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Microbial Ecology

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300 level

Microbes like soil bacteria & fungi play an important role in the food chain as they are decomposers which acts in the last stage of the food chain. These microorganisms cause the breakdown of energy rich organic compounds. These compounds come from decaying matter of plants such as leaves or from animal waste and dead bodies.

Nutrient recycling occurs when nutrients are released into the environment. Carnivorous animals feed on herbivorous animals that live on plants. When animals defecate, this waste material is broken down by worms and insects mostly beetles and ants. These small soil animals break the waste material into smaller bits on which microscopic bacteria and fungi can act. This material is thus broken down further into nutrients that plants can absorb and use for their growth. Similarly, the bodies of dead animals and plants are broken down into nutrients so that plants can absorb the nutrients through their roots. Thus, nutrients are recycled back from animals to plants and other organism by microbial consumers. If the dead material, or waste, is not broken down by microbes, those nutrients will never become available to help sustain the life of other organisms. As we know that Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus and Sulphur are important for living organism. Recycling of these elements in environment is called as biogeochemical cycle or nutrient cycle. Biogeochemical cycle is a pathway by which a chemical element or molecule moves through both biotic (biosphere) and abiotic (lithosphere, atmosphere, and hydrosphere) compartments of Earth. All are recycled in environment mainly by microbial activity. Microbes like photosynthetic algae and bacteria are the most important agents of CO2 fixation and recycle carbon in atmosphere. Recycling of H and O is actively involved with the other cycles like the carbon cycle, nitrogen cycle, sulfur cycle and phosphorous cycle as well.

Nitrogen Cycle

Nitrogen is a substance that is essential for all life on the earth. Most nitrogen can be found in air in the gaseous form (78%), but nitrogen can also be found in water and soil in different forms. There, it will be decomposed by bacteria (decomposer) and absorbed by plants and animals. Nitrogen is a part of vital organic compounds because it is chief constituents of amino acids, proteins and DNA. Nitrogen in the gaseous form cannot be absorbed and used as a nutrient by plants and animals; it must first be converted by nitrifying bacteria, so that it can enter food chains as a part of the nitrogen cycle. During the nitrogen fixation process cyanobacteria first convert nitrogen into ammonia and ammonium (ammonium fixation). Plants use ammonia as a nitrogen source. Ammonium fixation is carried out according to the following reaction: N2 + 3 H2 = 2 NH3 After ammonium fixation, the ammonia and ammonium is converted into nitrite (NO2-) by Nitrosomonas bacteria and subsequently Nitrobacter convert nitrite to nitrate (NO3-) through the nitrification process. Nitrite and nitrate are the main plant nutrients.

Nitrification is carried out according to the following reactions:

2NH3 + 3O2 = 2 NO2 + 2 H+ + 2 H2O

2 NO2- + O2 = 2 NO3

During the assimilation process, plants absorb ammonium and nitrate, after which they are converted into nitrogen-containing organic molecules, such as amino acids and DNA. Animals cannot absorb nitrates directly. They receive their nutrient supplies by consuming plants. When nitrogen nutrients have served their purpose in plants and animals, specialized decomposing bacteria will start a process called ammonification, to convert them back into ammonia and water-soluble ammonium salts. After the nutrients are converted back into ammonia, anaerobic bacteria such as Thiobacillus denitrificans, Micrococcus denitrificans, and Achromobacter will convert them back into nitrogen gas, during a process called denitrification. Finally, nitrogen is released into the atmosphere again. Denitrification is carried out according to the following reaction:

NO3- + CH2O + H+ = ½ N2O + CO2 + 1½ H2O

Phosphorous Cycle

Phosphorus is found on earth in water, soil, rock and sediments. Phosphorus is taken by plants and animals in the form of phosphate (PO43-) and Monohydrogen phosphate (HPO42-) ions. It is a part of DNA, store energy molecules like ATP and ADP, and of fats of cell membranes. Phosphorus is also a building block of bones and teeth of the human and animal body. Phosphorus is usually liquid at normal temperatures and pressures. In the atmosphere phosphorus can mainly be found as very small dust particles. Phosphate salts that are released from rocks through weathering process usually dissolve in soil water and is absorbed by plants. The phosphorus cycle is the slowest one of the matter cycles that is described here. Because the quantities of phosphorus in soil are generally small, it is often the limiting factor for plant growth. That is why humans often apply phosphate fertilizers on farmland. Animals absorb phosphates by eating plants or plant-eating animals. When animals and plants die, phosphates will return to the soils or oceans (environment) again during decay of dead bodies (either plant or animal) by microbial enzymatic activity. Important organisms active in phosphate recycling are bacteria and fungi such as species of Bacillus, Pseudomonas, Micrococcus, Flavobacterium, Aspergillus, Penicillium, Fusarium. The enzymes involved in cleaving phosphate from organic phosphorus compounds are collectively known as phosphatases. These enzymes show a broad range of substrate specificity and are grouped into two groups based on their pH optima the alkaline phosphatases and the acid phosphatases. Bacteria play the role of disintegrator in the phosphorus cycle.

Sulphur Cycle

Sulphate ion (SO42-) is taken up from soil by plants, which incorporate it into protein, and plant protein is consumed by animals that convert plant protein to animal protein. Death of plants and animals allows bacterial decomposition of protein in remains to produce hydrogen sulphide and other products. Members of the genus Thiobacillus are the main organisms involved in the oxidation of elemental sulphur. The ability to oxidize sulphur is not restricted to only the genus Thiobacillus. Heterotrophic bacteria (Proteus vulgaris), actinomycetes and fungi are also reported to oxidize sulphur compounds. For example, species of Bacillus, Pseudomonas, Arthrobacter and Flavobacterium are known to oxidize elemental sulphur or thiosulphate to sulphate. Some bacteria can function in the transition zone between aerobic and anaerobic environments. Hydrogen sulphide may be oxidized to sulphur by such bacteria which deposit elemental sulphur in their cells while using oxygen as the terminal electron acceptor. Hydrogen sulphide may also be oxidized to sulphate photosynthetically by the bacteria, Chromtiacceae and Chlorobiaceae. Sulphur is first converted enzymatically to sulphite which is then oxidized to sulphate.

It is believed that some of the sulphite from the first reaction reacts with sulphur to yield thiosulphate which is then either cleaved to sulphur and sulphite or converted into tetrathionite. The latter is then metabolized to sulphur or sulphite which is then oxidized to sulphate. Under anaerobic conditions, sulphate is first reduced to H2S by sulphate reducing microorganisms, mostly the bacteria. Many bacteria including species of Bacillus and Pseudomonas are known to reduce sulphur or sulphate to H2S but among these, Desulfovibrio desulfuricans seems to be the most important.

Carbon Cycle

Carbon is another important element for life as it makes up every organic compound. Despite the fact that carbon is the foundation for all life, its concentration must be kept constant. Carbon occurs in many forms such as limestones (calcium carbonate), dissolved in oceans and fresh water and in the atmosphere as carbon dioxide. An example of a carbon cycle is the microbial digestion of cellulose. The carbon cycle takes place in two stages: oxic and anoxic. Carbon fixation is carried out by photoautotrophic and chemolithotrophic bacteria such as Synechococcus and Thiobacillus respectively. The cycle consists mainly of one group of bacteria aerobically converting methane to CO2 (Methanotrophy) while another group convert CO2 to methane (Methanogenesis).