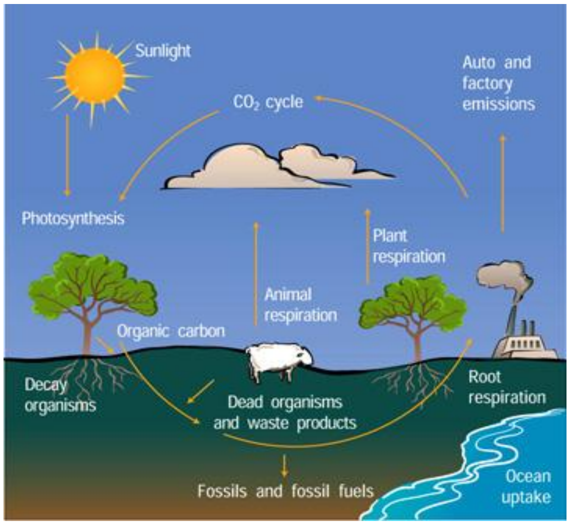
Carbon cycle – C: N ratio. Soil biology – Biomass – Soil organisms – Their beneficial and harmful roles.

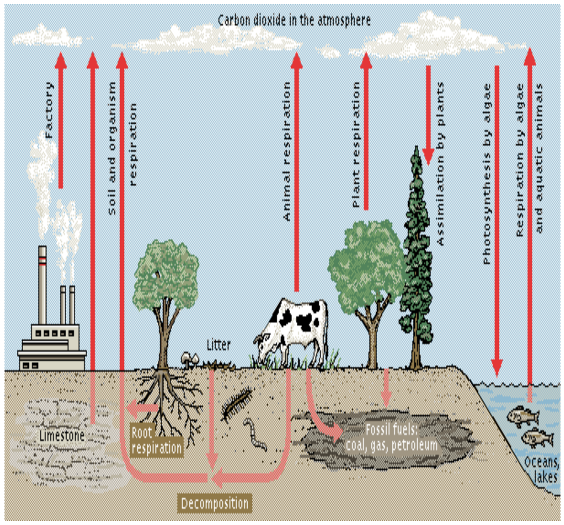
Carbon cycle

Carbon is a common constituent of all organic matter (plant and animal residues).carbon is continually being fixed into organic form by photosynthetic organisms under the influence of light and once bound, the carbon becomes unavailable for use in the generation of new plant life. Therefore, it is essential for the carbonaceous materials to be decomposed and returned to the atmosphere for the survival of the higher organisms.

The decomposition of plant and animal remains in soil constituents a basic biological process in that carbon (C) is recirculated to the atmosphere as CO_2, nitrogen (N) is made available as NH_4 and NO_3 and other associated nutrient elements like P, S, Fe, Mn, Cu and Zn etc, appear in plant available forms. In the process, part of the nutrient elements is assimilated by micro organisms and incorporated into microbial tissues (Soil biomasses). The conversion of organic forms of C, N, P and S into inorganic or mineral forms is called mineralization and the conversion of inorganic forms of those elements to their organic forms is known as immobilization.

The carbon cycle revolves about CO_2 and its fixation and regeneration. Chlorophyll containing plants utilize the gas as their sole carbon source, and the carbonaceous matter thus synthesized serves to supply the animal world with preformed organic carbon. Upon the death of the plant or animal, microbial world with performed organic carbon. Upon the death of the plant or animal, microbial metabolism assumes the dominant role in the cyclic sequence. The dead tissues undergo decay and are transformed into microbial cells and a large amount of heterogeneous carbonaceous compounds togetherly known as humus ar as the soil organic fraction. The cycle is completed and caron made available with the final decomposition and production of CO_2 from humus and the rotting tissues.





C: N ratio

- The ratio between the nitrogen content in the microbes and in the organic residues and to the carbon content is called as C:N ratio.
- When fresh plant residues are added to the soil they are rich in carbon and poor in N.
- This results in wider C: N ratio (40:1) decomposition of the organic matter in the soil changes to humus resulting in a narrow C: N ratio (10:1).
- When materials high in carbon are added to the soil the microbial population increase due to the plentiful supply of food material.
- A lot of CO2 is released.
- During this process the micro organisms utilize the soil N for their body build up and there is a temporary block of N.
- When the decomposition of fresh organic residues reaches to the stage where the C: N ratio is 20:1 there is an increase in the availability of N.

- The C: N ratio of cultivated soils ranges from 8:1 to 15:1.
- Average: 10:1 to 12:1.
- Legumes and Farm manure: 20:1 – 30:1.
- Straw : 100:1
- Saw Dust : 400:1
- In micro organisms : 4:1 to 9:1
- There exists a relationship between the organic matter and N content. Soil carbon has a definite proportion of the organic matter.
- Hence the C to N ratio in soils is fairly constant.
- The C: N ratio is lower in soils of arid regions than humid regions.
- C: N ratio is smaller in subsoils.

It is the intimate relationship between organic matter and nitrogen contents of soils. The ration of the weight of organic carbon to the weight of total nitrogen in a soil or organic material is known as C: N ratio. The importance of C: N ratio in controlling the available nitrogen, total organic matter and rate of organic materials decomposition is recognized in developing appropriate soil management practices.

Ratio in soils:

The C: N ratio of soil is one of its characteristics equilibrium values, the figure for humus being roughly 10:1 although values from 5:1 to 15:1 are generally found in most arable soils. The critical ratio (10:1) is a reflection of the dynamic equilibrium that results from the dominating presence of a microbial population, the ratio being similar to the average chemical composition of microbial cells. As a rule microbial protoplasm contains 5 to 15 parts of carbon to 1 part of nitrogen , but 10: 1 is a reasonable average for the predominant aerobic of fractions resistant to further decomposition can modify the C:N equilibrium value of humus. Such C: N ratio of soils can vary with the climates i.e. rainfall, temperature etc. the C:N ratio is generally lower in warmer (arid soil conditions) regions than that of cooler ones (humid soil conditions) inspite of having the same rainfall under both the soil conditions. The ratio is also narrower for sub soils as compared to surface soil horizons.

Ratio in plants and microbes:

The carbon and nitrogen (C:N) ratio in plant material is variable and ranges from 20:1 to 30:1 to legumes and farm yard manure to as high as 100:1 in certain straw residues. On the other hand C: N ratio of the bodies of micro organisms is not only more constant but much narrower between 4:1 and 9:1. Bacterial tissue in general is somewhat richer in protein than fungi and consequently has a narrow C: N ratio.

Therefore, it is usually found that most of the applied fresh organic materials in soils carry large amounts of carbon with relatively very small amounts of total nitrogen .As a result , the value C:N ratio for soils are in between those of higher plants and the microbes.

Implications of the C: N ratio:

The C: N ratio in soil organic matter is important for two major reasons:

The keen competition for available nitrogen results when organic residues of high C: N ratio are added to soils and because this C: N (10:1) is relatively constant in soils, the maintenance of carbon and hence soil organic matter is dependent to no small degree on the level of soil nitrogen. So the C: N ratio obviously has practical implications on the availability of nitrogen in soils as well as in plants. As for example, large amount of fresh organic materials having wide C: N ratios (50:1) are incorporated into the soil under favourable soil conditions for decomposition. A rapid change will found. The heterotrophic micro organisms – bacteria, fungi and actinomycetes become active and increases their population with the production of large amounts of CO_2. Under these conditions, nitrate nitrogen (NO_3-N) disappears from the soil because of the urgent needs by the micro organisms, and for the time being, little or no nitrogen is available to plants. As the decomposition precedes, the C: N ratio on the organic materials decreases with the loss of carbon and conservation of nitrogen.

Reasons for the stabilization of C: N ration to a constant value

As the decay process proceeds, both carbon and nitrogen are now subject to loss as CO_2 and nitrates respectively. It is only a question of time until their percentage rate of disappearance from the soil becomes more or less the same, *i.e*, the percentage of the total carbon being lost. At this point the C: N ratio becomes more or less constant 10:1 to 12:1 always being somewhat greater than that of the ratio in microbial tissue.

C: N ratio and the level of organic matter

Since carbon and nitrogen are reduced to almost a definite ratio, the amount of soil nitrogen largely determines the amount of organic carbon present when stabilization occurs. Thus, the greater the amount of nitrogen present in the original organic material, the greater will be the possibility of an accumulation of organically bound carbon. Since a definite ratio (1:17) exists between the organic carbon and the soil humus, the amount of organic matter to be maintained in any soil is largely conditional on the amount of organic nitrogen present. The ratio between nitrogen and organic matter is thus constant (organic matter: nitrogen, 20; 1 for most soils).

Soil biology

Soil biology is the study of microbial and faunal activity and ecology in soil. These organisms include earthworms, nematodes, protozoa, fungi and bacteria. Soil biology plays a vital role in determining many soil characteristics yet, being a relatively new science, much remains unknown about soil biology and about how the nature of soil is affected.

Scope

- Modelling of biological processes and population dynamics.
- Soil biology, physics and chemistry: occurrence of physiochemical parameters and surface properties on biological processes and population behavior.
- Population biology and molecular ecology: methodological developnment and contribution to study microbial and faunal populations; diversity and population dynamics; genetics transfers, influence of environmental factors.
- Community ecology and functioning processes: interactions between organisms and mineral or organic compounds ; involvement of such interactions in soil pathogenecity; transformation of mineral and organic compounds,cycling of elements ; soil structuration

Complementary disciplinary approaches are necessarily utilized which involve molecular biology, genetics, ecophysiology, biogeography, ecology, soil processes, organic matter, nutrient dynamics and land scape ecology.

Biomass

Biomass, as a renewable energy source, refers to living and recently dead biological material that can be used as fuel or for industrial production. In this context, biomass refers to plant matter grown to generate electricity or produce. For example, trash such as dead trees and branches, yard clippings and wood chips are biofuel, and it also includes plant or animal matter used for production of fibers, chemicals or heat. Biomass may also include biodegradable wastes that can be burnt as fuel. It excludes organic material which has been transformed by geological processes into substances such ascoal or petroleum.

Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil). The particular plant used is usually not important to the end products, but it does affect the processing of the raw material. Production of biomass is a growing industry as interest in sustainable fuel sources is growing.

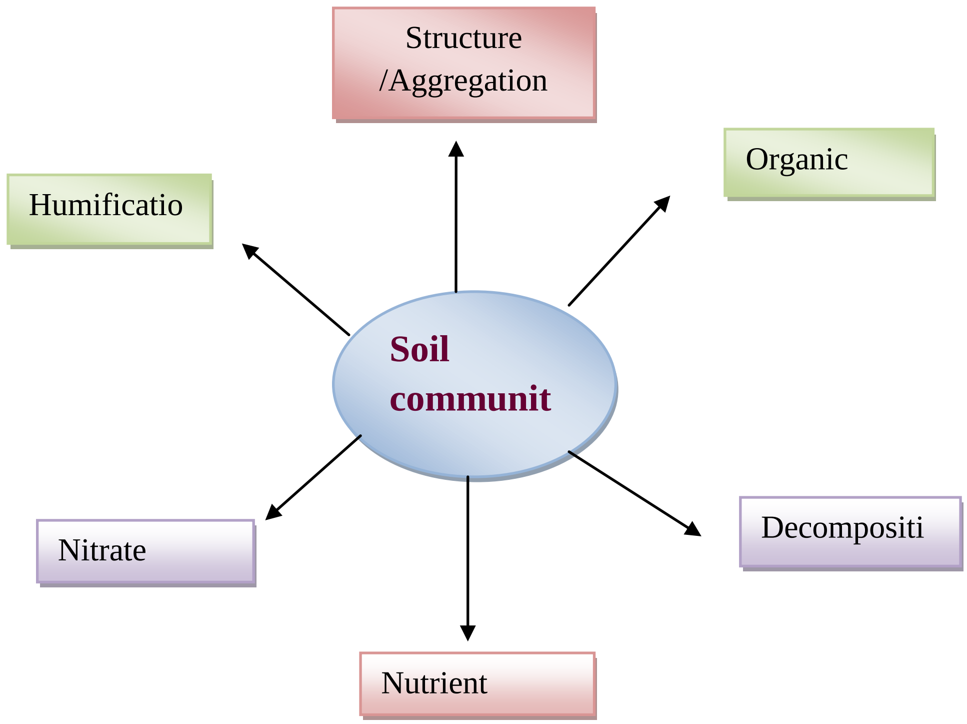
Although fossil fuels have their origin in ancient biomass, they are not considered biomass by the generally accepted definition because they contain carbon that has been "out" of the carbon cycle for a very long time. Their combustion therefore disturbs the carbon dioxide content in the atmosphere. Plastics from biomass, like some recently developed to dissolve in seawater, are made the same way as petroleum-based plastics. These plastics are actually cheaper to manufacture and meet or exceed most performance standards, but they lack the same water resistance or longevity as conventional plastics.

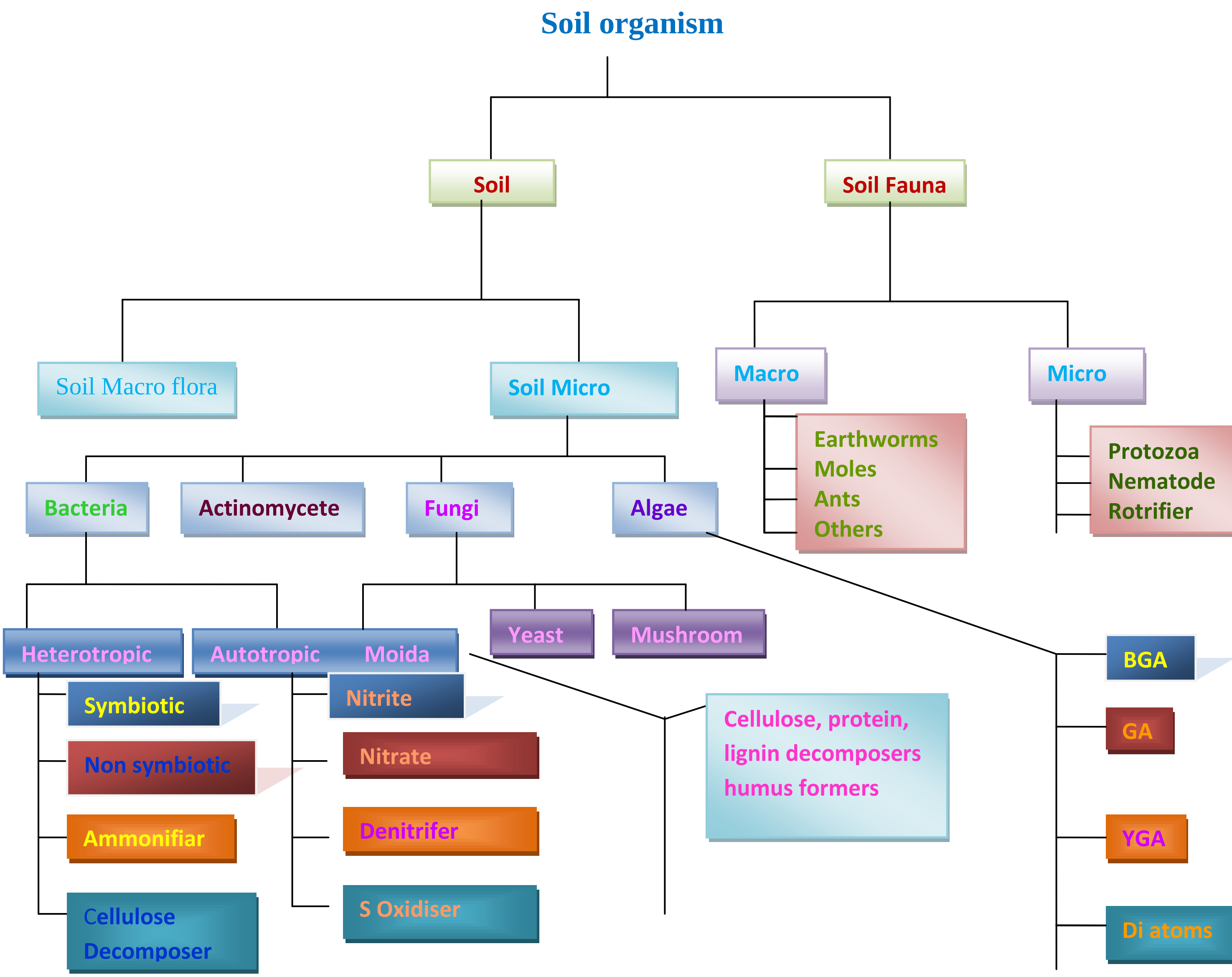
Soil organisms – Their beneficial and harmful roles.

Role of soil organisms are:

- Soil N utilization by plants
- Dead organic matters decomposed
- Nutrient transformation
- Physical and chemical properties of soil.
- The CO_2 content
- Soil formation

Soil organisms are involved in nearly every aspect of soil quality





Micro organisms are also classified based on their ability to grow in the presence or absence of molecular oxygen as aerobes and anaerobes.

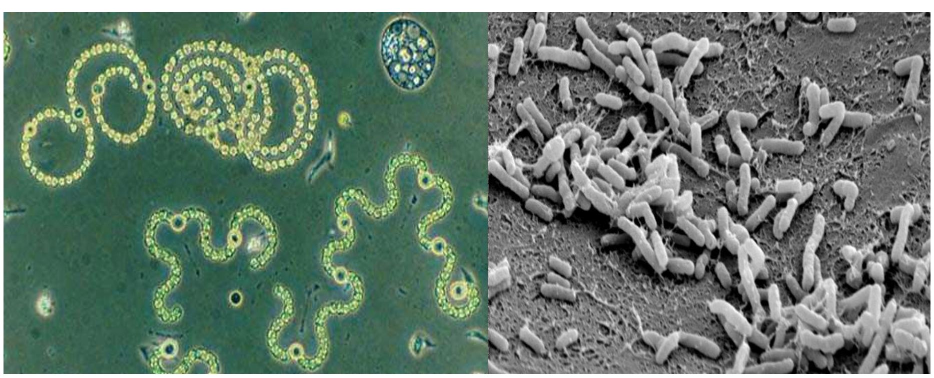
Based on temperature

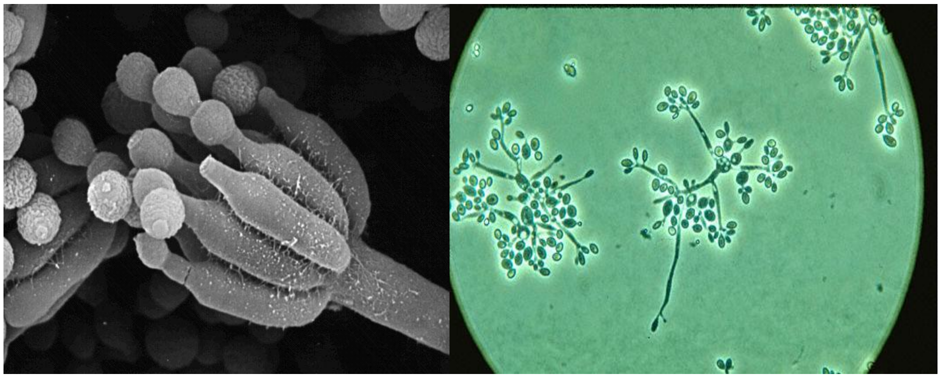
- Psychrophiles

- Mesophiles
- Thermophiles
- Micro organisms are also classified based on morphology, shape, size, biochemical transformations they carryout.
- Soil organism are classified broadly soil flora and soil fauna.
- These again may be subdivided into micro and macro.
- Micro flora again is classified into Bacteria, actinomycetes, fungi and Algae.

Bacteria:

- Single celled.
- The cells may be rod shaped or spherical.
- The rods may be about 1 µm wide and up to 3 µm long and about 2 µm in diameter.
- Bacteria are the most abundant group of micro organism in the soil.
- Their population in the soil is not uniform.





Classification of bacteria

- Based on O_2 requirement

Aerobic and anaerobic

Based on temperature

- Facultative
- Psychrophiles
- Mesophiles
- Theromophile

Based on their food preparation

- Autotroph
- Heterotroph
- Chemoautotroph
- Obligate chemoautotrophs: Prefer specific substrates
- Nitrobacter – Nitrite as substrate

- Nitrosomonas – Ammonia as substrate
- Thiobacillus - Converts sulphur compounds to SO_4
- Ferrobacillus – Converts ferrous to ferric

Based on symbiotic relationship:

Symbiotic N fixers:

- Associated with a host plant.
- Both the host and the bacteria get the benefit.
- Fix atmospheric N.

Non symbiotic N fixers:

- Bacteria present without the association of a plant.
- But fix atmospheric N.
- Symbiotic, non symbiotic and cellulose decomposers come under Heterotrophs
- Nitrifiers, denitrifiers Nitrate formers and sulphur oxidizers are autotrophs.

Role of Bacteria:

- Bacteria carryout the decomposition of organic matter and synthesis of humus
- Enzymatic transformations are carried out by bacteria
- Bacteria oxidize or reduce many chemical reactions such as N fixation, sulphur oxidation nitrification etc.

Conditions affecting the growth of bacteria:

- Oxygen
- Moisture
- Temperature
- Organic matter

- Exch.Ca and pH
- High Ca concentration and pH 6.0-8.0 optimum. Some bacteria function at pH <3.0.
- Exchangeable Ca is more important than pH . The bacterial population may be 10-8 - 10-9/gram.
- The biomass may vary from 450-4500 kg/ha.

Actinomycetes

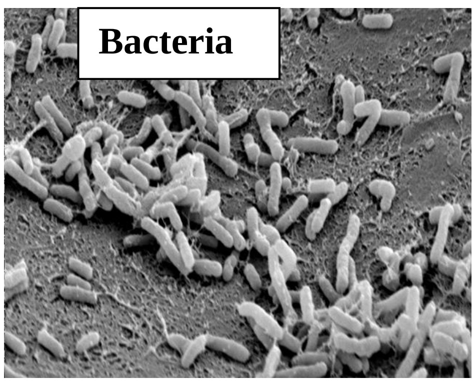
- Unicellular like bacteria. Have same size as bacteria.
- Filamentous and profusely branched.
- Mycelial threads are smaller than those of fungi.
- No nuclear membrane as in bacteria.
- Also called as filamentous.
- Sensitive to acid soils.
- Potato scab a disease due to actinomycetes can be controlled by lowering the soil pH by applying sulphur.
- Heterotrophic optimum temperature 25-30^{O}C, pH 6.5 – 8.0.
- Actionomycetes are important for organic matter decomposition.
- Chitin and phospholipids are reduced to simple compounds.
- The aroma of freshly ploughed land at certain times of the year is probably due to actinomycetes as well as certain molds.
- Actinomycete population in soil exceed all other organisms except bacteria.
- Their proportion increases with soil depth. Their population and biomass are almost equal to that of bacteria.

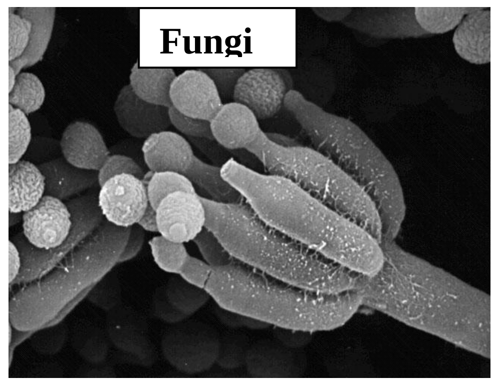
Fungi:

- Soil fungi may be parasitic or saprophytic.

- They possess filamentous mycelium composed of individual hyphae which are 5-20 µm in diameter and several centimeters in length.
- Most fungi are heterotrophic and hence they depend on the organic matter content of the soil.
- They are dominant in acid soils some can tolerate a pH upto 9.0.
- Fungi are strictly aerobic.
- Fungi are classified into phycomycetes, Ascomycets, Basidiomycetes and fungi imperfecti.

Soil micro organism





Fungi may also may be classificied as molds:

Molds,Yeast,Mushrooms

- **Molds:** Molds are filamentous microscopic molds develop vigorously in all types of soils
- In acid forest soils - decomposing organic matter.
- The common genera - mucor, Fusarium and Aspergillus.
- Their average population - 10-200 billion / m^2.
- In humus formation and aggregate stabilization molds are more important than bacteria.

- They continue to decompose complex organic substances after bacteria and actinomycetes have stopped function.

Yeast

- Yeast is a group of fungi which exist as an unicellular organism.
- Reproduce by fission or budding.
- Used as food supplement and also for the production of alcoholic beverages.
- Yeast is not common in soils.
- They produce several plant diseases.

Mushroom:

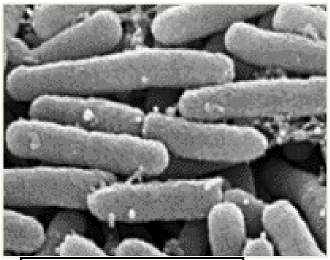
- Mushrooms are present in forests and grasslands where there are ample moisture and organic residues.
- Some mushrooms are edible.
- Mushrooms are also not common in cultivated soils.
- Their fruiting body is above the ground.

Algae

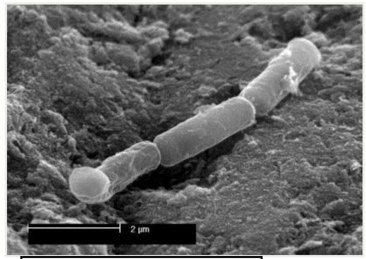
- Algae are filamentous u-10µm in diameter. Population in soil around 1-10 billion / m2.
- Their mass in soil may be 50-600 kg/ha of furrow slice.
- Algae are photo autotrophs
- They are divided into 4 general groups. Blue green,Green, yellow green and diatoms.
- Blue green algae are numerous in rice soils
- Blue green algae growing within the leaves of aquatic Fern.
- Azolla can also fix atmospheric N.

Microorganism

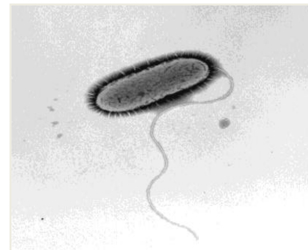
Bacteria



Pseudomonas



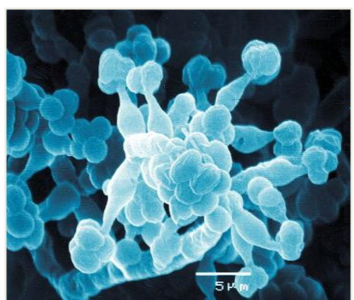
Arthrobacter



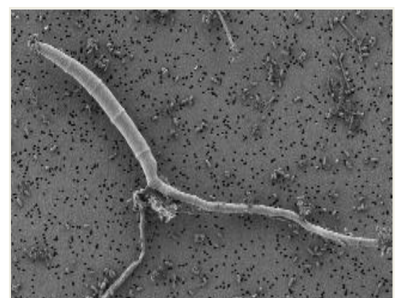
Bacillus

Fungi

Aspergillus

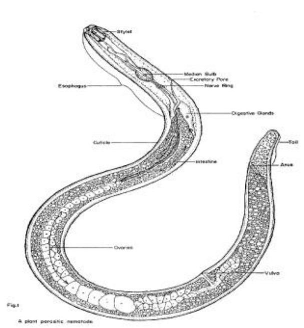


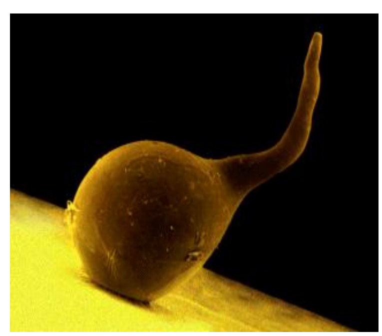
Trichoderma



Fusarium

Nematodes





SOIL FAUNA - Macro Fauna- Earthworm

- About 1800 species of earthworms are known.
- There are 293 species in the genus pheretima. The common earthworms found in India are pheretima posthuma, P.elongater Lampita mautritii etc.
- Their population may vary from 1,25000 to 1000000/ha.
- They are active in monsoon season. The worms prefer organic matter as their food.
- They also consume larvae of small animals and bacteria mixed with earth.
- They ingest soil in large quantities which pass through the alimentary canal which has many grinder gizzard
- The ingested soil and organic matter are ejected in the form of castings.
- They make crores of burrows which make the soil porous.
- Earth worms prefer warm (21^{o}C) well aerated soils. The casts have low C:N ratio.
- The burrows left in the soil increase aeration and drainage. They increase the size and stability of soil aggregates.
- The factors influencing the earth worm population and activity in the soil are availability of organic matter, soil pH, temperature and soil moisture.
- The biomass or live weight of earth worm may range from 110-1100 kg/ha.

Soil Animalia

Ants

- They have local effects. Some have the ability to break down woody materials.
- Some ants produce mounds and some have under ground nests.
- There is considerable turn over of the soil due to these.
- The ants and termites can modify soil structure and till the soil.

Nematodes

- Commonly called as thread worms or eelworms. Present in almost all soils.
- They are microscopic most of the nematodes are Saprophytes
- They may feed on other nematodes, bacteria, algae and protozoa.
- The genus Heterodera can infest the roots of all plants.
- Heavy infestation may cause severe damage in vegetable crops.

Protozoa

- Single celled, larger than bacteria and are more complex.

❖ Soil protozoa may be amoeba, celiates and flagellates.

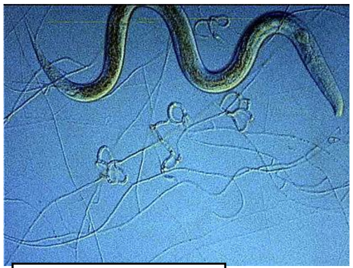
❖ Soils have more than 250 species. Live weight in soil ranges from 15-175 kg/ha.

❖ They cause a number of serious diseases in animals and plants.

❖ They thrive well in moist and well drained soils and on the surface.

❖ They are not abundant in soils to play a major role in the organic matter decomposition and nutrient release.

Soil Macrofauna



Nematodes

Mites

Rotifers:

❖ About 100 species have been studied. They thrive under moist and swampy lands.

❖ Activities are confined to peat bogs and wet areas of mineral soils.

Roots of higher plants

❖ Since the roots grow and die in the soil they supply food and energy for the soil microflora and fauna.

❖ They physically modify the soil as they push through cracks and make new openings.

❖ By removing moisture from the soil the plant roots create physical stress that stimulates soil aggregation.

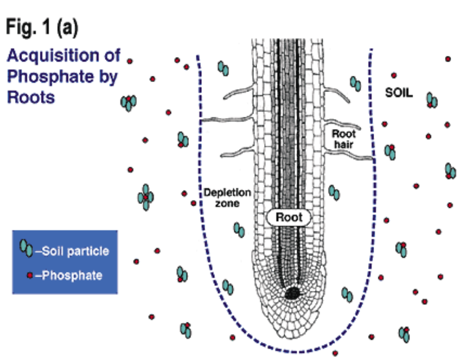
❖ Plant roots exudates several chemicals which stabilize the soil structure.

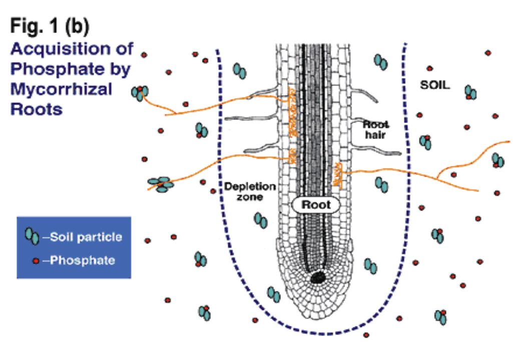
❖ They decay and supply the material for the synthesis of humus.

❖ Roots constitute about 15-40% that of above ground crop.

Mycorrhizae

- The symbiotic association between numerous fungi and the roots of higher plants is called mycorrhizae which means fungus roots".
- This association increases the availability of several essential nutrients to plants especially from low fertile soils
- This association provides sugars and other organic exudates from higher plants as food to the fungi.
- The fungi in turn provide an enhanced availability of several essential nutrients including P, zn, Cu, Ca, Mg, Mn and Fe
- There are 2 types of mycorrhizal associations. Ecto mycorrhizae and endo mycorrhizae
- The vesicular asbuscular mycorrhizae (VAM) is the most important endo mycorrhizae.





Injurious effects of soil organisms on higher plants.

❖ Some rodents and moles may severely damage crops.

❖ Snails and slugs in some climates are dreaded pests.

- Ants transmit aphids which are major pests. Nematodes infest roots of all plants which in severer cases result in crop failure.
- Microflora exerts the most devastating effect on plants.
- Fungi are responsible for most soil borne diseases wilt, damping off, root rots and club root of cabbage are caused by fungi.
- Actinomycetes and bacteria also cause several diseases.
- Some bacteria are involved in the denitrification of NO_3 to, elemental N which is a loss.
- Beneficial effects include N fixation, increased nutrient availability, improvement in soil physical properties oxidation and reduction of Fe and Mn.
- Oxidation of S. Conversion of ammonia to Nitrate form.