

Collegedunia NCERT Formula Sheet

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

Chapter 8: Microbes in Human Welfare

Quantitative microbiology — fermentation, sewage, biogas, antibiotics, biocontrol, biofertilisers

Chapter-Wide Key Quantitative Reference

Parameter	Typical Value / Range	Significance
BOD of clean river water	< 5 mg O ₂ /L	Healthy aquatic ecosystem
BOD of treated effluent (safe)	≤ 20 mg O ₂ /L	Discharge limit; above = hazardous
BOD of raw sewage	200–600 mg O ₂ /L	High organic load
COD : BOD ratio (sewage)	1.5–2.5	Higher ⇒ less biodegradable
Biogas CH ₄ / CO ₂ / H ₂	50–70 / 25–30 / 5–10%	CH ₄ is the combustible fraction
Curd pH (final) / temp	4.0–4.6 / 37–45 °C	Lactic acid coagulates casein
Ethanol fermentation yield	0.51 g/g glucose (theoretical)	Gay-Lussac stoichiometry
Citric acid yield	~ 0.9 g/g sucrose	<i>A. niger</i> , fed-batch
Penicillin G potency	~ 1500–1670 IU/mg	1 IU = 0.6 μg pure Na salt
PHA bioplastic yield	up to ~ 80 % dry cell weight	<i>Cupriavidus</i> / <i>Alcaligenes</i>
<i>Rhizobium</i> N-fixation rate	50–200 kg N/ha/yr	Legume–rhizobium symbiosis
Free-living N fixers	20–30 kg N/ha/yr	<i>Azospirillum</i> , <i>Azotobacter</i>

1 8.1 Microbes in Household Products

Covers LAB used in curd, budding yeast in bread & beverages, the pH / temperature regimes, and traditional ferments — toddy, idli, dosa, cheese.

Curd setting by *Lactobacillus*

Lactobacillus (LAB) converts milk lactose to lactic acid:



Optimum: pH start ≈ 6.5 , end 4.0–4.6; temperature 37–45 °C; time 6–8 h.

Lactic acid **denatures and coagulates casein**, setting the curd. A small inoculum of starter is enough — bacteria multiply exponentially. LAB also raise **vitamin B₁₂** content in the stomach.

Dough leavening by yeast

Saccharomyces cerevisiae (baker's yeast) — anaerobic respiration of dough sugars:



Optimum: 25–30 °C; proofing time 1–2 h.

CO₂ bubbles trapped in the gluten network make the dough **puffy and porous**. Ethanol evaporates on baking. The same reaction underlies all alcoholic fermentation.

Traditional Indian fermented foods

Idli / dosa batter — leavened by LAB + wild yeast; rice + black-gram dal fermented overnight at $\sim 30^\circ\text{C}$. **Toddy** — sap of palm fermented by natural yeast. **Cheese** — milk curdled by LAB; ripened by specific microbes: *Propionibacterium shermanii* (Swiss cheese, makes the large holes via CO₂); *Penicillium roqueforti* (Roquefort blue cheese, gives flavour).

Curd vs cheese mix-up

Curd setting requires **only LAB** — no fungus, no ripening. Cheese ripening uses **additional** bacteria/fungi (*P. shermanii*, *P. roqueforti*). Holes in Swiss cheese come from **CO₂ from propionic acid bacteria**, not from yeast.

2 8.2 Microbes in Industrial Products

Industrial fermentation products — alcohols, organic acids, antibiotics, bioactives — each pinned to its microbe and fermenter regime (100–1000 L batch / fed-batch).

Ethanol fermentation — alcoholic beverages

Gay-Lussac stoichiometry (yeast *S. cerevisiae*):



Theoretical yield: 0.51 g ethanol per g glucose ($\approx 92 \text{ g/mol}$ ethanol out of 180 g/mol glucose, $\times 2$).

Practical yield: $\sim 90\text{--}95\%$ of theoretical $\Rightarrow \approx 0.46\text{--}0.48 \text{ g/g}$.

Without distillation: wine, beer, cider, toddy. **With distillation:** whisky, brandy, rum. *Brewer's yeast* = same species as baker's yeast.

Citric acid from *Aspergillus niger*

Net stoichiometry:



Yield: up to $\sim 0.9 \text{ g}$ citric acid / g sucrose; pH dropped to ~ 2.0 to suppress oxalic acid by-product.

Industrial fed-batch fermenter, 5–15 days. World demand > 2 million tonnes/yr. Used in soft drinks, food, pharmaceuticals.

Other organic acids and their microbes

Product	Microbe	Notes
Citric acid	<i>Aspergillus niger</i>	up to 0.9 g/g sucrose
Acetic acid	<i>Acetobacter aceti</i>	ethanol → acetic acid
Butyric acid	<i>Clostridium butylicum</i>	anaerobic
Lactic acid	<i>Lactobacillus</i>	dairy / industrial

All four are produced via aerobic or anaerobic fermentation in stirred-tank bioreactors of 100–1000 L.

Antibiotics — *Penicillium* & others

Penicillin (Fleming, 1928 → Chain & Florey, 1945) by *Penicillium chrysogenum* (formerly *P. notatum*).

Potency (Penicillin G, Na salt): ≈ 1500–1670 IU/mg; 1 IU ≡ 0.6 μg pure crystalline.

Mechanism: inhibits bacterial cell-wall **peptidoglycan** biosynthesis (transpeptidase block); *ineffective on viruses*.

Nobel Prize 1945 to Fleming, Chain, Florey. Widely used against WW-II wound infections. Today > 7000 antibiotics known; only ~ 100 in clinical use.

Bioactive molecules — table

Molecule	Source microbe	Use
Cyclosporin A	<i>Trichoderma polysporum</i>	Immunosuppressant — organ transplant
Statins	<i>Monascus purpureus</i>	Blood-cholesterol-lowering (HMG-CoA reductase inhibitor)
Streptokinase	<i>Streptococcus</i> sp.	Clot buster (cardiac thrombolysis)
Lipases	various bacteria	Detergent additive (oil stains)
Pectinases / proteases	various microbes	Bottled-juice clarification

Statins inhibit cholesterol synthesis by competing with HMG-CoA reductase. Streptokinase is modified by genetic engineering for safer thrombolysis.

Antibiotic discovery timeline

1928: Fleming observes *Penicillium* kills *Staphylococcus* on a plate. **1939-41:** Chain & Florey purify penicillin. **1944:** mass production for WW-II. **1945:** Nobel Prize. **1944:** Streptomycin (Waksman, from *Streptomyces griseus*) — first effective TB drug.

Antibiotics do NOT kill viruses

Antibiotics target **peptidoglycan, 70S ribosomes, or bacterial enzymes**. Viruses have none of these — they use the host cell's machinery. Hence antibiotics are useless against the common cold or COVID-19. Antivirals (interferons, acyclovir) are a different class.

3 8.3 Microbes in Sewage Treatment

Covers conversion of municipal sewage to safe effluent in a Sewage Treatment Plant (STP) — primary (physical) + secondary (biological); key metric is BOD.

Biochemical Oxygen Demand (BOD)

Definition: O_2 (mg/L) consumed by aerobic microbes oxidising all organic matter in 1 L of water over 5 days at 20 °C.

Standard test: $BOD = (D_1 - D_2)/f$, where D_1, D_2 = initial / final dissolved O_2 (mg/L); f = sample dilution fraction.

Higher BOD \Rightarrow more organic pollution. Clean river < 5 ; safe effluent ≤ 20 ; raw sewage 200–600 mg O_2 /L.

COD and the COD/BOD ratio

COD = mg O_2 /L needed to chemically oxidise all organics (acid dichromate, 2 h).

Ratio: $\frac{COD}{BOD} \approx 1.5-2.5$ for biodegradable domestic sewage.

Ratio ≈ 1 means everything is biodegradable; ratio $\gg 3$ means a large **non-biodegradable / toxic** fraction (industrial effluent). COD always \geq BOD.

STP — operating parameters

Stage	Mechanism	Output / parameter
Primary (physical)	sedimentation of grit + suspended solids	primary effluent + primary sludge
Secondary (biological)	aerobic flocs (<i>Zoogloea</i>) in aeration tank	BOD drops by $\sim 80-90\%$
Sludge digestion	anaerobic methanogens	biogas (CH_4, CO_2, H_2S)

Significant drop in BOD in aeration tank \Rightarrow effluent passed to settling tank. Activated sludge recycled; excess pumped to anaerobic sludge digester.

Flocs and activated sludge

Flocs = masses of aerobic bacteria (mainly *Zoogloea ramigera*) associated with fungal filaments, forming mesh-like structures. They consume the major part of organic matter while the sewage is aerated and agitated. Their gravity-settled biomass is the **activated sludge**, a small fraction of which is recycled as inoculum.

Ganga Action Plan & Yamuna Action Plan

Launched by Government of India to save river waters from huge sewage loads which lower DO (dissolved O₂) and damage aquatic biodiversity. Solution: more sewage treatment plants. Discharge standard: **BOD ≤ 20 mg O₂/L**; above this is hazardous to aquatic life.

BOD vs DO

BOD is the demand for oxygen (consumption), measured in mg O₂/L. **DO** is the dissolved O₂ present (concentration), also mg/L. Polluted water has **high BOD and low DO** — they vary in opposite directions.

4 8.4 Microbes in Production of Biogas

Covers anaerobic digestion of cattle dung (gobar) by methanogens into a combustible gas, the biogas-plant design, and the IARI / KVIC popularisation drive in India.

Anaerobic methanogenesis

Overall (cellulose → biogas):



Carried out by **methanogens** — strictly anaerobic archaea such as *Methanobacterium*. Same organisms live in the rumen of cattle, which is why cattle dung is the prime feed-stock.

Biogas composition & calorific value

Component	% (vol)	Role
Methane CH ₄	50–70 %	Combustible — lights the flame
Carbon dioxide CO ₂	25–30 %	Inert — dilutes
Hydrogen H ₂	5–10 %	Combustible (minor)
Hydrogen sulphide H ₂ S	traces	Odour, corrosive
Nitrogen N ₂	traces	Inert

Calorific value ≈ **20–26 MJ/m³** (about **60 %** of natural gas). Used for cooking, lighting, and small-scale electricity.

Biogas plant — design

Inputs: cattle dung slurry (gobar). **Tank:** 10–15 feet deep concrete tank with a floating cover that rises as gas accumulates. **Outputs:** biogas through pipes; spent slurry through outlet → used as fertiliser. In India, biogas plants are popularised by **IARI** (Indian Agricultural Research Institute) and **KVIC** (Khadi and Village Industries Commission).

Why cattle dung?

Cattle are ruminants — their rumen already harbours large numbers of **methanogenic archaea**. Their excreta (called **gobar**) is therefore a ready inoculum + substrate, which is why "gobar gas" became the colloquial name.

5 8.5 Microbes as Biocontrol Agents

Beneficial microbes (and select insects) replacing chemical pesticides / herbicides — backbone of **organic farming**.

Bacillus thuringiensis (Bt) biopesticide

Bacillus thuringiensis → spores containing **Cry protein crystals**.

Spray dosage: ~ 0.5–2.0 kg/ha; gut pH of larva (≥ 9.5) solubilises Cry → perforates midgut → larva dies in ~ 48 h.

Highly **insect-specific** (lepidopteran larvae, e.g. cotton bollworm); harmless to mammals, birds, fish. Genes (*cryIAC*, *cryIIAb*) cloned into cotton (Bt cotton) and maize.

Other biocontrol agents

Agent	Type	Targets
<i>Trichoderma</i> sp.	free-living fungus	root-disease fungi in many crops
<i>Baculovirus</i> (genus <i>Nucleopolyhedrovirus</i>)	DNA virus	arthropod insect pests; very narrow host range
Ladybird beetle	insect	aphids
Dragonflies	insect	mosquitoes

Baculoviruses are excellent candidates for **species-specific, narrow-spectrum** insecticide that doesn't harm plants, mammals, birds, fish, or non-target insects ⇒ ideal for IPM and organic farming.

Organic farming — definition

Holistic farming that **eliminates synthetic pesticides, herbicides, and fertilisers**. Relies on biocontrol agents, biofertilisers, crop rotation, and natural predators. Healthier produce; protects pollinators and soil microbiota.

6 8.6 Microbes as Biofertilisers

Symbiotic and free-living microbes that enrich soil with N, P, and organic matter — foundation of sustainable agriculture.

Biological nitrogen fixation by *Rhizobium*

Symbiotic reaction in root nodules of legumes (catalyst: nitrogenase):



Rate: ~ 50–200 kg N / ha / yr (legume–*Rhizobium*); free-living systems are slower. Nitrogenase is **O₂-sensitive**; protected inside nodules by **leghaemoglobin** (pink colour). Replaces nitrogenous chemical fertiliser; eliminated need for top-dressing in legume crops.

Biofertilisers — agents and roles

Agent	Type	Role / fixation rate
<i>Rhizobium</i>	symbiotic bacterium	legume root nodules; 50–200 kg N/ha/yr
<i>Azospirillum, Azotobacter</i>	free-living bacteria	fix atmospheric N in soil; 20–30 kg N/ha/yr
<i>Anabaena, Nostoc, Oscillatoria</i>	cyanobacteria (free-living)	N + organic matter; important in paddy
<i>Anabaena</i> in <i>Azolla</i>	symbiotic cyanobacterium	N in paddy fields
<i>Glomus</i> (mycorrhizae)	symbiotic fungus	absorbs phosphorus from soil; gives to root

Mycorrhizae also confer **drought tolerance, disease resistance, and overall plant vigour**. Cyanobacteria add organic matter to soil and raise fertility.

Why biofertilisers?

Chemical fertilisers contribute to **eutrophication, soil acidification, and groundwater pollution**. Biofertilisers (living organisms that enrich soil with N or P) are renewable, eco-friendly, and central to organic farming.

JEE/NEET extension — leghaemoglobin chemistry

Leghaemoglobin in root nodules has **very high O₂ affinity** ($K_d \approx 10$ nM vs ~ 1 μ M for human haemoglobin). It keeps free O₂ near zero around nitrogenase while still ferrying O₂ to bacteroid mitochondria for ATP production. Pink colour is a quick visual cue that the nodule is active.

JEE/NEET extension — bioplastics (PHA)

Polyhydroxyalkanoates (PHA) are biodegradable polyesters synthesised by bacteria (*Cupriavidus necator*, formerly *Ralstonia eutropha*; *Alcaligenes*). Stored as intracellular granules. Yield can reach **up to** $\sim 80\%$ **of dry cell weight** under N-limited, C-excess conditions. Commercial brand: Biopol (PHB/PHV copolymer). Substitute for petroleum plastics.

Microbes by product — quick recall

“CALM-PAL” (Curd, Alcohol, Lactic acid, Methane — Penicillin, Acetic acid, Lactose breakdown):

Curd → *Lactobacillus* | **A**lcohol → *Saccharomyces* | **L**actic acid → *Lactobacillus* | **M**ethane → *Methanobacterium* | **P**enicillin → *Penicillium* | **A**cetic acid → *Acetobacter*.

Quick Reference — Microbe → Product Index

Microbe (Genus / Species)	Product / Function	Key Numerical Datum
<i>Lactobacillus</i> (LAB)	Curd, yoghurt, lactic acid	pH ↓ 6.5 → 4.0–4.6; 37–45 °C
<i>Saccharomyces cerevisiae</i>	Bread, beer, wine (ethanol)	0.51 g EtOH / g glucose theoretical
<i>Propionibacterium shermanii</i>	Swiss-cheese holes	CO ₂ bubbles in matrix
<i>Penicillium roqueforti</i>	Roquefort blue cheese	ripening fungus
<i>Aspergillus niger</i>	Citric acid	~ 0.9 g / g sucrose; pH ≈ 2
<i>Acetobacter aceti</i>	Acetic acid (vinegar)	ethanol → CH ₃ COOH
<i>Clostridium butylicum</i>	Butyric acid	anaerobic
<i>Penicillium chrysogenum</i>	Penicillin antibiotic	~ 1500–1670 IU/mg
<i>Streptomyces griseus</i>	Streptomycin (anti-TB)	Waksman, 1944
<i>Trichoderma polysporum</i>	Cyclosporin A	immunosuppressant
<i>Monascus purpureus</i>	Statins	cholesterol-lowering
<i>Streptococcus</i> sp.	Streptokinase	clot buster (cardiac)
<i>Zoogloea ramigera</i>	STP aerobic flocs	BOD ↓ 80–90%
<i>Methanobacterium</i>	Biogas (methane)	CH ₄ 50–70 %, CO ₂ 25–30 %
<i>Bacillus thuringiensis</i>	Bt biopesticide (Cry)	lepidopteran larvae killed
<i>Trichoderma</i> sp.	Biocontrol fungus	root pathogens
<i>Baculovirus</i> (NPV)	Insect biocontrol virus	narrow host range
<i>Rhizobium</i>	N-fixation in legumes	50–200 kg N/ha/yr
<i>Azospirillum, Azotobacter</i>	Free-living N fixers	20–30 kg N/ha/yr
<i>Anabaena, Nostoc, Oscillatoria</i>	Free-living cyanobacteria	N + organic matter in paddy
<i>Anabaena</i> in <i>Azolla</i>	Symbiotic cyanobacterium	paddy biofertiliser
<i>Glomus</i> (mycorrhiza)	P uptake; drought tolerance	symbiotic fungus
<i>Cupriavidus / Alcaligenes</i>	PHA bioplastic	up to ~ 80 % dry-cell weight