Collegedunia NCERT Notes

The Ultimate NCERT Revision Guide for Class 12 Biology — Full-colour diagrams

Chapter 8: Microbes in Human Welfare

Class 12 / 12th Biology — NCERT 2024-25 (New NCERT)

Why this chapter matters

Microbes are invisible workhorses that shape food, medicine, fuel and farming. Chapter 8 is a high-yield NEET chapter — expect 2–3 direct factual questions on micro-organism names, products and processes every year. The chapter is also a frequent source of board short-answer questions on sewage treatment and biogas plants. Master the species–product–application triplets and you secure easy marks.

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1 Introduction to Useful Microbes

The biosphere is dominated, in numbers, by organisms we cannot see. Microbes thrive in soil, water, air, inside our gut and at the most hostile sites on the planet

— thermal vents at $100°$C, under metres of glacial ice, and in highly acidic environments. NCERT groups microbes into protozoa, bacteria, fungi, microscopic animal and plant viruses, viroids and prions (proteinaceous infectious agents).

Chapter 7 introduced the harmful face of microbes (disease). Chapter 8 corrects that one-sided view: most microbes are either neutral or beneficial. From the curd you eat at breakfast to the antibiotics that keep you alive, from the sewage plant that recycles city water to the rhizobium nodule that fertilises the field — microbes are doing the work.

1.1 The Microbial World at a Glance

The six broad groups studied in Class 11 (Kingdoms) that fall under "microbes" are:

- **Bacteria** (Monera) — prokaryotes, single-celled. Examples: *Lactobacillus*, *Rhizobium*.
- **Archaea** (also Monera) — prokaryotes of extreme habitats; methanogens belong here.
- **Fungi** — eukaryotic; yeasts (*Saccharomyces*), moulds (*Penicillium*, *Aspergillus*) and mycorrhizal symbionts (*Glomus*).
- **Protozoa** — single-celled eukaryotes (e.g. *Amoeba*, *Paramecium*).
- **Viruses** — acellular, obligate intracellular parasites (bacteriophages, adenoviruses, TMV).
- **Viroids & Prions** — viroids are naked RNA (potato spindle tuber viroid); prions are protein-only infectious agents (mad-cow disease).

NCERT illustrates representative bacteria in Fig. 8.1 and viruses in Fig. 8.2; cultivable colonies on nutrient media are shown in Fig. 8.3.

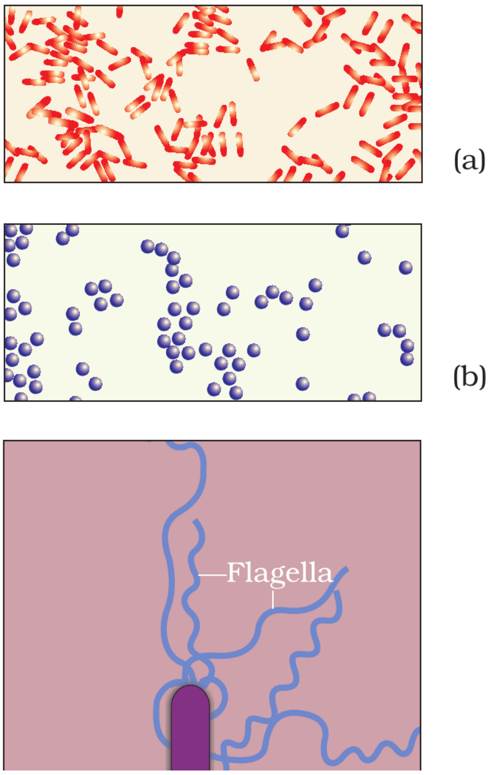


*Fig. 8.1 (NCERT): Bacteria — (a) rod-shaped (*bacilli*), magnified 1500X; (b) spherical (*cocci*), magnified 1500X; (c) a rod-shaped bacterium showing flagella, magnified 50,000X.*

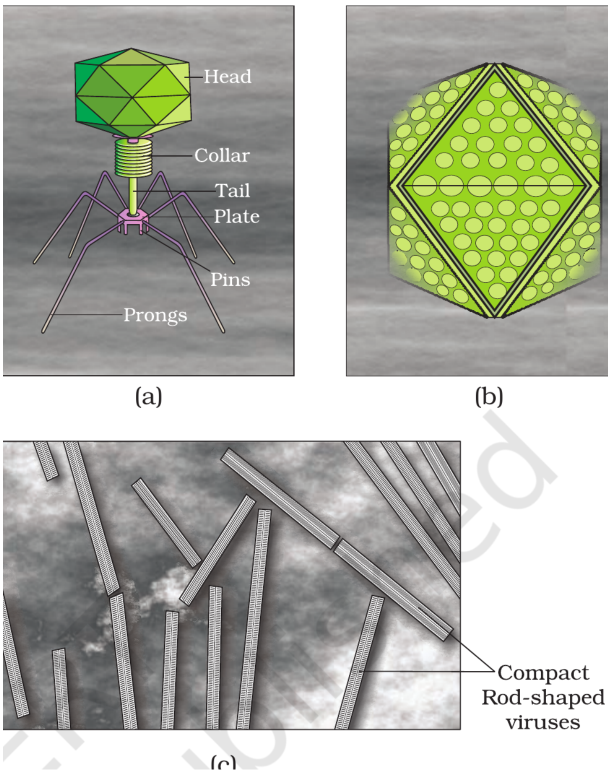


Fig. 8.2 (NCERT): Viruses — (a) a bacteriophage with head, collar, tail-plate, pins and prongs; (b) Adenovirus, the cause of respiratory infections; (c) rod-shaped Tobacco Mosaic Virus (TMV). Magnified about 1 00 000 to 1 50 000X.

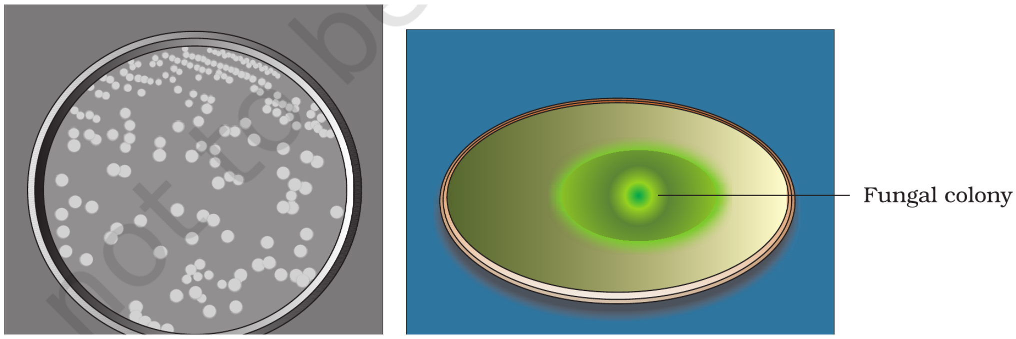


Fig. 8.3 (NCERT): Cultured microbes — (a) bacterial colonies on a petri dish; (b) a fungal colony. Colonies are visible to the naked eye and are the starting point for almost every microbiological study.

The five everyday faces of useful microbes

This chapter covers **six** NCERT sub-topics: microbes in (1) household products, (2) industrial products, (3) sewage treatment, (4) biogas production, (5) biocontrol, and (6) biofertilisers. Each one is a separate question target for boards and NEET.

Microbes are everywhere — even inside you

The adult human body carries roughly 3.8×10^{13} bacterial cells — about the same order of magnitude as our own human cell count. The vast majority are harmless or beneficial gut residents (*Lactobacillus*, *Bifidobacterium*, *E. coli* K12). They synthesise vitamin K, train the immune system and out-compete pathogens.

2 Microbes in Household Products

The food on an average Indian dining table is the work of bacteria and fungi. Curd, dosa-idli batter, bread, cheese, fermented fish, soyabean and bamboo shoot foods, the traditional southern drink *toddy* — all are microbial fermentations. The same metabolic toolkit (lactic acid production, CO_2 release, protein digestion) is reused across these products.

2.1 Curd from Milk — Lactic Acid Bacteria

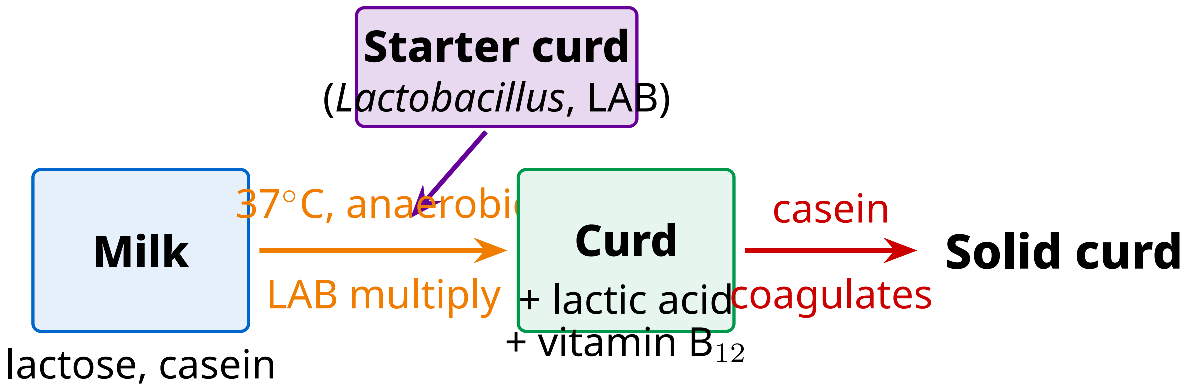
A spoon of starter curd added to warm milk delivers millions of **lactic acid bacteria (LAB)** — chiefly *Lactobacillus*. At a suitable temperature ($\sim 37°$C) the LAB multiply rapidly. They ferment lactose and release lactic acid, which lowers the pH. Milk protein (casein) is destabilised by the acid, coagulates into a soft network and partially digests — giving curd its characteristic texture and tang.

Curd formation in one line

$$\text{Milk (lactose)} \xrightarrow[37^\circ\text{C}]{\textit{Lactobacillus}\text{, LAB}} \text{Curd} + \text{Lactic acid} + \uparrow \text{Vitamin B}_{12}$$

LAB lower the pH; casein coagulates; B-complex vitamins (especially **B**$_{12}$) increase.

- Improved nutritional quality — vitamin B_{12} increases.
- In our stomach, LAB check the growth of disease-causing microbes (probiotic action).
- LAB are obligate or facultative anaerobes — they do not need oxygen for fermentation.



Conversion of milk to curd by lactic acid bacteria.

Quick Tip

Two NEET-favourite one-liners: (i) the bacterium that turns milk into curd is *Lactobacillus*; (ii) the vitamin enhanced during curdling is **vitamin B**$_{12}$. Curd starter "inoculum" is the technical word — expect it in fill-in-the-blanks.

2.2 Dosa, Idli, Bread — Fermenters that Puff the Dough

Dosa and idli batters are fermented by bacteria (mostly *Leuconostoc* along with LAB and yeasts). The puffed-up appearance is due to trapped **CO_2 gas** released during **anaerobic respiration** (fermentation pathway).

Bread dough is fermented by *Saccharomyces cerevisiae* (baker's yeast); yeast respires sugars anaerobically:

Alcoholic fermentation by yeast

$$C_6H_{12}O_6 \xrightarrow{\text{yeast (anaerobic)}} 2\,C_2H_5OH + 2\,CO_2 + \text{ATP (small)}$$

The CO_2 raises the dough; ethanol evaporates during baking. The enzyme catalysing the final step is **pyruvate decarboxylase** (NEET extra).

Same yeast, two products

Saccharomyces cerevisiae is used in **baking** (bread, dosa, idli — CO_2 is the wanted product) and in **brewing** (wine, beer — ethanol is the wanted product). The metabolic pathway is identical; what differs is which by-product industry harvests.

2.3 Cheese — Microbes Give Flavour and Holes

Cheese is among the oldest microbe-derived foods. Different cheeses get their characteristic taste, smell and texture from the specific microbes used during ripening.

Cheese type	Microbe responsible	Distinct feature
Swiss cheese (Emmental)	Bacterium *Propionibacterium shermanii*	Large holes (eyes) from CO_2
Roquefort	Fungus *Penicillium roqueforti*	Blue veins; pungent flavour
Camembert / Brie	Fungus *Penicillium camemberti*	Soft, white-rind ripening
Cheddar / mozzarella	Lactic acid bacteria + rennet	Mild, firm; rennet curdles casein

Quick Tip

The classic NCERT mnemonic question: "Holes in Swiss cheese are produced by which bacterium?" — always *Propionibacterium shermanii*, and the gas is **CO_2**.

2.4 Traditional Indian Fermentations

A short list worth memorising for NEET fact-recall:

- **Toddy** — traditional drink from southern India; made by fermenting *palm sap*. The fermentation is by wild yeasts and bacteria; product is mildly alcoholic.
- **Idli, dosa, dhokla, jalebi** — fermented batters of cereal + pulse using LAB and yeasts.
- **Fermented fish, soyabean, bamboo shoots** — products eaten in north-east India; microbes break down proteins to release umami flavours.

Remember LAB, the laboratory of curd

Lactose → **A**cid → **B**etter B_{12}. The three letters "LAB" double up as: **L**actobacillus, **A**cidic milieu, **B**etter nutrition.

3 Microbes in Industrial Products

Industrial microbiology grows microbes at the scale of thousands of litres inside polished stainless-steel vessels called **fermentors** (Fig. 8.4). Process control — pH, temperature, aeration, agitation — decides the yield of beverage, antibiotic, enzyme or organic acid.

Fig. 8.4 (NCERT): Industrial ***fermentors*** *— large stainless-steel vessels where microbes are cultured in carefully controlled conditions (temperature, pH, dissolved oxygen, mixing speed) to produce commercial quantities of beverages, antibiotics, enzymes or organic acids.*

3.1 Fermented Beverages

The same brewer's yeast (*Saccharomyces cerevisiae*) ferments malted cereals or fruit juices into ethanol. The product depends on **raw material** and **processing**:

Beverage	Raw material	Distillation?	Microbe
Wine	Grapes / fruit juice	No	*S. cerevisiae*
Beer	Malted barley	No	*S. cerevisiae*
Whisky	Fermented malt / grain	Yes	*S. cerevisiae*
Brandy	Fermented fruit wine	Yes	*S. cerevisiae*
Rum	Fermented sugar-cane molasses	Yes	*S. cerevisiae*

Fig. 8.5 (NCERT): A modern ***fermentation plant*** *where industrial-scale brewing or antibiotic production happens. Stainless-steel pipework, jacketed vessels and aseptic transfer lines are the hallmark.*

Quick Tip

Beer / wine = no distillation. Whisky / brandy / rum = distilled. A favourite NEET MCQ: "Which of these involves distillation?" — the answer is always the trio of W/B/R.

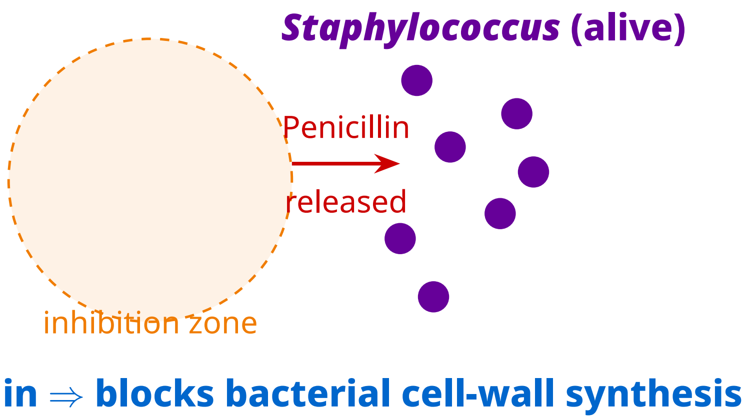
3.2 Antibiotics — The Twentieth Century's Greatest Drug Class

Anti- (against) + *bio* (life) — against the life of disease-causing microbes, "pro-life" for the patient. An **antibiotic** is a chemical produced by a microbe that kills or retards the growth of another microbe.

The Penicillin story — a chance discovery

Alexander Fleming (1928) noticed that a contaminating mould had cleared the *Staphylococcus* colonies around it on an unwashed culture plate. The mould was *Penicillium notatum*; he named the active substance **Penicillin**. The clinical-scale purification, dosing and trials were done much later by **Ernst Chain** and **Howard Florey**. The trio received the **Nobel Prize in Physiology/Medicine in 1945**. Penicillin saved countless American soldiers wounded in World War II.

- Antibiotics treat plague, whooping cough (*kali khansi*), diphtheria (*gal ghotu*) and leprosy (*kusht rog*).
- Other antibiotic-producing genera: *Streptomyces*, *Bacillus* and *Cephalosporium*.



Fleming's plate. The mould Penicillium notatum *secretes penicillin which inhibits the surrounding bacteria.*

Antibiotic resistance — a growing crisis

Indiscriminate use selects for resistant strains. MRSA (methicillin-resistant *Staphylococcus aureus*) and XDR-TB are real-world descendants of Fleming's plate. The WHO classifies AMR as one of the top ten threats to global health — a NEET-favourite "current-affairs" question.

Quick Tip

Antibiotic vs antiseptic vs disinfectant. Antibiotic = chemical from microbe, used inside the body. Antiseptic = applied on living tissue (e.g. Dettol). Disinfectant = applied on surfaces (e.g. Phenol). Don't confuse them in MCQs.

3.3 Chemicals, Enzymes & Other Bioactive Molecules

Microbes manufacture a wide menu of useful chemicals. Memorise this table — it is the densest single source of MCQs in the chapter.

Product	Microbe	Group / Use
Citric acid	*Aspergillus niger*	Fungus — food and pharma acid
Acetic acid	*Acetobacter aceti*	Bacterium — vinegar manufacture
Butyric acid	*Clostridium butylicum*	Bacterium — solvent industry
Lactic acid	*Lactobacillus*	Bacterium — food, plastics (PLA)
Ethanol	*Saccharomyces cerevisiae*	Yeast — beverages, biofuel
Lipases	Bacteria & fungi	Detergent enzymes — remove oil stains
Pectinases / proteases	Fungi & bacteria	Clarify bottled fruit juice
Streptokinase	*Streptococcus* (genetically modified)	Clot-buster after heart attack
Cyclosporin A	*Trichoderma polysporum*	Fungus — immunosuppressant for transplants
Statins	*Monascus purpureus*	Yeast — blood-cholesterol lowering

How statins work — a NEET favourite

Statins competitively **inhibit HMG-CoA reductase**, the rate-limiting enzyme of cholesterol biosynthesis. Less mevalonate ⇒ less cholesterol output by the liver ⇒ lower LDL in blood.

Acid producers — "CAB-L"

Citric — ***A****spergillus niger*; **A**cetic — ***A****cetobacter*; **B**utyric — ***C****lostridium butylicum*; **L**actic — ***L****actobacillus*. "Aspergillus + acid C + B + L" — string the letters together to recall the genus–acid pairing.

Quick Tip

Cyclosporin A vs Statins — a classic mix-up. Cyclosporin = immunosuppressant from *Trichoderma* (a fungus). Statins = cholesterol-lowering from *Monascus* (a yeast/fungus). Both are fungal products; the function distinguishes them.

Common Mistake

"Streptokinase is the same as Streptomycin." **It is not**. Streptokinase is an *enzyme* (clot-buster) from *Streptococcus*. Streptomycin is an *antibiotic* from *Streptomyces*. Different microbe, different product, different use.

4 Microbes in Sewage Treatment

A growing city generates millions of litres of waste water every day. Human excreta dominates the load; the slurry is called **sewage**. Untreated sewage contains pathogenic microbes, decomposable organic matter and nutrients (N, P) that fuel algal blooms in receiving water bodies. Discharge into rivers and streams without treatment leads to outbreaks of cholera, typhoid and hepatitis A. Hence sewage is processed through **Sewage Treatment Plants (STPs)** that exploit the very organisms naturally present in the waste to break down its organic content.

4.1 Primary (Physical) Treatment

The first stage removes **solids** mechanically.

- **Sequential filtration** skims off floating debris.
- **Sedimentation** settles grit (soil, pebbles).
- Solids that settle form the **primary sludge**; the liquid above is the **primary effluent** and goes to secondary treatment.

Primary = physical, Secondary = biological

The defining contrast: **primary treatment removes particles physically**; **secondary treatment removes dissolved organic matter biologically**. NCERT specifically asks "key difference" (Q-8 in the chapter exercises) — the answer is this contrast.

4.2 Secondary (Biological) Treatment

The primary effluent flows into large **aeration tanks** where it is constantly agitated and air is pumped in. Aerobic microbes thrive — bacteria and fungi grow together into mesh-like masses called **flocs**.

Fig. 8.6 (NCERT): Inside view of a secondary (biological) treatment tank — vigorous aeration is visible from the surface turbulence. Microbial flocs do the heavy lifting of digesting dissolved organic matter.

The flocs consume dissolved organic matter and dramatically reduce the **Biochemical Oxygen Demand (BOD)** of the water.

BOD — the headline pollution metric

BOD = the amount of oxygen (in mg) that would be consumed by aerobic microbes to oxidise the organic matter in **one litre** of water. Unit: **mg/L**. Measured by holding a sealed sample at $20°$C for 5 days and recording the drop in dissolved oxygen.

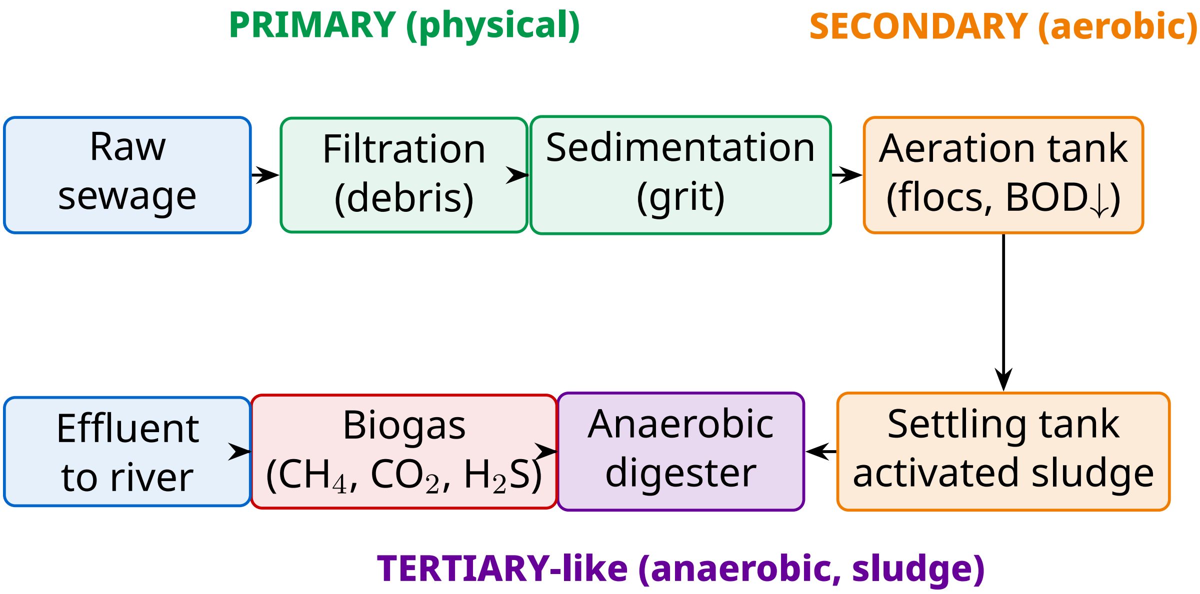
Higher BOD $\Longleftrightarrow$ more organic pollution $\Longleftrightarrow$ poorer water quality

- Clean drinking water — BOD $<$ 1 mg/L.
- Treated effluent — BOD typically 5–20 mg/L (safe to discharge).
- Raw sewage — BOD 200–600 mg/L.

Once BOD is reduced sufficiently, the effluent passes into a **settling tank**. The flocs settle out as **activated sludge**. A small fraction is recycled back to the aeration tank to serve as the next inoculum; the bulk is pumped to large **anaerobic sludge digesters**.

4.3 Anaerobic Sludge Digestion

Inside the digester, anaerobic bacteria digest the dead bacteria and fungi from the activated sludge. They release a mixture of gases — **methane (CH_4), hydrogen sulphide (H_2S) and carbon dioxide (CO_2)** — collectively called **biogas**. The biogas is inflammable and can power the plant or be supplied to nearby households.



The end-to-end sewage treatment pipeline. Two zones — primary (mechanical) and secondary (biological) — followed by anaerobic sludge digestion that recovers biogas.

Fig. 8.7 (NCERT): Aerial view of a sewage treatment plant. The circular tanks are the aerator/settler combinations of the secondary treatment loop; the rectangular tank is the primary sedimentation basin.

Ganga and Yamuna Action Plans

The Ministry of Environment, Forest and Climate Change launched the **Ganga Action Plan** (and its sister **Yamuna Action Plan**) to build new STPs along the two rivers, so that only treated sewage — not raw waste — is discharged. Despite the effort, India still treats only about 28% of its urban sewage; the remaining 72% reaches rivers untreated. Direct sewage release is the chief cause of waterborne disease outbreaks.

Quick Tip

NCERT exercise Q. 11 — BOD calculation. Three samples A, B, C report BOD = 20, 8, 400 mg/L. The *most polluted* is the sample with *highest BOD* = 400 mg/L. River water (cleanest) = 8 mg/L; secondary effluent = 20 mg/L; untreated sewage = 400 mg/L.

Common Mistake

"Lower BOD means the water is more polluted." **Wrong — the opposite is true.** A high BOD means microbes need a lot of oxygen to digest the organic load, which means more pollution. Drinking water has very low BOD.

5 Microbes in Biogas Production

Biogas is a mixture of gases (predominantly methane, with CO_2 and trace H_2S) produced by anaerobic microbial decomposition of organic waste. It is renewable, locally producible from cattle dung or sludge, and burns cleanly.

5.1 The Methanogens

Anaerobic bacteria that grow on cellulose-rich substrates and release methane are called **methanogens**. The textbook example is *Methanobacterium*. Methanogens are found in:

- **Anaerobic sludge digesters** of sewage plants (last stage above).
- The **rumen of cattle** — a stomach chamber harbouring methanogens that break down cellulose. This is why cattle digest grass and we cannot.
- **Marshes, paddy fields, termite guts** — all anaerobic, cellulose-rich.

Cattle excreta (dung, *gobar*) is rich in methanogens. Hence "**gobar gas**" — biogas produced from cow dung.

Cellulose to methane — the methanogen pathway

$$\underbrace{(C_6H_{10}O_5)_n}_{\text{cellulose}} \xrightarrow{\text{hydrolytic bact.}} \text{Glucose} \xrightarrow{\text{fermentative bact.}} \text{Acetate} + H_2 + CO_2$$

$$\text{Acetate} + H_2 + CO_2 \xrightarrow{\text{methanogens (}\textit{Methanobacterium}\text{)}} CH_4 + CO_2$$

The overall yield: roughly 50–75% CH_4, 25–50% CO_2, with trace H_2S, NH_3, H_2.

5.2 The Biogas Plant

A typical Indian biogas plant (Fig. 8.8) is a concrete tank, 10–15 feet deep, into which a slurry of dung and water is fed. A floating cover (gas-holder) rises as methanogens generate gas. A side pipe carries the biogas to nearby kitchens; an outlet at the bottom drains spent slurry (used as fertiliser).

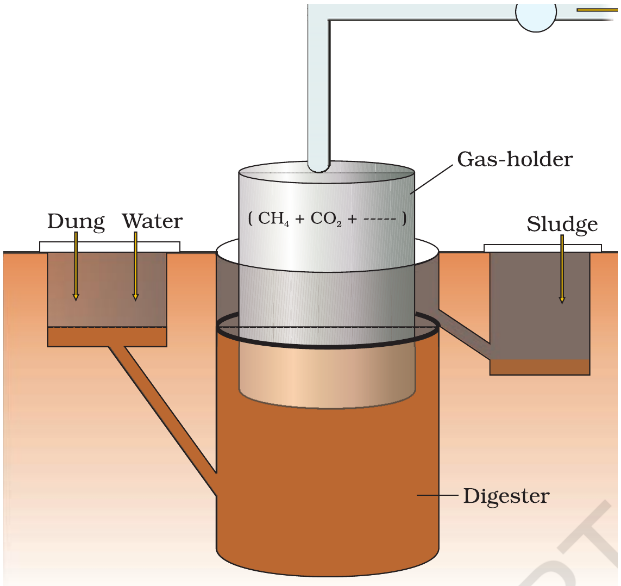
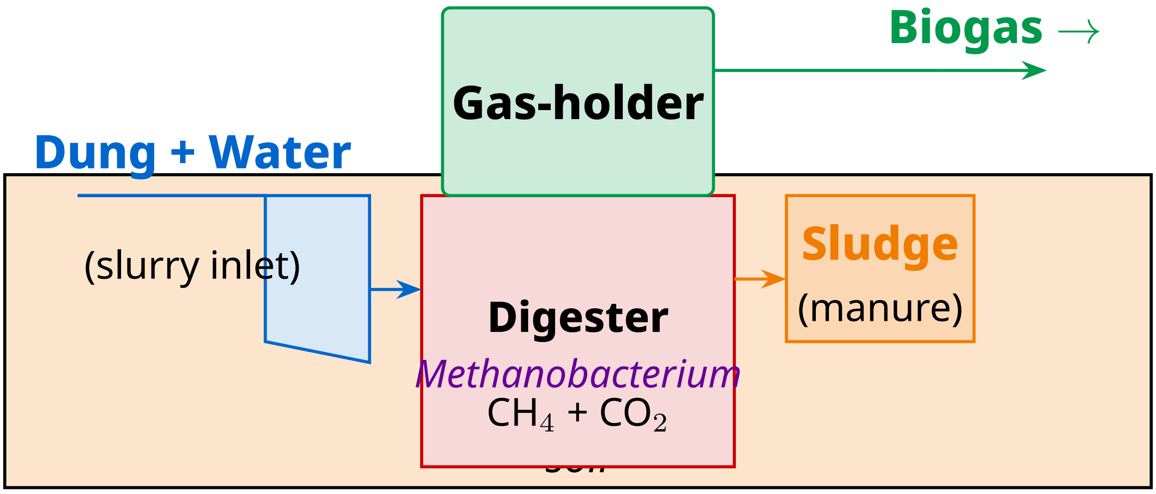


Fig. 8.8 (NCERT): A typical biogas plant. Dung–water slurry enters from the inlet (left). The digester (the deep tank) holds the slurry anaerobically. Methanogens produce CH_4 + CO_2, which collects in the floating gas-holder. The gas is tapped out via a pipe; the spent slurry leaves through the sludge outlet (right) and is used as manure.



Schematic of a biogas plant. Anaerobic digestion converts cellulose-rich dung slurry into combustible biogas + nutrient-rich manure slurry.

KVIC and IARI — two acronyms NCERT wants

The technology of biogas production in India was developed largely by:

- **IARI** — Indian Agricultural Research Institute.
- **KVIC** — Khadi and Village Industries Commission.

Both names are common one-mark questions.

Why rural India and not urban India?

Biogas plants need a steady supply of cattle dung, which is abundant in villages. Urban India lacks this input but has plenty of organic waste (vegetable peels, food waste) that can be substituted in modern community biogas plants. The output (clean cooking gas + bio-manure) reduces both LPG dependence and chemical-fertiliser load.

Quick Tip

NEET frequent question: "Which gas predominates in biogas?" — **Methane (CH_4)**. Composition typically 55–70% CH_4, 30–45% CO_2, trace H_2S.

6 Microbes as Biocontrol Agents

Biocontrol is the use of **biological methods to control plant diseases and pests**, replacing synthetic chemical insecticides, fungicides and weedicides. The chemical-spray strategy is fast and broad-spectrum but indiscriminate — it kills beneficial pollinators, predators of pests, and pollutes soil, water and food. Biocontrol instead relies on natural predator–prey or host–pathogen relationships, killing only the target pest.

6.1 Why Biocontrol — The Organic Farming Philosophy

The organic farmer accepts that pests cannot (and should not) be eradicated. Their predators depend on them for survival. The aim is to keep the pest population **below the economic injury threshold**, not zero. This requires:

- Familiarity with the **life cycles, feeding habits and habitats** of every pest, predator and parasite in the field.
- Maintenance of biodiversity — the more variety, the more checks and balances.
- Integration with cultural practices — crop rotation, polyculture, refuge crops.

Macro- vs micro-biocontrol agents

NCERT names two classes:

- **Insect biocontrol agents.** Ladybird beetle (red with black markings) eats aphids; dragonflies eat mosquitoes.
- **Microbial biocontrol agents.** Bacterium *Bacillus thuringiensis* (Bt) kills caterpillars; fungus *Trichoderma* controls soil-borne plant pathogens; *Nucleopolyhedrovirus* (a baculovirus) controls insect pests narrowly.

6.2 Bacillus thuringiensis (Bt) — The Caterpillar Killer

Bt is sold as a powder of dried spores. Mixed with water and sprayed on brassicas (cabbage, cauliflower) and fruit trees, it is eaten by caterpillar larvae. In the alkaline midgut of the caterpillar the Bt crystal protein (**Cry protein**) becomes toxic, perforates the gut wall and kills the larva. Adult butterflies, beneficial insects and humans are unharmed — our gut is too acidic to activate the toxin.

Why Bt is so selective

$$\text{Cry protoxin (crystal)} \xrightarrow{\text{alkaline midgut pH}} \text{active Cry toxin}$$
$$\to \text{binds gut-cell receptor} \to \text{gut perforates} \to \text{larva dies}$$

The receptor for Cry exists on caterpillar gut cells but not on mammalian gut cells. Hence the toxin is species-specific.

Bt cotton — biocontrol via genetic engineering

The **cry** gene of Bt has been cloned into the cotton genome, giving **Bt cotton**. The plant itself now produces the Cry toxin in its tissues, so caterpillars that bite the cotton boll die without a single chemical spray. This is the same idea as Bt biocontrol — but inside the plant, not on its surface. (Detailed mechanism covered in Chapter 10.)

Quick Tip

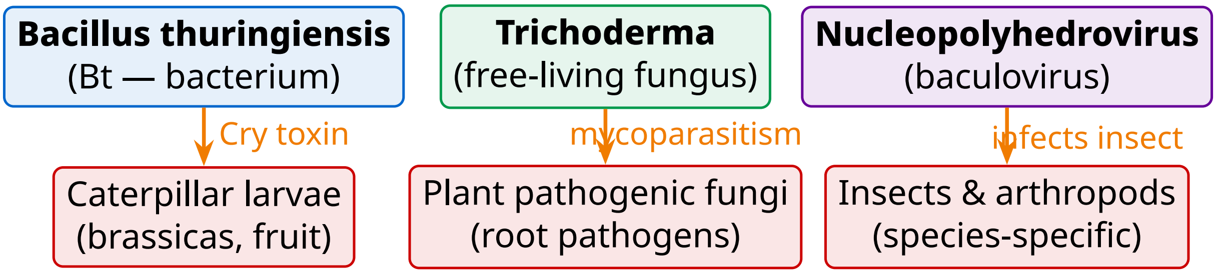
NCERT mentions "Bt cotton is being cultivated in some states of our country." For NEET, just remember — **Bt = bacterium *B. thuringiensis*; toxin = Cry protein; target = caterpillar/larvae of butterflies and moths (Lepidoptera).**

6.3 Trichoderma and Baculovirus

Trichoderma is a free-living fungus, common in root ecosystems. Several species (*T. viride*, *T. harzianum*) are biocontrol agents against soil-borne fungal pathogens of plants. They parasitise pathogenic fungi (*mycoparasitism*) and out-compete them for nutrients.

Baculoviruses are insect-attacking viruses. The genus *Nucleopolyhedrovirus* is the most-used biocontrol genus. Their virtues:

- **Species-specific** — one virus targets one insect species, not its neighbours.
- **Narrow-spectrum** — no off-target damage to plants, mammals, birds or fish.
- Excellent for **Integrated Pest Management (IPM)** programmes and ecologically sensitive sites.



Three microbial biocontrol agents and what each kills.

Three biocontrol heroes — "BTN"

Bt (*Bacillus thuringiensis*) **=** caterpillars. **T**richoderma **=** plant-pathogen fungi. **N**ucleopolyhedrovirus **=** insects. Bacterium–Fungus–Virus, in that order.

Common Mistake

"Ladybirds and dragonflies are microbial biocontrol agents." **They are not microbial** — they are insect biocontrol agents (still "biological" but not "microbial"). MCQs love this distinction. Microbial biocontrol = bacteria + fungi + viruses only.

7 Microbes as Biofertilisers

Decades of chemical fertiliser use have boosted yields but loaded soils with salts, damaged microbial communities and polluted ground water with nitrates. The shift to **organic farming** centres on **biofertilisers** — organisms that enrich soil nutrient quality naturally. The three main sources of biofertilisers are **bacteria, fungi and cyanobacteria**.

7.1 Bacteria as Biofertilisers — Nitrogen Fixers

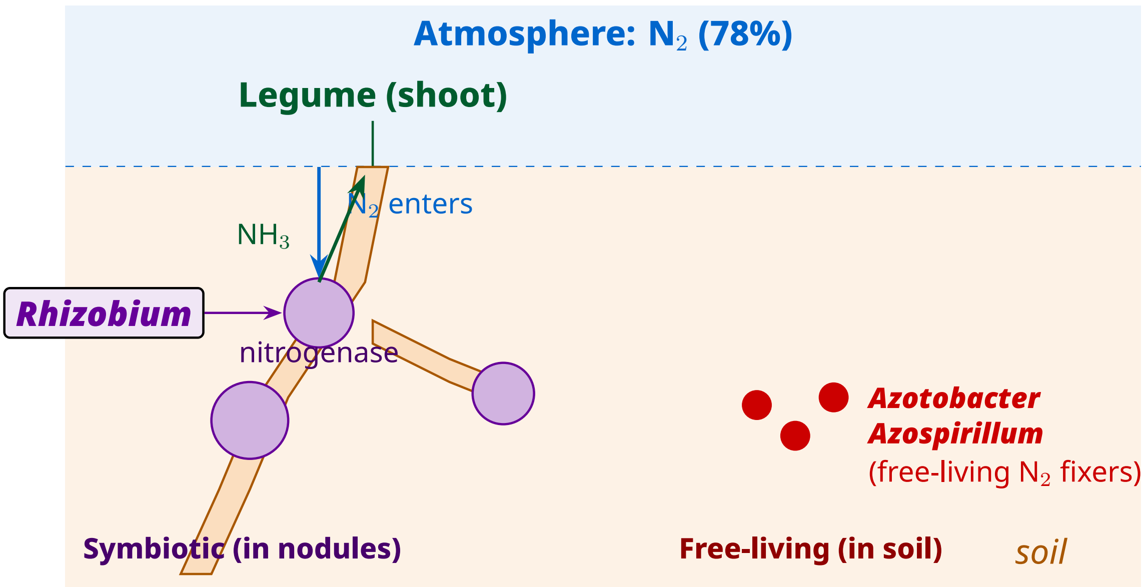
The nitrogen content of soil is renewed primarily by **biological nitrogen fixation** — atmospheric N_2 converted by bacteria into ammonia/organic forms that plants can absorb. NCERT highlights three styles:

- **Symbiotic nitrogen fixation** — *Rhizobium* forms root nodules on **leguminous** plants (pea, gram, soyabean, clover). Inside the nodule it fixes N_2 in exchange for plant sugars.
- **Free-living nitrogen fixation in soil** — *Azospirillum* and *Azotobacter* live freely in soil and fix atmospheric N_2 on their own.
- Result — soil nitrogen content goes up, the crop benefits, and chemical urea applications can be reduced.

The nitrogenase reaction

$$N_2 + 8\,H^+ + 8\,e^- + 16\,ATP \xrightarrow{\text{nitrogenase}} 2\,NH_3 + H_2 + 16\,ADP + 16\,P_i$$

Nitrogenase is the central enzyme; it is irreversibly destroyed by O_2, which is why nitrogen fixation is anaerobic. Inside legume nodules the protein **leghaemoglobin** (pink, NEET extra) sequesters O_2 and protects nitrogenase.



Symbiotic and free-living nitrogen fixation. Rhizobium *colonises legume root nodules;* Azotobacter *and* Azospirillum *live freely in soil.*

7.2 Fungi as Biofertilisers — Mycorrhiza

A **mycorrhiza** is a symbiotic association between a fungus and the roots of a higher plant. Members of the fungal genus *Glomus* form mycorrhizae with most crop plants. The fungal symbiont absorbs **phosphorus** from soil and passes it to the plant; the plant supplies the fungus with sugars.

Benefits of mycorrhiza to the host plant

- Extended phosphorus uptake (P is poorly mobile in soil).
- Resistance to root-borne pathogens.

- Increased tolerance to salinity and drought.
- Overall improvement in plant growth and seedling vigour.

The fungus, in return, gets a steady supply of fixed carbon (sugars) — a textbook mutualism.

7.3 Cyanobacteria as Biofertilisers — Blue-Green Algae

Cyanobacteria are autotrophic prokaryotes widely distributed in aquatic and terrestrial environments. Many of them fix atmospheric nitrogen. Important examples:

- *Anabaena* — common in paddy fields.
- *Nostoc* — aquatic, free-living.
- *Oscillatoria* — thermal-spring and pond mats.
- *Anabaena azollae* — lives symbiotically inside the water-fern *Azolla*; a major rice-paddy biofertiliser.

In paddy fields cyanobacteria serve as both nitrogen fixer and organic-matter contributor — they add **both N and C** to the soil. "Blue-green algae" (BGA) is the traditional name; it is a misnomer because they are prokaryotic and not true algae.

Biofertiliser type	Example	Mode	Crop benefit
Bacterium — symbiotic	*Rhizobium*	In root nodules	Legume N nutrition
Bacterium — free-living	*Azotobacter*, *Azospirillum*	Soil free-living	Adds soil N
Fungus — mycorrhiza	*Glomus*	Root symbiosis	P uptake, drought tolerance
Cyanobacterium	*Anabaena*, *Nostoc*, *Oscillatoria*	Free / symbiotic	N & organic matter
Cyanobacterium (symbiotic)	*Anabaena azollae* inside *Azolla*	Paddy field symbiosis	Massive N input to rice

Why Indian paddy farmers love *Azolla*

A single hectare of paddy soil with healthy *Azolla–Anabaena* cover can fix **40–60 kg of nitrogen per crop cycle** — roughly equivalent to one bag of urea per acre. The cover also smothers weeds and supplies organic matter when it decays. It is one of India's oldest documented biofertiliser practices.

Free-living N_2 fixers — the "A team"

Azotobacter, **Azosp**irillum, **Anab**aena, **Nost**oc, **Oscill**atoria. The first three letters of each are enough — "Azo, Azo, Ana, Nos, Osc". A frequent NEET MCQ asks to identify the non-fixer in such a list.

Common Mistake

"Rhizobium is the only nitrogen fixer." **Wrong.** *Rhizobium* is the *symbiotic* fixer of legumes. Free-living N-fixers (*Azotobacter*, *Azospirillum*, *Nostoc*, *Anabaena*) work outside roots. Both groups matter for soil fertility.

8 NEET / JEE Extensions Beyond NCERT

This section consolidates the high-yield "extra" facts NCERT does not derive explicitly but that competitive exams test every year.

8.1 Single Cell Protein (SCP)

Single Cell Protein = protein extracted from microbial biomass (algae, yeast, bacteria) for use as a human or animal food supplement. Reasons it matters:

- Microbes have a very high protein content by dry weight ($\sim$60%).
- Production is independent of agricultural land or climate.
- Common sources — *Spirulina* (cyanobacterium), *Methylophilus methylotrophus* (bacterium on methanol substrate), *Saccharomyces cerevisiae* (yeast), *Chlorella* (alga).
- NCERT exercise Q. 13(a) asks about SCP explicitly — a direct question.

The number worth memorising

A 250 kg cow produces $\sim$200 g of protein per day. In the same 24 hours, 250 g of microbes can produce $\sim$**25 tonnes** of protein. The yield ratio is staggering — one reason SCP is a serious strategy against world hunger.

8.2 Organic Acids & Industrial Chemicals — Quick Recap

- **Citric acid** — *Aspergillus niger*; food preservative, cosmetics.
- **Itaconic acid** — *Aspergillus terreus*; plastics industry.
- **Gluconic acid** — *Aspergillus niger*; pharmaceuticals.
- **Vinegar** (acetic acid) — *Acetobacter aceti*.
- **Lactic acid** — *Lactobacillus* (used to make poly-lactic acid bio-plastics).

8.3 Vitamins & Pigments from Microbes

- Vitamin B_{12} — *Pseudomonas denitrificans*.
- Riboflavin (B_2) — *Eremothecium ashbyii*.
- β-carotene (pro-vitamin A pigment) — *Blakeslea trispora*.

8.4 Microbes that Produce Enzymes

- **Lipase** — removes oil stains in detergent formulations.
- **Protease** — used in detergents and leather tanning.
- **Pectinase & Protease** — clarify bottled fruit juice (NCERT text).
- **Streptokinase** (clot-buster, genetically modified *Streptococcus*).
- **Cellulase** — *Trichoderma reesei*; biofuels.

8.5 Sewage Treatment — The Numbers

- Aeration tank retention time — typically **6–8 hours**.
- Anaerobic digester retention — **20–40 days**.
- Activated sludge $\rightarrow$ recycled inoculum fraction $\approx$ 25%.
- Tertiary treatment (chlorination, UV, filtration) is NOT in NCERT but is in modern STPs; do not confuse with the NCERT "secondary" step.

8.6 NEET-favourite Misconceptions to Avoid

Common Mistake

- **Methanogens are bacteria, not fungi.** They belong to the domain Archaea (NCERT-style: "a type of bacterium"). They are anaerobes.
- **Biogas is not pure methane.** It is CH_4 (predominant) + CO_2 + H_2S + traces.
- **LAB are not viruses.** They are bacteria (*Lactobacillus*). Easy MCQ trick option.
- **Bt vs Bt cotton.** Bt = the bacterium sprayed externally. Bt cotton = transgenic plant carrying the *cry* gene.
- **Rhizobium fixes N_2 *inside* nodules, not in free soil.** The free-living N-fixers are *Azotobacter* & *Azospirillum*.

9 Quick Reference Summary

9.1 Master Species–Product–Application Table

Microbe	Group	Product / Role
Lactobacillus	Bacterium	Curd (lactic acid, B_{12})
Saccharomyces cerevisiae	Yeast (fungus)	Bread, beverages, ethanol
Propionibacterium shermanii	Bacterium	Swiss cheese (CO_2 holes)
Penicillium roqueforti	Fungus	Roquefort cheese
Penicillium notatum	Fungus	Penicillin antibiotic
Streptococcus	Bacterium	Streptokinase (clot-buster)
Trichoderma polysporum	Fungus	Cyclosporin A (immunosuppressant)
Monascus purpureus	Yeast	Statins (cholesterol lowering)
Aspergillus niger	Fungus	Citric acid
Acetobacter aceti	Bacterium	Acetic acid
Clostridium butylicum	Bacterium	Butyric acid
Methanobacterium	Bacterium (archaea-like)	Biogas / methane
Bacillus thuringiensis	Bacterium	Cry toxin — caterpillar biocontrol
Trichoderma spp.	Fungus	Plant fungal-pathogen biocontrol
Nucleopolyhedrovirus	Baculovirus	Insect biocontrol
Rhizobium	Bacterium	Symbiotic N_2 fixation, legume nodules
Azotobacter, *Azospirillum*	Bacteria	Free-living N_2 fixation in soil
Glomus	Fungus	Mycorrhiza — P uptake
Anabaena, *Nostoc*, *Oscillatoria*	Cyanobacteria	N_2 fixation, paddy biofertiliser
Anabaena azollae in *Azolla*	Cyanobacteria (symbiotic)	Massive paddy-field N input

9.2 Key Definitions to Memorise

- **LAB** — Lactic Acid Bacteria; ferment lactose to lactic acid, curdle milk.
- **Antibiotic** — chemical produced by a microbe that kills/inhibits another microbe.
- **Fermentor** — large stainless-steel vessel for industrial microbial culture.
- **BOD** — Biochemical Oxygen Demand; oxygen needed (mg) to oxidise organic matter in 1 L water.
- **Flocs** — mesh-like aggregates of bacteria + fungal filaments in secondary treat-

ment.

- **Activated sludge** — settled flocs at the end of secondary treatment.
- **Biogas** — microbial CH_4 + CO_2 + H_2S mixture; inflammable.
- **Methanogens** — anaerobic bacteria producing methane (*Methanobacterium*).
- **Biocontrol** — using biology, not chemistry, to manage pests and pathogens.
- **Biofertiliser** — organism that enriches soil nutrient content (N, P, organic matter).
- **Mycorrhiza** — fungus–root symbiosis; fungus absorbs P, plant gives sugars.
- **SCP** — Single Cell Protein from microbial biomass.
- **IPM** — Integrated Pest Management; combines biological, cultural and (minimal) chemical control.

9.3 Two-Minute Chapter-in-Numbers

Memorise the numbers

- Drinking water BOD — < 1 mg/L.
- Treated sewage effluent BOD — 5–20 mg/L.
- Raw municipal sewage BOD — 200–600 mg/L.
- Biogas composition — CH_4 55–70%, CO_2 30–45%, traces H_2S, H_2.
- Biogas plant depth — 10–15 feet.
- *Azolla* N fixation — 40–60 kg/ha per crop cycle.
- Penicillin Nobel — **1945** (Fleming, Chain, Florey).

9.4 Final Exam Strategy

Quick Tip

Three-step revision plan for chapter 8:

1. Memorise the species–product table (table above) — this alone answers 60–70% of NEET MCQs from this chapter.
2. Understand the *flow* of sewage treatment (primary $\rightarrow$ aeration $\rightarrow$ settling $\rightarrow$ anaerobic digester $\rightarrow$ biogas + effluent). NCERT loves the sequence question.
3. Distinguish symbiotic vs free-living N_2 fixers; bacterial vs fungal vs cyanobacterial biofertilisers; insect vs microbial biocontrol agents.

The big picture

Every product or process in this chapter — curd, antibiotic, biogas, biocontrol, biofertiliser — shows the same idea: **microbes do for us, at scale, what**

chemistry can only imitate at higher cost and with worse side effects. The future of food, medicine and sustainable agriculture rides on understanding these tiny partners.