

## 7. Introduction to Microbiology



- Applied Microbiology
- Industrial Microbiology
- Products



**Can you recall?**

1. Which different microbes are useful to us?
2. Which different products can be produced with the help of microbes?

### Applied Microbiology

Branch of biology in which study of the enzymes related to some prokaryotes and eukaryotic microbes, proteins, applied genetics, molecular biology, etc. is performed; is called as applied microbiology. This study is used for the society and various products like food and medicines are produced on large scale with the help of microorganisms.

### Industrial microbiology

This science is related to commercial use of microbes in which various economic, social and environment related processes and products are included. Various microbial processes useful for this purpose are carried out.

#### Industrial Microbiology: main features

- A. Various productions with the help of fermentation process. Ex. Bread, cheese, wine, raw material for chemicals, enzymes, nutrients, medicines, etc.
- B. Use of microbes for garbage management and pollution control.



**Can you recall?**

We use the fermentation process while conversion of milk into yoghurt. Which microbes are useful for this process?

### Products

#### A. Dairy Products

Since ancient days, milk is converted into various products for its preservation purpose. Ex. Cheese, butter, cream, kefir, yoghurt, etc. Water content and acidity of the milk changes during formation of these products and texture, taste and flavour is improved.

These processes are performed on large scale with more skill. For production of most of the milk products, bacteria in milk itself are used; only cheese is produced with the help of fungi. Basic process for production of yoghurt, cheese and cream is same. Milk is pasteurized at the beginning to destroy unwanted microbes. It is then fermented with the help of lactobacilli. In this process, lactose sugar of the milk is converted into lactic acid and milk proteins are coagulated with the help of lactic acid. Besides, compounds with taste and flavour are also formed. Ex. Diacetyl has the flavour of butter.

## 2. Yoghurt Products

Yoghurt is a milk product produced with the help of lactobacilli (inoculant). For maintaining the protein content, condensed milk powder is mixed with milk to be fermented for industrial production of yoghurt. Milk is boiled and once it cools to warm temperature, bacterial strains of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* are added to it in 1:1 proportion. Lactic acid is formed due to Streptococcus that makes the proteins to gel out that gives dense consistency to the yoghurt.

Acetaldehyde like compounds are formed due to lactobacilli that gives characteristic taste to the yoghurt. Now a day, various fruit juices are mixed with yoghurt to impart different flavours. Ex. Strawberry yoghurt, banana yoghurt, etc. Shelf life of yoghurt and its probiotic properties can be improved by pasteurization.

## 3. Butter

Two types of butter like sweet cream and cultured are produced on large scale. Microbes are used for production of cultured variety.

## 4. Cheese production

Cheese is produced on large scale from the abundantly available cow milk all over the world. First, chemical and microbiological tests of milk are performed. Some colours and microbes like *Lactobacillus lactis*, *Lactobacillus cremoris*, and *Streptococcus thermophilus* are mixed with milk. It imparts sourness to the milk. After this, to impart the dense texture, whey (water in yoghurt) needs to be removed.

An enzyme, rennet obtained from alimentary canal of cattle was being traditionally used earlier. However, an enzyme protease obtained from fungi is used at present to produce vegetarian cheese.

The whey is separated from yoghurt (which has some other uses). Then, process of production of cheese is started through steps like cutting the solid yoghurt into pieces, washing, rubbing, salting, and mixing of essential microbes, pigments and flavours. Then, cheese is pressed and cut in to pieces and stored for ripening.



## 7.1 Cheese and Butter



### Let's think

1. Which different types of cheese are used in western food like pizza, burger, sandwich, etc?
2. What is difference between those types of cheese?



### Do you know?

During industrial production of milk products, strict cleanliness and sterilization is essential as bacteria can be attacked by viruses. Hence, virus-resistant varieties of bacteria are developed. Recently, use of mutant varieties of bacteria has been increased. Artificially, some strains are developed that will help to avoid unnecessary steps / materials.

Freshly prepared cheese is always soft e.g. cottage cheese, cream cheese, mozzarella cheese. On storing for 3 to 12 months, semi-hard cheddar cheese is formed whereas after ripening for 12 – 18 months, very hard cheese called parmesan cheese is formed.



### Can you tell?

What for probiotic food is famous?

### Probiotics

These are also milk products, but contain active bacteria e.g. *Lactobacillus*, *Acidophilus*, *Lactobacillus casei*, *Bifidobacterium bifidum*, etc. These microbes maintain the balance of intestinal microorganisms i.e. increase the population of microbes helping the digestion and decrease the population of harmful microbes (ex. *Clostridium*). Probiotic products are available in various forms like yoghurt, kefir, sauerkraut (pickle of cabbage), dark chocolate, miso soup, pickles, oils, corn syrup, artificial sweeteners, microalgae (Sea food like *Spirulina*, *Chlorella*, Blue green algae, etc.).

Why the probiotics have developed much importance in recent days? These products form the colonies of useful microbes in alimentary canal and control other microbes and their metabolic activities, improve resistance and lower the ill-effects of harmful substances formed during metabolic activities. Useful microbes become inactive due to antibiotics; probiotics make them active again.



7.2 Probiotics

Nowadays, probiotics are used for treatment of diarrhoea and treatment of poultry also.



### Use your brain power

In the earlier class, you had prepared the solution of dry yeast for observation of yeast. Which substance is prepared by its use on commercial basis?

### Bread

Different types of breads are produced from flour of cereals. Dough is formed by mixing of baker's yeast – *Saccharomyces cerevisiae*, water, salt and other necessary materials with flour. Due to fermentation of carbohydrates by yeast, sugar is converted in to carbon dioxide (CO<sub>2</sub>) and ethanol. Dough rises up due to CO<sub>2</sub> and the bread becomes spongy.

Compressed yeast is used in commercial bakery industry. It is available in dry, granular form for domestic use. Yeast produced for commercial use contains various useful contents like carbohydrates, fats, proteins, various vitamins, and minerals. Due to this, bread and other products produced with the help of yeast become nutritive. Ingredients like vinegar, soya sauce and monosodium glutamate (ajinomoto) that are used in presently popular chinese food are produced by microbial fermentation.

### Vinegar Production

Vinegar is used in each country of the world to impart sour taste to food materials and for preservation of pickles, sauce, ketch-up, chutneys, etc. Chemically, vinegar is 4% acetic acid (CH<sub>3</sub>COOH).

Ethanol, an alcohol is obtained by fermentation of carbon compounds like fruit juices, maple syrup, sugar molasses, starch of the roots; with the help of yeast *Saccharomyces cerevisiae*.



7.3 Vinegar

Mixture of bacterial strains like *Acetobacter* and *Glucanobacter* is mixed with ethanol for its microbial degradation. Acetic acid and other by-products are obtained through it. Acetic acid is separated from mixture by rarefaction. Acetic acid is bleached with the help of potassium ferrocynide. Then, it is pasteurized. Finally, very small quantity of SO<sub>2</sub> gas is mixed to produce vinegar.



7.4 *Aspergillus oryzae*

Soya sauce is produced by fermentation of the mixture of flour of wheat or rice and soyabean with the help of the fungus *Aspergillus oryzae*.

### Production of beverages

Sr. No.	Fruit	Microbe used	Role of microbe	Name of beverage
1	<i>Coffea arabica</i>	<i>Lactobacillus brevis</i>	Separating seeds from fruit	Coffee
2	<i>Theobroma cacao</i>	<i>Candida, Hansenula, Pichia, Saccharomyces.</i>	Separating seeds from fruit	Cocoa
3	Grapes	<i>Saccharomyces cerevisiae</i>	Fermentation of juice	Wine
4	Apple	<i>Saccharomyces cerevisiae</i>	Fermentation of juice	Cider



*Saccharomyces cerevisiae*



Fruit and seeds of coffee



Cocoa seeds

### 7.5 Some ingredients of beverages production



Can you tell?

1. Which functions are performed by enzymes secreted in human digestive system?
2. Give names of some such enzymes.

### Microbial Enzymes

Nowadays, instead of chemical catalysts, microbial enzymes are used in chemical industry. These enzymes are active at low temperature, pH and pressure; due to which energy is saved and erosion-proof instruments are also not necessary. Enzymes carry out specific processes; hence unnecessary by-products are not formed due to which expenses on purification are minimised.

In case of microbial enzymatic reactions, elimination and decomposition of waste material is avoided and enzymes can be reused. Hence, such enzymes are eco-friendly. Some examples of microbial enzymes are oxidoreductases, transferases, hydrolases, lyases, isomerases, ligases, etc.

Process of dirt / muck removal occurs at low temperature too due to mixing of enzymes with detergents. Glucose and fructose syrup can be obtained from corn flour by action of enzymes obtained from bacilli and streptomyces. Microbial enzymes are used in various industries like cheese, plant extracts, textile, leather, paper, etc.



### Use your brain power

Food materials like cold drinks, ice creams, cakes, juices are available in various colours and flavours. Whether these colours and flavours are really derived from fruits?

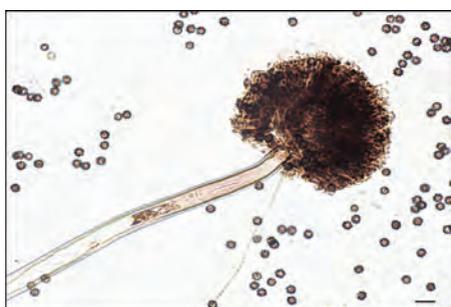


### Search

Read the ingredients and their proportion printed on bottles of cold drinks and juices and wrappers of ice creams. Find out the natural and artificial ingredients. Wheat or rice flour is inoculated with *Aspergillus*.

### Organic acids used in various commercial products and microbes useful for the same

Source	Microbe	Amino acid	Use
Sugar and beet molasses, ammonia salt	<i>Brevibacterium</i> , <i>Corynebacterium</i>	L-glutamic acid	Production of monosodium glutamate (Ajinomoto)
Sugar molasses, salt	<i>Aspergillus niger</i>	Citric acid	Drinks, toffees, chocolate production
Glucose, corn steep liquor	<i>Aspergillus niger</i>	Gluconic acid	Production of minerals used as supplement for calcium and iron
Molasses, corn steep liquor	<i>Lactobacillus delbrueckii</i>	Lactic acid	Source of nitrogen, production of vitamins.
Molasses, corn steep liquor	<i>Aspergillus itaconius</i>	Itaconic acid	Paper, textile, plastic industry, gum production



7.6 *Aspergillus niger*

What is the xanthan gum that imparts thickness to your favourite ice creams, puddings, chocolates, milk shakes, chocolate drinks, instant soups, etc.? This gum is obtained by fermentation of starch and molasses with the help of *Xanthomonas* species. It is variously useful due to properties like solubility in hot and cold water, high density, etc. It is used for production of pigments, fertilizers, weedicides, textile pigments, tooth pastes, high quality paper, etc.

### Substances obtained by microbial processing and their roles

Substances obtained by microbial processing	Roles
Citric, Malic and Lactic acid	To impart acidity
Glutamic acid, Lysine, Tryptophan	Protein binding
Nisin and natamycin	Microbial restrictor
Ascorbic acid (Vit. C), B <sub>12</sub> , B <sub>2</sub>	Antioxidants, vitamins.
Beta carotene, lycopenes, xanthenes, lutein	Edible colours
Polysaccharides, glycolipids	Emulsifiers
Vanillin, Ethyl butyrate (fruit flavour), peppermint flavour, essence of various fruits and flowers	Essence
Xylitol, aspartame	Artificial sweetener (low calorie)



### Can you recall?

1. What do you mean by antibiotic?
2. Which precautions should be taken about their consumption?

### Antibiotics

Many diseases of human and other animals have been controlled due to antibiotics obtained from different types of bacteria and fungi. Antibiotics like penicillin, cephalosporins, monobactam, bacitracin, erythromycin, gentamycin, neomycin, streptomycin, tetracyclins, vancomycin, etc. are used against various strains of gram positive and gram negative bacteria. Rifamycin is effective against tuberculosis.

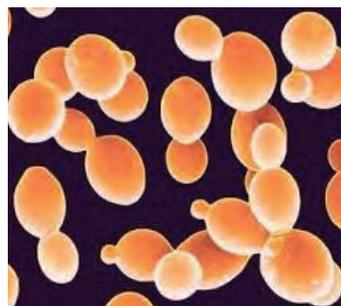


### Can you tell?

1. Which different materials are decomposed in biogas plant?
2. Which useful materials are obtained through it? Which is the fuel out of those?
3. Decomposition occurs through which organisms?

### Microbes and Fuels

1. Gaseous fuel- methane can be obtained by microbial anaerobic decomposition of urban agricultural and industrial waste.
2. Ethanol, an alcohol is a clean (smokeless) fuel obtained during fermentation of molasses by the yeast- *Saccharomyces*.
3. Hydrogen gas is considered to be the fuel of future. Hydrogen gas is released during bio-photolysis of water in which bacteria perform the photoreduction.



7.7 *Saccharomyces* (yeast)

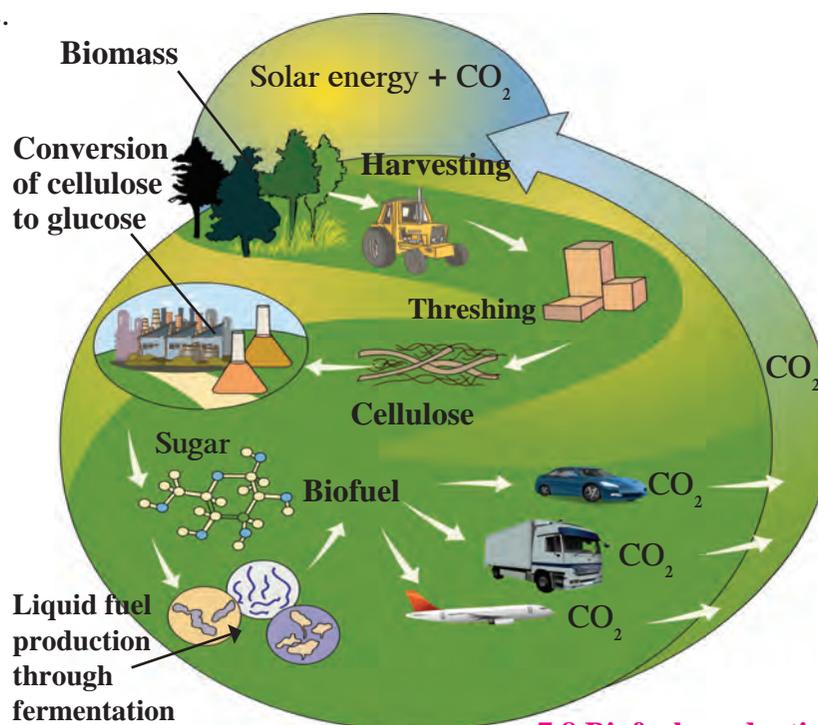
Similar to fuels, various industrial chemicals are also produced through microbial process. Ex. various alcohols, acetone, organic acids, fatty acids, polysaccharides, that are useful as raw materials in chemical industry. Some of these are useful as raw materials for plastic and food products.



### Observe

Observe the fig. 7.7. Discuss about bio-fuel.

**Bio-fuel** : Biofuel is important among the renewable source of good energy. These fuels are available in solid (coal, dung, crop residue), liquid (vegetable oils, alcohol), gaseous (gobar gas, coal gas) forms. These fuels are easily available and in plenty of quantity. These are reliable fuels of the future.



7.8 Biofuel production

## Microbial Pollution Control

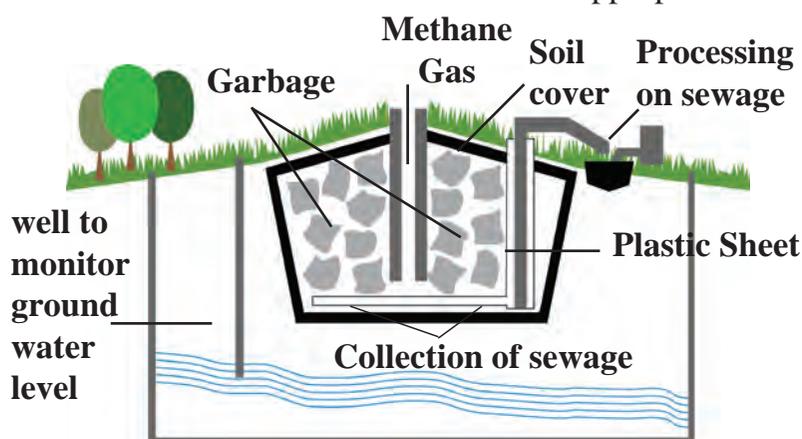
Solids wastes, sewage and various pollutants are ever increasing with increase in pollution. Along with it, ever increasing diseases and degradation of environment are the world-wide problems. Especially, cities in densely populated countries like India are affected with these problems. Life of the future generations will be difficult if these problems are not solved at right time and to right extent. Let us see the role of microbes in environment.

You already know that microbes are used for disposal of solid waste through biogas plant and compost production. How urban waste that is accumulated in terms of tonnes, may be disposed off ?



### Let's Think

1. Why is it asked to segregate wet and dry waste in each home?
2. What is done with the segregated waste?
3. Which is most appropriate method of disposal of dry waste?



7.9 Modern landfill site

### Land-filling sites

Degradable waste being accumulated in urban areas is used for this purpose. Large pits are dug in open spaces far away from the residential area and those pits are lined with plastic sheets as a precaution against pollution of soil due to leaching of toxic and harmful materials.

Compressed waste is dumped in the pit. It is covered with layers of soil, saw dust, leafy waste and specific biochemicals. Bioreactors are mixed at some places. Microbes present in soil and other top layers decompose the waste. Completely filled pit is sealed with soil slurry. Best quality compost is formed after few days. Such land filling sites can be reused after removal of compost.



### Observe

Observe the garbage vans of grampanchayat and municipality. Nowadays, there is facility of decreasing the volume of garbage by compaction in those vans. Explain the advantages of this activity.

## Sewage Management

In villages, domestic sewage is disposed off either in nearby soil or in biogas plant. However, in cities, sewage needs to be carried to processing unit and acted upon by microbial processes.

Microbes which can decompose any compound as well as destroy the pathogens of cholera, typhoid, etc. are mixed with sewage. They release methane and  $\text{CO}_2$  by decomposition of the carbon compounds present in sewage. Phenol oxidizing bacteria decompose the xenobiotic chemicals present in sewage.

The sludge that settles down in this process can again be used as fertilizer. Water released after microbial treatment is environmentally safe. Microbes are used for bioremediation of environment polluted due to sewage.



### Collect Information

1. Which materials should not be present in garbage for its proper microbial decomposition?
2. How the sewage generated in your house or apartment is disposed off ?

### Clean Technology

Human being has made a very fast progress in technology. However, environmental pollution is also increasing with same speed. Let us see the ways of control over air, soil and water pollution with the help of microbes.

Microbes have natural ability of decomposing the manmade chemicals. Hydrocarbons and other chemicals are transformed with the help of these abilities.

1. Some microbes remove the sulphur from fuels.

2. Metals like copper, iron, uranium, zinc, etc. leach into environment from low quality metalloids. These are converted into compounds before leaching, with the help of thiobacilli and sulphobacilli.

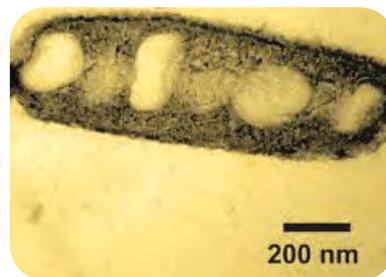


### Can you tell?

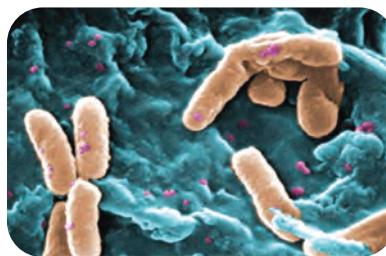
You must have seen or read the news of dead fishes or oily water accumulating at the sea coasts. Why does this happen?

Spilling of petroleum oil occurs in ocean due to various reasons. This oil may prove fatal and toxic to aquatic organisms. It is not easy to remove the oil layer from surface of water by mechanical method. However, bacteria like *Pseudomonas* spp. and *Alcanovorax borkumensis* have the ability to destroy the pyridines and other chemicals. Hence, these bacteria are used to clear the oil spills. These are called as hydrocarbonoclastic bacteria (HCB). HCB decompose the hydrocarbons and bring about the reaction of carbon with oxygen.  $\text{CO}_2$  and water is formed in this process.

Plastic bottles are formed from the chemical substance PET (Polyethylene Terephthalate Polyester). Now a day, most of the urban garbage consists of plastic. It has been observed that species like *Vibrio*, *Ideonella sakaiensis* can decompose the PET. Similarly, species of bacteria like *Actinomycetes*, *Streptomyces*, *Nocardia*, *Actinoplanes* have ability of decomposing rubber from garbage.



7.10 *Alcanovorax borkumensis*

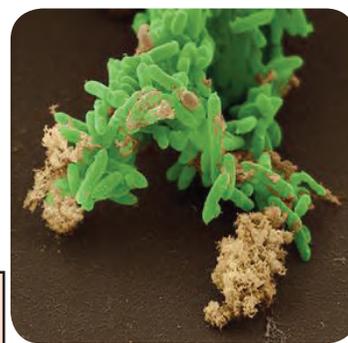


7.11 *Pseudomonas*



7.12 *Acidobacillus*

Sulphuric acid is present in the acid rain and materials coming out of mines. You know that erosion of metals present in statues, bridges and buildings occurs due to it. Sulphuric acid is source of energy for some species of bacteria like *Acidophillium* spp. and *Acidobacillus ferroxidens*. Hence, these bacteria can control the soil pollution occurring due to acid rain.



7.13 *Geobacter*



**Internet is My Friend**

Collect pictures of various useful microbes. Display chart of their information in classroom.

Water soluble salts of uranium are present in the wastes produced during electroplating and in effluent released in environment from the atomic energy plant. *Geobacter* convert these salts of uranium into insoluble salts and thereby prevent those salts from mixing with ground water sources.

### Microbes and Farming



**Can you tell?**

How the bacteria present in soil and root nodules of leguminous plants are useful?

### Microbial Inoculants

Some microbes-containing inoculants are produced by process of fermentation. These inoculants are sprayed on seeds before sowing and some of the inoculants are released into plants. Microbes in the inoculants help in plant growth by supplying nutrients. They improve the quality of vegetarian food. Solution containing *Azotobacter* and artificial nitrogenase is used in organic farming.

Soil pollution occurring due to chemical fertilizers is prevented due to use of these solutions. Fluoroacetamide-like chemicals are mixed with soil due to use of chemical pesticides in agriculture. These prove to be harmful to other plants and animals as well as cause skin diseases to human. These pesticides in the soil can be destroyed with the help of microbes.

### Bioinsecticides

Bacterial and fungal toxins which can destroy pests and pathogens can be directly integrated into plants with the help of biotechnology. Being toxic to insects, they do not consume the plants. Similar to bacteria, some species of fungi and viruses are useful as pesticides. Spinosad, a by-product of fermentation is a biopesticide.



**Always Remember**

Plastic being used for storing the garbage is biodegradable polylactic acid. Such material should be used as per need only and environment should be saved.



7.14 Caterpillar feeding on leaf

## Exercise

1. Rewrite the following statements using correct of the options and explain the completed statements.

(gluconic acid, coagulation, amino acid, acetic acid, clostridium, lactobacilli)

- Process of --- of milk proteins occurs due to lactic acid.
- Harmful bacteria in like --- in the intestine are destroyed due to probiotics.
- Chemically, vinegar is ---.
- Salts which can be used as supplement of calcium and iron are obtained from ----- acid.

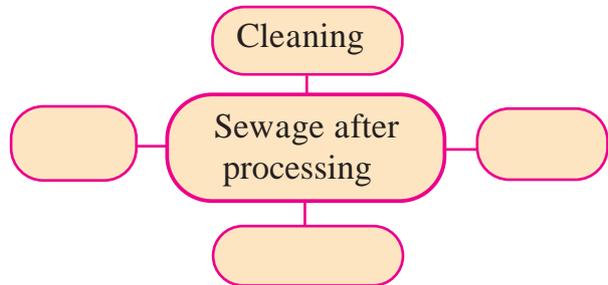
2. Match the pairs

- | ‘A’ group      | ‘B’ group                     |
|----------------|-------------------------------|
| a. Xylitol     | 1. Pigment                    |
| b. Citric acid | 2. To impart sweetness        |
| c. Lycopene    | 3. Microbial restrictor       |
| d. Nycin       | 4. Protein binding emulsifier |
|                | 5. To impart acidity          |

3. Answer the following.

- Which fuels can be obtained by microbial processes? Why is it necessary to increase the use of such fuels?
- How can the oil spills of rivers and oceans be cleaned?
- How can the soil polluted by acid rain be made fertile again?
- Explain the importance of bio-pesticides in organic farming.
- Which are the reasons for increasing the popularity of probiotic products?
- How the bread and other products produced using baker’s yeast are nutritious?
- Which precautions are necessary for proper decomposition of domestic waste?
- Why is it necessary to ban the use of plastic bags?

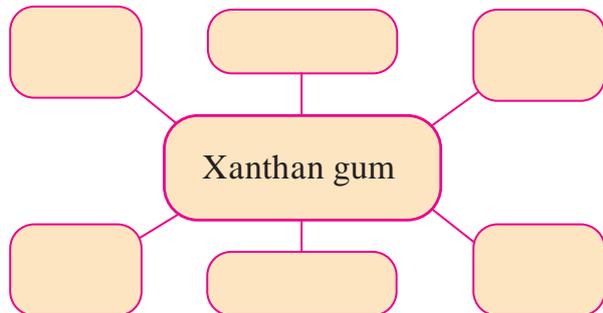
4. Complete the following conceptual picture.



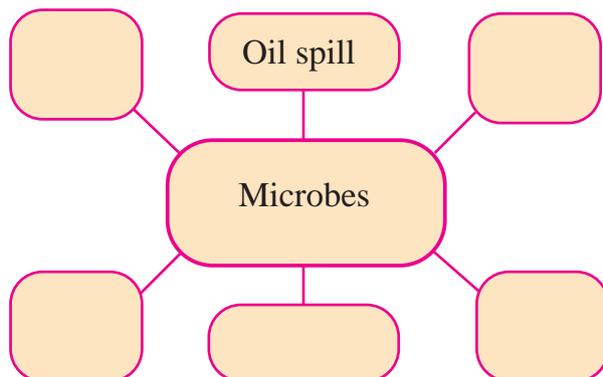
5. Give scientific reasons.

- Use of mutant strains has been increased in industrial microbiology.
- Enzymes obtained by microbial process are mixed with detergents.
- Microbial enzymes are used instead of chemical catalysts in chemical industry.

6. Complete the following conceptual picture with respect to uses.



7. Complete the following conceptual picture related to environmental management.



**8. Answer the following.**

- a. What is role of microbes in compost production?
- b. What are the benefits of mixing ethanol with petrol and diesel?
- c. Which plants are cultivated to obtain the fuel?
- d. Which fuels are obtained from biomass?
- e. How does the bread become spongy?

**Project :**

1. Find the ways to implement the zero garbage system at domestic level.
2. Which are the microbes that destroy the chemical pesticides in soil?
3. Collect more information about reasons for avoiding the use of chemical pesticides.

