BIOGEOCHEMICAL CYCLE:

The transfer of abiotic components from environment to living organism, and from living organism to environment in a cyclical path is known as biogeochemical cycle.

Oxygen cycle:

Oxygen cycle refers to the movement of oxygen through the atmosphere (air), Biosphere (plants and animals) and the Lithosphere (the earth's crust). The oxygen cycle demonstrates how free oxygen is made available in each of these regions, as well as how it is used. Oxygen is one of the most abundant elements on Earth and represents a large portion of each main reservoir.

By far the largest reservoir of Earth's oxygen is within the silicate and oxide minerals of the crust and mantle (99.5% by weight).

Sources and sinks:

There are many abiotic sources and sinks for O_2.The presence of the profuse concentration of free oxygen in modern Earth's atmosphere and ocean is attributed to O_2 production from the biological process of oxygenic photosynthesis in conjunction with a biological sink known as the biological pump and a geologic process of carbon burial involving plate tectonics.

Biological Production---

The main source of atmospheric free oxygen is photosynthesis, which produces sugars and free oxygen from carbon dioxide and water. Photosynthesizing organisms include the plant life of the land areas as well as the phytoplankton of the oceans.

The tiny marine cyanobacterium *Prochlorococcus* was discovered in 1986 and accounts for up to half of the photosynthesis of the open oceans.

Abiotic production----

An additional source of atmospheric free oxygen comes from photolysis, whereby high-energy ultraviolet radiation breaks down atmospheric water and nitrous oxide into component atoms. The free H and N atoms escape into space, leaving O_2 in the atmosphere.

Biological consumption---

The main way free oxygen is lost from the atmosphere is via respiration and decay, mechanisms in which animal life and bacteria consume oxygen and release carbon dioxide.

Carbon cycle:

The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere, and atmosphere of the Earth. Carbon is the main component of biological compounds as well as a major component of many minerals such as limestone. Along with the nitrogen cycle and the water cycle, the carbon cycle comprises a sequence of events that are key to make Earth capable of sustaining life. It describes the movement of carbon as it is recycled and reused throughout the biosphere, as well as long-term processes of carbon sequestration to and release from carbon sinks. Carbon sinks in the land and the ocean each currently take up about one-quarter of anthropogenic carbon emissions each year.

Carbon in the Earth's atmosphere exists in two main forms: carbon dioxide and methane. Both of these gases absorb and retain heat in the atmosphere and are partially responsible for the greenhouse effect.[13] Methane produces a larger greenhouse effect per volume as compared to carbon dioxide, but it exists in much lower concentrations and is more short-lived than carbon dioxide, making carbon dioxide the more important greenhouse gas of the two.

Carbon dioxide is removed from the atmosphere primarily through photosynthesis and enters the terrestrial and oceanic biospheres. Carbon dioxide also dissolves directly from the atmosphere into bodies of water (ocean, lakes, etc.), as well as dissolving in precipitation as raindrops fall through the atmosphere.

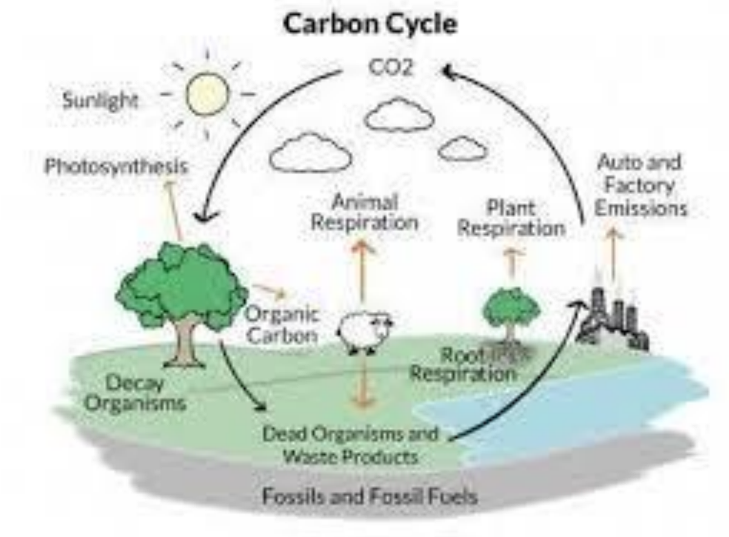
Carbon leaves the terrestrial biosphere in several ways and on different time scales. The combustion or respiration of organic carbon releases it rapidly into the atmosphere. It can also be exported into the ocean through rivers or remain sequestered in soils in the form of inert carbon. Carbon stored in soil can remain there for up to thousands of years before being washed into rivers by erosion or released into the atmosphere through soil respiration.

Carbon enters the ocean mainly through the dissolution of atmospheric carbon dioxide, a small fraction of which is converted into carbonate. It can also enter the ocean through rivers as dissolved organic carbon. It is converted by organisms into organic carbon through photosynthesis and can either be exchanged throughout the food chain or precipitated into the oceans' deeper, more carbon-rich layers as dead soft tissue or in shells as calcium carbonate. It circulates in this layer for long periods of time before either being deposited as sediment or, eventually, returned to the surface water.

Oceanic absorption of CO_2 is one of the most important forms of carbon sequestering which limit the human-caused rise of carbon dioxide in the atmosphere. However, this process is limited by a number of factors. CO_2 absorption makes water more acidic, which affects ocean ecosystem.

Most of the earth's carbon is stored inertly in the earth's lithosphere. Much of the carbon stored in the earth's mantle was stored there when the earth formed. Some of it was deposited in the form of organic carbon from the biosphere. Of the carbon stored in the geosphere, about 80% is limestone and its derivatives, which form from the sedimentation of calcium carbonate stored in the shells of marine organisms. The remaining 20% is stored as kerogens formed through the sedimentation and burial of terrestrial organisms under high heat and pressure. Organic carbon stored in the geosphere can remain there for millions of years.

Carbon can leave the geosphere in several ways. Carbon dioxide is released during the metamorphism of carbonate rocks when they are subducted into the earth's mantle. This carbon dioxide can be released into the atmosphere and ocean through volcanoes and hotspots. It can also be removed by humans through the direct extraction of kerogens in the form of fossil fuels. After extraction, fossil fuels are burned to release energy and emit the carbon they store into atmosphere.



Nitrogen cycle:

The nitrogen cycle is the biogeochemical cycle by which nitrogen is converted into multiple chemical forms as it circulates among atmosphere, terrestrial, and marine ecosystems. The conversion of nitrogen can be carried out through both biological and physical processes. The majority of Earth's atmosphere (78%) is atmospheric nitrogen. Nitrogen is a very important constituent of all living body, as it is the main constituent of amino acids, nucleic acids and other organic compounds.

a) Nitrogen Fixation: The conversion of nitrogen gas (N_2) into nitrates and nitrites through atmospheric, industrial and biological processes is called nitrogen fixation.

i) Nitrogen fixation by atmospheric process ---Nitrogen can be fixed by lightning converting nitrogen gas (N_2) and oxygen gas (O_2) in the atmosphere into NO(nitric oxides).The N_2 molecule is highly stable and nonreactive due to the triple bond between the nitrogen atoms. Lightning produces enough energy and heat to break this bond, allowing nitrogen atoms to react with oxygen, forming NO. These compounds cannot be used by plants, but as this molecule cools, it reacts with oxygen to form NO_2, which in turn reacts with water to produce HNO_2 (nitrous acid) or HNO_3 (nitric acid). When these acids seep into the soil, they make $NO^-{}_3$ (nitrate), which is of use to plants.

ii) Nitrogen fixation by micro-organisms ----More than 90 percent of all nitrogen fixation is effected by them.

Two kinds of nitrogen-fixing microorganisms are recognized: free-living (nonsymbiotic) bacteria, including the cyanobacteria (or blue-green algae) *Anabaena* and *Nostoc* and genera such as *Azotobacter*, *Beijerinckia*, and *Clostridium*; and

mutualistic (symbiotic) bacteria such as *Rhizobium*, associated with leguminous plants, and various *Azospirillum* species, associated with cereal grasses.

iii) Nitrogen fixation by industrial process ----

The dominant industrial method for producing ammonia is the Haber process also known as the Haber-Bosch process. Fertilizer production is now the largest source of human-produced fixed nitrogen in the terrestrial ecosystem. Ammonia is a required precursor to fertilizers, explosives, and other products. The Haber process requires high pressures (around 200 atm) and high temperatures (at least 400 °C), which are routine conditions for industrial catalysis. This process uses natural gas as a hydrogen source and air as a nitrogen source. The ammonia product has resulted in an intensification of nitrogen fertilizer globally.

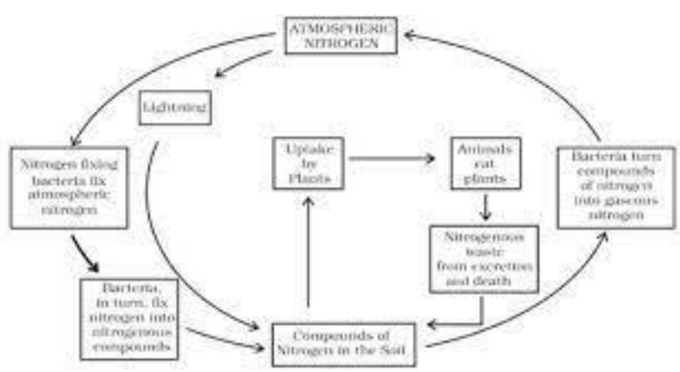
b) Plants can absorb nitrate or ammonium from the soil by their root hairs. If nitrate is absorbed, it is first reduced to nitrite ions and then ammonium ions for incorporation into amino acids, nucleic acids, and chlorophyll. In plants that have a symbiotic relationship with rhizobia, some nitrogen is assimilated in the form of ammonium ions directly from the nodules. Animals get the nitrogen while consuming plant protein directly or indirectly through food chain.

c) Removal of nitrogen from living organisms: The process includes three steps ---

   i) Ammonification ---When a plant or animal dies or an animal expels waste, the initial form of nitrogen is organic. Bacteria or fungi convert the organic nitrogen within the remains back into ammonium (NH_4^+), a process called ammonification or mineralization. Enzymes involved are:GS: Gln Synthetase (Cytosolic & Plastic), GOGAT: Glu 2-oxoglutarate aminotransferase. The bacteria involved in this process are ammonifying bacteria, like *Bacillus ramosus, Pseudomonas sp.* etc.

   ii) Nitrification ----The conversion of ammonium to nitrate is performed primarily by soil-living bacteria and other nitrifying bacteria. In the primary stage of nitrification, the oxidation of ammonium (NH+4) is performed by bacteria such as the *Nitrosomonas* species, which converts ammonia to nitrites (NO–2). Other bacterial species such as *Nitrobacter*, are responsible for the oxidation of the nitrites (NO–2) into nitrates (NO–3). It is important for the ammonia (NH_3) to be converted to nitrates or nitrites because ammonia gas is toxic to plants.

   iii) Denitrification ----Denitrification is the reduction of nitrates back into nitrogen gas (N_2), completing the nitrogen cycle. This process is performed by bacterial species such as *Thiobacillus denitrificans, Micrococcus denitrificans,* some species of *Pseudomonas* and *Paracoccus*, under anaerobic conditions. They use the nitrate as an electron acceptor in the place of oxygen during respiration. These facultatively anaerobic bacteria can also live in aerobic conditions. Denitrification happens in anaerobic conditions e.g. waterlogged soils. The denitrifying bacteria use nitrates in the soil to carry out respiration and consequently produce nitrogen gas, which is inert and unavailable to plants. Denitrification occurs in free-living microorganisms as well as obligate symbionts of anaerobic ciliates.



<u>Sulpher cycle ----</u>

The sulphur cycle is a biogeochemical cycle in which the sulphur moves between rocks, waterways and living systems Sulphur is one of the most abundant elements on the earth. It is a yellow, brittle, tasteless, odourless non-metal. Sulphur is present in all kinds of proteins. Plants directly absorb sulphur-containing amino acids such as methionine, cystine, and cysteine.

Sulphur is released into the atmosphere by the burning of fossil fuels, volcanic activities, and decomposition of organic molecules.

On land, sulphur is stored in underground rocks and minerals. It is released by precipitation, weathering of rocks and geothermal vents.

Earth's main sulfur sink is the oceans SO^{2-}_4, where it is the major oxidizing agent. When SO^{2-}_4 is assimilated by organisms, it is reduced and converted to organic sulphur, which is an essential component of proteins. However, the biosphere does not act as a major sink for sulphur, instead the majority of sulphur is found in seawater or sedimentary rocks including, pyrite rich shales, evaporite rocks (anhydrite and baryte), and calcium and magnesium carbonates (i.e. carbonate-associated sulfate).

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The process of sulphur cycle is explained below:

- The sulphur is released by the weathering of rocks.
- Sulphur comes in contact with air and is converted into sulphates.
- Sulphates are taken up by plants and microbes and are converted into organic forms.
- The organic form of sulphur is then consumed by the animals through their food and thus sulphur moves in the food chain.
- When the animals die, some of the sulphur is released by decomposition while some enter the tissues of microbes.
- There are several natural sources such as volcanic eruptions, evaporation of water, and breakdown of organic matter in swamps, that release sulphur directly into the atmosphere. This sulphur falls on earth with rainfall.

Steps of Sulphur Cycle

Following are the important steps of the sulphur cycle:

Decomposition of Organic Compounds

Protein degradation releases **amino acids** that contain sulphur. Sulphates are reduced to H_2S by the action of Desulfotomaculum bacteria.

Oxidation of Hydrogen Sulphide to Elemental Sulphur

Hydrogen sulphide oxidises to produce elemental sulphur. Certain photosynthetic bacteria from the families Chlorobiaceae and Chromatiaceae initiate the oxidation process.

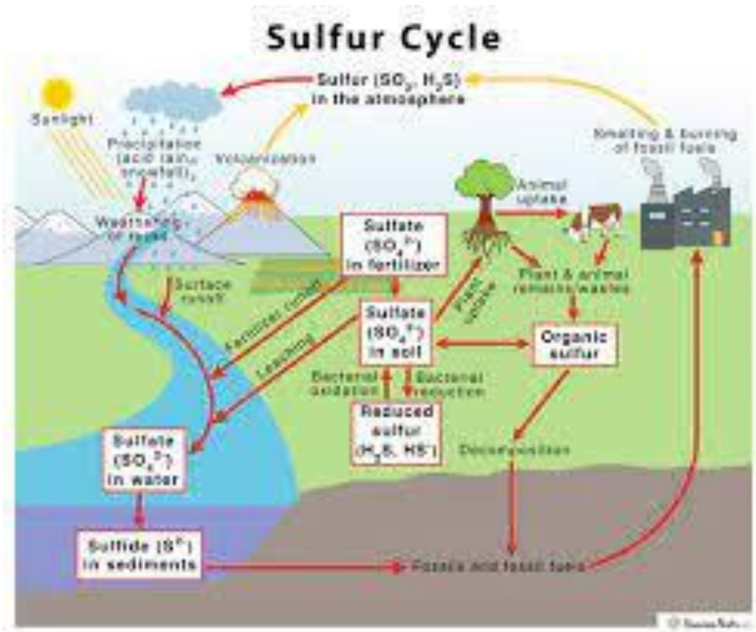
Oxidation of Elemental Sulphur

Elemental sulphur present in the soil cannot be utilized directly by the plants. Therefore, it is converted into sulphates by chemolithotrophic bacteria.

Reduction of Sulphates

Sulphates are reduced to hydrogen sulphide by *Desulfovibrio desulfuricans.* This occurs in two steps:

- Firstly, the sulphates are converted to sulphites utilizing ATP.
- Secondly, the reduction of sulphite to hydrogen sulphide.



Phosphorus cycle.----

The phosphorus cycle is the biogeochemical cycle that describes the movement of phosphorus through the lithosphere, hydrosphere, and biosphere. Unlike many other biogeochemical cycles, the atmosphere does not play a significant role in the movement of phosphorus.

Phosphorus is an important element for all living organisms. It forms a significant part of the structural framework of DNA and RNA. They are also an important component of ATP. Humans contain 80% of phosphorus in teeth and bones. Plants assimilate phosphorus as phosphate and incorporate it into organic compounds and in animals, phosphorus is a key component of bones, teeth, etc Soil microorganisms act as both sinks and sources of available phosphorus in the biogeochemical cycle On land most phosphorus is found in rocks and minerals. Phosphorus-rich deposits have generally formed in the ocean or from guano, and over time, geologic processes bring ocean sediments to land. Weathering of rocks and minerals release phosphorus in a soluble form where it is taken up by plants, and it is transformed into organic compounds. The plants may then be consumed by herbivores and the phosphorus is either incorporated into their tissues or excreted. After death, the animal or plant decays, and phosphorus is returned to the soil where a large part of the phosphorus is transformed into insoluble compounds. Runoff may carry a small part of the phosphorus back to the ocean.

Steps of Phosphorus Cycle

Following are the important steps of phosphorus cycle:

1. Weathering
2. Absorption by Plants
3. Absorption by Animals

4. Return to the Environment through Decomposition

Weathering

Phosphorus is found in the rocks in abundance. That is why the phosphorus cycle starts in the earth's crust. The phosphate salts are broken down from the rocks. These salts are washed away into the ground where they mix in the soil.

Absorption by Plants

The phosphate salts dissolved in water are absorbed by the plants. However, the amount of phosphorus present in the soil is very less. That is why the farmers apply phosphate fertilizers on agricultural land.

The aquatic plants absorb inorganic phosphorus from lower layers of water bodies. Since phosphate salts do not dissolve in water properly, they affect plant growth in aquatic ecosystems.

Absorption by Animals

The animals absorb phosphorus from the plants or by consuming plant-eating animals. The rate of the phosphorus cycle is faster in plants and animals when compared to rocks.

Return of Phosphorus Back to the Ecosystem

When the plants and animals die they are decomposed by microorganisms During this process, the organic form of phosphorus is converted into the inorganic form, which is recycled to soil and water.

Soil and water will end up in sediments and rocks, which will again release phosphorus by weathering.