

The Cycling of Matter in Ecosystems

1. Matter cycles through ecosystems and through living things.
 - a. **Organic** substances always contain atoms of carbon and hydrogen (they sometimes also contain oxygen and nitrogen atoms). Proteins, sugars, and fats, the important chemicals that make up your body, are all organic.
 - b. Matter that doesn't contain a combination of carbon and hydrogen atoms is called **inorganic**. For example, carbon dioxide (CO₂) and water (H₂O) are inorganic. Organic chemicals undergo changes within living things and within ecosystems. Their complex structures are broken and rebuilt in a continuous cycling of matter.
 - c. Remember that there is no matter reaching the Earth – everything living organisms need is here already. This means that all matter must be recycled.
 - d. Food is organic matter. Every time you eat, organic matter that was once part of other living things passes into your body. Through the process of digestion, complex organic molecules are broken down into simpler molecules. Cells use these simple molecules to build complex molecules, which become part of your body.
 - e. Another process involved in the cycling of matter is **decay**. Organic matter is held temporarily in the bodies of living organisms, but after death **decomposers** break down the organic matter in dead bodies and feces into small, inorganic molecules. Plants reassemble these inorganic substances (also called nutrients) to make food for themselves. In turn, animals may eat the plants, continuing the cycling of matter.

2. The carbon cycle moves carbon atoms between several large carbon reservoirs.
 - a. Carbon is required to build all organic molecules, thus is a vital element for living things. Carbon can be found in the atmosphere and dissolved in the oceans inorganic carbon dioxide (CO₂).
 - b. During photosynthesis, plants use light energy to combine carbon dioxide from the atmosphere and water from the soil. Photosynthesis can be represented by the equation:
$$6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$

carbon dioxide + water + light energy forms sugar (glucose) + oxygen
 - c. Some of the glucose formed in photosynthesis is used as a source of energy for organisms. The energy is released in the process of cellular respiration which converts the organic carbon in glucose to the inorganic carbon in carbon dioxide. The equation is.
$$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{H}_2\text{O} + 6\text{CO}_2$$

glucose + oxygen forms water + carbon dioxide + chemical energy
 - d. Inorganic carbon can remain in three main **reservoirs** (storage areas) for long periods.
 - i. The smallest of these reservoirs is the **atmosphere**. Carbon dioxide makes up a very small percentage (about 0.03%) of the gases that we breathe in. However, atmospheric carbon dioxide is easily accessed by land plants for use in photosynthesis.
 - ii. A huge amount of inorganic carbon is held as dissolved carbon dioxide in the **oceans**, where it is available to algae and other water plants for photosynthesis. Some carbon dioxide reacts with sea water to form carbonates that are used by marine animals (like clams) to build shells.
 - iii. Most of the carbon in carbonates in the ocean sinks to the bottom as sediment. As layers of sediment form, the carbonates are crushed and heated and eventually become rock. Limestone is made from the discarded shells and bones of living things. By far the largest reservoir of the Earth's carbon is in sedimentary rocks in the **Earth's crust**. Carbon can be trapped in rock for millions of years until volcanic activity or movement of tectonic plates brings it back to the surface.

Volcanoes release the carbon as carbon dioxide and acid rain falling on limestone also causes the release of carbon dioxide into the atmosphere.

- e. Organic carbon is also held in reservoirs - the bodies of living things.
 - i. When living things die, decomposers return the carbon to the cycle in inorganic form. Not all carbon makes it back to the ecosystem. **Bogs** store huge quantities of carbon in organic form.
 - ii. In a bog there is very little oxygen, and under these conditions decomposition is very slow. Carbon atoms may remain locked away in dead plant matter (**peat**) for many years in a bog.
 - iii. Sometimes these deposits are covered with layer upon layer of sediment and the slowly decaying organic matter can end up trapped between layers of rock. The result is the formation of a carbon-containing fossil fuel, coal. Oil and natural gas are formed in a very similar way. Carbon can be held in fossil fuels for millions of years.
 - f. Humans are having a major influence on the carbon cycle.
 - i. Humans have modified the global carbon cycle by releasing carbon from organic reservoirs by burning fossil fuels.
 - ii. Humans are also increasing the amount of carbon dioxide in the inorganic reservoir of the atmosphere by burning forests and clearing away vegetation, in order to build or farm. The loss of plants decreases the amount of carbon dioxide removed from the atmosphere by photosynthesis.
 - iii. Most carbon dioxide released into the air eventually becomes dissolved in the oceans, but the oceans can hold only so much. The amount of carbon dioxide in the atmosphere is rising.
3. The nitrogen cycle converts inorganic nitrogen in the atmosphere to organic nitrogen.
- a. Proteins are important for all organisms for many reasons including building muscle and performing chemical reactions in cells.
 - b. Proteins are made out of amino acids so all organisms need nitrogen to build those amino acids.
 - c. Nitrogen gas (N_2) makes up 78% of Earth's atmosphere so there is lots of nitrogen in the environment. The trouble is that very few organisms can use nitrogen gas.
 - d. To be useful to organisms, nitrogen must be converted to another form (nitrate or ammonia).
 - i. Certain bacteria can use nitrogen gas directly.
 - 1. They convert nitrogen gas into nitrates and ammonia (NH_3), in a process called **nitrogen fixation**.
 - 2. These bacteria are found mostly in soil. Nitrogen-fixing bacteria can also be found in small lumps called nodules on the roots of legumes such as clover, soybeans, peas, and alfalfa.
 - 3. The bacteria provide the plant with a built-in supply of usable nitrogen, while the plant supplies the nitrogen-fixing bacteria with the sugar they need for energy. This relationship produces much more nitrate than the plant or bacteria need. The excess moves into the soil, providing a source of nitrogen for other plants. The traditional agricultural practices of including legumes in crop rotation takes advantage of bacterial nitrogen fixation.

- ii. A small amount of nitrogen is fixed into nitrates by lightning.
 - 1. The energy from the lightning causes nitrogen gas to react with oxygen in the air, producing nitrates.
 - 2. The nitrates dissolve in rain or surface water, enter the soil, and then move into plants through their roots.
- e. Other bacteria in the soil convert the ammonia into nitrates and nitrites which plants use to make amino acids they need to build proteins.
- f. When a plant is consumed by an animal, the animal breaks down the plant proteins into amino acids and then can use the amino acids to make the proteins it needs.
- g. All organisms produce wastes and eventually die.
 - i. When they do, a series of decomposers break down the nitrogen-containing chemicals in the waste or body into simpler chemicals such as ammonia.
 - ii. The ammonia is converted into nitrates by the soil bacteria as discussed above.
 - iii. Farmers and gardeners who use manure and other decaying matter take advantage of the nitrogen cycle. Soil bacteria convert the decomposing protein in the manure into nitrates. Eventually, the nitrates are absorbed by plants.
- h. During decomposition, still other soil bacteria convert nitrates and nitrites back into nitrogen gas in a process called **denitrification**. The nitrogen gas is then released back into the atmosphere. This process completes the nitrogen cycle by putting nitrogen back into the atmosphere.
- i. Human activity adds nitrogen to the biosphere in the form of nitrate – a major component of plant fertilizers.