8 CHAPTER

Microbes in Human Welfare

Level - 1 CORE SUBJECTIVE QUESTIONS

MULTIPLE CHOICE QUESTIONS (MCQs) (1 Mark)

1. Option (B) is correct
   Explanation: The rising of idli- dosa dough is due to the generation of carbon dioxide gas by micro-organisms. Micro-organism consume carbohydrates molecules and converts them to alcohol and carbon dioxide.
2. Option (A) is correct
   Explanation: Flocs while growing consume organic matter and thus reduce the biochemical oxygen demand (BOD), the effluent is passed into settling tank.
3. Option (D) is correct
   Explanation: *Lactobacillus* is a type of heterotrophic bacteria that obtains its nutrients by converting lactose in milk into lactic acid, which helps set milk into curd.
4. Option (C) is correct
   Explanation: *Monascuspurpureus* is used to produce statins (cholesterol-lowering agents), not citric acid.
5. Option (A) is correct
   Explanation: *Glomus* forms a symbiotic relationship with plant roots, helping in the absorption of phosphorus from the soil.
6. Option (A) is correct
   Explanation: In the graph, point (i) represents the location where a sharp decline in oxygen levels is observed, indicating the introduction of untreated sewage at that point.
7. Option (D) is correct
   Explanation: *Glomus* does not fix atmospheric nitrogen. The other options:
   - *Oscillatoria* is a cyanobacterium capable of fixing nitrogen.
   - *Rhizobium* is a bacterium that forms symbiotic relationships with leguminous plants to fix nitrogen.
   - *Azospirillum* is a free-living nitrogen-fixing bacterium.
8. Option (D) is correct
   Explanation: The correct matching pairs are:
   (A) Cyclosporin A- *Tricoderma polysporum*
   (B) Statins – *Monascus purpureus*
   (C) Streptokinase- *Streptococcus*
   (D) Penicillin- *Pencillium notatum*

ASSERTION-REASON QUESTIONS (1 Mark)

1. Option (A) is correct
   Explanation: The microbial activity in the tank produces biogas, or which causes the floating cover that is placed over the slurry to continue rising. The gases that make up biogas include carbon dioxide, hydrogen sulfide, and methane. It has the potential to be an energy source.
2. Option (A) is correct
   Explanation: The holes in Swiss cheese (or "eyes") are formed by the carbon dioxide produced during the fermentation process by *Propioni bacterium shermanii*. This bacterium not only contributes to the formation of holes but also plays a significant role in developing the unique flavour, texture, and taste of Swiss cheese.
3. Option (B) is correct
   Explanation: *Lactobacillus* and lactic acid bacteria (LAB) are crucial in the fermentation process that converts milk into curd by producing lactic acid, which lowers the pH of milk and helps coagulate the proteins. Additionally, LAB in the gut can help maintain a healthy microbiome by inhibiting the growth of pathogenic bacteria, thereby playing a beneficial role in digestive health.

VERY SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. - The variation in colour of colonies is due to the principle of insertional inactivation.
   - In this, a recombinant DNA is inserted within the coding sequence of an enzyme, β-galactosidase.

This results into inactivation of the enzyme, which is referred to as insertional inactivation.

- The presence of a chromogenic substrate gives blue-coloured colonies if the plasmid in the bacteria does not have an insert.
- Presence of insert results into insertional inactivation of the β -galactosidase and the colonies do not produce any colour, these are identified as recombinant colonies.

2. The organic farmers hold the view that complete eradication of pests is not only possible but also undesirable because without them beneficial predatory and parasitic insects which depend upon them as food or hosts will not survive. One of the key belief of organic farmers is that biodiversity furthers health. Greater biodiversity leads to more sustainable ecosystem.

3. Swiss cheese, large holes in Swiss cheese are due to large amount of CO_2 produced by *Propioni bacterium sharmanii*.
Roquefort cheese, ripened by growing specific fungi on them, which give them a particular flavour.

4. **(i)** Primary effluent passes to aeration tank. It is constantly agitated mechanically and air is pumped into it. This allows vigorous growth of flocs (masses of bacteria associated with fungal filaments to form mesh like structure). The purpose is to consume organic matter and to reduce BOD level of primary effluents.
(ii) The B.O.D level in a secondary treatment plant is a key metric for assessing the plant's performance and its ability to protect the environment. Regular monitoring ensures compliance with environmental standards and helps in identifying issues in the treatment process.

5. **(i)** *Nucleopolyhedrovirus.*
(ii) (1) Species specific.
(2) No negative impact on other plants / mammals / birds / fish / non target insects.
(3) Beneficial insects are conserved,
(4) Useful for ecologically sensitive area.

6. Allows vigorous growth of microbes, formation of flocs to form mesh like structures. Microbes consume major part of organic waste in the sewage. Reduces BOD of the affluent and reduces polluting potential.

7. **(i)** Biogas / Gobar gas
Methane, CO_2 / H_2 / H_2S
(ii) Anaerobic digestion of cellulose

8. (1) Lactic Acid Bacteria (LAB) produce acids that coagulate milk.
(2) Partially digests milk proteins.

9. Two reasons are:
(1) Improves nutritional quality by increasing Vitamin B_{12}.
(2) Beneficial role in checking disease causing microbes in stomach.

10. **(i)** *Baculoviruses / Nucleopolyhedro virus*
(ii) Species specific, narrow spectrum insecticidal application, no negative impact on plants/ mammals/birds/fish/non-target insects, desirable for integrated pest management.

11. *Monascus purpureus*
It is used as blood-cholesterol lowering agent. It inhibits enzyme responsible for synthesis of cholesterol.

12. Biogas plant A
Methanogens present in the cow dung (grow anaerobically on cellulosic material), produce large amounts of methane along with carbon dioxide and hydrogen.

13. Floes are masses of bacteria associated with fungal filaments to form mesh like structures.
- They consume major part of organic matter in the effluent, lower BOD significantly and reduces polluting potential.

14. **(i)** *Rhizobium* forms symbiotic association with roots of leguminous plants and helps in nitrogen fixation.
(ii) *Anabaena helps* in nitrogen fixation in aquatic or terrestrial environment and serves as biofertiliser and increases organic matter of soil.

15. *Anabaena / Nostoc / Oscillatoria*
Advantage: (1) Fix atmospheric nitrogen, (2) It acts as biofertiliser, (3) It add organic matter to the soil, (4) It increases soil fertility, (5) It reduces dependence on chemical fertilisers, (6) It replenish the soil nutrients (any two)

16. (i) (A)
(ii) In the aeration tanks the effluent is constantly agitated mechanically and air is pumped into it.
Vigorous growth of aerobic microbes into flocs (masses of bacteria associated with fungal filaments to form mesh like structures) takes place.
While growing, these microbes consume the major part of the organic matter in the effluent thus decreasing / reducing BOD.

SHORT ANSWER TYPE QUESTIONS (3 Marks)

1. The main sources of biofertilisers are bacteria, fungi and cyanobacteria.
- The nodules on the roots of leguminous plants are formed by the symbiotic association of *Rhizobium*. These bacteria fix atmospheric nitrogen into organic forms, which is used by the plant as a nutrient. Other bacteria can fix atmospheric nitrogen while free-living in the soil (examples *Azospirillum and* Azotobacter), thus enriching the nitrogen content of the soil.
- Fungi are also known to form symbiotic associations with plants (mycorrhiza). Many members of the genus *Glomus* form mycorrhiza. The fungal symbiont in these associations absorbs phosphorus from soil and passes it to the plant. Plants having such associations show other benefits also, such as resistance to root-borne pathogens, tolerance to salinity and drought, and an overall increase in plant growth and development.

- Cyanobacteria are autotrophic microbes widely distributed in aquatic and terrestrial environments many of which can fix atmospheric nitrogen, e.g. *Anabaena*, *Nostoc*, *Oscillatoria*, etc. In paddy fields, cyanobacteria serve as an important biofertiliser. Blue green algae also add organic matter to the soil and increase its fertility.

2. **(i)** Two major reasons are:
(1) Cow dung has methanogens or Methanobacterium.
(2) Cow dung is rich in cellulosic material.
(3) Bacteria grows anaerobically on cellulosic material to produce large amount of methane. (Any two)

(ii) Used as manure/ fertiliser (Organic).

3.

		Bioactive molecule	Microbial source
(i)	Myocardial infraction	Streptokinase	*Streptococcus*
(ii)	High blood cholesterol level	Statins	*Monoascus purpureus*
(iii)	Organ transplatation	Cyclosporin A	*Trichoderma polysporum*

4. (i) Cheese/ curd/ dosa/ idli/toddy.
(ii) Fermented bamboo shoot/ Fermented fish.
Role:
(1) Microbes help in fermentation.
(2) Enhance nutritional value of food.
(3) Microbes helps food last long.
(4) It give flavour.

5. **(i)** **Primary Sludge:** All the solids that settle down, during the primary treatment of sewage water.

(ii) **Activated Sludge:** Produced during the secondary treatment or biological treatment of sewage, primary effluent + aerobic microbes flocs (bacteria and fungus) – get converted to a sediment whose BOD has reduced significantly.

(iii) **Anaerobic sludge digesters:** Large tanks where activated sludge is treated with anaerobic bacteria which digest the bacteria and fungi, and produce a mixture of CH_4, H_2S and CO_2/ Biogas.

6. Bacteria—*Rhizobium / Azospirillum / Azotobacter*.
Fungi—*Mycorrhiza / Glomus*.
Cyanobacteria—*Anabaena / Nostoc / Oscillatoria*.

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. **(i)** (1) In aeration tanks, there is growth of aerobic microbes and fungi (flocs) that consume major part of organic matter in effluent thus, reducing BOD.
(2) ● Activated sludge
● Used as inoculum in aeration tanks.
(3) Bacterial flocs are allowed to sediment. (Activated sludge)

(ii) ● *Rhizobium* (Bacteria), live symbiotically in nodules of roots of leguminous plants and fix atmospheric nitrogen into organic form and provide nitrogen to the plant.
● *Glomus* (fungi), live in symbiotic association with roots of higher plants and absorb phosphorus from the soil and passes it to plants.
● Cyanobacteria (*Anabaena*, *Nostoc*, *Oscillatoria*), Add organic matter to the soil and increase fertility (Paddy fields) (Any two)

2. The primary effluent is passed into large aeration tanks and constantly agitated mechanically and air is pumped into it. This give rise to flocs (masses of bacteria associated with fungal filaments to form mesh like structures) , which consume the major part of the organic matter in the effluent and reduces the BOD (biochemical oxygen demand) of the effluent. Effluent is passed into settling tank where flocs are allowed to sediment and sediment is called activated sludge, major part of it is pumped into large tank called anaerobic sludge digesters. Here anaerobic bacteria digest the bacteria and fungi in the sludge and produce biogas (methane, hydrogen sulphide and carbon dioxide), and effluent is released into natural water bodies like rivers and streams.

3. (i) During primary treatment the floating debris is removed by sequential filtration, then the grit (soil and small pebbles) are removed by sedimentation, all solids that settle form the primary sludge, and the supernatant forms the effluent.

(ii) **Secondary treatment:** It is biological treatment in which the primary effluent is passed into large aeration tanks where it is constantly agitated mechanically and air is pumped into it. This allows vigorous growth of useful aerobic microbes into flocs (masses of bacteria associated with fungal filaments to form mesh like structures), while growing these microbes consume the major part of the organic matter in the effluent which significantly reduces the BOD (biochemical oxygen demand) of the effluent, once the BOD of sewage or waste water is reduced significantly the effluent is then passed into a settling tank where the bacterial 'flocs' are allowed to sediment called activated sludge and effluent is released in natural water bodies like river, a small part of the activated sludge is pumped back into the aeration tank to serve as the inoculum, and the remaining major part of the sludge is pumped into large tanks called anaerobic sludge digesters to produce biogas.

4. (i) The biogas plant consists of a concrete tank (10-15 feet deep) in which bio-wastes are collected and a slurry of dung is fed. Certain bacteria

(methanogens) found in anaerobic sludge, help in breakdown of cellulose and production of biogas, outlet pipe of biogas plant connected to supply of biogas to nearby houses.

(ii) Methane, CO_2, and H_2S

(iii) (1) Cow dung is available in large quantities in rural areas.
(2) Cow dung is rich in methanogen bacteria, cheap,
(3) It is used as manure(sludge),
(4) It is rich in cellulosic material,
(5) It is used for generation of biogas,
(6) Ecofriendly. (Any three)

5. (i) • To make it less polluting
Steps in sewage treatment
Primary treatment: Physical removal of floating debris throug sequential filtration and sedimentation.
• Secondary treatement biological treatment
Primary effluent is passed to large aeration tank were it is constantly agitated and air is pumped into it.
This allow vigorous growth of aerabic microbes into floc which significantly reduces organic matter or BOD.
Flocs are allowed to settle in settling tank this sediment is called activated sludge.
Major part of sludge is pumped into anaerobic sludge digestor to produce biogas.

(ii) (1) Ganga Action plan,
(2) Yamuna action plan,
(3) To build a large number of sewage treatment plants so that only treated sewage may be discharged into the rivers.

Level - 2 ADVANCED COMPETENCY FOCUSED QUESTIONS

MULTIPLE CHOICE QUESTIONS (MCQs) (1 Mark)

1. Option (D) is correct
Explanation: Biological Oxygen Demand (BOD) is a measure of the amount of oxygen that microorganisms require to break down organic matter in water. Higher BOD indicates a greater presence of organic pollutants, which increases the polluting potential of the water.
2. Option (B) is correct
Explanation: Microbes that produce secondary metabolites harmful to other organisms play a crucial role in developing bio-pesticides and antibiotics. These substances can act as toxins or inhibitors, helping to protect crops from pests in bio-pesticides and fighting bacterial infections in antibiotics.
3. Option (A) is correct
Explanation: Water from a kitchen tap typically contains fewer organic pollutants than water from a sewer pipe which has a higher concentration of organic waste and pollutants. Consequently, the BOD of the sewer pipe sample is expected to be higher than that of the kitchen tap sample.
4. Option (C) is correct
Explanation: *Saccharomyces cerevisiae* is beneficial for producing beer, wine, and wheat bread, but its presence in fruit juice can cause unwanted fermentation, spoiling the juice by producing alcohol and altering its taste.
5. Option (B) is correct
Explanation: *Saccharomyces cerevisiae* is known as baker's yeast, it ferments sugars to produce ethanol in brewing and biofuel industries.
6. Option (A) is correct
Explanation: Methanobacterium is a type of methanogenicarchaea found in anaerobic environments such as cattle dung, sewage, and marshes.It plays a crucial role in biogas production by fermenting organic matter (like carbohydrates and cellulose), and producing methane (CH_4) as a metabolic by-product.
7. Option (B) is correct
Explanation: Swiss cheese (such as Emmental) is known for its distinct holes (also called "eyes") and unique nutty flavour. These features are due to the activity of Propioni bacterium shermanii, which ferments lactic acid into propionic acid, acetic acid, and carbon dioxide (CO_2).The CO_2 forms the holes, and the acids give the cheese its characteristic flavour.
8. Option (B) is correct
Explanation: Cyanobacteria such as Anabaena, Nostoc, and Oscillatoria are commonly found in paddy fields. They are capable of fixing atmospheric nitrogen into forms usable by rice plants, especially under flooded, anaerobic conditions. This acts as a natural bio-fertiliser, reducing the need for chemical nitrogen fertilisers.

ASSERTION-REASON QUESTIONS (1 Mark)

1. Option (A) is correct
Explanation: Assertion is true. Lactobacillus is a beneficial bacterium commonly used to convert milk into curd.
Reason is also true. Lactobacillus ferments lactose (milk sugar) to produce lactic acid.
This lactic acid lowers the pH and causes coagulation of casein (milk protein), leading to curd formation.
2. Option (C) is correct
Explanation: Assertion is true. Methanogens like Methanobacterium live in the anaerobic rumen (stomach) of cattle, where they help in digestion of cellulose and produce methane gas as a byproduct.
Reason is false.Methanogens do not oxidise methane. Instead, they are strict anaerobes that produce methane (CH_4) from carbon dioxide and hydrogen under anaerobic conditions.
3. Option (A) is correct
Explanation: Assertion is true.These are free-living nitrogen-fixing bacteria found in the rhizosphere (root zone) of various crops.

Reason is also true. They convert atmospheric nitrogen (N_2) into ammonia (NH_3) or related compounds, which plants can absorb and use for growth.

4. Option (D) is correct
Explanation: Assertion is false. *Penicillium notatum* is not used as a bio-control agent. Bio-control agents are organisms like *Trichoderma* (against plant pathogens) or Bacillus *thuringiensis* (against insect larvae).

Reason is true. *Penicillium notatum* is a fungus that produces penicillin, the first discovered antibiotic, effective against many bacterial infections.

5. Option (A) is correct
Explanation: Assertion is true. Biogas, composed mainly of methane (CH_4), is generated from organic waste and is sustainable and renewable.
Reason is also true. Methanogens (e.g., Methanobacterium) break down organic material anaerobically (without oxygen) to produce methane gas.

VERY SHORT ANSWER TYPE QUESTIONS (2 Marks)

1. *Lactobacillus* is a beneficial bacterium that ferments lactose (milk sugar) in milk to produce lactic acid. The lactic acid causescoagulation of milk proteins (mainly casein), leading to the formation of curd.
2. The primary microbes involved in biogas production are methanogens, specifically archaebacteria like *Methanobacterium*. These microbes anaerobically decompose organic matter (like cattle dung) to produce methane-rich biogas.
Advantage of using Biogas over conventional fuels:
Eco-Friendly and Renewable: Biogas is a clean, renewable source of energy that reduces dependence on non-renewable fossil fuels (like coal or LPG), which contribute to air pollution and greenhouse gas emissions.
3. Rhizobium forms symbiotic associations with leguminous plants and fixes atmospheric nitrogen into usable forms (like ammonia) in root nodules.
Azospirillumis a free-living nitrogen-fixing bacterium that lives in close association with the roots of non-leguminous plants (like cereals and grasses), enhancing nitrogen availability in the soil.
Environmental Benefit over Chemical Fertilisers:
Biofertilisers do not cause soil and water pollution, unlike chemical fertilisers which can lead to eutrophication and soil degradation.
They promote sustainable and eco-friendly farming by maintaining soil health and reducing the carbon footprint.
4. The clot-dissolving injection is Streptokinase.
Streptokinase is produced by the bacterium *Streptococcus* species, especially *Streptococcus pyogenes*.
Streptokinase is used to dissolve blood clots in patients suffering from myocardial infarction (heart attack) by converting plasminogen to plasmin, which breaks down fibrin clots.
5. *Trichoderma* is a fungus that lives in the root ecosystem and protects crops from soil-borne fungal pathogens. It works by secreting enzymes that degrade the cell walls of harmful fungi., outcompeting pathogens for nutrients and space, and inducing plant defence responses, improving resistance to diseases.
6. Microbes, especially bacteria, fungi, and protozoa, play a key role in the secondary (biological) treatment of sewage. In aeration tanks, aerobic microbes consume organic matter (like human waste, food particles), and convert it into harmless by-products such as carbon dioxide, water, and biomass (activated sludge). The activated sludge contains microbial flocs that are reused to seed new batches of sewage.
This process is crucial in urban areas because urban areas produce large volumes of sewage daily due to dense populations. Proper microbial sewage treatment prevents water pollution in rivers and lakes, protects public health by reducing disease-causing pathogens, and reduces environmental contamination and promotes water recycling.
7. Statins are produced by the fungus *Monascus purpureus*. Statins inhibit the enzyme HMG-CoA reductase, which is essential for cholesterol synthesis in the liver. By blocking this enzyme, statins reduce the production of LDL (bad cholesterol), thereby lowering the risk of heart diseases such as atherosclerosis and heart attacks.

SHORT ANSWER TYPE QUESTIONS (3 Marks)

1. (i) The secondary treatment (also called biological treatment) involves the use of aerobic microbes (mainly bacteria and protozoa) in aeration tanks. These microbes form flocs (masses of bacteria held together by fungal filaments) and consume organic matter (biological oxygen demand – BOD) present in the sewage. As a result, they convert complex organic pollutants into harmless by-products such as carbon dioxide, water, and biomass. The resulting sludge is called activated sludge, part of which is recycled to initiate further treatment.
2. (i) The two Microbial Bio-fertilisers Suitable for Rice Fields:
(1) *Azospirillum*
(2) *Anabaena* (a nitrogen-fixing cyanobacterium found in association with Azolla fern)
(ii) Advantage of using bio-fertilisersover chemical fertilisers:
Eco-friendly and sustainable: Bio-fertilisers do not pollute soil and water, unlike chemical fertilisers which can cause eutrophication and soil degradation.
(iii) These microbes fix atmospheric nitrogen into ammonia or nitrate, converting it into forms that can be readily absorbed by rice plants. This enhances soil fertility, promotes plant growth, and reduces the need for synthetic nitrogen inputs.

3. (i) *Saccharomyces cerevisiae*, commonly known as baker's yeast, is used to ferment sugars present in the dough. It helps in leavening the dough by producing carbon dioxide, which causes the dough to rise, making bread soft and fluffy.
   (ii) The key product is carbon dioxide (CO_2), released during anaerobic fermentation of sugars by the yeast. This gas forms bubbles in the dough, leading to its expansion and spongy texture.
   (iii) It is used in the alcoholic beverage industry for producing beer and wine through ethanol fermentation of sugars in malted grains or fruit juices.
4. (i) Methanogenicarchaea (methanogens), such as Methanobacterium, are involved in biogas production. These microbes thrive in anaerobic conditions (absence of oxygen).
   (ii) Methanogens decompose organic matter (like cattle dung and kitchen waste) in the absence of oxygen. During this process, they convert complex compounds into methane (CH_4) — the main component of biogas, which is a combustible fuel used for cooking and lighting.
   (iii) Biogas reduces air pollution and greenhouse gas emissions by providing a clean, renewable alternative to wood, coal, or fossil fuels. It also helps in managing organic waste, reducing environmental contamination.
5. (i) *Trichoderma polysporum*, a fungus, produces cyclosporin A.
   (ii) Cyclosporin A prevents the body's immune system from attacking the transplanted organ (such as a kidney). It does this by suppressing the activity of T-cells, which are responsible for rejecting foreign tissues.
   (iii) Cyclosporin A is classified as an immunosuppressive agent because it reduces or suppresses the immune response of the body. This helps in preventing organ rejection in transplant patients by inhibiting immune cell function, especially T-lymphocytes.

CASE BASED QUESTIONS (4 Mark)

1. **(i)** Option (C) is correct
   Explanation: The growth pattern indicates that *Acremonium* fungi successfully inhibited the growth of *Enterococcus faecalis* and *Pseudomonas aeruginosa*. Therefore, the antibiotics produced by these fungi can be effective against these specific microorganisms.
   (ii) Option (C) is correct
   Explanation: One of the benefits of using microbes for antibiotic production is that it is generally faster than chemical synthesis, not longer. The other options correctly highlight advantages, such as reduced hazardous waste and lower costs.
   (iii) Option (A) is correct
   Explanation: The renewable and sustainable nature of microbial processes allows for repeated use of cultures and minimises the depletion of resources, thereby reducing the environmental impact. In contrast, hazardous chemical reactions can lead to increased pollution.
   (iv) Option (B) is correct
   Explanation: Microbial fermentation processes for antibiotic production are generally less energy-intensive and can be completed more quickly than traditional chemical synthesis, making them a preferred method in the pharmaceutical industry. The other options do not accurately reflect the advantages of microbial production methods.
2. **(i)** BOD or Biological Oxygen Demand is a measure of the amount of dissolved oxygen consumed by microorganisms while breaking down organic matter in water, indicating its pollution level.
   - A: 300 mg/L
   - B: 250 mg/L
   - C: 30 mg/L

   (ii) A - Influent will have the highest organic pollutants and hence the highest BOD. (300 mg/L)
   B - Primary treatment will reduce the organic matter and hence the BOD to some extent with sedimentation and screening. (250 mg/L)
   C - Secondary treatment involves biological processes like activated sludge or trickling filters, which reduce BOD levels to the largest extent. (30 mg/L)
   (iii) (a) BOD (Biological Oxygen Demand) measures the amount of oxygen consumed by microorganisms for oxidising the organic matter present in water. Microorganisms need more oxygen to break down organic matter in the polluted water, hence increasing the value of BOD, and indicating the poor quality of water.
   OR
   (b) The level of pollution in these samples - Sample A > Sample C > Sample B

LONG ANSWER TYPE QUESTIONS (5 Marks)

1. (i) Methanogens (a group of anaerobic archaebacteria), such as Methanobacterium, are responsible for biogas production.
   (ii) The steps involved in biogas generation are:
   (1) **Collection of Waste:** Cattle dung and other organic waste are collected and mixed with water to form a slurry.
   (2) **Anaerobic Digestion:** This slurry is fed into an airtight biogas digester where methanogenic bacteria break down the organic matter in the absence of oxygen.
   (3) **Biogas Formation:** The microbes decompose the waste through stages (hydrolysis, acidogenesis, acetogenesis, and

methanogenesis), resulting in the production of biogas, mainly composed of methane (CH_4), carbon dioxide (CO_2), and traces of hydrogen sulfide (H_2S).

(4) **Gas Collection:** The biogas is collected from the top of the digester and used for cooking, lighting, or generating electricity.

(5) **Slurry Output:** The leftover slurry is rich in nutrients and used as organic manure.

(iii) The advantages of using biogas over fossil fuels are:

(1) **Eco-friendly:** Biogas burns cleanly and produces fewer pollutants compared to fossil fuels.

(2) **Renewable and Sustainable:** Biogas is produced from biodegradable waste and is a renewable source of energy.

(iv) This practice contribute to waste management and rural sustainability by:

(1) **Effective Waste Management:** It converts cattle dung and other organic waste into useful energy and organic manure, reducing waste accumulation and pollution.

(2) **Rural Sustainability:** It provides a clean, low-cost energy source for cooking and lighting, reduces dependency on firewood and fossil fuels, and promotes organic farming through the use of enriched slurry, thereby supporting sustainable rural livelihoods.

2. (i) (1) **Medicine:**
Penicillium notatum → Penicillin (an antibiotic)
Trichoderma polysporum → Cyclosporin A (an immunosuppressive drug)

(2) Food industry:
Lactobacillus spp. → Curd/yogurt (through lactic acid fermentation)
Saccharomyces cerevisiae (yeast) → Bread and alcoholic beverages (through ethanol fermentation)

(ii) Fermentation is the process of using microbes to convert raw materials into useful products under controlled conditions. In industrial fermenters, large volumes of microbial cultures are grown in sterile, temperature-controlled tanks. Nutrients, pH, temperature, aeration, and agitation are carefully maintained to optimize microbial growth and product yield. Microbes metabolise the substrates (like sugars) and produce desired products such as antibiotics, enzymes, alcohol, acids, etc. The product is then extracted, purified, and processed for commercial use.

(iii) *Aspergillus niger* is widely used because:

(1) It produces citric acid in large quantities, a key industrial acid used in food, pharmaceuticals, and cosmetics.

(2) It can secrete various enzymes like pectinase and amylase, which are useful in the food and textile industries.

(3) It grows rapidly, utilises inexpensive substrates, and is easy to handle in bioreactors, making it cost-effective for industrial-scale production.

3. (i) (1) **Primary Treatment (Physical Process):** It involves removal of large and solid particles (like plastic, rags, sand) using screens, grit chambers, and sedimentation tanks. Suspended solids settle at the bottom as primary sludge, while the liquid moves to the next stage.

(2) **Secondary Treatment (Biological Process):** It uses aerobic microorganisms to degrade organic matter in aeration tanks. Microbes consume organic pollutants, converting them into carbon dioxide, water, and microbial biomass. The resulting mixture is passed into a settling tank to form activated sludge.

(3) **Tertiary Treatment (Advanced/Chemical/Physical):** It removes remaining inorganic nutrients, pathogens, or toxins. Methods include filtration, chlorination, UV treatment, or chemical precipitation before discharge into water bodies.

(ii) Activated sludge is the flocculent mass of microorganisms formed during secondary treatment, consisting mainly of bacteria and protozoa.It is partially recycled back into the aeration tank to maintain microbial population and enhance degradation of organic matter. The rest is removed, dewatered, and can be used as bio-fertiliser or processed for biogas generation.

(iii) The environmental benefits of microbial sewage treatment over chemical methods are:

(1) **Eco-friendly and sustainable:** Microbial methods use natural biological processes, avoiding harmful chemicals that can pollute water bodies and soil.

(2) **Resource recovery:** Microbial treatment produces biogas and bio-fertiliser, promoting energy recovery and circular waste management.

4. (i) Biological control is the use of natural predators, parasites, or microbial agents to control pests and plant diseases. It is an eco-friendly alternative to chemical pesticides.
Two commonly used microbes are *Trichoderma* spp. (a fungus), and *Bacillus thuringiensis* (a bacterium).

(ii) *Trichoderma* spp: These are free-living fungi found in root ecosystems. They attack and parasitise disease-causing fungi (like *Fusarium, Rhizoctonia*), thereby protecting plants from fungal infections.
*Bacillus thuringiensis***(Bt):** Bt produces crystal (Cry) proteins that are toxic to insect larvae (such as caterpillars). When pests ingest Bt spores or Cry toxins, their gut lining is damaged, causing death. Bt is widely used in sprays and also in Bt crops like Bt cotton.

(iii) The advantages of biological control over chemical pesticides are:

(1) **Eco-friendly and non-polluting:** Biological control does not contaminate soil, water, or air and preserves environmental balance.

(2) **Target-specific and safe:** It affects only specific pests or pathogens, sparing beneficial organisms like pollinators and natural predators, unlike broad-spectrum chemical pesticides.