ENHANCEMENT OF FOOD PRODUCTION

for class 12th

by

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Improvement In Food Production :

- Food is one of the basic needs as it gives us energy for everything.
- It keeps us alive, strong and healthy.
- It can be defined as any thing solid or liquid, which when swallowed, digested and assimilated in the body, keeping us well.
- It is organic, energy rich, non-poisonous, edible and nourishing substance.

- Green plants synthesize their own food through photosynthesis. But animals including humans cannot synthesize their food on their own, hence are dependent on plants directly.
- The famine is responsible for dearth of food, besides the rapid and dramatic increase in world population over the time.
- To meet the increasing demand for food, there is need for improvement of food production, both quantity wise and quality wise (nutritive).
- **Plant breeding** and **animal breeding** help us to increase the food production.

Biofortification :

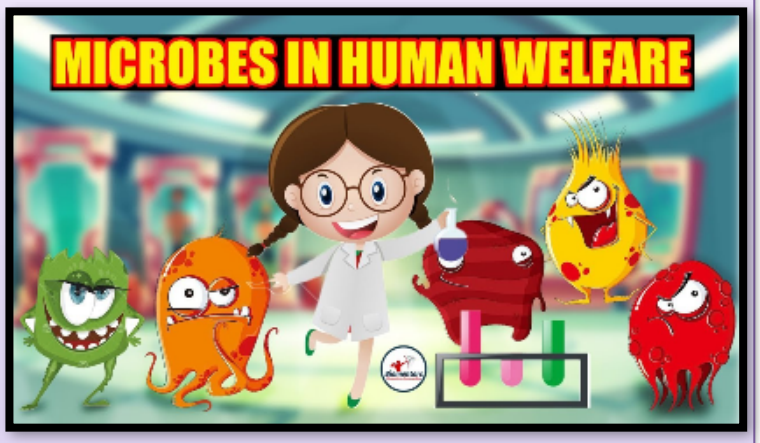
- It is a method in which crops are breed (produced) for having higher levels of vitamins, minerals and fats (i.e. better nutritive value).
- Due to this, problem of malnutrition can be overcome. Following objectives were considered for the breeding program :
  - Protein content and quality
  - Oil content and quality
  - Vitamin content
  - Micronutrient content and quality
- Biofortification can be achieved through conventional selective-breeding practices and also through r-DNA technology. It focuses on making plant food more nutritive as plants grow or develop.

Some examples of biofortification :

- Fortified Maize having twice the amount of amino acids- lysine and tryptophan.
- Wheat- Atlas 66 has a high protein content and iron-fortified rice has 5 times more iron, are developed.
- Vegetables crops like carrot and spinach have more vitamin A and minerals.
- Vitamin C enriched bitter gourd, tomato have been developed by IARI.

Microbes in human welfare :

- Biotechnology is the applications of ‘Scientific and Engineering principles for the processing of materials by biological agents to provide goods and service to humans or for human welfare’.



- There are variety of micro-organisms like algae, fungi, bacteria, viruses, protozoans, nematodes, etc. and their products that exhibit beneficial activities which are used for welfare of humans in regard to food, health, industry, agriculture, medicine, biocontrol, etc.
- These organisms are used variously in food and feed technology, industry, waste utilization, energy, etc.

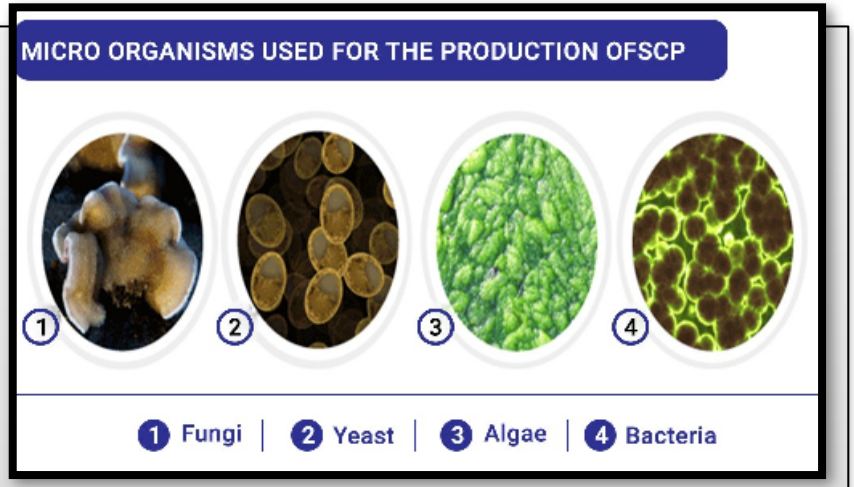
Microbes in food preparation :

- The development of biotechnology occurred in two phases viz, **traditional** (till 1971) and **modern** (after 1970).
- Traditional biotechnology is based on the fermentation principle by using fermenting bacteria. These were used in the preparation of variety of indigenous fermented food products.

1. Dosa, Dhokla and Idli :

- The dosa, idli and dhokla are fermented products produced due to activity of bacteria.
- They are fermented preparation of rice and black Gram with air borne *Leuconostoc* and *Streptococcus* species of bacteria.
- Co_2 produced during fermentation causes puffing up of the dough.

2. Microbes as the Source of Food :



- Some microbes or their fruiting bodies are directly used as a food, as they are rich in vitamins and proteins.
- The term “SCP” or “single cell protein” denotes, dead and dried cells of microbes like bacteria, algae, molds and yeasts.
- Some mushrooms and truffles are directly used as food. They belong to higher fungi. They produce large, fleshy fruiting bodies which are edible. Fruiting bodies are sugar free, fat free but rich in proteins, vitamins, minerals and amino acids. The food in the fruiting body is low caloried.

3. Dairy Products :

- Lactic acid bacteria (LAB) like *Lactobacillus* are added to milk.
- It ferments lactose sugar of milk into lactic acid.
- Lactic acid causes coagulation and partial digestion of milk protein casein.
- Milk is changed into curd, yoghurt and cheese.
- The starter or inoculum used in preparation of milk products actually contains millions of lactic acid bacteria (LAB).

i. Curd :

- Indian curd is prepared by inoculating milk with *Lactobacillus acidophilus*.
- It also checks growth of disease causing microbes.

ii. Yoghurt (Yogurt) :

- It is produced by curdling milk with the help os *Streptococcus thermophilus* and *Lactobacillus bulgaricus*.

iii. Butter Milk :

- The acidulated liquid left after churning of butter from curd, is called butter milk.

iv. **Cheese** :

- The milk is coagulated with lactic acid bacteria and the curd formed is filtered to separate whey.
- The solid mass is then ripened with growth of mould that develops flavour in it.
- Different varieties of cheese are known by their characteristic texture, flavour and taste which are developed by different specific microbes.

Roquefort cheese

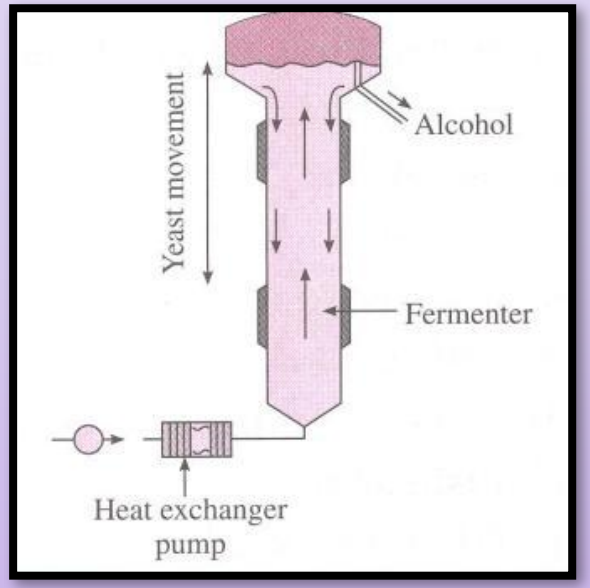
Camembert cheese

- The 'Roquefort and Camembert cheese' are ripened by blue-green algae molds *Penicillium roquefortii* and *Penicillium camembertii* respectively.
- The large holes in Swiss cheese are developed due to production of a large amount of Co_2 by a bacterium known as *Propionibacterium shermanii*.

Swiss cheese

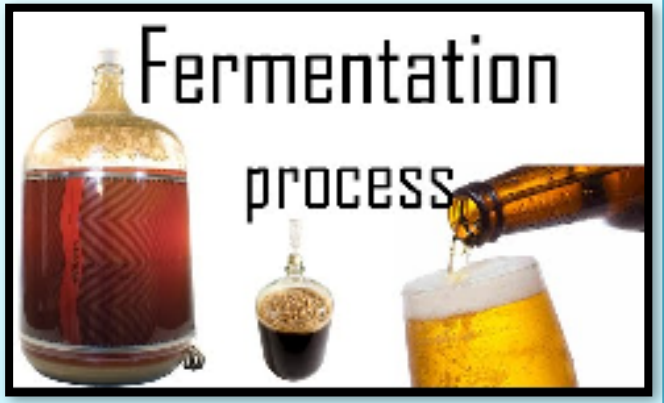
Role of Microbes in Industrial Production:

- During fermentation, variety of products like alcoholic beverages, organic acids, vitamins, growth hormones, enzymes, antibiotics, etc. are produced.
- Production on an industrial scale requires growing microbes in very large vessels, called **fermenters**.
- The main function of a fermenter is to provide a controlled environment for growth of a microorganism, or a defined mixture of microorganisms, to obtain the desired product.



Tubular tower fermenter

a. Production of Alcoholic Beverages :



i. Beverage is a liquid used or prepared for drinking e.g. tea, coffee, beer, wine, which acts as stimulant.

ii. Alcoholic beverages are the products of alcoholic fermentation of specific substrates.

iii. Use of microbes in making alcoholic beverages is known since Vedic period- 5000 to 7000Bc.

iv. Microbes especially yeast have been used from time immemorial for the production of beverages like wine, beer, whiskey, brandy or rum.

v. For this purpose, the yeast *Saccharomyces cerevisae* var. *ellipsoidis* (commonly called Brewer's Yeast) is used for fermenting malted cereals and fruit juices to produce ethanol.

vi. Among the beverages, Wine and Beer are produced without distillation whereas Whiskey, Brandy and Rum are distilled beverages.

vii. Tubular tower fermenter is used for large scale production of alcohols.

viii. Several traditional drinks and foods are also made through fermentation by yeast.

ix. Today, a traditional drink of the coastal region, in South India, is made by fermenting the sugar sap extracted from palm plants and coconut palm.

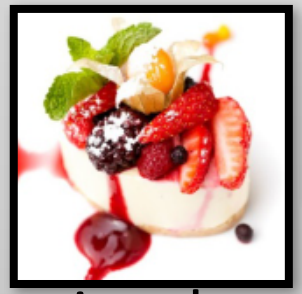
x. The famous wine of Goa, traditionally known as ‘fenny’ is made by fermenting fleshy pedicels of cashew fruits.

b. Production of organic acids :

i. Microbes are also used for the commercial and industrial production of certain **organic acids**.

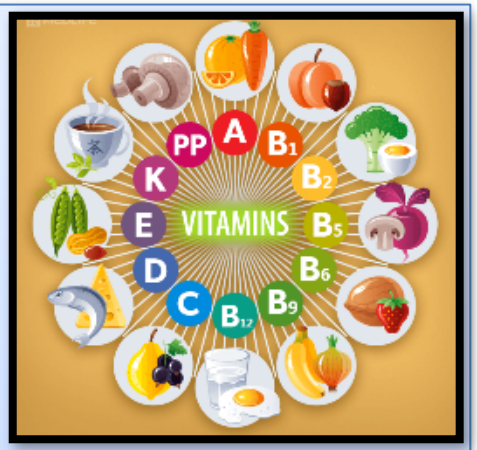
ii. These compounds can be produced directly from **glucose** (e.g. **gluconic acid**) or formed **as end products** from **pyruvate** or **ethanol**.

	Organic acid	Microbes used
i.	Citric acid	*Aspergillus niger*
ii.	Gluconic acid	*Aspergillus niger*
iii.	Fumaric acid	*Rhizopus arrhizus*
iv.	Acetic acid (Vinegar)	*Acetobacter aceti*



iii. The organic acids are further used variously e.g. citric acid is used in confectionary, fumaric acid in resins as wetting agents and gluconic acid in medicine for solubility of Ca^{++}.

c. Production of vitamins :



i. Vitamins are some organic nitrogenous compounds which are capable of performing many life-sustaining functions inside our body.

ii. These compounds cannot be synthesized by humans (except vitamin D), and therefore they have to be supplied in small amounts in the diet.

iii. Microbes are capable of synthesizing the vitamins and hence they can be successfully used for the commercial production of many of the vitamins e.g. thiamine, riboflavin, pyridoxine, folic acid, pantothenic acid, biotin, vitamin B_{12} , ascorbic acid, beta-carotene (pro-vitamin A) and ergosterol (provitamin D).

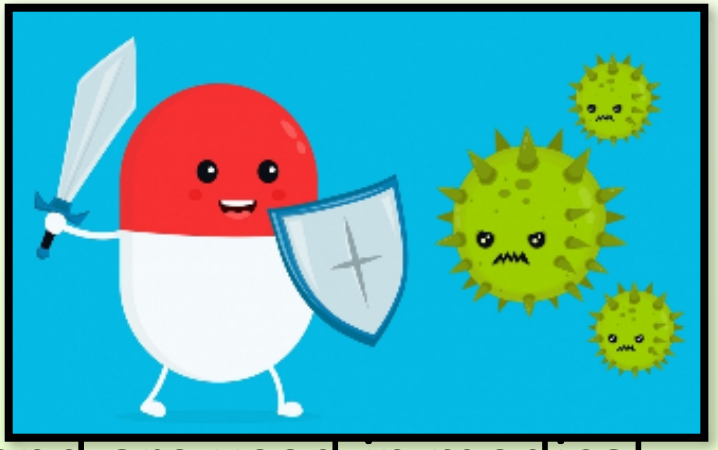
CHEMICAL NAME OF VITAMINS

VITAMINS	CHEMICAL NAMES
Vitamin A	Retinol
Vitamin D	Calciferol
Vitamin E	Tocopherol
Vitamin K	Phylloquinone
Vitamin B1	Thiamine
Vitamin B2	Riboflavin
Vitamin B3	Niacin
Vitamin B5	PantoThenic acid
Vitamin B6	Pyridoxine
Vitamin B7	Biotin
Vitamin B9	Folic acid
Vitamin B12	Cyanocobalamin
Vitamin C	Ascorbic acid

iv. Vitamins are manufactured by fermentation using different microbial sources as mentioned below :

Name of the vitamin	Microbial source
i. Vitamin B_2	*i. Neurospora gossypii* *ii. Eremothecium ashbyi*
ii. Vitamin B_{12}	*Pseudomonas denitrificans*
iii. Vitamin C	*Aspergillus niger*

d. Production of Antibiotics :



i. Antibiotics are probably the most important group of compounds synthesized by industrial microorganisms.
ii. Most antibiotics are secondary metabolites.
iii. They have therapeutic importance and are used in medical treatment.
iv. These are produced in small amounts by certain microbes (like bacteria, fungi and few algae), which inhibit growth of other microbial pathogens. Therefore, they are used in medicine.
v. The antibiotics are antibacterial, antifungal, etc.
vi. Antibiotics have greatly improved our capacity to treat deadly diseases such as plague, whooping cough, diphtheria, leprosy, etc.

Some common antibiotics and their microbial sources are listed below :

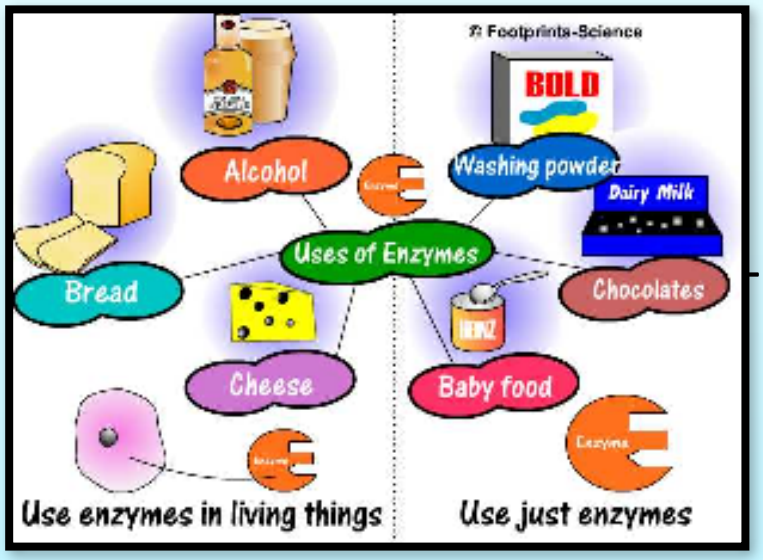
Table 11.11 : Antibiotic producing microbes

Antibiotic produced	Microbial sources
Chloromycetin	*Streptomyces venezuelae*
Erythromycin	*Streptomyces erythreus*
Penicillin	*Penicillium chrysogenum*
Streptomycin	*Streptomyces griseus*
Griseofulvin	*Penicillium griseofulvum*
Bacitracin	*Bacillus licheniformis*
Oxytetracycline / Terramycin	*Streptomyces aurifaciens*

e. Production of Enzymes :

i. In living beings, enzymes play a key role in metabolic reactions and therefore, these are essential for the survival of such beings.

ii. Enzymes are proteins known as catalysts. Due to their ability to promote reactions more quickly at body temperature and more efficiently.



iii. Many microbes synthesize and excrete large quantities of enzymes into the surrounding medium.

iv. Using this feature of these tiny organisms, many enzymes are produced commercially. These enzymes are **Amylase, Cellulase, Protease, Lipase, Pectinase, Streptokinase** and many others.

v. Several industrial sectors, use enzymes from microorganisms for specific applications.

vi. In the textile industry, enzymes are able to improve the quality of the fabrics.

vii. In the pulp and paper industry, they are involved in biomechanical pulping and bleaching.

viii. In the food industry, they are used in the fermentation processes for the production of bread and drinks such as wine and beer.

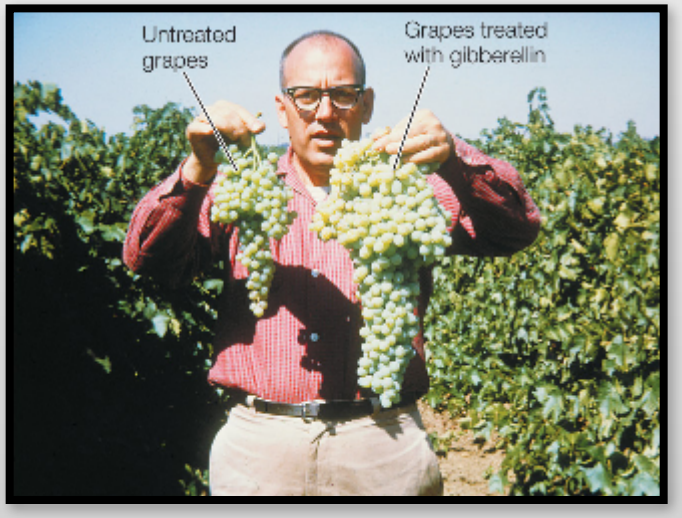
ix. Enzymes also participate in the extraction of substances, such as carotenoids and olive oil; lipases are used in detergent industry, because they have superior cleaning properties, increasing the brightness and removing of oil stains; they are also used in cosmetics, animal feed and agricultural industries, among others.

Following are the few examples of enzymes used in industrial food processing :

Name of the enzyme	Microbial source
i. Invertase	*Saccharomyces cerevisiae*
ii. Pectinase	*Sclerotinia libertine* *Aspergillus niger*
iii. Lipase	*Candida lipolytica*
iv. cellulase	*Trichoderma konigii*

f. Gibberellin production :

i. Gibberellin is a group of growth hormones mainly produced by higher plants and fungi to promote growth by stem elongation.



ii. The first gibberellin was isolated by two Japanese scientist – Yabuta and Sumiki (1938) from rice seedlings infected with the fungus *Gibberella fujikouri*.

iii. About 15 different types of gibberellins have been isolated.

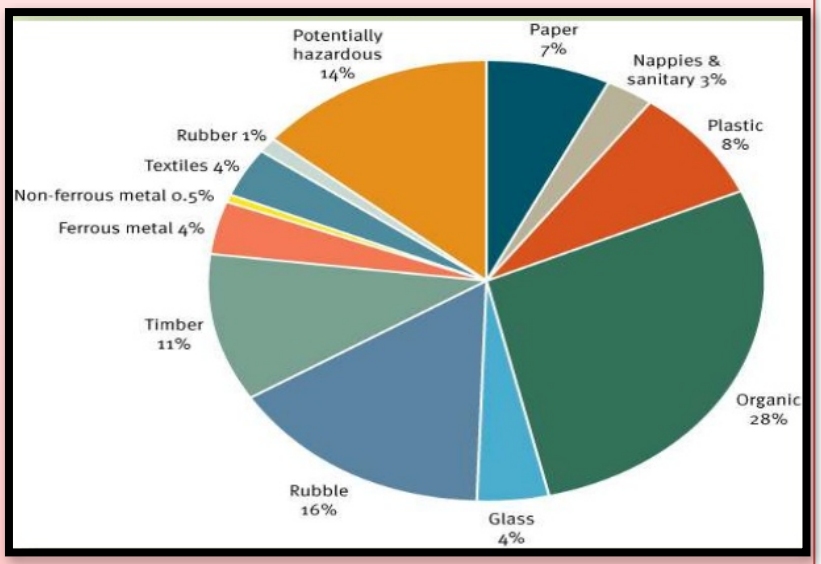
iv. Gibberellins have many practical applications. They are used to induce parthenocarpy in apple, pear, etc. They are used in breaking the dormancy of seed and also in inducing flowering in Long Day Plants (LDP). They are also used to enlarge the size of grape fruits.

Microbes in Sewage Treatment :

- Sewage is a matter carried off in drainage.
- It is a municipal waste containing human excreta, house hold waste, dissolved organic matter and even pathogenic microbes (bacteria, viruses, protozoans, nematodes and micro fungi).

- It also includes discharged water from hospital waste, slaughter house waste, animal dung, etc. Discharge from industrial waste (contains toxic dissolved organic and inorganic chemicals), tannery, pharmaceutical waste, etc. also add to sewage.

Composition of sewage :

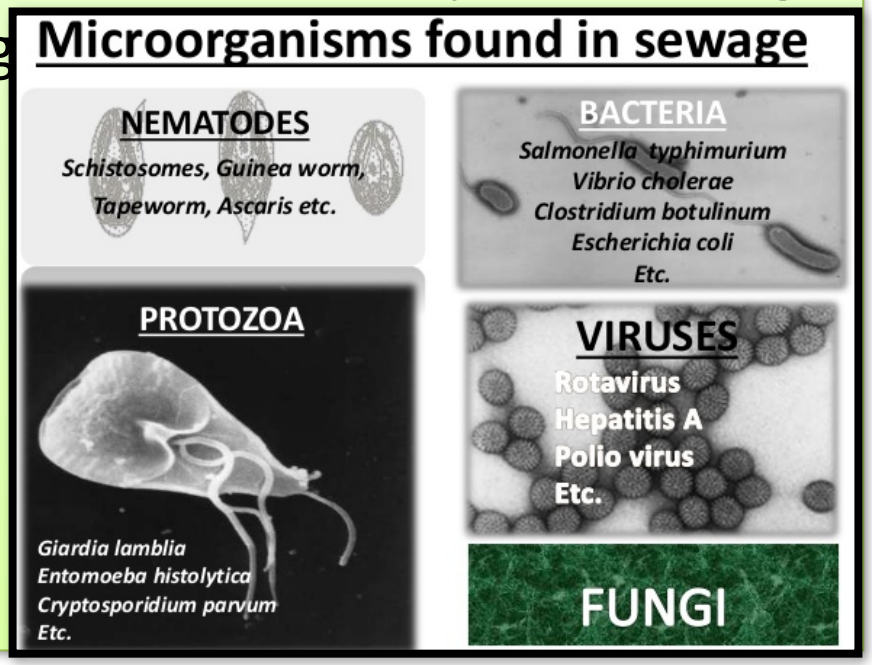


- Sewage consists of approximately 99.5% to 99.9% water and 0.1 to 0.5% inorganic and organic matter in suspended and soluble form.
- Composition of sewage varies depending upon the type of waste discharged into water from different industries. E.g. textile, chemicals, pharmaceuticals, dairy, canning, brewing, meat packing, tannery, oil refineries and meat industries, etc.

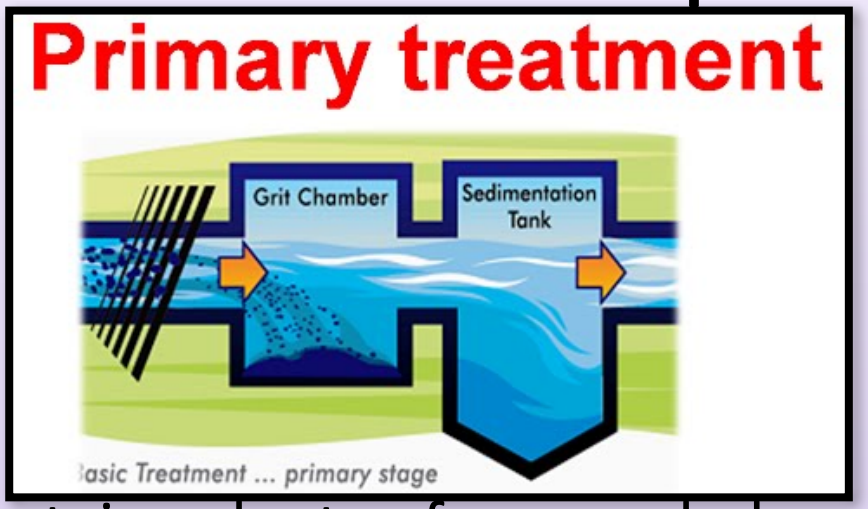
Microorganisms in Sewage :

- Various types of microorganisms are also present in sewage. Bacteria, viruses, fungi, protozoa, nematodes, algae, etc. are found in sewage. However, their number and type, fluctuate depending upon the sewage composition and source of sewage.

- Raw sewage may contain millions of bacteria per ml. these include coliforms, faecal *Streptococci*, anaerobic spore forming *bacilli* and other types originating humans.
- Before waste water is made available for human use, it has to be treated properly, so as to remove organic matter, inorganic salts and pathogens as well.



Sewage treatment process includes four basic steps as follows :



1. Preliminary Treatment :

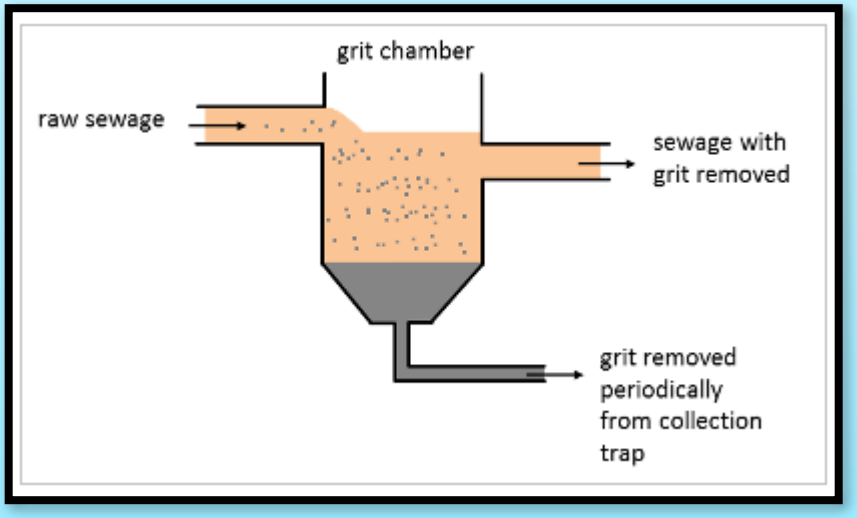
The preliminary treatment includes Screening and Grit Chamber.

i. Screening :

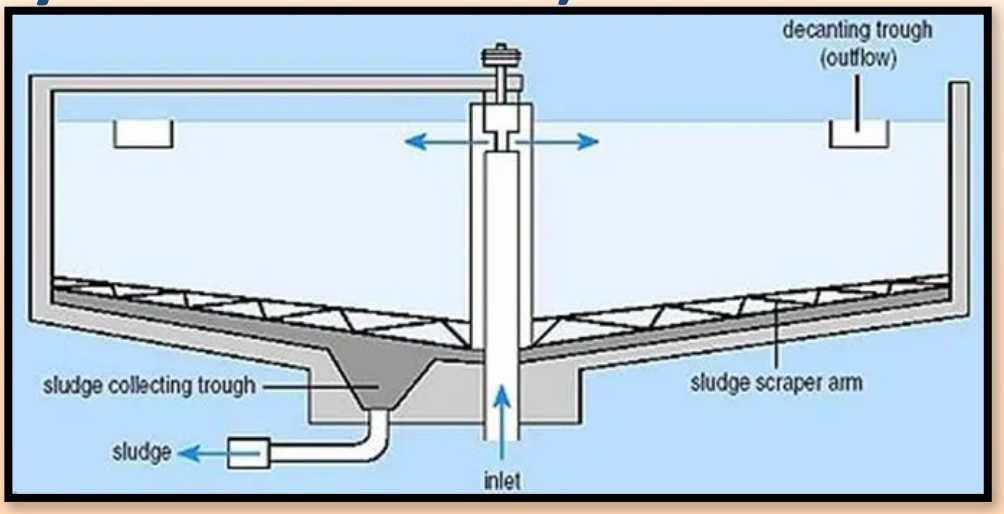
- Sewage and waste water contains plenty of suspended, floating materials, coarse and solid particles along with dissolved substances.
- The suspended objects are filtered and removed. This is done in screening chambers. The sewage is passed through screens or net in the chambers.
- Larger suspended or floating objects are held back in the screening chambers. These have to be removed before the biological treatment.

ii. Grit Chamber :

- After screening, the filtered sewage is passed into series of grit chambers. These chambers contain large stones (pebbles) and brick-ballast.
- Coarse particles settle down by gravity. Thus, passage of filtered sewage removes much of the coarse particulate matter.



2. Primary treatment (physical treatment) :



i. After the preliminary treatment, the sewage water is pumped into the **primary sedimentation tank**. The sedimentation of suspended solid or organic matter occurs in this tank. About 50-70% of the solids settle down.

ii. There is reduction of about 30-40%(in number) of *coliform* organisms. The organic matter which settled down, is called **primary sludge** which is removed by mechanically operated devices.

iii. The supernatant (effluent) in the primary sedimentation tank still contains large amount of dissolved organic matter and micro-organisms which can then be removed by the secondary treatment.

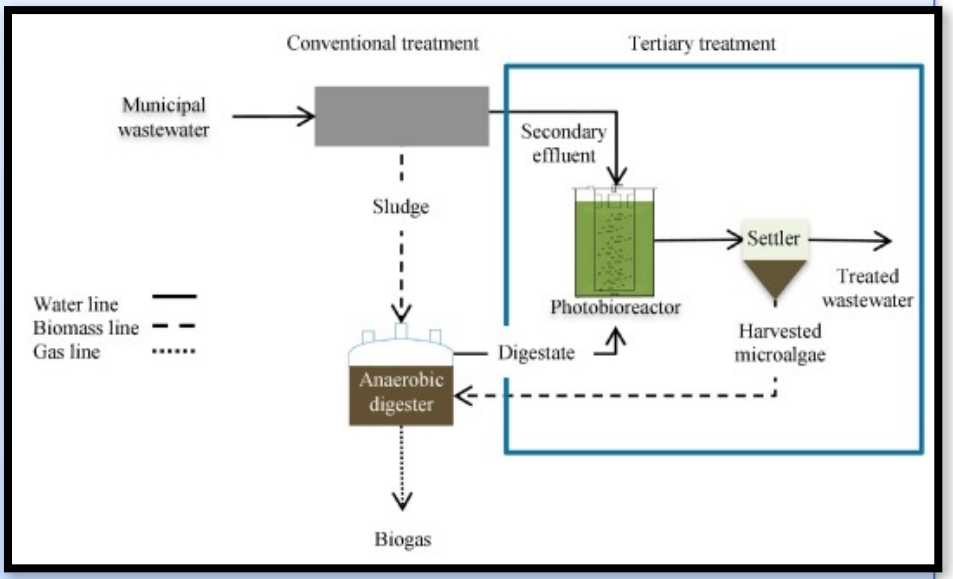
3. Secondary treatment (biological treatment) :

i. The primary effluent is passed into large aeration tanks. Here it is constantly agitated mechanically and air is pumped into it. Aerobic bacteria grow vigorously and form flocs.

ii. Flocs are the masses of bacteria held together by slime and fungal hyphae to form mesh like masses.

iii. These aerobic microbes consume the major part of the organic matter present in the effluent, as they grow. Due to this BOD(Biological Oxygen Demand) of the effluent is significantly reduced.

4. Tertiary treatment :



i. Once the BOD of waste water is reduced, it is passed into a **settling tank**. Here the bacterial flocs are allowed to sediment. The sediment is now called **activated sludge**.

ii. Small part of this is passed back in to aeration tank and the major part is pumped in to large tanks called **anaerobic sludge digesters**. In these tanks, anaerobic bacteria grow and digest the bacteria and fungi in the sludge.

iii. During this anaerobic digestion, gases such as methane, hydrogen sulphide, Co_2, etc. are produced.

iv. Effluents from these plants (digester) after chlorination, are released in natural bodies like rivers and streams. Chlorination kills pathogenic bacteria. Digested Sludge is then disposed.

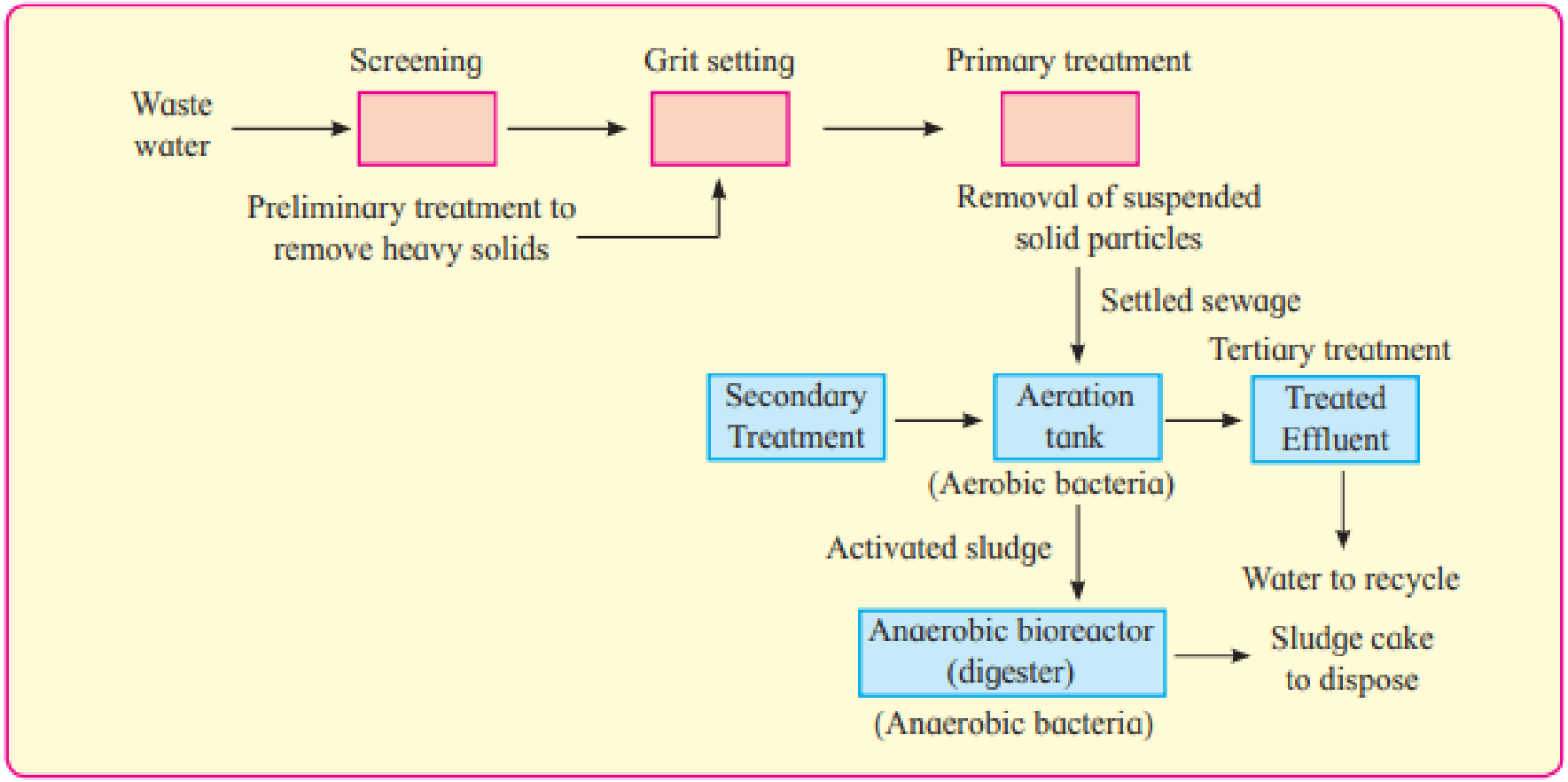
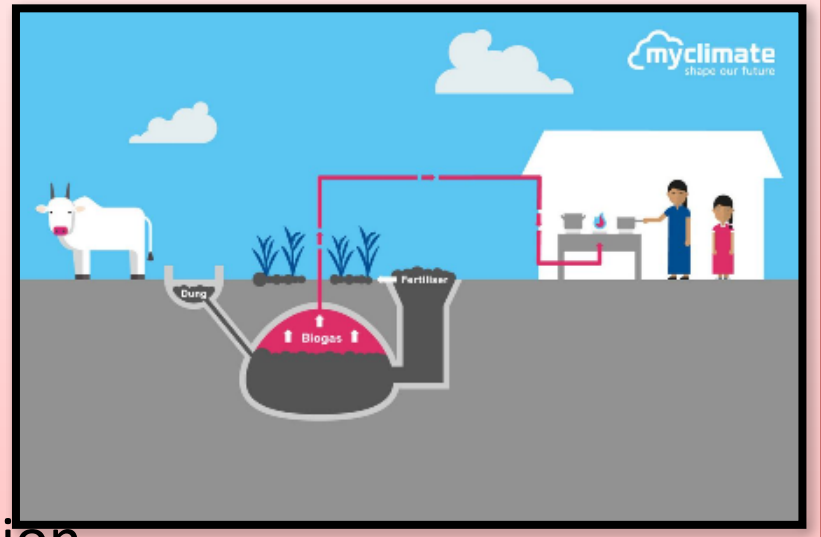


Fig. 11.12 : Diagrammatic representation of various stages in wastewater treatment

Microbes in Energy Generation:



i. Many developing countries are encouraging for installation of biogas plants to meet out the requirements of energy.
ii. Biogas is used as a domestic as well as industrial fuel.
iii. It is a non-conventional and renewable source of energy and is obtained by microbial fermentation.
iv. Biogas is a mixture of methane CH_4 (50-60%), Co_2 (30-40%), H_2S (0-3%) and other gases (CO, N_2, H_2) in traces.
v. Biogas is highly inflammable and is used as a source of energy.
vi. Plant wastes, animal wastes, domestic wastes, agriculture waste, municipal wastes, forestry wastes, etc. are commonly used for biogas production.
vii. Cattle dung is most commonly employed substrate for biogas production. It is a rich source of cellulose from plants.

Biogas Production :

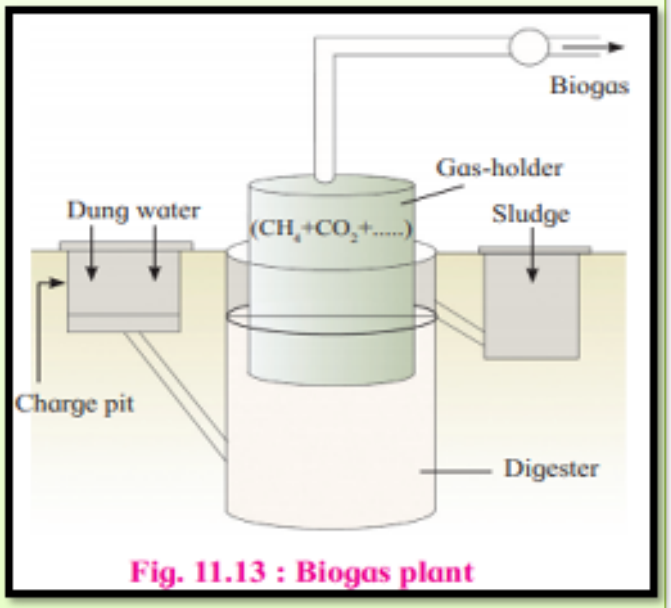


Fig. 11.13 : Biogas plant

i. Most commonly used models of biogas plants are KVIC and IARI. The digester used for biogas production is called Biogas Plant.

ii. A typical biogas plant using cattle dung as a raw material, consists of digester and gas holder.

iii. Digester is made up of concrete bricks and cement or steel. There is cylindrical gas holder or gas tank above it to collect gases.

iv. Digester has a side opening (charge pit) into which raw material as cow dung is fed. The digester is partly buried in the soil.

Anaerobic digestion involves in three processes :

1. **Hydrolysis or solublization :**
   i. In initial stage raw material (cattle dung) is mixed with water in equal proportion to make slurry which is then fed into the digester.
   ii. Here anaerobic hydrolytic bacteria (e.g. *Clostridium*, *Pseudomonas*) hydrolyse carbohydrates into simple sugars, proteins into amino acids and lipids into fatty acids.
2. **Acidogenesis :**

   In this stage, facultative anaerobic, acidogenic bacteria and obligate anaerobic organisms, convert simple organic material into acids like formic acid, acetic acid, H_2 and CO_2.

3. Methanogenesis :

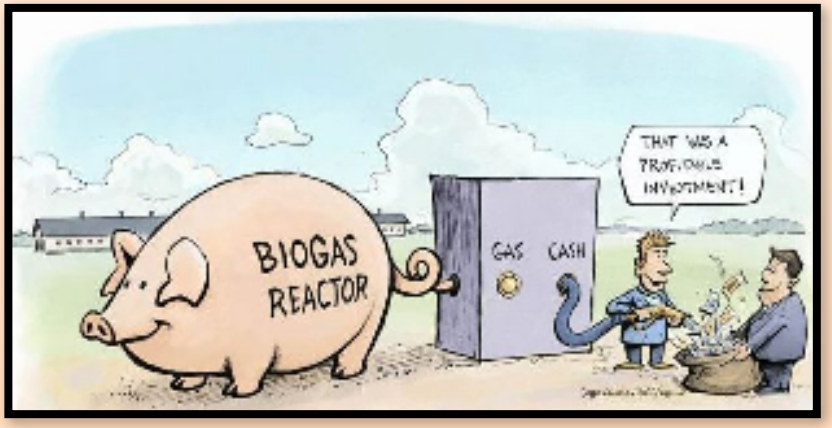
i. This is last stage in which anaerobic Methanogenic bacteria like *Methanobacterium*, *Methanococcus* convert acetate, H_2 and CO_2 into Methane, CO_2 and H_2O and other products.

a. 12mol CH_3COOH (acetic acid) $\longrightarrow$ $12CH_4 + 12CO_2$ (methane)

b. 4mol H.COOH (formic acid) $\longrightarrow$ $CH_4 + 3CO_2 + 2H_2O$

c. $CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$

Benefits of Biogas Production :



1. It is a cheap, safe and renewable source of energy. It can be easily generated, stored and transported.
2. It can be used for domestic lighting, cooking, street lighting as well as small scale industries.
3. It burns with blue flame and without smoke.
4. It helps to improve sanitation of the surrounding.
5. It is eco-friendly and does not cause pollution and imbalance of the environment. Sludge which is left over is used as a fertilizer.

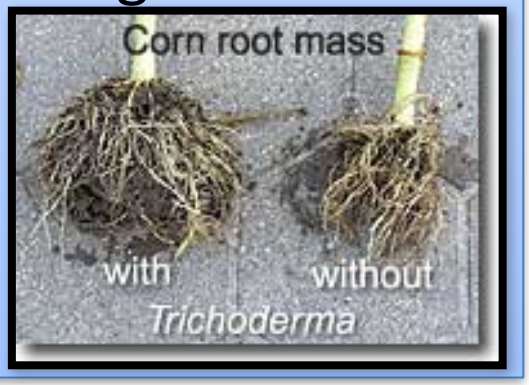
Role of Microbes as Biocontrol Agents :

- The term biocontrol refers to the use of biological methods to control diseases and pests.
- The natural method of eliminating and controlling insects, pests and other disease-causing agents, is by using **biocontrol** or **biological control**.
- The agents which are employed for this are called biocontrol agents. Microbes are one among them. These microbes include bacteria, fungi, viruses and protozoans.
- Microbes as biocontrol agents act in three ways, either they cause the disease to the pest or compete or kill them.
- Chemicals, insecticides and pesticides are extremely harmful to human beings and also pollute our environment.
- Hence, the use of biocontrol measures will greatly reduce our dependence on toxic chemicals and pesticides.

Examples of Microbial bio-control :

i. *Bacillus thuringiensis* (Bt) is used to get rid of butterfly, caterpillars where dried spores of *Bacillus thuringiensis* are mixed with water and sprayed onto vulnerable plants such as *Brassicas* and fruit trees. These spores are then eaten by the insect larvae. In the gut of the larvae, the toxin (cry protein) is released and the larvae get killed eventually.

ii. *Trichoderma* species are free-living fungi found in the root ecosystem (rhizosphere). These are effective as biocontrol agents of several soil borne fungal plant pathogens. The fungus produces substances like viridin, gliotoxin, gliovirin, etc. that inhibit the other soil borne pathogens attacking root, rhizones, etc. causing root disease.



Four groups of biochemical agents are known. They are bacteria, fungi, viruses and protozoans.

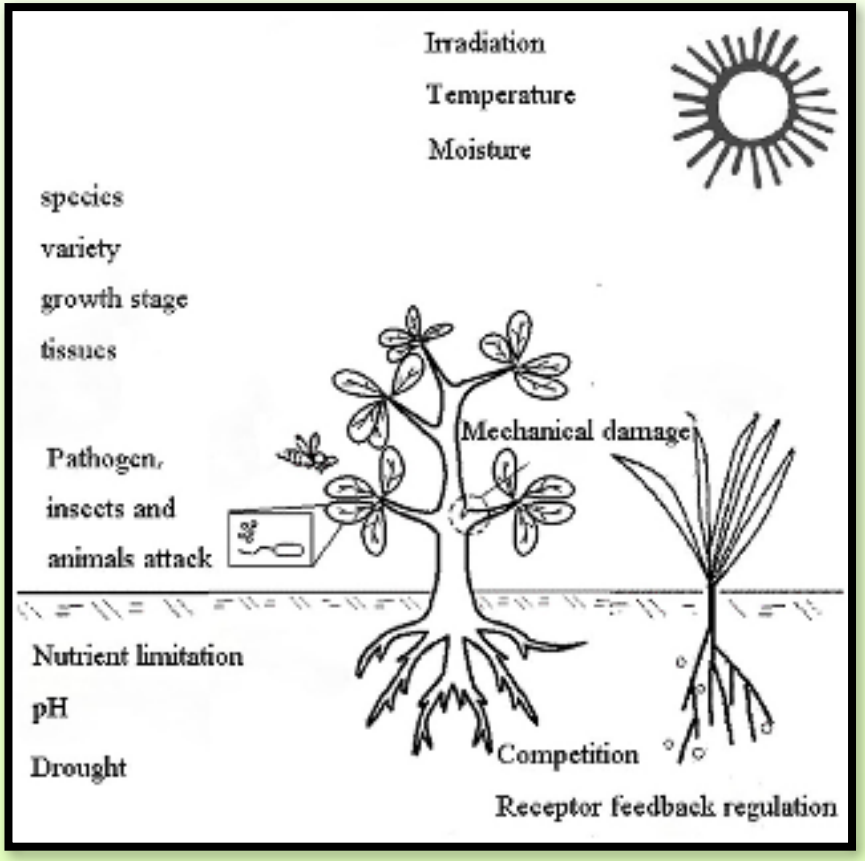
I. Microbial Pesticides and their host :

The correlation is depicted as per the following table :

Table 11.14 : Microbes and their host

Pathogen	Host
Bacteria: *Bacillus thuringiensis* (Bt) *B. papilliae* and *B.lentimorbus*	Caterpillars, cabbage worm, adult beetle,etc.
Fungi: *Beavueria bassiana, Entomophthora. pallidaroseum,* and *Zoopthora radicans*	*Aphid crocci, A. unguiculata,* mealy bugs, *mites, white flies* etc
Protozoans: *Nosema lacustae*	Grasshopper, caterpillars, crickets
Viruses: Nucleopolyhedrovirus (NPV) and Granulovirus (GV)	Caterpillars and Gypsy moth, ants, wasps and beetles.

Bioherbicides :



- Weeds are the unwanted plants that grow in agricultural fields, ponds, lakes, etc.
- Weeds compete with the main crop in the farm-land for water, space, minerals, light, air, etc. and also act as collateral hosts for several pathogens.
- Microbes are also used as herbicides.
- Many dicot herbs that grow in the field of cereals as weeds, can be killed by certain microbes. For examples :

II. Microbial Herbicides and Their Host :

1. Pathogenic fungi as mycoherbicides :
   i. *Phytophthora palmivora* – controls milk weed in orchards.
   ii. *Alternaria crassa* – controls water hyacinth.
   iii. *Fusarium spp.* – control most of the weeds.
2. Bacterial pathogens as herbicides :
   i. *Pseudomonas spp.* – attacks several weeds
   ii. *Xanthomonas spp.* – attacks several weeds
   iii. *Agrobacterium spp.* – attacks several weeds
3. Insects as herbicides :
   i. *Tyrea* moth – controls the weed Senecio jacobeac
   ii. *Cactoblastis cactorum* – controls cacti weeds

Role of Microbes as Biofertilizers :

i. Fertilizers are nutrients which are necessary for the growth of plants and thus for the productivity of cultivated plants.

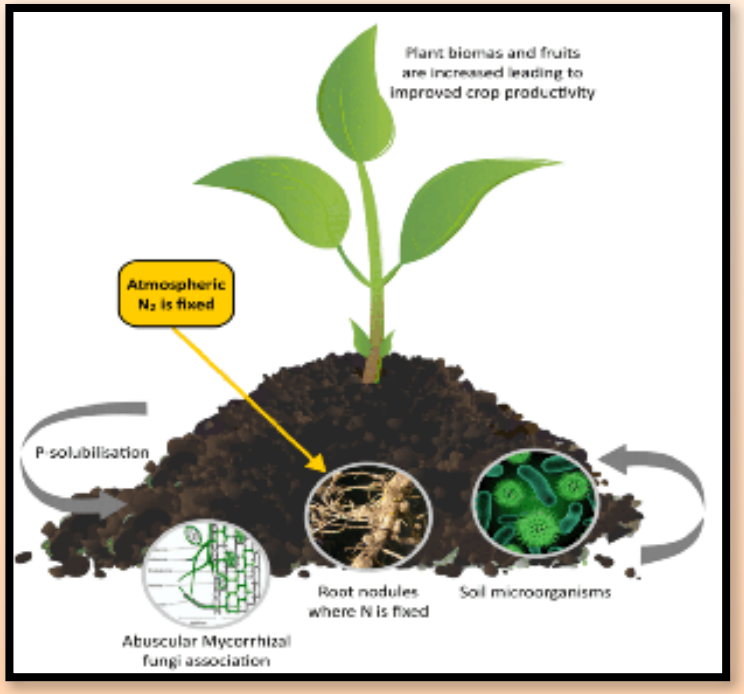
ii. Use of fertilizers for increasing productivity is one of the aspects of green revolution.

iii. Fertilizers are classified as **inorganic** (chemical) and **organic** (biological).

iv. Inorganic fertilizers are synthetic where mineral salts of NPK are mixed in definite proportion and then dusted in the field. Non-judicious or excessive use of such fertilizers lead to pollution of soil, air and ground water. Soil becomes acidic.

v. Organic fertilizers are biological in origin and include Farm Yard Manure (FYM), compost and green manure. Use of these fertilizers increases the fertility of soil.

vi. Now a days for better and sustainable agricultural production, farmers use **biofertilizers** and practise organic farming.

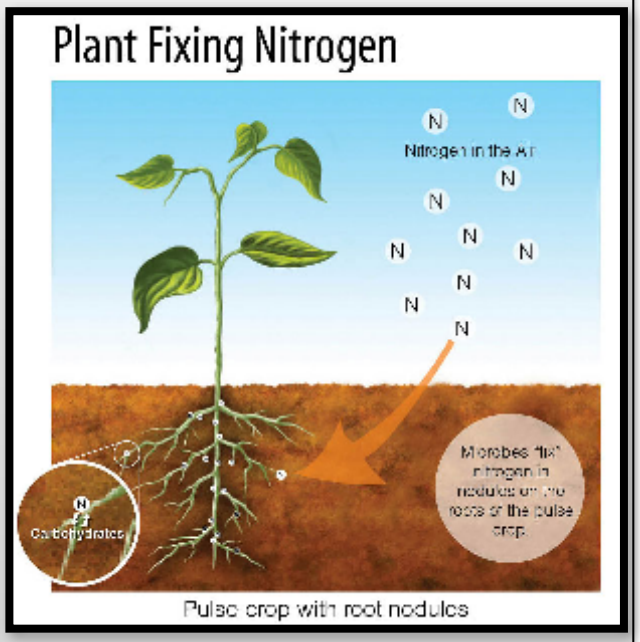


vii. Biofertilizers are mostly N_2 -fixing, living microorganisms which enrich the nutrient quality of soil. They include bacteria, cyanobacteria and fungi.

viii. Biofertilizers are commercial preparation of ready-to-use live bacterial or fungal formulations. Their application to plant, soil or composting pits, helps to enrich the soil fertility due to their biological activity.

ix. Use of Biofertilizers is cost effective and eco-friendly. They play a vital role in maintaining a long term soil fertility and sustainability.

Types of Biofertilizers :



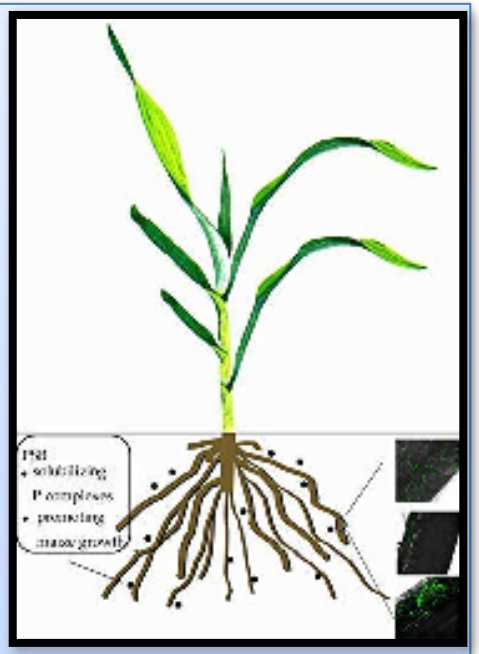
1. **N_2 fixing Biofertilizers** :The nitrogen fixing microorganisms which convert atmospheric nitrogen into nitrogenous compounds like nitrites and nitrates via ammonia. Nitrogen fixing microorganisms, also called **diazotrophs**, are of two types :

   i. **Symbiotic N_2 fixing microorganisms** : for e.g. *Rhizobium*, *Anabaena*, *Frankia*. These are always associated generally with underground parts i.e. roots of higher plants.

   ii. **Free-living or Non-symbiotic N_2 fixing microorganisms** : e.g. *Azotobacter, Nostoc, Clostridium, Beijerinkia, Klebsiella,* etc.

2. Phosphate solubilizing biofertilizers :

These are the bacterial species which solubilize the insoluble inorganic phosphate compound, such as rock phosphate. For e.g. *Pseudomonas striata, Bacillus polymyxa, Agrobacterium, Micrococcus, Aspergillus spp* etc.



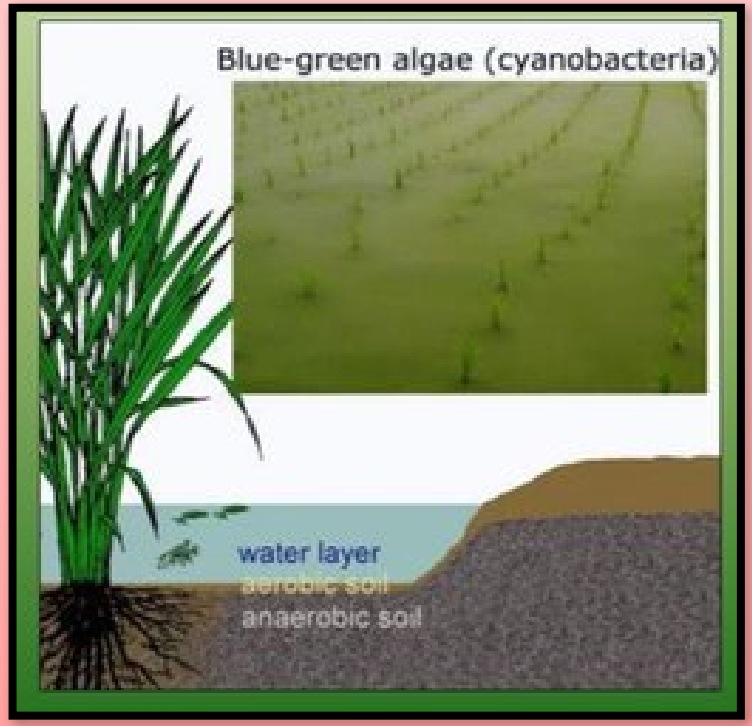
3. Compost making biofertilzers :

- Composting is a natural process that turns organic material into a dark rich substance called as compost or humus.
- The composting process is dependent on microorganisms to break down organic matter into compost.

- There are many types of microorganisms found in active compost such as bacteria, fungi, actinobacteria, protozoa and rotifers.

4. Cyanobacteria as biofertilizers :

Many cyanobacteria are aquatic and terrestraial, free-living or symbiotric, aerobic, photosynthetic, N_2 fixing, heterocystous or non-heterocystous forms. e.g. *Anabaena, Nostoc, Plectonema, Oscillatoria,* etc. *Anabaena, Nostoc* and *Tolypothrix* are associated with lichens while *Anabaena* is associated with plants like *Azolla* and *Cycas*.

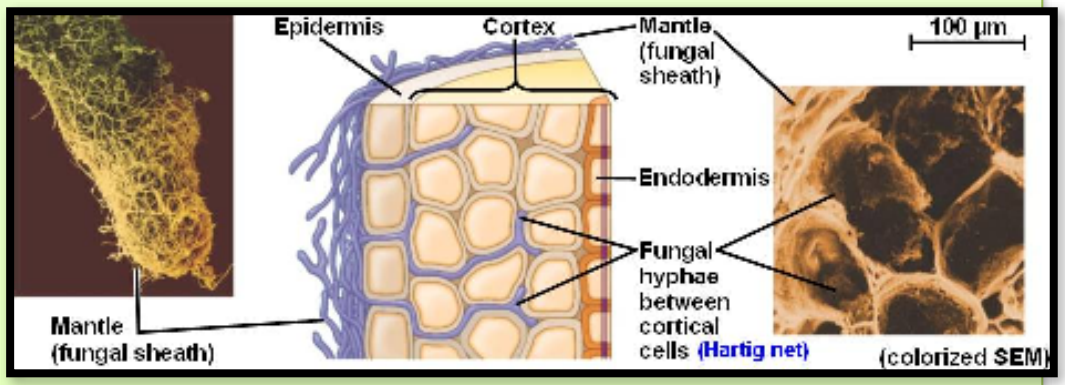


5. Fungal biofertilizers :

Mycorrhiza is a fungus. It forms symbiotic association with the underground parts like rhizomes and root of higher plants occuring in thick humid forests. These are discovered by Frank (1885). There are two types viz. **Ectomycorrhizae** and **Endomycorrhizae**.

Ectomycorrhizae

I. Ectomycorrhizae :



- They have well developed mycelium that forms mantle on the outside of the roots.
- This increases absorptive surface area of roots and accelerates uptake of water and nutrients (N, P, Ca & K). Due to this the plant vigour, growth and yield increase.
- Some hyphae of mycorrhizal fungus, penerate into the root and forms **hartig-net** in the intercellular spaces of root cortex.

II. Endomycorrhizae :

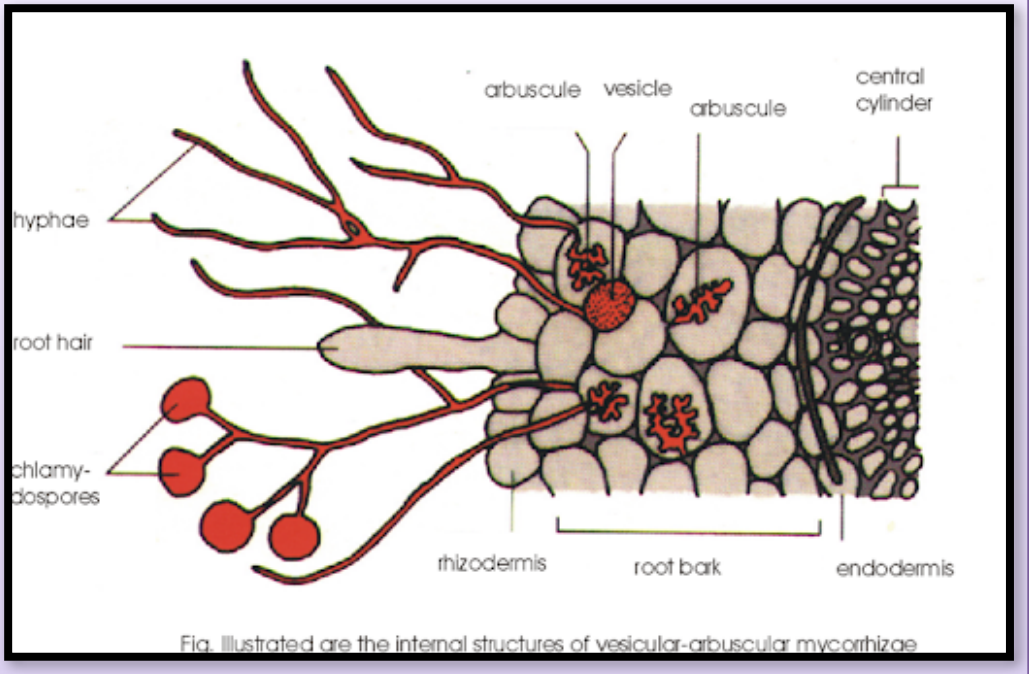


Fig. Illustrated are the internal structures of vesicular-arbuscular mycorrhizae

- They grow in between and within the cortical cells of roots.
- Fungal hyphae penetrate the cells and form finely branched **arbuscules** intracellularly and form **vesicles** mostly in the intercellular spaces of cortical cells. Hence they are called Vesculo Arbuscular Mycorrhizae or VAM. Now a days they are described as AM fungi.
- The plants with VAM grow luxuriantly in less irrigated lands. The association of VAM with crop plants helps in conversion of less productive field into more productive field.

Benefits of Mycorrhiza :

1. Selective absorption of P, Zn, Cu, Ca, N, Mn, Br and Fe.
2. Enhance water uptake.
3. Induce growth by secreting hormones.
4. Offer protection to host plant from other microbes, by secreting antibiotics.

Biofertilizer microorganisms :

1. *Rhizobium :*

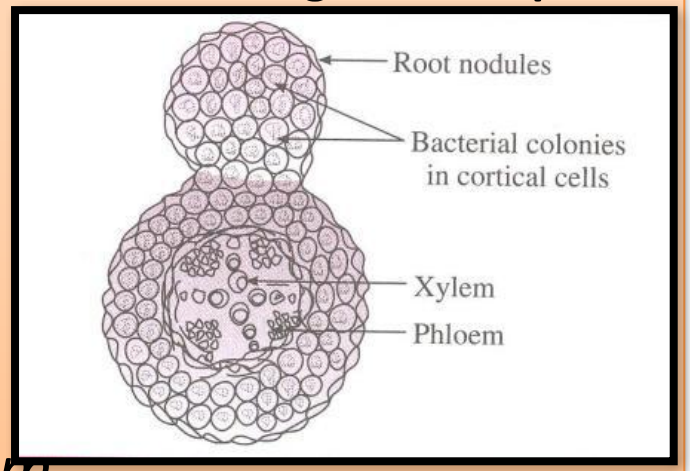
i. Rhizobia are rod shaped, motile, aerobic, gram negative, non spore forming, nitrogen-fixing bacteria containing *Nod* genes and *Nif* genes.

ii. They form symbiotic association with roots of leguminous plants.

iii. They bring about nodule formation on the roots and multiply inside the nodule.

iv. They fix atmospheric nitrogen into organic forms, which can be used by plants as nutrients. For e.g. *Rhizobium leguminosarum* is specific to pea and *Rhizobium phaseoli* to beans.

Root system of Leguminous plant



T. S. root nodule

2. *Azotobacter :*

i. It is the important and well known free living, nitrogen fixing, aerobic, non-photosynthetic, non-nodule forming, bacterium, intimately associated with roots of grasses and certain plants.

ii. It is used as a Bio-fertilizer for all non-leguminous plants especially rice, cotton, vegetables, etc.

3. *Azospirillum :*

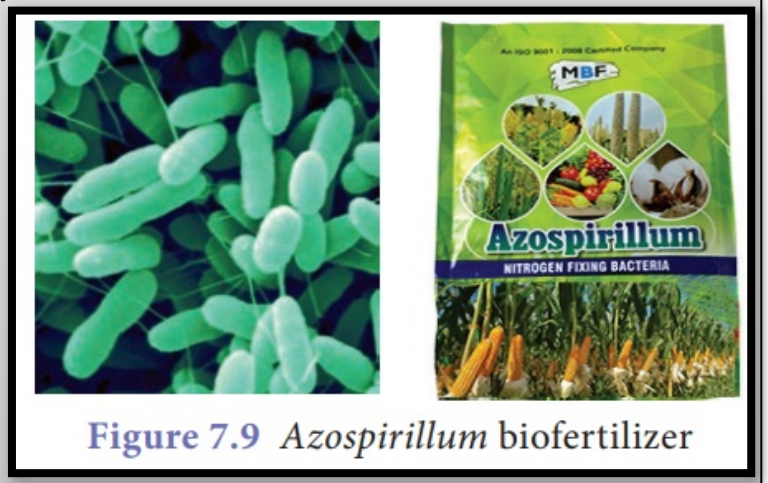


Figure 7.9 *Azospirillum* biofertilizer

i. It is free living, aerobic nitrogen fixing bacterium associated with roots of corn, wheat and jowar.

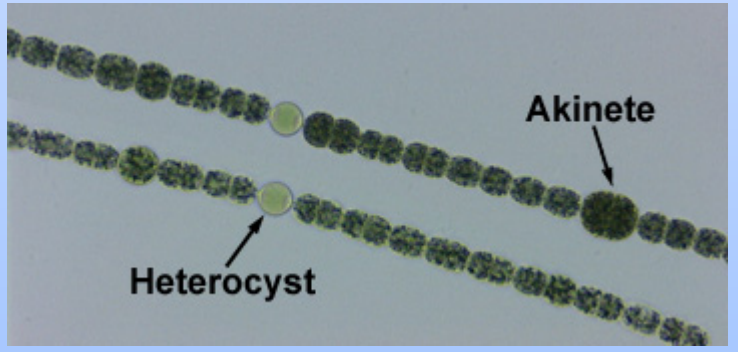
ii. It fixes the considerable quantity of nitrogen (20-40kg N/ha) in non-leguminous plants such as cereals, millets, cotton, oilseed, etc.

4. *Anabaena :*

i. It is a genus of multicellular, filamentous cyanobacteria that exits as plankton.

ii. It has ability to fix nitrogen and also forms symbiotic relationships with certain plants, such as the coralloid roots of *Cycas* and *Anthoceros* thalus.

iii. It has some specialized and colourless cells, called **Heterocysts** which are the sites for nitrogen fixation.



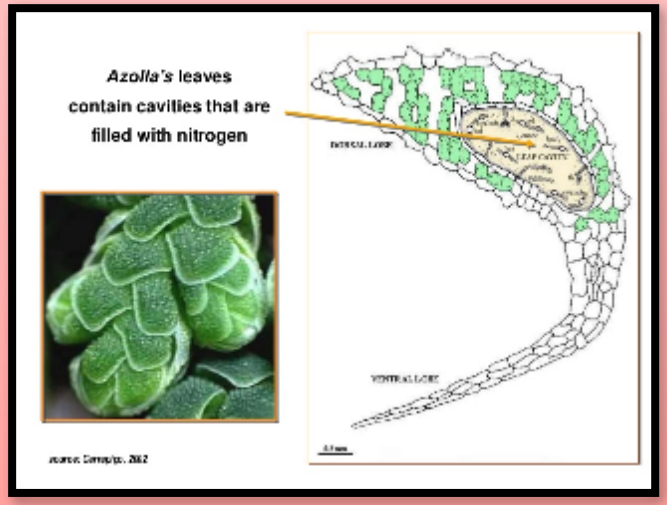
5. *Azolla :*

i. Azolla is a free-floating water fern.

ii. Azolla plant consist of a floating rhizome (stem) with small overlapping bi-lobed leaves and roots. The leaf shows dorsal and ventral lobe.

iii. In the dorsal lobe, *Anabaena* filaments are present in the aerenchyma, which fixes nitrogen.

iv. *Azolla* can be used as biofertilizer in the rice field.



Benefits of Biofertilizers :

1. Low cost and can be used by marginal farmers.
2. Free from pollution hazards.
3. Increase soil fertility.
4. BGA as biofertilizers secret growth promoting substances, organic acids, proteins and vitamins.
5. *Azotobacter* supply nitrogen and antibiotics in the soil.
6. Biofertilizers increase physico-chemical properties of soil-like texture, structure, pH, water holding capacity of soil by providing nutrients and organic matter.

Now in our country many biofertilizers are available in market to reduce the use of chemical fertilizers and thus, the pollution.