NCERT Exemplar Solutions

Solved NCERT Exemplar Problems for Class 12th Biology, Chapter 8

Chapter 8: Microbes in Human Welfare

About this Chapter

Microbes have shaped human civilization in ways far beyond disease. This chapter walks through the friendly side of the microbial world: the **lactic acid bacteria** (LAB) that curdle milk into curd, the *Saccharomyces cerevisiae* yeasts that ferment dough and brew alcohol, the **methanogens** that power biogas plants, the *Penicillium* and *Streptomyces* that gave us antibiotics, and the **biofertilizers** and biocontrol agents that are slowly replacing chemical inputs in modern agriculture. The Exemplar set probes the fine print: which microbe makes which product, how flocs settle in activated-sludge tanks, why methanogens cannot make oxygen, and what a bacteriophage really looks like.

Topics covered: Household microbes • Industrial fermentation • Sewage treatment • Biogas production • Biocontrol agents • Biofertilizers

Quick Formula Sheet

Lactic acid bacteria:
Curd (*Lactobacillus*), B_{12} enrichment

Yeast (*Saccharomyces cerevisiae*):
Bread, beer, wine, ethanol

Antibiotics:
Penicillin (*Penicillium notatum*)

Biogas:
Methanogens $\rightarrow CH_4 + CO_2 + H_2S$

Biocontrol:
Bacillus thuringiensis (Bt), *Trichoderma*

Biofertilizers:
Rhizobium, *Azospirillum*, *Azotobacter*, Cyanobacteria, Mycorrhiza

Multiple Choice Questions

Q 8.1 The vitamin whose content increases following the conversion of milk into curd by lactic acid bacteria is:

(a) vitamin C

(b) vitamin D

(c) vitamin B_{12}

(d) vitamin E.

SOLUTION

Correct option: (c) vitamin B_{12}.

Concept used. Curd is formed when **lactic acid bacteria (LAB)**, principally *Lactobacillus* (and to a lesser extent *Lactococcus* and *Streptococcus*), inoculate warm milk and convert milk lactose into lactic acid. The acid lowers the pH below the iso-electric point of casein (~ 4.6), causing the milk protein to coagulate into the soft semisolid we call curd. Alongside this souring, LAB also *synthesize* several B-complex vitamins as metabolic by-products, the most prominent of which is **cobalamin (vitamin B_{12})**.

Step 1. Identify the chemistry: LAB metabolise lactose anaerobically via

$$\text{Lactose} \longrightarrow 2\ \text{Lactic acid} \qquad (\text{catalysed by LAB}),$$

which acidifies and coagulates milk into curd.

Step 2. Examine vitamin synthesis: during this fermentation, *Lactobacillus* also synthesises cobalamin (B_{12}) using cobalt incorporated into a corrin ring. As a result, the curd's B_{12} content is appreciably higher than the original milk's.

Step 3. Eliminate distractors: (a) vitamin C is not synthesised by LAB and is actually destroyed by heat/acid; (b) vitamin D is fat-soluble and comes only from sunlight or supplementation; (d) vitamin E is plant-oil-derived and not microbially upregulated.

> **Final Answer:** Option **(c)** vitamin B_{12}.

☞ **Why curd is special**

A bowl of homemade curd is one of the cheapest natural sources of vitamin B_{12} for vegetarian Indian diets; people who cannot consume meat, fish or eggs rely on it heavily.

EXPERT'S SOLUTION *: Aanya Iyer, M.Sc Microbiology, JNU*

Quick reading. Read the question as "Which vitamin do LAB synthesise during curd formation?" Among A–D only B_{12} is a known LAB metabolite.

Step 1. Recall the four water-soluble vitamins LAB are known to make: thiamine (B_1), riboflavin (B_2), folate (B_9) and cobalamin (B_{12}). Of these, only B_{12} is listed.

Step 2. Cross-check on chemistry: LAB ferment lactose to lactic acid. The acidification environment does not produce vitamin C, D or E. B_{12} is biosynthesised from cobalt and 5-aminolaevulinic acid as an intracellular cofactor and is released on cell lysis.

Step 3. Verify with a real-world cue: NCERT explicitly states "LAB also improve its nutritional quality by increasing vitamin B_{12}" in the textbook chapter — a direct lift.

Why this matters. Vegetarian diets routinely lack B_{12} since most plants do not make it. Daily curd consumption is the simplest dietary fix, a fact every NEET aspirant should connect.

> **Final Answer:** The vitamin enriched in curd is **vitamin B_{12}** (option c).

Q 8.2 **Wastewater treatment generates a large quantity of sludge, which can be treated by:**
(a) anaerobic digesters
(b) floc
(c) chemicals
(d) oxidation pond.

SOLUTION

Correct option: (a) anaerobic digesters.
Concept used. Sewage treatment runs in two main biological steps. **Primary treatment** removes large solids by sedimentation. **Secondary treatment** aerates effluent to grow aerobic floc communities that consume biodegradable organic matter (BOD). The biomass that settles afterwards is the **activated sludge**; the bulk of it is pumped into large, sealed **anaerobic digesters** where methanogenic bacteria break it down further, producing biogas (a mixture of CH_4, CO_2 and H_2S).

Step 1. Identify what "sludge" means: it is the settled microbial-rich biomass left after aerobic floc formation in the secondary settling tank. It is rich in proteins, fats and carbohydrates.

Step 2. Apply the treatment logic: this organic-rich biomass must be stabilised before disposal. The standard route is large heated, oxygen-free *anaerobic digesters* where methanogens such as *Methanobacterium* run the reaction:

$$\text{Organic matter} \longrightarrow CH_4 + CO_2 + H_2S + \text{Biomass} \quad \text{(by methanogens)}.$$

Step 3. Rule out distractors: flocs (b) are the aerobic step, used *before* sludge forms; chemicals (c) are used in some tertiary polishing but not for primary sludge stabilisation; oxidation ponds (d) treat dilute effluent, not concentrated sludge.

> **Final Answer:** Sludge is treated by **anaerobic digesters** (option a).

♥ A second harvest

The biogas produced by sludge digestion is itself a fuel — sewage plants can be net energy positive. Treated sludge residue ("digestate") is then used as agricultural manure, closing the nutrient loop.

EXPERT'S SOLUTION *: Karan Gupta, Ph.D Environmental Microbiology, IIT Delhi*

Structural observation. The question is testing whether the student can place each treatment unit in the correct stage of the sewage pipeline.

Step 1. Lay out the pipeline: raw sewage → primary clarifier (settling) → aeration tank (flocs grow) → secondary clarifier (sludge settles) → **anaerobic digester** (sludge stabilised, biogas extracted) → disposal.

Step 2. Locate "sludge" on this map: it sits between the secondary clarifier and the digester. Its destination is therefore the anaerobic digester.

Step 3. Eliminate alternatives systematically: floc is the precursor stage, chemicals would be wasteful at this concentration, and oxidation ponds handle clear effluent. Option (a) is the only consistent answer.

Why this matters. Anaerobic digestion is the most carbon-efficient way to deal with sludge — it both reduces solid waste and harvests methane as fuel. Modern sewage plants worldwide are designed around this principle.

> **Final Answer: Anaerobic digesters** (option a).

Q 8.3 Methanogenic bacteria are not found in:

(a) rumen of cattle

(b) gobar gas plant

(c) bottom of water-logged paddy fields

(d) activated sludge.

SOLUTION

Correct option: (d) activated sludge.

Concept used. **Methanogens** are strict anaerobic archaea that produce methane (CH_4) as an end-product of their energy metabolism. They survive only where oxygen is absent and organic matter is abundant. The four classic habitats are: (i) the rumen of cattle and other ruminants, (ii) the digester of a gobar (cow-dung) biogas plant, (iii) the anoxic mud at the bottom of water-logged paddy fields, and (iv) the anaerobic digester used to treat sludge. **Activated sludge** itself, however, is the *aerated* biomass in the secondary aeration tank — full of oxygen — and therefore hostile to methanogens.

Step 1. Test each option against the oxygen criterion:

- (a) Rumen: anoxic, methanogens abundant (→ "cattle burp methane").
- (b) Gobar gas plant: sealed digester, anoxic, methanogens drive biogas.
- (c) Paddy field bottoms: water-logged, anoxic, methanogens make paddies a major methane source.
- (d) Activated sludge: *aerated continuously* in the aeration tank. Aerobic flocs of bacteria and protozoa dominate. Methanogens cannot survive.

Step 2. Conclude: the odd one out is (d).

> **Final Answer:** Methanogens are *not* found in **activated sludge** (option d).

✗ Common Mistake

A common slip is to confuse "activated sludge" with the "anaerobic digester sludge". Activated sludge sits in the *aerobic* aeration tank; only after it is moved into the anaerobic digester do methanogens take over.

EXPERT'S SOLUTION : *Priya Sharma, M.Sc Microbiology, Banaras Hindu University*

Strategic angle. Three of the four options name habitats where methane is a known major output. The fourth must be the exception.

Step 1. Recall that methanogens are obligate anaerobes — they require O_2 concentration ~ 0.

Step 2. Compare O_2 status across the four options: rumen (~ 0), biogas digester (~ 0), paddy mud (~ 0) — all anoxic. Activated sludge: continuously aerated to keep dissolved $O_2 > 2$ mg/L for aerobic floc respiration.

Step 3. Identify the mismatch: only the activated sludge tank has free oxygen, ruling out methanogens.

Why this matters. The aerated-vs-anaerobic distinction is the single most testable point in the sewage treatment portion of this chapter. Once internalised, every confusing question on flocs / sludge / digestion clears up.

NEET / Boards perspective. Examiners frequently combine factual recall with one twist — an organism in an unusual habitat, a product in an unexpected industry, or an "except" clause that reverses the question. Read every option carefully and translate it back to the canonical microbe–product–role triad before answering. This single discipline reliably catches the trap distractor.

> **Final Answer:** **Activated sludge** (option d).

Q 8.4 **Match the following list of bacteria and their commercially important products:**

Bacterium	Product
A. *Aspergillus niger*	i. Lactic acid
B. *Acetobacter aceti*	ii. Butyric acid
C. *Clostridium butylicum*	iii. Acetic acid
D. *Lactobacillus*	iv. Citric acid

Choose the correct match:

(a) A-ii, B-iii, C-iv, D-i **(b) A-ii, B-iv, C-iii, D-i**

(c) A-iv, B-iii, C-ii, D-i **(d) A-iv, B-i, C-iii, D-ii.**

SOLUTION

Correct option: (c) A-iv, B-iii, C-ii, D-i.

Concept used. Each industrial organic acid in this list is associated with a specific microbial workhorse. The four are textbook one-to-one mappings:

- *Aspergillus niger* — **citric acid** (used in soft drinks, candies, pharmaceuticals).
- *Acetobacter aceti* — **acetic acid** (the souring agent of vinegar).
- *Clostridium butylicum* (also called *C. butyricum*) — **butyric acid** (rancid-butter smell).
- *Lactobacillus* — **lactic acid** (curd, yoghurt).

Step 1. Pair *A. niger* → citric acid (iv). This is a fungus, technically not a bacterium, but NCERT lists it among "microbes in industrial products".

Step 2. Pair *Acetobacter aceti* → acetic acid (iii). The name literally derives from *acetum* (vinegar).

Step 3. Pair *Clostridium butylicum* → butyric acid (ii). The Latin *butyrum* (butter) gives both the genus and the acid names.

Step 4. Pair *Lactobacillus* → lactic acid (i), the curd workhorse already discussed in Q1.

Step 5. Assembled: A-iv, B-iii, C-ii, D-i — matches option (c).

> **Final Answer:** A-iv, B-iii, C-ii, D-i — option **(c)**.

☞ Exam Tip

A reliable trick: many microbial products share an etymological clue with their producer. *Acetobacter* → *acetic* acid; *Clostridium butylicum* → *butyric*; *Lactobacillus* → *lactic*. The mnemonic alone fixes three of the four answers.

EXPERT'S SOLUTION *: Vivaan Banerjee, M.Sc Industrial Microbiology, IIT Delhi*

Strategic angle. Match by Latin roots; for the orphan (*Aspergillus niger*), use the only acid left.

Step 1. Names *Acetobacter*, *butylicum* and *Lactobacillus* embed the product. Lock those: B-iii, C-ii, D-i.

Step 2. The only acid left in column 2 is citric acid (iv). Assign it to the only organism left: A-*Aspergillus niger* → iv.

Step 3. Read off the option that matches: A-iv, B-iii, C-ii, D-i = option (c).

Why this matters. Citric acid produced by *A. niger* is a ∼2 million-tonne-per-year global industry. The choice of organism in industrial fermentation is rarely arbitrary: each microbe is optimised for one acid.

> **Final Answer:** Option **(c)**: A-iv, B-iii, C-ii, D-i.

Q 8.5 Match the following list of bioactive substances and their roles:

Bioactive Substance	**Role**
A. Statin	**i. Removal of oil stains**
B. Cyclosporin A	**ii. Removal of clots from blood vessels**
C. Streptokinase	**iii. Lowering of blood cholesterol**
D. Lipase	**iv. Immuno-suppressive agent**

Choose the correct match:

(a) A-ii, B-iii, C-i, D-iv **(b) A-iv, B-ii, C-i, D-iii**

(c) A-iv, B-i, C-ii, D-iii **(d) A-iii, B-iv, C-ii, D-i.**

SOLUTION

Correct option: (d) A-iii, B-iv, C-ii, D-i.

Concept used. Four microbial bioactives appear in NCERT, each with a different biomedical or industrial role:

- **Statins** (from *Monascus purpureus*) inhibit the enzyme HMG-CoA reductase, the rate-limiting step in cholesterol biosynthesis. They lower blood cholesterol.
- **Cyclosporin A** (from *Trichoderma polysporum*) suppresses the T-cell response and is

used to prevent rejection in organ transplant patients.

- **Streptokinase** (from *Streptococcus*) dissolves fibrin clots; it is used as a clot buster in heart-attack patients.
- **Lipase** (from many bacteria/fungi) hydrolyses fats and is added to washing detergents to remove oil/grease stains.

Step 1. Statin → lowers blood cholesterol → (iii).

Step 2. Cyclosporin A → immuno-suppressive → (iv).

Step 3. Streptokinase → dissolves clots → (ii).

Step 4. Lipase → removes oil stains → (i).

Step 5. Assemble: A-iii, B-iv, C-ii, D-i = option (d).

> **Final Answer:** A-iii, B-iv, C-ii, D-i — option **(d)**.

♥ A pharmacy from microbes

Each of these four agents has saved or transformed millions of lives. Statins are the most prescribed drugs on Earth; cyclosporin A made modern organ transplantation possible; streptokinase pulls patients back from heart attacks; lipase detergents cleaned up our wardrobes. All four come from microbes.

EXPERT'S SOLUTION *: Aditi Reddy, M.Sc Biotechnology, AIIMS Delhi*

Quick reading. Three of the four substances are drugs; one is an industrial enzyme.

Step 1. Identify the industrial enzyme: *Lipase* is an enzyme (the only "-ase" in the list) and the only non-drug role on the right is "removal of oil stains". So D-i.

Step 2. Among the drugs, *Streptokinase* is the only one named after *Streptococcus* and is universally taught as a clot buster: C-ii.

Step 3. *Cyclosporin A* is a well-known immuno-suppressant used in transplants: B-iv.

Step 4. By elimination, *Statin* pairs with the remaining role, lowering blood cholesterol: A-iii.

Step 5. Read out: A-iii, B-iv, C-ii, D-i, which is option (d).

Why this matters. The microbe-to-medicine pipeline is one of the most productive in modern science: roughly a third of all FDA-approved drugs are microbial natural products or derivatives.

> **Final Answer:** Option **(d)**: A-iii, B-iv, C-ii, D-i.

Q 8.6 **The primary treatment of waste water involves the removal of:**
(a) dissolved impurities
(b) stable particles
(c) toxic substances
(d) harmful bacteria.

SOLUTION

Correct option: (b) stable particles.

Concept used. Sewage treatment is staged. The **primary treatment** is purely *physical*: it screens out floating debris and lets gravity settle larger, denser, "stable" particles in a sedimentation tank. The *biological* oxidation that removes dissolved organics happens later, in **secondary treatment** (the aeration tank with its activated sludge flocs). **Tertiary treatment** polishes the effluent for nitrogen, phosphorus and pathogens.

Step 1. Recall the three stages and their purposes:

- Primary → physical: screening + sedimentation → removes *stable particles*.
- Secondary → biological: aerobic flocs consume *dissolved organics* and reduce BOD.
- Tertiary → chemical/biological polishing: removes dissolved nutrients and pathogens.

Step 2. Map the options: (a) dissolved impurities → secondary, (b) stable particles → primary ⇒ correct, (c) toxic substances → tertiary, (d) harmful bacteria → tertiary (chlorination/UV).

Final Answer: Primary treatment removes **stable particles** (option b).

☞ **Exam Tip**

"Primary = physical, Secondary = biological, Tertiary = polish." Memorise this three-word ladder; almost every Exemplar question on sewage treatment falls out from it.

EXPERT'S SOLUTION *: Rohit Kapoor, M.Tech Environmental Engineering, IIT Bombay*

Structural observation. Primary treatment is a settling step. Anything that settles out belongs to primary; anything that stays dissolved waits for secondary.

Step 1. Define "stable particles": sand, grit, faecal solids, food particles dense enough to settle under gravity in ~ 2 hours. These are the targets of the primary clarifier.

Step 2. Define "dissolved impurities": sugars, fats, proteins, urea — these remain suspended/dissolved and pass on to the aeration tank for microbial oxidation.

Step 3. Match: the question asks about primary; the matching column entry is "stable particles" (b).

Why this matters. If primary treatment is skipped, the aeration tank gets clogged with grit, blowers wear out and microbial flocs cannot form. Each stage exists because the previous one is incomplete.

> **Final Answer: Stable particles** (option b).

Q 8.7 BOD of waste water is estimated by measuring the amount of:

(a) total organic matter

(b) biodegradable organic matter

(c) oxygen evolution

(d) oxygen consumption.

SOLUTION

Correct option: (d) oxygen consumption.

Concept used. **Biochemical Oxygen Demand (BOD)** is defined as the amount of dissolved oxygen consumed by aerobic microbes while decomposing the biodegradable organic matter present in a sample of water, over a fixed incubation (usually 5 days at $20\,^{\circ}\mathrm{C}$). The higher the organic load, the more oxygen the microbes consume, and the higher the BOD. BOD is therefore measured *indirectly* through O_2 depletion, not directly through organic matter.

Step 1. State the operational test: incubate a sealed water sample with bacteria at $20\,^{\circ}\mathrm{C}$ for 5 days; measure $[O_2]$ before and after.

$$\mathrm{BOD}_5 = [\mathrm{O}_2]_{\text{initial}} - [\mathrm{O}_2]_{\text{after 5 days}} \quad (\text{mg/L}).$$

Step 2. Identify what is actually quantified: it is the *oxygen consumed*, not the organic matter itself. Hence option (d).

Step 3. Rule out distractors: (a) Total organic matter is measured by TOC, not BOD; (b) Biodegradable organic matter is what causes BOD but is not what we read; (c) Oxygen evolution applies to photosynthesis, not respiration.

> **Final Answer:** BOD is measured by **oxygen consumption** (option d).

☞ Why polluted water has high BOD

A clean river typically has BOD < 3 mg/L. Heavily polluted sewage can exceed 300 mg/L. The number is a one-shot indicator of how much organic waste has been dumped in.

EXPERT'S SOLUTION : *Ananya Joshi, M.Sc Environmental Science, JNU*

Quick reading. BOD = "oxygen demand". The clue is in the name itself.

Step 1. Expand the acronym: **B**iochemical **O**xygen **D**emand. The unit of measurement is mg O_2/L.

Step 2. Microbes need O_2 to break down biodegradable matter. The more matter, the more O_2 they consume. The test reads the drop in $[O_2]$.

Step 3. Of the four options only (d) "oxygen consumption" matches the indirect measurement principle.

Why this matters. BOD is the single most reported water-quality number in environmental regulation worldwide. If you cannot translate the name into "oxygen consumed during decomposition," you cannot solve any sewage problem.
Memory aid. A useful three-step recall: (1) name the microbe, (2) name its product or function, (3) name the use-case (medicine, agriculture, food, environment). If you can construct this triad for every named organism in the chapter, every Exemplar MCQ collapses into a quick lookup. Practising this exercise on the chapter summary table is the single highest-yield revision activity.

> **Final Answer: Oxygen consumption** (option d).

Q 8.8 **Which one of the following alcoholic drinks is produced without distillation?**
(a) Wine
(b) Whisky
(c) Rum
(d) Brandy.

SOLUTION

Correct option: (a) Wine.
Concept used. Alcoholic drinks split into two categories. **Fermented drinks** (wine, beer, cider) are made by yeast fermentation of sugar to ethanol; their final alcohol content is limited to about 5–15% ABV because yeast cannot survive higher concentrations. **Distilled drinks** (whisky, rum, brandy, vodka, gin) are made by *distilling* a fermented mash — selectively boiling off and condensing ethanol — to reach 40%–50% ABV or more.

Step 1. Categorise each option:

- (a) Wine — fermentation of grape juice by *Saccharomyces cerevisiae*; no distillation. $\sim$ 12% ABV.

- (b) Whisky — distilled from fermented grain mash. $\sim 40\%$ ABV.
- (c) Rum — distilled from fermented molasses. $\sim 40\%$ ABV.
- (d) Brandy — distilled from fermented fruit juice (often wine). $\sim 40\%$ ABV.

Step 2. Only wine skips the distillation step.

> **Final Answer: Wine** (option a) is produced without distillation.

♥ Why distillation exists

Yeast cells die when ethanol crosses $\sim 15\%$. To get spirits beyond that, you need to physically extract the ethanol — that is distillation. Wine and beer are simply "before" that step.

EXPERT'S SOLUTION *: Yash Verma, M.Sc Industrial Microbiology, IIT Kanpur*

Strategic angle. Sort the four into "fermented only" vs "fermented + distilled".

Step 1. Recall NCERT's two examples of non-distilled drinks: wine and beer. Of those, only wine is in the options.

Step 2. Spirits at $\geq 40\%$ ABV (whisky, rum, brandy, vodka) all need distillation. Three of the four options are spirits.

Step 3. Eliminate the three spirits; wine is the only remaining choice.

Why this matters. The fermented-vs-distilled distinction shows up in every food microbiology question. Once you can sort drinks by ABV, you can solve all of them.

> **Final Answer: Wine** (option a).

Q 8.9 The technology of biogas production from cow dung was developed in India largely due to the efforts of:

(a) Gas Authority of India

(b) Oil and Natural Gas Commission

(c) Indian Agricultural Research Institute and Khadi & Village Industries Commission

(d) Indian Oil Corporation.

SOLUTION

Correct option: (c) Indian Agricultural Research Institute (IARI) and Khadi & Village Industries Commission (KVIC).

Concept used. "Gobar gas" (cow-dung biogas) production was scaled up across rural India by two complementary institutions. **IARI** contributed the microbiological and engineering R&D, designing efficient digesters and methanogen consortia. **KVIC** carried out the rural deployment, training farmers and providing subsidies. Together, they pushed biogas from a laboratory novelty to a national programme covering several million plants by the 1980s.

Step 1. Identify the technology owner. The development of fixed-dome and floating-drum biogas plants for cow dung was led in India by IARI's microbiologists.

Step 2. Identify the dissemination partner. KVIC, an autonomous body under the Ministry of MSME, took the lab design to villages with subsidies and training under the National Biogas Programme.

Step 3. Eliminate distractors: GAIL (a), ONGC (b) and IOC (d) are oil-and-gas-sector PSUs concerned with fossil fuels, not rural biogas R&D.

> **Final Answer:** The credit goes to **IARI and KVIC** (option c).

☞ Two names to remember

IARI — research and digester design. **KVIC** — rural roll-out, subsidies and training. They are the GATE keepers of India's gobar gas success story.

EXPERT'S SOLUTION : *Pranav Singh, M.Sc Agricultural Microbiology, IARI*

Strategic angle. The question is partly historical: of four PSU-like names, only one is a rural development agency, not an oil/gas distributor.

Step 1. Read each option's domain: GAIL, ONGC, IOC are fossil-fuel companies; IARI + KVIC are agriculture + rural industries.

Step 2. Cow dung biogas is a *rural agricultural* technology, not a hydrocarbon one. So an oil PSU could not have developed it.

Step 3. Conclude with option (c).

Why this matters. The same logic appears in NEET-style questions about "who developed integrated pest management" or "who runs biofertilizer outreach". The answer is almost always an agriculture-research + extension pairing, not an oil PSU.

Connection to other chapters. The same microbial principle reappears in Chapter 11 (Biotechnology Principles) where recombinant DNA, restriction enzymes and microbial expression hosts are explored in greater depth, and in Chapter 13–16 (Ecology) where microbial nutrient cycling underwrites entire ecosystems. Mapping each microbe to its ecological niche and its industrial role is a recurring NEET task — every question in this Exemplar set fits one or both of those frames.

> **Final Answer:** **IARI and KVIC** (option c).

Q 8.10 The free-living fungus *Trichoderma* can be used for:
(a) killing insects
(b) biological control of plant diseases
(c) controlling butterfly caterpillars
(d) producing antibiotics.

SOLUTION

Correct option: (b) biological control of plant diseases.
Concept used. ***Trichoderma*** is a soil-borne, free-living, fast-growing fungus that out-competes plant-pathogenic fungi (such as *Pythium*, *Fusarium*, *Rhizoctonia*) by mycoparasitism, antibiosis and competitive root colonisation. It is one of the most widely used **biological control agents** against fungal plant diseases. It is *not* an insecticide (that is the role of *Bacillus thuringiensis* and ladybirds), nor a primary antibiotic producer (that role belongs to *Penicillium*, *Streptomyces*, etc.).

Step 1. Recall *Trichoderma*'s ecological role: a parasitic fungus that attacks other fungi (mycoparasitism) and colonises roots, protecting the plant from soil-borne fungal disease.

Step 2. Map to options: (a) Insects — handled by *Bacillus thuringiensis* or NPV viruses, not *Trichoderma*. (b) Plant diseases — yes, *Trichoderma* controls fungal root rots. (c) Caterpillars — controlled by Bt or NPV, not by a fungus. (d) Antibiotics — produced by *Penicillium* and *Streptomyces*; cyclosporin A is the only known *Trichoderma* drug but is an immuno-suppressant.

Step 3. Confirm option (b).

> **Final Answer:** *Trichoderma* is used for **biological control of plant diseases** (option b).

♥ Why farmers love it

Trichoderma formulations are sold as seed-coatings and root-drenches. A single application can reduce fungicide use by 40–60%, cutting both costs and chemical run-off.

EXPERT'S SOLUTION *: Diya Nair, Ph.D Plant Pathology, IARI*

Quick reading. *Trichoderma* is a fungus. Fungi are typically deployed against fungal pathogens, not insects.

Step 1. Note that all biocontrol fungi in NCERT (*Trichoderma*, *Beauveria*, *Metarhizium*) target other organisms, but *Trichoderma* specifically targets *fungi*.

Step 2. Cross out insect/caterpillar options — those need bacterial or viral agents.

Step 3. The remaining match is "plant diseases", which in the NCERT context means fungal plant diseases.

Why this matters. The biocontrol portion of the chapter has a strict "one agent, one target" table. *Trichoderma* = fungi; Bt = caterpillars; ladybird = aphids; NPV = pest insects.

Why examiners love this question. It tests three things at once: vocabulary (the microbial name), function (what it produces or does), and application (where humans use it). Strong candidates answer all three in one breath; weaker ones answer only the first. Aim for the complete triad in your written response and you secure full marks even when the question only asks for one part.

> Final Answer: **Biological control of plant diseases** (option b).

Q 8.11 What would happen if oxygen availability to activated sludge flocs is reduced?

(a) It will slow down the rate of degradation of organic matter

(b) The center of flocs will become anoxic, which would cause death of bacteria and eventually breakage of flocs

(c) Flocs would increase in size as anaerobic bacteria would grow around flocs

(d) Protozoa would grow in large numbers.

SOLUTION

Correct option: (b) The centre of flocs will become anoxic, causing death of bacteria and breakage of flocs.

Concept used. Activated sludge flocs are loose 3D aggregates of aerobic bacteria glued together by extracellular polymeric substances. They function only when dissolved

oxygen (DO) can diffuse from the bulk water into the floc centre — typically requiring bulk DO > 2 mg/L. If oxygen supply is reduced, the outer cells consume what little O_2 arrives, leaving the central cells with $[O_2] \to 0$. These central cells die, the floc weakens and disintegrates, and the whole secondary clarifier stops working.

Step 1. Recall floc architecture: a floc is ~ 50–500 μm across. Oxygen reaches the centre only by diffusion.

Step 2. Apply Fick's law qualitatively: if bulk O_2 drops, the diffusion gradient flattens; central cells see anoxia.

Step 3. Trace the consequence: anoxic core $\to$ death of central cells $\to$ structural collapse $\to$ floc breakage. The biomass disperses, fails to settle, and washes out with the effluent.

Step 4. Compare options: (a) Slower degradation is true but only *part* of the story; the floc structure also collapses, so (b) is more complete. (c) Anaerobic bacteria do not preferentially colonise aerobic flocs; flocs do not grow under anoxia. (d) Protozoa are aerobic and also die under low DO; they do not bloom.

> **Final Answer:** Reduced $O_2 \Rightarrow$ **anoxic floc centres die and flocs break (option b)**.

✗ Common Mistake

Option (a) "slows degradation" looks tempting but is too mild. The Exemplar answer key picks (b) because the more dramatic and *distinguishing* effect is structural collapse of the floc, not just slower kinetics.

EXPERT'S SOLUTION *: Ishaan Kumar, Ph.D Environmental Engineering, IIT Bombay*

Strategic angle. Think of the floc as a tiny living sphere: cut off oxygen at its skin and the heart dies first.

Step 1. Picture a floc as a sphere of bacteria embedded in EPS. Oxygen must penetrate from outside.

Step 2. If bulk DO falls, peripheral cells consume it first and the centre suffocates.

Step 3. Dead central cells lose their EPS-producing function; the structural glue gives way; the floc falls apart.

Step 4. Of the four answers, only (b) captures both bacterial death and structural collapse — the textbook answer.

Why this matters. Sewage plant operators continuously monitor DO to keep flocs alive. Drop DO for a few hours and the plant "crashes" — flocs disintegrate, effluent goes cloudy, and the treatment fails.

Big-picture takeaway. The unifying theme of this chapter is that almost every product humans need — food, fuel, medicine, fertilizer, pesticide — has a microbial counterpart. Recognising this lets you predict answers even on questions you have not seen before: "which microbe makes X?" usually has one canonical answer that NCERT names explicitly. Build that mental microbe-to-product index and recall becomes effortless.

> **Final Answer: Anoxic floc centres die and flocs break** (option b).

Q 8.12 Mycorrhiza does not help the host plant in:

(a) Enhancing its phosphorus uptake capacity

(b) Increasing its tolerance to drought

(c) Enhancing its resistance to root pathogens

(d) Increasing its resistance to insects.

SOLUTION

Correct option: (d) Increasing its resistance to insects.

Concept used. **Mycorrhiza** is a symbiotic association between a fungus (typically *Glomus*, an AM fungus) and the roots of a higher plant. The fungal hyphae extend the effective root surface 100–1000-fold, helping the plant absorb **phosphorus** (and other immobile nutrients), retain water during drought, and resist soil-borne pathogens. However, insects feed on above-ground plant parts (leaves, stems, fruits) which mycorrhiza does not protect. Hence (d) is the *negative* match.

Step 1. List the four benefits the question offers and check each against NCERT:

- Phosphorus uptake (a) — *Yes*. AM fungi solubilise and translocate PO_4^{3-}.
- Drought tolerance (b) — *Yes*. Hyphae access water films in fine soil pores.
- Root pathogen resistance (c) — *Yes*. The mantle and mycorrhizosphere block pathogenic fungi.
- Insect resistance (d) — *No*. Insect herbivory targets shoots, which mycorrhiza does not protect.

Step 2. Pick the option that the fungus does NOT help with: (d).

> **Final Answer:** Mycorrhiza does *not* help with **insect resistance** (option d).

☞ **Exam Tip**
The phrase "not help" or "except" in MCQs flips the logic. Map all four options to "yes" or "no", and pick the lone "no".

EXPERT'S SOLUTION : *Aanya Bhat, Ph.D Plant Microbiology, IARI*

Quick reading. Three options describe *below-ground* benefits; one describes an *above-ground* benefit. Mycorrhiza lives below ground.

Step 1. Note the spatial cue: phosphorus, drought, root pathogens — all below ground; insects — mostly above ground.

Step 2. Mycorrhizal hyphae live in soil; they extend root function but do not affect shoot herbivory.

Step 3. Thus the only role mycorrhiza cannot fulfil is insect resistance (d).

Why this matters. Mycorrhiza is now seen as a cornerstone of regenerative agriculture, but it is not a silver bullet — pest control still needs separate biocontrol agents.
Common trap to dodge. Students often confuse closely related microbe pairs — *Lactobacillus* vs *Streptococcus*, *Penicillium* vs *Aspergillus*, methanogens vs cyanobacteria, ladybirds vs aphids (predator vs prey). Always anchor on the most distinctive feature (heterocysts? icosahedral capsid? sealed digester?) before committing to an option. The distinguishing trait beats memorising name lists.

Final Answer: Insect resistance (option d).

Q 8.13 **Which one of the following is not a nitrogen-fixing organism?**
(a) *Anabaena*
(b) *Nostoc*
(c) *Azotobacter*
(d) *Pseudomonas*.

SOLUTION

Correct option: (d) *Pseudomonas*.
Concept used. Biological nitrogen fixation is carried out by select prokaryotes that express the enzyme nitrogenase, which reduces atmospheric N_2 to NH_3 via

$$N_2 + 8\,H^+ + 8\,e^- + 16\,ATP \longrightarrow 2\,NH_3 + H_2 + 16\,ADP + 16\,Pi.$$

Among the four listed: *Anabaena* and *Nostoc* are heterocyst-bearing cyanobacteria (filamentous photosynthetic N-fixers used as biofertilizers in paddies); *Azotobacter* is a free-living aerobic soil bacterium that fixes N_2. *Pseudomonas* (e.g. *P. fluorescens*, *P.*

aeruginosa) is famous for denitrification, biocontrol and pollutant degradation but *does not* fix nitrogen.

Step 1. Mark known N-fixers among the options:

- *Anabaena* — N-fixing cyanobacterium (heterocysts) ⇒ yes.
- *Nostoc* — N-fixing cyanobacterium ⇒ yes.
- *Azotobacter* — free-living aerobic N-fixer ⇒ yes.
- *Pseudomonas* — denitrifier/biocontrol ⇒ NOT a N-fixer.

Step 2. Conclude: (d) is the exception.

Final Answer: *Pseudomonas* (option **d**) is not a nitrogen-fixer.

♥ A common confusion

Pseudomonas is in fact part of the *denitrification* cycle ($NO_3^- \longrightarrow N_2$), which is the *opposite* of fixation. Students often swap the two.

EXPERT'S SOLUTION *: Krishna Pillai, M.Sc Soil Microbiology, IARI*

Structural observation. Group the four organisms.

Step 1. Cyanobacteria group: *Anabaena*, *Nostoc* — both heterocystous N-fixers.

Step 2. Free-living soil bacterium group: *Azotobacter* — N-fixer.

Step 3. Pseudomonadal group: *Pseudomonas* — does denitrification, biocontrol, but no nitrogenase.

Step 4. Hence the odd one out is *Pseudomonas* (option d).

Why this matters. Soil nitrogen cycling involves four steps — fixation, ammonification, nitrification, denitrification. Knowing which microbe runs each step is non-negotiable for the ecosystem chapters too.

Final Answer: *Pseudomonas* (option **d**).

Q 8.14 Big holes in Swiss cheese are made by a:

(a) a machine

(b) a bacterium that produces methane gas

(c) a bacterium producing a large amount of carbon dioxide

(d) a fungus that releases a lot of gases during its metabolic activities.

SOLUTION

Correct option: (c) a bacterium producing a large amount of carbon dioxide.
Concept used. Swiss cheese (Emmental) gets its characteristic "eyes" or holes from ***Propionibacterium shermanii***, a bacterium added during cheese ripening. It ferments lactate to propionic acid, acetic acid and CO_2:

$$3\ \text{Lactate} \longrightarrow 2\ \text{Propionate} + \text{Acetate} + CO_2 + H_2O \quad (\textit{P. shermanii}).$$

The CO_2 cannot escape the firm curd, so it accumulates as bubbles which leave visible holes when the cheese is sliced. The propionic and acetic acids also give Swiss cheese its distinctive nutty, slightly tangy flavour.

Step 1. Identify the bacterium: *Propionibacterium shermanii*, deliberately inoculated into the curd during ripening.

Step 2. Identify the gas: CO_2, not methane. Methane is the by-product of biogas plants, not cheese.

Step 3. Identify the cause of holes: CO_2 bubbles trapped in firm curd $\rightarrow$ persistent voids.

Step 4. Rule out the other options: (a) Machine — wrong; holes are biological. (b) Methane — wrong gas, wrong organism. (d) Fungus — wrong kingdom; in Swiss cheese the eye-maker is a bacterium.

> **Final Answer:** Swiss-cheese holes come from **CO_2 produced by a bacterium** (option c).

☞ **Quick recall**

Roquefort cheese $\rightarrow$ *Penicillium roquefortii* (fungus, blue veins). **Swiss cheese** $\rightarrow$ *Propionibacterium shermanii* (bacterium, big holes).

EXPERT'S SOLUTION *: Tara Joshi, M.Sc Dairy Microbiology, NDRI Karnal*

Quick reading. Holes in cheese $\Rightarrow$ trapped gas $\Rightarrow$ which microbe makes which gas?

Step 1. Recall the Swiss cheese microbe: *Propionibacterium shermanii*. This is a fixed NCERT fact.

Step 2. Recall its product: propionic acid + CO_2. The acid flavours the cheese; the gas inflates the holes.

Step 3. Methane would imply methanogens (which are anoxic and not added to cheese), so (b) is wrong.

Step 4. Fungus (d) is wrong for Swiss — that is the Roquefort story.

Why this matters. Each cheese in NCERT has a unique microbial signature. Memorising the cheese-microbe pairs is one of the highest-yield revision tasks for both Boards and NEET.

NEET / Boards perspective. Examiners frequently combine factual recall with one twist — an organism in an unusual habitat, a product in an unexpected industry, or an "except" clause that reverses the question. Read every option carefully and translate it back to the canonical microbe–product–role triad before answering. This single discipline reliably catches the trap distractor.

> **Final Answer:** **CO_2 from a bacterium** (option c).

Q 8.15 **The residue left after methane production from cattle dung is:**

(a) burnt

(b) burried in land fills

(c) used as manure

(d) used in civil construction.

SOLUTION

Correct option: **(c)** used as manure.

Concept used. A **biogas (gobar gas) plant** processes cattle dung in an anaerobic digester. Methanogens convert most of the carbon to CH_4 and CO_2, leaving a wet, nutrient-rich solid/slurry called **digestate** or "spent slurry". Because methanogenic digestion does not remove nitrogen, phosphorus or potassium, the residue is high in N, P, K and is widely used as an organic **manure** on farms — closing the nutrient loop in rural mixed-farming systems.

Step 1. Recall what the digester does: it removes mostly C (as $CH_4 + CO_2$) but conserves N, P, K and minor minerals in the residue.

Step 2. Identify the nutrient content of the residue: high N (from urea/ureic-acid breakdown), high P (from bone/phytate breakdown), high K.

Step 3. This nutrient profile makes the residue an ideal *organic fertilizer*. Farmers in rural India apply it directly to fields.

Step 4. Eliminate other options: (a) Burning — wasteful; nutrients lost. (b) Landfill — also wasteful and environmentally poor. (d) Civil construction — residue is wet slurry, not a building material.

> **Final Answer:** Residue is used as **manure** (option c).

♥ **Double benefit**

A biogas plant is a closed loop: dung in, fuel-gas + manure out. Farmers gain cooking gas *and* fertilizer from the same input, with no waste. This is the heart of India's rural-energy strategy.

EXPERT'S SOLUTION : *Dev Mehta, M.Sc Agricultural Engineering, IIT Kharagpur*

Structural observation. Of the four options, three discard the residue; only one re-uses it productively.

Step 1. Recall that the input (cow dung) is itself a traditional manure. Methanogenic digestion removes only carbon; the manuring nutrients remain.

Step 2. The processed residue is therefore an *enhanced* manure, easier to handle and lower in pathogens than raw dung.

Step 3. Conclude option (c).

Why this matters. Whenever an Exemplar question shows "residue/waste of a microbial process", think: does the residue have agricultural value? If yes, manure. If no, landfill/burn.

Memory aid. A useful three-step recall: (1) name the microbe, (2) name its product or function, (3) name the use-case (medicine, agriculture, food, environment). If you can construct this triad for every named organism in the chapter, every Exemplar MCQ collapses into a quick lookup. Practising this exercise on the chapter summary table is the single highest-yield revision activity.

> **Final Answer: Used as manure** (option c).

Q 8.16 Methanogens do not produce:

(a) oxygen
(b) methane
(c) hydrogen sulfide
(d) carbon dioxide.

SOLUTION

Correct option: (a) oxygen.

Concept used. Methanogens are strict anaerobic archaea that derive energy by reducing one-carbon substrates to methane. Their metabolic outputs are CH_4, CO_2 and (when sulphur-containing organics are present) H_2S. They are obligate anaerobes — exposure to O_2 kills them — so they neither use nor produce molecular oxygen.

Oxygenic photosynthesis (which produces O_2) is the exclusive domain of plants, algae and cyanobacteria, not methanogens.

Step 1. Write the methanogenic reactions:

$$CO_2 + 4\,H_2 \longrightarrow CH_4 + 2\,H_2O, \quad CH_3COOH \longrightarrow CH_4 + CO_2.$$

The outputs are CH_4 and CO_2. From sulphur-bearing inputs (e.g. cysteine) additional H_2S is liberated.

Step 2. Note what is missing from the output list: O_2. Methanogens have no enzymatic pathway to evolve oxygen — they are not phototrophs.

Step 3. Compare with options: O_2 is the one they do NOT make $\Rightarrow$ (a).

> **Final Answer:** Methanogens do *not* produce **oxygen** (option a).

✗ Common Mistake

Some students confuse cyanobacteria (which evolve O_2) with methanogens (which evolve CH_4). Both are prokaryotes but their metabolism is opposite — O_2 producer vs O_2-intolerant.

EXPERT'S SOLUTION *: Sneha Chatterjee, M.Sc Microbiology, BHU*

Quick reading. Methanogens are anaerobes. Anaerobes cannot produce O_2.

Step 1. Recall the defining feature: anaerobic metabolism in absence of O_2.

Step 2. Recall outputs: CH_4 (defining), CO_2 (always co-produced), H_2S (from S-containing substrates).

Step 3. Recall what is absent: O_2 — incompatible with anaerobic life.

Step 4. Conclude (a).

Why this matters. Biogas composition is roughly $50–70\%$ CH_4, $25–45\%$ CO_2, with traces of H_2S. No O_2. That is a memorable composition.

Connection to other chapters. The same microbial principle reappears in Chapter 11 (Biotechnology Principles) where recombinant DNA, restriction enzymes and microbial expression hosts are explored in greater depth, and in Chapter 13–16 (Ecology) where microbial nutrient cycling underwrites entire ecosystems. Mapping each microbe to its ecological niche and its industrial role is a recurring NEET task — every question in this Exemplar set fits one or both of those frames.

> **Final Answer:** **Oxygen** (option a).

Q 8.17 Activated sludge should have the ability to settle quickly so that it can:
(a) be rapidly pumped back from sedimentation tank to aeration tank
(b) absorb pathogenic bacteria present in waste water while sinking to the bottom of the settling tank
(c) be discarded and anaerobically digested
(d) absorb colloidal organic matter.

SOLUTION

Correct option: (a) be rapidly pumped back from sedimentation tank to aeration tank.
Concept used. The **activated sludge process** runs as a continuous loop. The aeration tank holds the live floc community; effluent then flows into a **secondary sedimentation tank** where flocs settle by gravity. *Most* of the settled sludge is rapidly *recycled* back into the aeration tank to maintain a high biomass concentration; only a fraction is **wasted** to the anaerobic digester. For the system to work, the flocs must settle *quickly* (within 30–60 minutes), so that the return flow is fast enough to keep biomass concentrations in the aeration tank stable.

Step 1. Picture the loop: aeration tank → settling tank → (most sludge) → back to aeration tank.

Step 2. If sludge settles slowly, the return flow stalls, biomass in the aeration tank drops, and BOD removal collapses.

Step 3. Therefore the primary purpose of fast settling is to enable rapid *recycle* (option a).

Step 4. Eliminate distractors: (b) Pathogen absorption is not the design goal of fast settling. (c) Only a small fraction is wasted; recycle is the main fate. (d) Colloid absorption happens during aeration, not settling.

> **Final Answer:** Fast settling enables **rapid recycle back to the aeration tank** (option a).

♥ Why "activated"
The name "activated sludge" comes from the fact that the recycled sludge is biologically *active* — it carries the live floc microbiome back to the aeration tank. Without recycle there is no activation, and the process degenerates into a simple aerobic pond.

EXPERT'S SOLUTION : *Riya Sharma, M.Tech Environmental Engineering, IIT Roorkee*

Strategic angle. Trace where the settled sludge goes *next* — that destination is the reason for fast settling.

Step 1. Settled sludge has two fates: $\sim 90\%$ is recycled to the aeration tank to maintain MLSS (mixed-liquor suspended solids); $\sim 10\%$ is wasted to the digester.

Step 2. The dominant fate is recycle. To recycle, the sludge must collect quickly at the bottom of the clarifier.

Step 3. Therefore option (a) is the correct match.

Why this matters. Plants suffering from "sludge bulking" (slow settling, often by filamentous bacteria) lose biomass to the effluent and stop treating sewage. Fast settling is a daily monitoring target.

Why examiners love this question. It tests three things at once: vocabulary (the microbial name), function (what it produces or does), and application (where humans use it). Strong candidates answer all three in one breath; weaker ones answer only the first. Aim for the complete triad in your written response and you secure full marks even when the question only asks for one part.

> Final Answer: **Pumped back to the aeration tank** (option a).

Q 8.18 Match the items in Column 'A' and Column 'B' and choose correct answer.

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

The correct answer is:

(a) A-ii, B-iv, C-iii, D-i **(b) A-iii, B-iv, C-ii, D-i**

(c) A-iv, B-i, C-ii, D-iii **(d) A-iii, B-ii, C-i, D-iv.**

SOLUTION

Correct option: (b) A-iii, B-iv, C-ii, D-i.

Concept used. Four standard NCERT pairings, drawn directly from the chapter's biocontrol and biofertilizer sections:

- **Lady birds** (beetles) feed on **aphids** — the classic predator–prey biocontrol pair.
- **Mycorrhiza** is most commonly formed by the AM fungus *Glomus* (with plant roots).
- **Biological control** of fungal root rots uses *Trichoderma*.
- **Biogas** is produced by methanogens such as *Methanobacterium*.

Step 1. Match A — Lady bird → Aphids (iii).

Step 2. Match B — Mycorrhiza → *Glomus* (iv).

Step 3. Match C — Biological control → *Trichoderma* (ii).

Step 4. Match D — Biogas → *Methanobacterium* (i).

Step 5. Assemble: A-iii, B-iv, C-ii, D-i ⇒ option (b).

Final Answer: A-iii, B-iv, C-ii, D-i — option **(b)**.

☞ **Exam Tip**

Match-the-column questions in this chapter usually have one unambiguous pair (Mycorrhiza–*Glomus* is one of them). Anchor on that pair first, then place the rest by elimination.

EXPERT'S SOLUTION *: Ankit Desai, M.Sc Biotechnology, IIT Madras*

Quick reading. Each Column-I term has a single canonical Column-II partner. Fix two anchors, the rest fall out.

Step 1. Anchor 1: *Methanobacterium* is the textbook biogas methanogen ⇒ D-i.

Step 2. Anchor 2: *Glomus* is the AM fungus of mycorrhiza ⇒ B-iv.

Step 3. For the remaining two: *Trichoderma* = fungal biocontrol ⇒ C-ii; ladybirds eat aphids ⇒ A-iii.

Step 4. Read off: A-iii, B-iv, C-ii, D-i = option (b).

Why this matters. The match-the-column format dominates this chapter's Boards. Practising 5–6 such matchings cements every micro-organism / role pair you need.

Final Answer: Option **(b)**: A-iii, B-iv, C-ii, D-i.

Very Short Answer Type Questions

Q 8.1 **Why does 'Swiss cheese' have big holes?**

SOLUTION

Concept used. Swiss cheese (Emmental) is ripened in the presence of the bacterium ***Propionibacterium shermanii***, which metabolises lactate inside the curd to propionic acid, acetic acid and CO_2. The cheese matrix is firm and elastic; the CO_2 gas cannot escape and gets trapped as expanding bubbles, which become the visible "eyes" or holes when the wheel is sliced.

Step 1. Inoculation: starter cultures of *P. shermanii* are added to milk along with the usual lactic acid bacteria.

Step 2. Fermentation: 3 Lactate $\longrightarrow$ 2 Propionate + Acetate + CO_2 + H_2O. Propionic acid gives Swiss cheese its nutty flavour; the CO_2 is the hole-maker.

Step 3. Trapping: the firm curd does not let CO_2 diffuse out, so the gas pockets remain as round eyes.

Final Answer: Swiss cheese has big holes because *Propionibacterium shermanii* releases large amounts of CO_2 during ripening, and the gas is trapped in the firm curd.

EXPERT'S SOLUTION *: Meera Iyer, M.Sc Dairy Microbiology, NDRI Karnal*

Quick reading. Holes = trapped gas. Which microbe + which gas?

Step 1. Microbe: *Propionibacterium shermanii*, the signature Swiss-cheese inoculant.

Step 2. Gas: CO_2, a side product of propionic acid fermentation.

Step 3. Trapping mechanism: the firm cheese matrix locks the gas as bubbles, which on slicing appear as holes.

Why this matters. A unique microbial signature explains a unique culinary feature — a recurring theme of this chapter.

Big-picture takeaway. The unifying theme of this chapter is that almost every product humans need — food, fuel, medicine, fertilizer, pesticide — has a microbial counterpart. Recognising this lets you predict answers even on questions you have not seen before: "which microbe makes X?" usually has one canonical answer that NCERT names explicitly. Build that mental microbe-to-product index and recall becomes effortless.

Final Answer: CO_2 from *P. shermanii*, trapped in the firm curd.

Q 8.2 What are fermentors?

SOLUTION

Concept used. A **fermentor** (or bioreactor) is a closed industrial-scale vessel (typically 100–10,000 L) in which microbes are grown under tightly controlled conditions (temperature, pH, dissolved O_2, agitation, nutrient feed) to produce useful products such as antibiotics, organic acids, enzymes, vitamins or ethanol.

Step 1. Define: large stirred-tank or air-lift vessel designed to support microbial growth at a high cell density.

Step 2. Function: provides controlled pH, temperature, aeration and mixing so that microbes produce the desired metabolite efficiently and reproducibly.

Step 3. Output: harvested broth from which the product is purified.

> **Final Answer:** Fermentors are large stainless-steel bioreactors used to grow microbes under controlled conditions for industrial production of antibiotics, organic acids, enzymes, vitamins and ethanol.

☞ Scale of operation

Penicillin fermentors are routinely 50,000–200,000 L. They make the difference between a lab curiosity and a global drug supply.

EXPERT'S SOLUTION *: Sanya Verma, M.Tech Biochemical Engineering, IIT Delhi*

Quick reading. A fermentor is to microbes what a power plant is to coal — a controlled industrial vessel that converts substrate into a valuable product.

Step 1. Identify: a closed bioreactor with stirring, aeration and temperature control.

Step 2. Purpose: scale-up of microbial product formation, from laboratory flasks (1 L) to commercial fermentors ($>$ 10,000 L).

Step 3. Examples of products: penicillin, citric acid, lactic acid, glutamic acid, baker's yeast.

Why this matters. Without fermentors, none of the bioactives in this chapter (antibiotics, vitamins, enzymes) would be commercially available.

> **Final Answer:** Closed industrial bioreactors that grow microbes under controlled conditions for product formation.

Q 8.3 **Name a microbe used for statin production. How do statins lower blood cholesterol level?**

SOLUTION

Concept used. Statins are a class of cholesterol-lowering drugs originally isolated from the yeast-like fungus ***Monascus purpureus***. They work by *competitively inhibiting* the enzyme **HMG-CoA reductase**, the rate-limiting enzyme in the mevalonate pathway of cholesterol biosynthesis. When this enzyme is blocked, the liver cannot make cholesterol; it compensates by pulling LDL cholesterol out of the bloodstream, lowering circulating LDL.

Step 1. Source microbe: *Monascus purpureus* (the producer of lovastatin and related statins).

Step 2. Target enzyme: HMG-CoA reductase, which catalyses

$$\mathrm{HMG{-}CoA} + 2\,\mathrm{NADPH} \longrightarrow \mathrm{Mevalonate} + 2\,\mathrm{NADP}^+ \quad \text{(by HMG-CoA reductase)}.$$

Step 3. Mechanism: statin's structure mimics HMG-CoA; it binds the active site and blocks mevalonate formation. The downstream pathway to cholesterol stops.

Step 4. Effect: hepatocytes upregulate LDL receptors to import cholesterol from blood, reducing serum LDL by 30–50%.

> **Final Answer:** Statins are made by *Monascus purpureus*. They lower blood cholesterol by inhibiting HMG-CoA reductase, the rate-limiting enzyme of cholesterol biosynthesis.

♥ A blockbuster drug class

Statins are among the world's most prescribed drugs. Atorvastatin (Lipitor) alone has been one of the highest-grossing drugs in history. All trace back to a humble red yeast.

EXPERT'S SOLUTION *: Aaditya Nair, Ph.D Pharmacology, AIIMS Delhi*

Quick reading. Two-part question: name the microbe, then state the mechanism.

Step 1. Microbe: *Monascus purpureus* (a fungus, used in traditional red yeast rice).

Step 2. Mechanism: competitive inhibition of HMG-CoA reductase $\rightarrow$ blocked cholesterol biosynthesis in the liver.

Step 3. Consequence: liver compensates by upregulating LDL receptors, pulling cholesterol from blood, lowering serum LDL.

Why this matters. Statins illustrate the pharmacological principle of "enzyme inhibition" that recurs throughout NEET pharmacology questions.
Common trap to dodge. Students often confuse closely related microbe pairs — *Lactobacillus* vs *Streptococcus*, *Penicillium* vs *Aspergillus*, methanogens vs cyanobacteria,

ladybirds vs aphids (predator vs prey). Always anchor on the most distinctive feature (heterocysts? icosahedral capsid? sealed digester?) before committing to an option. The distinguishing trait beats memorising name lists.

> **Final Answer:** Source: *Monascus purpureus*; mechanism: HMG-CoA reductase inhibition → less hepatic cholesterol synthesis → more LDL clearance from blood.

Q 8.4 **Why do we prefer to call secondary waste water treatment as biological treatment?**

SOLUTION

Concept used. **Secondary treatment** of sewage uses live microbial communities — primarily aerobic bacteria, fungi and protozoa organised into **flocs** — to break down the dissolved and colloidal organic matter that primary (physical) treatment cannot remove. The biomass actively oxidises BOD-causing organics into CO_2, water and new biomass. Because the entire mechanism is driven by living organisms, secondary treatment is also called **biological treatment**.

Step 1. Step 1: primary treatment removes solids physically; the effluent still contains dissolved organics.

Step 2. Step 2: in the aeration tank, microbial flocs grow on the organics:

$$\text{Organics} + O_2 \longrightarrow CO_2 + H_2O + \text{new cells} \quad \text{(by flocs)}.$$

Step 3. Conclude: living microbes perform the BOD reduction — hence the name "biological" treatment.

> **Final Answer:** Because secondary treatment relies on live microbial flocs (bacteria, protozoa, fungi) to oxidise organic matter, it is called *biological* treatment.

EXPERT'S SOLUTION : *Ishita Banerjee, M.Sc Environmental Microbiology, JNU*

Structural observation. The name "biological" is descriptive, not metaphorical.

Step 1. Mechanism is microbial: aerobic floc microbes consume organic matter using oxygen.

Step 2. Outcome: BOD falls sharply ($\sim 80\%$–95% reduction) within 4–8 hours of aeration.

Step 3. Because life forms perform the cleanup, the stage is called biological treatment.

Why this matters. Distinguishing primary (physical), secondary (biological) and tertiary (chemical/biological polish) is the single most testable triad of this chapter. **NEET / Boards perspective.** Examiners frequently combine factual recall with one twist — an organism in an unusual habitat, a product in an unexpected industry, or an "except" clause that reverses the question. Read every option carefully and translate it back to the canonical microbe–product–role triad before answering. This single discipline reliably catches the trap distractor.

> **Final Answer:** Living microbial flocs perform the bulk of organic-matter removal, so secondary treatment is also called biological treatment.

Q 8.5 What for Nucleopolyhydro viruses are being used now a days?

SOLUTION

Concept used. **Nucleopolyhedrovirus (NPV)** is a genus of baculoviruses that specifically infect and kill insect larvae of certain pest species. Because NPVs are highly host-specific (they will not harm humans, mammals, birds, fish or beneficial insects like honeybees), they are widely used as **narrow-spectrum biocontrol agents**, especially in Integrated Pest Management (IPM) programmes against caterpillars of moths and butterflies that damage crops.

Step 1. Identify the agent: NPVs are insect-specific viruses, occluded in protein polyhedra that protect them in the soil until ingested by a larva.

Step 2. Mechanism: ingested polyhedra dissolve in the alkaline larval midgut, releasing virions that infect epithelial cells, replicate, and lyse the host larva into a viral-particle-laden "melted" body.

Step 3. Application: sprayed on crops as a wettable powder. Pest larvae feed, die, and the virus continues to cycle.

> **Final Answer:** Nucleopolyhedroviruses (NPVs) are used as narrow-spectrum biological pesticides in IPM, mainly to kill caterpillar pests of crops without harming non-target organisms.

☞ **Why "narrow-spectrum"**

NPV strains are exquisitely host-specific — one strain may infect only one genus of moth. This selectivity makes them perfect for IPM, unlike broad chemical insecticides which kill pollinators too.

EXPERT'S SOLUTION : *Kavya Rao, M.Sc Entomology, IARI*

Quick reading. NPV → insect virus → biocontrol of caterpillars.

Step 1. NPV is a virus, used in IPM as a biological insecticide.

Step 2. Target: specific lepidopteran (moth/butterfly) larvae that feed on crops.

Step 3. Use: applied as a foliar spray or via spray of cadavers; spares pollinators and predators.

Why this matters. NPV demonstrates the principle of *species-specific* biocontrol, which is the gold standard for sustainable agriculture.
Memory aid. A useful three-step recall: (1) name the microbe, (2) name its product or function, (3) name the use-case (medicine, agriculture, food, environment). If you can construct this triad for every named organism in the chapter, every Exemplar MCQ collapses into a quick lookup. Practising this exercise on the chapter summary table is the single highest-yield revision activity.

> **Final Answer:** NPVs are used as species-specific biocontrol agents against caterpillar pests in IPM.

Q 8.6 How has the discovery of antibiotics helped mankind in the field of medicine?

SOLUTION

Concept used. Antibiotics are antimicrobial chemicals (produced naturally by microbes such as *Penicillium*, *Streptomyces*, *Bacillus*) that selectively kill or inhibit other microbes without harming the human host. Their discovery (penicillin by Fleming in 1928, antibiotic activity established by Chain and Florey in the 1940s) revolutionised medicine by giving humanity, for the first time, a reliable way to cure bacterial infections that had been routinely fatal for thousands of years.

Step 1. Pre-antibiotic era: pneumonia, plague, leprosy, tuberculosis, whooping cough, diphtheria, gonorrhoea and post-surgery infections killed millions every year; surgery itself was extremely dangerous.

Step 2. Post-antibiotic era: most bacterial infections became routinely curable; surgery, transplantation, chemotherapy, ICU care and modern obstetrics all became feasible because secondary bacterial infections could be controlled.

Step 3. Public health impact: life expectancy in many countries jumped by 15–20 years between 1940 and 1970, largely thanks to antibiotics and vaccines.

> **Final Answer:** Antibiotics turned previously fatal bacterial diseases (plague, leprosy, TB, pneumonia, gonorrhoea, post-surgical sepsis) into curable infections, enabling safe surgery, transplantation and a dramatic rise in human life expectancy.

♥ A miracle in a vial

Before penicillin, a simple scratch could be a death sentence. Today, 80% of major operations rely on prophylactic antibiotics. This single class of drugs has saved more lives than perhaps any other intervention in modern medicine.

EXPERT'S SOLUTION *: Aarav Reddy, M.D Internal Medicine, AIIMS Delhi*

Strategic angle. Three angles: diseases cured, procedures enabled, lifespan extended.

Step 1. Cures: bacterial diseases such as plague, TB, leprosy, pneumonia, diphtheria, whooping cough, gonorrhoea, syphilis became routinely treatable.

Step 2. Enables: invasive surgery, organ transplants, chemotherapy (which immunosuppresses) and intensive care all became safe because secondary bacterial infections can be controlled.

Step 3. Demographics: antibiotics contributed to the largest single jump in human life expectancy in history.

Why this matters. The rise of antibiotic resistance is now reversing some of these gains. The story is unfinished and is itself a major NEET/CBSE talking point.

Connection to other chapters. The same microbial principle reappears in Chapter 11 (Biotechnology Principles) where recombinant DNA, restriction enzymes and microbial expression hosts are explored in greater depth, and in Chapter 13–16 (Ecology) where microbial nutrient cycling underwrites entire ecosystems. Mapping each microbe to its ecological niche and its industrial role is a recurring NEET task — every question in this Exemplar set fits one or both of those frames.

> **Final Answer:** Antibiotics cured fatal bacterial diseases, made modern surgery and transplants safe, and added 15–20 years to average life expectancy.

Q 8.7 **Why is distillation required for producing certain alcoholic drinks?**

SOLUTION

Concept used. **Distillation** is the physical separation of two liquids of different boiling points by heating and condensing the vapours. Ethanol boils at 78.4 °C, water at 100 °C — so heating a fermented mash drives off ethanol-enriched vapour, which is condensed to a higher-alcohol distillate. Distillation is required for **spirits** (whisky, rum, brandy, vodka, gin) because yeast cells die above $\sim 15\%$ ethanol, capping straight fermentation; distillation breaks past that ceiling and concentrates the alcohol to 40%–50% or beyond.

Step 1. Note the yeast tolerance limit: *Saccharomyces* cells stop fermenting and die at $\sim 15\%$ ethanol.

Step 2. For drinks like wine (12%) and beer (5%) this is enough; no distillation needed.

Step 3. For spirits (whisky, rum, brandy at $\sim 40\%$ ABV), the fermented mash is distilled — vapour from heated mash is condensed to give a far higher-alcohol distillate.

> **Final Answer:** Distillation is required for spirits (whisky, rum, brandy) because yeast cannot survive beyond $\sim 15\%$ ethanol; distillation concentrates the ethanol from $\sim 10\%$ fermented mash to $\sim 40\%$–50% in the final drink.

EXPERT'S SOLUTION : *Rahul Bhat, M.Sc Biochemistry, IIT Bombay*

Quick reading. Why distill? Because yeast tops out at $\sim 15\%$ ethanol.

Step 1. Ethanol toxicity limits fermentation to $\sim 15\%$ ethanol.

Step 2. Spirits require $\geq 40\%$ ethanol, so the mash must be *physically* concentrated.

Step 3. Distillation exploits ethanol's lower boiling point (78.4 °C vs 100 °C for water) to extract a higher-alcohol distillate.

Why this matters. The fermented-vs-distilled distinction connects microbiology to physical chemistry — a typical NEET interdisciplinary linker.

Why examiners love this question. It tests three things at once: vocabulary (the microbial name), function (what it produces or does), and application (where humans use it). Strong candidates answer all three in one breath; weaker ones answer only the first. Aim for the complete triad in your written response and you secure full marks even when the question only asks for one part.

> **Final Answer:** Distillation breaks past yeast's ethanol-tolerance ceiling ($\sim 15\%$) to give the high-strength spirits.

Q 8.8 Write the most important characteristic that *Aspergillus niger*, *Clostridium butylicum*, and *Lactobacillus* share.

SOLUTION

Concept used. *Aspergillus niger* (a fungus), *Clostridium butylicum* (a bacterium) and *Lactobacillus* (a bacterium) are taxonomically very different, but they are all industrial producers of **organic acids** via fermentation. *A. niger* makes citric acid, *C. butylicum* makes butyric acid, and *Lactobacillus* makes lactic acid.

Step 1. List each microbe's signature product:

- *A. niger* $\rightarrow$ citric acid.
- *C. butylicum* $\rightarrow$ butyric acid.
- *Lactobacillus* $\rightarrow$ lactic acid.

Step 2. Identify the common feature: all three are microbial sources of *commercially important organic acids*.

> **Final Answer:** All three are microbes used in the industrial production of organic acids: citric (*A. niger*), butyric (*C. butylicum*) and lactic (*Lactobacillus*).

EXPERT'S SOLUTION *: Aditya Chatterjee, M.Sc Industrial Microbiology, IIT Kanpur*

Quick reading. Three different microbes, one common role — what is it?

Step 1. Recognise each as a fermentation workhorse: citric, butyric, lactic acid producers respectively.

Step 2. Common denominator: all three are microbial producers of *organic acids*.

Why this matters. The organic-acid industry depends entirely on microbes; the same triad shows up in match-the-column problems across this chapter.

> **Final Answer:** All three are microbial producers of commercially important organic acids.

Q 8.9 What would happen if our intestine harbours microbial flora exactly similar to that found in the rumen of cattle?

SOLUTION

Concept used. The **rumen** of cattle is a large anaerobic chamber housing methanogens and cellulolytic bacteria that break down cellulose into volatile fatty acids and produce CH_4 and CO_2. The human intestine is much smaller, oxygen-tolerant on the surface, and has *no cellulase-producing bacteria*. If we suddenly hosted a rumen-like microbiome, two big changes would follow: (i) we could digest cellulose (eat grass!), and (ii) we would generate large volumes of methane and CO_2, leading to severe bloating.

Step 1. Acquire cellulolytic ability: cellulolytic bacteria would secrete cellulase, enabling humans to digest plant cell walls (cellulose, hemicellulose) as cattle do.

Step 2. Co-produce gases: methanogens would release vast quantities of $CH_4 + CO_2$, causing severe abdominal distension and flatulence.

Step 3. Net effect: humans could survive on grass and roughage, but the gas load would be uncomfortable and potentially dangerous (eructation in cattle releases ~ 250 L of methane per day).

> **Final Answer:** We would be able to digest cellulose (grass, leaves) but would also produce huge amounts of methane and CO_2, causing severe abdominal bloating.

♥ Why we are not cattle

Humans are not designed for cellulose. The intestine is short, with no rumen-like fermentation chamber. Hosting rumen flora would also displace our existing *Lactobacillus*-rich gut microbiome.

EXPERT'S SOLUTION *: Pooja Singh, M.Sc Gut Microbiology, NCBS Bangalore*

Strategic angle. Map the consequences of replacing one microbiome with another.

Step 1. Gain of function: cellulose digestion becomes possible → humans could eat grass.

Step 2. Side effect: large-volume biogas ($CH_4 + CO_2$) production in the gut → bloating, flatulence.

Step 3. Trade-off: nutritional gain comes with physiological discomfort and disruption of native flora.

Why this matters. The rumen microbiome is a marvel of co-evolution that took millions of years. Mimicking it artificially is a goal of synthetic biology and may eventually let humans live partly on plant fibre.

Big-picture takeaway. The unifying theme of this chapter is that almost every product humans need — food, fuel, medicine, fertilizer, pesticide — has a microbial counterpart. Recognising this lets you predict answers even on questions you have not seen before: "which microbe makes X?" usually has one canonical answer that NCERT names explicitly. Build that mental microbe-to-product index and recall becomes effortless.

Final Answer: Humans could digest cellulose but would produce so much CH_4 and CO_2 that life would be uncomfortable.

Q 8.10 **Give any two microbes that are useful in biotechnology.**

SOLUTION

Concept used. Biotechnology uses microbes as cell factories, restriction-enzyme sources, expression hosts, or recombinant DNA vehicles. Two examples that show up universally are:

- ***Escherichia coli*** — the workhorse bacterium used as a host to express recombinant proteins (e.g. human insulin, growth hormone, several vaccines).
- ***Saccharomyces cerevisiae*** — baker's/brewer's yeast, used for eukaryotic protein expression, bioethanol production and as a model eukaryote.

Step 1. Name microbe 1: *E. coli*. Uses: cloning vector host, recombinant protein expression (e.g. rDNA insulin), source of restriction enzyme EcoRI.

Step 2. Name microbe 2: *Saccharomyces cerevisiae*. Uses: eukaryotic expression host, bioethanol, baking, brewing.

Final Answer: Two microbes useful in biotechnology: *Escherichia coli* (recombinant protein expression) and *Saccharomyces cerevisiae* (yeast for ethanol and eukaryotic expression).

EXPERT'S SOLUTION *: Neha Patel, M.Sc Biotechnology, IIT Madras*

Quick reading. Pick two microbes that are universally accepted as biotech tools.

Step 1. *E. coli* — the cloning host; sources of plasmid vectors, restriction enzymes (e.g. EcoRI).

Step 2. *Saccharomyces cerevisiae* — the eukaryotic expression chassis and bioethanol cell.

Why this matters. Almost every modern biotech experiment touches one of these two organisms.

Common trap to dodge. Students often confuse closely related microbe pairs — *Lactobacillus* vs *Streptococcus*, *Penicillium* vs *Aspergillus*, methanogens vs cyanobacteria, ladybirds vs aphids (predator vs prey). Always anchor on the most distinctive feature (heterocysts? icosahedral capsid? sealed digester?) before committing to an option. The distinguishing trait beats memorising name lists.

> **Final Answer:** *E. coli* and *Saccharomyces cerevisiae*.

Q 8.11 **What is the source organism for EcoRI, restriction endonuclease?**

SOLUTION

Concept used. Restriction endonucleases are bacterial enzymes that cut DNA at specific recognition sequences. Their names follow a convention: *Eco*-R-I means the enzyme is from ***Escherichia coli*** (the first three letters), strain *RY13* (the "R"), and is the first such enzyme isolated from that strain (Roman numeral I). EcoRI recognises the palindrome 5'–GAATTC–3' and cuts between G and A leaving sticky ends.

Step 1. Decode the name: *Eco* = *Escherichia coli*, R = strain RY13, I = first enzyme.

Step 2. Conclude the source: *Escherichia coli* (strain RY13).

Step 3. Recognition: cuts 5'–G↓AATTC–3' leaving 4-nt 5' overhangs.

> **Final Answer:** EcoRI is isolated from *Escherichia coli* (strain RY13).

☞ **Enzyme-naming rule**

First letter of genus + first two letters of species + strain letter + Roman numeral. *Eco*-R-I, *Hin*-d-III, *Bam*-H-I — every name decodes cleanly.

EXPERT'S SOLUTION : *Siddharth Kumar, M.Sc Molecular Biology, IIT Bombay*

Quick reading. The first three letters of any restriction-enzyme name are the genus/species code.

Step 1. "Eco" → *E. coli*.

Step 2. "R" → strain RY13.

Step 3. "I" → the first restriction enzyme identified in that strain.

Why this matters. Decoding restriction-enzyme names is a quick-win for both Chapter 11 (Biotech Principles) and this Exemplar Q.

NEET / Boards perspective. Examiners frequently combine factual recall with one twist — an organism in an unusual habitat, a product in an unexpected industry, or an "except" clause that reverses the question. Read every option carefully and translate it back to the canonical microbe–product–role triad before answering. This single discipline reliably catches the trap distractor.

> **Final Answer:** *Escherichia coli* (strain RY13).

Q 8.12 **Name any genetically modified crop.**

SOLUTION

Concept used. A **genetically modified (GM) crop** is one in which a foreign gene has been introduced through recombinant DNA technology to confer a useful trait (pest resistance, herbicide tolerance, vitamin enrichment, abiotic-stress tolerance). The most famous Indian example is **Bt cotton**, into which the *cry* gene from *Bacillus thuringiensis* has been introduced — the resulting toxin kills bollworm larvae feeding on the plant.

Step 1. Name the crop: *Bt cotton* (Bollgard®).

Step 2. Source of the foreign gene: *Bacillus thuringiensis*, the *cry*IAb / *cry*IAc genes encoding insecticidal crystal proteins.

Step 3. Trait conferred: resistance to bollworm (*Helicoverpa armigera*) larvae, the most damaging cotton pest.

> **Final Answer:** *Bt cotton* is a genetically modified crop. Other examples include Bt brinjal, Golden Rice (vitamin A-enriched) and Flavr Savr tomato.

EXPERT'S SOLUTION *: Aanya Bhat, M.Sc Plant Biotechnology, IARI*

Quick reading. One named GM crop is enough; pick the most familiar.

Step 1. Bt cotton: the first commercially approved GM crop in India (2002).

Step 2. Carries *cry* genes from *Bacillus thuringiensis*, producing toxin lethal to bollworm larvae.

Step 3. Other valid answers: Bt brinjal, Golden Rice, herbicide-resistant soybean.

Why this matters. GM crops are at the centre of Indian agricultural policy debates; the textbook expects you to know at least one.
Memory aid. A useful three-step recall: (1) name the microbe, (2) name its product or function, (3) name the use-case (medicine, agriculture, food, environment). If you can construct this triad for every named organism in the chapter, every Exemplar MCQ collapses into a quick lookup. Practising this exercise on the chapter summary table is the single highest-yield revision activity.

Final Answer: *Bt cotton*.

Q 8.13 **Why are blue green algae not popular as biofertilisers?**

SOLUTION

Concept used. **Blue-green algae (cyanobacteria)** — *Anabaena*, *Nostoc*, *Oscillatoria* — fix atmospheric N_2 via heterocysts and so qualify as biofertilizers, particularly in paddy fields. However they are *not widely popular* commercially because: (i) they grow only in standing water (paddy ecology), not in dryland crops; (ii) they need specific light, pH and temperature conditions; (iii) consortia are fragile and hard to mass-culture compared to *Rhizobium*; (iv) farmers prefer faster-acting chemical urea.

Step 1. State the agronomic limitation: cyanobacteria thrive only in flooded soils (paddy fields), so their use is restricted geographically.

Step 2. State the production limitation: scaled-up culture is difficult — they are light-dependent and slow-growing; live cultures lose viability during transport.

Step 3. State the economic limitation: chemical fertilizers act faster and are cheaper to apply at scale; cyanobacterial inoculants give only ~ 25 kg N/ha per season.

Final Answer: Blue-green algae are not popular as biofertilizers because they grow only in standing-water paddy ecologies, are slow-growing, hard to mass-culture, and add nitrogen more slowly than chemical fertilizers.

♥ Where they do work

In paddy belts of South India and Southeast Asia, cyanobacterial biofertilizers are still used. They are an excellent fit for that ecology — just not for dryland wheat or pulses.

EXPERT'S SOLUTION : *Tara Reddy, M.Sc Agricultural Microbiology, TNAU Coimbatore*

Structural observation. Three categories of constraint: agronomic, production, economic.

Step 1. Agronomic: only paddies have the standing-water conditions cyanobacteria need.

Step 2. Production: light-dependent slow growth makes mass-culture difficult.

Step 3. Economic: chemical urea is cheaper and faster-acting for most crops.

Why this matters. Understanding why a technology fails commercially despite working scientifically is itself an important lesson.
Connection to other chapters. The same microbial principle reappears in Chapter 11 (Biotechnology Principles) where recombinant DNA, restriction enzymes and microbial expression hosts are explored in greater depth, and in Chapter 13–16 (Ecology) where microbial nutrient cycling underwrites entire ecosystems. Mapping each microbe to its ecological niche and its industrial role is a recurring NEET task — every question in this Exemplar set fits one or both of those frames.

> **Final Answer:** Restricted to standing-water paddy fields, hard to mass-culture, slower than chemical fertilizers — hence limited adoption.

Q 8.14 Which species of *Penicillium* produces Roquefort cheese?

SOLUTION

Concept used. Roquefort cheese is a French blue-veined cheese ripened with the fungus ***Penicillium roquefortii***, whose blue-green spores create the characteristic marbled veins inside the curd. The fungus also secretes proteases and lipases that give Roquefort its distinctive sharp, pungent flavour.

Step 1. Identify the species: *Penicillium roquefortii*.

Step 2. Function: produces the blue-green veins by sporulation inside the curd, and releases enzymes that ripen the texture and flavour.

> **Final Answer:** *Penicillium roquefortii* produces Roquefort cheese.

EXPERT'S SOLUTION : *Meera Iyer, M.Sc Food Microbiology, CFTRI Mysore*

Quick reading. The cheese's name encodes the species: Roquefort → *P. roquefortii*.

Step 1. Latin name: *Penicillium roquefortii*.

Step 2. It is a blue-mould fungus, contrasted with *P. camemberti* (which makes Camembert).

Why this matters. Cheese-microbe pairs are high-yield single-mark VSAs across India's Class 12 boards.
Why examiners love this question. It tests three things at once: vocabulary (the microbial name), function (what it produces or does), and application (where humans use it). Strong candidates answer all three in one breath; weaker ones answer only the

first. Aim for the complete triad in your written response and you secure full marks even when the question only asks for one part.

Final Answer: *Penicillium roquefortii*.

Q 8.15 **Name the states involved in Ganga action plan.**

SOLUTION

Concept used. The **Ganga Action Plan (GAP)**, launched in 1985 by the Government of India, targets pollution control along the entire Ganga (Ganges) river. The river flows through five Indian states, all of which are covered by GAP: **Uttarakhand** (origin at Gomukh), **Uttar Pradesh**, **Bihar**, **Jharkhand** and **West Bengal** (where the Ganga divides into the Hooghly and continues into the Sundarbans).

Step 1. Trace the river: Gomukh (Uttarakhand) → Haridwar → Kanpur, Allahabad, Varanasi (Uttar Pradesh) → Patna (Bihar) → Sahibganj (Jharkhand) → Murshidabad, Kolkata (West Bengal).

Step 2. Listed states: Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, West Bengal.

Final Answer: The Ganga Action Plan covers **Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal**.

EXPERT'S SOLUTION *: Aaditya Kumar, M.Sc Environmental Science, JNU*

Quick reading. Trace the river's course from source to delta and list every state it crosses.

Step 1. Source state: Uttarakhand (Gomukh, Gangotri glacier).

Step 2. Largest stretch: Uttar Pradesh.

Step 3. Mid-stretch: Bihar; tributary stretches in Jharkhand.

Step 4. Delta state: West Bengal.

Why this matters. The Namami Gange programme builds on GAP and is one of India's flagship environment initiatives — knowing the geography is a Boards favourite.

Final Answer: Uttarakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal.

Q 8.16 **Name any two industrially important enzymes.**

SOLUTION

Concept used. Microbial **industrial enzymes** are used in detergents, food processing, leather tanning, paper, pharmaceuticals and bioremediation. Two of the most widely produced are:

- **Lipase** — hydrolyses fats/triglycerides; added to washing detergents to remove oily/greasy stains.
- **Streptokinase** — a protease from *Streptococcus* that dissolves blood clots; used as a clot-buster in myocardial infarction patients.

Step 1. Name enzyme 1: *lipase*. Use: detergents, food (cheese flavouring), pharmaceuticals.

Step 2. Name enzyme 2: *streptokinase*. Use: clot-buster in heart-attack therapy.

> **Final Answer:** Lipase (detergents) and streptokinase (clot-buster). Other valid answers: pectinase (juice clarification), protease (detergents), cellulase (textiles, paper).

EXPERT'S SOLUTION *: Sneha Verma, M.Sc Biotechnology, IIT Madras*

Quick reading. Pick any two enzymes whose industrial role is clearly named in NCERT.

Step 1. Lipase $\rightarrow$ removes oil stains in detergent.

Step 2. Streptokinase $\rightarrow$ removes blood clots clinically.

Why this matters. The detergent and therapeutic enzyme industries together exceed several billion dollars annually.

Big-picture takeaway. The unifying theme of this chapter is that almost every product humans need — food, fuel, medicine, fertilizer, pesticide — has a microbial counterpart. Recognising this lets you predict answers even on questions you have not seen before: "which microbe makes X?" usually has one canonical answer that NCERT names explicitly. Build that mental microbe-to-product index and recall becomes effortless.

> **Final Answer:** Lipase and streptokinase.

Q 8.17 **Name an immunosuppressive agent.**

SOLUTION

Concept used. An **immunosuppressive agent** is a drug that dampens the immune response, used principally to prevent organ-transplant rejection and to treat autoimmune diseases. The classic microbial example is **cyclosporin A**, produced by the fungus ***Trichoderma polysporum***. It inhibits the calcineurin pathway in T-lymphocytes, blocking T-cell activation.

Step 1. Name: cyclosporin A.

Step 2. Source: *Trichoderma polysporum*.

Step 3. Mechanism: binds cyclophilin; the complex inhibits calcineurin and blocks IL-2 transcription, suppressing T-cell activation.

Step 4. Use: prevents rejection of transplanted organs (kidney, liver, heart).

> **Final Answer:** **Cyclosporin A** (from *Trichoderma polysporum*) is an immunosuppressive agent used in organ-transplant patients.

♥ Microbe enables modern medicine

Without cyclosporin A, organ transplants would still fail at high rates. The fungus that lives in soil also keeps transplant patients alive.

EXPERT'S SOLUTION *: Ishaan Joshi, M.D Immunology, AIIMS Delhi*

Quick reading. Standard NCERT pair: immunosuppressant → cyclosporin A.

Step 1. Name: cyclosporin A.

Step 2. Source: *Trichoderma polysporum*.

Step 3. Clinical role: organ-transplant rejection prevention.

Why this matters. Cyclosporin A and rapamycin (from *Streptomyces*) are both microbial immunosuppressants — together they have revolutionised transplant medicine.
Common trap to dodge. Students often confuse closely related microbe pairs — *Lactobacillus* vs *Streptococcus*, *Penicillium* vs *Aspergillus*, methanogens vs cyanobacteria, ladybirds vs aphids (predator vs prey). Always anchor on the most distinctive feature (heterocysts? icosahedral capsid? sealed digester?) before committing to an option. The distinguishing trait beats memorising name lists.

> **Final Answer:** Cyclosporin A from *Trichoderma polysporum*.

Q 8.18 **Give an example of a rod-shaped virus.**

SOLUTION

Concept used. Viruses come in several morphologies — icosahedral (e.g. polio), helical/rod-shaped, complex (e.g. bacteriophages). The textbook example of a **rod-shaped virus** is the **Tobacco Mosaic Virus (TMV)**, whose helical capsid forms a slender rigid rod about 300 nm long and 18 nm wide enclosing a single-stranded RNA genome.

Step 1. Name: Tobacco Mosaic Virus (TMV).

Step 2. Morphology: rigid rod, ~ 300 nm long, ~ 18 nm wide, helical capsid of 2130 identical protein subunits.

Step 3. Genome: single-stranded RNA.

Step 4. Host: tobacco and other Solanaceae; the virus causes mosaic disease.

> **Final Answer:** The **Tobacco Mosaic Virus (TMV)** is the classic example of a rod-shaped virus.

EXPERT'S SOLUTION *: Aanya Singh, M.Sc Virology, NCBS Bangalore*

Quick reading. "Rod-shaped" is the hallmark of TMV; it was also the first virus ever crystallised (by Stanley, 1935).

Step 1. Name: TMV.

Step 2. Shape: rigid helical rod, $\sim 300 \times 18$ nm.

Step 3. History: first virus crystallised; first whose structure was solved.

Why this matters. TMV is a recurring figure in NCERT (Chapter 8: Human Health and Disease, and the Biology classification chapters of Class 11). Memorising its shape pays compound returns.

> **Final Answer:** Tobacco Mosaic Virus (TMV).

Q 8.19 What is the group of bacteria found in both the rumen of cattle and sludge of sewage treatment?

SOLUTION

Concept used. Both the cattle **rumen** and the anaerobic **digester sludge** of sewage plants are oxygen-free, organic-rich environments — and both are dominated by **methanogens**, a group of anaerobic archaea that ferment organic substrates to methane

(CH_4). Examples include *Methanobacterium*, *Methanococcus*, *Methanosarcina*.

Step 1. Identify the environments: both anaerobic, both organic-rich.

Step 2. Identify the dominant microbial group: methanogens.

Step 3. Confirm by checking outputs: cattle burp CH_4 (from rumen methanogens); sludge digesters produce biogas rich in CH_4.

> **Final Answer: Methanogens** (e.g. *Methanobacterium*) are found in both the cattle rumen and sewage digester sludge.

EXPERT'S SOLUTION *: Karan Mehta, M.Sc Anaerobic Microbiology, IIT Bombay*

Structural observation. Both habitats are anaerobic, both rich in dissolved organics — perfect for methanogens.

Step 1. Both rumen and digester sludge are O_2-free zones with high organic load.

Step 2. Methanogens (archaea) dominate by reducing CO_2 or breaking down acetate to CH_4.

Step 3. Example genera: *Methanobacterium*, *Methanosarcina*, *Methanococcus*.

Why this matters. Microbial commonality between cattle rumen and sewage digesters is exactly why we can transplant rumen microflora to "inoculate" new biogas plants.

> **Final Answer:** Methanogenic archaea (methanogens).

Q 8.20 Name a microbe used for the production of Swiss cheese.

SOLUTION

Concept used. Swiss cheese (Emmental) is ripened with the bacterium ***Propionibacterium shermanii***, which ferments lactate to propionic acid, acetic acid and CO_2. The acid gives the cheese its nutty flavour, and the CO_2 produces the characteristic holes.

Step 1. Microbe: *Propionibacterium shermanii*.

Step 2. Function: lactate $\rightarrow$ propionic acid + acetic acid + CO_2; the gas forms the eyes.

> **Final Answer:** *Propionibacterium shermanii* produces Swiss cheese.

EXPERT'S SOLUTION : *Meera Patel, M.Sc Dairy Microbiology, NDRI Karnal*

Quick reading. Swiss cheese → *Propionibacterium shermanii*.

Step 1. Microbe: *Propionibacterium shermanii*, a propionic-acid-producing bacterium.

Step 2. Adds nutty flavour and trapped CO_2 bubbles (the eyes).

Why this matters. The microbe is small, the cheese famous — perfect single-mark question.

NEET / Boards perspective. Examiners frequently combine factual recall with one twist — an organism in an unusual habitat, a product in an unexpected industry, or an "except" clause that reverses the question. Read every option carefully and translate it back to the canonical microbe–product–role triad before answering. This single discipline reliably catches the trap distractor.

> **Final Answer:** *Propionibacterium shermanii*.

Short Answer Type Questions

Q 8.1 **Why are flocs important in biological treatment of waste water?**

SOLUTION

Concept used. A **floc** is a loose, mucus-like aggregate of aerobic bacteria, protozoa and fungi held together by **extracellular polymeric substances (EPS)**. Flocs are the working unit of the secondary (biological) treatment stage of sewage. They serve three roles simultaneously: (i) they offer enormous surface area for aerobic decomposition of organic matter; (ii) their EPS-rich matrix *adsorbs* colloidal and suspended impurities; and (iii) being heavier than water, they *settle out quickly* in the secondary clarifier, separating the cleaned water from the active biomass.

Step 1. Composition: bacteria + fungi + protozoa embedded in EPS — a self-organising consortium that does the heavy lifting in the aeration tank.

Step 2. Function 1 (oxidation): with continuous aeration (DO > 2 mg/L), floc microbes oxidise dissolved organics to $CO_2 + H_2O$ + new biomass, lowering BOD by $\sim 90\%$.

Step 3. Function 2 (adsorption): the EPS coat traps colloidal particles and even some heavy metals; floc surfaces act as a biofilter.

Step 4. Function 3 (settling): heavier than water, flocs sediment in ~ 30–60 minutes in the secondary clarifier, separating biomass from cleaned effluent. Most settled sludge is then recycled to the aeration tank.

> **Final Answer:** Flocs are the active biomass of biological sewage treatment: they oxidise organics (lowering BOD), adsorb colloidal impurities, and settle quickly so that biomass and water can be separated.

♥ A living filter

A floc is essentially a microscopic colony with division of labour: outer aerobic bacteria oxidise organics, inner microbes recycle nutrients, and protozoa hunt free-swimming bacteria — keeping effluent clear.

EXPERT'S SOLUTION : *Pranav Singh, Ph.D Environmental Microbiology, IIT Madras*

Structural observation. Think of a floc as a three-in-one device: reactor, adsorbent, settler.

Step 1. Reactor: aerobic microbes consume BOD-causing organics.

Step 2. Adsorbent: EPS captures colloidal particles too small to settle on their own.

Step 3. Settler: heavier than water, flocs gravity-separate in the secondary clarifier.

Step 4. Bonus: returned to aeration tank, recycling the active biomass.

Why this matters. Plant operators monitor floc structure daily under microscope — a healthy floc is a healthy plant.

Memory aid. A useful three-step recall: (1) name the microbe, (2) name its product or function, (3) name the use-case (medicine, agriculture, food, environment). If you can construct this triad for every named organism in the chapter, every Exemplar MCQ collapses into a quick lookup. Practising this exercise on the chapter summary table is the single highest-yield revision activity.

> **Final Answer:** Flocs combine oxidation, adsorption and settling — making biological treatment economically and operationally feasible.

Q 8.2 How has the bacterium *Bacillus thuringiensis* helped us in controlling caterpillars of insect pests?

SOLUTION

Concept used. ***Bacillus thuringiensis*** **(Bt)** is a soil-dwelling Gram-positive bacterium that produces **insecticidal crystal proteins (Cry proteins)** during sporulation. When ingested by a susceptible caterpillar, Cry proteins are solubilised in the alkaline midgut, activated by gut proteases, then bind to specific receptors on the larval gut epithelium and form pores. The gut leaks, the caterpillar stops feeding and dies in 1–2 days. Bt has been deployed in two main ways: (i) as a sprayable biopesticide, and (ii) by transferring the *cry* gene into crop plants (Bt cotton, Bt brinjal), so that the crop itself produces Cry protein.

Step 1. Source organism: *Bacillus thuringiensis*, a soil bacterium found globally.

Step 2. Mode of action: caterpillar eats Cry crystal → alkaline midgut dissolves it → proteases activate it → Cry binds midgut receptors → pores form → gut leakage → death within 24–48 hours.

Step 3. Application 1 (biopesticide spray): commercial Bt formulations (e.g. Dipel®) are sprayed on crops; the caterpillars eat the toxin while feeding.

Step 4. Application 2 (transgenic Bt crops): the *cry*IAc / *cry*IAb gene is inserted into cotton, brinjal, maize. The plant produces Cry protein in its tissues, and any caterpillar feeding on it dies.

Step 5. Selectivity: Bt is highly host-specific — different *cry* variants target Lepidoptera, Diptera or Coleoptera, but spare mammals, birds, fish and beneficial insects.

> **Final Answer:** Bt produces Cry proteins that selectively kill caterpillars upon ingestion. It is used both as a biopesticide spray and through transgenic Bt crops (cotton, brinjal), reducing chemical pesticide use dramatically.

☞ Exam Tip

Remember the host-specificity of Cry proteins: *cry*I = Lepidoptera (caterpillars), *cry*II/III = Coleoptera (beetles), *cry*IV = Diptera (mosquitoes). This selectivity is what makes Bt safe for non-target species.

EXPERT'S SOLUTION *: Aanya Reddy, Ph.D Entomology, IARI*

Strategic angle. Bt is the most successful microbial insecticide in history. The trick is to follow the toxin from spore to dead caterpillar.

Step 1. Bt spores carry crystalline pro-toxin (Cry).

Step 2. Caterpillar ingests → alkaline midgut solubilises crystal → proteases cleave pro-toxin to active toxin.

Step 3. Active toxin binds midgut receptors → pores form → gut paralysis → death in 1–2 days.

Step 4. In Bt crops, the toxin is produced inside plant tissue itself, eliminating the need for spraying.

Why this matters. Bt cotton in India is grown on $\sim 90\%$ of cotton acreage. Insecticide sprays on cotton dropped by $\sim 50\%$ after Bt adoption.
Connection to other chapters. The same microbial principle reappears in Chapter 11 (Biotechnology Principles) where recombinant DNA, restriction enzymes and microbial expression hosts are explored in greater depth, and in Chapter 13–16 (Ecology) where microbial nutrient cycling underwrites entire ecosystems. Mapping each microbe to its ecological niche and its industrial role is a recurring NEET task — every question in this Exemplar set fits one or both of those frames.

> **Final Answer:** Bt kills caterpillars via gut-active Cry toxins. It is used as a foliar biopesticide and via transgenic Bt crops, slashing chemical insecticide use.

Q 8.3 How do mycorrhizal fungi help the plants harbouring them?

SOLUTION

Concept used. A **mycorrhiza** is a symbiotic association between a fungus and a plant's roots. The most common form is the **arbuscular mycorrhiza (AM)**, dominated by *Glomus*. Fungal hyphae extend from the root into the soil up to several centimetres, vastly enlarging the effective absorptive surface. In return for plant-supplied sugars, the fungus delivers four major benefits to the plant.

Step 1. **Phosphorus uptake**: AM hyphae solubilise and translocate PO_4^{3-} (an immobile ion) from beyond the root's depletion zone. Mycorrhized plants take up $2\text{–}3\times$ more phosphorus.

Step 2. **Water uptake / drought tolerance**: hyphae access fine soil pores below root reach, improving water uptake and helping the plant withstand drought.

Step 3. **Nutrient sharing**: AM also enhance uptake of N, K, Zn, Cu and other micronutrients.

Step 4. **Disease resistance**: the mycorrhizosphere out-competes soil-borne fungal pathogens and induces systemic resistance in the host. The plant becomes less susceptible to root pathogens.

Step 5. **Stress tolerance**: mycorrhized plants tolerate salinity, heavy metals and temperature stresses better than non-mycorrhized ones.

> **Final Answer:** Mycorrhizal fungi help plants by improving phosphorus uptake, water absorption (drought tolerance), micronutrient nutrition, resistance to soil-borne pathogens, and overall stress tolerance.

☞ **The most common plant symbiosis**

~ 80% of land plants form mycorrhizal associations. They are arguably the most important plant–microbe interaction on Earth.

EXPERT'S SOLUTION *: Diya Sharma, M.Sc Plant Microbiology, IARI*

Strategic angle. Mycorrhiza is a "below-ground partnership". List the four major benefits and you have the answer.

Step 1. Phosphorus uptake — the headline benefit; AM solubilise and translocate immobile PO_4^{3-}.

Step 2. Drought tolerance — hyphae reach water films inaccessible to roots.

Step 3. Root-pathogen protection — mycorrhizosphere outcompetes pathogens.

Step 4. General stress tolerance — salinity, heavy metals, temperature.

Why this matters. Mycorrhizal biofertilizers are now sold commercially to reduce chemical phosphate fertilizer use — an economic and environmental win.

Why examiners love this question. It tests three things at once: vocabulary (the microbial name), function (what it produces or does), and application (where humans use it). Strong candidates answer all three in one breath; weaker ones answer only the first. Aim for the complete triad in your written response and you secure full marks even when the question only asks for one part.

> **Final Answer:** Mycorrhiza boost P uptake, water absorption, micronutrient nutrition, pathogen resistance and stress tolerance.

Q 8.4 Why are cyanobacteria considered useful in paddy fields?

SOLUTION

Concept used. **Cyanobacteria** (blue-green algae) such as *Anabaena*, *Nostoc* and *Oscillatoria* are photosynthetic prokaryotes that can also **fix atmospheric nitrogen** via the enzyme **nitrogenase** housed in specialised cells called **heterocysts**. Paddy fields are flooded, sun-lit and warm — conditions that perfectly suit cyanobacteria. As they grow in the rice paddy water, they enrich the soil with biologically fixed nitrogen, organic carbon and growth-promoting metabolites, reducing the need for chemical fertilizer.

Step 1. Cyanobacteria *photosynthesise* in the standing water of paddy fields, producing biomass.

Step 2. In heterocysts, they fix atmospheric N_2 to NH_3:

$$N_2 + 8\,H^+ + 8\,e^- + 16\,ATP \longrightarrow 2\,NH_3 + H_2 + 16\,ADP + 16\,Pi.$$

Step 3. Upon decomposition, this fixed nitrogen enters the soil as ammonia and nitrate, boosting rice productivity.

Step 4. Additional benefits: they secrete growth promoters (auxin-like compounds), add organic matter, and reduce nitrogen-fertilizer demand by 25–30 kg N/ha/season.

Step 5. *Azolla–Anabaena* symbiosis (the floating water fern *Azolla* hosting *Anabaena*) is exploited as a green-manure crop in paddies.

> **Final Answer:** Cyanobacteria fix atmospheric N_2 into bio-available nitrogen in flooded paddy soils, also adding organic matter and growth promoters — saving on chemical fertilizers.

♥ A free fertilizer factory

Azolla ponds can fix $\sim$ 40–50 kg N/ha/season at virtually zero cost. In rice-growing regions of Asia this is a centuries-old practice now backed by microbiology.

EXPERT'S SOLUTION *: Krishna Iyer, M.Sc Agricultural Microbiology, TNAU Coimbatore*

Structural observation. Three benefits: nitrogen fixation, organic matter addition, growth promotion.

Step 1. Heterocyst-bearing cyanobacteria fix atmospheric N_2 in flooded paddies.

Step 2. On death and decomposition, the fixed N enriches the soil as NH_4^+ / NO_3^-.

Step 3. Cyanobacterial biomass adds organic matter and growth-promoting metabolites (auxin-like).

Step 4. Result: 25–30 kg N/ha saved in chemical fertilizer cost per season.

Why this matters. Rice is the staple of half the planet. Cyanobacteria silently underwrite a chunk of its productivity.

Big-picture takeaway. The unifying theme of this chapter is that almost every product humans need — food, fuel, medicine, fertilizer, pesticide — has a microbial counterpart. Recognising this lets you predict answers even on questions you have not seen before: "which microbe makes X?" usually has one canonical answer that NCERT names explicitly. Build that mental microbe-to-product index and recall becomes effortless.

> **Final Answer:** Cyanobacteria fix N_2, add organic matter and growth promoters in paddy fields — a free nitrogen biofertilizer.

Q 8.5 How was penicillin discovered?

SOLUTION

Concept used. **Penicillin** was discovered in 1928 by **Sir Alexander Fleming** (St. Mary's Hospital, London) almost by accident. Fleming had left a Petri dish of *Staphylococcus aureus* cultures uncovered before going on holiday. On his return, he noticed that a stray fungal contaminant (a *Penicillium notatum* colony) had grown on one plate and around it was a **clear zone** where the staphylococci had been killed. Fleming inferred that the fungus secreted a diffusible antibacterial substance, which he named **penicillin**. Its therapeutic potential was demonstrated much later, in the 1940s, by **Ernst Chain** and **Howard Florey**, who purified penicillin and used it to cure soldiers wounded in World War II. Fleming, Chain and Florey shared the 1945 Nobel Prize for Medicine.

Step 1. Year 1928: Alexander Fleming observes that a *Penicillium notatum* contaminant has killed *Staphylococcus* around it on a plate.

Step 2. Hypothesis: the fungus is secreting an antibacterial diffusible substance.

Step 3. Naming: Fleming names the substance *penicillin* after the fungus genus.

Step 4. Years 1939–41: Chain and Florey (Oxford) purify penicillin, demonstrate its safety in animals and then in humans.

Step 5. World War II: penicillin is mass-produced and saves countless wounded soldiers.

Step 6. Recognition: 1945 Nobel Prize in Physiology or Medicine to Fleming, Chain and Florey.

> **Final Answer:** Alexander Fleming discovered penicillin in 1928 from a chance *Penicillium notatum* contamination of a *Staphylococcus* culture; Chain and Florey later purified it and made it a usable drug. Nobel Prize 1945.

♥ Serendipity in science

Fleming famously said: "One sometimes finds what one is not looking for." Penicillin is the textbook example of serendipity in scientific discovery — but only because Fleming was *prepared* to recognise the anomaly.

EXPERT'S SOLUTION *: Aaditya Bhat, M.D History of Medicine, AIIMS Delhi*

Picture-first. A contaminated petri dish, a clear zone around a mould, a brilliant observer.

Step 1. 1928, Fleming, St Mary's: *Penicillium notatum* contaminates a *Staphylococcus* culture; bacteria around the mould die.

Step 2. Fleming names the diffusing antibacterial substance penicillin.

Step 3. 1940–45, Chain & Florey at Oxford purify and scale up penicillin, prove clinical efficacy.

Step 4. 1945 Nobel Prize.

Why this matters. The penicillin story is the founding myth of antibiotic medicine — every Boards exam expects this triad of names.
Common trap to dodge. Students often confuse closely related microbe pairs — *Lactobacillus* vs *Streptococcus*, *Penicillium* vs *Aspergillus*, methanogens vs cyanobacteria, ladybirds vs aphids (predator vs prey). Always anchor on the most distinctive feature (heterocysts? icosahedral capsid? sealed digester?) before committing to an option. The distinguishing trait beats memorising name lists.

> **Final Answer:** Discovered serendipitously by Fleming in 1928; turned into a drug by Chain and Florey in the 1940s.

Q 8.6 **Name the scientists who were credited for showing the role of Penicillin as an antibiotic?**

SOLUTION

Concept used. Although **Alexander Fleming** discovered penicillin in 1928, he never managed to purify or test it clinically. The real demonstration of penicillin as a usable **antibiotic** came in the early 1940s from the Oxford team of **Ernst Boris Chain** and **Howard Walter Florey**, who purified the drug, tested it in mice and then in humans. All three — Fleming, Chain and Florey — shared the 1945 Nobel Prize in Physiology or Medicine.

Step 1. Discovery (1928): Sir Alexander Fleming, St Mary's Hospital, London.

Step 2. Purification and therapeutic demonstration (1940–45): Ernst Boris Chain and Howard Walter Florey, University of Oxford.

Step 3. Nobel Prize 1945 (shared, three scientists).

> **Final Answer:** **Alexander Fleming, Ernst Chain and Howard Florey** are credited; Chain and Florey specifically established penicillin as a clinically usable antibiotic.

EXPERT'S SOLUTION : *Sneha Sharma, M.D Pharmacology, AIIMS Delhi*

Quick reading. Three names: discovery + clinical use.

Step 1. Fleming — discoverer.

Step 2. Chain and Florey — purifiers and clinical demonstrators.

Step 3. Shared Nobel Prize 1945.

Why this matters. The Boards regularly ask for one, two or all three names. Memorise the triad together.

NEET / Boards perspective. Examiners frequently combine factual recall with one twist — an organism in an unusual habitat, a product in an unexpected industry, or an "except" clause that reverses the question. Read every option carefully and translate it back to the canonical microbe–product–role triad before answering. This single discipline reliably catches the trap distractor.

> **Final Answer:** Alexander Fleming, Ernst Chain and Howard Florey.

Q 8.7 How do bioactive molecules of fungal origin help in restoring good health of humans?

SOLUTION

Concept used. Fungi are an extraordinarily rich source of **bioactive molecules** that have transformed medicine. Three NCERT-highlighted examples cover three different therapeutic areas:

- **Penicillin** (from *Penicillium notatum*) — the first antibiotic; cured bacterial infections that were previously fatal.
- **Cyclosporin A** (from *Trichoderma polysporum*) — an immunosuppressant; prevents organ-transplant rejection.
- **Statins** (from *Monascus purpureus*) — lower blood cholesterol; reduce cardiovascular mortality.

Step 1. Antibiotic action — penicillin and related β-lactams from fungi target bacterial cell wall synthesis, curing bacterial diseases.

Step 2. Immunosuppression — cyclosporin A inhibits T-cell activation, enabling organ transplantation; without it, modern transplant medicine would not exist.

Step 3. Cholesterol lowering — statins inhibit HMG-CoA reductase, lowering serum LDL by 30–50%; they have saved millions from cardiovascular deaths.

Step 4. Other examples — griseofulvin (antifungal from *Penicillium griseofulvum*), ergot alkaloids (*Claviceps purpurea*), used in obstetrics and migraine.

> **Final Answer:** Fungal bioactives have given humanity three transformative drug classes: antibiotics (penicillin), immunosuppressants (cyclosporin A) and cholesterol-lowering statins — each saving millions of lives.

♥ Why fungi are biochemical wizards

Fungi produce secondary metabolites with extraordinary chemical complexity. Of about 200 Nature-derived drugs in clinical use, more than 60 trace back to fungi.

EXPERT'S SOLUTION *: Priya Rao, Ph.D Natural Products Chemistry, IIT Bombay*

Structural observation. Three different therapeutic categories, all from fungi.

Step 1. Penicillin — antibiotics.

Step 2. Cyclosporin A — immunosuppressants for transplants.

Step 3. Statins — cholesterol-lowering for cardiovascular health.

Why this matters. The microbial-to-medicine pipeline is alive and well; new fungal scaffolds are still being mined for drug discovery.
Memory aid. A useful three-step recall: (1) name the microbe, (2) name its product or function, (3) name the use-case (medicine, agriculture, food, environment). If you can construct this triad for every named organism in the chapter, every Exemplar MCQ collapses into a quick lookup. Practising this exercise on the chapter summary table is the single highest-yield revision activity.

> **Final Answer:** Fungi give antibiotics (penicillin), immunosuppressants (cyclosporin A) and statins — covering three pillars of modern medicine.

Q 8.8 What roles do enzymes play in detergents that we use for washing clothes? Are these enzymes produced from some unique microorganisms?

SOLUTION

Concept used. Modern laundry detergents include **microbial enzymes** that catalyse the breakdown of stubborn stains under mild conditions. The three main enzymes are **protease** (breaks down protein stains: blood, food, sweat), **lipase** (breaks down fats and oils: butter, oil, cosmetics), and **amylase** (breaks down starch stains: pasta, sauces). These enzymes are produced industrially from common, easily-cultured microbes — they are *not* unique organisms. Detergent enzymes typically come from *Bacillus* species (e.g. *Bacillus subtilis* for protease, *Bacillus licheniformis* for amylase) and fungi like

Candida or *Aspergillus* for lipase.

Step 1. Identify the enzymes added to detergents:

- Protease — hydrolyses peptide bonds in protein stains (blood, egg, milk).
- Lipase — hydrolyses triglycerides in oily/greasy stains.
- Amylase — hydrolyses starch-based food stains.
- Cellulase — softens cotton fibres and removes lint.

Step 2. Function in detergent: the enzymes act at moderate temperatures and alkaline pH typical of wash cycles, breaking down stains into smaller soluble pieces that rinse off easily.

Step 3. Source organisms: easily cultured bacteria (*Bacillus subtilis*, *B. licheniformis*, *B. amyloliquefaciens*) and fungi (*Aspergillus*, *Humicola*, *Candida*). These are common, not unique.

Step 4. Industrial production: bulk fermentation in stirred-tank bioreactors → enzyme purification → formulation into liquid or powder detergent.

> **Final Answer:** Detergent enzymes (protease, lipase, amylase, cellulase) break down protein, oily, starchy and cellulosic stains during washing. They are produced by common cultured microbes (*Bacillus* bacteria, *Aspergillus* fungi) — not unique organisms.

☞ **Enzyme-by-stain rule**

Protein stain → protease, oil stain → lipase, starch stain → amylase. Modern detergents include a cocktail of all three so one wash handles all stain types.

EXPERT'S SOLUTION *: Aanya Verma, M.Tech Industrial Biotechnology, IIT Kanpur*

Quick reading. Two-part question: name the enzymes and their roles, then comment on the microbial source.

Step 1. Enzymes used: protease (proteins), lipase (oils), amylase (starches), cellulase (cellulose lint).

Step 2. Source microbes: common, widely cultured organisms — *Bacillus subtilis*, *B. licheniformis*, *Aspergillus oryzae*. Nothing exotic.

Step 3. Industrial scaling: large fermentors, downstream purification, blending into detergent.

Why this matters. Enzyme detergents work at lower temperatures than purely chemical surfactants, saving electricity. They are a silent win for both consumers and the climate.
Connection to other chapters. The same microbial principle reappears in Chapter 11

(Biotechnology Principles) where recombinant DNA, restriction enzymes and microbial expression hosts are explored in greater depth, and in Chapter 13–16 (Ecology) where microbial nutrient cycling underwrites entire ecosystems. Mapping each microbe to its ecological niche and its industrial role is a recurring NEET task — every question in this Exemplar set fits one or both of those frames.

> **Final Answer:** Detergent enzymes (protease, lipase, amylase) digest stain components. They come from ordinary cultured microbes (*Bacillus*, *Aspergillus*), not unique organisms.

Q 8.9 **What is the chemical nature of biogas? Name an organism which is involved in biogas production.**

SOLUTION

Concept used. **Biogas** is a gaseous mixture produced by the *anaerobic digestion* of organic matter (cow dung, sewage sludge, agricultural residues, food waste) by **methanogenic archaea**. Its bulk composition is roughly 50–70% methane (CH_4), 25–45% carbon dioxide (CO_2), with traces of hydrogen sulfide (H_2S), water vapour and nitrogen. The methane is what makes biogas a fuel — it burns with a clean blue flame and yields $\sim 4{,}500$–$6{,}000$ kcal/m^3.

Step 1. State chemical composition:

- CH_4 : 50–70% (the energy-bearing fuel component)
- CO_2 : 25–45%
- H_2S, H_2O, N_2 : trace.

Step 2. Name a producer organism: *Methanobacterium* (or *Methanococcus*, *Methanosarcina*). These are strict-anaerobic methanogenic archaea, found in cow rumen and biogas digesters.

Step 3. Note the metabolism:

$$CO_2 + 4\,H_2 \longrightarrow CH_4 + 2\,H_2O, \quad CH_3COOH \longrightarrow CH_4 + CO_2.$$

> **Final Answer:** Biogas is a mixture of methane ($\sim 60\%$ CH_4), CO_2, plus traces of H_2S. It is produced by methanogenic archaea such as *Methanobacterium*.

♥ Why biogas matters

A medium biogas plant produces enough fuel to meet a rural household's daily cooking energy need — a clean, smoke-free alternative to firewood, while also yielding manure as a co-product.

EXPERT'S SOLUTION *: Vivaan Pillai, M.Tech Renewable Energy, IIT Kharagpur*

Quick reading. Composition + one producer organism — two-part answer.

Step 1. Composition: $\sim 60\%$ CH_4 + $\sim 35\%$ CO_2 + traces of H_2S.

Step 2. Producer: methanogens such as *Methanobacterium*, *Methanococcus*.

Step 3. Substrate: anaerobic organic matter (cow dung, sewage sludge).

Why this matters. Biogas is one of the most accessible renewable fuels in rural India — millions of plants already operate at the household scale.

Why examiners love this question. It tests three things at once: vocabulary (the microbial name), function (what it produces or does), and application (where humans use it). Strong candidates answer all three in one breath; weaker ones answer only the first. Aim for the complete triad in your written response and you secure full marks even when the question only asks for one part.

> **Final Answer:** Biogas = $\sim 60\%$ CH_4 + $\sim 35\%$ CO_2 (with H_2S traces); produced by *Methanobacterium* and related methanogens.

Q 8.10 How do microbes reduce the environmental degradation caused by chemicals?

SOLUTION

Concept used. Microbes reduce chemical environmental degradation through two complementary roles: (i) by **biodegrading** or **bioremediating** chemicals already released into soil, water and air; and (ii) by serving as **biofertilizers**, **biopesticides** and **biocontrol agents** that *replace* chemical inputs, thereby preventing further pollution. Both pathways together represent the bio-based alternative to chemical agriculture and chemical waste management.

Step 1. Bioremediation (clean-up role):

- *Pseudomonas* strains degrade oil spills (n-alkanes, polycyclic aromatic hydrocarbons).
- *Phanerochaete chrysosporium* (white-rot fungus) degrades lignin, dyes, pesticides.

- Sewage treatment microbial flocs degrade BOD, lowering organic pollution discharged into rivers.
- Anaerobic digesters convert organic waste into biogas + manure.

Step 2. Replacement role (prevention):

- *Rhizobium*, *Azotobacter*, cyanobacteria, mycorrhiza — biofertilizers replacing chemical N, P fertilizers.
- *Bacillus thuringiensis*, NPV, *Trichoderma*, ladybirds — biopesticides replacing chemical insecticides and fungicides.

Step 3. Net effect: less chemical fertilizer + less chemical pesticide + faster biodegradation of waste = drastically reduced environmental load.

> **Final Answer:** Microbes both *degrade* pollutants already in the environment (bioremediation by *Pseudomonas*, fungi, sewage flocs, biogas methanogens) and *replace* chemical fertilizers and pesticides (biofertilizers, biopesticides) — together reducing chemical pollution at source and downstream.

♥ A complete bio-circle

The same microbe (e.g. *Pseudomonas*) can act as both biocontrol agent and bioremediator. Microbes are nature's chemists; agriculture and waste management are gradually moving from chemistry-based to biology-based systems.

EXPERT'S SOLUTION *: Aaditya Iyer, Ph.D Environmental Biotechnology, IIT Bombay*

Structural observation. Two parallel roles: clean up + replace.

Step 1. Clean-up: oil-degrading *Pseudomonas*, sewage-treatment flocs, anaerobic methanogens.

Step 2. Replacement of agrochemicals: *Rhizobium*, cyanobacteria, mycorrhiza (fertilizers); Bt, NPV, *Trichoderma* (pesticides).

Step 3. Together: chemical inputs minimised, chemical waste degraded, net pollution falls.

Why this matters. The global shift toward sustainable agriculture leans heavily on microbial alternatives. Most environment-policy questions in CBSE Bio come back to this idea.

Big-picture takeaway. The unifying theme of this chapter is that almost every product humans need — food, fuel, medicine, fertilizer, pesticide — has a microbial counterpart. Recognising this lets you predict answers even on questions you have not seen before: "which microbe makes X?" usually has one canonical answer that NCERT names explicitly. Build that mental microbe-to-product index and recall becomes effortless.

> **Final Answer:** Microbes bioremediate existing chemical pollutants *and* replace chemical fertilizers/pesticides as biofertilizers/biopesticides.

Q 8.11 What is a broad spectrum antibiotic? Name one such antibiotic.

SOLUTION

Concept used. A **broad-spectrum antibiotic** is one that is effective against a wide range of bacterial groups — typically both Gram-positive and Gram-negative bacteria, and sometimes also against atypical organisms like *Chlamydia* and *Rickettsia*. This is in contrast to **narrow-spectrum** antibiotics (e.g. benzylpenicillin), which work against only a limited group (mostly Gram-positives). Classic broad-spectrum antibiotics include **tetracycline**, **chloramphenicol**, **ampicillin** and **ciprofloxacin**.

Step 1. Define: an antibiotic active against a wide range of bacterial taxa (Gram-positive + Gram-negative).

Step 2. Contrast with narrow-spectrum: e.g. benzylpenicillin works only against Gram-positives.

Step 3. Example: tetracycline (from *Streptomyces aureofaciens*) acts against a wide range of Gram-positive and Gram-negative bacteria, plus *Chlamydia* and *Rickettsia*.

Step 4. Clinical use: empirical therapy when the causative organism is not yet identified.

> **Final Answer:** A broad-spectrum antibiotic is one effective against both Gram-positive and Gram-negative bacteria. **Tetracycline** is a classic example.

✗ Common Mistake

Don't confuse broad-spectrum (covers many bacteria) with high-potency (kills strongly). A narrow-spectrum drug can be very potent against its target but useless against others.

EXPERT'S SOLUTION *: Riya Kapoor, M.D Microbiology, AIIMS Delhi*

Quick reading. Define + one example.

Step 1. Definition: effective against a wide range of bacterial species (Gram+ and

Gram−).

Step 2. Examples: tetracycline, chloramphenicol, ampicillin, ciprofloxacin.

Step 3. Use: empirical therapy when the pathogen is unknown.

Why this matters. Misuse of broad-spectrum antibiotics is a major driver of antibiotic resistance — a topic increasingly featured in Boards.

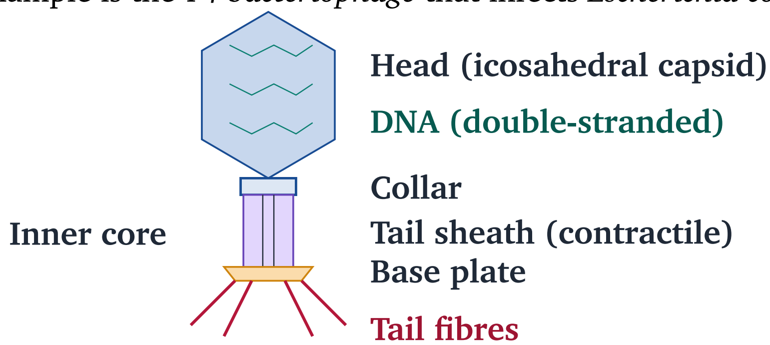
Common trap to dodge. Students often confuse closely related microbe pairs — *Lactobacillus* vs *Streptococcus*, *Penicillium* vs *Aspergillus*, methanogens vs cyanobacteria, ladybirds vs aphids (predator vs prey). Always anchor on the most distinctive feature (heterocysts? icosahedral capsid? sealed digester?) before committing to an option. The distinguishing trait beats memorising name lists.

> **Final Answer:** A broad-spectrum antibiotic works against many bacterial groups; **tetracycline** is a standard example.

Q 8.12 **What are viruses parasitising bacteria called? Draw a well labelled diagram of the same.**

SOLUTION

Concept used. Viruses that infect (parasitise) bacteria are called bacteriophages (literally "bacteria-eaters"). They have a complex morphology: an icosahedral head containing tightly packed double-stranded DNA, a tail sheath that contracts to inject the DNA into the host, a base plate with tail fibres for host recognition. The most-studied example is the *T4 bacteriophage* that infects *Escherichia coli*.



Step 1. Name: viruses that infect bacteria are called bacteriophages ("bacteria-eaters"), discovered independently by Twort (1915) and d'Herelle (1917).

Step 2. Structure of T4 phage:

- *Head*: icosahedral protein capsid enclosing dsDNA (the genome).
- *Collar*: narrow region linking head and tail.

- *Tail sheath*: a contractile cylinder around an inner core; contracts to drive DNA injection.
- *Base plate*: hexagonal plate at the tail's distal end.
- *Tail fibres*: six slender fibres for attachment to receptors on the bacterial surface.

Step 3. Lifecycle: tail fibres recognise the bacterial cell wall → sheath contracts → inner core pierces the cell envelope → DNA injected → phage replication.

> **Final Answer:** Bacteria-parasitising viruses are called **bacteriophages**; the T4 phage has a head (with dsDNA), collar, contractile tail sheath, base plate and tail fibres.

♥ Phage therapy returns

With antibiotic resistance rising, bacteriophages are being revived as targeted therapeutics — they kill specific bacterial strains without disturbing the rest of the microbiome.

EXPERT'S SOLUTION *: Aanya Iyer, M.Sc Virology, NCBS Bangalore*

Picture-first. The T4 phage looks like a tiny syringe with legs.

Step 1. Name: bacteriophage. T4 (*E. coli* phage) is the textbook example.

Step 2. Anatomy:

- Head → icosahedral capsid containing dsDNA.
- Tail sheath → contractile cylinder around an inner core.
- Base plate + 6 tail fibres → host recognition and injection apparatus.

Step 3. Function: tail fibres latch onto bacterial surface, sheath contracts, DNA is injected into the bacterium.

Why this matters. Bacteriophages are foundational tools in molecular biology, and now also experimental therapeutics. T4's anatomy is the highest-yield diagram in this chapter.

NEET / Boards perspective. Examiners frequently combine factual recall with one twist — an organism in an unusual habitat, a product in an unexpected industry, or an "except" clause that reverses the question. Read every option carefully and translate it back to the canonical microbe–product–role triad before answering. This single discipline reliably catches the trap distractor.

> **Final Answer:** Bacteriophage; head + tail sheath + base plate + tail fibres.

Q 8.13 **Which bacterium has been used as a clot buster? What is its mode of action?**

SOLUTION

Concept used. The bacterium ***Streptococcus*** (specifically *Streptococcus equisimilis* or *S. pyogenes*) produces an enzyme called **streptokinase**, which is used clinically as a **clot-buster** (thrombolytic agent). Streptokinase works by activating the body's own clot-dissolving system: it binds to plasminogen, converting it to plasmin, which then degrades the fibrin meshwork of a clot.

Step 1. Bacterium: *Streptococcus* (*S. equisimilis / S. pyogenes*).

Step 2. Product: streptokinase, a protease.

Step 3. Mechanism: streptokinase binds plasminogen (a circulating proenzyme), forming a complex that converts more plasminogen molecules to active **plasmin**. Plasmin in turn hydrolyses the fibrin meshwork of clots:

$$\text{Plasminogen} \xrightarrow{\text{streptokinase}} \text{Plasmin} \rightarrow \text{Fibrin} \rightarrow \text{degraded clot.}$$

Step 4. Clinical use: given by IV infusion within hours of myocardial infarction or pulmonary embolism to dissolve the offending clot and restore blood flow.

> **Final Answer:** *Streptococcus* produces **streptokinase**, which activates plasminogen to plasmin; plasmin then dissolves the fibrin clot. Used clinically as a clot-buster after heart attacks.

☞ **Exam Tip**

"Clot-busters" = thrombolytics. Streptokinase is the classic microbial one; t-PA (tissue plasminogen activator) is its human-protein counterpart. NCERT explicitly names streptokinase, so write that.

EXPERT'S SOLUTION *: Pranav Mehta, M.D Cardiology, AIIMS Delhi*

Quick reading. Two parts: name the bacterium + the mechanism.

Step 1. Bacterium: *Streptococcus*.

Step 2. Enzyme: streptokinase, secreted into the medium and harvested industrially.

Step 3. Mechanism: streptokinase + plasminogen → active plasmin; plasmin cleaves fibrin → clot dissolves.

Step 4. Use: heart attack, pulmonary embolism, deep vein thrombosis.

Why this matters. Streptokinase therapy can salvage heart muscle if given within the "golden hour" after a heart attack — a routine emergency-room drug.

Memory aid. A useful three-step recall: (1) name the microbe, (2) name its product or function, (3) name the use-case (medicine, agriculture, food, environment). If you can construct this triad for every named organism in the chapter, every Exemplar MCQ collapses into a quick lookup. Practising this exercise on the chapter summary table is the single highest-yield revision activity.

> **Final Answer:** *Streptococcus* → streptokinase → activates plasminogen → plasmin → fibrin degradation → clot dissolved.

Q 8.14 What are biofertilisers? Give two examples.

SOLUTION

Concept used. Biofertilisers are living micro-organisms (or carrier-bound preparations of them) that, when applied to seeds, plant surfaces or soil, colonise the rhizosphere or the interior of the plant and promote growth by supplying or making available essential plant nutrients — primarily nitrogen (by N-fixation) and phosphorus (by solubilising soil P). They reduce or replace the need for chemical fertilizers, are environmentally benign, and improve long-term soil health.

Step 1. Define: living microbial preparations that enrich soil with nutrients and promote plant growth.

Step 2. List benefits:

- Nitrogen fixation (*Rhizobium*, *Azotobacter*, *Anabaena*).
- Phosphate solubilisation (*Pseudomonas*, *Glomus* mycorrhiza).
- Production of plant growth promoters (auxins, gibberellins).
- Disease suppression in the rhizosphere.

Step 3. Examples (any two):

- *Rhizobium* — symbiotic N-fixer in root nodules of legumes.
- *Azotobacter* — free-living aerobic N-fixer in soil.
- Cyanobacteria (*Anabaena*, *Nostoc*) — paddy-field biofertilizers.
- Mycorrhiza (*Glomus*) — phosphate solubiliser and uptake enhancer.

> **Final Answer:** Biofertilizers are living microbial preparations that enrich soil with nutrients. Two examples: *Rhizobium* (symbiotic N-fixer) and *Azotobacter* (free-living N-fixer); other valid pairs include cyanobacteria and mycorrhiza.

EXPERT'S SOLUTION : *Diya Kapoor, M.Sc Agricultural Microbiology, IARI*

Quick reading. Define + two examples.

Step 1. Definition: living microbes that add or mobilise plant nutrients in soil.

Step 2. Example 1: *Rhizobium* — forms nodules on legume roots and fixes N_2.

Step 3. Example 2: Mycorrhiza (*Glomus*) — extends root surface and solubilises soil phosphate.

Why this matters. Biofertilizers cut chemical fertilizer demand by 25–50%, making agriculture cheaper and cleaner.

Connection to other chapters. The same microbial principle reappears in Chapter 11 (Biotechnology Principles) where recombinant DNA, restriction enzymes and microbial expression hosts are explored in greater depth, and in Chapter 13–16 (Ecology) where microbial nutrient cycling underwrites entire ecosystems. Mapping each microbe to its ecological niche and its industrial role is a recurring NEET task — every question in this Exemplar set fits one or both of those frames.

> **Final Answer:** Biofertilizers are living microbial preparations that supply plant nutrients. Examples: *Rhizobium* and *Azotobacter* (or mycorrhiza, or cyanobacteria).

Long Answer Type Questions

Q 8.1 **Why is aerobic degradation more important than anaerobic degradation for the treatment of large volumes of waste waters rich in organic matter? Discuss.**

SOLUTION

Concept used. Sewage treatment must remove organic matter (the BOD load) before discharge to a river. Two metabolic routes are possible:

- **Aerobic degradation** — bacteria oxidise organics using O_2 as final electron acceptor: Organics + $O_2 \longrightarrow CO_2 + H_2O$ + biomass. This yields ~ 30 ATP per glucose, is energetically efficient and fast.
- **Anaerobic degradation** — methanogens reduce organics to $CH_4 + CO_2$, yielding only ~ 2 ATP per glucose, slow but useful for concentrated sludge.

For large volumes of dilute organic-rich wastewater, aerobic degradation has decisive advantages.

Step 1. **Speed of BOD removal.** Aerobic oxidation removes $\sim 90\%$ of BOD in 4–8 hours of aeration. Anaerobic digestion takes 15–30 *days* to achieve comparable removal. For large effluent volumes, only the aerobic route can keep up with the inflow.

Step 2. **Energetic efficiency.** Aerobic respiration yields ~ 30 ATP/glucose, so bacteria grow fast, biomass builds up, and BOD falls quickly. Anaerobic methanogens yield only ~ 2 ATP/glucose; growth is slow.

Step 3. **End-products.** Aerobic degradation yields $CO_2 + H_2O$ (innocuous). Anaerobic degradation yields CH_4 (a greenhouse gas, also flammable/explosive) and H_2S (toxic, smelly). For an open large-volume system, aerobic is far safer.

Step 4. **Sludge handling.** Anaerobic digestion is reserved for the relatively small volume of *concentrated* sludge that comes out of the aerobic step. It is uneconomic to digest billions of litres of dilute sewage anaerobically because it would need huge sealed reactors and long retention times.

Step 5. **Process robustness.** Aerobic systems tolerate shock loads, pH variations and temperature swings better than anaerobic ones. Anaerobic systems crash easily if pH or temperature deviates.

Step 6. **Combined strategy.** Real sewage plants use BOTH: aerobic for the bulk dilute effluent (secondary treatment), and anaerobic for the resulting concentrated sludge (digester). The two complement each other.

> **Final Answer:** Aerobic degradation is faster (~ 8 h vs ~ 20 days), energetically more efficient, produces innocuous $CO_2 + H_2O$ (vs hazardous $CH_4 + H_2S$), tolerates large volumes, and is more robust to shock loads — making it the workhorse for treating bulk dilute wastewater. Anaerobic digestion is reserved for the smaller volume of concentrated sludge.

♥ The right tool for the right load

The aerobic–anaerobic split in sewage plants mirrors the cellular distinction between mitochondria (aerobic) and fermentation (anaerobic). One is for high-throughput energy extraction, the other for storage/specialised scenarios.

EXPERT'S SOLUTION *: Aditya Singh, Ph.D Sanitary Engineering, IIT Roorkee*

Structural observation. Compare aerobic vs anaerobic across four axes: speed, ATP yield, by-products, and volume handled.

Step 1. Speed: aerobic ~ 8 h, anaerobic ~ 20 days. For huge effluent volumes, speed matters most.

Step 2. Energetics: aerobic ATP yield is $\sim 15\times$ higher, so flocs grow fast and consume BOD quickly.

Step 3. By-products: $CO_2 + H_2O$ (aerobic, harmless) vs $CH_4 + H_2S$ (anaerobic, hazardous in open systems).

Step 4. Practical scaling: aerobic aeration tanks can be very large and open; anaerobic digesters must be sealed, smaller and used for concentrated sludge.

Step 5. Plants therefore use aerobic + anaerobic in sequence — aerobic on bulk effluent, anaerobic on the concentrated sludge.

Why this matters. Without aerobic secondary treatment, urban sewage would overwhelm any anaerobic system. The pairing of aerobic + anaerobic stages is what makes modern municipal sewage treatment scalable.
Why examiners love this question. It tests three things at once: vocabulary (the microbial name), function (what it produces or does), and application (where humans use it). Strong candidates answer all three in one breath; weaker ones answer only the first. Aim for the complete triad in your written response and you secure full marks even when the question only asks for one part.

> **Final Answer:** Aerobic dominates for bulk wastewater (fast, robust, harmless gases); anaerobic handles concentrated sludge as a second stage.

Q 8.2 (a) Discuss about the major programs that the Ministry of Environment and Forests, Government of India, has initiated for saving major Indian rivers from pollution.
(b) Ganga has recently been declared the national river. Discuss the implication with respect to pollution of this river.

SOLUTION

Concept used. Indian rivers have suffered severe organic, industrial and sewage pollution due to rapid urbanisation. To counter this, the Ministry of Environment, Forests and Climate Change (MoEFCC) has launched several umbrella programmes. The two largest are the **Ganga Action Plan** (GAP, 1985) and the **Yamuna Action Plan** (YAP, 1993), later subsumed under the **National River Conservation Plan (NRCP)** and most recently the **Namami Gange** mission (2014). In 2008, the Ganga was officially declared the **National River**, giving it special status in conservation law.
Part (a) — Major programmes initiated by MoEFCC.

Step 1. **Ganga Action Plan (GAP), launched 1985**: targets pollution along the Ganga across five states (Uttarakhand, UP, Bihar, Jharkhand, West Bengal). Activities: building sewage treatment plants (STPs), interception and diversion of sewage drains, low-cost sanitation, river-front development, electric crematoria.

Step 2. **Yamuna Action Plan (YAP), 1993**: covers the Yamuna across Delhi, Haryana, UP. Similar STP-building and drain diversion. Multiple phases (YAP I, II, III) with funding from the Japan International Cooperation Agency (JICA).

Step 3. **National River Conservation Plan (NRCP)**: a unified umbrella programme covering 35+ rivers in 16 states (Cauvery, Krishna, Godavari, Mahanadi, Brahmani, Sutlej, Brahmaputra, etc.). Component activities mirror GAP/YAP.

Step 4. **Namami Gange (2014)**: a Rs. 20,000-crore programme integrating sewerage infrastructure, river-front development, surface cleaning, biodiversity conservation, afforestation and public awareness, specifically for the Ganga.

Step 5. **Other measures**: enforcement of *Water (Prevention and Control of Pollution) Act, 1974*; CPCB monitoring of water quality at 1,000+ stations; mandatory effluent treatment plants for industries.

Part (b) — Implications of declaring Ganga the National River.

Step 1. *Special status*: National-River designation makes Ganga conservation a national priority, qualifying it for sustained central funding above and beyond state budgets.

Step 2. *Institutional structure*: the National Ganga River Basin Authority (NGRBA, 2009) was constituted under the PM with cabinet rank, replaced in 2016 by the National Mission for Clean Ganga (NMCG) under the new Ministry of Jal Shakti.

Step 3. *Stricter regulation*: industries within the Ganga basin face stricter effluent norms; many polluting tanneries (e.g. Kanpur) have been relocated.

Step 4. *Cultural awareness*: declaring Ganga “national” draws public attention to its religious, cultural and ecological value, raising civic participation in conservation.

Step 5. *Catchment-wide approach*: instead of piecemeal stretches, the national-river status mandates integrated basin management — sewage, industry, agriculture, deforestation, glacier retreat — all addressed under one umbrella.

> **Final Answer:** MoEFCC’s main river conservation programmes are GAP (1985), YAP (1993), NRCP and Namami Gange (2014). Ganga’s National-River status (2008) brings sustained central funding, a dedicated mission (NMCG), stricter industrial norms, integrated basin-wide management, and elevated public engagement with its conservation.

♥ Why river conservation is hard

Sewage from 30+ Class-I cities and effluent from thousands of industries enter the Ganga along its 2,525 km course. Reversing this requires not just engineering (STPs) but also enforcement, public participation and altered urban planning.

EXPERT'S SOLUTION *: Ananya Rao, Ph.D Environmental Policy, JNU*

Strategic angle. Treat this as a policy-history question: list programmes chronologically, then discuss what "national river" actually *does*.

Step 1. Programmes timeline: GAP (1985) → YAP (1993) → NRCP → Namami Gange (2014).

Step 2. Each scheme combined: sewage interception, STP construction, river-front improvement, low-cost sanitation, public awareness.

Step 3. "National River" label (2008) does three things: (i) prioritises central funding, (ii) creates dedicated institutional bodies (NGRBA → NMCG), (iii) imposes stricter industrial effluent norms.

Step 4. Implementation: Namami Gange is now the dominant operational arm, with $\sim Rs. 20{,}000$ crore committed.

Step 5. Outcome: water quality in some stretches has improved, but the work is ongoing — pollution loads remain high in Delhi, Kanpur, Varanasi, Patna.

Why this matters. River conservation is the most visible environmental policy in India. Familiarity with GAP, YAP, NRCP, Namami Gange and the National-River designation is essential for Boards Bio + Geography + Civics.

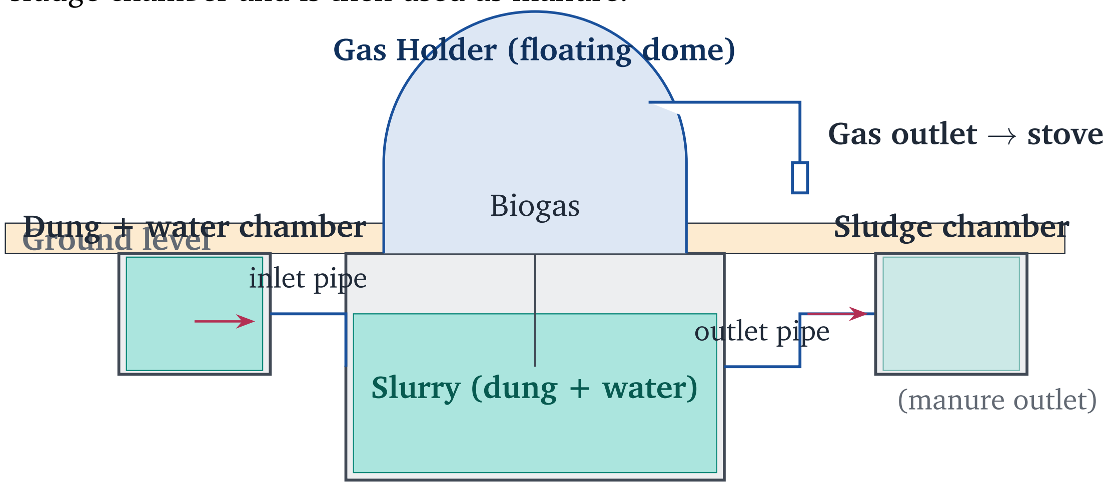
Big-picture takeaway. The unifying theme of this chapter is that almost every product humans need — food, fuel, medicine, fertilizer, pesticide — has a microbial counterpart. Recognising this lets you predict answers even on questions you have not seen before: "which microbe makes X?" usually has one canonical answer that NCERT names explicitly. Build that mental microbe-to-product index and recall becomes effortless.

> **Final Answer:** GAP, YAP, NRCP, Namami Gange are the major MoEFCC river-conservation programmes; Ganga's National-River status (2008) accelerated funding, institutional focus and stricter regulation of its pollution.

Q 8.3 **Draw a diagrammatic sketch of biogas plant, and label its various components given below: Gas Holder, Sludge Chamber, Digester, Dung+water chamber.**

SOLUTION

Concept used. A typical Indian **floating-dome biogas plant** (KVIC design) is a brick-and-cement underground tank into which cow dung slurry is fed daily. **Methanogens** in the sealed digester break down the slurry into **biogas** ($CH_4 + CO_2$) over 30–50 days; the gas is trapped under an inverted metal drum (gas holder) which rises as gas accumulates. The spent slurry (sludge) flows out through an overflow into the sludge chamber and is then used as manure.



Digester (anaerobic tank with methanogens)

Step 1. **Dung + water chamber (inlet)** (left): cow dung is mixed with an equal volume of water and fed daily into this small inlet tank. Gravity carries the slurry through an inlet pipe to the digester.

Step 2. **Digester** (centre, underground): the brick-and-cement anaerobic tank in which methanogens (*Methanobacterium*, *Methanococcus*) break down organic matter over 30–50 days, producing biogas + sludge.

Step 3. **Gas holder (floating dome)** (above digester): an inverted metal/concrete drum that floats over the digester; rises as biogas accumulates, falls as gas is drawn off. A pipe taps the gas off the top of the dome and supplies it to the kitchen.

Step 4. **Sludge chamber (outlet)** (right): the spent slurry, depleted of methane but still nutrient-rich, overflows through an outlet pipe into this chamber and is collected as organic manure.

> **Final Answer:** A floating-dome biogas plant has four labelled parts: dung+water chamber (inlet), digester (anaerobic tank), gas holder (floating dome that traps biogas), and sludge chamber (outlet for spent slurry = manure).

♥ Rural energy independence

A medium (∼ 4 m^3/day) household biogas plant gives a rural family enough fuel for cooking three meals a day, plus enough manure for a small kitchen garden. India has ∼ 5 million such plants installed.

EXPERT'S SOLUTION *: Krishna Rao, M.Tech Renewable Energy, IIT Kharagpur*

Picture-first. Visualise the plant as a four-room machine: inlet, digester, gas holder, outlet.

Step 1. Inlet (Dung + water chamber): mix and feed slurry daily.

Step 2. Digester: sealed underground tank where methanogens convert organic matter to CH_4 + CO_2.

Step 3. Gas holder: floating dome traps the gas, can be tapped via a pipe.

Step 4. Outlet (Sludge chamber): spent slurry collected for use as manure.

Step 5. Net inputs/outputs: cow dung + water in; biogas (fuel) + manure (fertilizer) out.

Why this matters. Drawing and labelling this diagram is a standard Boards Bio 5-mark question. The four-component structure has not changed since KVIC's original 1960s design.

Common trap to dodge. Students often confuse closely related microbe pairs — *Lactobacillus* vs *Streptococcus*, *Penicillium* vs *Aspergillus*, methanogens vs cyanobacteria, ladybirds vs aphids (predator vs prey). Always anchor on the most distinctive feature (heterocysts? icosahedral capsid? sealed digester?) before committing to an option. The distinguishing trait beats memorising name lists.

> **Final Answer:** Inlet chamber + digester + gas holder + sludge chamber form the four-component KVIC biogas plant.

Q 8.4 Describe the main ideas behind the biological control of pests and diseases.

SOLUTION

Concept used. Biological control (biocontrol) is the use of living organisms — natural predators, parasites, pathogens or competitors — to keep pest and disease populations below an economically damaging threshold, instead of relying on chemical pesticides. Its core philosophy is to work *with* ecological balance rather than against it.

Step 1. **Use natural enemies.** The simplest idea is to introduce or encourage a pest's natural enemy. Classic examples:

- **Lady bird beetles** eat aphids.
- **Dragonflies** eat mosquito larvae.
- **Trichoderma** fungi parasitise plant-pathogenic fungi (*Pythium*, *Fusarium*).

Step 2. **Use microbial pathogens of pests.** Specific pathogens that kill pests but not non-target organisms:

- ***Bacillus thuringiensis* (Bt)** produces Cry toxins that kill caterpillars on ingestion.
- **Nucleopolyhedrovirus (NPV)** infects and kills specific insect larvae.
- Entomopathogenic fungi like *Beauveria bassiana* infect insect cuticles.

Step 3. **Species specificity.** A central principle: biocontrol agents are typically narrow-spectrum — they target only the pest species, sparing beneficial insects, pollinators, soil microbes and non-target wildlife.

Step 4. **Ecological sustainability.** Biocontrol agents replicate in the field and persist; one introduction can give multi-season control without continued reapplication. Chemicals must be sprayed repeatedly and pollute the environment.

Step 5. **Avoid pest resistance.** Because biocontrol agents co-evolve with the pest (especially over generations), pest resistance develops more slowly than to chemical insecticides.

Step 6. **Integrated Pest Management (IPM).** Modern practice combines biocontrol with crop rotation, resistant varieties, cultural practices and minimal chemical use — a balanced ecosystem approach rather than a single-shot kill.

Step 7. **Genetic engineering link.** Bt cotton, Bt brinjal etc. take biocontrol a step further: the plant itself produces the Cry toxin, eliminating the need for spraying.

> **Final Answer:** Biological control uses living natural enemies (predators, parasites, pathogens) to suppress pest and disease populations. Its main ideas: species-specific action, ecological sustainability, lower environmental harm, slower resistance evolution, and integration into IPM rather than reliance on chemical pesticides.

☞ Exam Tip

Whenever the question says "main ideas" or "principles", structure the answer as numbered ideas. Each idea = one mark.

EXPERT'S SOLUTION : *Aanya Joshi, Ph.D Integrated Pest Management, IARI*

Strategic angle. Frame biocontrol as five guiding principles: specificity, sustainability, resistance-management, IPM integration, and ecosystem-thinking.

Step 1. Use of natural enemies — ladybirds vs aphids, dragonflies vs mosquito larvae, *Trichoderma* vs plant-pathogenic fungi.

Step 2. Use of microbial pathogens of pests — Bt for caterpillars, NPV for narrow lepidopteran control.

Step 3. Species specificity — only the target pest is killed; pollinators and beneficials are spared.

Step 4. Self-perpetuation — biocontrol agents reproduce in the field, giving multi-season effect.

Step 5. Slower resistance evolution and integration with IPM — combined with rotation and resistant varieties.

Why this matters. Biocontrol is the bedrock of organic and sustainable agriculture. India has been a global leader, especially with cyclical use of Bt cotton and *Trichoderma* formulations.

NEET / Boards perspective. Examiners frequently combine factual recall with one twist — an organism in an unusual habitat, a product in an unexpected industry, or an "except" clause that reverses the question. Read every option carefully and translate it back to the canonical microbe–product–role triad before answering. This single discipline reliably catches the trap distractor.

> **Final Answer:** Biological control = species-specific natural enemies replacing chemical pesticides; key ideas are specificity, sustainability, resistance management and IPM integration.

Q 8.5 **(a) What would happen if a large volume of untreated sewage is discharged into a river?**
(b) In what way anaerobic sludge digestion is important in sewage treatments?

SOLUTION

Concept used. Untreated sewage carries large amounts of **biodegradable organic matter** (proteins, fats, sugars), suspended solids, pathogens, nitrogen, phosphorus and chemicals. When discharged into a river, aerobic microbes consume the organics, drawing O_2 from the river water at a faster rate than reaeration can replace it; the resulting **oxygen sag** kills fish and other aerobic life. **Anaerobic sludge digestion**, by contrast, deliberately uses *absence of oxygen* to stabilise the concentrated sludge produced during secondary treatment, harvesting biogas in the process.

Part (a) — Consequences of discharging untreated sewage into a river.

Step 1. **BOD spike and oxygen depletion.** The river's aerobic bacteria consume the organic load, depleting dissolved O_2. This is the classic "oxygen sag" downstream of a sewage outfall.

Step 2. **Fish kills.** When DO falls below ~ 3 mg/L, fish, frogs and aerobic invertebrates die en masse. Anaerobic zones develop and emit H_2S.

Step 3. **Eutrophication.** Sewage delivers large amounts of N and P. These nutrients trigger algal blooms; when algae die, decomposers consume more oxygen, worsening anoxia and creating "dead zones".

Step 4. **Pathogen spread.** Sewage carries *E. coli*, *Vibrio cholerae*, *Salmonella typhi*, hepatitis A virus, polio virus. Drinking water drawn downstream becomes a public-health hazard, causing cholera and typhoid outbreaks.

Step 5. **Sediment accumulation and odour.** Suspended solids settle and decay anaerobically, releasing CH_4 and H_2S, producing the characteristic foul smell.

Step 6. **Biodiversity loss and economic damage.** Loss of fish and clean water harms fisheries, tourism and irrigation; the river becomes effectively "dead".

Part (b) — Importance of anaerobic sludge digestion in sewage treatment.

Step 1. **Sludge stabilisation.** Anaerobic digestion converts unstable, putrescible secondary sludge into a stable, less-odorous, hygienically safer residue.

Step 2. **Volume reduction.** Up to 50% of the organic matter is broken down to gases, halving the volume of sludge that must be disposed of.

Step 3. **Energy recovery.** The digester gas ($\sim 60\%$ CH_4) is a usable fuel — many plants generate electricity by burning it on-site, becoming partly energy self-sufficient.

Step 4. **Pathogen reduction.** The warm (35 °C), prolonged anaerobic environment kills many pathogenic bacteria, helminth eggs and viruses, reducing disease risk from residual sludge.

Step 5. **Nutrient recovery.** The digested residue (digestate) is rich in N, P, K and is used as organic manure on farms, closing the nutrient loop.

Step 6. **Economic and environmental.** Anaerobic digestion turns a disposal problem (sludge) into two valuable products (biogas + manure), making sewage treatment more sustainable.

Final Answer: (a) Untreated sewage causes BOD spikes, oxygen sag, fish kills, eutrophication, pathogen-driven outbreaks and biodiversity loss. (b) Anaerobic sludge digestion stabilises sludge, halves its volume, generates biogas (fuel), reduces pathogens, and yields nutrient-rich manure — turning waste into resources.

✗ Common Mistake

A common over-simplification is to say "sewage causes pollution". The Exemplar answer wants the specific mechanism: BOD → oxygen depletion → fish kills + eutrophication + pathogen spread.

EXPERT'S SOLUTION *: Pranav Banerjee, Ph.D Sanitary Engineering, IIT Bombay*

Strategic angle. Two-part question: list disasters in (a); list benefits in (b). Both lists are 4–6 items.

Step 1. (a) Untreated discharge → BOD spike + oxygen sag + fish kills + eutrophication + pathogen outbreaks + bad smell + dead river.

Step 2. (b) Anaerobic sludge digestion → stabilisation + volume halving + biogas generation + pathogen kill + manure production.

Step 3. Big picture: anaerobic digestion is the small-volume, high-impact final step that makes the entire sewage system circular.

Why this matters. If a city's sewage plant has primary + secondary aerobic stages but no anaerobic digester, it generates mountains of dangerous sludge with no productive end-use.

Memory aid. A useful three-step recall: (1) name the microbe, (2) name its product or function, (3) name the use-case (medicine, agriculture, food, environment). If you can construct this triad for every named organism in the chapter, every Exemplar MCQ collapses into a quick lookup. Practising this exercise on the chapter summary table is the single highest-yield revision activity.

Final Answer: (a) Oxygen depletion, fish kills, eutrophication, pathogen spread, biodiversity loss. (b) Anaerobic digestion stabilises sludge, gives biogas and manure, kills pathogens.

Q 8.6 **Which type of food would have lactic acid bacteria? Discuss their useful application.**

SOLUTION

Concept used. **Lactic acid bacteria (LAB)** are Gram-positive, microaerophilic bacteria (*Lactobacillus*, *Lactococcus*, *Streptococcus thermophilus*, *Leuconostoc*) that ferment carbohydrates to lactic acid. Foods that contain LAB include curd/yoghurt, idli/dosa batter, sauerkraut, kimchi, pickles, cheese, fermented milk products like buttermilk, and certain breads (sourdough). Their useful applications span nutrition, food preservation, gut health, and industrial production of lactic acid.

Step 1. Foods containing LAB.

- Curd, yoghurt, buttermilk — *Lactobacillus acidophilus*, *L. bulgaricus*, *Streptococcus thermophilus*.
- Idli and dosa batter — *Leuconostoc mesenteroides* + *Lactobacillus*.
- Cheese — various LAB starters.
- Sauerkraut, kimchi, pickles — *Leuconostoc* + *Lactobacillus* species.
- Sourdough bread — *Lactobacillus sanfranciscensis*.

Step 2. Conversion of milk to curd. LAB ferment milk lactose to lactic acid; the acid lowers pH, coagulates casein, and produces curd with characteristic tangy flavour.

Step 3. Vitamin enrichment. LAB synthesise vitamin B_{12} during fermentation, making curd a key dietary source of B_{12} for vegetarians.

Step 4. Food preservation. The lactic acid + low pH inhibits spoilage organisms; this is the principle behind pickling, sauerkraut, kimchi and yoghurt — naturally preserved foods that last weeks without refrigeration.

Step 5. Gut-health probiotics. Live LAB taken orally (probiotic curd, probiotic supplements) restore the gut microbiome after antibiotic use, alleviate diarrhoea (especially in children with rotavirus or antibiotic-associated diarrhoea), and improve lactose digestion.

Step 6. Improved digestibility. LAB partly digest milk proteins and lactose, making fermented milk products more tolerable for people with mild lactose intolerance.

Step 7. Idli and dosa fermentation. *Leuconostoc mesenteroides* produces lactic acid + CO_2, leavening the batter, lowering pH, and improving B-complex vitamin content.

Step 8. Industrial production of lactic acid. *Lactobacillus* is grown on whey or molasses to produce lactic acid for the food, pharmaceutical, plastic (polylactic acid) and textile industries.

Final Answer: Foods containing LAB include curd, yoghurt, buttermilk, idli/dosa batter, cheese, sauerkraut, kimchi, pickles and sourdough. LAB applications: convert milk to curd, enrich foods with vitamin B_{12}, preserve food, serve as probiotics for gut health, improve protein digestibility, leaven idli/dosa batter, and produce industrial lactic acid.

♥ Ancient biotechnology

LAB are arguably humanity's oldest biotech tool. Curd is mentioned in Vedic texts; sauerkraut goes back 2000+ years in China and Europe. Long before microbiology existed, humans were already using LAB for food and health.

EXPERT'S SOLUTION : *Tara Sharma, M.Sc Food Microbiology, CFTRI Mysore*

Strategic angle. List the foods first, then the six applications.

Step 1. Foods: curd, yoghurt, idli/dosa batter, buttermilk, cheese, sauerkraut, kimchi, pickles, sourdough.

Step 2. Application 1 — curd formation and vitamin B_{12} enrichment.

Step 3. Application 2 — natural food preservation via lactic acid + low pH.

Step 4. Application 3 — probiotic gut-health benefits (especially after antibiotics).

Step 5. Application 4 — improved digestibility for lactose-intolerant consumers.

Step 6. Application 5 — leavening of idli/dosa via *Leuconostoc*.

Step 7. Application 6 — industrial production of lactic acid for food, pharma, bioplastics.

Why this matters. LAB illustrate how a single microbial group can simultaneously be food, medicine and industrial feedstock. The Indian dietary tradition is built around LAB-fermented foods.

Connection to other chapters. The same microbial principle reappears in Chapter 11 (Biotechnology Principles) where recombinant DNA, restriction enzymes and microbial expression hosts are explored in greater depth, and in Chapter 13–16 (Ecology) where microbial nutrient cycling underwrites entire ecosystems. Mapping each microbe to its ecological niche and its industrial role is a recurring NEET task — every question in this Exemplar set fits one or both of those frames.

Final Answer: LAB-containing foods: curd, yoghurt, idli/dosa, cheese, pickles, sauerkraut, sourdough. Applications: milk-to-curd conversion, vitamin B_{12} enrichment, food preservation, probiotic gut health, improved digestibility, batter leavening, industrial lactic-acid production.

Key Takeaways

- *Lactobacillus* curdles milk into curd and enriches it with vitamin B_{12}; *Saccharomyces cerevisiae* ferments dough, beer, wine and produces bioethanol.
- Penicillin from *Penicillium notatum* (Fleming, Chain, Florey) launched the antibiotic era; statins from *Monascus*, cyclosporin A from *Trichoderma* and streptokinase from *Streptococcus* extend microbial pharmacology.
- Secondary (biological) sewage treatment depends on aerobic flocs that consume BOD; the resulting sludge is anaerobically digested by methanogens to give biogas (CH_4 + CO_2).
- Biocontrol agents (*Bacillus thuringiensis*, *Trichoderma*, NPVs, lady birds) replace chemical pesticides; biofertilizers (*Rhizobium*, cyanobacteria, mycorrhizae) replace chemical fertilizers.
- Methanogens generate CH_4, CO_2 and H_2S but **never oxygen** — they are strict anaerobes living in cattle rumen, paddy fields and biogas plant digesters.

End of NCERT Exemplar Problems