Chapter 8: Microbes in Human Welfare

Exercises — Chapter-end Exercises

Q1 Bacteria cannot be seen with the naked eyes, but these can be seen with the help of a microscope. If you have to carry a sample from your home to your biology laboratory to demonstrate the presence of microbes with the help of a microscope, which sample would you carry and why?

SOLUTION

A suitable sample to carry would be curd (yoghurt) or a small piece of bread left in warm, moist conditions for a day or two.

Curd is an excellent choice because it is made by the action of lactic acid bacteria (LAB) such as Lactobacillus. These bacteria are present in enormous numbers — millions per millilitre — and can be directly mounted on a slide, stained, and observed under a light microscope as rod-shaped or spherical bacteria.

Alternatively, a small scraping from a moist bread surface showing visible mould growth would demonstrate fungal microbes (such as Rhizopus or Penicillium) with clearly visible hyphae and spores.

Curd is the most practical choice because: (i) LAB are always present in large, easily observable numbers; (ii) curd is readily available in any home; (iii) the sample remains stable during transport if kept cool; (iv) no special growth medium or incubation is needed before observation.

Answer: Curd — it contains millions of lactic acid bacteria (Lactobacillus) per mL, easily visible under a microscope after simple smear preparation.

Q2 Give examples to prove that microbes release gases during metabolism.

SOLUTION

Microbes release various gases as metabolic by-products. Several examples demonstrate this:

1. Production of CO_2 during fermentation of dough: When dough for idli, dosa, or bread is prepared, bacteria (in idli/dosa dough) or the yeast Saccharomyces cerevisiae (in bread dough) ferment the sugars present. CO_2 is released during this fermentation (glycolysis followed by anaerobic respiration), causing the dough to puff up and rise.

2. Holes in Swiss cheese: Propionibacterium sharmanii produces large amounts of CO_2 during ripening of Swiss cheese. This CO_2 creates the characteristic large holes seen in Swiss cheese.

3. Biogas production by methanogens: Bacteria such as Methanobacterium, which grow anaerobically on cellulosic material, release a mixture of methane (CH_4), CO_2, and H_2. This forms biogas (gobar gas), demonstrating gas release during microbial metabolism.

4. Sewage treatment — anaerobic sludge digesters: During the anaerobic digestion of activated sludge, anaerobic bacteria digest the organic matter and produce methane, hydrogen sulphide (H_2S), and CO_2. These gases are collected as biogas.

5. Fermented beverages: During production of wine, beer, and other alcoholic drinks, yeast (Saccharomyces cerevisiae) ferments sugars to produce ethanol and CO_2. The effervescence seen in beer is due to dissolved CO_2 released during fermentation.

Answer: Microbes release CO_2 during dough fermentation (bread/idli/dosa), CO_2 causing holes in Swiss cheese (Propionibacterium sharmanii), and methane + CO_2 + H_2S during biogas production by methanogens and anaerobic sludge digestion.

Q3 In which food would you find lactic acid bacteria? Mention some of their useful applications.

SOLUTION

Lactic acid bacteria (LAB) are found in curd (yoghurt). When a small amount of curd (inoculum/starter) is added to fresh warm milk, the LAB present multiply and ferment the lactose in milk, converting it into lactic acid. This acid coagulates and partially digests the milk proteins, converting milk into curd.

LAB are also found in fermented foods such as cheese and certain fermented beverages.

Useful applications of lactic acid bacteria:

1. Curd/yoghurt production: LAB (Lactobacillus and related bacteria) convert milk to curd through lactic acid fermentation, making it more digestible.

2. Improvement of nutritional quality: LAB increase the vitamin B_{12} content of curd, making it nutritionally superior to milk.

3. Checking disease-causing microbes in the stomach: In the human gut, LAB play a beneficial role by producing lactic acid, which creates an acidic environment that inhibits the growth of harmful, disease-causing bacteria.

4. Cheese making: LAB are used in the ripening of various types of cheese, contributing to their characteristic texture, flavour, and taste.

5. Industrial production of lactic acid: Lactobacillus is used commercially to produce lactic acid, which is used in the food and pharmaceutical industries.

Answer: LAB are found in curd. Applications: curd/yoghurt production, increasing vitamin B_{12} content, inhibiting gut pathogens, cheese ripening, and industrial lactic acid production.

Q4 Name some traditional Indian foods made of wheat, rice and Bengal gram (or their products) which involve use of microbes.

SOLUTION

Several traditional Indian foods made from wheat, rice, and Bengal gram involve microbial fermentation:

Rice-based foods:
- Idli: Made from a fermented batter of rice and black gram (urad dal). The batter is fermented overnight by bacteria, producing CO_2 that makes idlis soft and spongy.
- Dosa: Made from the same fermented rice and black gram batter as idli. Fermentation by bacteria gives dosa its characteristic slightly sour taste.

Wheat-based foods:
- Bread: Wheat flour dough is fermented using baker's yeast (Saccharomyces cerevisiae), which produces CO_2 causing the dough to rise and giving bread its porous texture.
- Bhattura/Naan: Leavened flatbreads made with wheat flour, in which yeast or LAB are used for fermentation.

Bengal gram-based foods:
- Dhokla: Made from fermented batter of Bengal gram (chickpea) flour and rice flour. Bacterial fermentation produces CO_2 and organic acids giving dhokla its spongy texture and sour taste.
- Khaman: Similar to dhokla, made from fermented Bengal gram batter.

Answer: Idli and dosa (rice + black gram, fermented by bacteria); bread (wheat, fermented by Saccharomyces cerevisiae); dhokla and khaman (Bengal gram, fermented by bacteria).

Q5 In which way have microbes played a major role in controlling diseases caused by harmful bacteria?

SOLUTION

Microbes have played a major role in controlling diseases caused by harmful bacteria primarily through the production of antibiotics.

Antibiotics are chemical substances produced by certain microbes (bacteria and fungi) that can kill or inhibit the growth of other disease-causing microbes. They are among the most significant discoveries of the twentieth century.

The first antibiotic, Penicillin, was discovered by Alexander Fleming in 1928. He observed that the mould Penicillium notatum produced a substance that prevented the growth of Staphylococci bacteria around it. Ernest Chain and Howard Florey later established its full potential as an effective antibiotic. Fleming, Chain, and Florey were awarded the Nobel Prize in 1945.

Penicillin was extensively used to treat soldiers wounded in World War II. After Penicillin, many other antibiotics were isolated from microbes.

Antibiotics have greatly improved the ability to treat deadly bacterial diseases such as:

- Plague
- Whooping cough (kali khansi)
- Diphtheria (gal ghotu)
- Leprosy (kusht rog)

These diseases used to kill millions of people worldwide. Today, antibiotics produced by microbes remain indispensable in modern medicine for treating a wide range of bacterial infections.

Answer: Microbes produce antibiotics (e.g., Penicillin from Penicillium notatum) that kill or inhibit harmful bacteria, enabling treatment of deadly diseases like plague, diphtheria, whooping cough, and leprosy.

Q6 Name any two species of fungus, which are used in the production of the antibiotics.

SOLUTION

Two fungal species used in the production of antibiotics are:

1. Penicillium notatum (also referred to as Penicillium chrysogenum in industrial production) — produces the antibiotic Penicillin, the first antibiotic to be discovered. Penicillin kills a wide range of disease-causing bacteria.

2. Trichoderma polysporum — produces the bioactive molecule Cyclosporin A. While Cyclosporin A is primarily used as an immunosuppressive agent in organ-transplant patients, it is also an antimicrobial product of fungal origin.

Note: Cephalosporium (Acremonium) species are also used to produce cephalosporin antibiotics, representing another fungal source of antibiotics.

Answer: Penicillium notatum (produces Penicillin) and Trichoderma polysporum (produces Cyclosporin A).

Q7 What is sewage? In which way can sewage be harmful to us?

SOLUTION

Sewage is the municipal waste water generated in cities and towns. It is also called urban waste water. Sewage consists of large amounts of organic matter (human excreta, food wastes, etc.) along with various microbes, many of which are pathogenic (disease-causing).

Ways in which sewage can be harmful to us:

1. Spread of water-borne diseases: Sewage contains a large number of pathogenic microbes. If discharged untreated into rivers, lakes, or other water bodies, these pathogens contaminate the drinking water supply and cause diseases such as cholera, typhoid, dysentery, and hepatitis.

2. Pollution of water bodies: Untreated sewage discharged into rivers and streams increases their organic load, leading to high BOD (biochemical oxygen demand). This depletes the dissolved oxygen in the water, killing aquatic life such as fish and other organisms.

3. Eutrophication: Nutrients in sewage (nitrogen, phosphorus) promote excessive growth of algae (algal blooms) in water bodies, further depleting oxygen and destroying aquatic ecosystems.

4. Soil and groundwater contamination: Untreated sewage seeping into the soil can contaminate groundwater, making it unsafe for drinking and irrigation.

This is why sewage must be treated in sewage treatment plants (STPs) before being discharged into natural water bodies.

Answer: Sewage is municipal waste water containing organic matter and pathogenic microbes. It is harmful because it contaminates drinking water (causing cholera, typhoid), reduces dissolved oxygen in rivers, and pollutes soil and groundwater.

Q8 What is the key difference between primary and secondary sewage treatment?

SOLUTION

Primary treatment and secondary (biological) treatment differ fundamentally in the nature of the process involved:

Primary Treatment:
- It is a physical process.
- Involves removal of large and small solid particles from sewage through sequential filtration and sedimentation.
- Floating debris is removed by filtration; grit (soil, small pebbles) is removed by sedimentation.
- The solids that settle out form the primary sludge; the liquid above (supernatant) forms the effluent that passes to secondary treatment.
- Does NOT reduce BOD significantly; does NOT remove dissolved organic matter.

Secondary Treatment (Biological Treatment):
- It is a biological process carried out by microbes.
- The primary effluent is passed into large aeration tanks, which are continuously agitated and aerated.
- Aerobic microbes grow vigorously, forming flocs (masses of bacteria associated with fungal filaments in mesh-like structures).
- These microbes consume the major part of the dissolved organic matter in the effluent.
- This significantly reduces the BOD (biochemical oxygen demand) of the effluent.
- The bacterial flocs then settle in a settling tank as activated sludge; a small portion is recycled as inoculum for the aeration tank.
- The remaining sludge is treated anaerobically in sludge digesters, producing biogas.

Key difference in one line: Primary treatment uses physical methods (filtration and sedimentation) to remove solid particles, while secondary treatment uses biological methods (aerobic microbial activity) to reduce dissolved organic matter and BOD.

Answer: Primary treatment is a physical process (filtration + sedimentation) that removes solid particles. Secondary treatment is a biological process (aerobic microbial action in aeration tanks) that reduces dissolved organic matter and significantly lowers BOD.

Q9 Do you think microbes can also be used as source of energy? If yes, how?

SOLUTION

Yes, microbes can be used as a source of energy, primarily through the production of biogas.

Biogas production by methanogens:
Certain bacteria called methanogens (e.g., Methanobacterium) grow anaerobically on cellulosic material and produce large amounts of methane (CH_4) along with CO_2 and H_2. Methane is a combustible gas and serves as the primary energy component of biogas.

Biogas plants (gobar gas plants): In rural areas, cattle dung (gobar) — which is rich in methanogenic bacteria — is fed into a concrete biogas plant along with water. As the methanogens break down the organic matter anaerobically, they produce biogas. The floating cover over the slurry rises as gas accumulates, and the gas is piped to nearby houses for use in cooking and lighting.

The technology for biogas production in India was developed mainly by the Indian Agricultural Research Institute (IARI) and the Khadi and Village Industries Commission (KVIC).

Energy from sewage treatment: During secondary sewage treatment, the activated sludge is digested anaerobically in sludge digesters by anaerobic bacteria. The gases produced — methane, H_2S, and CO_2 — form biogas that can be used as a source of energy.

Thus, microbial activity converts organic waste into usable energy in the form of biogas, making microbes an important renewable energy source.

Answer: Yes. Methanogens (e.g., Methanobacterium) break down organic matter anaerobically to produce biogas (predominantly methane), used for cooking and lighting. Anaerobic sludge digesters in sewage plants also generate biogas from activated sludge.

Q10 Microbes can be used to decrease the use of chemical fertilisers and pesticides. Explain how this can be accomplished.

SOLUTION

Microbes can reduce the need for chemical fertilisers and pesticides through their roles as biofertilisers and biocontrol agents respectively.

A. Replacing chemical fertilisers — Biofertilisers:

1. Nitrogen-fixing bacteria: Rhizobium lives in symbiotic association with the roots of leguminous plants, forming root nodules. These bacteria fix atmospheric nitrogen into organic compounds used by the plant. Free-living soil bacteria such as Azospirillum and Azotobacter also fix atmospheric nitrogen, directly enriching the soil's nitrogen content — reducing the need

for nitrogenous chemical fertilisers.

2. Mycorrhizal fungi: Members of the genus Glomus form mycorrhiza — symbiotic associations with plant roots. The fungal symbiont absorbs phosphorus from the soil and passes it to the plant, reducing the need for phosphatic chemical fertilisers. These associations also improve plant growth, drought tolerance, and resistance to root-borne pathogens.

3. Cyanobacteria (blue-green algae): Autotrophic microbes such as Anabaena, Nostoc, and Oscillatoria fix atmospheric nitrogen and also add organic matter to the soil. In paddy fields, they serve as important biofertilisers.

B. Replacing chemical pesticides — Biocontrol agents:

1. Bacillus thuringiensis (Bt): Dried spores of this bacterium are sprayed on vulnerable plants. When insect larvae (e.g., butterfly caterpillars) eat the sprayed plants, the toxin released in their gut kills them. Bt-toxin genes have also been introduced into crop plants (e.g., Bt-cotton) to make them pest-resistant.

2. Trichoderma: Free-living fungi in root ecosystems that act as effective biocontrol agents against several plant pathogens, reducing the need for fungicides.

3. Baculoviruses (Nucleopolyhedrovirus): These are species-specific insecticidal viruses that attack insects and arthropods without harming plants, mammals, birds, or non-target insects — making them ideal for integrated pest management.

4. Predatory insects supported by biodiversity: Maintaining a diverse ecosystem (organic farming approach) supports beneficial predatory insects like ladybirds (against aphids) and dragonflies (against mosquitoes), reducing dependence on insecticides.

Answer: Biofertilisers (Rhizobium, Azotobacter, mycorrhizal Glomus, cyanobacteria) fix nitrogen and supply phosphorus, reducing chemical fertiliser use. Biocontrol agents (Bt spores/Bt-crops, Trichoderma, baculoviruses) control pests biologically, reducing pesticide use.

Q11 Three water samples namely river water, untreated sewage water and secondary effluent discharged from a sewage treatment plant were subjected to BOD test. The samples were labelled A, B and C; but the laboratory attendant did not note which was which. The BOD values of the three samples A, B and C were recorded as 20mg/L, 8mg/L and 400mg/L, respectively. Which sample of the water is most polluted? Can you assign the correct label to each assuming the river water is relatively clean?

SOLUTION

BOD (Biochemical Oxygen Demand) is the amount of oxygen that would be consumed if all the organic matter in one litre of water were oxidised by bacteria. A higher BOD indicates more organic matter and therefore greater pollution.

The most polluted sample is Sample C with a BOD of 400 mg/L.

Assigning correct labels:

Sample C (BOD = 400 mg/L) — Untreated sewage water

Untreated sewage contains the highest amount of organic matter (human excreta, food waste, etc.) and pathogenic microbes. Therefore it has the highest BOD, indicating the greatest pollution.

Sample A (BOD = 20 mg/L) — Secondary effluent from sewage treatment plant
After secondary (biological) treatment, the effluent has had its organic load significantly reduced by aerobic microbial activity (BOD is reduced considerably from the raw sewage). However, it still has a higher BOD than clean river water, so it cannot be clean river water (BOD = 8 mg/L).

Sample B (BOD = 8 mg/L) — River water (relatively clean)
River water, being relatively clean with low organic matter, has the lowest BOD among the three samples.

Summary:
- Sample A (20 mg/L) = Secondary effluent (treated sewage)
- Sample B (8 mg/L) = River water (clean)
- Sample C (400 mg/L) = Untreated sewage water (most polluted)

Answer: Sample C (400 mg/L) is most polluted = untreated sewage. Sample A (20 mg/L) = secondary effluent (treated sewage). Sample B (8 mg/L) = river water (relatively clean).

Q12 Find out the name of the microbes from which Cyclosporin A (an immunosuppressive drug) and Statins (blood cholesterol lowering agents) are obtained.

SOLUTION

Cyclosporin A:
Cyclosporin A is produced by the fungus Trichoderma polysporum. It is used as an immunosuppressive agent in organ-transplant patients to prevent rejection of the transplanted organ by suppressing the immune response.

Statins:
Statins are produced by the yeast Monascus purpureus. They have been commercialised as blood-cholesterol-lowering agents. Statins act by competitively inhibiting the enzyme HMG-CoA reductase, which is responsible for the synthesis of cholesterol in the liver, thereby lowering blood cholesterol levels.

Answer: Cyclosporin A — from the fungus Trichoderma polysporum. Statins — from the yeast Monascus purpureus.

Q13 Find out the role of microbes in the following and discuss it with your teacher.
(a) Single cell protein (SCP)
(b) Soil

SOLUTION

(a) Single Cell Protein (SCP):
Single Cell Protein refers to the protein-rich biomass of microorganisms (bacteria, yeast, fungi, or algae) that is used as a protein supplement for human food or animal feed.

Role of microbes in SCP production:
- Microorganisms such as Spirulina (a cyanobacterium/blue-green alga), yeasts (Saccharomyces cerevisiae, Candida utilis), bacteria (Methylophilus methylotrophus), and fungi are grown in large quantities on cheap substrates (agricultural waste, molasses, whey, petroleum by-products, etc.).
- These microbes have a very high protein content (up to 60-80% of dry weight) and can be produced rapidly.
- SCP can meet protein demands for humans and livestock without requiring agricultural land, making it a sustainable alternative protein source.
- Spirulina, for example, is rich in protein, vitamins, and minerals and is already used as a human dietary supplement.
- SCP production can also help reduce organic waste by using waste materials as growth substrates.

(b) Role of microbes in Soil:
Microbes are essential for maintaining soil fertility and health through multiple mechanisms:

- Decomposition: Bacteria and fungi decompose dead organic matter (leaf litter, animal remains) into simpler inorganic compounds, recycling nutrients back into the soil.
- Nitrogen fixation: Free-living bacteria such as Azotobacter and Azospirillum fix atmospheric nitrogen into organic forms, enriching soil nitrogen. Rhizobium fixes nitrogen in root nodules of legumes.
- Nitrification: Nitrifying bacteria (e.g., Nitrosomonas, Nitrobacter) convert ammonium ions to nitrites and nitrates, forms that plants can absorb.
- Denitrification: Some bacteria return nitrogen to the atmosphere, completing the nitrogen cycle.
- Mycorrhizal associations: Fungi such as Glomus form mycorrhiza with plant roots, improving phosphorus uptake and plant growth.
- Cyanobacteria (Anabaena, Nostoc, Oscillatoria): Add organic matter and fixed nitrogen to the soil, especially important in paddy fields.
- Overall, microbes are the primary drivers of nutrient cycling in the soil, making soil a living ecosystem.

Answer: (a) SCP: Microbes (Spirulina, yeasts, bacteria) are grown as protein-rich biomass for human/animal nutrition. (b) Soil: Microbes decompose organic matter, fix nitrogen (Rhizobium, Azotobacter), form mycorrhizae, and drive nutrient cycling, maintaining soil fertility.

Q14 Arrange the following in the decreasing order (most important first) of their importance, for the welfare of human society. Give reasons for your answer.
Biogas, Citric acid, Penicillin and Curd

SOLUTION

Decreasing order of importance for human welfare:

1. Penicillin (most important)
Penicillin is the first antibiotic discovered and one of the most important discoveries in medical history. It has directly saved hundreds of millions of human lives by treating deadly bacterial infections such as plague, diphtheria, whooping cough, leprosy, and wound infections. Its impact on reducing mortality from infectious diseases is unmatched. Fleming, Chain, and Florey received the Nobel Prize in 1945 for this discovery. Today, antibiotics derived from microbes remain indispensable in modern medicine.

2. Curd
Curd (produced by lactic acid bacteria) is consumed by billions of people worldwide on a daily basis. It is a major source of nutrition — providing proteins, calcium, and vitamins (including vitamin B_{12}). LAB in curd also play a beneficial role in the human gut by suppressing harmful bacteria, contributing to health. As one of the oldest and most widely consumed fermented foods, its impact on human nutrition and health is enormous and continuous.

3. Biogas
Biogas (predominantly methane) produced by methanogens from cattle dung is a vital source of clean energy, particularly in rural areas of developing countries. It provides cooking fuel and lighting, reducing dependence on firewood (which causes deforestation and indoor air pollution). Biogas production also helps in waste management and provides a slurry that acts as fertiliser. While its importance is very significant for rural communities, its overall global reach is less than that of Penicillin or curd.

4. Citric acid (least important in terms of direct human welfare)
Citric acid, produced by Aspergillus niger, is used in the food and beverage industry as a flavouring and preservative, and has some pharmaceutical uses. While commercially valuable, it is not essential to human survival or health in the way that antibiotics, nutritious food (curd), or energy (biogas) are. It can also be obtained from natural plant sources (citrus fruits).

Final order: Penicillin > Curd > Biogas > Citric acid

Answer: Penicillin > Curd > Biogas > Citric acid. Penicillin saves lives from deadly bacterial diseases; curd provides daily nutrition and gut health benefits; biogas provides rural energy; citric acid has limited direct welfare impact.

Q15 How do biofertilisers enrich the fertility of the soil?

SOLUTION

Biofertilisers are organisms (mainly bacteria, fungi, and cyanobacteria) that enrich the nutrient quality of the soil. They improve soil fertility through the following mechanisms:

1. Biological nitrogen fixation by bacteria:
- Rhizobium forms symbiotic associations with roots of leguminous plants, forming root nodules. Inside these nodules, Rhizobium fixes atmospheric nitrogen (N_2) into organic nitrogen compounds (ammonia/amino acids) that the plant uses directly as nutrients. After the plant dies, this fixed nitrogen enriches the soil.
- Free-living soil bacteria such as Azospirillum and Azotobacter fix atmospheric nitrogen independently while living in the soil, directly increasing its nitrogen content without requiring a host plant.

2. Mycorrhizal associations (fungal biofertilisers):
- Fungi of the genus Glomus form mycorrhiza — symbiotic associations with plant roots.
- The fungal hyphae greatly increase the absorptive surface area of the root system and absorb phosphorus from the soil, passing it to the plant. This improves phosphorus nutrition of the plant.
- Mycorrhizal associations also confer other benefits: resistance to root-borne pathogens, tolerance to salinity and drought, and overall improvement in plant growth and development.

3. Nitrogen fixation and organic matter addition by cyanobacteria:
- Cyanobacteria (blue-green algae) such as Anabaena, Nostoc, and Oscillatoria are autotrophic microbes found widely in aquatic and terrestrial environments.
- Many of them fix atmospheric nitrogen, adding fixed nitrogen to the soil.
- They also add organic matter to the soil through photosynthesis and decomposition of their biomass, increasing soil fertility.
- In paddy fields, cyanobacteria serve as particularly important biofertilisers.

By fixing atmospheric nitrogen, improving phosphorus availability, and adding organic matter, biofertilisers replenish soil nutrients naturally and sustainably, reducing dependence on chemical fertilisers.

Answer: Biofertilisers enrich soil through: (i) nitrogen fixation by Rhizobium (symbiotic), Azotobacter/Azospirillum (free-living); (ii) phosphorus absorption and transfer by mycorrhizal fungi (Glomus); (iii) nitrogen fixation and organic matter addition by cyanobacteria (Anabaena, Nostoc, Oscillatoria).