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Soil Microbiology

Microbiology

is the study of all living organisms that are too small to be visible with the naked eye. (from Greek μῑκρος, mīkros, "small"; βίος, bios, "life"; and -λογία, -logia) is the study of microorganisms, those being unicellular (single cell), multicellular (cell colony), or acellular (lacking cells). This includes bacteria, archaea, viruses, fungi, prions, protozoa and algae, collectively known as 'microbes'. These microbes play key roles in nutrient cycling, biodegradation/, climate change, food spoilage, the cause and control of disease, and biotechnology.

microbiology divided in to:

1-Medical microbiology:.

2-Pharmaceutical microbiology

3-Industrial microbiology:

4-Microbial biotechnology:

5-Food microbiology:

6-Agricultural microbiology: classified into the following:

a-Plant microbiology

b-Soil microbiology:

7-Veterinary microbiology:

8-Environmental microbiology:

9-Water microbiology

10-Aeromicrobiology

Soil Microbiology

It is branch of science/microbiology which deals with study of soil microorganisms and their activities in the soil.

Soil:

From the microbiologist view point, soil is one of the most dynamic sites of biological interactions in the nature. It is the region where most of the physical, biological and biochemical reactions related to decomposition of organic weathering of parent rock take place.

Components of Soil

1. **Mineral / Inorganic Matter**
2. **Organic matter/components**
3. **Soil Water**
4. **Soil air (Soil gases**
5. **Soil microorganisms: Soil is an excellent culture media for the growth and development of various microorganisms. Soil is now believed to be dynamic or living system.**

Soil contains several distinct groups of microorganisms, the most important microorganisms are:

1- **Bacteria**

2- **Fungi**

3- Actinomycetes
4- Algae
5- Protozoa
6- Viruses.

Bacteria are more numerous than any other kinds of microorganisms. Microorganisms form a very small fraction of the soil mass and occupy a volume of less than 1%. In the upper layer of soil (top soil up to 10-30 cm depth i.e. Horizon A), the microbial population is very high which decreases with depth of soil. Each organisms or a group of organisms are responsible for a specific change / transformation in the soil. The final effect of various activities of microorganisms in the soil is to make the soil fit for the growth & development of higher plants.

Living organisms present in the soil are grouped into two categories as follows.

1. Soil flora (micro flora) include microorganisms which originally present in the soil , e.g. Bacteria, fungi, Actinomycetes, Algae
2. Soil fauna (micro fauna) include microorganisms which come from other environments (air , water, human ,….) in to soil and soil is not their origin, eg. Some Bacteria, fungi, Actinomycetes, Algae, Protozoa, Nematodes, earthworms, moles, ants, rodents.

Relative proportion / percentage of various soil microorganisms are: Bacteria-aerobic (70%), anaerobic (13 %), Actinomycetes (13%), Fungi /molds (03 %) and others (Algae Protozoa viruses) 0.2-0.8 %. Soil organisms play key role in the nutrient transformations.

Factors Affecting Distribution, Activity and Population of Soil Microorganisms

Soil microorganisms (Flora & Fauna), just like higher plants depends entirely on soil for their nutrition, growth and activity. The major soil factors which influence the microbial population, distribution and their activity in the soil are:

1. Soil fertility 2. Cultural practices 3. Soil moisture 4. Soil temperature 5. Soil aeration 6. Light 7. Soil PH (H-ion Concentration) 8. Organic matter 9. Food and energy supply 10. Nature of soil and 11. Microbial associations.

All these factors play a great role in determining not only the number and type of organism but also their activities. Variations in any one or more of these factors may lead to the changes in the activity of the organisms which ultimately affect the soil fertility level. Brief account of all these factors influencing soil micro flora / organisms and their activities:

1. Cultural practices: Cultural practices , cultivation, crop rotation, application of manures and fertilizers, also pesticide application have their effect on soil organism. tillage operations facilitate aeration in soil and exposure of soil to sunshine and thereby increase the biological activity of organisms, particularly of bacteria. Crop rotation with legume will maintain the favorable microbial population balance, particularly of N_2 fixing bacteria and thereby improve soil fertility.

Liming of acid soils increases activity of bacteria and actinomycetes and lowers the fungal population. Fertilizers and manures applied to the soil for increased crop production, supply food and nutrition not only to the crops but also to microorganisms in soil and thereby proliferate the activity of microbes.

Foliar or soil application of different chemicals (pesticides, fungicides, nematicides etc.) in agriculture are either degraded by the soil organisms or are liable to leave toxic residues in soil which are hazardous to cause profound reduction in the normal microbial activity in the soil.

2. Soil fertility: Fertility level of the soil has a great influence on the microbial population and their activity in soil. The availability of N, P and K required for plants as well as microbes in soil determines the fertility level of soil. On the other hand soil micro flora has greater influence on the soil fertility level.

3. Soil moisture: It is one of the important factors influencing the microbial population & their activity in soil. Water (soil moisture) is useful to the microorganisms in two ways a- it serve as source of nutrients and supplies hydrogen / oxygen to the organisms and b- it serve as solvent and carrier of other food nutrients to the microorganisms. Microbial activity & population become best in the moisture range of 20% to 60%. Under excess moisture conditions / water logged conditions due to lack of soil aeration (Oxygen) anaerobic microflora become active and the aerobes get suppressed. While in the absence of adequate moisture in soil, some of microbes die out due to tissue dehydration and some of them change their forms into resting stages spores or cysts and tide over

adverse conditions. Therefore optimum soil moisture (range 20 to 60 %) must be there for better population and activity of microbes in soil.

4. Soil temperature: Next to moisture, temperature is the most important environmental factor influencing the biological physical & chemical processes and of microbes, microbial activity and population in soil. Though microorganisms can tolerate high temperature (such as - 60 ° or + 60 u) conditions, but the optimum temperature range at which soil microorganisms can grow and function actively is rather narrow.

Depending upon the temperature range at which microorganisms can grow and function, are divided into three groups a-. psychrophiles (growing at low temperature below 10 °C) b- Mesophiles (growing well in the temp range of 20 ° C to 45° C) and c- thermopiles (can tolerate temperature above 45° C and optimum 45-60°C).

Most of the soil microorganisms are mesophilic (25 to 40 °) and optimum temperature for most mesophiles is 37° C. True psychrophiles are almost absent in soil, and thermopiles though present in soil behaves like mesophiles. True thermopiles are more abundant in decaying manure and compost heaps where high temperature prevails.

Seasonal changes in soil temperature affect microbial population and their activity especially in temperate regions. In winter, when temperature is low (below 50° C), the number and activity of microorganisms falls down, and as the soils warms up in spring, they increases in number as well as activity. In general, population and activities of soil microorganisms are the highest in spring and lowest in winter season.

5. Soil air (Aeration): For the growth of microorganisms better aeration (oxygen and sometimes CO_2) in the soil is essential. Microbes consume oxygen from soil air and gives out carbon dioxide. Activities of soil microbes is often measured in terms of the amount of oxygen absorbed or amount of Co_2 evolved by the organisms in the soil environment. Under high soil moisture level / water logged conditions, gaseous exchange is hindered and the accumulation of Co_4 occurs in soil air which is toxic to microbes. Depending upon oxygen requirements, soil microorganisms are grouped into categories viz aerobic (require oxygen for like processes), anaerobic (do not require oxygen) and microaerophilic (requiring low concentration / level of oxygen).

6. Light: Direct sunlight is highly injurious to most of the microorganisms except algae. Therefore upper portion of the surface soil a centimeter or less is usually sterile or devoid of microorganisms. Effect of sunlight is due to heating and increase in temperature (More than 45°)

7. Soil Reaction / Soil PH: Soil reaction has a definite influence / effect on quantitative and qualitative composite on of soil microbes. Most of the soil bacteria, blue-green algae, diatoms and protozoa prefer a neutral or slightly alkaline reaction between PH 4.5 and 8.0 and fungi grow in acidic reaction between PH 4.5 and 6.5 while actinomycetes prefer slightly alkaline soil reactions. Soil reactions also influence the type of the bacteria present in soil. For example nitrifying bacteria (*Nitrosomonas & Nitrobacter*) and diazotrophs like *Azotobacter* are absent totally or inactive in acid soils, while diazotrophs like Beijerinckia, Derxia, and sulphur oxidizing bacteria like *Thiobacillus thiooxidans* are active in acidic soils.

8. Soil Organic Matter: The organic matter in soil being the chief source of energy and food for most of the soil organisms, it has great influence on the microbial population. Organic matter influence directly or indirectly on the population and activity of soil microorganisms. It influences the structure and texture of soil and thereby activity of the microorganisms.

9. Food and energy supply: Almost all microorganisms obtain their food and energy from the plant residues or organic matter / substances added to the soil. Energy is required for the metabolic activities of microorganisms. The heterotrophs utilize the energy liberated during the oxidation of complex organic compounds in soil, while autotrophs meet their energy requirement form oxidation of simple inorganic compounds (chemoautotroph) or from solar radiation (Photoautotroph). Thus, the source of food and energy rich material is essential for the microbial activity in soil. The organic matter, therefore serves both as a source of food nutrients as well as energy required by the soil organisms.

10. Nature of Soil: The physical, chemical and physico-chemical nature of soil and its nutrient status influence the microbial population both quantitatively and qualitatively. The chemical nature of soil has considerable effect on microbial population in soil. The soils in good physical condition have better aeration and moisture content which is essential for optimum microbial activity. Similarly nutrients (macro and micro) and organic constituents of humus are responsible for absence or presence of certain type of microorganisms and their activity. For example activity and presence of nitrogen fixing bacteria is greatly influenced by the availability of molybdenum and absence of available phosphate restricts the growth of Azotobacter.

<u>11. Microbial associations</u> / interactions: Microorganisms interact with each other giving rise to antagonistic or symbiotic interactions. The association existing between one organism and another whether of symbiotic or antagonistic influences the population and activity of soil microbes to a great extent. The predatory habit of protozoa and some mycobacteria which feed on bacteria may suppress or eliminate certain bacteria. On the other hand, the activities of some of the microorganisms are beneficial to each other. For instance organic acids liberated by fungi, increase in oxygen by the activity of algae, change in soil reaction etc. favors the activity or bacteria and other organisms in soil.

<u>12. Root Exudates</u>: In the soil where plants are growing the root exudates also affects the distribution, density and activity of soil microorganism. Root exudates and sloughed off material of root surfaces provide an abundant source of energy and nutrients and thus directly or indirectly influence the quality as well as quantity of microorganisms in the rhizosphere region. Root exudates contain sugars, organic acids, amino acids, sterols, vitamins and other growth factors which have the profound effect on soil microbes.

Importance of Soil Microbiology

Though these organisms form only a fraction (less than one percent) of the total soil mass, but they play important role in supporting plant communities on the earth surface. While studying the importance of soil microbiology, soil-plant-animal ecosystem as such must be taken into account. Therefore, the scope and importance of soil microbiology, can be understood in better way by studying aspects like

- Soil as a living system
- Soil microbes and plant growth
- Soil microorganisms and soil structure
- Organic matter decomposition
- Humus formation
- Biogeochemical cycling of elements
- Soil microorganisms as bio-control agents
- Soil microbes and seed germination
- Biological N2 fixation
- Degradation of pesticides in soil.

1. Soil as a living system: Soil inhabit diverse group of living organisms, both micro flora (fungi, bacteria, algae and actinomycetes) and micro-fauna (protozoa, nematodes, earthworms, moles, ants). The density of living organisms in soil is very high i.e. as much as billions / gm of soil, usually density of organisms is less in cultivated soil than uncultivated / virgin land and population decreases with soil acidity. Top soil, the surface layer contains greater number of microorganisms because it is well supplied with Oxygen and nutrients. Lower layer / subsoil is depleted with Oxygen and nutrients hence it contains fewer organisms. Soil ecosystem comprises of organisms which are both, autotrophs (Algae, BOA) and heterotrophs (fungi, bacteria). Autotrophs use inorganic carbon from CO2 and are "primary producers" of organic matter, whereas heterotrophs use organic carbon and are decomposers/consumers.

2. Soil microbes and plant growth: Microorganisms being minute and microscopic, they are universally present in soil, water and air. Besides supporting the growth of various biological systems, soil and soil microbes serve as a best medium for plant growth. Soil fauna & flora convert complex organic nutrients into simpler inorganic forms which are readily absorbed by the plant for growth. Further, they produce variety of substances like IAA, gibberellins, antibiotics etc. which directly or indirectly promote the plant growth

3. Soil microbes and soil structure: Soil structure is dependent on stable aggregates of soil particles-Soil organisms play important role in soil aggregation. Constituents of soil are viz. organic matter, polysaccharides, lignins and gums, synthesized by soil microbes plays important role in cementing / binding of soil particles. Further, cells and mycelial strands of fungi and actinomycetes, Vormicasts from earthworm is also found to play important role in soil aggregation. Different soil microorganisms, having soil aggregation / soil binding properties are graded in the order as fungi > actinomycetes > gum producing bacteria > yeasts.
Examples are: Fungi like ***Rhizopus, Mucor, Chaetomium,***

Fusarium, Cladasporium, Rhizoctonia, Aspergillus, Trichoderma and Bacteria like ***Azotobacter, Rhizobium Bacillus*** and ***Xanthomonas.***

4. Soil microbes and organic matter decomposition:

The organic matter serves not only as a source of food for microorganisms but also supplies energy for the vital processes of metabolism that are characteristics of living beings. Microorganisms such as fungi, actinomycetes, bacteria, protozoa etc. and macro organisms such as earthworms, termites, insects etc. plays important role in the process of decomposition of organic matter and release of plant nutrients in soil. Thus, organic matter added to the soil is converted by oxidative decomposition to simpler nutrients / substances for plant growth and the residue is transformed into humus. Organic matter / substances include cellulose, lignins and proteins (in cell wall of plants), glycogen (animal tissues), proteins and fats (plants, animals). Cellulose is degraded by bacteria, especially those of genus ***Cytophaga*** and other genera ***(Bacillus, Pseudomonas, Cellulomonas, and Vibrio Achromobacter)*** and fungal genera ***(Aspergillus, Penicilliun, Trichoderma, Chactomium, Curvularia).*** Lignins and proteins are partially digested by fungi, protozoa and nematodes. Proteins are degraded to individual amino acids mainly by fungi, ***actinomycetes*** and ***Clostridium.*** Under unaerobic conditions of waterlogged soils, methane are main carbon containing product which is produced by the bacterial genera (strict anaerobes) ***Methanococcus, Methanobacterium*** and ***Methanosardna.***

5. Soil microbes and humus formation: Humus is the organic residue in the soil resulting from decomposition of plant and animal residues in soil, or it is the highly complex organic residual matter in soil which is not readily degraded by microorganism, or it is the soft brown/dark coloured amorphous substance composed of residual organic matter along with dead microorganisms.

6. Soil microbes as biocontrol agents: Several ecofriendly bioformulations of microbial origin are used in agriculture for the effective management of plant diseases, insect pests, weeds etc. eg: ***Trichoderma*** sp and ***Gleocladium*** sp are used for biological control of seed and soil borne diseases. Fungal genera ***Entomophthora, Beauveria, Metarrhizium*** and protozoa ***Maltesia grandis. Malameba locustiae*** etc are used in the management of insect pests. Nuclear polyhydrosis virus (NPV) is used for the control of ***Heliothis /*** American boll worm. Bacteria like ***Bacillus thuringiensis, Pseudomonas*** are used in cotton against Angular leaf spot and boll worms.

7. Degradation of pesticides in soil by microorganisms: Soil receives different toxic chemicals in various forms and causes adverse effects on beneficial soil micro flora / micro fauna, plants, animals and human beings. Various microbes present in soil act as the scavengers of these harmful chemicals in soil. The pesticides/chemicals reaching the soil are acted upon by several physical, chemical and biological forces exerted by microbes in the soil and they are degraded into non-toxic substances and thereby minimize the damage caused by the pesticides to the ecosystem. For example, bacterial genera like ***Pseudomonas, Clostridium, Bacillus, Thiobacillus, Achromobacter etc. and*** fungal genera like ***Trichoderma, Penicillium, Aspergillus, Rhizopus, and Fusarium*** are playing important role in the degradation of the toxic chemicals / pesticides in soil.

8. Biodegradation of hydrocarbons: Natural hydrocarbons in soil like waxes, paraffin's, oils etc are degraded by fungi, bacteria and actinomycetes. E.g. ethane ***(C2*** H6) a paraffin hydrocarbon is metabolized and degraded by ***Mycobacteria, Nocardia, Streptomyces Pseudomonas, Flavobacterium*** and several fungi.

7. Soil microbes and biological N2 fixation: Conversion of atmospheric nitrogen in to ammonia and nitrate by microorganisms is known as biological nitrogen fixation.

Fixation of atmospheric nitrogen is essential because of the reasons:

- Fixed nitrogen is lost through the process of nitrogen cycle through denitrification.
- Demand for fixed nitrogen by the biosphere always exceeds its availability.
- The amount of nitrogen fixed chemically and lightning process is very less (i.e. 0.5%) as compared to biologically fixed nitrogen

- Nitrogenous fertilizers contribute only 25% of the total world requirement while biological nitrogen fixation contributes about 60% of the earth's fixed nitrogen
- Manufacture of nitrogenous fertilizers by "Haber" process is costly and time consuming.

The numbers of soil microorganisms carry out the process of biological nitrogen fixation at normal atmospheric pressure (1 atmosphere) and temp (around 20 °C).

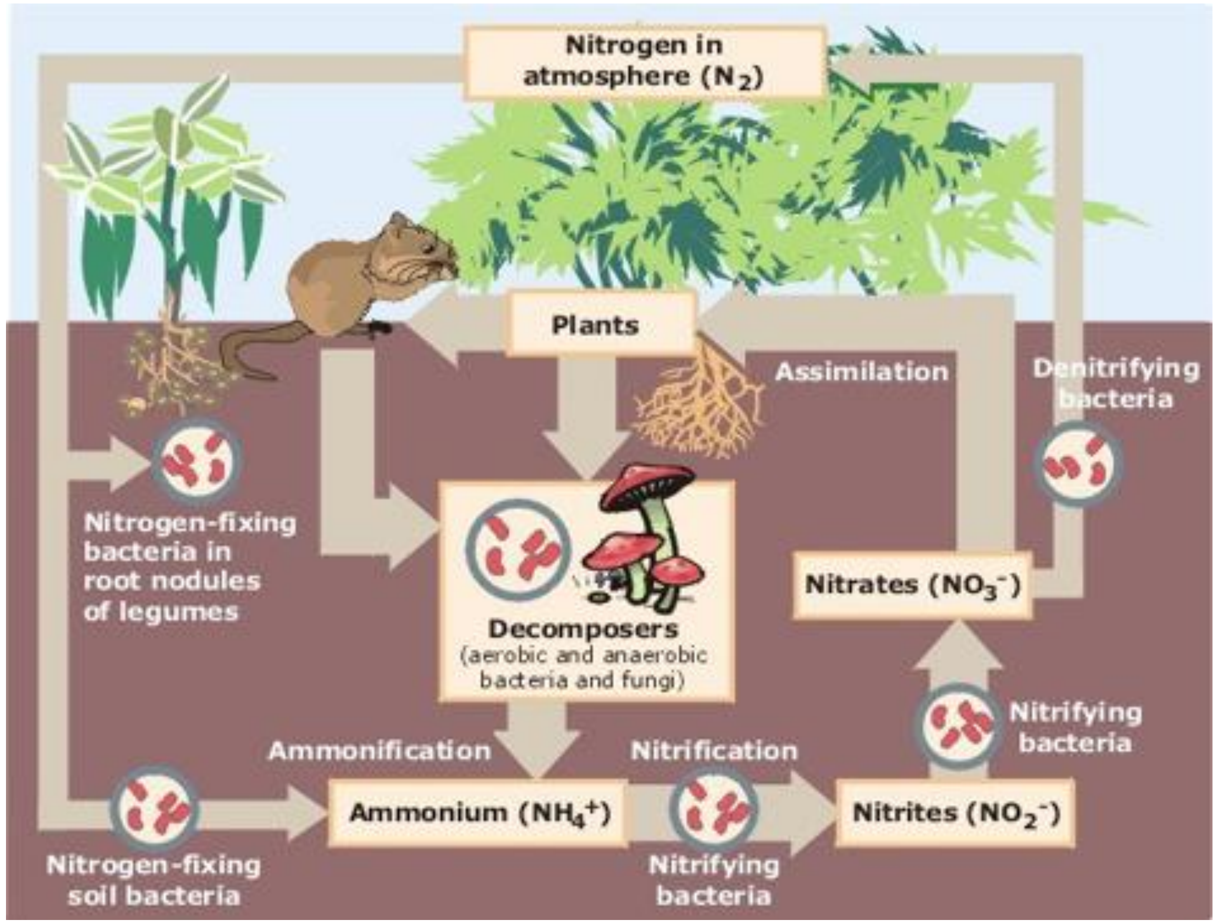
Two groups of microorganisms are involved in the process of BNF.
A. Non-symbiotic (free living) and B. Symbiotic (Associative)

- **Non-symbiotic (free living):** Depending upon the presence or absence of oxygen, non symbiotic N2 fixation prokaryotic organisms may be aerobic heterotrophs (***Azotobacter, Pseudomonas, Achromobacter)*** or aerobic autotrophs ***(Nostoc, Anabena, Calothrix, BGA)*** and anaerobic heterotrophs ***(Clostridium, Kelbsiella. Desulfovibrio)*** or anaerobic Autotrophs ***(Chlorobium, Chromnatium, Rhodospirillum, Meihanobacterium etc)***
- **Symbiotic (Associative):** The organisms involved are ***Rhizobium, Bradyrhizobium*** in legumes (aerobic): ***Azospirillum*** (grasses), Actinonycetes franciac(with ***Casuarinas,*** Alder).

9. Soil microbes and cycling of elements: Life on earth is dependent on cycling of elements from their organic / elemental state to inorganic compounds, then to organic compounds and back to their elemental states. The biogeochemical process through which organic compounds are broken down to inorganic compounds or their constituent elements is known "Mineralization", or microbial conversion of complex organic compounds into simple inorganic compounds & their constituent elements is known as mineralization.

Soil microbes plays important role in the biochemical cycling of elements in the biosphere where the essential elements (C, P, S, N & Iron etc.) undergo chemical transformations. Through the process of mineralization organic carbon, nitrogen, phosphorus, Sulphur, Iron etc. are made available for reuse by plants.

Nitrogen cycle



Nitrification is the biological oxidation of ammonia with oxygen into nitrite followed by the oxidation of these nitrites into nitrates. Degradation of ammonia to nitrite is usually the rate limiting step of nitrification. Nitrification is an important step in the nitrogen cycle in soil.

The oxidation of ammonia into nitrite is performed by two groups of organisms, ammonia-oxidizing bacteria (AOB) and ammonia-oxidizing archaea (AOA). In soils the most studied AOB belong to the genera *Nitrosomonas* and *Nitrosococcus*. Although in soils ammonia oxidation occurs by both AOB and AOA, AOA dominate in both soils and marine

environments, suggesting that Crenarchaeota may be greater contributors to ammonia oxidation in these environments.

The second step (oxidation of nitrite into nitrate) is done (mainly) by bacteria of the genus *Nitrobacter*.

Nitrification is a process of nitrogen compound oxidation (effectively, loss of electrons from the nitrogen atom to the oxygen atoms):

- $NH_3 + CO_2 + 1.5\ O_2$ + Nitrosomonas $\rightarrow NO_2^- + H_2O + H^+$
- $NO_2^- + CO_2 + 0.5\ O_2$ + Nitrobacter $\rightarrow NO_3^-$
- $NH_3 + O_2 \rightarrow NO_2^- + 3H^+ + 2e^-$
- $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e$

Nitrogen Fixation

1-Biological Nitrogen fixation is the process by which atmospheric nitrogen gas is converted into ammonia. The ammonia is subsequently available for many important biological molecules such as amino acids, proteins, vitamins, and nucleic acids. The reaction can be presented as follows:

$N_2 + 16\ ATP + 8e^- + 8H^+ \Rightarrow 2NH_3 + 16\ ADP + 16\ Pi + H_2$

Rhizobium species	**Host plants**
Bradyrhizobium japanicum	*Glycine max* (soybean)
Rhizobium fredii	*Glycine max* (soybean)

R. phaseoli	*Phaseolus vulgaris* (common bean)
R. meliloti	*Medicago sativa* (alfalfa)
	Melilotus sp. (sweet clovers)
R. trifolii	*Trifolium* sp. (clovers)
R. leguminosarum	*Pisum sativum* (peas)
	Vicia faba (broad bean)
"Cowpea rhizobia" group or *Rhizobium* sp.	*Vigna unguiculata* (cowpea),
	Arachis hypogaea (peanut),
	Vigna subterranea (Bambara groundnut)
	Leucaena sp., *Albizia* sp.,
Azarhizobium caulinodans	*Sesbania* sp. *Sesbania rostrata* (stem nodulating)

2-Another way in which molecular nitrogen is modified is via the discharge of lightning. The tremendous energy released by the electrical discharges in our atmosphere breaks the rather strong bonds between nitrogen atoms, causing them to react with oxygen. Note in this process, nitrogen is oxidized and oxygen is reduced.

$$N_2 + O_2 \xrightarrow{\text{lightning}} 2\,NO \text{ (nitric oxide)}$$

3-The nitrous oxide formed combines with oxygen to form nitrogen dioxide.

$$2\,NO + O_2 \longrightarrow 2NO_2$$

Nitrogen dioxide readily dissolves in water to product nitric and nitrous acids;

$$2\,NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$$

Denitrification

is a microbially facilitated process of nitrate reduction that may ultimately produce molecular nitrogen (N_2)

Denitrification generally proceeds through some combination of the following intermediate forms:

$NO_3^- \rightarrow NO_2^- \rightarrow NO + N_2O \rightarrow N_2$ (g)

The process is performed primarily by heterotrophic bacteria (such as *Paracoccus denitrificans* and various pseudomonads),[1] although autotrophic denitrifiers have also been identified (e.g., *Thiobacillus denitrificans*).[2] Denitrifiers are represented in all main phylogenetic groups.

Assimilation

Plants get nitrogen from the soil, by absorption of their roots in the form of either nitrate ions or ammonium ions. All nitrogen obtained by animals can be traced back to the eating of plants at some stage of the food chain.

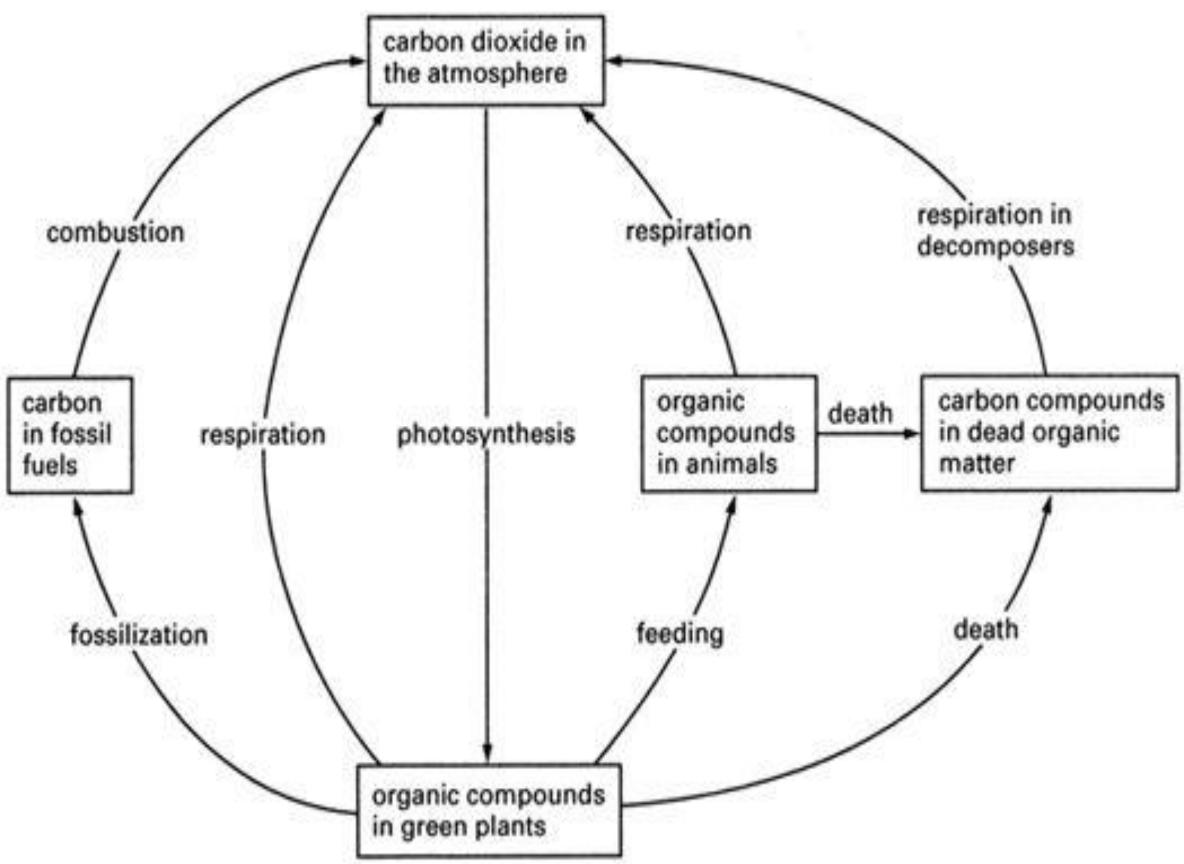
Plants can absorb nitrate or ammonium ions from the soil via their root hairs. If nitrate is absorbed, it is first reduced to nitrite ions and then ammonium ions for incorporation into amino acids, nucleic acids, and chlorophyll.[2] In plants that have a mutualistic relationship with rhizobia, some nitrogen is assimilated in the form of ammonium ions directly from the nodules. Animals, fungi, and other heterotrophic organisms obtain nitrogen as amino acids, nucleotides and other small organic molecules.

Ammonification

the conversion of organic nitrogen to ammonium (NH4+) by the action of decomposers (bacteria).

When a plant or animal dies, or an animal expels waste, the initial form of nitrogen is organic. Bacteria, or fungi in some cases, convert the organic nitrogen within the remains back into ammonium (NH4+), a process called ammonification or mineralization.

Carbon cycle



Role of Micro-organisms in Carbon Cycle

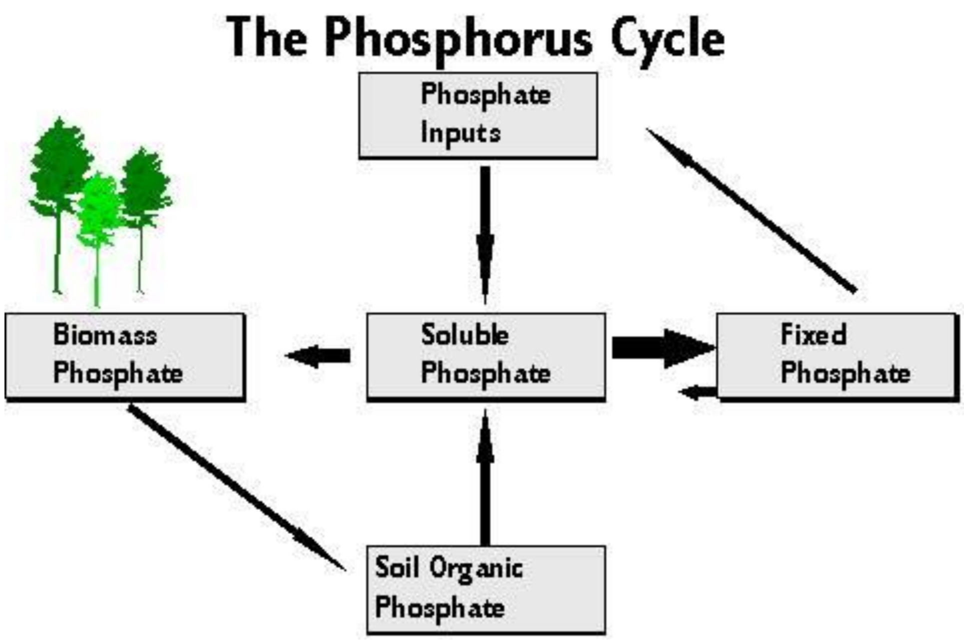
1-Fungi: The prominent role of fungi in the environment is in the carbon cycle, during the process of decomposition, especially in the soil.
2-Algae: The algae are also an important part of the carbon cycle. They are the predominant photosynthetic organisms in many aquatic environments. The algae are autotrophs, which means they use carbon dioxide (CO_2) as a source of carbon for growth. Hence they convert atmospheric CO_2 into organic material (i.e., algal cells).

3-Prokaryotic bacteria and archaea: As a result of their diversity and unique types of metabolism, are involved in the cycles of virtually all essential elements. Methanogenesis (conversion of carbon dioxide into methane) are unique to prokaryotes and earns them their "essential role" in the carbon cycle.

Bacterial heterotrophs: They are important in the carbon chain for the processes of biodegradation and decomposition under aerobic and anaerobic conditions.

In bacteria, there is a unique type of photosynthesis that does not use H_2O or produce O_2 which impacts on the carbon and sulfur cycles. Cyanobacteria fix CO_2 and produce O_2 during photosynthesis, and they make a very large contribution to the carbon and oxygen cycles.

Phosphorus Cycle



Soil phosphates are rendered available either by plant roots or by soil microorganisms through secretion of organic acids (eg. lactic, acetic, formic, fumaric, succinic acids etc). Thus, phosphate-dissolving / solubilizing soil microorganisms (eg. species of Pseudomonas, Bacillus, Micrococcus, Mycobacterium, Flavobacterium, Penicillium, Aspergillus, Fusarium etc.) plays important role in correcting phosphorus deficiency of crop plants. They may also release soluble inorganic phosphate (H2PO4), into soil through decomposition of phosphate-rich organic compounds.

Solubilization of phosphate by plant roots and soil microorganisms is substantially influenced by various soil factors, such as PH, moisture and aeration.

In neutral or alkaline soils solubilization of phosphate is more as compared to acidic soils. Many phosphates solubilizing microorganisms are found in close proximity of root surfaces and may appreciably enhance phosphate assimilation by higher plants.

By their action, fungi bacteria and actinomycetes make available the organically bound phosphorus in soil and organic matter and the process is known as mineralization. On the other hand, certain microorganisms especially bacteria assimilate soluble phosphate and use for cell synthesis and on the death of bacteria, the phosphate is made available to plants. A fraction of phosphate is also lost in soil due to leaching. One of the ways to correct deficiency of phosphorus in plants is to inoculate seed or soil with commercial preparations (eg. Phosphobacterin) containing phosphate - solubilizing microorganisms along with phosphatic fertilizers.

The commercially used species of phosphate solubilizing bacteria and fungi are: *Bacillus polymyxa, Bacillus megatherium. Pseudomonas strita, Aspergillus, Penicllium avamori and Mycorrhiza.*

Mycorrhizae

The term Mycorrhizae comes from the greek words myco, meaning fungus, and rhiza, meaning root, it defines the symbiotic (mutually beneficial) relationship between root system of plants and fungi.

There are two general types of Mycorrhizae, Endomycorrhizae & Ectomycorrhizae.

Benefits of Mycorrhiza:

- **Enhanced plant efficiency in absorbing water and nutrients from the soil.**
- **Reducing fertility and irrigation requirements.**
- **Increased drought resistance**
- **Increased pathogen resistance/protection.**
- **Enhancing plant health and vigor, and minimizing stress.**
- **Enhanced seedling growth.**
- **Enhanced rooting of cuttings.**
- **Enhanced plant transplant establishment.**
- **Improved phytoremediation of petroleum and heavy metal contaminated sites.**

Different Types of Mycorrhiza:

ARBUSCULAR MYCORRHIZA:

The name arbuscular mycorriza (AM) comes from the structure that characterizes the symbiotic associations; an intracelular finely branched hyphae (haustoria) that is called "arbuscule" where the metabolic exchanges between the fungus and the host plant takes place. The others structures that are produced by some genera of arbuscular mycorrhiza are the vesicles for lipid storage and reproductive structures present in intracellular spaces

Morton and Benny (1990) classified the Arbuscular Mycorrhiza in the Order Glomales and in two suborders: Glomineae with vesicles in the roots and formation of asexual spores (Chlamydospores) and the Order Gigasporineae with absence of vesicles in the roots and formation of auxiliary cells and azygospores.

The suborder Glomineae was divided into two families:

- Glomaceae.-With the genus Glomus and Sclerocystis.
- Acaulosporaceae.- With the genus Acaulospora and Entrophospora.

The suborder Gigasporineae family Gigasporiaceae are divided into two genera Scutellospora with a germination shield and Gigaspora with bigger spores.

ECTOMYCORRHIZAS

Ectomycorrhizal synbiosis is comon in the families Pinaceae, Fagaceae, Myrtaceae and Betulaceae.Most of these fungi are Ascomycetes and Basidiomycetes and there are several species of Zygomycetes. The colonization is characterized by an external coat of fungal hyphae that may completely cover the host root (fungal mantel) and the presence of hyphae between root cortical cells that constitute a structure called "Harting Net".

'Bio-fertilizer'

is a substance which contains living microorganisms which, when applied to seed, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant.

Bio-fertilizers add nutrients through the natural processes of Nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth promoting substances. Bio-fertilizers can be expected to reduce the use of chemical fertilizers and pesticides. The microorganisms in bio-fertilizers restore the soil's natural nutrient cycle and build soil organic matter. Through the use of bio-fertilizers, healthy plants can be grown while enhancing the sustainability and the health of soil. Since they play several roles, a preferred scientific term for such beneficial bacteria is plant-growth promoting rhizobacteria (PGPR). Therefore, they are extremely advantageous in enriching soil fertility and fulfilling plant nutrient requirements by supplying the organic nutrients through microorganism and their byproduct. Hence, bio-fertilizers do not contain any chemicals which are harmful to the living soil. Bio-fertilizers are Eco-friendly organic agro-input and more cost effective than chemical fertilizers.

Type of Bio-fertilizers

1-N-biofertilizer like *Rhizobium, Azotobacter, Azospirillum* and blue green algae(BGA).

2-P-solubilizing microorganism: Other types of bacteria, so-called phosphate solubilizing bacteria like, and *Pseudomonas putida* strain are able to solubilize the insoluble phosphate from organic and inorganic phosphate source.

3- immobilization of phosphate and mineral ions such as Fe, Al and Ca or organic acids by microorganisms,

Benefits

1- Cost effective :Since bio-fertilizer is technically living, it can symbiotically associate with plant root. Involved microorganisms could readily and safely convert complex organic material in simple compound, so that plants are easily taken up. Microorganism function is in long duration causing improvement of the soil fertility. It maintains the natural habitat of the soil. It increases crop yield by 20-30%, replaces chemical nitrogen and phosphorus by 25%, and stimulates plant growth. It can also provide protection against drought and some soil-borne diseases.

2-Bio-fertilizers are cost effective relative to chemical fertilizers. They have lower manufacturing costs especially regarding nitrogen and phosphorus use.

3-It is environmentally friendly in that it not only prevents damaging the natural source but also helps to some extent cleanse the plant from precipitated chemical fertilizer.

4- Stimulate plant growth.

5- Activate the soil biologically.

6-Restore natural soil fertility.

7-Provide protection against drought and some soil borne diseases.

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How biofertilizers are applied to crops?

1**-Seedtreatment:**

2-Seedlingroot dip:

3-Soiltreatment:

What is Bioremediation?

Bioremediation is the process of using organisms to neutralize or remove contamination from waste. It is very important to understand that this form of waste remediation uses no toxic chemicals, although it may use an organism that can be harmful under certain circumstances. A gross, but simple explanation of bioremediation is the use of maggots in wound care control. Wounds that have contamination can have maggots introduced to them. The maggots then eat the contamination, allowing the wound to heal correctly. That is a form of medical bioremediation but there are many other types that are used to control different waste contamination.

At sites filled with waste organic material, bacteria, fungi, protists, and other microorganisms keep on breaking down organic matter to decompose the waste. If such environment is filled with oil spill, some organisms would die while some would survive. Bioremediation works by providing these organisms with different materials like fertilizer, oxygen and other conditions to survive. This would help to break the organic pollutant at a faster rate. In other words, bioremediation can help to clean up oil spills.

"Bioremediation is a waste management technique that involves the use of organisms to remove or neutralize pollutants from a contaminated site."

According to the EPA,

Bioremediation is a "treatment that uses naturally occurring organisms to break down hazardous substances into less toxic or non toxic substances."

Why Bioremediation is Important?

Bioremediation is important for two reasons.

1. It uses no chemicals – One of the issues with using man-made chemicals in the treatment and removal of contamination is that the chemicals eventually make it into the water supply. There were many chemicals used at the beginning of the waste management era that we now know were very harmful to plant, animal and human life once they reached the water supply.

2. It can allow waste to be recycled – Another major reason that bioremediation is preferred is that once the waste is treated and the contamination neutralized or removed, the waste itself can then be recycled. When chemical remediation types are used, the waste is still contaminated just with a less toxic substance and in general, cannot then enter into the recycle process. Bioremediation allows for more waste to be recycled while chemical methods still create waste that cannot be used and has to be stored somewhere.

What are the 2 classes of Bioremediation used?

There are two classes of bioremediation used. Don't confuse the class type with the actual types of bioremediation available, the classes describe the general application of the organisms. The two classes are:

- **In-situ** – In situ refers to when contaminated waste is treated right at its point of origin. For example, there may be soil that is contaminated. Rather than remove the soil from its point of origin, it is treated right where it is. The benefit to in situ treatment is that it prevents the spread of contamination during the displacement and transport of the contaminated material.

- **Ex-situ** – Ex situ refers to treatment that occurs after the contaminated waste has been removed to a treatment area. To use soil as the example again, the soil may be removed and transported to an area where the bioremediation may be applied. The main advantage to this is it helps to contain and control the bioremediation products, as well as making the area that was contaminated available for use.