# Department of biology

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## ((soil microbiology))

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**The Carbon Cycle and Its Relationship with Soil Microorganisms**

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Carbon exists in the atmosphere mainly in the form of carbon dioxide ($CO_2$). It is also found in the compounds that form the bodies of terrestrial organisms, in soil as organic matter and humus, and in aquatic environments as bicarbonates and carbonates. In addition, carbon is found dissolved in water, within the lithosphere, and in fossil fuels .such as coal, oil, and natural gas

The carbon cycle in nature begins with photosynthesis, which is the driving force of carbon movement in ecosystems. If photosynthesis were to stop, carbon would cease to exist in other usable forms. During this process, green plants (producers) take carbon dioxide from the atmosphere, along with water and sunlight, to synthesize carbohydrates (organic matter). This process can be summarized by the following :equation

$$CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_26$$

In photosynthesis, plants consume carbon dioxide and release oxygen. Through this process, plants and other photosynthetic organisms help reduce the amount of $CO_2$ in the atmosphere and in aquatic systems, including the excess $CO_2$ produced by .fossil fuel combustion

Plants also undergo respiration, during which $CO_2$ is released back into the atmosphere. This carbon dioxide is then reused by plants in photosynthesis, completing the carbon cycle. Thus, the carbon cycle is closely linked to the movement of .atmospheric $CO_2$

Carbon follows complex pathways in ecosystems. After plants convert carbon into organic compounds, animals consume plant material, and these organic substances are digested, absorbed, and assimilated to build animal tissues. Carbon atoms that were part of plant tissues become incorporated into the cells and tissues of animals. Carbon returns to the atmosphere through .respiration as $CO_2$

After the death of plants and animals, carbon becomes part of soil organic matter. Some of this carbon returns to the atmosphere through aerobic decomposition carried out by microorganisms (decomposers). However, part of the organic carbon follows slower pathways, such as incorporation into hard structures. In marine organisms, carbon becomes part of shells in the form of calcium carbonate. Over long periods, this carbon becomes fixed in limestone rocks formed .from marine sediments

Large amounts of $CO_2$ also dissolve in oceans, seas, and lakes, contributing to carbon fixation through sedimentation. Limestone rocks undergo chemical weathering, releasing part of the fixed carbon back into the atmosphere as $CO_2$. Carbon can also become trapped in fossil fuels when organic matter is preserved from aerobic decomposition. When fossil fuels are burned, carbon is released again into the atmosphere as .$CO_2$, re-entering the carbon cycle

Role of Soil Microorganisms in the Carbon Cycle

Soil organisms decompose natural organic materials, improving soil fertility by breaking down plant and animal tissues and mixing decomposition products and released minerals with soil particles. Some soil microorganisms are also capable of .degrading certain synthetic organic products

Soil organisms convert decomposed plant and animal residues into an important organic compound called humus, which contains approximately 60% carbon and 6% nitrogen, in addition to phenolic compounds, organic phosphates, sugars, and other substances. The movement of soil fauna helps mix humus with soil, improving soil structure, aeration, and water movement, and making humus available to .microorganisms

Microorganisms slowly decompose humus, releasing plant nutrients. After the death of these microorganisms, nutrients are further recycled. The most important microorganisms involved in the .carbon cycle are bacteria and fungi

## Decomposition of Organic Matter

Plant tissues are the primary source of organic matter subjected to microbial decomposition in soil. These include leaves, branches, and roots. Other sources include animal residues, microorganisms, decomposed remains after death, and industrial organic materials such as organic fertilizers.

Plant residues consist of a mixture of compounds that differ in their physical and chemical properties. These compounds are generally classified into six :main groups

Cellulose compounds: 15–60%

Hemicellulose compounds: 10–30%

Lignin: 5–30% .3

Water-soluble compounds (simple sugars, organic . acids, amino acids): 5–30%

Alcohol- or ether-soluble compounds (oils, fats, . waxes): ~2%

Proteins, which contain nitrogen and sulfur .

As plants age, the proportion of water-soluble compounds, proteins, and minerals decreases, .while cellulose, hemicellulose, and lignin increase

Microbial decomposition of organic matter serves :two main purposes

Obtaining energy for growth .

Obtaining carbon for the formation of new cell .2 material

Most microbial cells contain 40–50% carbon of their dry weight. The conversion of organic carbon .into microbial cell carbon is called assimilation

## Microbial Efficiency in Carbon Utilization

Soil microorganisms differ in their efficiency of organic carbon assimilation. Fungi are generally more efficient than other microorganisms, releasing less $CO_2$ per unit of carbon decomposed under aerobic conditions. Higher efficiency means more carbon is converted into microbial biomass and less .is lost as $CO_2$

Actinomycetes and fungi are more efficient in carbon assimilation than aerobic bacteria, while anaerobic bacteria are less efficient and produce more organic residues and less complete oxidation products. Anaerobic microorganisms release large amounts of energy from organic matter, producing intermediate compounds that can later be used by .other microorganisms

Under aerobic conditions, fungi may assimilate 30–40% of organic carbon into new mycelium, whereas aerobic bacteria typically assimilate 5–.10%, and anaerobic bacteria only 2–5%

Carbon assimilation is accompanied by the assimilation of nitrogen, phosphorus, potassium, sulfur, and other mineral elements. The assimilation of these nutrients is proportional to microbial biomass formation. For example, if microbial cells contain about 50% carbon and 5% nitrogen, then nitrogen assimilation is .approximately one-tenth of the carbon assimilated

Indicators of Microbial Activity

:Microbial activity in soil can be assessed by

Measuring $CO_2$ released or $O_2$ consumed .1

Estimating the decrease in organic matter .2 content

Monitoring the disappearance of specific .3 compounds such as cellulose, lignin, or hemicellulose during decomposition

Processes Occurring During Organic Matter Decomposition

Three processes occur simultaneously:

1-Disappearance of plant and animal tissues due . to microbial enzyme activity

2-Formation of new microbial cells (proteins, . nucleic acids) from decomposition products

3-Metabolic transformation of microbial by- . products, which may be reused, modified, or accumulated in soil

Despite the diversity of organic compounds, microorganisms obtain energy only from compounds that enter the cell. Large molecules must be broken down into simpler compounds before energy extraction. Although the chemical nature of carbohydrates, proteins, and lipids differs, their intracellular metabolic pathways eventually converge into common biochemical routes.