11 Enhancement of Food Production

Can you recall?

1. What are hybrid plants?
2. Different examples of microbes used in household production.
3. The types or groups of micro-organisms that produce antibiotics.
4. What are biofertilizers?
5. What is the source of silk thread?

11.1 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 can not 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** mainly help us to increase the food production.

11.2 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.

Do you know ?

Primary aim of plant breeding is to obtain a new crop veriety superior to the existing type, in all characters. This purposeful manipulation incorporates various objectives which differ form plant to plant depending upon its type and the use. Some objectives are common- like yield, quality, resistance, life cycle span, etc., while some objectives will differ on the basis of the type and use of plant.

Plant breeding is a method of altering the genetic pattern of plants to increase their value and utility for human welfare. The plant breeding is done to increase crop yield, improve quality, increase tolerance to environmental stresses, make the plants resistant to pathogens and increase tolerance to insect pest. Green Revolution was the result of a sequence of scientific breakthroughs and developmental activities that successfully fought hunger by increasing food production. Seeds with superior quality, use of chemicals - pesticides and fertilizers, and multiple cropping system supported by the use of modern farm machinery and proper irrigation system, helped for the development of high-yielding and disease resistant varieties in wheat, rice, maize, etc.

In fact, plant breeding dates back to about 10,000 years ago. The present day crops are the result of domestication and acclimatization.

Do you know ?

Different methods of plant breeding include Introduction, Selection, Hybridization, Mutation breeding, Polyploidy breeding, Molecular plant breeding, Tissue culture, rDNA technology, SCP, etc.

Know the Scientist :

Dr. Norman E. Borlaug:

An American biologist, who has been called "Father of the Green Revolution", "Agriculture's greatest spokesperson" and "The Man Who Saved a Billion Lives", Dr. Borlaug, a 1970 Nobel Laureate, was honoured for his work in the 'Green Revolution,' saving millions of lives from famine in India, Mexico, and the Middle East.

Dr. M. S. Swaminathan:

He has been called the "Father of Green Revolution in India" for his role in introducing and further developing high-yielding varieties of wheat in India. He advocated moving India to sustainable development, especially using environmentally sustainable agriculture, sustainable food security and the preservation of biodiversity. He is pioneer in mutation breeding in India. He developed new varieties of wheat like Sonora, NP 165 and Sharbati.

A. Hybridization and its technique :

It is the cheif 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. It also exploits and utilizes hybrid-vigour.

Internet my friend

Try to know more about the hybrid-vigour.

Hybridization can be **intravarietal**, **intervarietal** (between two varieties of the same species), **interspecific** (between two species of the same genus) and **intergeneric** (between two genera of the same family). As parental plants are distantly related, such crosses are also called **wide/ distant crosses**. Interspecific and intergeneric hybrids are seldom to occur in the nature.

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 two plants selected as 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.

3. Hybridization :

The variety showing maximum desirable features is selected as female (recurrent) parent and the other one as male parent (donor) which lacks good characters found in recurrent parent.

The pollen grains from anthers of male parent are collected and then artificially dusted over stigmas of emasculated flowers of female parent. Pollination is followed by seed and fruit formation in due course. The seed, thus obtained represents the hybrid generation.

The hybrid F_1 progeny is selected and evaluated for the desired combinations of characters.

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 F_1 hybrid plants showing superiority over both the parents and having high hybrid-vigour, 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 segeregate 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. and their performance is recorded. The selected lines are then grown for three generations at least in natural field, in different agroclimatic zones. Finally variety is released as new variety for use by the farmers.

The cultivation of many high yielding, hybrid varieties of rice, wheat, sugarcane, millets, developed through hybridization, fertilizers pesticides and proper irrigation have helped farmer community to attain record agricultural production in India since 1961. This is called **green revolution**.

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), *Jowar* (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 Red rot of sugarcane 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 chemicals.

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.
- Biochemical characters provide resistance to insects and pests. For example, the high aspartic acid, and low nitrogen and sugar content in maize, lead to resistance against stem borers.
- The nectar-less cotton having smooth leaves develop resistance against bollworms.

Some pest-resistant varieties are-

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

11.3 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**.

Plant tissue culture is based on principle of **Totipotency** which is an inherent ability of living plant cell to grow, divide, redivide and give rise to a whole plant. Haberlandt (1902) for the first time conceived this idea and developed the concept of ***in vitro* cell culture** (plant morphogenesis).

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 types 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.

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

In **callus culture**, the solid medium is used. The development and organisation of tissue is lost. Hence, the cells of explant, divide and redivide to form a mass of undifferentiated cells, called **callus**. It is maintained on solid medium. Callus can be induced to form organs like root (rhizogenesis) and shoot (caulogenesis) and thus the plantlet. No shaker (agitator) is needed.

In **suspension culture**, small groups of cells or a single cell are used as explant in the liquid medium. The liquid medium is constantly agitated by using shakers (agitators) so that there is constant mixing of medium and the explant.

Both the callus and suspension cultures die in due course of time. Therefore, subculturing is neccessary for continuation of the technique.

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

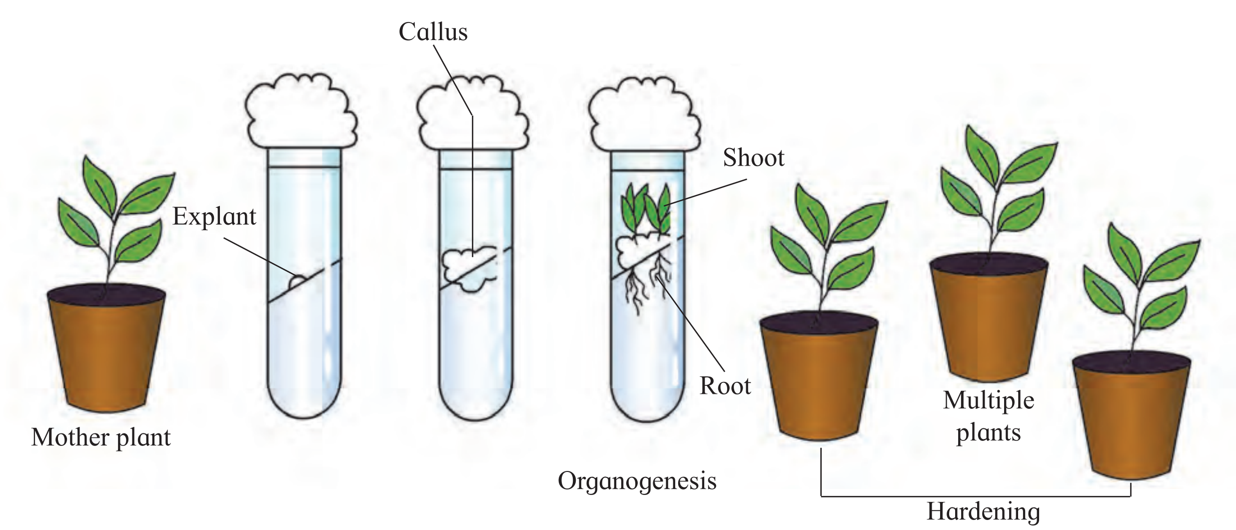


Fig. 11.2 : Steps in plant tissue culture (callus culture)

> **Do you know ?**
>
> **Applications of tissue culture :**
> There are various application of tissue culture in forestry, agriculture, horticulture, genetic engineering, 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.

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 micropropagation:

1. It helps in rapid multiplication of plants.
2. A large number of plantlets are obtained within a short period and in a small space.
3. Plants are obtained throughout the year under controlled conditions, independent of seasons.
4. Genetically identical 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 15lb/ square inch.

↓

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

6. With the help of somatic hybrids (cybrids), we are able to obtain new variety in short time span.

Do you know ?

High yielding varieties of Banana viz. 'Shrimati', 'Basarai' and G- 9 are mostly used in Maharashtra.

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 suffereing 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 non-conventional way. One such way is production of SCP- single cell proteins. Improtance of SCP was realised during World War I.

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

Microorganisms like algae, fungi, yeast, and bacteria have very high protein content in their biomass. These microbes can be grown using inexpensive substrates like agricultural waste viz. wood shavings, sawdust, corn cobs, paraffin, N-alkanes, sugarcane molasses, even human and animal wastes.

The microorganisms utilize the carbon and nitrogen present in these materials and convert them into high-quality proteins that can be used as a supplement, in both human and animal feed. Besides proteins, SCP is also rich in vitamins, vitamin B complex, minerals and fats. The single-cell proteins can be readily used as fodder for achieving fattening of calves, pigs, in breeding fish and even in poultry and cattle farmimg. 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). It can also be achived by supplemeneting nutrients from outside, besides breeding. 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 focusses 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 than normal.
- Vegetable crops like carrot and spinach have more vitamin A and minerals.
- Vitamin C enriched bitter gourd and tomato have been developed by IARI.

11.6 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. It also includes poultry farming, fish farming, bee keeping, sericulture, lac culture, etc. Animals like honey bees, silk worms, prawns, crabs, birds, fish, pigs, cattle, sheep and camels have been used by humans for the products like milk, eggs, meat, wool, honey, silk, etc.

During the conventional practices of animal breeding, just taking care is not enough to give maximum yield. Although India and China have 70% of the world's livestock population, surprisingly the productivity serves only 25% of the world farm-produce.

So professional approach is needed to boost the production. It requires management procedures, new technologies to be employed in various farm system to achieve improvement in quality and productivity. Industrial principles of production, processing and marketing are to be employed.

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.

Animal breeding is done for getting improved breeds with desirable qualities of product and also to increase yield of animals, Desirable characters such as increased production of milk, quality of product, quality of meat or maximum yield of eggs per year etc., are necessarily achieved through animal breeding.

Can you tell?

Find out the name of common breeds of cattle and poultry in the farms, found in your area.

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 the problem of normal mating and inconvenience 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.

B. 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. Silage is supplemented with oil cakes, minerals, vitamins and salts. Cleanliness and hygiene of the cattles and handlers is of more importance while milking, storage and transport of milk and milk products. In recent years, much of these processes are mechanised, which reduce the chance of direct contact with the product. The shed must be cleaned daily. It should be spacious with adequate facilities for feeding, watering and lighting.

Do you know ?

Regular visit of veterinary doctor to dairy farm is mandatory, why ?

Milk processing, marketing and distribution, play an important role in dairy industry. Variety of milk product like curd, cream, butter, ghee, condensed milk, khoa, cheese must be prepared from extra milk and on demand. An additional income can be obtained in the cattle farms from cow dung, manure, fuel cakes and gobar gas for cooking and lighting.

C. Poultry farm management :

Poultry includes number of bird species such as chicken, ducks, turkey, and fowls which are domesticated for their eggs and meat.

Can you tell?

1. What is a layer ?
2. What is a broiler ?

Allied professions to poultry include processing of eggs and meat, marketing of poultry products, compounding and sale of poultry feed, poultry equipment, pharmaceuticals, feed additives, etc.

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 breeds** include Australorp; **Indian breeds** are Chittagong, Aseel, Brahma, and Kadaknath.

Leghorn is best layer (for eggs) while Playmouth rock, Rhode Island Red, Aseel, Brahma and Kadaknath, are preferred as broilers (for meat).

Management of layers, requires purchase of high yielding chicken, well ventilated farms, proper feed, debeaking, lighting, waterer, sanitation, culling and vaccination. Management of broilers requires selection of breed, housing, temperature, ventilation, lighting, floor space and broiler feed. Different types of poultry diseases are:

i. **Viral diseases** include Ranikhet, Bronchitis, Avian influenza (bird flu), etc. Few years ago, bird flu had seriously influenced poultry farming and caused human infection too.

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

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

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

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

D. 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.

Fig. 11.4 : Bee hive

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.

Can you tell?

Why are honey bees called as best pollinators?

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).

> **Knowledge enhancer :**
> For bee keeping, *Apis mellifera* and *Apis indica* are the suitable species, hence they are known as domesticated species.

Fig. 11.5 : Honey bee (*Apis mellifera)*

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.

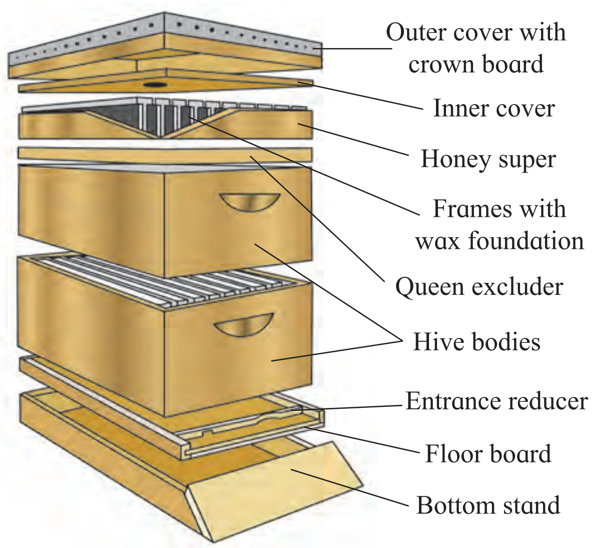


Fig. 11.6 : Artificial bee hive

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.

Many Indian crop fields need the services of honey bees as the pollinators. Bee keeping in the crop field of sunflower, mustard, safflower, chilly, cabbage, cucumber, legumes, fruits like apple, mango, citrus, etc. help in increasing the productivity of honey as well as crops tremendously.

E. 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.

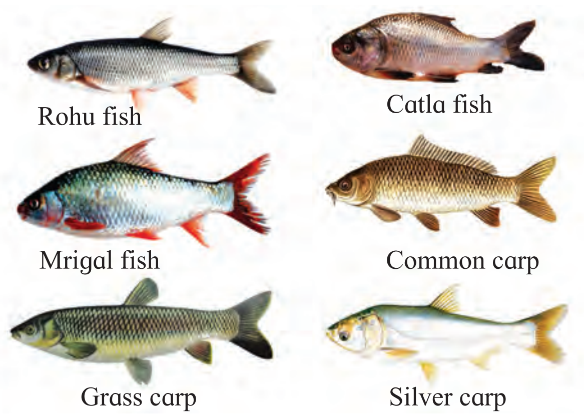


Fig. 11.7 : Fresh water fish forms

Knowledge enhancer :

Fish farming or culturing of edible and commercially important fish is only possible in fresh water bodies.

Marine fishery includes capture of fish from sea water. Indian coastal line is about 7500 km long. The common marine fish are *Harpadon* (Bombay duck), *Sardinella* (sardine), *Rastrelliger* (mackerel) and *Stromateus* (pomphret).

Can you tell?

1. Give the names of estuaries found in Maharashtra and mention their locations.
2. Enlist the names of different fish found at an estuary.

Estuarine fishery includes capture of fish from estuary. Estuary is a place where river meets the sea. e.g. Sunderban area in west bengal.

The common factors for the maintenance of fish farm, includes selection of suitable site, excavation of ponds, requirements of hatchery tank, nursery tank, rearing tank, stocking tank or ponds, water source, manures, supplementary feed, etc. The culture fishery may be monoculture (only one species) or polyculture (many species) type.

After catching of fish, the fish spoilage is prevented by different preservation methods like chilling, freezing, freeze drying, sun drying, smoke drying, salting and canning. In addition to the source as nutritious food, fish yield a number of by-products which are of commercial value. They are fish oil, fish meal, fertilizers, fish guano, fish glue and isinglass. These by-products are widely used in paints, soaps, oils, and medicine. Prawns and Lobsters have market value all over the world. Fishery provides good job opportunities and self employment to many people.

F. 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.

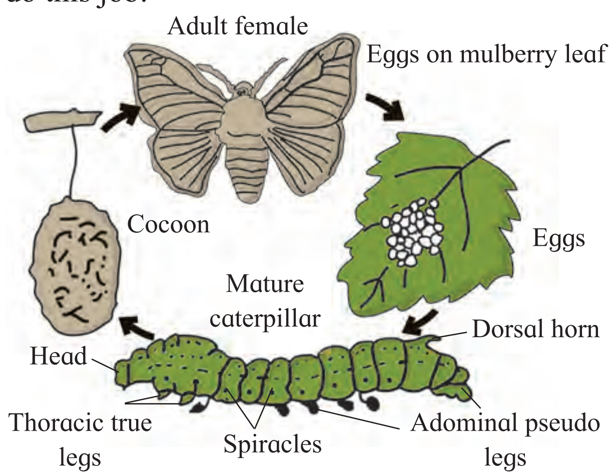


Fig. 11.8 : Life cycle of silk moth (Mulberry silk worm)

Internet my friend

Collect information about life cycle of silk moth.

The best quality silk called mulberry silk, is produced by silkworm *Bombyx mori*, while Tussar silk and Eri silk are of inferior quality. The quality and quantity of silk depends on the quality of mulberry leaves on which the larvae feed.

Rearing, development and looking after the silkworms, involve skill and labour for constant watch. A little negligence can spoil the complete industry. Silkworm larvae may be infected by protozoans, viruses and fungi. Besides these, ants, crows, birds, and other predators are ready to attack these insects, hence the cages of these larvae must be managed to prevent predators attack.

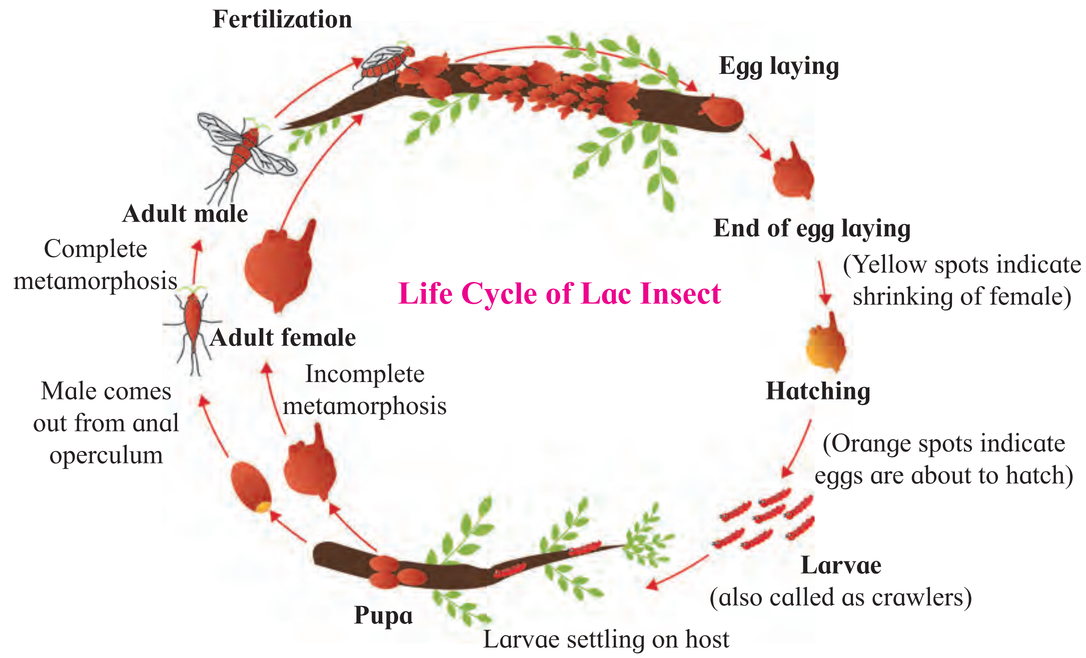


Fig. 11.9 : Life Cycle of Lac Insect

Can you tell?

1. What are the different stages found in life cycle of silkworm?
2. Process of cocoon formation.
3. Which process is involved in silk production from cocoon ?

G. 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. Production of lac requires an artificial inoculation of plants which give better and regular supply of good quality and quantity of lac.

11.7 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. Their products having beneficial activities 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** (upto1970) 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.

Can you tell?

Name the microbes used in fermentation of dhokla.

Find out

Names of some edible mushrooms and poisonous mushrooms.

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:

It is the partially degraded concentrate of milkfat and protein. 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. 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*.

11.8 Role of Microbes in Industrial Production:

During fermentation, variety of products like alcoholic beverages, organic acids, vitamins, growth hormones, enzymes, antibiotics, etc. are produced.

Do you know ?

These are actually the secondary metabolites produced during **idio phase** and are not required by micro-organisms for their growth. The type of substrate and the type of micro-organism result into the production of particular secondary metabolites.

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 alcoholic or non-alcoholic liquid produced or prepared and used 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.

Several traditional drinks and foods are also made through fermentation by yeast. 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. The famous wine of Goa, traditionally known as 'fenny' is made by fermenting fleshy pedicels of cashew fruits.

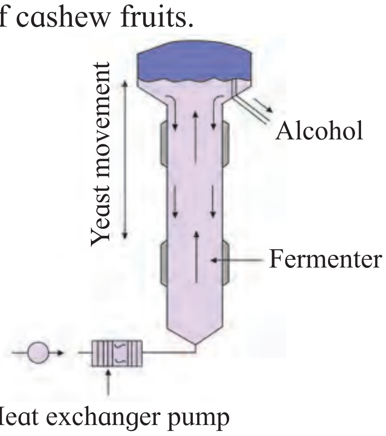


Fig. 11.10 : Tubular tower fermenter

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 complex organic nitrogenous compounds required in small amount and 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*

Can you recall?

1. What are antibiotics?
2. Who invented first antibiotic?

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.

Use your brain power

Can antibiotics kill viruses?

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*

Can you recall?

What are Enzymes? How are they classified?

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.

Several industrial sectors, use enzymes from microorganisms for specific applications. In the textile industry, enzymes are able to improve the quality of the fabrics. In the pulp and paper industry, they are involved in biomechanical pulping and bleaching, in the food industry, they are used in the fermentation processes for the production of bread and drinks such as wine and beer, also they 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
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*.

Extra information: *Streptokinase* enzyme (TPA) is produced by the bacterium *Streptococcus spp*. It has fibrinolytic effect. Hence, it is used as a 'clot buster' for clearing blood clots in the blood vessels of patients, which may cause heart attack.

Statins produced by the yeast *Monascus purpureus* have been produced on commercial scale. It is a blood-cholesterol lowering agent. This agent acts as competitive inhibitor of the enzyme responsible for synthesis of cholesterol.

About 15 different types of gibberellins have been isolated. 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.

11.9 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.

Extra Information : Sewage is also a potential source of pathogenic bacteria, viruses and protozoa. The causative agents of dysentery, cholera, typhoid, polio and infectious hepatitis may occur in sewage. The bacteria from the soil are also present in the sewage. During the course of sewage decomposition, initially aerobic and facultative anaerobic organisms predominate which are then followed by strict anaerobic especially methogenic bacteria that produce methane (CH_4) and CO_2.

Do you know ?

The oil eating bacteria can clean up crude spills. Collect more information about these bacteria.

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 chambers. These have to be removed before the biological treatment.

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.

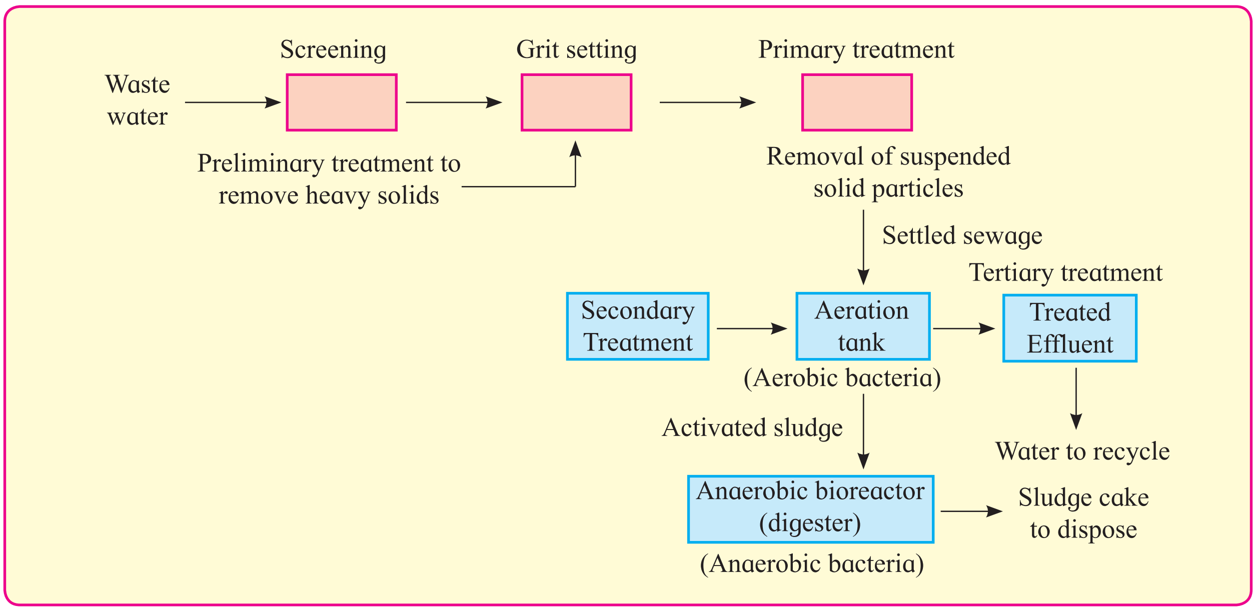


Fig. 11.12 : Diagrammatic representation of various stages in wastewater treatment

11.10 Microbes in Energy Generation :

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.

Plant wastes, animal wastes, domestic wastes, agriculture waste, municipal wastes, forestry wastes, etc. are commonly used for biogas production. Cattle dung is most commonly employed substrate for biogas production. It is a rich source of cellulose from plants.

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. Digester is made up of concrete bricks and cement, or steel. There is cylindrical gas holder or gas tank above it to collect gases. Digester has a side opening (charge pit) into which raw material as cow dung is fed. The digester is partly burried in the soil.

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.

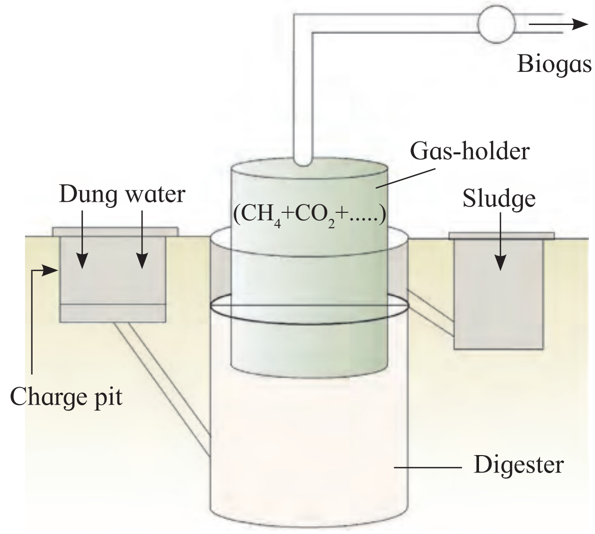


Fig. 11.13 : Biogas plant

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. $\underset{\text{(acetic acid)}}{12\text{mol } CH_3COOH} \longrightarrow \underset{\text{methane}}{12CH_4} + 12CO_2$

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

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 is eco-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**.

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, 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 (biocontrol agent)	Host (target pest)
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 as weeds in the field of cereals, can be killed by certain microbes. Some examples are as below :

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 pathogen 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.

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.

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.

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.

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:

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:

i. Symbiotic N_2 fixing microorganisms: for eg. *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 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*.

Do you know ?

Classification of Biofertilizers :

On the basis of **nature** or group of organisms, biofertilizers are classified as **bacterial** fertilizers and **fungal** fertilizers.

Bacterial fertilizers include eubacteria and cyanobacteria. On the basis of **function**, bacterial fertilizers are further grouped as **nitrogen fixing**, **phosphate solubalizing** and **compost making** biofertilizers. Cynobacterial biofertilizers, on the basis of function, are nitrogen fixing type.

Fungal biofertilizers include mycorrhizal fungi. On the basis of function, they are classified as **ectomycorrhizae** and **endomycorrhizae**.

3. Fungal biofertilizers:

Mycorrhiza is a fugus. It forms symbiotic association with the underground parts like rhizomes and roots of higher plants occuring in thick humid forests. These were discovered by Frank (1885). There 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. 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 secreating antibiotics.

Do you know ?

Now a days, mycorrhiza are classified into 8 different types viz, Ectomycorrhizae, Endomycorrhizae, Ectendomycorrhizae, Orchidaceous mycorrhizae, Ericoid mycorrhizae, Arbutoid mycorrhizae, Monotrapoid mycorrhizae and Ophioglossoid mycorrhizae.

Use your brain power

Why are healthy root nodules pink in colour?

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 an important and well known free living, nitrogen fixing, aerobic, non-photosynthetic, non-nodule forming bacterium which is 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.

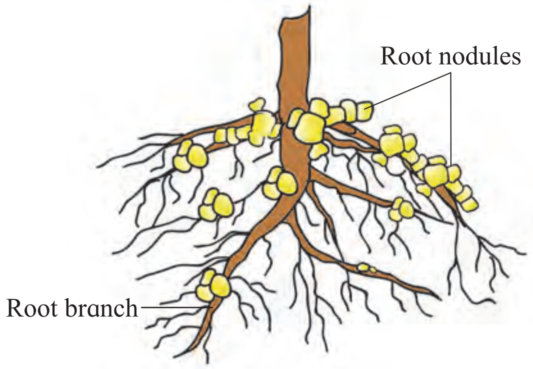


Fig. 11.15 : Root system of Leguminous plant

Fig. 11.17 : *Azolla*

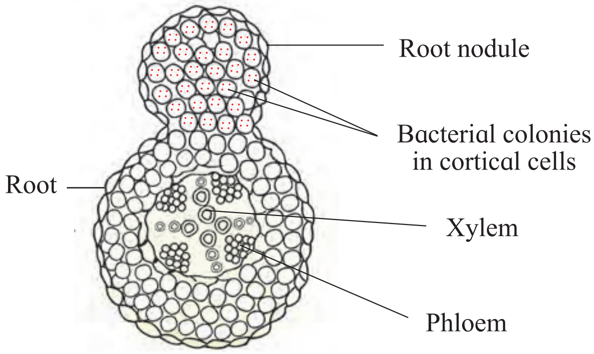


Fig. 11.16 : T. S. of root nodule

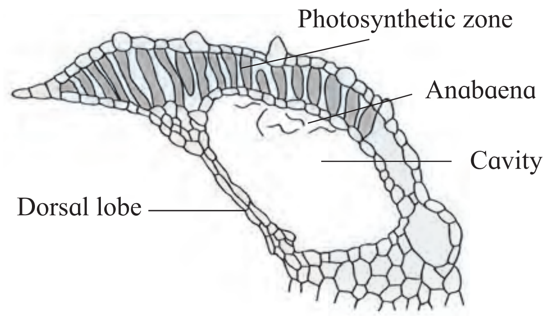


Fig. 11.18 : L. S. of *Azolla* leaf showing filamentous *Anabaena*

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.

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

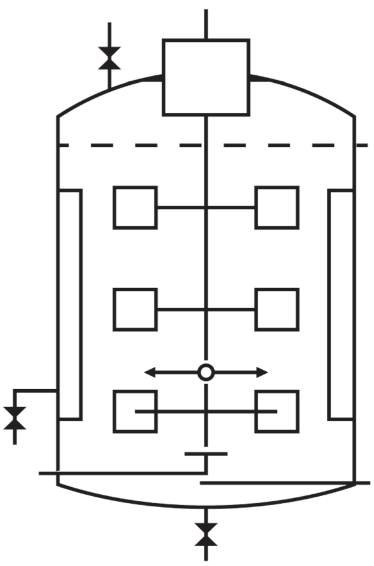
Now in our country many biofertilizers are available in market to reduce the use of chemical fertilizers and thus, the pollution.

Activity :

1. **Visit fish market and enlist different types of fresh water and marine water fish mentioning their local and scientific names along with their salient features.**

Type	Local Name	Scientific Name	Detail Information
1.			
2.			
3.			
4.			
5.			
6.			
7.			

2. **Label the different parts of the fermenter and mention functions of each part.**



Exercise

Q. 1 Multiple Choice Questions.

1. Antibiotic Chloromycetin is obtained from ....
   a. *Streptomyces erythreus*
   b. *Penicillium chrysogenum*
   c. *Streptomyces venezuelae*
   d. *Streptomyces griseus*

2. Removal of large pieces of floating debris, oily substances, etc. during sewage treatment is called ....
   a. primary treatment
   b. secondary treatment
   c. final treatment
   d. amplification

3. Which one of the following is free living bacterial biofertilizer?
   a. *Azotobacter*
   b. *Rhizobium*
   c. *Nostoc*
   d. *Bacillus thuringiensis*

4. Most commonly used substrate for industrial production of beer is ....
   a. barley　　b. wheat
   c. corn　　d. sugarcane molasses

5. Ethanol is commercially produced through a particular species of ....
   a. *Aspergillus*
   b. *Saccharomyces*
   c. *Clostridium*
   d. *Trichoderma*

6. One of the free-living anaerobic nitrogen-fixer is ....
   a. *Azotobacter*　　b. *Beijerinckia*
   c. *Rhodospirillum*　　d. *Rhizobium*

7. Microorganisms also help in production of food like ....
   a. bread　　b. alcoholic beverages
   c. vegetables　　d. pulses

8. MOET technique is used for ....
   a. production of hybrids
   b. inbreeding
   c. outbreeding
   d. outcrossing

9. Mule is the outcome of ....
   a. inbreeding
   b. artificial insemination
   c. interspecific hybridization
   d. outbreeding

Q. 2 Very Short Answer Questions:

1. What does make idlies puffy?
2. Name any two bacterial biofertilizers.
3. What is the microbial source of vitamin B_{12}?
4. What is the microbial source of enzyme Invertase?
5. Milk start to coagulate when Lactic Acid Bacteria (LAB) is added to warm milk as a starter. Mention any two other benefits of LAB.
6. Name the enzyme produced by *Streptococcus* bacterium. Explain importance in medical sciences.
7. What is breed?
8. Define estuary.
9. What is shellac?

Q. 3 Short Answer Questions.

1. Many microbes are used at home during preparation of food items. Comment on such useful ones with examples.
2. What is biogas? Write in brief about the production process.
3. Write a note on biocontrol agents.
4. Name any two enzymes and antibiotics with their microbial source.
5. Write priciples of farm management.
6. Give economic importance of fishery.
7. Enlist the species of honey bee mentioning their specific uses.

8. What are A, B, C and D in the table given below :

Types of microbe	Name	Commercial product
Fungus	A	Penicillin
Bacterium	*Acetobacter aceti*	B
C	*Aspergillus niger*	Citric acid
Yeast	D	Ethanol

Q. 4 Long Answer Questions.

1. Explain the process of sewage water treatment before it can be discharged into natural bodies. Why this treatment is essential?
2. Write a note on lac culture.
3. Describe various methods of fish preservation.
4. Give an account of poultry diseases.
5. Give an account of mutation breeding with examples.
6. Describe briefly various steps of plant breeding methods.

Project :

Collect information about :

A) Different types of worms/organisms used in sericulture.

B) How is silk obtained and isolated ?

C) Types of silk.

D) Job potential of sericulture.