)**
5. Organisms in ecosystems exchange energy and nutrients among themselves and with the environments. As a basis for understanding this concept:

   b. Students know matter is transferred over time from one organism to others in the food web and between organisms and the physical environment.
   e. Students know the number and types of organisms an ecosystem can support depends on the resources available and on abiotic factors, such as quantities of light and water, a range of temperatures, and soil composition.

**Grade 8, Chemistry of Living Systems (Life Sciences)**
6. Principles of chemistry underlie the functioning of biological systems. As a basis for understanding this concept:

   b. Students know that living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur.

**Objective:**
Students understand the different phases of nitrogen and each stage of the nitrogen cycle. Students should know that the nitrogen cycle plays an important part in the ecosystem and it interacts with plants and microorganisms in a mutually beneficial way.

**Vocabulary:**
Nitrogen – a chemical element in gas form
Autotroph – organisms that obtain energy for life from solar energy or the oxidation of inorganic elements such as nitrogen, sulfur, and iron
Nitrification – the process when ammonia is oxidized into nitrate
Nitrogen Cycle – the process by which nitrogen is converted between its various chemical forms
**Heterotroph** – organisms that obtain energy only from the decomposition of organic compounds
**Denitrification** – the process when nitrate is ultimately converted back to nitrogen in the atmosphere
**Nitrogen Fixation** – the process when the nitrogen in the atmosphere is converted to ammonia due to interaction with microorganisms
**Chemoautotroph** – a kind of autotroph that obtains energy solely from oxidation
**The Haber-Bosch** – the conversion of nitrogen into ammonia through human processes

**Lesson:**
For many people, the only time they have to think about nitrogen is when staring down at the periodic table while taking a chemistry test. However, nitrogen plays a much bigger part in our lives than just a science test. **Nitrogen** is a chemical element in gas form. It is colorless, odorless, and tasteless. What is more important than these characteristics is how nitrogen plays a huge part in our ecosystem. First of all, we are surrounded by nitrogen everywhere we go! That is because almost 80 percent of the atmosphere consists of nitrogen (78% to be exact). Nitrogen can also be underneath the soil, as it changes from one form to another. The reason nitrogen has different phases is that plants and microorganisms require different forms of nitrogen in order to maintain their healthy growth and reproduction. In the end, this process is essential to sustain the ecosystem. The different stages of this process allow nitrogen to recycle through the ecosystem, and this cycle of conversion is called the **nitrogen cycle**.

Nitrogen is essential for plant growth. It is a basic nutrient found in young healthy plants. Nitrogen is also a major component of chlorophyll, the compound by which plants use sunlight energy to produce sugars from water and carbon dioxide. Chlorophyll is also the reason why plants are green. So without a sufficient amount of nitrogen in chlorophyll, plants can have all kinds of deficiencies. Examples include stunted growth and yellow leaves.
Nitrogen has three main stages that complete the cycle: nitrogen fixation, nitrification, and denitrification.

**Nitrogen fixation** is the process when the nitrogen in the atmosphere is converted to ammonia due to interaction with microorganisms. These microorganisms consume the nitrogen in the atmosphere as a form of nutrient and give out ammonia. Microorganisms that consume this nitrogen are mainly categorized as either autotrophs or heterotrophs. **Autotrophs** are organisms that obtain energy for life from solar energy or the oxidation of inorganic elements such as nitrogen, sulfur, and iron. **Heterotrophs** are organisms that obtain energy only from the decomposition of organic compounds. Humans are considered heterotrophs. Nitrogen in the atmosphere is also consumed by plants as a form of nutrient.

**Nitrification** is the process when ammonia is oxidized into nitrate. This process is performed by microorganisms, specifically chemoautotrophs. **Chemoautotroph** is a kind of autotroph and is important in this process because they obtain energy solely from oxidation.
**Denitrification** is the process when nitrate is ultimately converted back to nitrogen in the atmosphere because of reduction of nitrates due to microorganisms, mainly heterotrophic bacteria.

When the nitrogen cycle goes through its normal process, both plants and microorganisms will be able to take the proper amount of nutrients that will allow them to flourish. However, if the nitrogen cycle is disturbed, there will be changes to the ecosystem that can be detrimental to both plants and animals within the environment. An example of such disturbance is industrial nitrogen input (e.g., vehicle emissions and power plant emissions). Excessive amounts of nitrogen can lead to an imbalance of nitrogen in the atmosphere, which can eventually cause acid rain, high ozone layer, and overall climate change.

Another serious issue caused by excess nitrogen is an increase in dead zones around the world. A dead zone is an area in oceans or large lakes that has no oxygen due to excessive nitrogen pollution. Because of anthropological disturbances, mainly factory emissions, excess nitrogen gets into the ocean and causes depletion of oxygen and increases in a chemical nutrient called eutrophication. This kind of nitrogen nutrient causes a rapid accumulation of algae. Low oxygen levels can also be dangerous for the marine habitat. Many marine animals will either die from not enough oxygen or migrate to a different area.
The Haber-Bosch Process is the conversion of nitrogen into ammonia through human processes. Although 78 percent of Earth’s atmosphere consists of nitrogen, it was not until the 1920s that scientist Fritz Haber came up with the practical solution to produce ammonia from atmospheric nitrogen. Carl Bosch, a German chemist, eventually took Haber’s invention and helped him expand this process into an industrial level production. Later, both Haber and Bosch were awarded Nobel prizes.

The Haber-Bosch Process led to a number of changes in human history. The most important is the mass production of fertilizer generated by ammonia, which sustains roughly one-third of the population in the world. This invention led to an overwhelming increase in population in the 20th century.

Materials:
Plants in pots (different stages of a plant)

Activities:
Activity 1:
Place several potted plants on the table, each representing a stage in a plant’s life cycle. On one end of the table, there should be a label that says “nitrogen” and on the other end there should be a label that says “carbon.”

The students will get into groups and try to put the potted plants in order. Their goal is to figure out which potted plant has the most nitrogen and which potted plant has the most carbon. They should record their explanations in their lab notebook.

Activity 2:
Divide students into groups. Each group takes a turn walking in the garden and trying to find plants that are nitrogen deficient. In their notebooks, they should write the reason why they think a plant is nitrogen deficient. After all have walked in the garden, have them compare answers and explain their reasoning.

Sources and Links:

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http://www.youtube.com/watch?v=AqE-0VPHWbM (video)
http://www.calepa.ca.gov/Education/EEI/Curriculum/Default.htm
http://www.ncagr.gov/cyber/kidswrld/plant/nutrient.htm