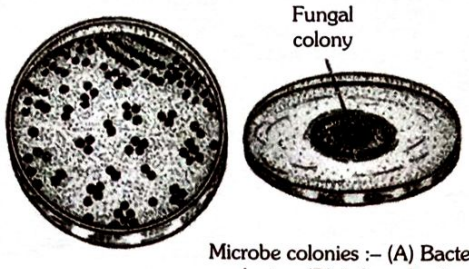
32. Microbes in Human Welfare

1. Introduction

Microbes or microorganisms are those organisms which are not visible to naked eye because they have a size of 0.1 μm or less. Microbes belong to diverse groups of organisms-bacteria, fungi, protozoa, microscopic plants. Viruses, viroids and prions are also included amongst microbes. Most of the microbes can be grown on nutritive media where they form colonies, e.g., bacteria, fungi. The colonies can be seen with naked eyes



Microbe colonies :– (A) Bacterial colonies, (B) A fungal colony.

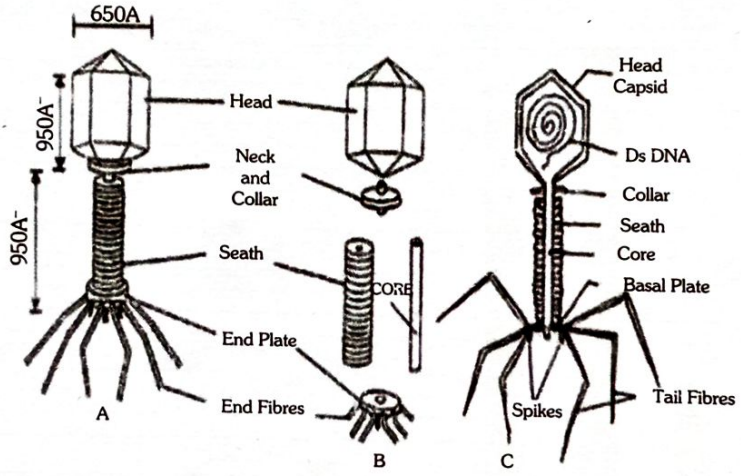


Figure :– (A) T_4 Bacteriophage. (B) External Structure. (C) Parts: L.S. of a virion.

The microorganisms influence man in several ways. They are ubiquitous in our environment i.e., they are found in the soil, mud, water, air, in animals, plants, food products, dead wood, clothes, jams and shoes, optical instruments, nails, skin, even in space and at Antarctica. Literature survey reveal that biosphere contains a variety of microorganism that biosphere contains a variety of microorganisms that proliferate in extreme environments. The diversity of their activities varies from causing diseases in human and other animals and plants to the production of various useful products, recovery of metals, increasing in soil fertility and the deterioration of aeroplanes.

2. Microbes in Household Products

2.1 Curd

Lactic acid bacteria (LAB) like lactobacillus are added to milk. It converts lactose sugar of milk into lactic acid. Lactic acid cause coagulation of milk protein casein. Milk is changed into curd, yogurt and cheese. The starter or inoculums used in preparation of milk products actually contains millions of LAB.

Indian curd is prepared by inoculating cream and skimmed milk with lactobacillus acidophilus at a temperature of about 40° C or less. Curd is more nutritious than milk as it contains a number of vitamins and organic acids. LAB present in curd also checks growth of disease causing microbes. It is also used to obtain butter and butter milk

2.2 Dosa, uppma and idli

These are fermented preparation of rice and black gram (Vigna mungo). The two are allowed to ferment for 3-12 hours with leuconostoc and streptococcus species of bacteria

2.3 Bread

Bread is made from flour obtained by grinding cereal grain usually wheat. Selected strains of saccharomyces cerevisiae grown on molasses are used as baker's yeast. The puffed up appearance of dough is due to the production of CO_2 gas.

2.4 Toddy

The unopened spadices of coconut are tapped to obtain toddy. It is a refreshing drink which can be heated to produce jaggery or palm sugar.

Toddy left for a few hours undergoes fermentation with the help of naturally occurring yeast of form beverage containing about 6% alcohol. After 24 hours toddy becomes unpalatable. It can be now used for producing vinegar.

Toddy is a traditional drink of some parts of south India. Microbes are also used to ferment fish, soyabean and bamboo shoots to make foods.

A most popular type of fermented food is produced from soyabeans called tempeh kedele. It is important source of vitamin B_{12}. Tofu and sufu are also obtained from soyabeans.

2.5 Cheese

The name cheese is derived from Latin name caseus. There are two groups of cheese, fresh or unripened cheese and ripened cheese. The unripened cheese are made up of milk coagulated by acid or high heat e.g., cottage cheese, while ripened cheese are made through lactic acid bacterial fermentation and coagulated by an enzyme preparation.

The large number of microorganisms play a role in the ripening process. The gas forming CO_2 producing culture of propioni bacterium sharmanii is essential for giving swiss cheese its eye or holes, and flavor. Roquefort cheese uses penicillium roqueforti while camembert cheese employs P.camemberti for ripening.

Points to be Noted

Yogurt is produced by curding milk with the help of streptococcus thermophilus and lactobacillus bulgaricus.

Butter milk is a liquid substance which is separated from cream during churning process. Lactobacillus lactis and leuconostoc mesenteroides produce butter milk.

Curding is done with the help of lactic acid bacteria and enzyme rennin.

Soft cheese is ripened by the enzymes from yeast and other fungi that grow on the surface.

Hard cheese is ripened by lactic acid bacteria which grows throughout the cheese, die, autolyse and release hydrolytic enzymes.

The semisoft cheese is ripened by proteolytic and lipolytic organisms which soften the curd and give it a flavor

(1) **Unripened or Cottage cheese** is prepared by single step fermentation which involves inoculation of skimmed milk with cheese culture and addition of rennin or rennet after 1-2 hours. Curd is placed in cloth lined porous containers for draining out whey.

(2) **Ripened Cheese** is prepared from unripened cheese by first dipping in brine, wiping and then maturation with different strain of bacteria and fungi. It takes 1-16 months for ripening.

3. Microbes in Industrial Products

Fermentative activity of microbes is used industrially to obtain a number of products. The two common ones are alcoholic fermentation and antibiotics. The container, where fermentation is carried out, is called fermenter or bioreactor.

3.1 Fermentation

Fermentation refers to the metabolic process by which organic molecules (normally glucose) are converted into acids, gases, or alcohol in the absence of oxygen or any electron transport chain. Fermentation pathways regenerate the coenzyme nicotinamide adenine dinucleotide (NAD^+), which is used in glycolysis to release energy in the form of adenosine triphosphate (ATP). Fermentation only yields a net of 2 ATP per glucose molecule (through glycolysis), while aerobic respiration yields as many as 32 molecules of ATP per glucose molecule with the aid of the electron transport chain

(1) **Fermented Beverages** : Louis Pasteur found for the first time that beer and butter milk are produced due to activity of yeast and yeast like microorganisms. Yeast species used in alcoholic fermentation are saccharomyces cerevisiae (brewer's yeast), S. ellipsoideus (wine yeast), S. sake (sake yeast) and S. piriformis (ginger beer/ale yeast).

Different types of alcoholic drinks are obtained depending upon the type of raw material used for fermentation. Wine and beer are alcoholic products obtained by non distillation method. Whisky, brandy, and rum are distilled beverages and are called hard liquors.

- **Ethanol Fermentation :** In ethanol fermentation, the pyruvate produced through glycolysis is converted to ethanol and carbon dioxide in two steps. First, the pyruvate releases carbon dioxide to form a two-carbon compound called acetaldehyde. Next, acetaldehyde is reduced by NADH to ethanol, thereby regenerating the NAD^+ for use in glycolysis. Overall, one molecule of glucose is converted into two molecules of carbon dioxide and two molecules of ethanol.

  Ethanol fermentation is typically performed by yeast, which is a unicellular fungus.

  Equation of Ethanol Fermentation

  Glucose $\rightarrow$ 2 ethanol + 2 carbon dioxide $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

(2) **Alcoholic Beverages :** All ethanol contained in alcoholic beverages (including ethanol produced by carbonic maceration) is produced by means of fermentation induced by yeast.

Wine is produced by fermentation of the natural sugars present in grapes; cider and perry are produced by similar fermentation of natural sugar in apples and pears, respectively; and other fruit wines are produced from the fermentation of the sugars in any other kinds of fruit. Brandy are produced by distillation of these fruit-fermented beverages.

Mead is produced by fermentation of the natural sugars present in honey. Beer, whiskey, and vodka are produced by fermentation of grain starches that have been converted to sugar by the enzyme amylase, which is present in grain kernels that have been malted (i.e. germinated). Other sources of starch (e.g. potatoes and unmalted grain) may be added to the mixture, as

the amylase will act on those starches as well. Whiskey and vodka are also distilled; gin and related beverages are produced by the addition of flavouring agents to a vodka-like feedstock during distillation.

Rice wines (including sake) are produced by the fermentation of grain starches converted to sugar by the mold *Aspergillus oryzae*. Rum and some other beverages are produced by fermentation and distillation of sugarcane. Rum is usually produced from the sugarcane product molasses.

4. Antibiotics

The term was coined by Waksman (1942). Antibiotics (Fr. anti = against; bios = life) are chemical substances secreted by some microorganisms which inhibit the growth and development of other microbes. Most of them are produced by actinomycetes, specially the genus streptomyces, and filamentous fungi.

The study of antibiotics began by the discovery of penicillin in 1929, when Alexander Fleming proved that the filtrate of a broth culture of penicillium notatum has antibacterial properties H.Florey commercially extracted a relatively stable preparation of penicillin. The chemical was extensively used in treating wounded American soldiers in world war II. Fleming, chain and Florey were awarded Nobel Prize in 1945. Waksman and woodruff is isolated actinomycin in 1941 and streptothricin in 1942.

Waksman and albert (1943) and Waksman (1944) discovered streptomycin. Burkholder (1947) isolated chloromycetin. Over 7000 antibiotics are known. Antibiotics are obtained from lichens, eubacteria, fungi and actinomycetes.

4.1 Industrial Production of Antibiotics by Fermentation

Industrial microbiology can be used to produce antibiotics via the process of fermentation, where the source microorganism is grown in large containers (100,000–150,000 liters or more) containing a liquid growth medium. Oxygen concentration, temperature, pH and nutrient levels must be optimal, and are closely monitored and adjusted if necessary.

As antibiotics are secondary metabolites, the population size must be controlled very carefully to ensure that maximum yield is obtained before the cells die. Once the process is complete, the antibiotic must be extracted and purified to a crystalline product. This is easier to achieve if the antibiotic is soluble in organic solvent. Otherwise it must first be removed by ion exchange, adsorption or chemical precipitation.

4.2 Strains Used for the Production of Antibiotics

In the earliest years of antibiotic discovery the antibiotics being discovered were naturally produced antibiotics and were either produced by fungi, such as the antibiotic penicillin, or by soil bacteria, which can produce antibiotics including streptomycin and tetracycline.

Some antibiotics are produced naturally by fungi. These include –

(i) Cephalosporin producing *Acremonium chrysogenum.*
(ii) Geldanamycin is produced by Streptomyces hygroscopicus.
(iii) Erythromycin is produced by what was called Streptomyces erythreus and is now known as *Saccharopolyspora erythraea.*
(iv) Streptomycin is produced by *Streptomyces griseus.*
(v) Tetracycline is produced by *Streptomyces aureofaciens*
(vi) Vancomycin is produced by Streptomyces orientalis, now known as *Amycolatopsis orientalis.*

4.3 Types of Antibiotics

There are five basic classes of antibiotics -

Antibiotics	Source	Action
Chloramphenicol	S. venezuelae	Typhoid, whooping cough (kali khansi)
Erythromycin	S.erythreus	Diphtheria (gal ghotu)
Chloromycetin	S.lavendulae	Pneumonia
Streptomycin	S.griseus	Meningitis, pneumonia, TB
Bacitracin	Bacillus licheniformis	Syphilis

4.4 Uses of Antibiotics

(i) As medicines for treatment of a number of pathogenic or infectious diseases. Because of antibiotics and their more new potent forms, a number of formidable diseases are now curable, e.g., plague, typhoid, tuberculosis etc.
(ii) As preservative in perishable fresh food articles (e.g., meat and fish), pasteurized and canned foods.
(iii) As feed supplement for animals, especially poultry birds because they enhance growth.

5. Chemicals, enzymes and other bioactive molecules

Microbes are also used for commercial and industrial production of certain chemicals like organic acids, alcohols and enzymes.

5.1 Organic Acids

There are mainly two step in acetic acid or vinegar production. In the first stage, yeast converts sugar into ethanol anaerobically while in the second step ethanol is oxidized to acetic acid aerobically by Acetobacter and Gluconobacter. This process is called acetification. The organic acid is employed in pharmaceuticals, colouring agents, insecticides, plastics, etc.

Citric acid : is obtained through the fermentation carried out by aspergillus niger and mucor species on sugary syrups. Yeast can also be employed, provide its nutrient medium is made deficient of iron and manganese.

Lactic acid : was the first organic acid to be produced from the microbial fermentation. Lactic acid fermentation is carried out by both bacteria (e.g., streptococcus lactis, Lactobacillus species) and fungi (e.g., rhizopus).

Clostridium butylicum is the bacteria that is used for production of butyric acid.

Gluconic acid : is prepared by the activity of *Aspergillus niger* and Penicillium species.

(1) Uses of Organic Acids

- The organic acids and their derivatives are used in various type of chemically manufactured substances. These molecules are considered generally as irritant, the level of such irritant is decided partially by dissociation of acids along with their water solubility capacity. Some of these could result in severe burning or almost similar effects as the mineral acids.
- Many of these carboxylic acids have importance in food and beverage industries along with drugs and other manufacturing processes. The most common organic acids which are used in such manufacturing are adipic acid, azelaic acid, Fumaric acid, maleic acid, malic acid, malonic acid, oxalic acid, succinic acid, tartaric acid and sebacic acid.
- The saturated long chain of the monocarboxylic acids are basically fatty acids. These are the main chain resourced from various natural sources. Synthetic fatty acids could also be prepared by oxidation of paraffin using metals as catalysts. These could also be prepared by alcohol oxidation in presence of alkaline potassium di chromates. The commercial naphthenic acid are derived from cyclo-paraffins in petroleum, by oxidation.
- The organic acids are utilised in plastic making, tanning, textiles, paper, metal, pharmaceuticals, food industries, beverage making as well as and in manufacturing of cosmetics. These are also used in manufacturing of perfumes, herbal insecticides, colours and dyes, various lubricants and common household cleaners.

5.2 Enzymes

Enzymes are proteinaceous substances of biological origin which are capable of catalysing biochemical reactions without themselves undergoing any change.

(1) Streptokinase (Tissue Plasminogen Activator or TPA) is an enzyme obtained from the cultures of some haemolytic streptococci. It has fibrinolytic effect. Therefore, it helps in clearing blood clots inside the blood vessels through dissolution of intravascular fibrin.

(2) Pectinases are obtained commercially form Byssochlamys fulvo. Along with proteases, they are used in clearing of fruit juices. Other uses are in retting of fibres and preparation of green coffee.

(3) Lipase are lipid dissolving enzymes that are obtained from candiada lipolytica and Geotrichum candidum. Lipases are added in detergents for removing oily stains from laundry. They are also used in flavouring cheese.

(4) Proteases A protease (also called a peptidase or proteinase) is an enzyme that performs proteolysis; protein catabolism by hydrolysis of peptide bonds. Proteases can be found in Animalia, Plantae, Fungi, Bacteria, Archaea and Viruses. Proteases are obtained from Mortierella renispora, Aspergillius and Bacillus species.

(5) Rennet is a complex of enzymes produced in the stomachs of ruminant mammals. Rennet and Chymosin is now being obtained from Mucor and Endothio species. Chymosin its key component, is a protease enzyme that curdles the casein in milk. This helps young mammals digest their mothers' milk. Rennet can also be used to separate milk into solid curds for cheese making and liquid whey.

(6) Lactases are obtained from *Saccharomyces fragilis* and *Torula cremoris*. It is located in the brush border of the small intestine of humans and other mammals. Lactase is essential to the complete digestion of whole milk; it breaks down lactose, a sugar which gives milk its sweetness.

5.3 Bioactive Molecules

(1) Cyclosporin-A is an important bioactive chemical produced by the fungus Trichoderma polysporum. This chemical is used as an immunosuppressive agent in organ transplantation.

(2) Statin is produced by yeast monascus pupureus. It is used as blood cholesterol lowering agent by acting as a competitive inhibitor of enzyme for cholesterol synthesis.

Other Important points :

The sweetened nutrient medium prior to alcoholic fermentation is called wort.

The crushed food mixed with hot-water for obtaining malt is called mash.

Rectified spirit is 98% alcohol. Absolute alcohol is 100% alcohol.

Broad spectrum antibiotics can kill or destroy a number of pathogens that belong to different groups with different structures and wall composition. Specific antibiotic is effective only against one type of pathogen.

Gluconic acid is prepared by the activity of Aspergillus niger and penicillum species.

Proteases degrade proteins and polypeptides. Amylases degrade starch.

6. Microbes in Sewage Treatment

Sewage is waste water having food residues, animal and human excreta, detergents, discharges from commercial and industrial establishments and pathogenic microbes. Sewage may drain directly into major watersheds with minimal or no treatment. Water polluted with domestic sewage can spread such epidemic diseases as cholera, typhoid, dysentery or diarrhea, and a number of other minor ailments and water borne diseases. The major effect of sewage in the water is that it reduces the oxygen content of the water. The high organic content of the sewage is immediately subjected to chemical and biochemical oxidation process.

Sewage water can be purified by passing it through sewage treatment plants with the action of microorganisms. A sewage treatment plant separated solids from liquids by physical processes and purifies the liquid by biological processes. There are three stages of this treatment; primary, secondary and tertiary.

6.1 Primary Treatment

It removes floating and suspended solids from sewage through two processes of filtration and sedimentation.

First floating matter is removed through sequential filtration. The filtrate is kept in large open settling tanks where grit settles down.

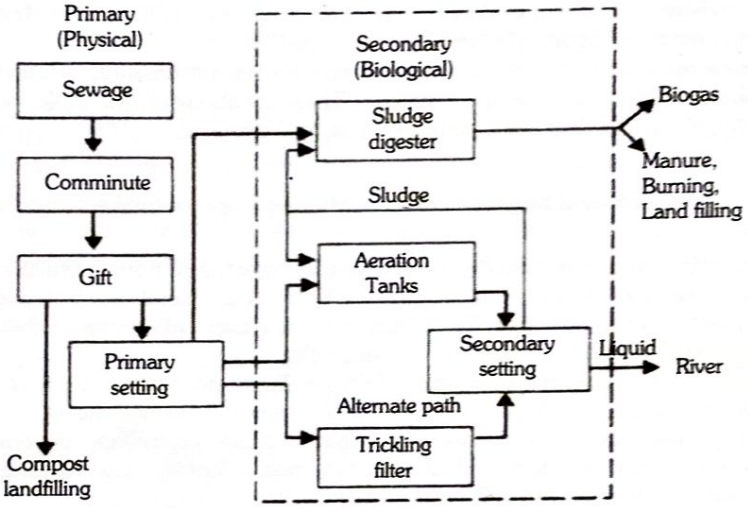
Aluminium or iron sulphate is added in certain places to flocculation and settling down of solids. The sediment is called primary sludge while the supernatant is called effluent. The primary sludge traps a lot of microbes and debris. It is subjected to composting or land fill where anaerobic digestion removes the organic matter.

6.2 Secondary Treatment (Biological treatment)

There are several methods of secondary treatment, e.g., oxidation tanks, trickling filter, and activated sludge system. In activated sludge system, the primary effluent is taken to aeration tanks. A large number of aerobic heterotrophic microbes grow in the aeration tank. They form flocs. Flocs are masses of bacteria held together by slime and fungal filaments to form mesh like structures.

The microbes digest a lot of organic matter, converting it into microbial biomass and releasing a lot of minerals.

As the BOD (Biochemical oxygen demand) of the waste matter is reduced to 10-15% of raw sewage, BOD refers to the amount of the oxygen that would be consumed if all the organic matter in one liter of water were oxidised by bacteria



Flow chart :– Sewage treatment process

The sewage water is treated till the BOD is reduced. The BOD test measures the rate of uptake of oxygen by micro-organisms in a sample of water and thus, indirectly, BOD is a measure of the organic matter present in the water. The greater the BOD of waste water, more is its polluting potential. Once the BOD of sewage or waste water is reduced significantly. It is passed into settling tank. Thus secondary treatment is more or less biological. The sediment of settling tank is called activated sludge.

A part of it is used as inoculums in aeration tank. The remaining is passed into a large tank called anerobic sludge digestor.

It is designed for continuous operation. The aerobic microbes present in the sludge get killed. Anaerobic microbes digest the organic mass as well as aerobic microbes of the sludge. They are of two types, nonmethanogenic and methanogenic. Methanogenic bacteria produce a mixture of gases containing methane, H_2S and CO_2. The mixture called biogas is inflammable and is a source of energy.

The spent sludge can be used as manure of part of compost.

6.3 Tertiary Treatment

If the waste water is to be used for domestic purposes then tertiary treatment is done. It is a physio- chemical process in which chlorine gas, ozone gas, zirconium, perchlorate, and salts, U.V. rays etc. are used to remove D.D.T., pesticides, pathogens and turbidity in waste water.

7. River Action Plan

Before 1985, very few cities and towns had sewage treatment plants. The municipal waste water was discharged directly into rivers resulting in their pollution and high incidence of water borne disease. In order of protect the major rivers of India from sewage pollution, the Ministry of Environment and Forests, has initiated development of sewage treatment plants under the National River Conservation Authority, e.g., Ganga Action Plan (GAP), Yamuna Action Plan, Gomti Action Plant.

8. Microbes in Production of Biogas

Biogas is a methane rich fuel gas produced by anaerobic breakdown or digestion of biomass with the help of methanogenic bacteria. Metahnobacterium is a common methanogenic bacteria.

Biogas is made up of methane (50-70%), carbon dioxide (30-40%) with traces of nitrogen, hydrogen sulphide and hydrogen. 50% of the combustible energy present in the organic waste can be changed into methane gas. The energy released from biogas depends upon the proportion of methane present in it. The calorific value of biogas is 23-28 MJ / m^3.

8.1 Biogas Plant

As the biogas production is an anaerobic process, it is carried out in an air tight, closed cylindrical concrete tank called a digester. The tank has a concrete inlet basin on one side for side for feeding fresh cattle dung. There is a concrete outlet on the outer side for removing the digested sludge. The top of the tank serves as the gas tank. It has an outlet pipe for the biogas. Fresh cattle remain there. The accumulated gas is conducted through the outlet pipe and used for domestic purposes. The digested sludge is removal from the tank and is used as fertilizer. The technology of biogas production was developed in India mainly due to the efforts of Indian Agriculture research institute (IARI) and khadi and village industries commission (KVIC).

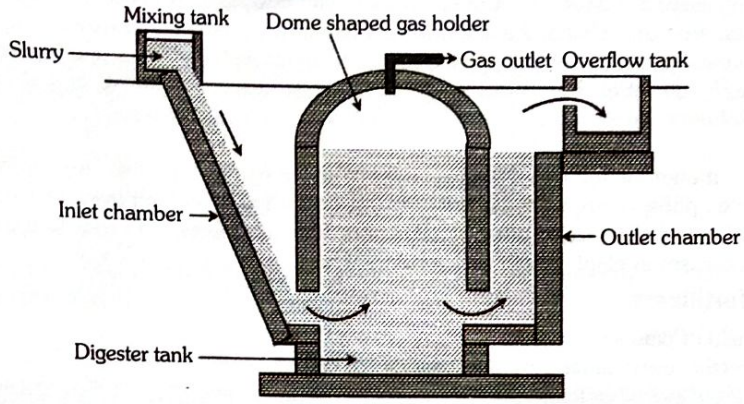


Figure :– A typical Biogas plant

8.2 Applications

Biogas can be used for electricity production on sewage works,[1] in a CHP gas engine, where the waste heat from the engine is conveniently used for heating the digester; cooking; space heating; water heating; and process heating. If compressed, it can replace compressed natural gas for use in vehicles, where it can fuel an internal combustion engine or fuel cells and is a much more effective displacer of carbon dioxide than the normal use in on-site CHP plants.

9. Microbes as Biocontrol Agents

(1) The natural method of pest and pathogen control involving use of viruses, bacteria and other insects (which are their natural predators and pests) is called biocontrol or biological control.

(2) For example, Lady bird beetle (beetle with red and black markings) feeds on aphids while dragonflies prey upon mosquitoes.

(3) An example of microbial biocontrol agents that can be introduced in order to control butterfly caterpillars is the bacteria bacillus thuringiensis (often written as Bt). These are available in sachets as fried spores which are mixed with water and sprayed onto vulnerable plants such as brassica and fruit trees, where these are eaten by the insect larvae. In the gut of the larvae, the toxin is released and the larvae get killed.

(4) The bacterial disease will kill the caterpillars, but leave other insects unharmed. Because of the development of methods of genetic engineering in the last decade or so, the scientists have introduced B. thuringiensis toxin genes into plants. Such plants are resistant to attack by insect pests. Bt-cotton is one such example, which is being cultivated in some states of our country.

(5) Trichoderma species are free-living fungi that are very common in root ecosystems. They are effective biocontrol agents of several plant pathogens.

(6) Baculoviruses are pathogens that attack insects and other arthropods. The majority of baculoviruses used as biological control agents are in the genus nucleopolyhedro virus. These viruses are excellent candidate for species-specific, narrow spectrum insecticidal applications. They have been shown to have no negative impacts on plants, mammals, birds, and fish or even on non-target insects. This is especially desirable when beneficial insects are being conserved to aid in an overall integrated pest management (IPM) programme, or when an ecologically sensitive area is being treated.

Important -

Advantage of biogas :

Gobar gas is mainly used for cooking and lighting in rural areas. Used as fuel, it is comparatively less polluting than conventional fuels. Also used in internal combustion engines to power water pumps and electric generators. Bioherbicides are those organisms or their extracts that destroy weeds without harming useful plants. Devine and collego are fungal spores which can be sprayed over weeds for their elimination. Sporeine developed in Germany is the first commercial bioinsecticide obtained from bacillus thuringiensis. Natural insecticides are obtained from microbes and plants. e.g., azadirachtin from margosa, rotenones from roots of Derris elliptica and Lonchocarpus nicou. Trichoderma species are free-living fungi that are very common in root ecosystems. They are effective biocontrol agents of several plant pathogens.

10. Microbes as Biofertilizers

- Biofertilizers are organism which bring about nutrient enrichment of the soil by enhancing the availability of nutrients like nitrogen and phosphorous to the crops.
- Biofertilizers are of three types-nitrogen fixing bacteria, nitrogen fixing cyanobacteria and mycorrhiza. Azotobacter occurring in fields of cotton, maize, jowar and rice, not only increases yield but also saves nitrogen fertilizer upto 10-25 kg/ha.

- A number of free living cyanobacteria or blue-green algae (BGA) have the property of nitrogen fixation, e.g., anabaena, nostoc, oscillatoria. Cyanobacteria are extremely low cost biofertilizers.
- The most important of the symbiotic nitrogen fixing bacteria is Rhizobium. It forms nodules on the roots of legume plants. There are about a dozen species of rhizobium which form association with different legume roots, e.g., leguminosarum, R. trifolii, R. meliloti, R. phaseoli.
- Nitrogen fixing cyanobacteria (blue-green algae) form symbiotic association with several plants, e.g., cycad roots, lichens, liverworts, azola (fern). Azolla-anabaena association is of great importance to agriculture. Azolla pinnata is a free floating fresh water fern which multiples rapidly, doubling every 5-7 days. The fern can coexist with rice plants because it does not interfere with their growth. It some south-east Asian countries, especially China, the rice fields are regularly provided with Azolla.
- Mycorrhiza is a mutually beneficial or symbiotic association of a fungus with the roots of a higher plant. Many members of the genus glomus form mycorrhiza. Mycorrhizal roots show a sparse or dense wooly growth of fungal hyphae on their surface. Mycorrhiza perform several functions for the plant :
- Absorption of water.
- Solubilisation of organic matter of the soil humans, release of inorganic nutrients, absorption and their transfer to rootDirect absorption of minerals (e.g., phosphorus) form the soil over a large area and bending over the same to the root.
- Plants having mycorrhizal associations show other benefits also, such as resistance to root-borne pathogens, tolerance to salinity and drought and an overall increases in plant growth and development.

10.1 Importance of Bio-fertilizers

(1) They increase the yield of plants by 15-35%.
(2) Bio-fertilizers are effective even under semi-arid conditions,
(3) Farmers can prepare the inoculum themselves,
(4) They improve soil texture,
(5) Bio-fertilizers do not allow pathogens to flourish,
(6) They produce vitamins and growth promoting bio-chemical's,
(7) They are non-polluting.

Important -

Leghaemoglobin is the pink-red coloured pigment present in the nodules of leguminous plants. Frankia (actinomycete) is a symbiotic nitrogen fixer of several nonlegume plants. Many members of genus glomus form mycorrhiza. In ectomycorrhiza, the fungus forms a mantle on the surface of the root. In endomycorrhiza, only a little of the mycelium lies on the surface. The remaining lives in the cortex of the root. Endomycorrhiza is also called vesicular-arbuscular mycorrhiza or VAM. Manure is semi-decayed organic matter which is added to the soil in order to maintain its fertility, aeration and hydration capacities. In addition to nitrogen, green manures also provide organic matter, NPK and minimize the number of pathogenic micro-organisms in soil. Sustainable agriculture is the practice of obtaining optimum agricultural yield as per changing human needs while maintain or enhancing the quality of environment and conserving natural resources through judicious management of available resources.

11. Bioenergy

- The energy obtained from biological sources is called bioenergy. Bioenergy is the use of biomass (organic matter) to produce electricity, transportation fuels or chemicals.
- Bioenergy sources include agriculture and forestry residues and the organic components of municipal and industrial wastes. Fossil fuels (coal, petroleum and natural gas) are not included under bioenergy.
- Only 0.2% of solar radiations reaching the earth are converted into biomass. This amount is about-10 times the energy produced from nonbiomass sources. Being a tropical country, India receives more solar radiations and therefore has high potential for biomass synthesis to meet the requirement of energy.
- Bioenergy is obtained from following types of biological sources

12. Animal Energy

Animal energy is basically of two forms :

12.1 Human Muscle Power (HMP)

It is the form of animal energy, which is used throughout the world in the form of physical work by human race like farmers in the field, women in house work and non agricultural labourers like artisans in wood work, gardeners, etc.

A major part of the energy utilized today belongs to this type and it constitutes about $1/5^{th}$ of the total generated electricity in India. Thus, it constitutes the significant part of energy used.

12.2 Draught Animal Power (DAP)

Animals are domesticated not only for providing us with food, hides and bones but they are also used in agriculture and transport. These animals play an important role in villages.

India has about 84 million of work animals; 70 million bullocks; 8 million buffaloes and one million each of horses and camels.

In addition mules, donkeys, elephants and yaks are also used. 50 percent of the Indian farmers have holdings less than two acres each, as a result they cannot use tractors. More than 15 million animal-drawn carts are used in India. Carts have the advantage that they can be used on all types of roads in all terrains.

The energy potential of DAP is enormous. Suppose if each animal generates 0.5 horsepower then the installed capacity of animals comes about 42 million horsepower or 30,500 MW. This value is almost equal to total electric power generation in India. Because of poor quality of animals and outdated designs of carts and agricultural machinery, full potential of DAP has not been released in India.

Methods recommended achieving this are :

(i) Improved breeds of draught animals.
(ii) Use of better carts.
(iii) Proper management of grazing lands and pastures.
(iv) Supply of nutritious fodder.

13. Biofuels and Biomass

They are fuels of biological origin. Biofuels are major source of energy.

They are renewable and if used properly and efficiently they can solve the energy problems of developing countries.

Biomass is the term applied to all materials whose origin can be traced to photosynthesis.

Biomass can be used to generate producer gas, to run water pumps for irrigation, to obtain alcohol, to replace petrol, to generate biogas for cooking and lighting and to generate electricity.

Table : Ways of utilising biomass as fuel

Biomass	Process	Form / Source of energy produced
Wood	Direct burning, Gasification, Carbonisation, Pyrolysis, Hydrolysis, Fermentation and Synthesis.	Heat, Producer gas, Charcoal gas, Oil and Charcoal, Methanol, Ethanol.
Agro-industrial residues.	Fermentation/Distillation, Anaerobic digestion.	Ethanol, Biogas.
Petroleum and Oil producing plants	Cracking and direct use.	Petroleum products, Heating, Running engines.
Energy cropping	Fermentation/ Distillations.	Ethanol.

13.1 Wood

It is the renewable and most common source of energy in use since time immemorial.

Wood which is used as source of energy is called fuel wood and about 2 billion people in world are dependent upon wood as source of fuel.

Excessive use of wood as fuel has led to deforestation, soil erosion, loss in fertility of soil and hence deterioration of environment.

The consumption of fuel wood was estimated at 1.7 billion m^3 in 1984 of which more than two third was consumed in Asia and Africa.

13.2 Characteristics of good fire wood

(1) It should be highly combustible and catch fire easily.
(2) It should have high calorific value and should be free of disagreeable odour.
(3) The fuel wood plants should be present everywhere.
(4) These should be easy to dry and should not split when burnt.
(5) Should be non-resinous in nature and smokeless.

Table : Good fire woods and bad fire woods

Good fire-Woods	Bad fire-Woods
Acacia senegal (Gum Arabic)	*Pinus roxburghii* (Chir Pine)
Acacia nilotica (Kikar) (Black wood tree)	*Mangifera indica* (Mango)
Albizzia (Siris)	*Madhuca indica* (Mahua)
Azadirachta indica (Neem)	*Bauhinia racemosa* (Kachnar)
Quercus (Oak)	*Bombax* (Red silk cotton)
Casuarina equisetifolia (Jhau)	*Michelia excelsa* (Champak)
Adina cordifolia (yellow teak) *Hopea* (Dammar tree) *Dalbergia sisso* (Shisham) *Prosopis* (Jand) *Anogeissus latifolia* (Axle wood, Dhawra) *Ceripos tagal* (Goran) *Gmelina arborea* (Gumhar) *Terminalia tomentosa* (Asna) *Syzygium cumini* (Jambolana Jamun)	

The angiospermic wood (hard wood) is generally better than gymnospermic wood (soft wood). Soft wood produces intense heat but for shorter periods and hard wood gives uniform heat for longer periods. Bad fuel wood does not catch fire quickly, has low flame, low calorific value, gets burnt quickly, and is full of smoke with offensive odour.

Due to increase in population, the demand of fuel wood is increasing day by day and this has led to fuel wood crisis. In order to overcome fuel wood crisis, following methods have been suggested :

(1) To grow more fuel wood trees, *i.e.*, energy plantations.
(2) Proper designing of wood stoves or chullahs in order to increase efficiency of these and hence to save energy loss.
(3) Electric cremation should be enhanced
(4) Energy production from woods by different processes like carbonisation (Change of wood into carbon/charcoal by heating), gasification (change of wood into producer gas by passing steam over incandescent coke), pyrolysis (thermochemical conversion of wood into charcoal, pyroligneous acid (10% acetic acid), wood gas, wood tar, wood alcohol, etc.).

13.3 Energy Plantations

Energy plantations mean to grow more trees for fuelwood. The uses of energy plantations are :

(1) Solar energy can be stored continuously.
(2) Minimum technology is required for raising the trees.
(3) hey are ecologically safe, economical, renewable and sufficient manpower is available to raise them.

13.4 Mobilisation of land Resources

To minimise the danger of loss of agricultural land for growing fuelwood, trees should be grown for fuelwood on :

(1) On farmer's own land where cultivation is not done.
(2) Village common lands
(3) Along both sides of road, canals and railway tracks
(4) On degraded forests and
(5) On wastelands

Over 30 million hectares of land is available in India for energy plantations, without affecting land under agricultural and industrial use.

13.5 Selection of Suitable Species

While selecting suitable species following criteria can be considered :

(1) The saplings should establish quickly and rapidly.
(2) The species should be preferably local and well adapted to local climatic and soil conditions.
(3) It should have high coppicing ability or regenerative potential. Coppicing means thick growth of branches from the stump after the aerial branches have been removed. Coppiced growth is faster as compared to the growth of new saplings because they have already established root system.
(4) The plant should be able to grow with minimum water and fertilizer requirement.
(5) The plant should draw minimum quantity of nutrients from soil.
(6) Plants should be able to improve the soil quality like sterilization, correction of alkalinity or acidity etc.
(7) Plants should have the xerophytic character when grown under xeric conditions.
(8) Plants should be resistant to pests and diseases.
(9) Plants grown along both the sides of roads and railway tracks should be able to tolerate water logging

13.6 Development of Suitable agro-Technology

Techniques of growing particular species in particular habitat must be carried out to get maximum yield. Cultivating grasses and fodder crops along with fuel wood species brings out maximum land use.

13.7 Producer Gas

It is mixture of mainly *CO*, H_2, *and* O_2. Producer gas is produced due to incomplete combustion of coal and wood. With restricted supply of air, coal and wood is burnt.

Mixture gas thus produced is passed through filter to remove shoot and ashes. Now the gas is passed through coolers to condense other waste residue. Now the gas is released for industrial use. This gas is free from pollution.

Raw material for producer gas is easily available and can be produced at normal temperature. The gas produced is inflammable but otherwise costly and generates less power.

13.8 Agro-industrial Residues

Some methods have been devised for bioconversion of agricultural residues, industrial waste materials and animal wastes into energy. This is very important in solving the environmental pollution problems.

About 28 percent of population in the developing countries uses dung and crop residues as fuel for cooking food. Thus potential fertilizer of the agricultural fields is wasted in burning. The problem can be solved by using dung to produce gobar gas (biogas) and residue can be used as manure. The aerobic fermentation of dung yields fuel as well as fertilizer.

13.9 Biogas (Gobar gas)

Biogas is methane rich fuel gas produced by anaerobic breakdown and fermentation of biomass.

Biogas consists of 50- 70% CH_4 (methane), 30- 40% CO_2, 1% H_2S and traces of H_2, N_2, O_2 and *CO*. Calorific value of biogas is 4,429 $kcal/m^3$ (23-28 MJ/m^3), and its CH_4 content is 50%.

Table : Composition of biogas

S.N.	Name of gas	Chemical formula	Percentage
(1)	Methane	CH_4	50-68%
(2)	Carbon dioxide	CO_2	25–35%
(3)	Hydrogen	H_2	1–5%
(4)	Nitrogen	N_2	2–7%
(5)	Oxygen	O_2	0–0.1%
(6)	Hydrogen sulphide	H_2S	Rare

Biogas generation is a three stage anaerobic digestion of animal and other organic wastes.

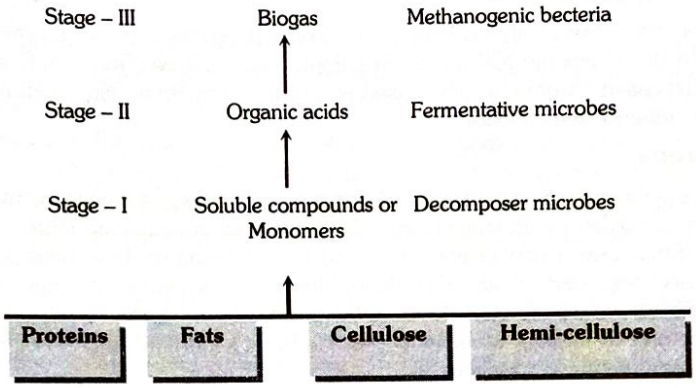


Fig : Possible stages in anaerobic digestion during biogas formation

(1) **First Stage :** The facultative anaerobic micro-organisms breakdown the polymers into soluble monomers with the help of enzymatic hydrolysis. The complex carbohydrates such as cellulose and hemicellulose are degraded by cellulytic enzymes.Proteins are broken by proteolytic enzymes and lipids by lipolytic enzymes.Lignin cannot be broken down by micro-organisms, so it remains as residue along with inorganic salts.

(2) **Second Stage :** Here the monomers become the substrate for micro-organisms. These are then converted into organic acids.

(3) **Third Stage :** In this stage soluble organic acids (acetic acid) are formed for the substrates of the last stage.Finally methanogenic anaerobic bacteria (*e.g., Methanobacterium, Methanobacillus, Methanosarcina* and *Methanococcus*) produce methane (biogas).

13.10 Biogas plants

Biogas (gobar gas) generation has been taken up in India on a large scale. One such plant already exists at Okhla near New Delhi which generates a total of about 0.6 million cubic feet of gas per day. About 1.95 lakh biogas plants were set up during 1985-86 under the National Biogas Development Programme.

(1) **Important Substrates in Biogas Production :** Animal wastes like dung of cattle, urine and slaughter house wastes; agroindustrial wastes like oil cakes, sugar industry wastes, wastes from fruits and vegetables processing; agricultural or crop residues; human wastes (night soil); urban solid wastes and also aquatic plants like *Eichhorina* (water hyacinth), *Wolffia, Hydrilla, Salvinia, Azolla* and algae, etc.
In biogas production, water content is maintained at 90% at which most methanogenic bacteria are active.
The biogas so produced can be used for different purposes, can be efficiently used and stored easily. Further pathogens of faecal matter can be reduced (sanitation) and thus disease cycles are broken.

(2) **Benefits of Biogas:**

- Availability of power at affordable rates has the following benefits:
- Reduces pollution
- Reduces time wastage while collecting firewood
- Reduces reliance on fossil fuels
- Lowers fuel import bill
- Saves on the environment (Reduces deforestation)
- Improves living standards in rural areas.
- Reduces global warming
- Produces good quality enriched manure to improve soil fertility.
- Effective and convenient way for sanitary disposal of organic wastes,
- Improving the hygienic conditions.

14. Energy Cropping and Petroplants

These are renewable resources of energy. Growing of crops from which alcohol and other energy fuels can be produced, constitute energy cropping.

Important plants of energy cropping (*i.e.*, energy crops) are :

(a) Saccharum officinarum (Sugarcane)

(b) Beta vulgaris (Beet root or Chukandar)

(c) Solanum tuberosum (Potato)

(d) Zea mays (Maize)

(e) Manihot glaziovii (Tapioca)

These plants are efficient users of solar energy.

These plants can be easily changed into ethanol (ethyl alcohol).

The pioneer country in the production of fuel alcohol is Brazil. Pro alcohol programme in Brazil is aimed at completely replacing petrol with alcohol for running automobiles. In Brazil, ethanol fuel is used in automobiles (95% alcohol), where as in USA, 85-90% petrol is mixed with 10- 15% alcohol to form a new fuel called gasohol, which is used as fuel in automobiles. But slight modification is required in conventional engines to use these new fuels, *i.e.*, ethanol and gasohol.

14.1 Petroplants or Petrocrops

- Latex of some plants containing long chain hydrocarbons is considered to be a good substitute for liquid fuels or petroleum. Such plants having large amount of latex with long chain hydrocarbons are called petroplants.
- Cultivation of petroplants is also a part of energy-cropping. Cultivation of these petrocrops was first of all done by Italians in Ethiopia about fifty years back, although actual credit for identifying the petrocrops goes to Dr. Melvin Calvin.
- Dr. Calvin was first to identify few petroleum plants whose products can be used in place of petrol and oil.
- Most of such plants belong to families asclepiadaceae, euphorbiaceae and apocynaceae. These plants are able to convert a substantial amount of photosynthates into latex.
- Latex contains long chained liquid hydrocarbons. These can be used directly or broken to hydrocarbons of chain length similar to the ones present in petrol.
- Their hydrocarbon contents can be increased by genetic manipulations (genetic engineering). But commercial production of petroleum or liquid fuel alternative (through petroplants) is in early stage.

14.2 Most Common Petrocrops are

(a) Euphorbia antisyphilitica
(b) E. caudicifolia
(c) E. lathyris (Gasoline tree)
(d) E. royleana
(e) Calotropis procera
(f) Copaifera langsdorfii (A Brazilian tree and its sap is a good alternative for diesel. About 3 litres of sap per month is produced per tree, which can be filled directly in fuel tank of diesel engine automobile).
(g) Cryptostegia grandiflora
(h) Pittosporum resiniferum (Petroleum nut)

The use of these petroplants may reduce the pressure on liquid fuel or petroleum.

14.3 Biofertilizers

Fertilizers of biological origin are called biofertilizers. These provide the essential elements to the soil and hence maintain or increase the soil fertility. Use of these biological fertilizers is safe both economically as well as ecologically.

There are two main categories of fertilizers of biological origin:

(1) Green Manures : These are fast growing herbaceous crops which are ploughed down and mixed with the soil while still green for enrichment of soil.

These provide both organic matter and nitrogen to the soil, in which Indian soils are generally poor.

The green manure checks soil erosion by forming protective soil cover and also prevents leaching. Increase in yield by 30-50% has been observed by the use of green manuresSome important green manure crops, which are mostly members of family Leguminosae are as follows:

(i) *Trifolium alexandrianum* (Barseem or Egyptian clover)
(ii) *Melilotus parviflora* (Senji/Sweet clover)
(iii) *Dolichos biflorus* (Horse gram or Kulthi)
(iv) *Lens esculenta* (Lentil or Masure)
(v) *Cyamopsis tetragonoloba* (Guar or Cluster bean)
(vi) *Sesbania sesban* (Dhaincha)
(vii) *Crotalaria juncea* (Sunhemp or Sunn)
(viii) *Vigna sinensis* (Lobiya or Cowpea)

(2) Biofertilizers : These are the organisms which bring about nutrient enrichment of the soil. Some of the important biofertilizers are :

- **Blue-green algae (Cyanobacteria) as biofertilizers**

  (i) Symbiotic Nitrogen-fixing blue-green algae

  Anabaena azollae, *Anabaena cycadacae* and *Nostoc punctaeformae* are present symbiotically in leaves of *Azolla* (water fern), *Cycas* roots and *Anthoceros* thallus respectively, which fix atmospheric nitrogen. *Azolla-Anabaena* symbiotic system is the main biofertilizer which is inoculated in rice fields in South-Eastern Asia, which is found to increase yield upto 50%

  (ii) Free living Nitrogen-fixing blue-green algae

  Blue-green algae like *Nostoc*, *Anabaena*, *Aulosira*, *Tolypothrix*, *Plectonema* and *cylindrospermum* are the most common nitrogen fixing organisms, probably with the help of heterocysts. Photosynthesis provides the energy for nitrogen fixation. In the rice fields, *Aulosira* is the most active nitrogen fixing blue green algae. It is estimated that 7-8 lakh tons of nitrogen can be fixed by blue-green algae thus saving 15-17 lakh tons of urea every year.

- **Bacteria as Biofertilizers**

  (i) Free-living Nitrogen-fixing Bacteria : Some bacteria like *Azotobacter* (aerobic), *Clostridium* (anaerobic), *Rhodospirillum*, *Chromatium* (photosynthetic bacteria) are free living nitrogen fixing bacteria of soil, which increase fertility of soil and hence yield of crop plants.

  (ii) Symbiotic Nitrogen-fixing Bacteria : *Rhizobium leguminosarium* bacteria live symbiotically in root nodules of legumes and some non-legumes, which fix atmospheric N_2 and hence increase the fertility of soil.

  (iii) Loose association of Nitrogen-fixing Bacteria : A bacterium *Azosprillum lipoferum* forms loose association with roots of maize and some Brazilian grasses (Dobreiner, 1975), which increase the crop yield upto a large extent.

- **Fungi as Biofertilizers**

  (i) Mycorrhiza : Symbiotic association between roots of higher plants and fungal hyphae, is called mycorrhizal association or mycorrhiza. It is of 2 types :

  Endotrophic or Endophytic Mycorrhiza : Here, fungal hyphae are present inside or between the cells of cortex, *e.g.*, in Coffee, Pepper and Cardamon, etc.

  In many grasses and some other crops, the fungal hyphae penetrate to the cortical cells, which swell to form vesicles or arbuscules, called vesicular-arbuscular mycorrhiza (VAM). It has significant role in phosphate nutrition of plants

  (ii) Ectotrophic or Ectophytic Mycorrhiza :

  Here, fungal hyphae are present on the surface of roots. It increases water and nutrient absorption, growth, vigour and yield of plants, *e.g.*, in Pinus, Oak, Eucalyptus, Peach, etc.

14.4 Advantages of bio Fertilizers

(1) Bio fertilizers are usually eco-friendly and also guard the particular ecosystem in opposition to pollution.
(2) Bio fertilizers eliminate people damaging parts from your earth which usually result in conditions inside the crops. Crops can be safeguarded in opposition to drought as well as other stringent ailments through the use of resource fertilizers.
(3) Bio fertilizers usually are not expensive and also weak farmers can easily utilize these.
(4) They help acquire large produce regarding vegetation simply by creating the particular earth abundant together with vitamins and minerals and also microbes required for the particular progress with the crops.
(5) Bio fertilizer increases the actual and also substance attributes regarding earth.

15. Biological pest Control

Due to harmful effects of pesticides on organisms, some alternative methods of pest control are being used and biological pest control is one of the suitable methods, *i.e.*, use of other organisms to kill the pests constitutes biological pest control and such organisms are called biopesticides.

Bioherbicides / Biological Control of weeds

Bioherbicides are organisms or their extracts which destroy weeds without harming useful plants.

The first bioherbicide is devine, which is a mycoherbicide, based on fungus *Phytophthora palmivora*. It is being used since 1981 to control *Morrenia odorata* (milkweed vines) in *Citrus* orchards.

Similarly Collego is another mycoherbicide from conidia *Colletotrichum gloeosporioides* fungus.

16. Bioinsecticides

They are living organisms or their products which are able to kill or repel specific insects.

16.1 Use of Parasites, Predators and Pathogens

e.g., control of aphids by use of praying mantis or lady bug, *i.e.*, *Mantis*.

Bacillus Thuringiensis : One of the most widely used bioinsecticide is a naturally occurring soil bacterium called *Bacillus thuringiensis* or *Bt.* that produces a protein, poisonous to insects. Insects affecting maize, cotton, cabbage, sunflowers, etc. are controlled by mutant strains of *Bacillus thuringiensis (Bt) bacteria* (sporeine). Often within 15 minutes of being eaten, the poisons

begin to create ulcers in the insect's stomach lining. The insect stops eating and eventually dies. Researchers have identified between 500 and 600 strains, or types of *Bacillus thuringiensis*. *Bt* is very selective, it affects only a specific species of insect pest and does not harm humans, birds, fish or beneficial insects.

Prickly pear cactus (*Opuntia*) in Australia and India was effectively controlled by larvae of *Cactoblastis cactorum* (Cochineal insect). By use of lady bugs or praying mantis, aphids (plant bugs or homopterous insects) can be kept under control. Fluted scale insect (*Icerya purchasi*), a pest on *citrus* can be effectively controlled by lady bird beetles. Similarly mosquito larvae can be easily controlled by fish *Gambusia* and sugar cane scale insects are controlled by coccinellid predators.

16.2 Use of natural Insecticides

The insecticides of plant or micro-organisms origin are called natural insecticides. These have little toxicity for animals, *e.g.*, Rotenone (from roots of *Derris* sps. and *Lonchocarpus* sps.); different alkaloids like Nicotine (from tobacco), Pyrethrum and Cinerin (from *Chrysanthemum*); Azadirachtin (from *Margosa* or Neem) are useful natural insecticides.

Neem or margosa (*Azadirachta indica*) is most useful natural insecticide. It is resistant to about 200 species of insects, nematodes, mites, etc.

16.3 Sterilization Technique

This is a modern method of biological pest control. In this technique, male insects are sterilized by irradiation, these are released at the time of mating and hence their multiplication is checked, *e.g.*, screw worm (*Cochliomyia hominivorax*) and red weevil (a pest on coconut) have been checked by this method.

16.4 Use of insect hormones (Sex attractants)

The insect hormones called pherohormones (Pheromones) are useful in controlling insects. These pherohormones attract opposite sex insects during breeding season. The natural and synthetic pherohormones are now used to attract the insects towards death traps. The Orient-fruit fly has been eradicated by this method. Similarly, gipsy moth, a pest of conifers can be trapped.

Use of insect hormones like juvenile hormone and moulting hormone or ecdysone is also made as bioinsecticides, Juvenile hormone should be present in early stages of growth to prevent early maturation, but if the same is given artificially at later stage of growth, the insect is transformed into giant larva (immature adult) which dies quickly. Similarly, periodic shedding of insect cuticle (moulting) occurs during the process of growth and ecdysone hormone is associated with moulting. Use of this hormone at inappropriate time also results in early death of insect. 'Confusion Technique' is a variation of this approach and it involves use of pheromones or sex attractants. In this technique, hydrophobic paper having pheromones or sex attractants is placed over the crop area, due to which characteristic smell is spread over the whole field and thus males are unable to locate the females.

16.5 Integrated Pest Management (IPM)

IPM involves use of different pest control methods, which are ecologically sound (*i.e.*, not cause hazard to environment), *e.g.*, biological control methods, better agricultural practices like crop rotation, sanitation, etc. starvation method, *i.e.*, growing of target.

crop away from major crop, ultra low volume spraying method, *i.e.*, use of very low and most effective concentration of chemicals, which does not cause pollution etc.

Applications

IPM is used in agriculture, horticulture, forestry, human habitations, preventive conservation and general pest control, including structural pest management, turf pest management and ornamental pest management.

Do You Know

Per hectare potential production of alcohol 4000 litres for Sugarcane, 1800 litres for Sugarbeet, 1650 litres for Potato and 1125 litres for Maize. Fuel wood consumption provides 43% of total energy consumed in developing countries and amounts to about 14% of total world's energy production. Pyrolysis is heating of wood and waste wood to high temperature. The products are charcoal, pyroligneous acid, tar, oil, wood alcohol and wood gas. The energy potential of DAP is enormous. Hardwood is better as a fuel than softwood. Fuel gas (methane) is obtained by anaerobic fermentation of gobar gas. Fuel wood is a renewable energy source.

Gosohol : Brazil is obtaining alcohol from Sugarcane while USA is from Maize.

Methanogens : Essential for biogas production. Decomposers are required for breaking down organic wastes.

Sporeine developed in Germany is first commercial bioinsecticide obtained from Bacillus thuringenesis. Red squill (Urginea maritima) produce a raticide harmless to other animals.

Juvenile Hormone : spray prevents larvae to metamorphose. They die without reproduction.

Male Sterilisation : The technique was developed by Kiplings (1955). It has been used to eradicate Screw Worm.

Biological Control of Parthenium : Zygogramma bicolorata, a beetle, suppresses Parthenium hysterophorus effectively. It, however, also attacks sunflower, shoot and root borer insect Nupserha lenita reduces population of the weed. Marigold and Cassia tora are two plants that can displace Parthenium. The latter is also controlled by spray of Gliocladium virens and Trichoderma viride.

Parasitoids : They are organisms which are parasite in early stages (egg and larval) but live freely later on e.g., parasitoid Wasp or Cabbage Butterfly.

32. Microbes in Human Welfare – Multiple Choice Questions

1. House Hold Food Processing

1. Which of the following organism is useful in the preparation of Roquefort cheese
   (a) Mucor (b) Rhizopus
   (c) Aspergillus (d) Penicillium
2. Cheese is prepared from
   (a) Lactobacillus
   (b) Streptococcus
   (c) Myrothecium
   (d) *Streptococcus, Lactobacillus* and *Leuconostoc*
3. Lactic acid bacteria (LAB) at a suitable temperature converts milk to curd, which improves its nutritional quality by enhancing vitamin
   (a) A (b) B (B12)
   (c) C (d) D
4. Curdling of milk takes place by
   (a) Streptococcus lactis
   (b) Streptococcus thermophilus
   (c) Lactobacillus lactis
   (d) All the above

2. Industrial Production

1. A compound which is produced by an organism and inhibits the growth of other organism is called
   (a) Antigen (b) Antibiotic
   (c) Antibody (d) Interferon
2. Streptomycin was first isolated in 1944 – 45 by
   (a) Leeuwenhoek (b) Burkholder
   (c) Alexander Fleming (d) Waksman
3. For the manufacture of gluconic acid and citric acid, which of the following microorganism is used
   (a) Lactobacillus bulgaricus (b) Acetobacter sp.
   (c) Aspergillus niger (d) Gluconobacter sp.
4. Match the microbes in column I with their commercial/ industrial products in column II and choose the correct answer

Column I		Column II	
A.	Aspergillus niger	1.	Ethanol
B.	Clostridium butylicum	2.	Stains
C.	Saccharomyces cerevisiae	3.	Citric acid
D.	Trichoderma polysporum	4.	Butyric acid
E.	Monascus purpureus	5.	Cyclosporin A

   (a) A-4, B-5, C-2, D-1, E-3 (b) A-5, B-4, C-1, D-2, E-3
   (c) A-3, B-4, C-1, D-5, E-2 (d) A-3, B-4, C-5, D-1, E-2
   (e) A-2, B-3, C-4, D-5, E-1
5. Germinating barley seeds are employed in the preparation of
   (a) Cheese (b) Wine
   (c) Beer (d) Lactic acid
6. Conversion of sugar into alcohol during fermentation is due to the direct action of
   (a) Temperature
   (b) Micro-organisms
   (c) Concentration of sugar solution
   (d) Zymase
7. Vitamin B_{12} is produced directly during the course of fermentation by
   (a) Ashbya gossypii
   (b) Rhizopus stolonifer
   (c) Saccharomyces cerevisiae
   (d) Propionibacteria
8. Yeast is an important source of
   (a) Vitamin *C* (b) Vitamin *B*
   (c) Vitamin *A* (d) Vitamin *D*
9. Which one of the following is used in the baking of the bread

   Or

   Baker's yeast is

   Or

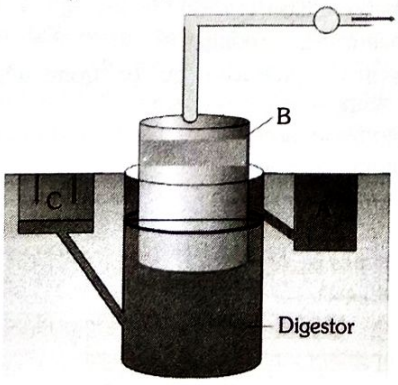
   The dough used for making bread is fermented by
   (a) Rhizopus stolonifer
   (b) Zygosaccharomyces
   (c) Saccharomyces cerevisiae
   (d) Saccharomycodes Ludwig
10. Antibiotics are mostly obtained from
    (a) Fungi (b) Actinomycetes
    (c) Cyanobacteria (d) Both (a) and (b)
11. Which of the molecules listed below is a product of fermentation of glucose by yeast
    (a) $(C_6H_{10}O_5)n$ (b) C_2H_5OH
    (c) $C_6H_{12}O_6$ (d) CH_3OH
12. The microbe *Pseudomonas denitrificans* produces Vitamin
    (a) *K* (b) *D*
    (c) B_2 (d) B_{12}
13. The 'clot buster' produced by *Streptococcus* and modified by genetic engineering is
    (a) Streptokinase (b) Penicillin
    (c) Strepsils (d) Cyclosporin A
    (e) Stains
14. Which of the following is maintained for optimum production of vinegar
    (a) Anaerobic condition
    (b) Temperature of 95°C
    (c) Aerobic condition
    (d) Microaerophilic condition
15. Streptomycin is produced by or from which micro-organism streptomycin is prepared
    (a) Streptomyces venezuelae
    (b) Streptomyces griseus
    (c) Streptomyces coleus
    (d) Streptomyces fradiae
16. *Torulopsis utilis* is
    (a) A food yeast
    (b) Employed for the synthesis of citric acid
    (c) An important intestinal commensal
    (d) A microorganism that yields third-generation vaccines
17. Neomycin is extracted from
    (a) Streptomyces griseus
    (b) Streptomyces venezuelae
    (c) Streptomyces fradiae
    (d) Streptomyces rimosus

3. Sewage Treatment

1. In the sewage treatment, bacterial flocs are allowed to sediment in a settling tank. This sediment is called as
   (a) Inactivated sludge (b) Activated sludge
   (c) primary sludge (d) secondary sludge
2. The solids which settle after primary treatment of sewage are called
   (a) Primary sludge (b) Activated sludge
   (c) Flocs (d) Total solids
3. Study the following statements and select the incorrect ones
   (i) Physical removal of large and small particles through filtration and sedimentation is called primary sewage treatment.
   (ii) Secondary sewage treatment is mainly a mechanical process
   (iii) Activated sludge sediment in a sewage treatment plant is a rich source of aerobic bacteria.
   (iv) Biogas, commonly called as gobar gas, is pure methane.
   (a) (i) and (ii) (b) (ii) and (iv)
   (c) (ii) and (iii) (d) (iii) and (iv)
4. Which of the option shows the following example in ascending order in terms of BOD
   (i) Distilled water
   (ii) Tap water
   (iii) Sewage wastes drained in the river
   (a) i - ii-iii (b) iii - iii
   (c) iii - iii (d) iii - ii – i

4. Bioenergy

1. Biogas can be a good substitute for
   (a) Fuel wood (b) Petroleum and oil
   (c) Coal (d) Charcoal
2. Biogas is a mixture of
   (a) $CO+H_2+CO_2$ (b) $CH_4+CO+CO_2$
   (c) $CH_4+CO_2+H_2$ (d) $CO+CO_2+NO_2$
3. In developing countries, the heaviest demand on forests is for
   (a) Fuel wood (b) Furniture wood
   (c) Fruits (d) None of these
4. The following figure shows a typical biogas plant. Select the right option in which products labelled as A, B and C are correctly identified



   (a) A - Sludge; B - Methane, CO_2; C - Sewage
   (b) A - Sludge; B - Ethylin Carbon dioxide; C - Dung, water
   (c) A - Sludge; B - Methane, CO_2; C - Dung, water
   (d) A - Sludge; B - Methane, Oxygen; C - Dung, water
5. Methanogenic bacteria are not found in
   (a) Rumen of cattle
   (b) Gobar gas plant
   (c) Bottom of waterlogged paddy fields
   (d) Activated sludge
6. The technology of biogas production from cow dung was developed in India largely due to the efforts of
   (a) Gas Authority of India
   (b) Oil and Natural Gas Commission
   (c) Indian Agricultural Research Institute and Khadi and Village Industries Commission
   (d) India Oil Corporation
7. The residue left after methane production from cattle dung is
   (a) Burnt
   (b) Buried in landfills
   (c) Used as manure
   (d) Used in civil construction
8. Methanogens do not produce
   (a) Oxygen (b) Methane
   (c) Hydrogen sulfide (d) Carbon dioxide
9. One of the following plants have contributed to coal formation
   (a) Pteridophytes (b) Gymnosperms
   (c) Bacteria (d) Archaebacteria
10. A Bioenergy source obtained by fermentation to supplement fossil fuel petrol is
    (a) Kerosene (b) Ethanol
    (c) Diesel (d) Methane
11. The pioneer country in the production of fuel-alcohol is
    (a) Saudi Arabia (b) Iran, Iraq
    (c) Brazil (d) Japan
12. The black wood tree of India is
    (a) Acacia nilotica (b) Dalbergia sissoo
    (c) Dalbergia latifolia (d) Mangifera indica

5. Biofertilizer

1. Cow dung is appropriately used as
   (a) Manure (b) Fuel
   (c) Medicine (d) Building material
2. Mycorrhiza is a symbiotic association between
   (a) Bacteria and fungi
   (b) Algae and fungi
   (c) Fungi and roots of higher plants
   (d) Blue green algae and roots of higher plants
3. Crop rotation is carried out for
   (a) Increasing acidity of soil
   (b) Decreasing fertility of soil
   (c) Increasing fertility of soil
   (d) All the above
4. VAM is important for
   (a) Breaking of dormancy (b) Phosphate nutrition
   (c) Water uptake (d) Retarding flowering
   (e) Decrease in yield
5. Mycorrhiza does not help the host plant in
   (a) Enhancing its phosphorus uptake capacity
   (b) Increasing its tolerance to drought
   (c) Enhancing its resistance to root pathogens
   (d) Increasing its resistance to insects
6. Which one of the following is not a nitrogen-fixing organism
   (a) Anabaena (b) Nostoc
   (c) Azotobacter (d) Pseudomonas
7. Which one is a biofertilizer
   (a) NPK mixture
   (b) Rhizobia in legume roots
   (c) Rhizobia in farmyard manure
   (d) Green manure

8. Rhizosphere is the region where
(a) *Rhizobium* form root nodules
(b) Algae and root make contact
(c) Soil and root make contact
(d) Bacterial and root nearly make contact

6. Pest control

1. Thurioside is proteinaceous toxin obtained from
(a) Biofertilizer (b) Green manure
(c) Bacterial origin (d) Farmyard manure
2. Confusion technique uses
(a) Juvenile hormone
(b) Ecdysone
(c) Pheromone
(d) A combination of hormones
3. Pyrethrin is extracted from
(a) Azadirachta indica
(b) Helianthus annuus
(c) Poa indica
(d) Chrysanthemum cinerariifolium
4. Match the items in Column 'A' and Column 'B' and choose correct answer

Column A		Column B	
A.	Lady bird	i.	Methanobacterium
B.	Mycorrhiza	ii.	Trichoderma
C.	Biological control	iii.	Aphids
D.	Biogas	iv.	Glomus

The correct answer is
(a) A-ii, B-iv, C-iii, D-i (b) A-iii, B-iv, C-ii, D-i
(c) A-iv, B-i, C-ii, D-iii (d) A-iii, B-ii, C-i, D-iv

7. NEET & AIIMS

1. The dough kept overnight in warm weather becomes soft and spongy because of **[2004]**
(a) Cohesion
(b) Osmosis
(c) Absorption of carbon dioxide from the atmosphere
(d) Fermentation
2. Conversion of milk to curd improves its nutritional value by increasing the amount of **[2018]**
(a) Vitamin E (b) Vitamin B_{12}
(c) Vitamin A (d) Vitamin D
3. Who coined the term 'antibiotics" **[2003; 2004]**
(a) Flemming (b) Florey
(c) Chain (d) S. Waksman
4. Citric acid is produced by **[1995, 98; 2013]**
(a) Aspergillus niger (b) Streptococcus lactic
(c) Acetobacter suboxydans (d) Candida utilise
5. The organism used for alcohol fermentation is **[1995; 1998, 2001]**
(a) Penicillium (b) Pseudomonas
(c) Aspergillus (d) Saccharomyces
6. Antibodies in our body are complex **[2006]**
(a) Prostaglandins (b) Glycoproteins
(c) Lipoproteins (d) Steroids
7. Saccharomyces is commonly used in the production of **[2006, 2011]**
(a) Ethyl alcohol (b) Curd
(c) Citric acid (d) Acetic acid
8. Which one of the following pairs is *not* correctly matched **[2004]**
(a) Spirulina - Single cell protein
(b) Rhizobium - Biofertilizer
(c) Streptomyces - Antibiotic
(d) Serratia - Drug addiction
9. Which one of the following is a wrong matching of a microbe and its industrial product, while the remaining three are correct **[2011]**
(a) *Clostridium butylicum* – lactic acid
(b) *Aspergillus niger* – citric acid
(c) *Yeast* – statins
(d) *Acetobacter aceti* – acetic acid
10. Yeast is used in the production of **[2012]**
(a) Citric acid and lactic acid (b) Lipase and pectinase
(c) Bread and beer (d) Cheese and butter
11. Which one of the following pairs is wrongly matched **[2007]**
(a) Methanogens – Gobar gas
(b) Yeast – Ethanol
(c) Streptomycetes – Antibiotic
(d) Coliforms – Vinegar
12. *Monascus purpureus* is a yeast used commercially in the production of **[2012]**
(a) Ethanol
(b) Streptokinase for removing clots from the blood vessels
(c) Citric acid
(d) Blood cholesterol lowering statins
13. Match the following list of microbes and their importance

(A)	Saccharomyces cerevisiae	(i)	Production of immunosuppressive agents
(B)	Monascus purpureus	(ii)	Ripening of swiss cheese
(C)	Trichoderma polysporum	(iii)	Commercial production of ethanol
(D)	Propionibacterium Sharman	(iv)	Production of blood cholesterol lowering agents

[2015]

	(A)	(B)	(C)	(D)
(a)	(iii)	(ii)	(i)	(iv)
(b)	(iv)	(ii)	(i)	(iii)
(c)	(iii)	(i)	(iv)	(ii)
(d)	(iii)	(iv)	(i)	(ii)

14. Which of the following is wrongly matched in the given table **[2016]**

	Microbe	Product	Application
(a)	Trichoderma polysporum	Cyclosporin A	Immunosupressive drug
(b)	Monascus purpureus	Statins	Lowering of blood cholesterol
(c)	Streptococcus	Streptokinase	Removal of a clot from a blood vessel
(d)	Clostridium butylicum	Lipase	Removal of oil stains

15. Which one of the following population interactions is widely used in medical science for the production of antibiotics **[2018]**
(a) Amensalism (b) Parasitism
(c) Mutualism (d) Commensalism
16. During sewage treatment, biogases are produced which include **[2013]**
(a) Hydrogen sulfide, nitrogen, methane
(b) Methane, hydrogen sulfide, carbon dioxide
(c) Methane, oxygen, hydrogen sulfide
(d) Hydrogen sulfide, methane, sulfur dioxide

17. With the exception of water, which one of the following is possibly the most important accessory chemical substance in industrial processes **[1994]**
(a) Petroleum (b) Rubber
(c) Ethanol (d) Liquid nitrogen

18. Major autotrophic biomass in oceans is contributed by **[2000]**
(a) Forests
(b) Algae and phytoplanktons
(c) Crops
(d) None of these

19. One of the following bacterial groups are exploited in biogas production **[2016]**
(a) Methanogens (b) Methanotrophs
(c) Organotrophs (d) Eubacteria

20. The current consumption on domestic firewood in India is about **[1990]**
(a) 18.6 million tonnes (b) 146.5 million tonnes
(c) 1246 million tonnes (d) 21870 million tones

21. What type of fuel are coal, petroleum and natural gas **[1990]**
(a) Biofuels (b) Electrical fuels
(c) Fossil fuels (d) Liquid fuels

22. In gobar gas, the maximum amount is that of **[2004; 2012]**
(a) Butane (b) Methane
(c) Propane (d) Carbon dioxide

23. Recently government of India has allowed mixing of alcohol in petrol. What is amount of alcohol permitted for mixing in petrol **[2004]**
(a) 2.5% (b) 10-15%
(c) 10% (d) 5%

24. A good fodder **[1991]**
(a) Contains high dry matter
(b) Is free from disease and pest
(c) Has nutrient without toxicity
(d) All of these

25. Which of the followings is mainly produced by the activity of anaerobic bacteria on sewage **[2011]**
(a) Marsh gas (b) Laughing gas
(c) Propane (d) Mustard gas

26. The biomass can be used to **[1992]**
(a) Obtain alcohol (b) Generate biogas
(c) Generate producer gas (d) All of these

27. The economically friendly measure to conserve solar energy is **[1999]**
(a) Sugarcane plantation (b) Energy plantation
(c) Both (a) and (b) (d) None of these

28. Which of the following plant species you would select for the production of bioethanol **[2009]**
(a) Brassica (b) Zea mays
(c) Pongamia (d) Jatropha

29. Which one of the following is being tried in India as a biofuel substitute for fossil fuels **[2008]**
(a) Musa (b) Aegilops
(c) Jatropha (d) Azadirachta

30. Which one of the following is being utilized as a source of biodiesel in the Indian countryside **[2007]**

Or

An example of Petrocrop is **[2012]**
(a) Euphorbia (b) Beetroot
(c) Sugarcane (d) Pongarnia

31. Select the correct statement from the following **[2010]**
(a) Activated sludge-sediment in settlement tanks of sewage treatment plant is a rich source of aerobic bacteria
(b) Biogas is produced by the activity of aerobic bacteria on animal waste
(c) *Methanobacterium* is an aerobic bacterium found in rumen of cattle
(d) Biogas, commonly called gobar gas, is pure methane

32. The common nitrogen-fixer in paddy fields is **[2010]**
(a) Frankia (b) Rhizobium
(c) Azospirillum (d) Oscillatoria

33. Red pigment (Leghaemoglobin) having affinity for oxygen is present in the roots of **[2001]**
(a) Mustard (b) Soybean
(c) Carrot (d) Radish

34. *Azolla* enriches rice fields with nitrogen due to its association with **[2012]**
(a) Anabaena (b) Nostoc
(c) Rhizobium (d) Frankia

35. An organism used as biofertilizer for raising soyabean crop is **[2011]**
(a) Nostoc (b) Azotobacter
(c) Azospirillum (d) Rhizobium

36. Which is correct **[1994]**
(a) Legumes fix nitrogen through bacteria in their leaves
(b) Legumes fix nitrogen through bacteria in their roots
(c) Legumes fix nitrogen independent of bacteria
(d) Legumes do not fix nitrogen

37. Mycorrhiza represents **[1994]**
(a) Antagonism (b) Endemism
(c) Symbiosis (d) Parasitism

38. Which one of the following is not biofertilizer **[2011]**
(a) Mycorrhiza (b) Agrobacterium
(c) Rhizobium (d) Nostoc

39. Azotobacter and Bacillus polymyxa are **[1996]**
(a) Decomposers
(b) Nonsymbiotic nitrogen fixers
(c) Symbiotic nitrogen fixers
(d) Pathogenic bacteria

40. Yield of paddy field can be increased by application of **[1997; 1999]**
(a) Iron bacteria (b) *Nostoc/Anabaena*
(c) Archaebacteria (d) Symbiotic bacteria

41. Biofertilizers include **[1997, 2001; 2004;]**
(a) Cow Dung manure and farmyard waste
(b) A quick growing crop ploughed back
(c) BGA/*Anabaena* and *Azolla*
(d) All the above

42. Aquatic fern which is an excellent biofertilizer **[1999, 2000,01]**
(a) Salvinia (b) Azolla
(c) Marsilea (d) Pteridium

43. Enzyme required for nitrogen fixation is **[2001]**
(a) Nitrogenase (b) Nitroreductase
(c) Transaminase (d) Transferase

44. Which of the following plants are used as green manure in crop fields and in sandy soils **[2003]**
(a) Dichanthium annulatum and Azolla pinnata
(b) Crotalaria juncea and Alhagi camelorum
(c) Calotropis procera and Phyllanthus niruri
(d) Saccharum munja and Lantana camara

45. Farmers have reported 50% higher yield of rice by using biofertilizer **[1993, 98, 99;1997]**
(a) Azolla pinnata
(b) Legume-Rhizobium symbiosis
(c) Cyanobacteria
(d) Mycorrhiza

46. The bacterium *Bacillus thuringiensis* is widely used in contemporary biology as **[2009]**
(a) Indicator of water pollution
(b) Insecticide
(c) Agent for production of dairy products
(d) Source of industrial enzyme

47. Biological control of pests is **[1994; 2000]**
(a) Polluting (b) Highly expensive
(c) Self perpetuating (d) Toxic

48. The phenomenon of using a predator for controlling a pest is **[1996]**
(a) Biological control (b) Genetic engineering
(c) Artificial control (d) Confusion technique

49. *Bacillus thuringiensis* forms protein crystals which contain insecticidal protein. This protein **[2011]**
(a) Is activated by acid pH of the foregut of the insect pest
(b) Does not kill the carrier bacterium which is itself resistant to this toxin
(c) Binds with epithelial cells of midgut of the insect pest ultimately killing it
(d) Is coded by several genes including the gene cry

50. Which one of the following is an example of carrying out biological control of pests/diseases using microbes **[2012]**
(a) *Trichoderma* spp against certain plant pathogens
(b) Nucleopolyhedrovirus against white rust in *Brassica*
(c) *Bt*–cotton to increase cotton yield
(d) Lady bird beetle against aphids in mustard

51. Microbe used for biocontrol of pest butterfly caterpillars is **[2013]**
(a) Saccharomyces cerevisiae
(b) Bacillus thuringiensis
(c) Streptococcus sp.
(d) Trichoderma sp.

52. Which of the following is not used as a biopesticide **[2009]**
(a) Bacillus thuringiensis
(b) Trichoderma harzianum
(c) Nuclear Polyhedrosis Virus (NPV)
(d) Xanthomonas campestris

53. Third generation pesticides are **[2000]**
(a) Insect repellents
(b) Pheromones
(c) Pathogens
(d) Insect (juvenile) hormone analogues

54. Consider the following statements (A-D) about organic farming
(A) Utilizes genetically modified crops like Bt cotton
(B) Uses only naturally produced inputs like compost
(C) Does not use pesticides and urea
(D) Produces vegetables rich in vitamins and minerals
Which of the above statements are correct **[2011]**
(a) (B) and (C) only (b) (A) and (B) only
(c) (B), (C) and (D) (d) (C) and (D) only

55. Which is a microbial insecticide **[1997]**
(a) Bacillus thuringiensis (b) B. subtilis
(c) B. polymyxa (d) B. brevis

8. Assertion and Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :
(a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion
(c) If the assertion is true but the reason is false
(d) If both the assertion and reason are false
(e) If the assertion is false but reason is true .

1. Assertion : The kneaded flour shows leavening when yeast is added to it.
Reason : Enzymes secreted by yeast cause leavening.

2. Assertion : Yeasts such as *Saccharomyces cerevisiae* are used in baking industry.
Reason : Carbon dioxide produced during fermentation causes bread dough to rise by thermal expansion.

3. Assertion : *Bacillus thuringiensis* is toxic to many insects.
Reason : It inhibits ion transport in the midgut.

4. Assertion : Extraction and purification of enzymes are laborious and expensive.
Reason : Protein engineering can be used to produce enzymes at large scale.

5. Assertion : Charcoal has equal heating power than wood.
Reason : Charcoal burns without producing flame or smoke.

6. Assertion : Pyrethrum is collected from the leaves of *Chrysanthemum cinerariifolium*.
Reason : Pyrethrin is prepared from pyrethrum.