CGR4M0 Grade 12 Environmental and Resource Management

The Biosphere

The biosphere is simply the place on earth where life dwells. It can be found in the lithosphere, atmosphere and hydrosphere. Chemicals in the environment are constantly being exchanged between the four spheres of earth. Carbon dioxide, for example, is a product of the burning of fossil fuels. It is transferred into the atmosphere and will eventually be processed in the biosphere by plants through photosynthesis.

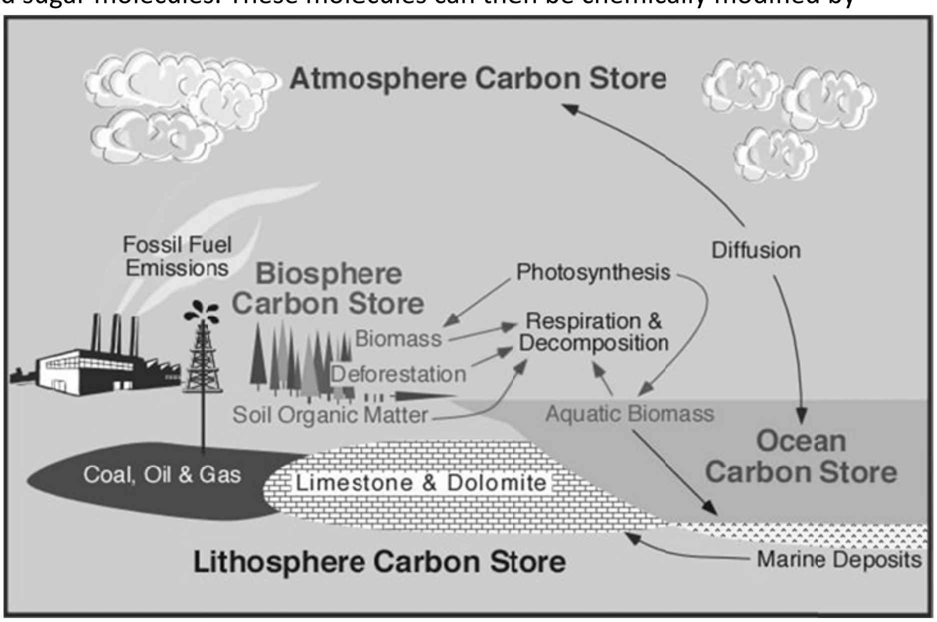
The Carbon Cycle

All life is based on the element *carbon*. Carbon is the major chemical constituent of most organic matter, from fossil fuels to the complex molecules (DNA and RNA) that control genetic reproduction in organisms. Yet by weight, carbon is not one of the most abundant elements within the Earth's crust. In fact, the lithosphere is only 0.032% carbon by weight. In comparison, oxygen and silicon respectively make up 45.2% and 29.4% of the Earth's surface rocks.

Carbon is stored on our planet in the following major sinks:

(1) as organic molecules in living and dead organisms found in the biosphere
(2) as the gas carbon dioxide in the atmosphere;
(3) as organic matter in soils;
(4) in the lithosphere as fossil fuels and sedimentary rock deposits such as limestone, dolomite and chalk; and
(5) in the oceans as dissolved atmospheric carbon dioxide and as calcium carbonate shells in marine organisms.

Ecosystems gain most of their carbon dioxide from the atmosphere. A number of autotrophic organisms have specialized mechanisms that allow for absorption of this gas into their cells. With the addition of water and energy from solar radiation, these organisms use photosynthesis to chemically convert the carbon dioxide to carbon-based sugar molecules. These molecules can then be chemically modified by these organisms through the metabolic addition of other elements to produce more complex compounds like proteins, cellulose, and amino acids. Some of the organic matter produced in plants is passed down to heterotrophic animals through consumption.



Carbon dioxide enters the waters of the ocean by simple diffusion. Once dissolved in seawater, the carbon dioxide can remain as is or can be converted into carbonate (CO_3^{-2}) or bicarbonate (HCO_3^-). Certain forms of sea life biologically fix bicarbonate with calcium (Ca^{+2}) to produce calcium carbonate ($CaCO_3$). This substance is used to produce shells and other body parts by organisms such as coral, clams, oysters, some protozoa, and some algae. When these organisms die, their shells and body parts sink to the ocean floor where they accumulate as carbonate-rich deposits. After long periods of time, these deposits are physically and chemically altered into sedimentary rocks. Ocean deposits are by far the biggest sink of carbon on the planet.

Carbon is released from ecosystems as carbon dioxide gas by the process of respiration. Respiration takes place in both plants and animals and involves the breakdown of carbon-based organic molecules into carbon dioxide gas and some other compound by products. The detritus food chain contains a number of organisms whose primary ecological role is the decomposition of organic matter into its abiotic components.

Over the several billion years of geologic history, the quantity of carbon dioxide found in the atmosphere has been steadily decreasing. Researchers theorized that this change is in response to an increase in the Sun's output over the same time period. Higher levels of carbon dioxide helped regulate the Earth's temperature to levels slightly higher than what is perceived today. These moderate temperatures allowed for the flourishing of plant life despite the lower output of solar radiation. An enhanced greenhouse effect, due to the greater concentration of carbon dioxide gas in the atmosphere, supplemented the production of heat energy through higher levels of long wave counter-radiation. As the Sun grew more intense, several biological mechanisms gradually locked some of the atmospheric carbon dioxide into fossil fuels and sedimentary rock. In summary, this regulating process has kept the Earth's global average temperature essentially constant over time. Some scientists suggest that this phenomenon is proof for the Gaia Hypothesis.

Carbon is stored in the lithosphere in both inorganic and organic forms. Inorganic deposits of carbon in the lithosphere include fossil fuels like coal, oil, and natural gas, oil shale, and carbonate based sedimentary deposits like limestone. Organic forms of carbon in the lithosphere include litter, organic matter, and humic substances found in soils. Some carbon dioxide is released from the interior of the lithosphere by volcanoes. Carbon dioxide released by volcanoes enters the lower lithosphere when carbon-rich sediments and sedimentary rocks are subducted and partially melted beneath tectonic boundary zones.

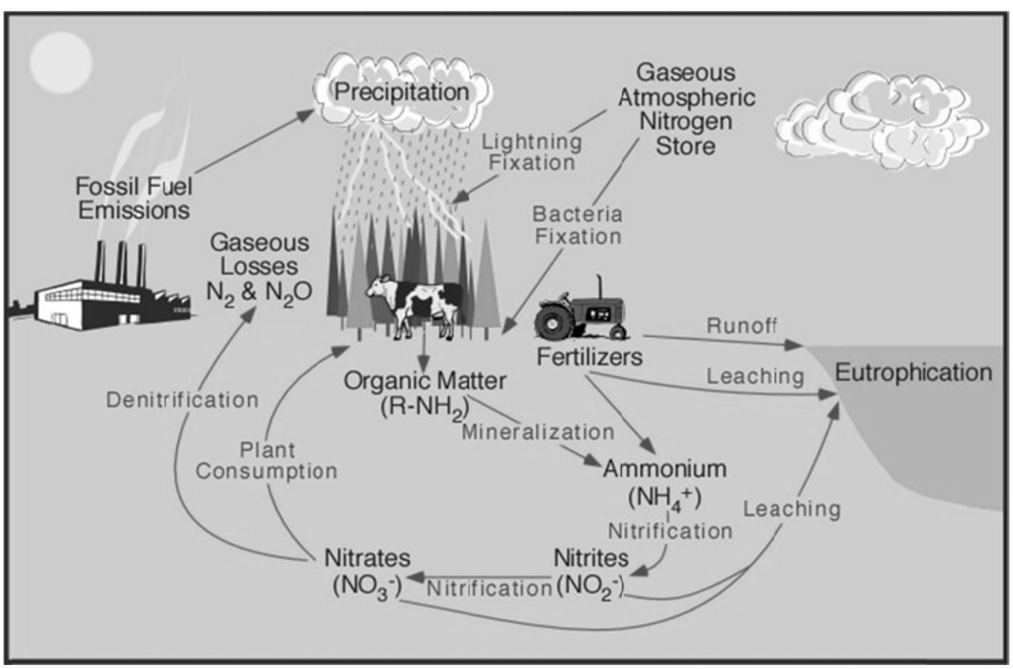
Since the Industrial Revolution humans have greatly increased the quantity of carbon dioxide found in the Earth's atmosphere and oceans. Atmospheric levels have increased by over 30%, from about 275 parts per million (ppm) in the early 1700s to just over 365 PPM today. Scientists estimate that future atmospheric levels of carbon dioxide could reach an amount between 450 to 600 PPM by the year 2100. The major sources of this gas due to human activities include fossil fuel combustion and the modification of natural plant cover found in grassland, woodland, and forested ecosystems. Emissions from fossil fuel combustion account for about 65% of the additional carbon dioxide currently found in the Earth's atmosphere. The other 35% is derived from deforestation and the conversion of natural ecosystems into agricultural systems. Researchers have shown that natural ecosystems can store between 20 to 100 times more carbon dioxide than agricultural land-use types.

The Nitrogen Cycle

The nitrogen cycle represents one of the most important nutrient cycles found in terrestrial ecosystems. Nitrogen is used by living organisms to produce a number of complex organic molecules like amino acids, proteins, and nucleic acids. The store of nitrogen found in the atmosphere, where it exists as a gas (mainly N_2), plays an important role for life. This store is about one million times larger than the total nitrogen contained in living organisms. Other major stores of nitrogen include organic matter in soil and the oceans. Despite its abundance in the atmosphere, nitrogen is often the most limiting nutrient for plant growth. This problem occurs because most plants can only take up nitrogen in two solid forms: ammonium ion (NH_4^+) and the ion nitrate (NO_3^-). Most plants obtain the nitrogen they need as inorganic nitrate from the soil solution. Ammonium is used less by plants for uptake because in large concentrations it is extremely toxic. Animals receive the required nitrogen they need for metabolism, growth, and reproduction by the consumption of living or dead organic matter containing molecules composed partially of nitrogen.

In most ecosystems nitrogen is primarily stored in living and dead organic matter. This organic nitrogen is converted into inorganic forms when it re-enters the biogeochemical cycle via decomposition. Decomposers, found in the upper soil layer, chemically modify the nitrogen found in organic matter from ammonia (NH_3) to ammonium salts (NH_4^+). This process is known as mineralization and it is carried out by a variety of bacteria, actinomycetes, and fungi.

Almost all of the nitrogen found in any terrestrial ecosystem originally came from the atmosphere. Significant amounts enter the soil in rainfall or through the effects of lightning. The majority, however, is biochemically fixed within the soil by specialized micro-organisms like bacteria, actinomycetes, and cyanobacteria. Members of the bean family (legumes) and some other kinds of plants form mutualistic symbiotic relationships with nitrogen fixing bacteria. In exchange for some nitrogen, the bacteria receive from the plants carbohydrates and special structures (nodules) in roots where they can exist in a moist environment. Scientists estimate that biological fixation globally adds approximately 140 million metric tons of nitrogen to ecosystems every year.



The activities of humans have severely altered the nitrogen cycle. Some of the major processes involved in this alteration include:

- The application of nitrogen fertilizers to crops has caused increased rates of denitrification and leaching of nitrate into groundwater. The additional nitrogen entering the groundwater system eventually flows into streams, rivers, lakes, and estuaries. In these systems, the added nitrogen can lead to eutrophication.
- Increased deposition of nitrogen from atmospheric sources because of fossil fuel combustion and forest burning. Both of these processes release a variety of solid forms of nitrogen through combustion.
- Livestock ranching. Livestock release large amounts of ammonia into the environment from their wastes. This nitrogen enters the soil system and then the hydrologic system through leaching, groundwater flow, and runoff.
- Sewage waste and septic tank leaching.

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1) Define these terms:
   - photosynthesis
   - ecosystem
   - heterotrophic
   - detritus
   - eutrophication
   - sink (not the thing in your bathroom and not what happens to stone in the water)

2) What are the areas in which carbon is stored?

3) How is carbon exchanged from the areas of storage?

4) What role does precipitation play in the transfer of nitrogen?

5) How does nitrogen from fertilizers enter the environment?

6) The carbon cycle article mentions the Gaia Hypothesis. Research this hypothesis: what does it say; how is it being proven and what is the opposition to it.

On a Word page, answer the following questions. When you are done, hand it in or email it to me as an attachment at rob.goodbun@ucdsb.on.ca.