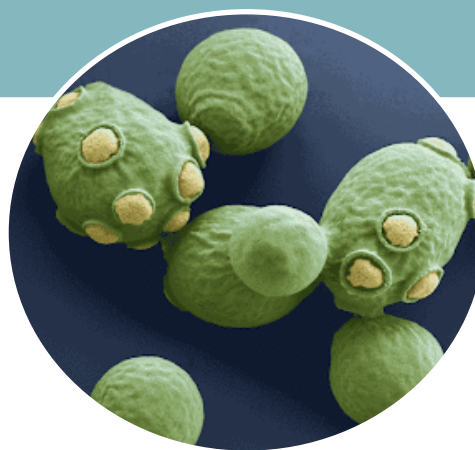


9

CHAPTER

UNIT - III

Microbes in Human Welfare



Saccharomyces cerevisiae, a species of yeast used in baking and brewing industry.

Chapter outline

- 9.1 Microbes in household products
- 9.2 Microbes in industrial products
- 9.3 Microbes in sewage treatment and energy generation
- 9.4 Microbes in the production of biogas
- 9.5 Bioremediation



Learning objectives

- Differentiates probiotics from pathogens.
- Understands the use of microbes in household products.
- Learns about antibiotic production and fermented beverages.
- Realizes the importance of microbes in sewage treatment and energy generation.
- Realizes the applications of microbes in bio-remediation.



Microbes such as bacteria, fungi, protozoa, certain algae, viruses, viroids and prions are some of the major components of the biological system on Earth. Several microorganisms are beneficial and contribute to human welfare. Microbes are present everywhere – in soil, water, air and within bodies of animals and plants. Microbes like bacteria and fungi can be grown on nutritive media to form colonies which can be visibly seen. Some of the microbes useful to human welfare are discussed here.

9.1 Microbes in household products

In every day life, microbes and their products are used in the preparation of idli, dosa, cheese, curd, yogurt, dough, bread, vinegar, etc., Bacteria like *Lactobacillus acidophilus*, *L. lactis* and *Streptococcus lactis* commonly called **lactic acid bacteria** (LAB) are probiotics which check the growth of pathogenic microbes in the stomach and other parts of the digestive tract.

The LAB bacteria grows in milk and convert it into curd, thereby digesting the milk protein casein. A small amount of curd added to fresh milk as a starter or inoculum contains millions of *Lactobacilli*, which under suitable

temperature ($\leq 40^{\circ}\text{C}$) multiply and convert milk into curd. Curd is more nutritious than milk as it contains a number of organic acids and vitamins.



Prebiotics are compounds in food (fibers) that induce the growth or activity of beneficial microorganisms.

Probiotics are live microorganisms intended to provide health benefits when consumed, generally by improving or restoring the gut flora.

Yogurt is produced by bacterial fermentation of milk, and lactic acid is produced as a byproduct. Microorganisms such as *Streptococcus thermophilus* and *Lactobacillus bulgaricus* coagulate the milk protein and convert the lactose in the milk to lactic acid. The flavour in yogurt is due to acetaldehyde.

Cheese is a dairy product produced in a wide range of flavours, textures and is formed by coagulation of the milk protein, casein. During cheese production, milk is usually acidified and the enzyme rennet is added to cause coagulation. The solids are separated and pressed to form cheese. Most cheese are made with a starter bacteria, *Lactococcus*, *Lactobacillus* or *Streptococcus*.

Paneer (cottage cheese) is fresh cheese common in South Asia, especially in India. It is made by curdling milk with lemon juice, vinegar and other edible acids. Large holes in Swiss cheese is due to the production of large amount of carbon-di-oxide by the bacterium *Propionibacterium shermanii*.

The dough used in the preparation of idlis and dosas are fermented by the bacteria *Leuconostoc mesenteroides* whereas the dough used in bread making is fermented by *Saccharomyces cerevisiae* (Baker's Yeast). Fermentation of glucose mainly forms ethyl alcohol and carbon-

di-oxide, which is responsible for leavening of dough. When leavened dough is baked, both carbon-di-oxide and ethyl alcohol evaporate making the bread porous and soft.

Single Cell Protein (SCP)

Single cell protein refers to edible unicellular microorganisms like *Spirulina*. Protein extracts from pure or mixed cultures of algae, yeasts, fungi or bacteria may be used as ingredient or as a substitute for protein rich foods and is suitable for human consumption or as animal feed.

9.2 Microbes in industrial products

Microbes are used to synthesize a number of products valuable to human beings. Products like beverages, antibiotics, organic acids, amino acids, vitamins, biofuels, single cell protein, enzymes, steroids, vaccines, pharmaceutical drugs, etc., are produced in industries. Production on a large scale requires growing microbes in very large vessels called fermentors. A fermentor (bioreactor) is a closed vessel with adequate arrangement for aeration, agitation, temperature, pH control and drain or overflow vent to remove the waste biomass of cultured microorganisms along-with their products.

9.2.1 Antibiotic production

Antibiotics are chemical substances produced by microorganisms which can kill or retard the growth of other disease causing microbes even in low concentration. Antibiotic means “**against life**”. Antibiotics are used to treat diseases such as plague, meningitis, diphtheria, syphilis, leprosy, tuberculosis etc., **Selman Waksman** discovered Streptomycin and was the first to use the term “**antibiotic**” in 1943.

While working on *Staphylococci* bacteria, Alexander Fleming observed a green mould growing in one of his unwashed culture plates around which *Staphylococci* could not grow. He

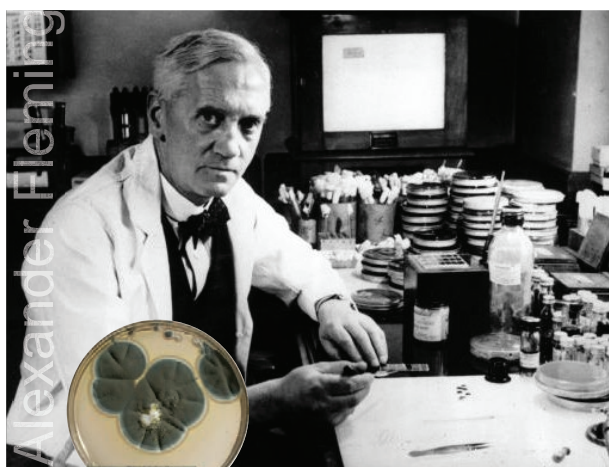
found that it was due to a chemical produced by the mould and he named it as penicillin, which was the first antibiotic discovered by Alexander Fleming in 1926 (Fig. 9.1). Penicillin is produced by the fungi *Penicillium notatum* and *Penicillium chrysogenum*. It is bactericidal (antibiotics that kill bacteria) in action and inhibits the synthesis of the bacterial cell wall.

Penicillin is also referred as the “**queen of drugs**” and its full potential as an effective antibiotic was established much later by **Ernest Chain** and **Howard Florey** when they treated the wounded soldiers in World War II with penicillin. **Fleming, Chain** and **Florey** were awarded the **Nobel prize** in 1945 for the discovery of penicillin.

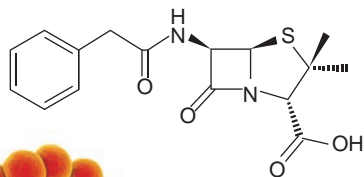
Antibiosis is the property of antibiotics to kill microorganisms.

Broad-spectrum antibiotics act against a wide range of disease-causing bacteria.

Narrow-spectrum antibiotics are active against a selected group of bacterial types.



పెన్సిలియం
క్రిసోజెనమ్



స్ట్రెప్టోకోకస్ ఆరియస్



Fig. 9.1 Discovery of penicillin



Hypersensitivity reaction is a major problem with the use of penicillin, resulting in nausea, vomiting, wheezing and ultimately cardiovascular collapse. To check the sensitivity reaction, doctors use a needle to prick the forearm of the patients to give a weak dose of penicillin. An itchy red region in the forearm is an indication that the patient is allergic to penicillin. This test is important before administration of penicillin to a patient.

Tetracycline is a broad spectrum bacteriostatic antibiotic (antibiotics that limit the growth of bacteria) that inhibits microbial protein synthesis. **Chlortetracycline** is the first antibiotic of this group, isolated from the cultures of *Streptomyces aureofaciens*. **Streptomycin** is a broad spectrum antibiotic isolated from the actinomycetes, *Streptomyces griseus*. It is bactericidal against both gram positive and gram negative bacteria, especially against *Mycobacterium tuberculosis*. Antibiotics, such as **erythromycin, chloromycetin, griseofulvin, neomycin, kenamycin, bacitracin**, etc., are also isolated as microbial products.

Antibiotic resistance

Antibiotic resistance occurs when bacteria develop the ability to defeat the drug designed to kill or inhibit their growth. It is one of the most acute threat to public health. Antibiotic resistance is accelerated by the misuse and over use of antibiotics, as well as poor infection prevention control. Antibiotics should be used only when prescribed by a certified health professional. When the bacteria become resistant, antibiotics cannot fight against them and the bacteria multiply. Narrow spectrum antibiotics are preferred over broad spectrum antibiotics. They effectively and accurately target specific pathogenic organisms and are less likely to cause resistance. “**Superbug**” is a term used to

describe strains of bacteria that are resistant to the majority of antibiotics commonly used today.

9.2.2 Fermented beverages

Microbes especially yeast is being used from time immemorial for the production of beverages like wine, beer, whisky, brandy and rum. Wine is among the oldest alcoholic beverages known and is produced by fermentation of fruit juice by yeast. **Zymology** is an applied science which deals with the biochemical process of fermentation and its practical uses.

Saccharomyces cerevisiae commonly called brewer's yeast is used for fermenting malted cereals and fruit juices to produce various alcoholic beverages. Wine and beer are produced without distillation, whereas whisky, brandy and rum are obtained by fermentation and distillation.



The Pasteur effect is the inhibiting effect of oxygen on the fermentation process.

Oenology is the science and study of **wine** and wine making. Wine is made from the fermentation of grape juice. Grape juice is fermented by various strains of *Saccharomyces cerevisiae* into alcohol. Grape wine is of two types, red wine and white wine. For red wine, black grapes are used including skins and sometimes the stems also are used. In contrast white wine is produced only from the juice of either white or red grapes without their skin and stems.

Beer is produced from germinated barley malt grain by *Saccharomyces carlsbergensis* or *Saccharomyces cerevisiae*. **Rum** is made from fermented sugarcane or molasses or directly from sugarcane juice by *Saccharomyces cerevisiae*. **Whisky** is a type of distilled alcoholic beverage made from fermented grain mash by *Saccharomyces cerevisiae*.

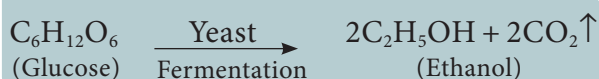
Alcohol content in various beverages

- Beer contains 3 to 5 percent of alcohol.
- Wine contains 9 to 14 percent alcohol. Wine coolers are made of wine mixed with carbonated water and flavourings. Wine coolers have about 4 to 6 percent alcohol.
- Distilled spirits such as whiskey, gin, scotch and vodka usually contain 35 to 50 percent alcohol.

In some parts of South India, a traditional drink called **pathaneer** is obtained from fermenting sap of palms and coconut trees. A common source is tapping of unopened spadices of coconut. It is a refreshing drink, which on boiling produces jaggery or palm sugar. When pathaneer is left undisturbed for few hours it gets fermented to form **toddy** with the help of naturally occurring yeast, to form a beverage that contains 4 percent alcohol. After 24 hours **toddy** becomes unpalatable and is used for the production of vinegar.

Saccharomyces cerevisiae is the major producer of ethanol (C_2H_5OH). It is used for industrial, laboratory and fuel purposes. So ethanol is referred to as **industrial alcohol**. Bacteria such as *Zymomonas mobilis* and *Sarcina ventriculi* are also involved in ethanol production. The principal substrates for the commercial production of industrial alcohol include molasses or corn, potatoes and wood wastes. The process of ethanol production starts by milling a feed stock followed by the addition of dilute or fungal **amylase (enzyme)** from *Aspergillus* to break down the starch into fermentable sugars. Yeast is then added to convert the sugars to ethanol which is then distilled off to obtain ethanol which is upto 96 percent in concentration. The two most common type of biofuels in use today are ethanol and biodiesel, both of them represent the first generation of biofuel technology. Ethanol is often used as a fuel, mainly as a biofuel additive for gasoline.

Biodiesel is a fuel made from vegetable oils, fats or greases. Biodiesel fuel can be used in diesel engines without altering the engine. Pure biodiesel is non-toxic, biodegradable and produces lower level of air pollutants than petroleum-based diesel fuel. The Government of India approved the National Policy on Biofuels in December 2009 and identified *Jatropha curcas* as the most suitable oilseed for biodiesel production. *Pongamia* species is also a suitable choice for production of biodiesel.



World biofuel day is observed every year on **10th August** to create awareness about the importance of renewable bio-fuels as an alternative to conventional non-renewable fossil fuels. This day also highlights the various efforts taken by the Government in the biofuel sector.

9.2.3 Chemicals, enzymes and other bioactive molecules

Microbes are not only used for commercial and industrial production of alcohol, but also used for production of chemicals like organic acids and enzymes. Examples of organic acid producers are *Aspergillus niger* for **citric acid**, *Acetobacter aceti* for **acetic acid**, *Rhizopus oryzae* for **fumaric acid**, *Clostridium butyricum* for **butyric acid** and *Lactobacillus* for **lactic acid**.

Yeast (*Saccharomyces cerevisiae*) and bacteria are used for commercial production of enzymes. Lipases are used in detergent formulations and are used for removing oily stains from the laundry. Bottled juices are clarified by the use of **pectinase**, **protease** and **cellulase**. Rennet can also be used to separate milk into solid curds for cheese making. Streptokinase produced by the bacterium *Streptococcus* and genetically engineered *Streptococci* are used as “**clot buster**” for

removing clots from the blood vessels of patients who have undergone myocardial infarction.

Cyclosporin A, an immunosuppressant used in organ transplantation is produced from the fungus *Trichoderma polysporum*. It is also used for its anti-inflammatory, anti-fungal and anti-parasitic properties. **Statins** produced by the yeast *Monascus purpureus* have been used to lower blood cholesterol levels. It acts by competitively inhibiting the enzyme responsible for the synthesis of cholesterol. Recombinant **human insulin** has been produced predominantly using *E. coli* and *Saccharomyces cerevisiae* for therapeutic use in human.

9.3 Microbes in sewage treatment and energy generation

Sewage is the waste generated every day in cities and towns containing human excreta. It contains large amounts of organic matter and microbes, which are pathogenic to humans and are bio-degradable pollutants. Domestic waste consists of approximately 99 percent water, suspended solids and other soluble organic and inorganic substances. Sewage should not be discharged directly into natural water bodies like rivers and streams. Before disposal, sewage should be treated in sewage treatment plants to make it less polluting.

Microbes (mass of bacteria floc) are allowed to grow in aerated water (secondary treatment). They consume major part of organic matter in the effluent and reduce the BOD in the waste water (The details on waste water treatment are discussed in chapter 13).

9.3.1 Microbial Fuel Cell (MFC)

A Microbial Fuel Cell is a bio-electrochemical system that drives an electric current by using bacteria and mimicking bacterial interaction found in nature (Fig. 9.2). Microbial Fuel Cells work by allowing bacteria to oxidize and reduce organic molecules. Bacterial respiration is basically one big redox reaction in which electrons are being moved around. A MFC consists of an anode and a cathode separated by a proton exchange membrane. Microbes at the anode oxidize the organic fuel generating protons which pass through the membrane to the cathode and the electrons pass through the anode to the external circuit to generate current.

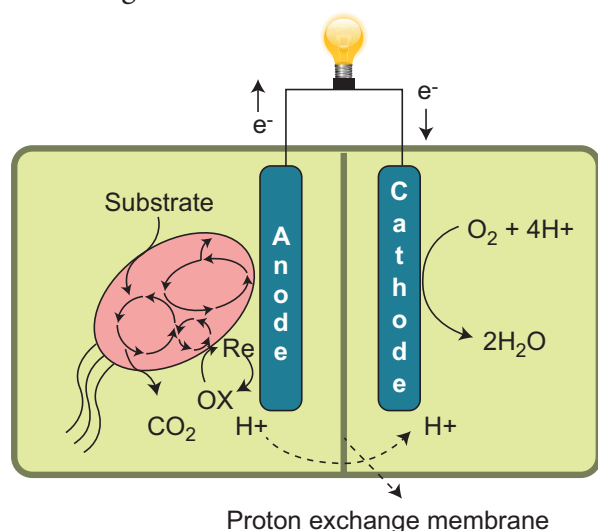


Fig. 9.2 Microbial Fuel Cell

9.4 Microbes in the production of biogas

Biogas is a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural wastes, manure, municipal wastes, plant material, sewage, food waste, etc., Biogas is produced under anaerobic condition, when the organic materials are converted through microbiological reactions into gas and organic fertilizer. Biogas primarily consists of methane (63 percent), along with CO_2 and hydrogen. Methane producing bacteria are called **methanogens** and one such common bacterium is *Methanobacterium*.

Biogas is devoid of smell and burns with a blue flame without smoke. The *Methanogens* are also present in anaerobic sludge and rumen of cattle. In rumen, these bacteria help in the breakdown of cellulose. The excreta of cattle called dung is commonly called "**Gobar**". Gobar gas is generated by the anaerobic decomposition of cattle dung. It consists of methane, CO_2 with some hydrogen, nitrogen and other gases in trace amounts.

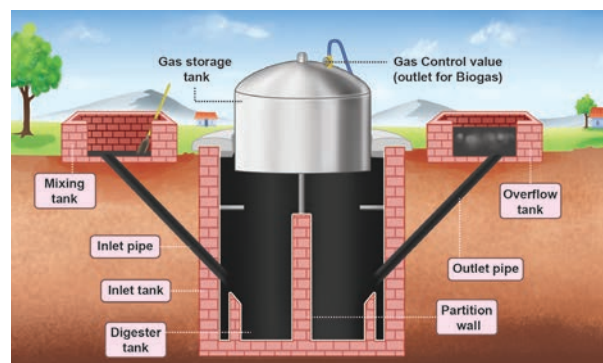


Fig. 9.3 Biogas Unit

In a biogas plant, anaerobic digestion is carried out in an air tight cylindrical tank known as digester (Fig. 9.3). It is made up of concrete bricks and cement or steel. Bio-wastes are collected and slurry of dung is fed into this digester. It has a side opening into which organic materials for digestion are incorporated for microbial activity. Anaerobic digestion is accomplished in three stages: solubilisation, acidogenesis and methanogenesis. The outlet is connected to a pipe to supply biogas. The slurry is drained through another outlet and is used as fertilizer. Biogas is used for cooking and lighting. The technology of biogas production was developed in India mainly due to the efforts of Indian Agricultural Research Institute (IARI) and Khadi and Village Industries Commission (KVIC).

9.5 Bioremediation

The use of naturally occurring or genetically engineered microorganisms to reduce or degrade pollutants is



called bioremediation. Bioremediation is less expensive and more sustainable than other remediations available. It is grouped into *in situ* bioremediation (treatment of contaminated soil or water in the site) and *ex situ* bioremediation (treatment of contaminated soil or water that is removed from the site and treated).

9.5.1 Microorganisms involved in bioremediation

Aerobic microbes degrade the pollutants in the presence of oxygen. They mainly degrade pesticides and hydrocarbons. *Pseudomonas putida* is a genetically engineered microorganism (GEM). Ananda Mohan Chakrabarty obtained patent for this recombinant bacterial strain. It is multi-plasmid hydrocarbon-degrading bacterium which can digest the hydrocarbons in the oil spills (Fig. 9.4).

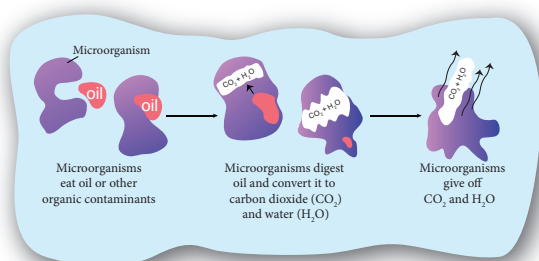


Fig. 9.4 The process of bioremediation

Nitrosomonas europaea is also capable of degrading benzene and a variety of halogenated organic compounds including trichloroethylene and vinyl chloride. *Ideonella sakaiensis* is currently tried for recycling of PET plastics (Fig. 9.6). These bacteria use PETase and MHETase enzymes to breakdown PET plastic into terephthalic acid and ethylene glycol.

Anaerobic microbes degrade the pollutants in the absence of oxygen. *Dechloromonas aromatica* has the ability to degrade benzene anaerobically and to oxidize toluene and xylene. *Phanerochaete*

chrysosporium an anaerobic fungus exhibits strong potential for bioremediation of pesticides, polyaromatic hydrocarbons, dyes, trinitrotoluene, cyanides, carbon tetrachloride, etc., *Dehalococcoides* species are responsible for anaerobic bioremediation of toxic trichloroethene to non-toxic ethane. *Pestalotiopsis microspora* is a species of endophytic fungus capable of breaking down and digesting polyurethane. This makes the fungus a potential candidate for bioremediation projects involving large quantities of plastics.

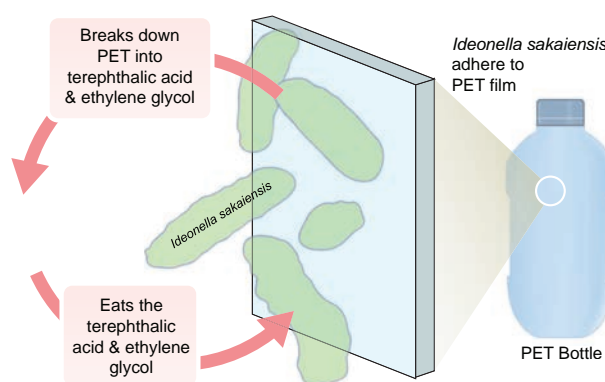


Fig. 9.6 Actions of *Ideonella sakaiensis*

Summary

All microbes are not pathogenic, many of them are beneficial to human beings. We use microbes and their derived products almost every day. Lactic acid bacteria convert milk into curd. *Saccharomyces cerevisiae* (yeast) is used in bread making. Idly and dosa are made from dough fermented by microbes. Bacteria and fungi are used in cheese making. Industrial products like lactic acid, acetic acid and alcohol are produced by microbes. Antibiotics are produced from useful microbes to kill the disease causing harmful microbes. For more than a hundred years, microbes are being used to treat sewage by the process of activated sludge formation. Bio-gas produced by microbes is used as a source of energy in rural areas. In bio-remediation naturally occurring or genetically engineered microorganisms are used to reduce or degrade pollutants.

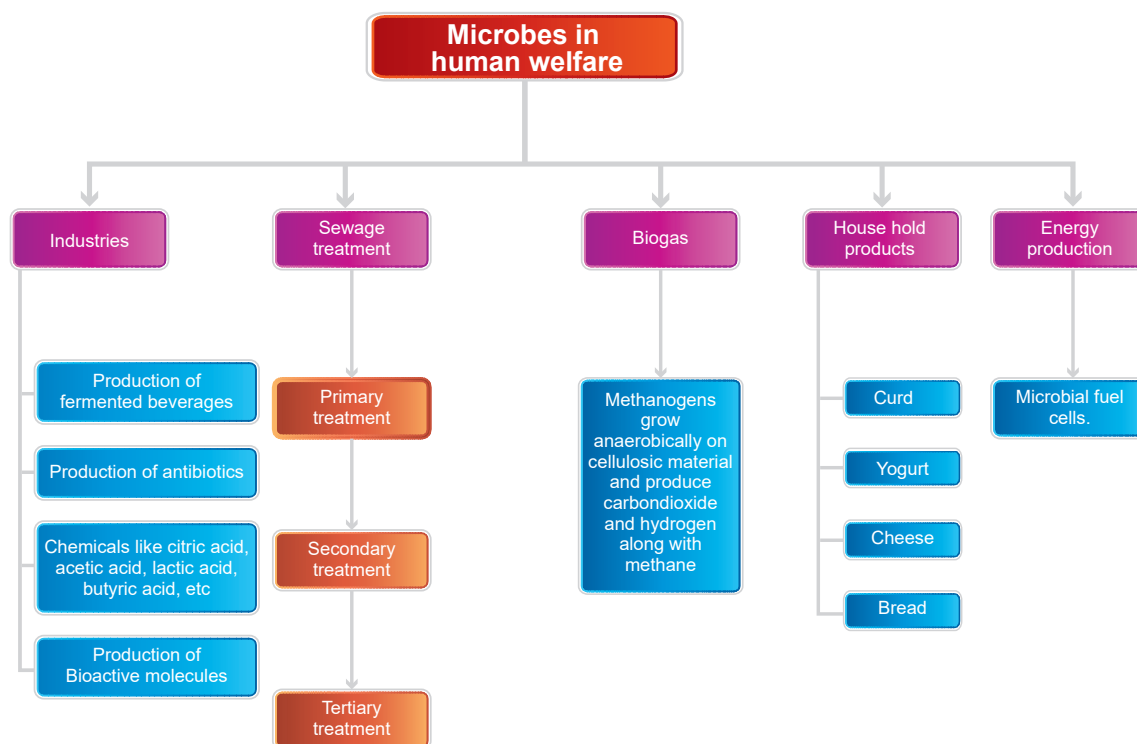


Evaluation



- Which of the following microorganism is used for production of citric acid in industries?
a) *Lactobacillus bulgaris*
b) *Penicillium citrinum*
c) *Aspergillus niger* d) *Rhizopus nigricans*
- Which of the following pair is correctly matched for the product produced by them?
a) *Acetobacter aceti* - Antibiotics
b) *Methanobacterium* - Lactic acid
c) *Penicillium notatum* - Acetic acid
d) *Saccharomyces cerevisiae* - Ethanol
- The most common substrate used in distilleries for the production of ethanol is _____
a) Soyameal b) Groundgram
c) Molasses d) Corn meal
- Cyclosporin – A is an immunosuppressive drug produced from _____
a) *Aspergillus niger*
b) *Manascus purpureus*
c) *Penicillium notatum*
d) *Trichoderma polysporum*
- CO₂ is not released during
a) Alcoholic fermentation
b) Lactate fermentation
c) Aerobic respiration in animals
d) Aerobic respiration in plants
- The purpose of biological treatment of waste water is to _____
a) Reduce BOD b) Increase BOD
c) Reduce sedimentation
d) Increase sedimentation
- The gases produced in anaerobic sludge digesters are
a) Methane, oxygen and hydrogen sulphide.
b) Hydrogen sulphide, methane and sulphur dioxide.
c) Hydrogen sulphide, nitrogen and methane.
d) Methane, hydrogen sulphide and CO₂.
- How is milk converted into curd? Explain the process of curd formation.
- Give any two bioactive molecules produced by microbes and state their uses.
- Define the following terms:
a) Antibiotics b) Zymology
c) Superbug
- Write short notes on the following:
a) Brewer's yeast b) *Ideonella sakaiensis*
c) Microbial Fuel Cell
- List the advantages of biogas plants in rural areas.
- When does antibiotic resistance develop?
- What is referred to as industrial alcohol? Briefly describe its preparation.
- What is bioremediation?

Concept Map



ICT CORNER

MICROBES IN HUMAN WELFARE

How the fermentation takes place? Let us experiment it virtually



Procedure :

Step -1: Type the **URL** or scan the **QR** code to open the activity page and click “**START**” to begin the fermentation experiment.

Step -2: Click “**next**” for all the flasks combination.

Step -3: When the “**Matching Game**” starts to know the result, “**Drag and place**” the combination perfectly to their respective flasks.

Step – 4 : Go on through the other tests, explanations and the principle involved in the fermentation process.

MICROBES IN HUMAN WELFARE URL:

<http://www.bch.cuhk.edu.hk/vlab2/animation/fermentation/>

*Pictures are indicative only

*Allow flash player

