## Why is the need of food production :-

- 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.

# Plant breeding :

- The improvement or purposeful manipulation in the heredity of crops and the production of new superior varieties of existing crop plants, constitute what is called plant breeding.
- It is, therefore, an applied branch of botany.
- It is infact an art and the science of changing and improving the heredity of plants.

Plant breeding can be carried out by using the applications of principles of

- genetics,
- taxonomy,
- physiology,
- pathology,
- agriculture,
- rDNA technology, etc.

- Plant breeding is a method of altering the genetic pattern of plants to increase their value and utility for human welfare.
- Primary aim of plant breeding is to obtain a new crop veriety superior to the existing type, in all characters.

Different methods of plant breeding include

- Introduction,
- Selection,
- Hybridization,
- Mutation breeding,
- Polyploidy breeding,
- Molecular plant breeding,
- Tissue culture,
- rDNA technology,
- SCP, etc.

# Hybridization and its technique :

- It is the chief method that offers greater possibilities in the crop improvement than other methods.
- The use of this method is the only effective means of combining together the desirable characters of two or more varieties.
- By this method, one can create new genetic combinations of already existing characters and new genetic variations.

## Hybridization can be

- intravarietal,
- intervarietal (between two varieties of the same species),
- interspecific (between two species of the same genus)
- intergeneric (between two genera of the same family).

# THE MAIN STEPS OF THE PLANT BREEDING PROGRAM (HYBRIDIZATION) ARE AS FOLLOWS :

## 1. Collection of variability :

- Wild species and relatives of the cultivated species having desired traits, should be collected and preserved.
- The entire collection having all the diverse alleles (i.e. variations) for all genes in a given crop, is called germplasm collection.
- Variations are useful in the selection.

Germplasm conservation can be done in following ways-

- *In situ* conservation : It can be done with the help of forests and Natural Reserves.
- *Ex situ* conservation : It is done through botanical gardens, seed banks, etc.

## 2. Evaluation and Selection of Parents :

- It is an important and essential step.
- The collected germplasm is evaluated (screened) to identify plants with desirable characters.
- The selected parents must be healthy, vigorous and should show desirable but complementary features.

- The selected parents are selfed for three to four generations to make them pure or homozygous.
- It is made sure that only pure lines are selected, multiplied and used in the hybridization.

## Chart 11.1 : Steps of Hybridization technique

Collection of variability from germ plasm/ gene bank

↓

Evaluation and selection of parents

↓

Selection of parent plants with different qualities

↓

Selected parents selfed for three to four generations to make them homozygous or true breeding

↓

Identification of parents as male parent (donor) and female parent (recurrent)

↓

Collection of pollen grains from the flowers of male parent

↓

Removal of stamens from the flowers of the female parent (emasculation)

Artificial cross pollination by using pollen grains collected from male parent

↓

Bagging, tagging of the emasculated flower of female parent

↓

Development of fruit and seed representing $F_1$ (hybrid)generation

↓

Selection and testing of $F_1$ hybrid for combination of desirable characters

↓

Field trials for yield (productivity)

↓

Testing and the release of variety

## 4. Selection and Testing of Superior Recombinants :

- The F1 hybrid plants showing superiority over both the parents and having high hybridvigour, are selected.
- Such hybrids are then selfed for few generations to make them homozygous for the said desirable characters till there is a state of uniformity, so that the characters will not segregate further.

## 5. Testing, Release and Commercialization of New Cultivars :

- The newly selected lines are evaluated for the productivity and other features like disease resistance, pest resistance, quality, etc.
- Initially, these plants are grown under controlled conditions of water, fertilizers, etc.

## Indian Hybrid Crops :

### 1. Wheat and Rice :

In 1960s, wheat and rice production increased tremendously. Norman E. Borlaug developed semi-dwarf varieties of wheat. *Sonalika* and *Kalyan Sona* are two of the hybrid wheat varieties, grown in India. Semi-dwarf rice varieties were taken from IR−8 (International Rice Research Institute) and Taichung native−I (from Taiwan) and introduced in India. *Jaya, Padma* and *Ratna* are the better-yielding, semi-dwarf rice varieties that were developed later.

## 2. Sugarcane :

- *Saccharum barberi* is a native of North India and *S. officinarum* belongs to South India.
- *S. officinarum* has thicker stem and high sugar contents, but it does not grow well in North India.
- These two varieties were crossed to get the desirable qualities of both (high sugar content, thicker stem and the ability to grow in North India). CO -419, 421, 453 are high yielding and having high sugar contents are developed in India at Coimbatore (Tamilnadu).

## 3. Millets :

- Hybrid maize (Ganga-3), J*owar* (CO-12), and B*ajra* (Niphad) have been successfully developed in India.
- These varieties are high yielding and resistant to water stress.

**Plant Breeding for Disease Resistance :**

Some of the diseases caused in plants are-

| Pathogen | Plant disease |
|---|---|
| Fungi | Brown rust of wheat<br>Red rot of sugarcane<br>Late blight of potato |
| Bacteria | Black rot of crucifers |
| Viruses | Tobacco mosaic virus |

The basic objective of breeding for disease resistance is to develop inherent quality in the plant to prevent the pathogen from causing the disease. Such varieties of plants are called disease resistant plants. The basic technique used is the same as for normal hybridization process.

**Some disease resistant plants developed are :**

| Crop | Variety | Resistant to Disease |
|---|---|---|
| Wheat | Himgiri | Leaf and stripe rust, hill bunt |
| *Brassica* | Pusa Swarnim | White rust |
| Cauliflower | Pusa Shubra | Black rot and Curl blight black rot |
| Chilli | Pusa Sadabahar | Chilli mosaic virus, Tobacco mosaic virus and leaf curl |

## B. Mutation Breeding :

- ✓ Mutation is sudden heritable change in the genotype, caused naturally.
- ✓ It can also be induced by application of chemical mutagens.

**Natural (physical) mutagens are :** High temperature, high concentration of $CO_2$, X rays, UV rays.

**Chemical mutagens are :** Nitrous acid, EMS (Ethyl- Methyl- Sulphonate), Mustard gas, Colchicine, etc.

Seedlings or seeds are irradiated by CO-60, exposed to UV bulbs, X ray machines, etc.

Mutagens cause gene mutations and chromosomal aberrations. The treated seedlings are then screened for resistance to diseases/ pests, high yield, etc. e.g. Jagannath variety of rice, NP 836 variety of wheat (rust resistant), Indore-2 variety of cotton (resistant to bollworm), Regina-II variety of cabbage (resistant to bacterial rot), etc.

## Plant Breeding for Developing a Resistance to Insect Pest:

Insects being herbivores, incur heavy loss in the quantity and quality of crops. Resistance in crops can be developed by following ways :

- Development of morphological characters like hairy leaves in cotton and wheat develop vector resistance from jassids and cereal leaf beetle, respectively.
- Solid stem in wheat leads to resistance to stem borers.

Some pest-resistant varieties are-

| **Crop** | **Variety** | **Insect pest** |
|---|---|---|
| *Brassica* | Pusa Gaurav | Aphids |
| Flat bean | Pusa sem 2<br>Pusa sem 3 | Jassids, aphids and fruit borer |
| Okra | Pusa Sawani,<br>Pusa A-4 | Shoot and fruit borer |

# Tissue culture :

- ✓ It is actually a collection of different techniques.
- ✓ It is infact, emerged as a technique of plant biotechnology.
- ✓ Here, isolated cells, tissues, organs are grown 'in vitro' on a solid/ liquid nutrient medium, under aseptic and controlled conditions of light, humidity and tempreature, for achieving different objectives.
- ✓ The part of plant used in tissue culture is called explant.

- ✓ The plant tissue culture medium contains all
  - essential minerals,
  - sources for carbohydrates,
  - proteins and fats, water,
  - growth hormones, vitamins and agar (for callus culture).
- ✓ The most commonly preferred medium for tissue culture is MS (Murashige and Skoog) medium.

**Based on the nature of explant :** There are three types viz, cell culture, organ culture and embryo culture.

**Based on the type of *in vitro* growth :** There are two tyes viz. Callus culture (solid medium) and Suspension culture (liquid medium).

**Maintenance of aseptic conditions :** Aseptic condition is essential so as to avoid contamination by other harmful micro-organisms.

It is accomplished by **sterilization** of : **glass ware** (use of detergents, hot air oven), **nutrient medium** (by autoclave under constant pressure of 15 lb/sq inch for continous 20 minutes), **Explant** (by treatment of 20% ethyl alcohol and 0.1% $HgCl_2$), **Inoculation chamber** (Laminar air flow) - by using UV ray tube for 1 hour before performing actual inoculation of explant on the sterilized nutrient medium.

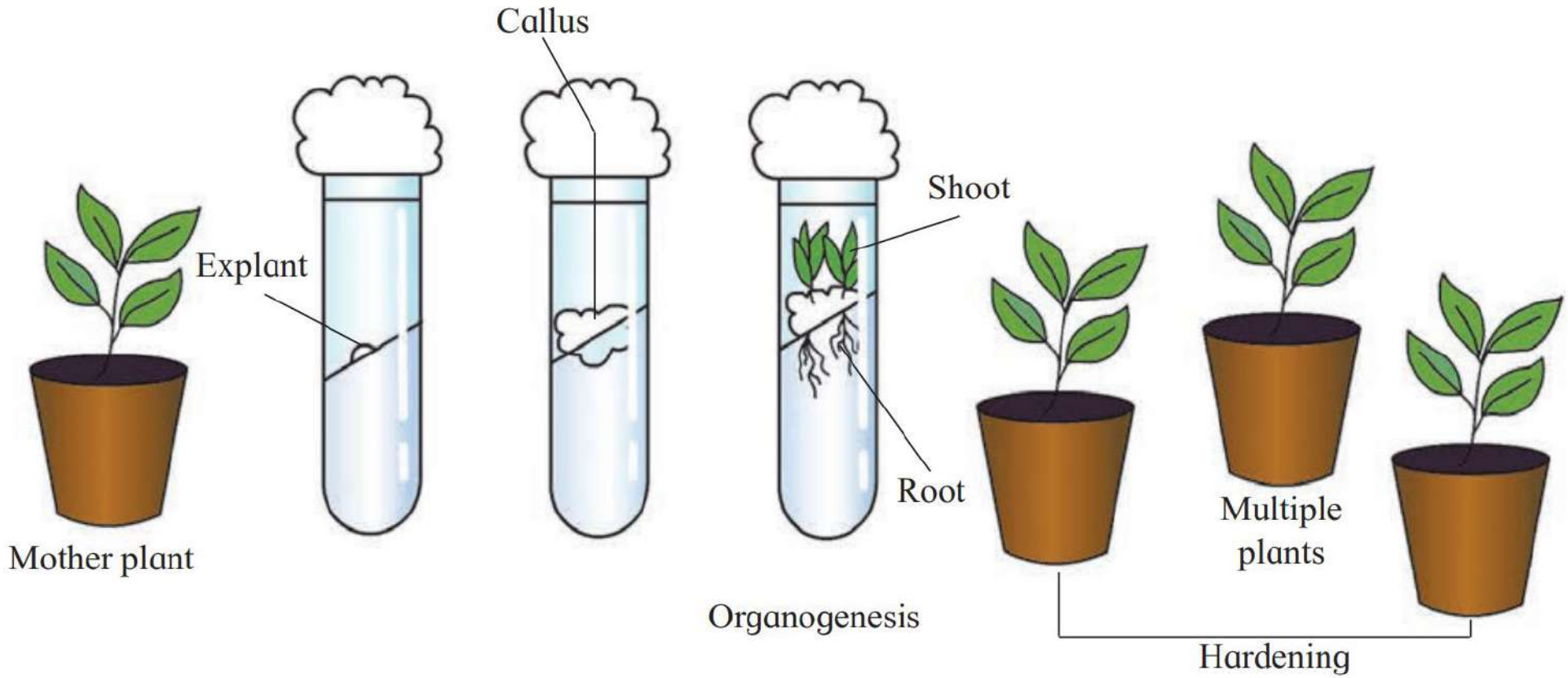



**Fig. 11.2 : Steps in plant tissue culture (callus culture)**

**Other conditions maintained are :** Temperature - 18$^0$C to 20$^0$C, pH of nutrient medium 5 to 5.8 and aeration particularly for suspension culture.

## Do you know ?

**Applications of tissue culture :**

There are various application of tissue culture in forestry, agriculture, horticulture, genetic enginearing, physiology, etc. The different applications of tissue culture include - Production of disease free plants and haploid plantlets, micropropagation, production of secondary metabolites, protoplast culture, culture of rare plants, somaclonal variations production of stress resistant plants, etc.

# Micropropagation (Clonal Propagation) :

- Organogenesis via shoots is considered as one of the most widely used commercial method of regeneration of plant.
- Micropropagation is also known as clonal propagation.
- It is the only process adopted by Indian plant biotechnologists in different
  - ✓ industries,
  - ✓ mainly for the commercial production of ornamental plants like orchids,
  - ✓ Chrysanthemum,
  - ✓ Eucalyptus, etc.
  - ✓ and fruit plants like banana, grapes, Citrus, etc.

## Advantages of microporpagation:

1. It helps in rapid multiplication of plants.
2. A large number of plantlets are obtained within a short period and from a small space.
3. Plants are obtained throughout the year under controlled conditions, independent of seasons.
4. Genetically similar plants (clones) are produced (formed) by this method. Therefore desirable characters (genotype) and desired sex of superior variety are kept constant for many generations.
5. The rare plant and endangered species are multiplied by this method and such plants are saved.

**Chart 11.3 : Flow chart for tissue culture technique.**

Cleaning of glass ware, sterilization of glass ware and instruments in an oven/ autoclave

↓

Selection and preparation of nutrient medium- MS medium with known concentrations and proportions of different components.

Sterilization of medium in an autoclave for continuous 20 minutes under constant pressure of 15/ lb/ inch$^2$.

↓

Preparation of plant material (explant) includes isolation of explant followed by surface sterilization and rinsing with water. Explant is obtained from the growing stock plant.

↓

Inoculation of the explant in the culture flask containing sterilized nutrient medium. Inoculation is done in the laminar air flow cabinet unit.

↓

Incubation of the inoculated explant. Here cells of explant grow, proliferate to form callus, within 2-3 weeks.

↓

Sub culturing of the callus (if callus is to be maintained for longer period, callus is divided into 3-4 segments and then transferred to fresh culture medium).

↓

Organogenesis - Initiation of rooting and shooting, that eventually leads to plantlet formation.

↓

Hardening - Plantlets are transferred to polythene bags containing sterilized soil and kept at low light and high humid conditions for suitable period of time.

↓

Transferred to field

## 11.4 Single cell protein (SCP) :

By 2050, the world would need to produce 1,250 million tonnes of meat and dairy products per year, to meet global demand for animal-derived protein at current consumption levels. However, growing demand for protein will not be met sustainably by increasing meat and dairy production because of the low efficiency of converting feed to meat and dairy products.

- More over, human population in underdeveloped and even in the developing countries is suffering from protein malnutrition, resulting into variety of nutritional diseases.
- To fight with this, efforts are undertaken by conventional methods to increase the food yield by different methods of
  - ✓ crop improvement,
  - ✓ use of biofertilizers,
  - ✓ biopesticides,
  - ✓ chemical fertilizers
  - ✓ and high yielding varieties (green revolution).

- The efforts in other direction are also undertaken in nonconventional way.
- One such way is production of SCP- single cell proteins.
- Improtance of SCP was realised during World War I.

## What SCP :-

- Single-cell protein refers to the crude, or a refined edible protein, extracted from pure microbial cultures or from dead or dried cell biomass.

The microorganisms used for the production of SCP are as follows :

**Fungi** : *Aspergillus niger*, *Trichoderma viride*

**Yeast** : *Saccharomyces cerevisiae*, *Candida utilis*

**Algae** : *Spirulina spp*, *Chlorella pyrenoidosa*

**Bacteria** : *Methylophilus methylotrophus*, *Bacillus megasterium*.

## Advantages of Single-Cell Protein :

- Microorganisms have a high rate of multiplication that means a large quantity of biomass can be produced in a comparatively short duration.
- The microbes can be easily genetically modified to vary the amino acid composition. They have high protein contents- 43% to 85% (W/W basis).
- A broad variety of raw materials, including waste materials, can be used as a substrate for SCP. This also helps in decreasing the number of pollutants.
- SCP serves as a good source of vitamins, amino acids, minerals, crude fibres, etc.

## 11.5 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

**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.
- Vegetable crops like carrot and spinach have more vitamin A and minerals.
- Vitamin C enriched bitter gourd, tomato have been developed by IARI.

# Animal husbandry :

- Animal husbandry is an agricultural practice of breeding and raising livestock.
- It is not only a skill of farmers but also is as much a science, as it is an art.
- Animal husbandry deals with care and breeding of livestock like
  - ✓ buffaloes,
  - ✓ cows, pigs, horses, cattles, sheeps, camels, goats, etc. which are useful to humans.

## Management of farms and farm animals :

Farm management starts from selection of high yielding breeds, their food requirements, supply of adequate nutritional sources, cleanliness of the environment and maintenance of health. Management of farm animals includes veterinary supervision, vaccination, high yielding cross breed development, production and preservation of products, distribution and marketing.

## A. Animal breeding :

Breeding of animals is an important aspect of animal husbandry. Animal breeding aims at increasing the yield of animals and improving the desirable qualities of the products.

**Breed:**

A group of animals related by descent and similar in most characters like general appearance, features, size, configuration, etc., are said to belong to a breed.

Breeding can be of two main types - inbreeding and outbreeding :

**a. Inbreeding :** It involves breeding of closely related individuals for 4 to 6 generations. Inbreeding increases homozygosity. By inbreeding, pure lines of animals can be obtained. Inbreeding is helpful in the elimination of harmful recessive genes and for the accumulation of superior genes. Inbreeding has the demerit that it usually reduces the fertility and productivity.

**b. Outbreeding:** It involves breeding of unrelated animals. The animals may be of the same breed but having no common ancestors for 4 to 6 generations.

**Outcrossing** involves breeding between the animals of different species. It is also known as interspecific hybridization. Outcrossing helps to remove the inbreeding depression.

**Crossbreeding** involves the breeding of superior male of one breed with superior female of another breed. By cross-breeding, new animal breeds of desirable characters are developed. e.g. Hisardale is a new breed of sheep developed from crossing of Bikaneri ewe and Marino rams in Punjab.

**Interspecific hybridization** involves breeding of animals of two different but related species. It result in the formation (production) of animals with desirable characters from both the parents. But such breeding is not always successful e.g. Mule is a breed obtained from horse and donkey.

**Artificial insemination technique** involves controlled breeding experiments. Semen from selected superior males is collected and preserved in frozen state or injected into the genital tract immediately. It is useful to overcome problem of normal mating and convenience of transportation.

# Multiple Ovulation Embryo Transfer (MOET)

- involves the technology which provides the chances of successful production of hybrids.
- In this method, cow is administered with FSH like hormone, to induce follicular maturation and then the super ovulation is brought about.
- In each cycle, 6 to 8 eggs mature simultaneously.
- The cow is either mated with an elite bull or artificially inseminated.

- The blastocysts at 8 to 32 cell stage are recovered non-surgically and transferred to surrogate mothers.
- This technology is successfully used in cattles, sheeps, rabbits, buffaloes, etc.
- High milk yielding breeds of female and high quality meat yielding bulls have been found to be successful, to increase herd size in a short period.

# Dairy farm management :

- Dairy industry involves production, processing and distribution of milk and milk products.
- Milk is a valuable food stuff universally consumed by human beings.
- Milk yield mainly depends on the quality of breeds in the farm.
- Selection of good breeds having high yielding potential under the climatic conditions of inhabiting area, and disease resistance is the basic requirement.

- In India, cows and buffaloes are mainly used for dairy farms.
- Sahiwal, Sindhi, Gir are Indian breeds and Jersy, Brown Swiss, Holstein are exotic breeds, which are used in dairy farming.
- Buffaloes are restricted to some part of Asia only.
- In India, six breeds occur viz,
  - ✓ Jaffarabadi,
  - ✓ Mehsana,
  - ✓ Murrah, Nagpuri, Nili, Surati, which are all good milk producers.

- Cattles have to be well looked after.
- Quality and quantity of fodder in proper ratio, should be given.
- Silage made from legumes and grasses, maize and jowar, makes good feed.

# Poultry farm management :

- Poultry includes number of bird species such as chicken, ducks, turkey, and fowls which are domesticated for their eggs and meat.
- Selection of proper and disease free breed, suitable and safe farm condition, proper feed and water, hygiene and health care, are important requirements for poultry farm Management.

- On the basis of their origin, different types of poultry breeds are :
  - ✓ American breeds Plymouth Rock,
  - ✓ New Hampshire, Rhode Island Red;
  - ✓ Asiatic breeds are Brahma,
  - ✓ Cochin and Langshan;
  - ✓ Mediterranean breeds are Leg horn,
  - ✓ Minorca; English breedsinclude Australorp;
  - ✓ Indian breeds are Chittagong, Aseel, Brahma, and Kadaknath.

i. **Viral diseases** like Ranikhet, Bronchitis, Avian influenza (bird flu), etc. Few years back, bird flu have seriously influenced poultry farming and human infection too.

ii. **Bacterial diseases** mainly includes Pullorum, Cholera, Typhoid, TB, CRD (chronic respiratory disease), Enteritis, etc.

iii. **Fungal diseases** are Aspergillosis, Favus and Thrush.

iv. **Parasitic diseases** include lice infection, round worm, caecal worm infections, etc.

v. **Protozoan diseases** e.g. Coccidiosis is a protozoan disease.

# Apiculture or bee keeping :

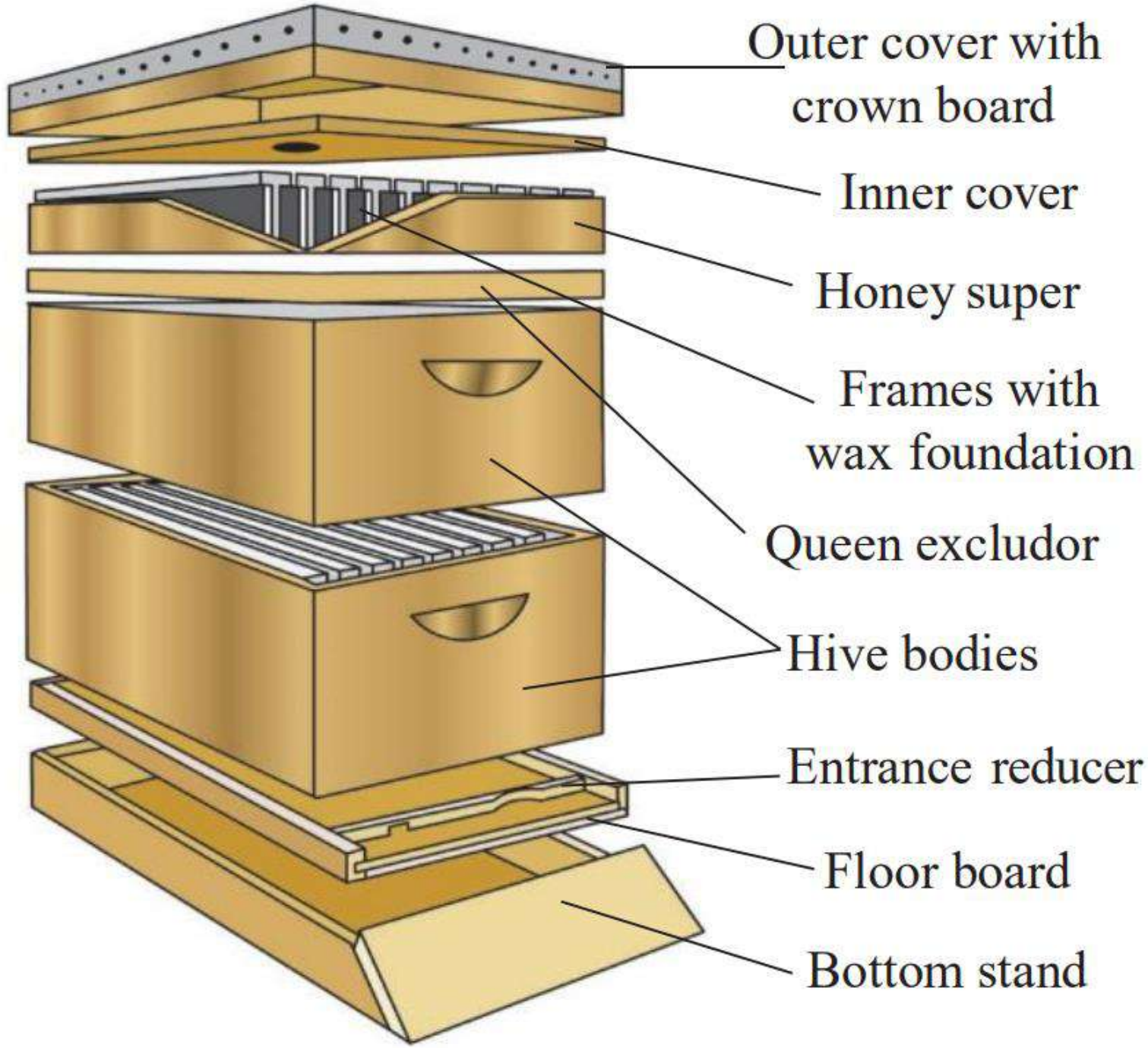
- Apiculture or bee keeping deals with an artificial rearing of honey bees to obtain bee products like
  - ✓ honey, wax, pollens, bee venom,
  - ✓ propolis (bee glue) and
  - ✓ royal jelly as well as pollinating agents for crop plants.
- Bee keeping is an ancient cottage industry.

- Honey is a food of high nutritive value and also finds uses in the indigenous system of medicines.
- The four species of honey bees commonly found in India are
  - ✓ Apis dorsata (rock bee or wild bee),
  - ✓ Apis florea (little bee),
  - ✓ Apis mellifera (European bee)
  - ✓ and Apis indica (Indian bee)

Worker Queen Drone

## Polymorphism in honey bee :

- Bee keeping is practiced in the areas where sufficient wild shrubs, fruit orchards and cultivated crops are present.
- Bee keeping requires the equipments like bee hive boxes, with comb foundation sheets, bee veil, smoker, bee brush, gloves, gumshoes, uncapping knife, swarm net, queen excluder, overall hive tool, etc.


Outer cover with
crown board
Inner cover
Honey super
Frames with
wax foundation
Queen excludor
Hive bodies
Entrance reducer
Floor board
Bottom stand

## Artificial bee hive :

- For successful bee keeping one must be familiar with the habits of
  - ✓ bees, selection of suitable location,
  - ✓ catching and hiving of swarms,
  - ✓ management of hives during different seasons,
  - ✓ handling and collection of honey,
  - ✓ bee wax and other products.
- Periodic inspection for cleanliness of hive boxes, activity of bees and queen, condition of brood, provision of water, is very much necessary.

# Fishery :

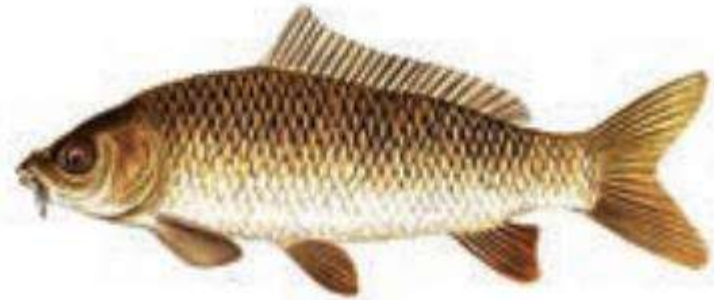
- Fishery is a branch of applied biology which deals with the catching, processing, fish farming and marketing of fish, and other useful aquatic animals such as, prawns, lobsters, oysters, mussels and crabs.
- Three division of fishery are- inland fishery, marine fishery and estuarine fishery.

- Inland fishery includes culturing and capturing of fish from fresh water bodies like ponds, lakes, dams and river.
- Inland aquatic area of our country covers about 40 to 50 lakh acres.
- The common fresh water fish are Labeo rohita (rohu), Catla (catla), Cirrhina mrigala (mrigala) and other carps.

Rohu fish

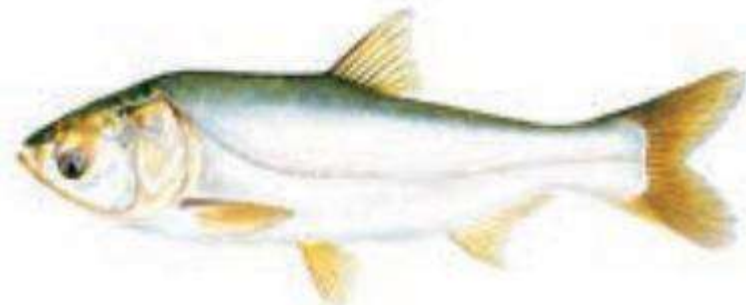
Catla fish

Mrigal fish



Common carp

Grass carp

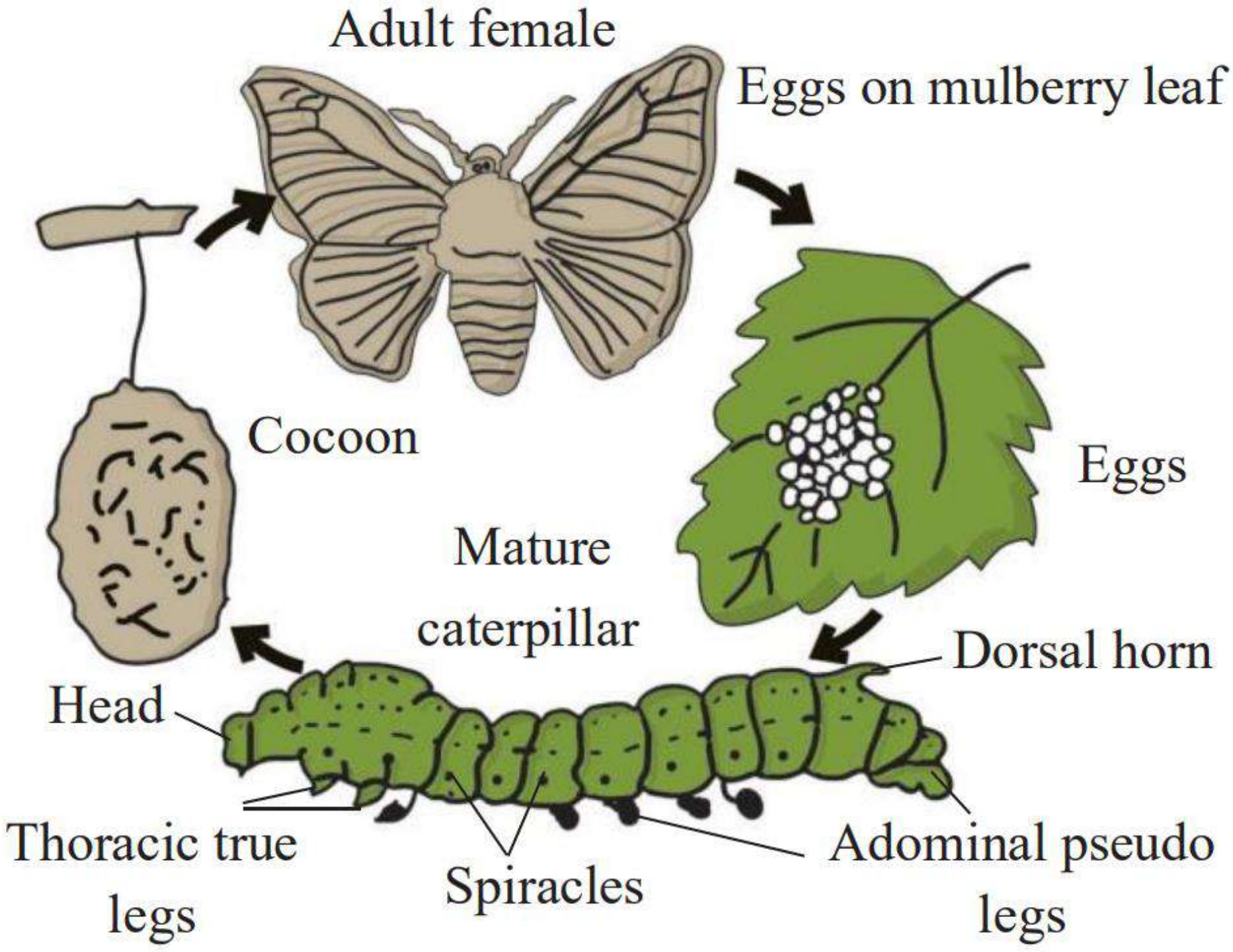


Silver carp

## Sericulture :

- Sericulture is the branch of applied zoology which deals with rearing of silkworm and production of silk.
- Like other farming, sericulture also involves skill and scientific knowledge for rearing and development.

- It require less investment and can be started in small space.
- It is the oldest business and large number of families are associated with the production of silk in India.
- Disabled, older persons, handicapped people can successfully do this job.


Adult female
Eggs on mulberry leaf
Cocoon
Eggs
Mature
caterpillar
Dorsal horn
Head
Thoracic true
legs
Spiracles
Adominal pseudo
legs

# Lac culture :

- Lac is produced by an insect Trachardia lacca, which is quite small in size and colonial in habit.
- Resin like substance is produced by Dermal glands of female lac insect.
- Insect feeds on succulent twigs of certain plants like ber, peeple, palas, kusum, babool, etc and secretes pink coloured resin, that hardens on coming in contact with air forming lac.

- It is produced on a large scale all over India.
- Lac is a complex substance having large amount of resin together with sugar, water, minerals and alkaline substances.
- Natural lac is always contaminated.
- Shellac is pure form of lac obtained by washing and filtering.
- Lac insect is a native of India and our share is 85 % of total lac produced in the world.
- Products of lac play a vital role in the economy of the farmers. Lac is used in bangles, toys, woodwork, inks, mirrors, etc.

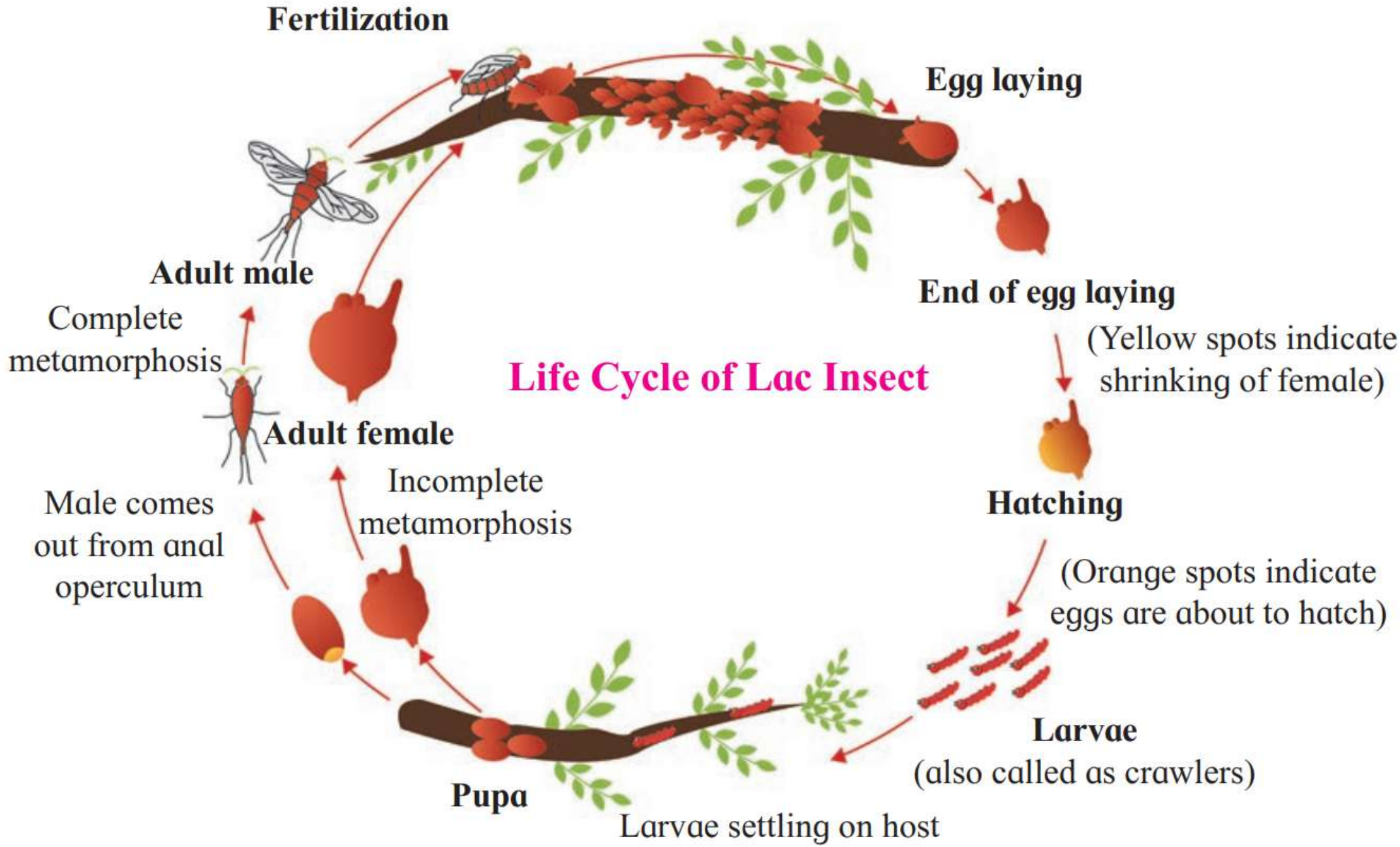



**Fig. 11.9 : Life Cycle of Lac Insect**

# 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 microorganisms like
  - ✓ algae, fungi, bacteria, viruses,
  - ✓ protozoans, nematodes, etc.
- and their products that exhibit benificial 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 source of 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 fruting bodies which are edible. Fruting bodies are sugar free, fat free but rich in proteins, vitamins, minerals and amino acids. The food in the fruting 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 of *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, flavor and taste which are developed by different specific microbes. The 'Roquefort and Camembert cheese' are ripened by blue-green molds *Penicillium roquefortii* and *P. camembertii* respectively.

# Role of Microbes in Industrial Production:

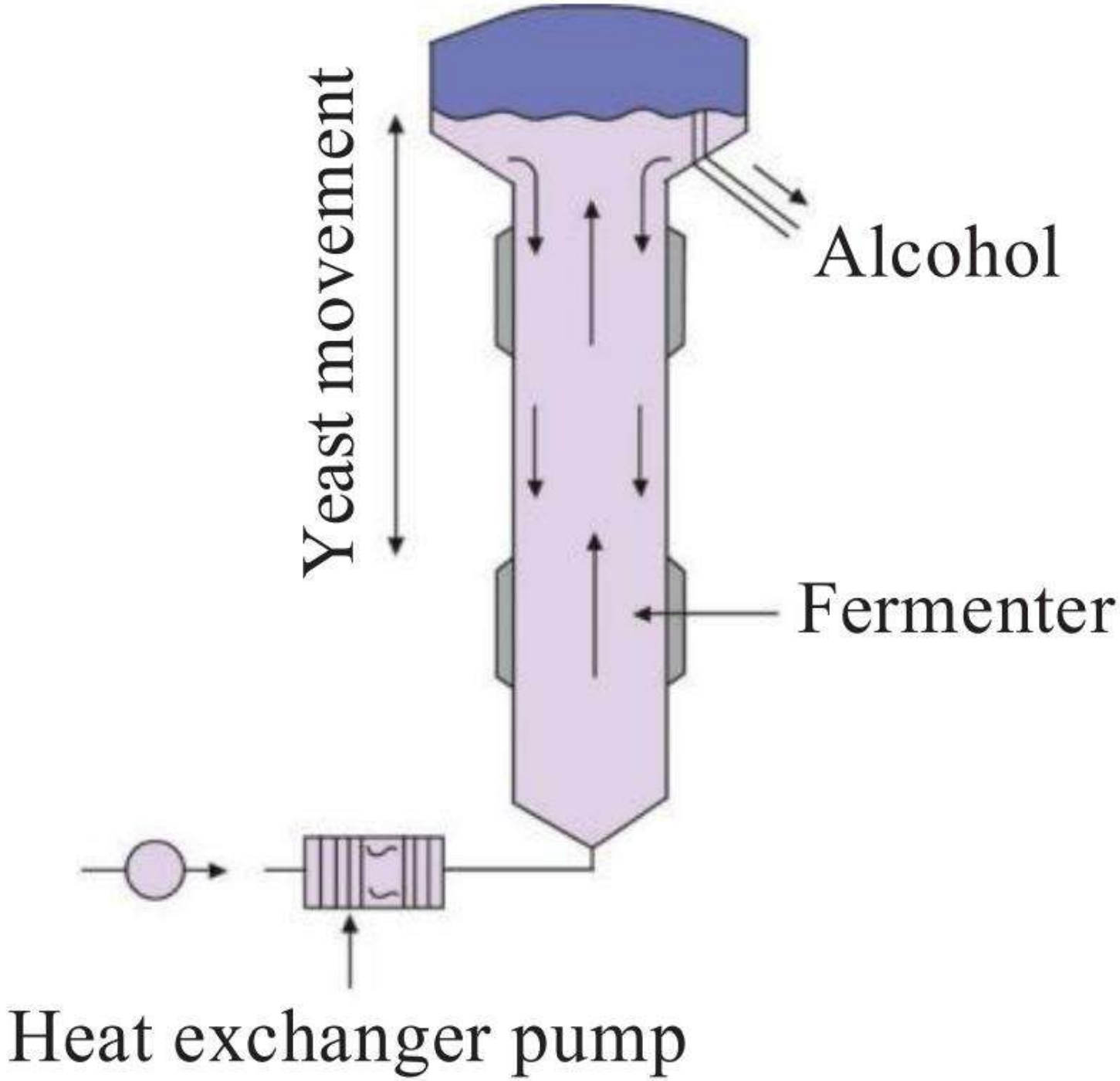
- During fermentation, variety of products like alcoholic beverages, organic acids, vitamins, growth hormones, enzymes, antibiotics, etc.are produced.
- Production on an industrial scale requires growing microbes in very large vessels, called fermenters.
- The main function of a fermenter is to provide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

## a. Production of Alcoholic Beverages :

Beverage is a liquid used or prepared for drinking e.g. tea, coffee, beer, wine, which acts as stimulant. Alcoholic beverages are the products of alcoholic fermentation of specific substrates. Use of microbes in malking alcoholic beverages, is known since vedic period- 5000 to 7000Bc.

- Microbes especially yeast have been used from time immemorial for the production of beverages like wine, beer, whiskey, brandy or rum.
- For this purpose, the yeast Saccharomyces cerevisiae var.
- ellipsoidis (commonly called Brewer's Yeast) is used for fermenting malted cereals and fruit juices to produce ethanol.

- Among the beverages, Wine and Beer are produced without distillation whereas whiskey, brandy and rum are distilled beverages.
- Tubular tower fermenter is used for large scale production of alcohols


Yeast movement
Alcohol
Fermenter
Heat exchanger pump

## b. Production of organic acids:

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

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:

- Vitamins are some organic nitrogenous compounds which are capable of performing many life-sustaining functions inside our body.
- These compounds cannot be synthesized by humans (except vitamin D), and therefore they have to be supplied in small amounts in the diet.

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).

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:

- Antibiotics are probably the most important group of compounds synthesized by industrial microorganisms.
- Most antibiotics are secondary metabolites.
- They have therapeutic importance and are used in medical treatment.

- 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.
- The antibiotics are antibacterial, antifungal, etc.
- Antibiotics have greatly improved our capacity to treat deadly diseases such as plague, whooping cough, diphtheria, leprosy, etc.

## 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:

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

Enzymes are proteins known as bio-catalysts. Due to their ability to promote reactions more quickly at body temperature and more efficiently. Many microbes **synthesize and excrete large quantities of enzymes** into the **surrounding medium**. Using this feature of these tiny organisms, many enzymes are produced commercially. These enzymes are **Amylase, Cellulase, Protease, Lipase, Pectinase, Streptokinase** and many others.

| **Name of the enzyme** | **Microbial source** |
| --- | --- |
| Invertase | *Saccharomyces cerevisiae* |
| Pectinase | *Sclerotinia libertine, Aspergillus niger* |
| Lipase | *Candida lipolytica* |
| Cellulase | *Trichoderma konigii* |

## f. Gibberellin production:

Gibberellin is a group of growth hormones mainly produced by higher plants and fungi to promote growth by stem elongation. The first gibberellin was isolated by two Japanese scientists -Yabuta and Sumiki (1938) from rice seedlings infected with the fungus *Gibberella fujikouri*.

- 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 microfungi).

- 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 micro-organisms 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, fecal *Streptococci*, anaerobic spore forming *bacilli* and other types originating in the intestinal tract of 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

ii. **Grit Chamber :** After screening, the filtered sewage is then 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):

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

The primary effluent is passed into large aeration tanks. Here it is constantly agitated mechanically and air is pumped into it. Aerobic bacteria grow vigourously and form **flocs.** Flocs are the masses of bacteria held together by slime and fungal hyphae to form mesh like masses. These aerobic microbes consume the major part of the organic matter present in the effluent, as they grow. Due to this BOD (Biochemical Oxygen Demand) of the effluent is significantly reduced.

## 4. Tertiary treatment:

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**. 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. During this anaerobic digestion, gases such as methane, hydrogen sulphide, $CO_2$, etc. are produced. Effluents from these plants (digester) after chlorination, are released in natural water bodies like rivers and streams. Chlorination kills pathogenic bacteria. Digested Sludge is then disposed.

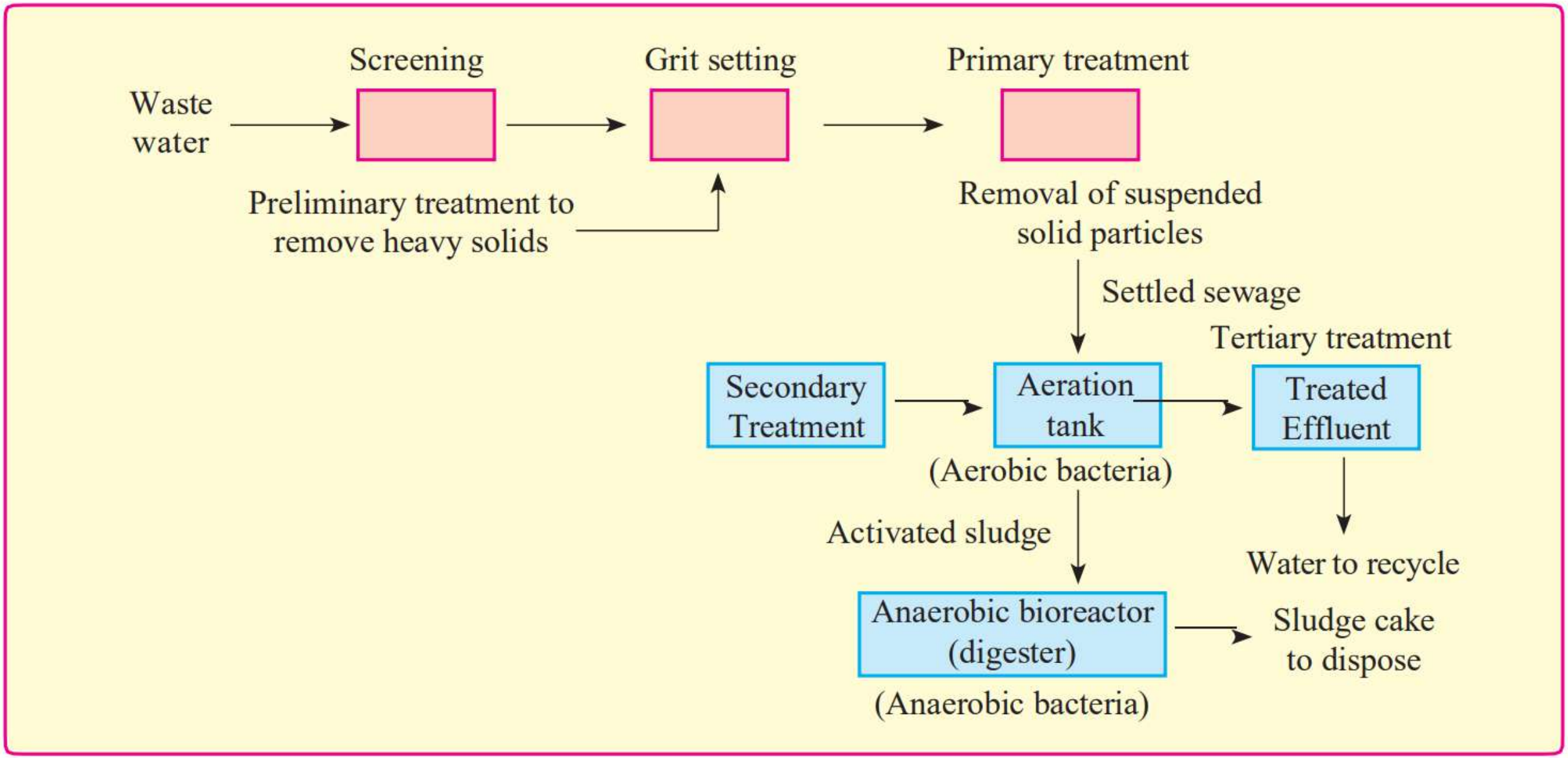



**Fig. 11.12 : Diagrammatic representation of various stages in wastewater treatment**

## 11.10 Microbes in Energy Genration :

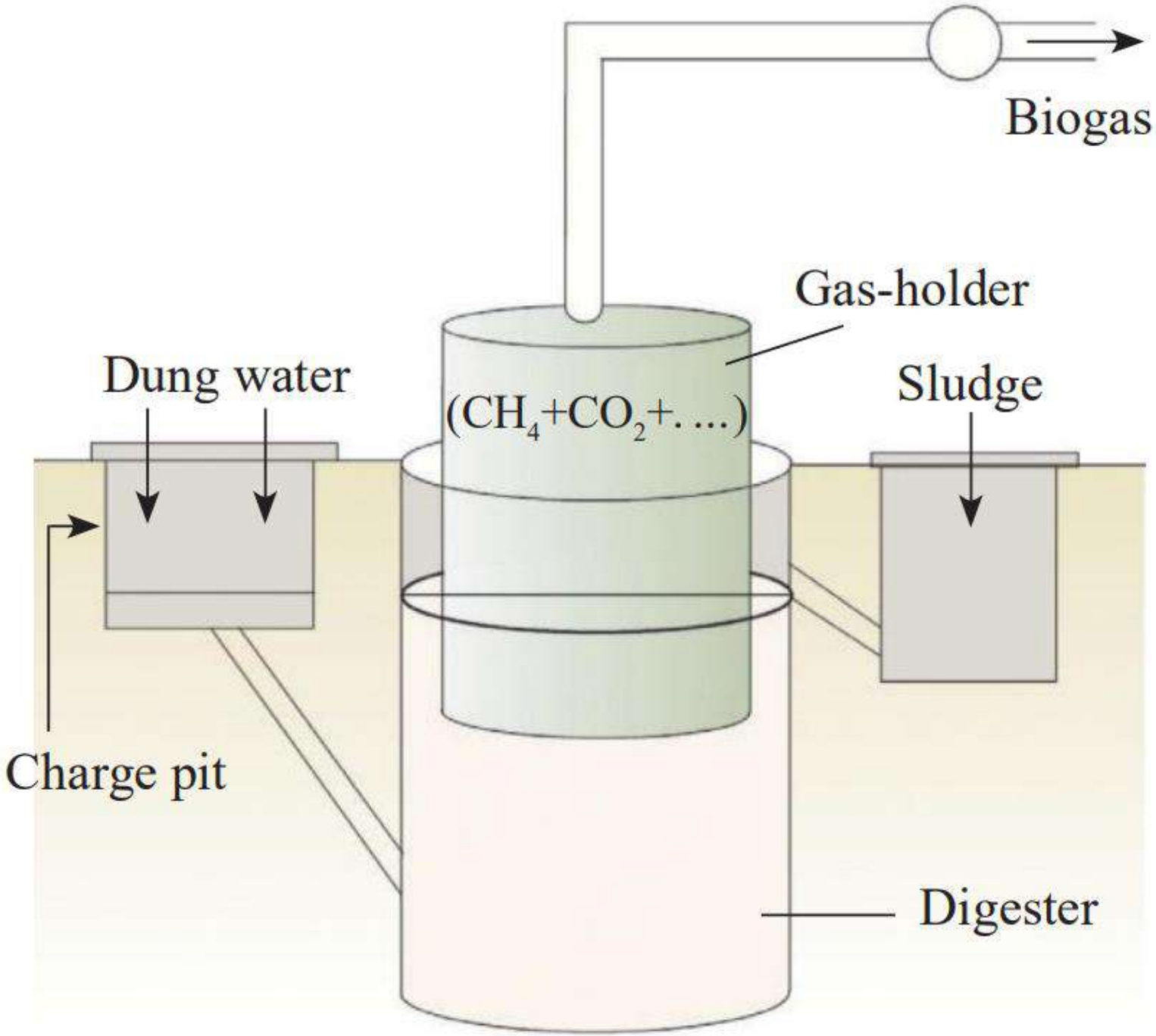
Many developing countries are encouraging for installation of biogas plants to meet out the requirement of energy. Biogas is used as a domestic as well as industrial fuel. It is a non-conventional and renewable source of energy and is obtained by microbial fermentation. Biogas is a mixture of methane $CH_4$ (50-60%), $CO_2$ (30-40%), $H_2S$ (0-3%) and other gases (CO, $N_2$, $H_2$) in traces. Biogas is highly inflamable and is used as a source of energy.

## Biogas Production:

Most commonly used models of biogas plants are KVIC and IARI. The digester used for biogas production is called **Biogas Plant**. A typical biogas plant using cattle dung as a raw material, consists of digester and gas holder.

Anaerobic digestion involves in three processes :

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


Biogas
Gas-holder
Dung water
$(CH_4+CO_2+....)$
Sludge
Charge pit
Digester

ii. **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 $CO_2$.

iii. **Methanogenesis :**

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.

1. $12mol\ CH_3COOH \longrightarrow 12CH_4 + 12CO_2$
   (acetic acid) methane

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

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

**Benefits:**

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 iseco-friendly and does not cause pollution and imbalance of the environment. Sludge which is left over is used as a fertilizer.

## 11.11 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 their natural, biological enemies. This is called **biocontrol** or **biological control**.

**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, rhizomes, etc. causing rot disease.

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

## I. Microbial Pesticides and their host :

The corelation 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:

iii. *Phytophthora palmivora* - controls milk weed in orchards.

iv. *Alternaria crassa* - controls water hyacinth.

v. *Fusarium spp.*- control most of theweeds.

2. Bacterial pathogen as herbicides:

i. *Pseudomonas spp.*- attacks several weeds

ii. *Xanthomonas spp.*- attacks several weeds

iii. *Agrobacterium spp.*- attacks scvcral weeds

## 11.12 Role of Microbes as Biofertilizers:

Fertilizers are nutrients which are necessary for the growth of plants and thus for the productivity of cultivated plants. Use of fertilizers for increasing productivity is one of the aspects of green revolution. Fertilizers are classified as **inorganic** (chemical) and **organic** (biological). 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.

Now a days for better and sustainable agricultural production farmers use **biofertilizers** and practise organic farming. Biofertilizers are mostly $N_2$ fixing, living microorganisms which enrich the nutrient quality of soil. They include bacteria, cyanobacteria and fungi.

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.

## Types of Biofertilizers:

On the basis of nature and function biofertilizers are divided into following groups-

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:

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

*iv.* 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 eg. *Pseudomonas striata, Bacillus polymyxa, Agrobacterium, Microccocus, Aspergillus spp., etc.*

**3. Compost making biofertilizers:**

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 terestrial, free-living or symbiotic, 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 fugus. 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). Their are two types viz, Ectomycorrhizae and Endomycorrhizae.

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 and K). Due to this the plant vigour, growth and yield increase. Some hyphae of mycorrhizal fungus, penetrate into the root and forms **hartig-net** in the intercellular spaces of root cortex.

II. **Endomycorrhizae:** 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 speces of cortical cells. Hence they are called Vesiculo Arbuscular Mycorrhizae or VAM.

**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 secreating antibiotics.

## Biofertilizer microorganisms:

1. ***Rhizobium:*** Rhizobia are rod shaped, motile, aerobic, gram negative, non spore forming, nitrogen-fixing bacteria containing *Nod* genes and *Nif* genes. They form symbiotic association with roots of leguminous plants. They bring about nodule formation on the roots and multiply inside the nodule. They fix atmospheric nitrogen into organic forms, which can be used by plants as nutrients. For eg. *R. leguminosarum* is specific to pea. and *R. phaseoli* to beans.

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

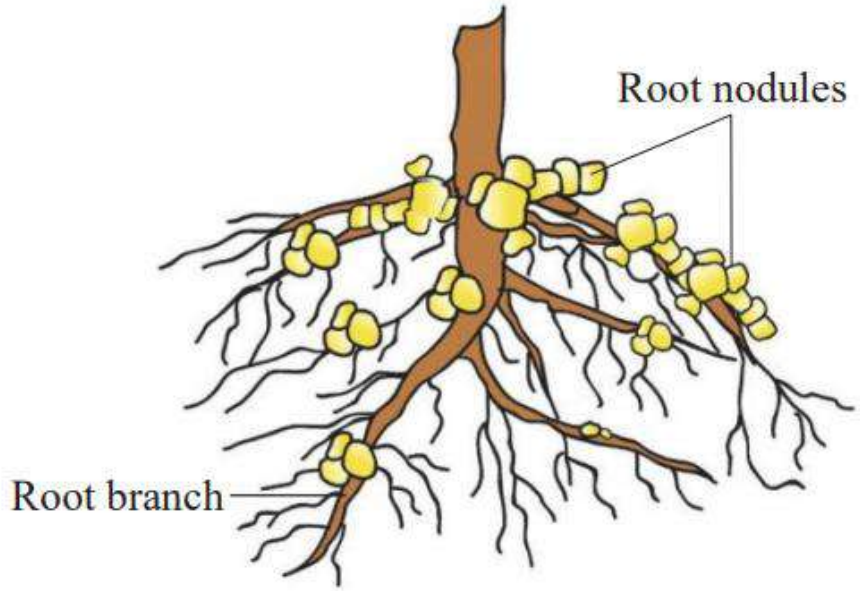



**Fig. 11.15 : Root system of Leguminous plant**

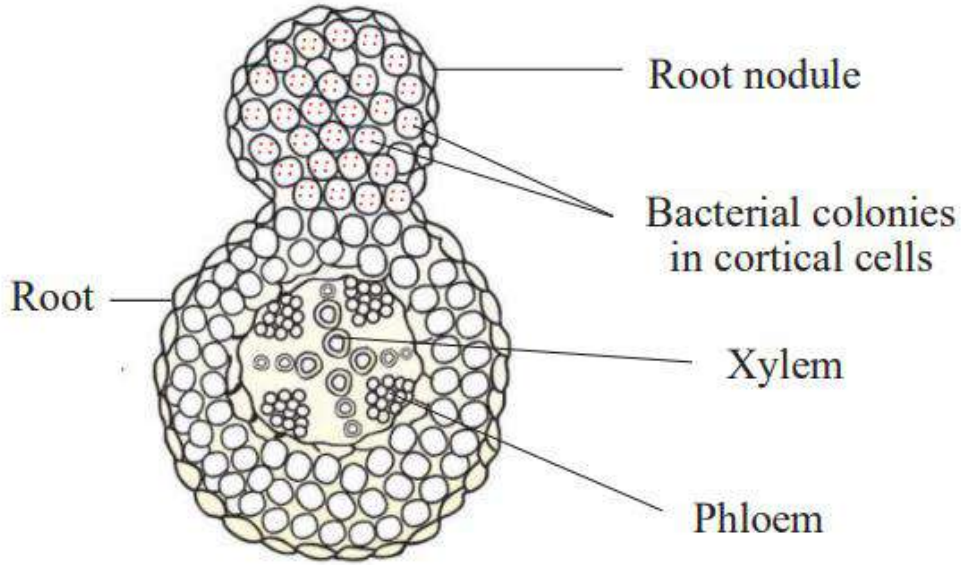



**Fig. 11.16 : T. S. of root nodule**

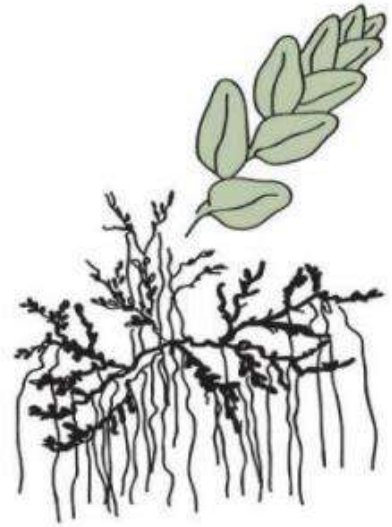


**Fig. 11.17 : *Azolla***

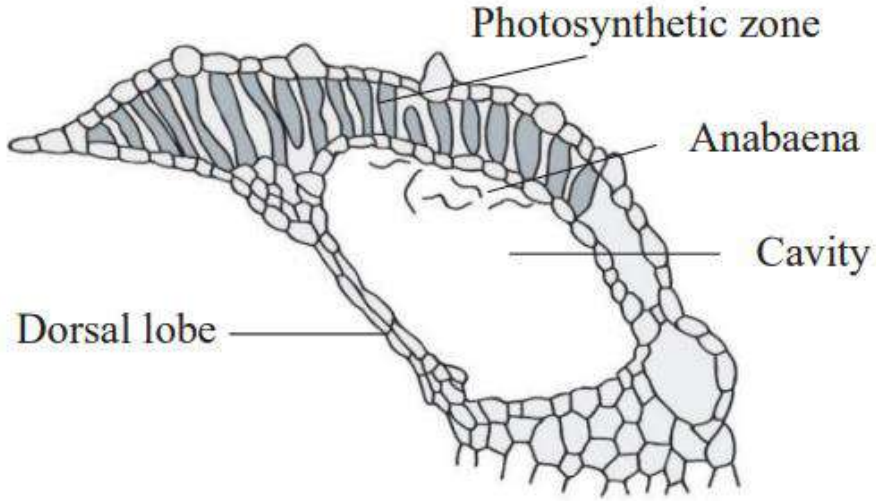



**Fig. 11.18 : L. S. of *Azolla* leaf showing filamentous *Anabaena***

3. ***Azospirillum:*** It is free living, aerobic nitrogen fixing bacterium associated with roots of corn, wheat and jowar. It fixes the considerable quantity of nitrogen (20-40kg N/ha) in non – leguminous plants such as cereals, millets, cotton, oilseed, etc.

4. ***Anabaena :*** It is a genus of multicellular, filamentous cyanobacteria that exits as plankton. It has ability to fix nitrogen and also forms symbiotic relationships with certain plants, such as the coralloid roots of *Cycas* and *Anthoceros* thallus. It has some specialized and colourless cells, called **Heterocysts** which are the sites for nitrogen fixation.

5. ***Azolla*:** *Azolla* is a free-floating water fern. *Azolla* plant consist of a floating rhizome (stem) with small overlapping bi-lobed leaves and roots. The leaf shows dorsal and ventral lobe.

**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.