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ASAC 1101 : FUNDAMENTALS OF SOIL SCIENCE (2+1)

Level : B.Sc (Ag), I semester

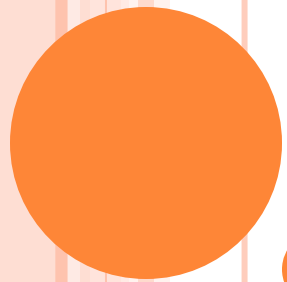
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SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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Topic

Soil biology and soil organic matter



SOIL BIOLOGY

- **Soil biology** deals with organisms and their function within the soil.

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.
- It refers to plant matter grown to generate electricity.
- Biomass may also include biodegradable wastes that can be burnt as fuel.



Roles of Microorganisms in soil fertility and crop production:

- Decompose and turn crop residues into humus, carbon dioxide and water and release their nutrients slowly for efficient plant use.
- Soil microorganisms are very important as almost every chemical transformation taking place in soil.
- Certain soil micro-organisms such as mycorrhizal fungi can also increase the availability of mineral nutrients (e.g. phosphorus) to plants.
- For instance, nitrogen-fixing bacteria can transform nitrogen gas present in the soil atmosphere into soluble nitrogenous compounds that plant roots can utilize for growth.

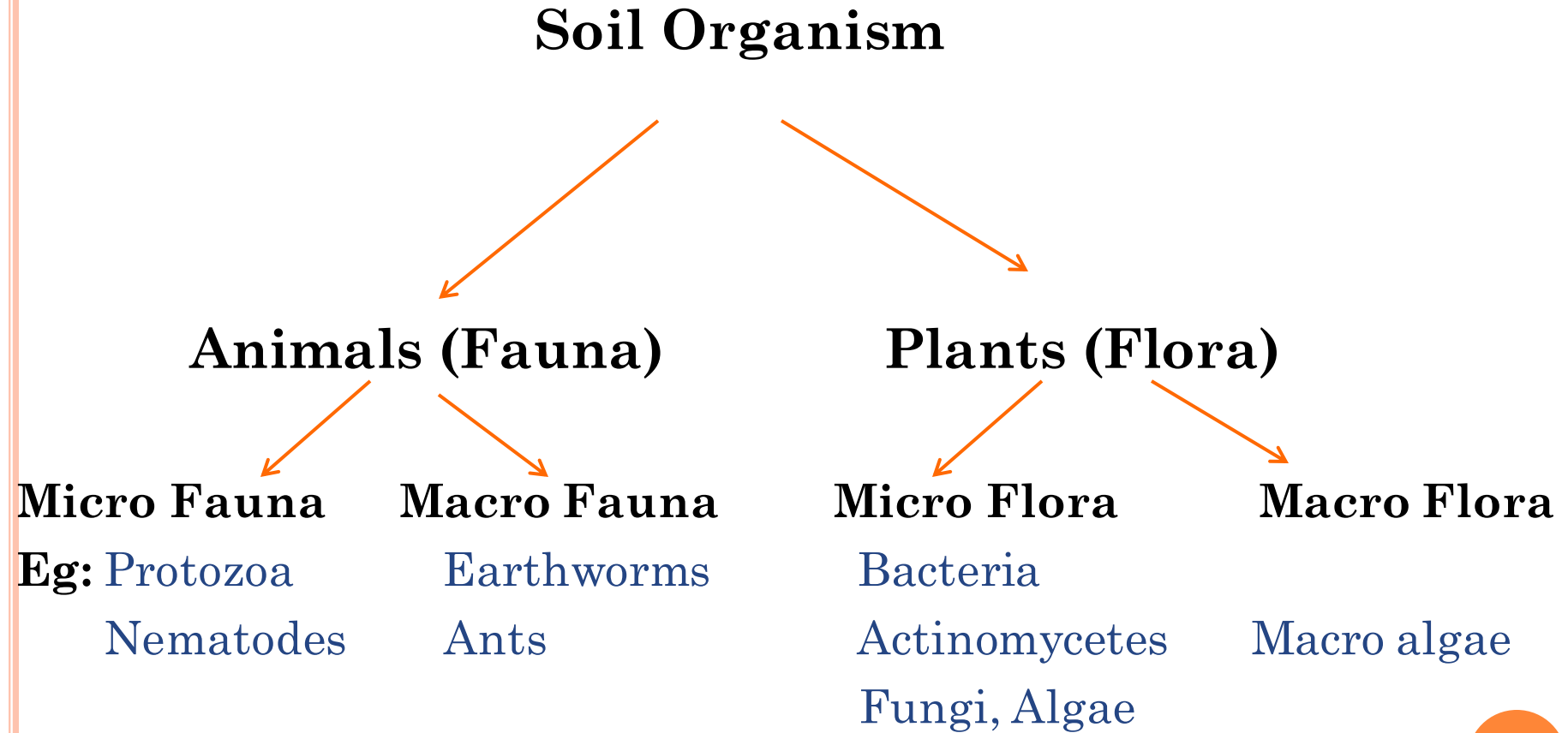


- Improve physical and chemical properties of soil.
- Improve water absorption, retention, drainage and aeration of the soil and creates a better environment for root growth.
- Increase the buffering capacity of the soil to hold nutrients and reduce the toxicity of soil and fertilizer salts.
- Breakdown and eliminate herbicide, pesticide and other chemical residues in the soil.
- Produce plant hormones like IAA.
- Produce antibiotic substances that inhibit potential disease producing organisms in the soil.
- They are active participators in soil formation.



Classification of organism in soil

- Organisms present in soil are mainly classified in to **Soil flora** and **Soil fauna**.



Classification based on requirement of molecular oxygen

Obligate aerobes

Facultative anaerobes

Obligate anaerobes

- **Obligate aerobes:** Organisms that need O_2 for respiration and cannot survive without it.

Eg: Nitrosomonas and Nitrobacter

- **Facultative anaerobes:** Organisms which are aerobic but also adapted to grow under anaerobic conditions using oxidized substances like NO_2 , SO_4 , etc. Eg: **Denitrifying bacteria (Bacillus)**

- **Obligate anaerobes:** The organisms which grow in the absence of O_2 .

Eg: Clostridium and Methenobacteria



- Classification based on optimum temperature for growth

Psychrophiles	Optimum temperature for growth <10 °C	Eg: Arthrobactor
Mesophiles	20-35 °C	Pseudomonas, E. coli
Thermophiles	>45 °C	<i>Thermus aquaticus</i>



Classification based on mode of nutrition

1. Autotrophs

2. Heterotrophs

1. Autotrophs: Those organisms that are able to make energy containing organic molecule from inorganic material by using sunlight as energy source and CO_2 as C source.

A. Chemoautotrophs: Which get energy from the oxidation of simple inorganic compounds. (chemosynthesis)

Eg: **Thiobacillus**

B. Photoautotrophs: Organisms that can make their own energy using light and CO_2 via the process of photosynthesis.

Eg: **Algae**

2. Heterotrophs: A heterotroph is an organism that cannot manufacture its own food and therefore drives its intake of nutrition from other sources of organic carbon mainly plant or animal matter.

○ Act as secondary and tertiary consumers.

Eg: **Fungi**





ORGANIC MATTER

Organic Matter

- Soil organic matter is the fraction of the soil that consists of plant or animal residues in various stages of breakdown (decomposition).
- In addition to these material, Soil organic matter consist of living and dead microbial cells, microbial synthesized compounds and a number of derivatives produced as a result of microbial activity.
- In general, cultivated soil in temperate regions has high OM levels (**5-10 %**), similarly in tropics have only **less than 1%**

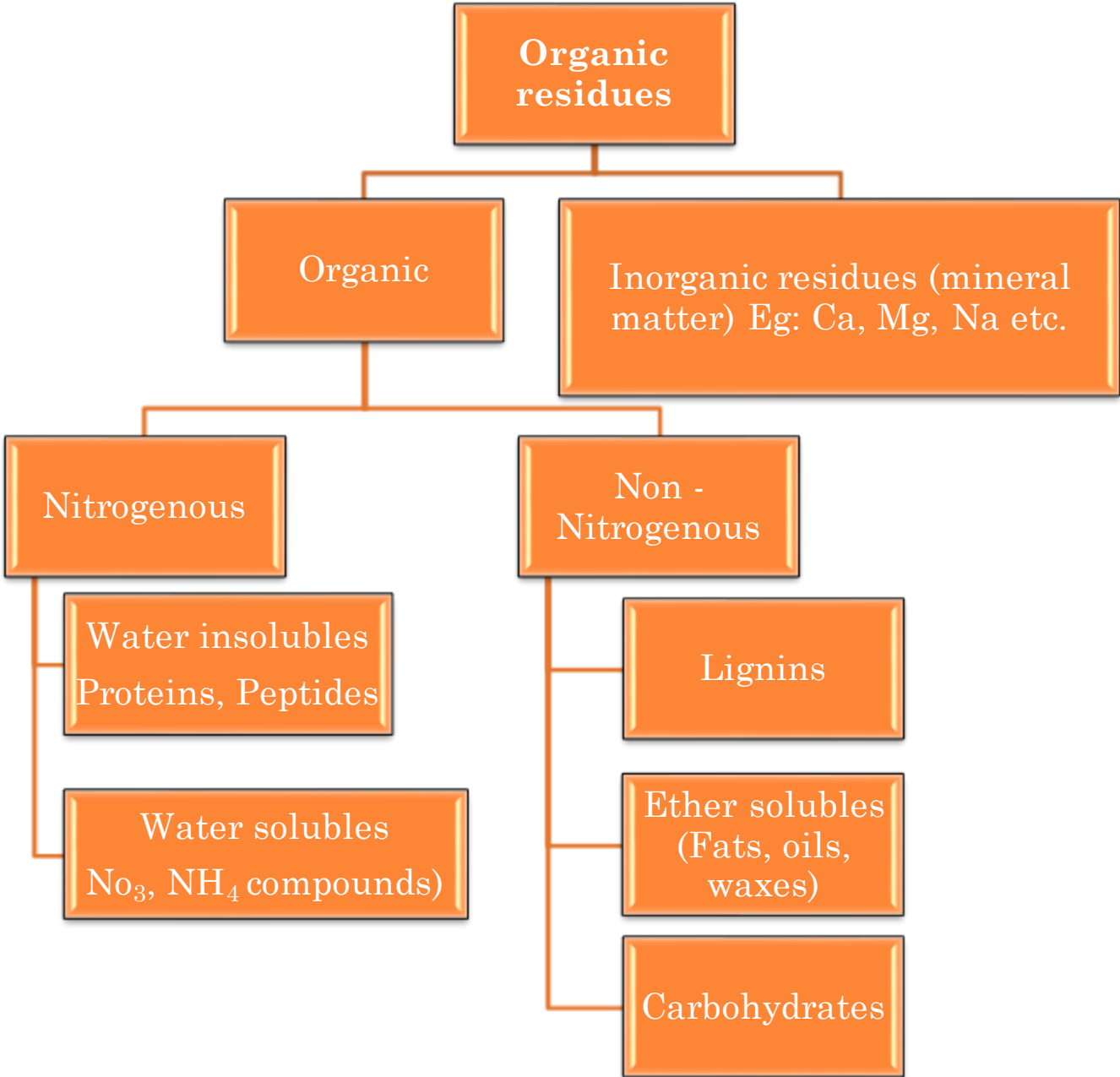


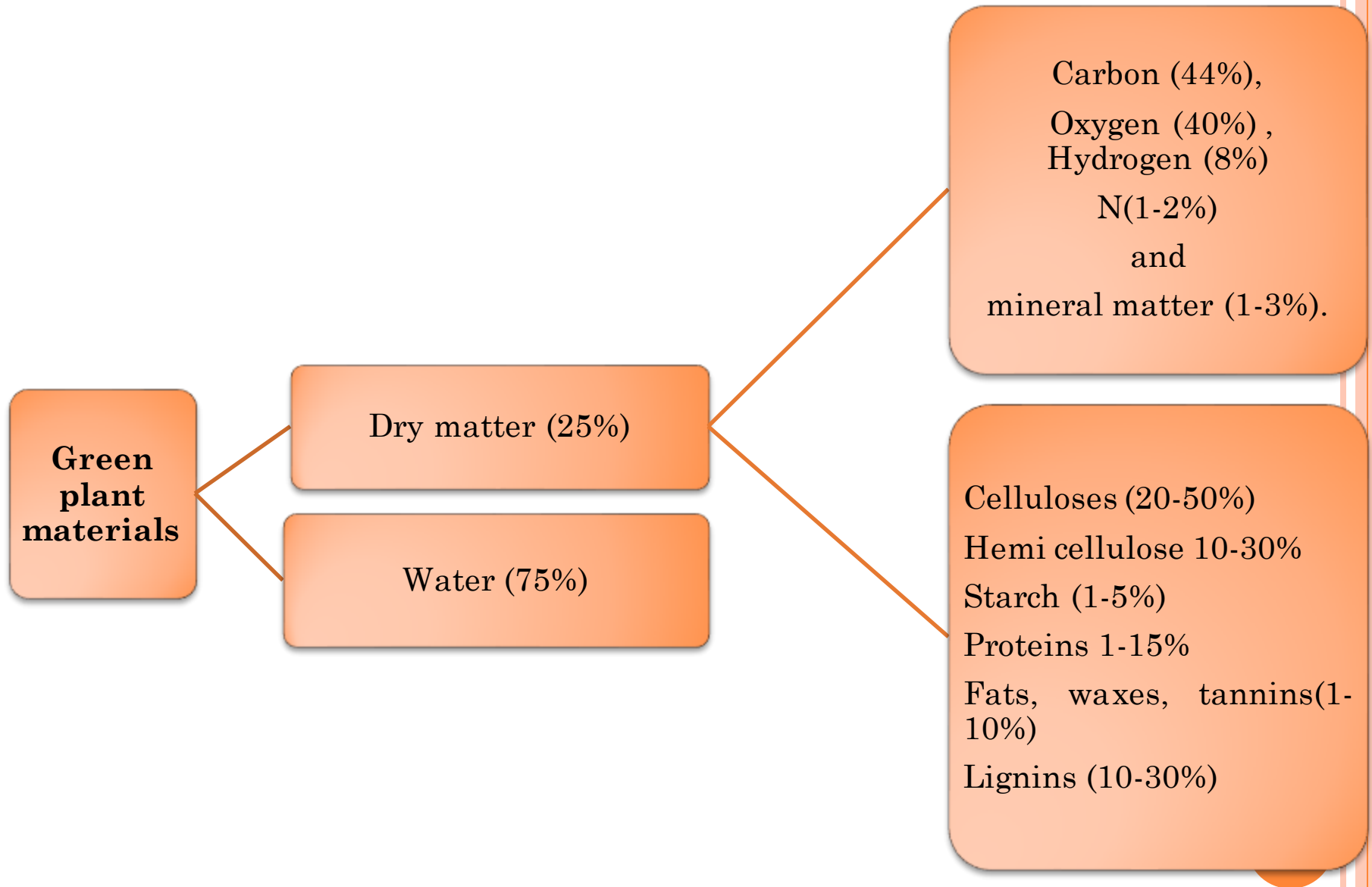
Sources of OM

- SOM mainly originates from the plant tissue.
- Leaves and roots of trees, shrubs, grasses and other plants etc.
- These plant constituents form primary material both for food of soil organisms and for the production of soil organic matter.
- Animals are generally considered as secondary sources of SOM.



Composition of organic residues:





Role of organic matter

A. Physical Benefits

- Enhances aggregate stability, improving water infiltration and soil aeration, reducing runoff.
- Improves water holding capacity.
- Creates a granular condition of soil which maintains favorable condition of aeration and permeability.
- Reduces surface crusting, facilitating seedbed preparation.
- Surface mulching with coarse organic matter lowers wind erosion and lowers soil temperatures in the summer and keeps the soil warmer in winter.

B. Chemical Benefits

- Increases the soil's CEC or its ability to hold and supply essential nutrients.
- Improves the ability of a soil to resist pH change; this is also known as buffering capacity.

- Humus (a highly decomposed organic matter) provides a storehouse for the exchangeable and available cations.
- Organic acids released from decomposing organic matter help to reduce alkalinity in soils.

C. Biological Benefits


- Organic matter serves as a source of energy for the microbes.
- Fresh Organic matter supplies food for earthworms, ants and rodents.
- Enhances soil microbial biodiversity and activity which can help in the suppression of diseases and pests.



Decomposition of soil organic matter:

- The term decomposition means “to break down”. It usually refers to the rupture or breakdown of the complex organic matter into a simpler inorganic matter.
- The organic matter is also classified on the basis of their rate of decomposition
 1. **Rapidly decomposed** : Sugars, starches, proteins *etc.*
 2. **Less rapidly decomposed** : Hemicelluloses, celluloses *etc.*
 3. **Very slowly decomposed** : Fats, waxes, resins, lignins *etc.*

The general reactions taking place during decomposition are

- Enzymatic oxidation with the release of CO_2 , water, energy and heat
 - Essential elements are released (N, P, S etc) and immobilized by a series of reactions.
 - Formation of compounds which are resistant to microbial action.
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Under aerobic conditions the products formed are

- CO_2 , NH_4 , NO_3 , H_2PO_4 , SO_4 , H_2O and essential plant nutrients like Ca, Mg, Fe, Cu, Zn etc.

Under anaerobic conditions

- CH_4 , organic acids like lactic, butyric, NH_4 , various amine residues (R-NH_2) H_2S and ethylene ($\text{CH}_2=\text{CH}_2$).



A. Decomposition of soluble substances

Aerobic conditions



Under partially oxidized conditions,


Sugar + Oxygen \longrightarrow **Aliphatic acids** (Acetic, formic *etc.*) or **Hydroxy acids** (Citric, lactic) *etc.* or **Alcohols** (ethyl alcohol) *etc.*



B. Decomposition of Insoluble Substances

i. Breakdown of Protein:

Proteins are first hydrolyzed to a number of intermediate products.

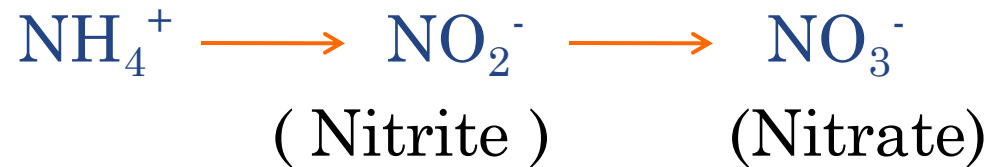
- **Aminization:** The process of conversion of proteins to amino acids.
 - **Ammonification:** The transformation of organic nitrogenous compounds (amino acids and amides) into ammonia is called ammonification.
 - This process occurs under aerobic conditions by heterotrophic microbes.
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Nitrification: The process of conversion of ammonia to nitrites (NO_2^-) and then to nitrate (NO_3^-) is known as nitrification.

- It is an aerobic process by autotrophic bacteria.
- Nitrification of ammonia to nitrate is a two step process:

Nitrosomonas

Nitrobacter



- (Oxidation of ammonium into nitrites and nitrites to nitrates).
- **Denitrification:** The process, which involves conversion of soil nitrate into gaseous nitrogen or nitrous oxide under anaerobic condition, is called Denitrification.



ii) Breakdown of cellulose:

The decomposition of the most abundant carbohydrates.



iii) Breakdown of Hemicellulose:

- Decompose faster than cellulose and are first hydrolyzed to their components sugars.
- Sugars are attacked by microbes and are converted to organic acids, alcohols, carbon dioxide and water.



Breakdown of Starch:

- It is chemically a glucose polymer and is first hydrolyzed to maltose by the action of amylases. Maltose is next converted to glucose by maltase.



Decomposition of ether soluble substances:



Decomposition of lignin:

- Lignin decomposes slowly, much slower than cellulose. Complete oxidation gives rise to CO_2 and H_2O .



Factors affecting OM decomposition

- 1. Temperature:** The decomposition of organic residues is accelerated in warm temperature than that of cold climate. Decomposition of SOM increases with rise in T from 0-35 °C
- 2. Soil moisture:** Extremes of both arid and anaerobic conditions reduce plant growth and microbial decomposition.
 - Near or slightly wetter than field capacity (60-80% of maximum water holding capacity) moisture conditions are most favorable for both processes.
- 3. Nutrients:** Lack of nutrients particularly N slows decomposition.
- 4. Soil PH:** Most of the microbes grow best at pH 6 – 8, but are severely inhibited below pH 4.5 and above pH 8.5.
- 5. Soil Texture:** Soils higher in clays tend to retain larger amounts of humus.

6. Type of vegetation: OM levels of cultivated area are lower compared to forest and grassland, legumes are more easily decomposed than grasses.

7. Other Factors: Toxic levels of elements (Al, Mn, B, Se, Cl), excessive soluble salts, shade and organic phytotoxins in plant materials.



Fractions of OM

1. Humic group
2. Non humic group

Humic group

- This group makes up about **60-80%** of the soil organic matter.
- They are most complex. They are most resistant to microbial attack.
- The humic substances are classified based on resistance to degradation and solubility in acids and alkalis into

Humic acid

Fulvic acid

Humin



Fulvic acid	lowest in molecular weight, lightest in colour, soluble in both acid and alkali and most susceptible to microbial attack
Humic acid	Medium in molecular weight and colour, soluble in alkali but insoluble in acid and intermediate in resistance to degradation
Humin	Highest in molecular weight, darkest in colour, insoluble in both acid and alkali and most resistant to microbial attack



Non humic group


- This group makes upto **20-30%** of the organic matter in soil.
- These are less complex and less resistant to microbial attack as compared to humic substances.
- These include proteins, carbohydrates, lignins, fats, waxes, resins, tannins and some compounds of low molecular weight.



Humus

- Humus is a complex and rather resistant mixture of brown or dark brown amorphous and colloidal organic substance that results from microbial decomposition and has chemical and physical properties of great significance to soils and plants.

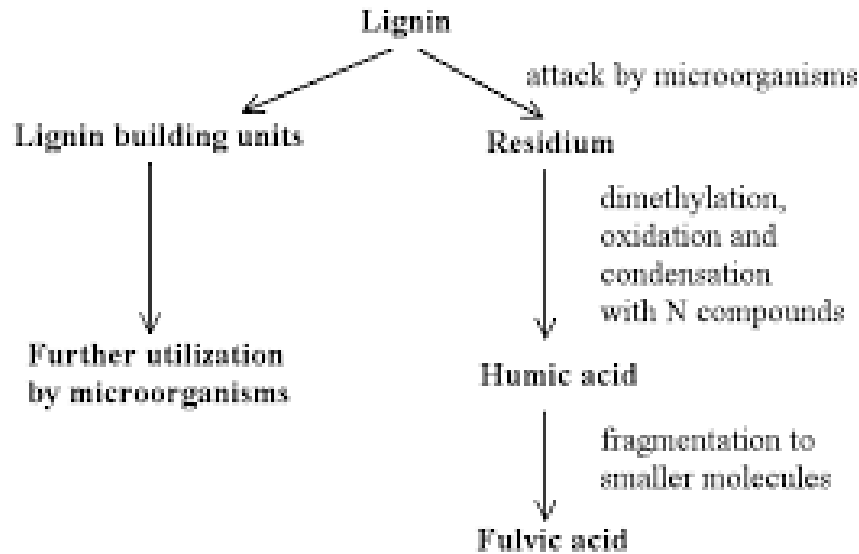
Properties of Humus

- The tiny colloidal particles are composed of C, H, and O
 - The colloidal particles are negatively charged (-OH, -COOH or phenolic groups).
 - Very high surface area.
 - Higher CEC (150 – 300 cmol/kg).
 - 4 -5 times higher WHC than that of silicate clays.
 - Humus has a very favorable effect on aggregate formation and stability.
 - Impart black colour to soils.
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Theories on humus formation

Lignin theory: Proposed by Waksman (1936).

- According to this theory humic substances are formed due to the incomplete degradation of lignin.



Kononovas theory: According to this theory humic substances are formed by cellulose decomposing mycobacteria earlier to lignin decomposition



Polyphenol theory: (Flaig and Sochtig (1964))

- As per this theory the humic substances are formed by the condensation of phenolic materials.
- The polyphenols of lignin are oxidized to quinones.
- These quinones are condensed with low molecular weight microbial products to form humic molecules.

