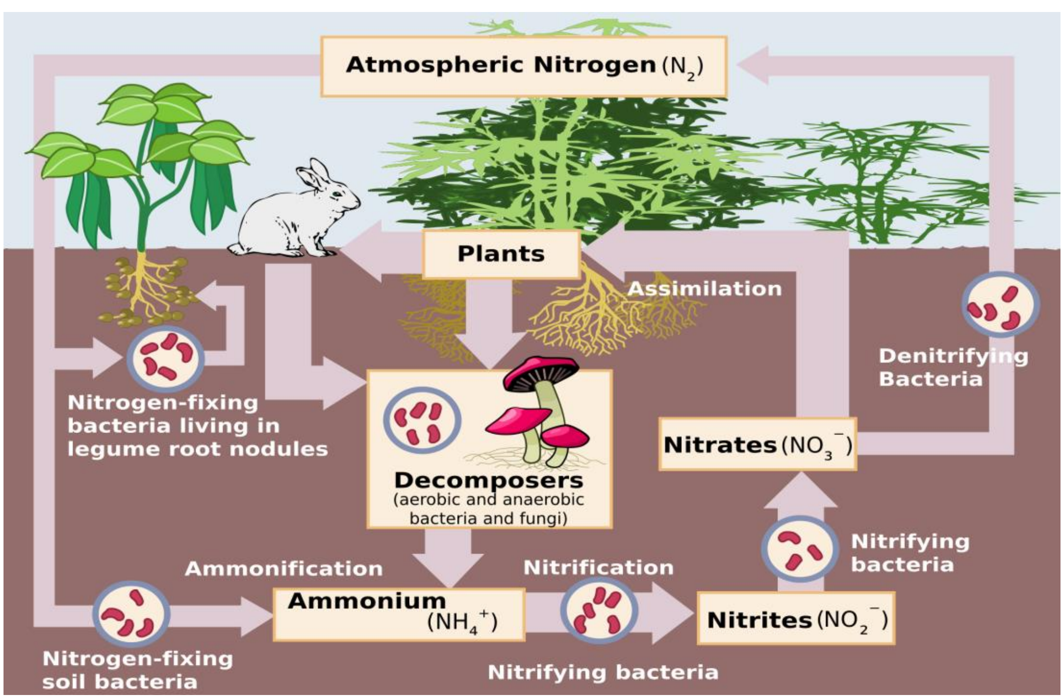
# TEACHER BACKGROUND:
# NITROGEN AND CLIMATE CHANGE

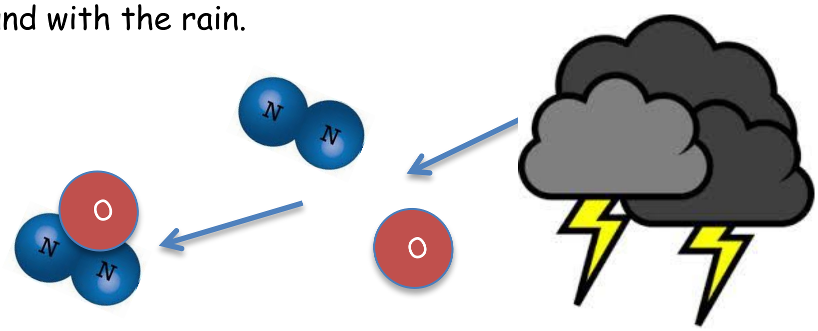
Nitrogen (N) is an essential component of DNA, RNA, and proteins, the building blocks of life. All organisms require nitrogen to live and grow. Although the majority of the air we breathe is $N_2$, most of the nitrogen in the atmosphere is unavailable for use by organisms. This is because the strong triple bond between the N atoms in $N_2$ molecules makes it relatively unreactive. However organisms need reactive nitrogen to be able to incorporate it into cells. In order for plants and animals to be able to use nitrogen, $N_2$ gas must first be converted to more a chemically available form such as ammonium $(NH_4+)$, nitrate $(NO_3-)$, or organic nitrogen (e.g. urea - $(NH_2)2CO$). The inert nature of $N_2$ means that biologically available nitrogen is often in short supply in natural ecosystems, limiting plant growth.

Nitrogen is an incredibly adaptable element, existing in both inorganic and organic forms as well as many different oxidation states. The movement of nitrogen between the atmosphere, biosphere, and geosphere in different forms is called the ***nitrogen cycle***, one of the major ***biogeochemical cycles***. Similar to the carbon cycle, the nitrogen cycle consists of various reservoirs of nitrogen and processes by which those reservoirs exchange nitrogen.



# THE STEPS IN THE NITROGEN CYCLE

1. **Atmospheric Nitrogen Fixation**- Lightning breaks nitrogen molecules ($N_2$) apart and combines them with oxygen ($O_2$) to form ***nitrogen oxides ($N_2O$)*** or with hydrogen (H) to form ***ammonia ($NH_3$)***. Nitrogen oxides dissolve in rain forming ***nitrates ($NO_3$)***. Nitrates are carried to the ground with the rain.



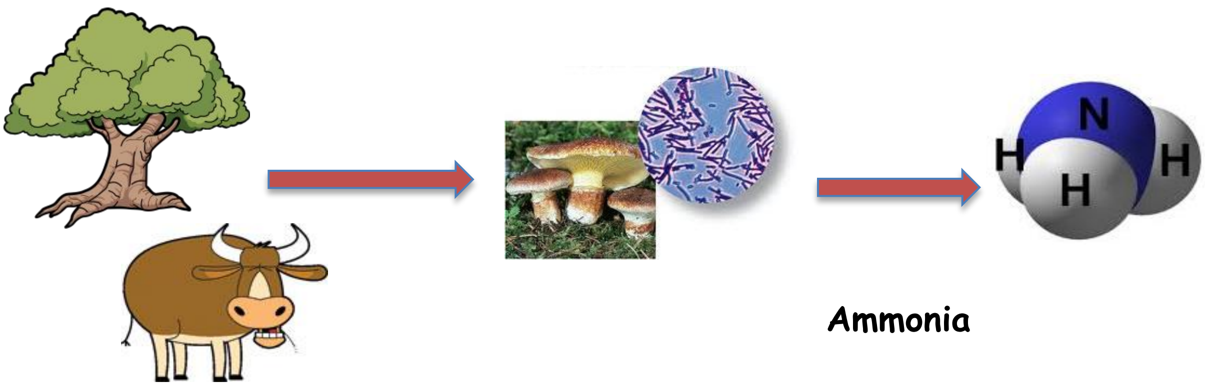

2. **Nitrification**-Most atmospheric nitrogen is "fixed" (made useable) and changed to ***ammonia ($NH_3$)*** by bacteria in the soil and attached to the roots of legumes (peas, beans, peanuts and soybeans). A few plants can use ammonia but most cannot. Through the process of nitrification, this problem is solved. Nitrifying bacteria change the ammonia in the soil to nitrites and then into nitrates. The nitrates are dissolved in water and absorbed through the roots of plants.

$$NH_4^{+} \longrightarrow NO_2^{-} \longrightarrow NO_3^{-}$$

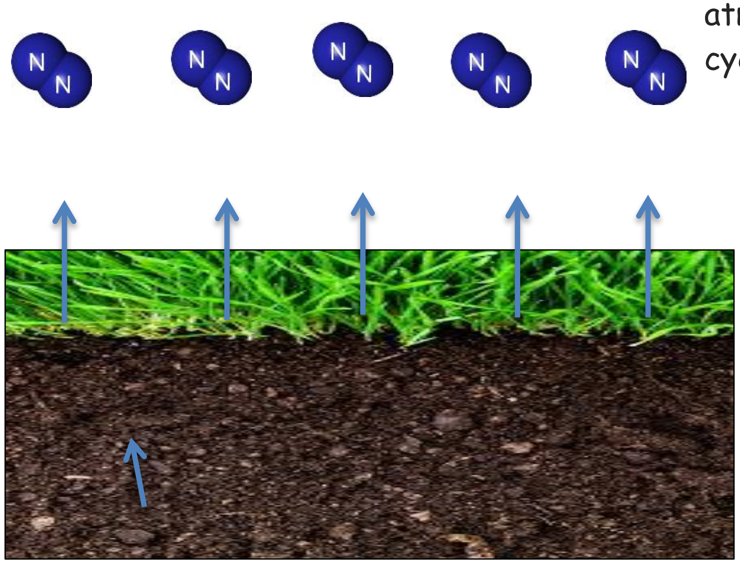
Ammonium → Nitrites → Nitrates

3. **Assimilation**- Assimilation in the process whereby plants absorb the nitrates and/or ammonium from the soil and use them to make proteins.

4. **Ammonification**-Decomposers (fungi and bacteria) convert the remains of dead plants and animals to ammonia plus other substances.




5. **Denitrification**- Nitrification occurs again, changing the ammonia back into nitrites and then nitrates. Denitrifying bacteria in the soil then change the nitrates into nitrogen gas ($N_2$), which is released back into the atmosphere to start the cycle again.



## HUMAN ALTERATION OF THE NITROGEN CYCLE

Human activities continue to increase the amount of nitrogen cycling between the living world and the soil, water, and atmosphere. This human-driven global change is having serious impacts on ecosystems around the world because nitrogen is essential to living organisms and its availability plays a crucial role in the organization and functioning of the world's ecosystems. In many ecosystems on land and sea, the supply of nitrogen is a key factor controlling the nature and diversity of plant life, the population dynamics of both grazing animals and their predators, and vital ecological processes such as plant productivity and the cycling of carbon and soil minerals. This is true not only in wild or unmanaged systems but in most croplands and forestry plantations as well. Excessive nitrogen can pollute ecosystems and alter both their ecological functioning and the living communities they support.

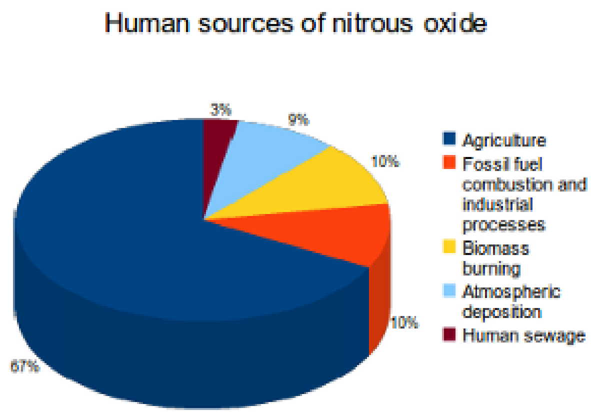
Most of the human activities responsible for the increase in global nitrogen are local in scale, from the production and use of nitrogen fertilizers to the burning of fossil fuels in automobiles, power generation plants, and industries. However, human activities have not only increased the supply, but also boosted the global movement of various forms of nitrogen through air and water. Because of this increased mobility, excess nitrogen from human activities has serious and long-term environmental consequences for large regions of the Earth.

The impacts of human interference in the nitrogen cycle that have been identified with certainty include:

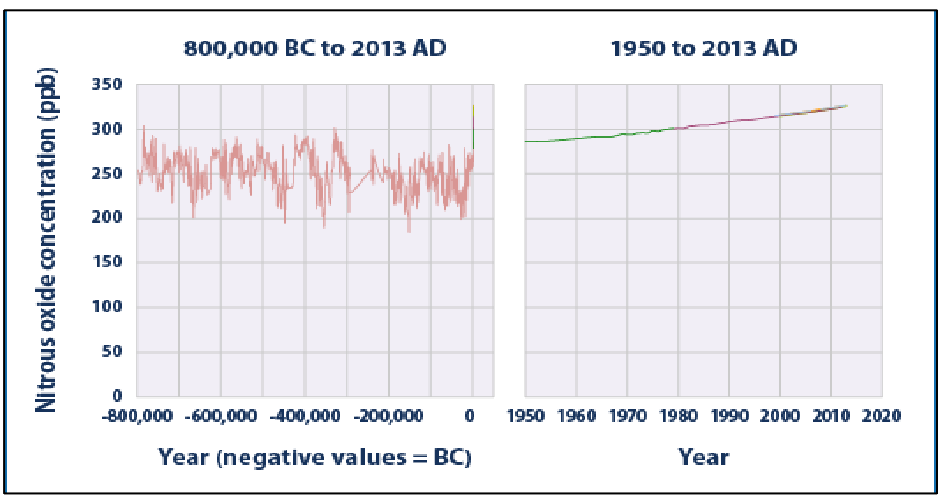
- Increased global concentrations of nitrous oxide ($N_2O$), a potent greenhouse gas, in the atmosphere as well as increased regional concentrations of other oxides of nitrogen (including nitric oxide, NO) that drive the formation of photochemical smog;
- Loss of soil nutrients that are essential for long-term soil fertility;
- Acidification of soils and of the waters of streams and lakes in several regions;
- Increased transport of nitrogen by rivers into estuaries and

coastal waters where it is a major pollutant.

## NITROUS OXIDE AND CLIMATE CHANGE




In 2012, nitrous oxide ($N_2O$) accounted for about 6% of all U.S. greenhouse gas emissions from human activities. Nitrous oxide is naturally present in the atmosphere as part of the Earth's nitrogen cycle, and has a variety of natural sources. However, human activities such as agriculture, fossil fuel combustion, wastewater management, and industrial processes are increasing the amount of $N_2O$ in the atmosphere. Nitrous oxide molecules stay in the atmosphere for an average of 120 years before being removed by a sink or destroyed through chemical reactions. The impact of 1 pound of $N_2O$ on warming the atmosphere is over 300 times that of 1 pound of carbon dioxide.




**Global concentrations of nitrous oxide over time**

Globally, about 40% of total $N_2O$ emissions come from human activities. Nitrous oxide is emitted from agriculture, transportation, and industry activities, described below.

- **Agriculture-** Nitrous oxide is emitted when people add nitrogen to the soil through the use of synthetic fertilizers. Agricultural soil management is the largest source of $N_2O$ emissions in the United States, accounting for about 75% of total U.S. $N_2O$ emissions in 2012. Nitrous oxide is also emitted during the breakdown of nitrogen in livestock manure and urine, which contributed to 4% of $N_2O$ emissions in 2012.

- **Transportation**- Nitrous oxide is emitted when transportation fuels are burned. Motor vehicles, including passenger cars and trucks, are the primary source of $N_2O$ emissions from transportation. The amount of $N_2O$ emitted from transportation depends on the type of fuel and vehicle technology, maintenance, and operating practices.

- **Industry**- Nitrous oxide is generated as a byproduct during the production of nitric acid, which is used to make synthetic commercial fertilizer, and in the production of ***adipic acid***, which is used to make fibers, like nylon, and other synthetic products.

Nitrous oxide ($N_2O$) emissions in the United States have increased by about 3% between 1990 and 2012. This increase in emissions is due in part to annual variation in agricultural soil emissions and an increase in emissions from the electric power sector. Nitrous oxide emissions from agricultural soils have varied during this period and were about 9% higher in 2012 than in 1990. $N_2O$ emissions are projected to increase by 5% between 2005 and 2020, driven largely by increases in emissions from agricultural activities.

Nitrous oxide emissions occur naturally through many sources associated with the nitrogen cycle, which is the natural circulation of nitrogen among the atmosphere, plants, animals, and microorganisms that live in soil and water. Nitrogen takes on a variety of chemical forms throughout the nitrogen cycle, including $N_2O$. Natural emissions of $N_2O$ are mainly from bacteria breaking down nitrogen in soils and the oceans. Nitrous oxide is removed from the atmosphere when it is absorbed by certain types of bacteria or destroyed by ultraviolet radiation or chemical reactions.

Within the last century, humans have become as important a source of fixed nitrogen as all natural sources combined. Burning fossil fuels, using synthetic nitrogen fertilizers and cultivation of legumes all fix nitrogen. Through these activities, humans have more than doubled the amount of fixed nitrogen that is pumped into the biosphere every year.