BIOGEOCHEMICAL CYCLING:

*An Introduction*-

Nutrient cycling in the environment takes place through biogeochemical cycles.

Biogeochemical cycles are important because they regulate the elements necessary for life on earth by cycling them through the biological and physical aspects of the world. Biogeochemical cycles are a form of natural recycling that allows the continuous survival of ecosystems.

Biogeochemical cycles are named for the cycling of biological, geological and chemical elements through earth and its atmosphere. The cycles move substances through the biosphere, lithosphere, atmosphere and hydrosphere. Cycles are gaseous and sedimentary.

Gaseous cycle are – nitrogen, oxygen, carbon and water. These elements cycle through evaporation, absorption by plants and dispersion by wind. Sedimentary cycles include the leaching of minerals and salts from the Earth’s crust, which then settle as sediment or rock before the cycle repeats.

Repetition of the cycles is important. Plants also acquire nutrients from plants and other animals, and the death of plants and animals returns these nutrients from plants and other animals, and the death of plants and animals returns these nutrients to the sediment as they decay. The cycle then repeats and allows other living things to benefit.

The simplest example of biogeochemical cycles at work includes water. Water evaporates from the oceans, condenses as clouds and precipitates as rain, which return the water bach to the earth in a cycle.

Biogeochemical cycles important to living organisms include the water, carbon, nitrogen, phosphorus and sulphur cycles.

Energy flows directionally through earth’s ecosystems, typically entering in the form of sunlight and exiting in the form of heat. However the chemical components that make up living organisms are different; they get recycled.

**THE CARBON CYCLE** –

Carbon is an essential element in the bodies of living organisms. It is also economically important to modern humans, in the form of fossil fuels.

Carbon dioxide from the atmosphere is taken up by photosynthetic organisms and used to make organic molecules,which travel through food chains. In the end,the carbon atoms are released as CO2 in respiration.

Slow geological processes,including the formation of sedimentary rock and fossil fuels, contribute to the carbon cycle over long timescales.

Some human activities, such as burning of fossil fuels and deforestation increase atmospheric CO2 and affect earth’s climate and oceans. Our bodies are 18% to 19% carbon by mass.

The carbon cycle is most easily studied as two interconnected subcycles: 1. One dealing with rapid carbon exchange among living organisms. 2. One dealing with long term cycling of carbon through geologic processes. These cycles are linked together, carbon exists in the air largely as CO2  or bicarbonate into organic molecules.

Organic molecules made by photosynthesizers are passed through food chains and cellular respiration converts the organic carbon back into CO2 gas.

Longterm storage of organic carbon occurs when matter from living organisms is buried deep underground or sinks to the bottom of the oceans and forms sedimentary rock. Volcanic activity and more recently , human burning of fossil fuels bring this stored carbon back into the carbon cycle. Although the formation of fossil fuels happens on a slow geologic timescale, human release of the carbon they contain – as CO2- is on a very fast timescale.

The biological carbon cycle-

Carbon enters all food webs , both terrestrial and aquatic , through autotrophs , or self – feeders. Almost all of these autotrophs are photosynthesizers, such as plants or algae.

Autotrophs capture CO2 from the air or bicarbonate ions from the water and use them to make organic compounds such as glucose. Heterotrophs , or other feeders, such as humans , consume the organic molecules and the organic carbon is passed through food chains and webs.

Question: How does carbon cycles back to the atmosphere or ocean?

Answer: To release the energy stored in carbon containing molecules, such as sugars, autotrophs and heterotrophs break these molecules down in a process, the carbons of the molecule are released as carbon dioxide. Decomposers also release organic compounds and CO2 when they break down dead down dead organisms and waste products.

Carbon can quickly cycle through this biological pathway, especially in aquatic ecosystems. Overall, an estimated 1000 to 100000 million metric tonnes of carbon move through the biological pathway each year.



The geological carbon cycle-

The geological pathway of the carbon cycle takes much longer than the biological pathway. It usually takes millions of years for carbon to cycle through the geological pathway. Carbon may be stored for long periods of time in the atmosphere, bodies of liquid water- mostly oceans- ocean sediment, soil, rocks, fossil fuels and earth’s interior.

The level of CO2 in the atmosphere is influenced by the reservoir of carbon in the oceans and vice-versa. CO2 from the atmosphere dissolves in water and reacts with H2O molecules in the following reaction-

CO2 +H2O H2 CO3 HCO3- + H+ CO32- + 2H+

The carbonate released in this process combined with Ca2+ ions to make calcium carbonate (CaCO3), a key component of the shells of marine organisms. When the organisms die, their remains may sink and eventually become part of the sediment turns into limestone, which is the largest carbon reservoir on earth.

On land, carbon is stored in soil as organic carbon from the decomposition of living organisms or as inorganic carbon from weathering of terrestrial rock and minerals. Deeper under the ground are fossil fuels such as oil, coal and natural gas, which are the remains of plants decomposed under anaerobic – oxygen free conditions. Fossil fuels take millions of years to form. When humans burn them, carbon is released into the atmosphere as CO2.

Another way for carbon to enter the atmosphere is by the eruption of volcanoes. Carbon containing sediments in the ocean floor are taken deep within the earth in a process called subduction, in which one tectonic plate moves under another.

Decomposition of organic residues:

Soil organic matter is the largest terrestrial carbon pool and contains more than 3 times as much carbon as either the atmospheric or living plant pools. The formation of soil organic matter and the decomposition of residue are closely associated.

Decomposition of organic residue is one of the major functions of microorganisms in the soil. The soil microorganisms utilize the residue components for energy and carbon source to synthesize the new cells. The organic material added to the soil are primarily plant residues from either cultivated crops or native vegetation, which are the source of energy stored in the carbon compounds.

The crop agricultural ecosystems primarily include the combination of leaf, stem, and root tissues remaining after harvest .

The composition of the crop residues added to decaying in soil are varied. Plant residues are comprised of many complex polymers such as lignin and cellulose and contains water soluble organic compounds such as proteins, carbohydrates, and organic acids.

Carbohydrates- From 5-25% of soil organic matter is combined in the form of carbohydrates, which include simple sugars, cellulose, and hemicelluloses. These carbohydrates are rapidly degraded by varied microorganisms in the soilincluding bacteria, archaea, actinomycetes, and fungi. During degradation soil microorganisms synthesize extracellular polysaccharides. These polysaccharides bind soil into water stable aggregates so that the aggregates are more permeable to water and air. Polysaccharides also affect the cation exchange capacity of soil and act as an energy source for other microbes.

Heterotrophic microbes can easily metabolize simple sugars. Plants like glucose molecules and other sugar monomers into long chains to produce polymers such as cellulose, which requires more specialized organisms to degrade.e.g., Starch is made of amylase and amylopectin and is relatively easy for most organisms to degrade. Cellulose, however, is a polysaccharide of glucose connected with beta 1,4 bonds and is more difficult to degrade. No animal can degrade cellulose, so bacteria can frequently be found in mutualistic relationships with detrivores: the bacteria degrade the cellulose enough that the animal is able to digest it.

Cellulose- Cellulose is most abundant carbon input in soil. It is a structural polysaccharide that is made of 1400 to 10000 glucose units. In order to access the glucose monomer, the cellulose must be cleaved by extracellular enzymes. These pieces are then transported into the cell for energy generation or production of biomass. Cellulose is used by a diverse group of soil organisms including fungi such as Penicillium and Aspergillus and bacteria such as Streptomyces and Pseudomonas. Fungi and bacteria are important participants in the extracellular cleavage of cellulose.

Hemicellulose (the decomposition of Pectin)- Hemicellulose is the next most common carbohydrate in plants. It is a branched polymer with varied sugar monomers (glucose, mannose and galactose) and bonds. The decomposition of hemicellulose is similar to that of cellulose in that the initial depolymerization step takes place outside of the cell, and the sugars produced are then transported into the cell for catabolism or anabolism. Even though hemicelluloses decomposition is much quicker than cellulose decomposition, cells will utilize simple sugars as substrates before hemicellulose.

The decomposition of Chitin and Chitosan under aerobic soil conditions- Chitin is a special compound which can be found in the integument of arthropods and the cell walls of fungi. Chitin is one of the cell wall component of many common soil fungi e.g., Aspergillus and Penicillium as around 3% to 25% of these soil fungal biomass are chitin. Chitin is usually protected from degradation by the protein-chitin complex in its natural normal stage in soil. Due to this type of protection, chitin is an important component in soil organic matter formation. The polymer is not easily degraded and requires a variety of enzymes to do so. The dominant chitin degraders are the Actinomycetes, Streptomyces and Nocardia. Less important than Actinomycetes, fungi such as Trichoderma and Verticillum and bacteria, such as Bacillus and Pseudomonas can also degrade chitin.

Lignin decomposition- Lignin is the main component of wood in trees. Lignin has a varied, unique, and complicated chemical structure which contains many aromatics.Aromatics are part of the reason why lignin is more difficult to be decomposed. Even with strong acid treatment, the plant residues are not solubilized due to the complex ring structure. These aromatics can be released from the lignin structure by fungal enzymes such as peroxidases and oxidases. The enzymes utilize H2O2 and OH radicals to break the bonds in the lignin. Lignin is decomposed through groups of specialized fungi. Common types of fungi which depolymerize lignin are white rot, brown rot, and soft rot. Once the aromatics are released from the original lignin structure they are incorporated into the metabolic pathway as pyruvate, acetyl CoA, and into the TCA cycle.

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