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HIGHLIGHTED HANDOUT

BT512T

Microbial Biotechnology (Theory)

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BT512T

Microbial Biotechnology (Theory)

This handout covers the complete course topic by topic in simple, exam-focused language. Each chapter begins with learning objectives and ends with key points and exam pointers. Definitions are boxed in green-friendly format, examples are worked out step by step, and very important exam points are flagged separately. Study the highlighted points carefully before your papers. 

Course Information	
Course Code	BT512T
Course Title	Microbial Biotechnology (Theory)
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1. Introduction to Microbial Biotechnology

Learning Objectives

- Define microbial biotechnology and its scope
- Describe historical milestones of industrial microbiology

Microbial biotechnology is defined as the use of microorganisms (bacteria, fungi, algae, viruses) and their cellular machinery to develop products and processes useful to humans, including food, medicine, fuel and environmental services.

- Traditional applications: bread, cheese, yogurt, beer, wine — fermentation is thousands of years old.
- Modern applications: antibiotics, enzymes, biofuels, probiotics, bioremediation, recombinant proteins.
- Why microbes: fast growth, easy genetic manipulation, diverse metabolism, cheap substrates.

Historical milestones

- Louis Pasteur: proved fermentation is caused by microbes; developed pasteurization and vaccines.
- Alexander Fleming (1928): discovered penicillin from *Penicillium notatum*.
- 1940s: deep-tank fermentation made penicillin mass production possible in WWII.
- 1970s: recombinant DNA technology — insulin produced in *E. coli* (1978).
- Today: synthetic biology, CRISPR-engineered strains, and microbial cell factories.

Key Points to Remember

- Microbial biotechnology = microbes as factories for useful products.
- Pasteur, Fleming and recombinant DNA are the three landmark eras.

Exam Pointer

Very important for exams: The "why microbes" advantages list is a standard 5-mark question.

Biotechnology vs traditional technology

- Traditional: selective breeding, fermentation by trial and error.
- Modern: recombinant DNA, genomics, synthetic biology — precise and predictable.
- Both serve human needs; modern tools accelerate ancient practices.

Careers in microbial biotechnology

- Fermentation scientist, QC microbiologist, bioprocess engineer.
- Employers: pharma, food, breweries, environmental firms.
- Practical aseptic skills matter more than theory alone.

Women in biotechnology

- Growing female enrolment in Pakistani bioscience programs.
- Role models in research leadership inspire retention.
- Flexible lab policies support career continuity.

Lab safety essentials

- Autoclave waste before disposal; never mouth-pipette.
- Know MSDS for every chemical used.
- Report spills and exposures immediately.

Biotech industry in Pakistan

- Faisalabad and Karachi host the main fermentation plants.
- Local citric acid and ethanol production uses molasses feedstock.
- Import substitution drives government interest.
- Skilled fermentation technologists are in short supply.
- University-industry links remain the weak link.

Pasteur and fermentation science

- Pasteur proved fermentation is microbial, not spontaneous.
- His swan-neck flask experiments ended spontaneous generation.
- Pasteurization still protects milk worldwide.
- He founded industrial microbiology.
- Know his contributions for history questions.

2. Microbial Diversity and Industrial Microorganisms

Learning Objectives

- Classify industrially important microorganisms
- State criteria for selecting industrial strains

Key industrial microbes

Microorganism	Type	Industrial products
<i>Saccharomyces cerevisiae</i>	Yeast	Bread, beer, wine, bioethanol
<i>Aspergillus niger</i>	Mould	Citric acid, enzymes (amylase, pectinase)
<i>Penicillium chrysogenum</i>	Mould	Penicillin
<i>Escherichia coli</i>	Bacterium	Recombinant insulin, enzymes
<i>Bacillus thuringiensis</i>	Bacterium	Biopesticide (Bt toxin)
<i>Lactobacillus</i> spp.	Bacteria	Yogurt, cheese, probiotics
<i>Spirulina</i> / <i>Chlorella</i>	Algae	Single-cell protein, pigments
<i>Streptomyces</i> spp.	Actinomycetes	Antibiotics (streptomycin)

Criteria for an ideal industrial strain

- Genetically stable and non-pathogenic (GRAS — generally regarded as safe).
- High product yield and fast growth on cheap substrates.
- Easy downstream recovery of the product.
- Amenable to genetic improvement and scale-up.

Key Points to Remember

- Match each microbe to its product — examiners love this table.
- GRAS status is essential for food and pharma microbes.

Exam Pointer

Very important for exams: Short notes on any two industrial microorganisms appear in almost every paper.

Microbial nutrition and growth

- Needs: carbon, nitrogen, minerals, water, energy source.
- Growth phases: lag, log (exponential), stationary, death.
- Industrial strains are harvested in log or early stationary phase.

Culture collections

- ATCC, DSMZ supply authenticated strains worldwide.
- Deposit novel strains when publishing — a scientific norm.

- Pakistan needs a national culture collection.

Microscopy for industry

- Monitor contamination and cell morphology routinely.
- Gram staining is the fastest contamination check.
- Train every operator — eyes beat instruments for oddities.

Data recording (GMP)

- Record contemporaneously — "if it isn't written, it didn't happen".
- No overwriting; single-line corrections with initials.
- Batch records trace every production step.

Extremophiles

- Thermophiles yield heat-stable enzymes like Taq polymerase.
- Halophiles thrive in salt; acidophiles in low pH.
- Their enzymes survive industrial harshness.
- Pakistan's hot springs are unexplored sources.
- Bioprospecting them is a research frontier.

Culture preservation

- Lyophilization keeps strains viable for decades.
- Glycerol stocks at -80°C suit working banks.
- Periodic revival checks viability.
- Documented strain lineage is a regulatory requirement.
- Contamination during storage ruins collections.

3. Fermentation Technology

Learning Objectives

- Define fermentation and its types
- Describe the stages of a fermentation process

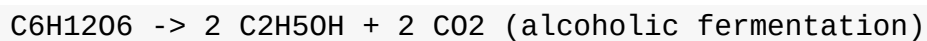
Fermentation is defined as a metabolic process in which microorganisms convert organic substrates (usually sugars) into products such as acids, alcohols, gases or biomass, with or without oxygen.

- Alcoholic fermentation: yeast converts glucose to ethanol + CO₂ (beer, wine, bioethanol).

- Lactic acid fermentation: Lactobacillus converts milk sugar to lactic acid (yogurt, cheese).
- Aerobic processes: citric acid, vinegar, antibiotics need oxygen.
- Solid-state fermentation: growth on moist solids (tempeh, koji); submerged fermentation: growth in liquid medium (most industry).

Stages of an industrial fermentation

- 1. Strain selection and inoculum preparation (seed culture).
- 2. Medium formulation and sterilization.
- 3. Fermentation in the bioreactor under controlled pH, temperature, aeration.
- 4. Monitoring growth and product formation.
- 5. Downstream processing: recovery and purification.



Key Points to Remember

- Aerobic vs anaerobic decides reactor design and products.
- Sterility and inoculum quality decide success or contamination.

Exam Pointer

Very important for exams: The fermentation equation and the five stages are core short questions.

Media for fermentation

- Cheap substrates: molasses, corn steep liquor, whey.
- Defined vs complex media — defined gives control, complex gives yield.
- Pakistan: sugarcane molasses is an abundant cheap feedstock.

Kinetics: Monod equation

- Growth rate depends on limiting substrate: $\mu = \mu_{\text{max}} S / (K_s + S)$.
- Guides fed-batch feeding strategies.
- Very important for exams: know the Monod terms.

pH and temperature control

- Most processes run pH 6.5-7.5, 28-37°C.
- Deviations signal contamination or metabolic shifts.
- Automated control beats manual adjustment.

Inoculum development

- Scale stepwise: slant -> shake flask -> seed fermenter -> production.
- Use log-phase, contamination-free inoculum.
- Inoculum size (5-10%) balances lag time and cost.

Inoculum development

- Seed trains scale cultures stepwise to production volume.
- Healthy inoculum shortens lag phase.
- Contamination at seed stage ruins whole batches.
- Cryopreserved master cell banks ensure consistency.
- Document every passage for GMP compliance.

Fed-batch strategy

- Feed substrate to avoid inhibition.
- Exponential feeding maintains constant growth rate.
- Common in antibiotic and yeast production.
- Requires good process models.
- Beats simple batch for high cell densities.

4. Bioreactors and Fermentation Systems

Learning Objectives

- Describe bioreactor types and their parts
- Compare batch, fed-batch and continuous modes

Bioreactor (fermenter) is defined as a vessel that provides a controlled environment (temperature, pH, aeration, agitation, sterility) for the growth of microorganisms and formation of products.

Main parts of a stirred-tank bioreactor

- Vessel with jacket for heating/cooling; impeller/agitator for mixing.
- Sparger for air supply; baffles to improve mixing; foam breaker.
- Sensors: pH, dissolved oxygen, temperature probes; sampling and inoculation ports.
- Sterilization in place (SIP) systems.

Mode	Operation	Advantage	Example
Batch	All nutrients added at start; harvest at end	Simple, low contamination risk	Penicillin (classic)
Fed-batch	Substrate fed during run	Avoids substrate inhibition, high yield	Baker's yeast
Continuous (chemostat)	Fresh medium in, culture out at same rate	Steady state, high productivity	Single-cell protein

Key Points to Remember

- Fed-batch avoids catabolite repression; continuous gives steady-state production.
- Scale-up keeps oxygen transfer and mixing constant, not just volume.

Exam Pointer

Very important for exams: Batch vs fed-batch vs continuous comparison table is a classic 5-mark question.

Sterilization methods

- Moist heat (autoclave 121C), dry heat, filtration for heat-labile fluids.
- Aseptic technique prevents contamination — the costliest fermentation failure.
- Monitor sterility with biological indicators.

Oxygen transfer

- $k_L a$ measures aeration efficiency — the key scale-up parameter.
- Viscous broths and pellets reduce oxygen transfer.
- Pure oxygen enrichment helps high-demand processes.

Foam control

- Antifoams (silicone, oils) prevent vessel overflow.
- Mechanical foam breakers avoid chemical contamination.
- Excessive antifoam can reduce oxygen transfer.

Contamination case study

- One phage infection can wipe out a dairy plant's cultures.
- Rotate starter strains to outrun phages.
- Air handling and personnel flow prevent recurrence.

Oxygen transfer

- k_La measures oxygen transfer efficiency.
- High-density cultures demand aggressive aeration.
- Impeller design balances mixing against shear.
- Oxygen limitation shifts metabolism to byproducts.
- Monitor dissolved oxygen continuously.

Foam control

- Foam carries cells out and invites contamination.
- Mechanical breakers avoid chemical additives.
- Antifoams can hinder oxygen transfer.
- Headspace design reduces foaming.
- Monitor and dose automatically.

5. Strain Improvement

Learning Objectives

- Describe mutation, selection and recombinant methods
- Explain the role of rDNA in strain development

- Random mutagenesis: UV or chemical mutagens create mutants; best producers selected (classical, e.g. penicillin yield raised 1000-fold).
- Selection and screening: rational screens for desired traits (antibiotic resistance, product tolerance).
- Protoplast fusion: combines genomes of two strains without full sexual cycle.
- Recombinant DNA: precise — insert genes for heterologous proteins (insulin, growth hormone, vaccines) into *E. coli*, yeast or CHO cells.
- CRISPR-Cas9: targeted genome editing for pathway engineering and removing competing pathways.

Metabolic engineering concept

Instead of random changes, metabolic engineering redesigns the cell's metabolic network: overexpress rate-limiting enzymes, delete competing branches, and balance cofactors — turning the microbe into an optimized cell factory for the target product.

Example

Artemisinin (antimalarial drug) precursor is produced by engineered yeast carrying plant genes — a landmark of synthetic biology replacing agricultural extraction.

Key Points to Remember

- Classical mutagenesis = random; rDNA/CRISPR = precise.
- Metabolic engineering optimizes whole pathways, not single genes.

Exam Pointer

Very important for exams: Contrast classical vs recombinant strain improvement with one example each.

Preservation of industrial strains

- Lyophilization (freeze-drying), cryopreservation in glycerol at -80C.
- Working vs master cell banks prevent genetic drift.
- Revive and verify productivity before production runs.

Genome shuffling

- Recursive protoplast fusion accelerates classical strain improvement.
- Combines whole genomes without rDNA regulation issues.
- Used for industrial yeast and antibiotic producers.

Regulatory affairs

- DRAP regulates biologics in Pakistan.
- GMP compliance is mandatory for pharma production.
- Documentation culture decides audit outcomes.

Ethics of strain engineering

- Engineered microbes need containment and risk assessment.
- Dual-use awareness: tools can heal or harm.
- Follow national biosafety guidelines strictly.

Protoplast fusion

- Removes cell walls, fuses genomes directly.
- Creates hybrids impossible by mating.
- Useful for industrial yeast improvement.
- Regeneration of walls is the tricky step.

- Largely superseded by recombinant methods.

Genome shuffling

- Recursive protoplast fusion accelerates evolution.
- Combines beneficial mutations from many parents.
- Faster than sequential mutagenesis.
- Used for industrial strain improvement.
- Screening capacity limits the approach.

6. Microbial Enzymes

Learning Objectives

- List industrially important enzymes and their uses
- Explain enzyme immobilization and its advantages

Enzyme	Source microbe	Application
Amylase	Bacillus, Aspergillus	Starch liquefaction, baking, brewing
Protease	Bacillus subtilis	Detergents, leather, food
Lipase	Candida, Rhizopus	Detergents, dairy flavour, biodiesel
Cellulase	Trichoderma reesei	Textiles, paper, bioethanol
Pectinase	Aspergillus niger	Fruit juice clarification
Glucose isomerase	Streptomyces	High-fructose corn syrup
Lactase	Kluyveromyces	Lactose-free milk

Enzyme immobilization is defined as the confinement of an enzyme to a solid support or matrix so it can be reused in continuous processes and easily separated from products.

- Methods: adsorption, covalent binding, entrapment in gels (alginate), cross-linking.
- Advantages: reusability, stability, continuous operation, no enzyme in final product.
- Example: immobilized glucose isomerase columns produce high-fructose syrup continuously.

Key Points to Remember

- Enzymes are the largest-volume microbial products after antibiotics.
- Immobilization = reuse + continuous processing.

Exam Pointer

Very important for exams: Any enzyme table row (source + use) makes a perfect short note.

Extremozymes

- Taq polymerase from hot-spring *Thermus aquaticus* enabled PCR.
- Cold-active enzymes for detergents; salt-tolerant enzymes for food.
- Extremophiles are bioprospecting gold mines.

Enzyme kinetics basics

- Michaelis-Menten: $v = V_{\max} S / (K_m + S)$; low K_m means high affinity.
- Industrial enzymes need stability more than speed.
- Immobilization often improves operational stability.

Food-grade enzymes

- Must meet purity and allergen standards.
- Halal certification matters for Pakistani and export markets.
- Local production could cut import bills.

Enzyme market trends

- Detergent enzymes are the largest segment.
- Growth in food, biofuel and textile enzymes.
- Pakistan imports most enzymes — a local opportunity.

Enzyme immobilization methods

- Adsorption: simple but leaky.
- Covalent binding: stable, may reduce activity.
- Entrapment: protects but limits diffusion.
- Cross-linking: carrier-free aggregates.
- Choose by cost, stability and reuse needs.

Biosensors

- Enzymes or cells coupled to transducers.
- Glucose meters are the iconic success.
- Detect pollutants, pathogens, metabolites.
- Immobilization extends sensor life.
- Point-of-care diagnostics depend on them.

7. Antibiotics and Biopharmaceuticals

Learning Objectives

- Describe antibiotic production and its challenges
- List recombinant biopharmaceuticals made by microbes

- Antibiotics are secondary metabolites — produced after active growth, in stationary phase.
- Penicillin: *Penicillium chrysogenum* in deep-tank aerobic fermentation; recovered by solvent extraction.
- Streptomycin, tetracycline, erythromycin from *Streptomyces* species.
- Semi-synthetic derivatives (amoxicillin) improve spectrum and stability.

The antibiotic resistance crisis

Overuse and misuse of antibiotics select resistant bacteria (MRSA, drug-resistant TB). Very important for exams: stewardship, completing courses, and avoiding self-medication slow resistance; industry now seeks new antibiotics and alternatives like phage therapy.

Recombinant biopharmaceuticals

- Human insulin (*E. coli*/yeast) — first recombinant drug, 1982.
- Growth hormone, interferons, hepatitis B vaccine (yeast), clotting factors.
- Monoclonal antibodies are mostly made in mammalian cells, but microbes make antibody fragments and many therapeutic enzymes.

Key Points to Remember

- Antibiotics = secondary metabolites; resistance is driven by selection pressure.
- Recombinant microbes produce insulin, vaccines and growth factors.

Exam Pointer

Very important for exams: Why antibiotics are called secondary metabolites, and the resistance mechanism, are hot questions.

Antibiotic discovery pipeline

- Screen soil microbes -> isolate compound -> test activity -> clinical trials.
- Most soil antibiotics are rediscoveries — new sources (marine, uncultured) needed.
- Genome mining finds silent antibiotic gene clusters.

Vaccines from microbes

- Hepatitis B vaccine: yeast-expressed surface antigen.
- Growing shift to recombinant and mRNA platforms.
- Cold-chain remains the delivery challenge in Pakistan.

Phage therapy revival

- Bacteriophages kill specific bacteria — an antibiotic alternative.
- Georgia and Poland kept the tradition alive.
- Personalized phage cocktails face regulatory hurdles.

Antimicrobial stewardship

- Use antibiotics only when needed, at right dose and duration.
- Hospitals need stewardship committees.
- Biotechnology can supply rapid diagnostics to guide use.

Antibiotic resistance crisis

- Overuse in humans and livestock drives resistance.
- Last-resort drugs are failing in hospitals.
- New antibiotic pipelines are nearly dry.
- Stewardship programs restrict unnecessary prescriptions.
- Biotech answers: phages, antimicrobial peptides.

Vaccines from microbes

- Recombinant hepatitis B vaccine is yeast-made.
- Subunit vaccines avoid live pathogens.
- Fermentation scale decides vaccine cost.
- Cold chain remains the delivery bottleneck.
- Pakistan imports most human vaccines.

8. Biofuels from Microbes

Learning Objectives

- Describe bioethanol, biodiesel, biogas and biohydrogen production
- Compare fuel generations

- Bioethanol: yeast ferments sugars/starch (sugarcane, corn); lignocellulosic ethanol uses pretreated straw/wood with cellulases — second generation.
- Biodiesel: transesterification of oils; oleaginous microbes (*Yarrowia lipolytica*, microalgae like *Chlorella*) accumulate lipids as feedstock.
- Biogas: anaerobic digestion of waste by methanogenic archaea produces methane + CO₂; used for cooking and electricity in rural Pakistan.
- Biohydrogen: photosynthetic bacteria and dark fermentation of waste.

Transesterification: Triglyceride + 3 Methanol → 3 FAME (biodiesel) + Glycerol

Generation	Feedstock	Issue
1st	Food crops (corn, sugarcane)	Competes with food
2nd	Agri-residues, non-food biomass	Pretreatment cost
3rd	Microalgae	Scale-up cost
4th	Engineered microbes/algae	Regulation, containment

Key Points to Remember

- Second-generation fuels avoid the food-vs-fuel conflict.
- Anaerobic digestion gives both fuel and fertilizer (digestate).

Exam Pointer

Very important for exams: The four generations table and the biogas process steps are standard questions.

Algal biofuels promise

- Algae yield far more oil per hectare than soy or palm.
- Challenges: harvesting cost, contamination, water use.
- Pakistan's sunny climate suits algal ponds.

Biogas plant design basics

- Feedstock + digester + gas holder; retention time 30-50 days.
- Pakistan's PCRET promotes household biogas plants.
- Digestate is excellent fertilizer — double benefit.

Waste valorization

- Whey → biogas or protein; bagasse → ethanol or xylitol.

- Turns disposal costs into revenue.
- Circular bioeconomy is Pakistan's opportunity.

Bio-CNG potential

- Upgraded biogas fuels vehicles — Sweden leads.
- Pakistan's transport sector could absorb bio-CNG.
- Needs gas cleaning and compression infrastructure.

Algal biofuels

- Algae yield far more oil per hectare than crops.
- They grow on non-arable land with wastewater.
- Harvesting and extraction costs remain high.
- Co-products (feed, pigments) improve economics.
- Pakistan's sunlight is a natural advantage.

Second-generation bioethanol

- Uses straw and bagasse, not food crops.
- Pretreatment breaks lignin barriers.
- Enzyme cost was the historic blocker.
- Pakistan's bagasse is an ideal feedstock.
- Blending mandates create the market.

9. Probiotics, Prebiotics and Single-Cell Protein

Learning Objectives

- Define probiotics and list selection criteria
- Explain single-cell protein production

Probiotic is defined as a live microorganism which, when administered in adequate amounts, confers a health benefit on the host.

Criteria for a probiotic strain

- Safety: non-pathogenic, no transferable antibiotic resistance (GRAS).
- Survival: tolerates stomach acid (pH 2-3), bile salts and digestive enzymes.
- Adhesion to intestinal cells for temporary colonization.
- Antimicrobial activity: produces lactic acid, bacteriocins, hydrogen peroxide.

- Technological suitability: survives processing, drying and storage with high viable counts.
- Common genera: Lactobacillus, Bifidobacterium, Saccharomyces boulardii.
- Benefits: gut health, diarrhoea control, immunity, lactose digestion.
- Prebiotics are non-digestible fibres (inulin, FOS) that feed beneficial bacteria — synbiotics combine both.

Single-cell protein (SCP) is defined as protein-rich microbial biomass (bacteria, yeast, algae) grown for use as food or animal feed.

- Spirulina: 60-70% protein, vitamins and minerals; grown in ponds.
- Mycoprotein (Quorn): Fusarium venenatum fungus as meat alternative.
- Advantages: fast production, no farmland needed, high protein content.

Key Points to Remember

- Probiotic = live beneficial microbe; prebiotic = its food.
- SCP turns waste substrates into protein.

Exam Pointer

Very important for exams: The probiotic selection criteria list is a guaranteed 5-mark question.

Fermented foods of Pakistan

- Yogurt (dahi), lassi, pickles (achar) — lactic fermentation traditions.
- Probiotic potential of indigenous dahi strains is under research.
- Standardization could turn tradition into industry.

Prebiotic sources

- Inulin from chicory, FOS from onions and garlic.
- Pakistani diet already includes many prebiotic foods.
- Functional food market is growing locally.

Clinical trials of probiotics

- Strain-specific evidence is required — not all probiotics work for all conditions.
- Dose and duration matter as much as strain.
- Pakistani trials on local strains are needed.

Probiotic foods market

- Yogurt drinks with added cultures sell globally.

- Label claims need scientific backing.
- Local brands can leverage traditional dahi trust.

Kefir and traditional ferments

- Kefir grains host symbiotic bacteria and yeasts.
- Traditional dahi is a natural probiotic source.
- Standardizing them creates commercial products.
- Health claims need clinical evidence.
- Fermented foods are biotech's oldest branch.

Prebiotic mechanisms

- Inulin and FOS feed bifidobacteria selectively.
- Fermentation yields beneficial short-chain fatty acids.
- Dose and chain length decide effects.
- Synbiotics pair pre- with probiotics.
- Evidence is strongest for gut outcomes.

10. Biofertilizers and Biopesticides

Learning Objectives

- Describe major biofertilizers and their mechanisms
- Explain Bt and other biopesticides

Biofertilizers

Biofertilizer	Microorganism	Mechanism
Rhizobium	Rhizobium leguminosarum	Symbiotic N ₂ fixation in legume nodules
Azotobacter	Azotobacter spp.	Free-living N ₂ fixation
Azospirillum	Azospirillum spp.	Associative N ₂ fixation in cereals
Phosphate solubilizers	Bacillus, Pseudomonas	Release bound soil phosphate
Mycorrhizae	Glomus spp.	Extend root absorption, P uptake

Biopesticides

- Bt (*Bacillus thuringiensis*): produces Cry protein crystals toxic to insect larvae but safe for humans — used as spray and in Bt cotton/maize.

- Trichoderma: fungus parasitizing plant-pathogenic fungi.
- Beauveria bassiana: insect-killing fungus.
- Neem-based and viral (NPV) biopesticides.
- Advantages: target-specific, biodegradable, no harmful residues; limitation: slower action, shorter shelf life.

Key Points to Remember

- Biofertilizers add nutrients; biopesticides kill pests — both reduce chemical inputs.
- Bt toxin is the flagship microbial biopesticide worldwide.

Exam Pointer

Very important for exams: Two examples each of biofertilizers and biopesticides with mechanisms — classic question.

Mycorrhizae in Pakistani agriculture

- Wheat and maize benefit from mycorrhizal phosphorus uptake.
- Reduces fertilizer bills for small farmers.
- Local inoculum production is an emerging business.

Integrated pest management

- Combine biopesticides with resistant varieties and monitoring.
- Reduces chemical load and resistance risk.
- Bt cotton in Pakistan shows both promise and resistance lessons.

Biofertilizer quality control

- Viable cell counts decide field performance.
- Expiry dates and storage conditions are critical.
- Farmers need extension support for adoption.

Farmer field schools

- Demonstration plots convince faster than lectures.
- Show biofertilizer side-by-side with chemical plots.
- Extension workers multiply impact.

Rhizobium inoculants

- Coat legume seeds with nitrogen-fixing bacteria.

- Carrier material (peat, charcoal) keeps cells alive.
- Quality control counts viable cells per gram.
- Can replace 20-30 kg of urea per hectare.
- Pakistani pulse farmers underuse them.

Mycorrhizae

- Fungi extend root absorption networks.
- Improve phosphorus uptake dramatically.
- Reduce fertilizer needs in poor soils.
- Commercial inoculants are gaining ground.
- Compatible with organic farming.

11. Bioremediation

Learning Objectives

- Define bioremediation and its strategies
- Give examples of pollutant-degrading microbes

Bioremediation is defined as the use of living microorganisms (or their enzymes) to degrade, detoxify or remove environmental pollutants such as oil, pesticides, heavy metals and industrial wastes.

- Biostimulation: adding nutrients/oxygen to boost native degraders.
- Bioaugmentation: adding specialized pollutant-degrading strains.
- In situ: treatment on site (bioventing); ex situ: excavated soil treated in biopiles/bioreactors.
- Phytoremediation uses plants; microbial remediation uses bacteria/fungi.

Pollutant	Degrading microbe/process
Crude oil spills	Alcanivorax, Pseudomonas (hydrocarbon degraders)
Pesticides	White-rot fungi (lignin enzymes degrade DDT-like compounds)
Heavy metals	Biosorption by algae/fungi; sulfate-reducing bacteria precipitate metals
Textile dyes	Bacterial azoreductases decolorize effluents
Plastics (PET)	Ideonella sakaiensis PETase enzyme (research stage)

Key Points to Remember

- Bioremediation is cheaper and greener than chemical cleanup but slower.
- Match pollutant to microbe for exam tables.

Exam Pointer

Very important for exams: Biostimulation vs bioaugmentation difference is a favourite short question.

Oil spill case study

- Exxon Valdez (1989): bioremediation with fertilizer sped oil degradation.
- Natural attenuation works but is slow for heavy spills.
- Pakistan's coastal spills need local degrader strains.

Constructed wetlands

- Plants + microbes treat wastewater naturally.
- Low cost suits small towns and housing societies.
- Lahore pilot projects show textile effluent potential.

Heavy metal biosorption

- Dead algal/fungal biomass binds metals cheaply.
- Regeneration allows multiple cycles.
- Suits small electroplating units in Pakistan.

E-waste and microbes

- Bioleaching recovers metals from electronic waste.
- Less toxic than smelting or acid leaching.
- An emerging green industry.

Oil spill cleanup

- Hydrocarbon-degrading bacteria eat crude oil.
- Biostimulation adds nutrients to speed them.
- Bioaugmentation adds specialist strains.
- Monitored natural attenuation suits mild spills.
- Warm climates accelerate biodegradation.

Heavy metal biosorption

- Dead biomass binds metals from wastewater.
- Cheaper than ion-exchange resins.
- Regenerate biosorbents with mild acids.
- Tannery effluent is a local application.
- pH control decides binding efficiency.

12. Downstream Processing

Learning Objectives

- List the steps of downstream processing
- Explain why it dominates production cost

Downstream processing is defined as the sequence of recovery and purification steps that convert fermentation broth into a finished product.

- 1. Cell separation: filtration or centrifugation removes biomass.
- 2. Cell disruption (for intracellular products): homogenization, sonication, bead milling.
- 3. Concentration: evaporation, ultrafiltration, precipitation (ammonium sulfate).
- 4. Purification: chromatography (ion exchange, affinity, gel filtration).
- 5. Formulation and drying: lyophilization (freeze-drying), spray drying.
- 6. Quality control and packaging.

Very important for exams: downstream processing often accounts for 50-80% of total production cost, because biological broths are dilute and products must meet strict purity standards, especially for pharmaceuticals.

Key Points to Remember

- Order matters: separate -> disrupt -> concentrate -> purify -> formulate.
- Downstream cost dominates bioprocess economics.

Exam Pointer

Very important for exams: List the downstream steps in order — a direct 5-mark question.

Membrane filtration in downstream

- Micro/ultrafiltration concentrate cells and proteins gently.
- Diafiltration washes impurities without dilution.
- Fouling is the main operational challenge.

Chromatography types

- Ion exchange, size exclusion, affinity — each separates differently.
- Affinity gives highest purity in one step (e.g. protein A for antibodies).
- Scale-up keeps resolution while raising throughput.

Lyophilization

- Freeze-drying preserves cultures and proteins long-term.
- Expensive but unmatched for stability.
- Starter cultures and vaccines depend on it.

Process analytical technology

- Online sensors monitor pH, oxygen and biomass live.
- Real-time control beats end-point testing.
- PAT is standard in modern biopharma.

Membrane filtration

- Microfiltration removes cells; ultrafiltration concentrates proteins.
- Fouling is the main operating cost.
- Diafiltration washes out small contaminants.
- Ceramic membranes survive harsh cleaning.
- Sizing uses molecular weight cut-offs.

Spray drying

- Atomized droplets dry in hot air instantly.
- Makes stable powders of enzymes and cultures.
- Heat damage needs protective carriers.
- Particle size affects reconstitution.
- Energy-intensive but scalable.

13. Omics and Future Trends

Learning Objectives

- Define genomics, proteomics, metabolomics
- Describe future directions of microbial biotechnology

Omics field	Studies	Use in microbial biotechnology
Genomics	Complete DNA sequences	Find new enzymes/antibiotic gene clusters
Transcriptomics	All RNA transcripts	See which genes switch on during production
Proteomics	All proteins	Identify stress and production proteins
Metabolomics	All small metabolites	Optimize fermentation, detect bottlenecks

- Systems biology integrates omics data to model the whole cell.
- Synthetic biology: designing new genetic circuits and minimal genomes.
- CRISPR-based strain engineering is now routine.
- Circular bioeconomy: waste (agricultural, food, plastic) as feedstock for microbial factories.
- Pakistan relevance: local strains for textile effluent treatment, biofertilizers for wheat/cotton, and biogas from farm waste.

Key Points to Remember

- Omics moves biotechnology from trial-and-error to data-driven design.
- Future = synthetic biology + waste valorization.

Exam Pointer

Very important for exams: Define the four omics with one application each — a modern favourite question.

Biosafety levels

- BSL-1 (harmless) to BSL-4 (deadly pathogens) — practices scale with risk.
- Industrial microbes are BSL-1; pathogens need containment.
- Pakistan's biosafety rules govern GMO field trials.

One health perspective

- Human, animal and environmental health are linked.
- Antibiotic resistance spreads across all three.
- Microbial biotechnology serves each domain.

Science communication

- Explain GMOs and biosafety honestly to build trust.
- Counter misinformation with accessible evidence.
- Biotechnologists owe the public clear communication.

Exam revision checklist

- Microbe-product table, fermentation stages, bioreactor parts.
- Probiotic criteria, downstream steps, bioremediation strategies.
- Draw one labelled diagram per major topic.

Synthetic biology circuits

- Genetic toggle switches and oscillators exist.
- Standardized BioBricks enable assembly.
- Whole pathways can be refactored.
- Biosafety concerns grow with capability.
- The field blurs biology and engineering.

CRISPR in industry

- Precise strain engineering without markers.
- Multiplex edits in one step.
- Regulatory status varies by country.
- Speeds the design-build-test cycle.
- Expect exam questions on applications.

Glossary of Key Terms

Learning Objectives

- Revise all key terms quickly before exams

Term	Meaning
Microbial biotechnology	the use of microorganisms (bacteria, fungi, algae, viruses) and their cellular machinery to develop products and processes useful to humans, including food, med...
Fermentation	a metabolic process in which microorganisms convert organic substrates (usually sugars) into products such as acids, alcohols, gases or biomass, with or without...

Term	Meaning
Bioreactor (fermenter)	a vessel that provides a controlled environment (temperature, pH, aeration, agitation, sterility) for the growth of microorganisms and formation of products.
Enzyme immobilization	the confinement of an enzyme to a solid support or matrix so it can be reused in continuous processes and easily separated from products.
Probiotic	a live microorganism which, when administered in adequate amounts, confers a health benefit on the host.
Single-cell protein (SCP)	protein-rich microbial biomass (bacteria, yeast, algae) grown for use as food or animal feed.
Bioremediation	the use of living microorganisms (or their enzymes) to degrade, detoxify or remove environmental pollutants such as oil, pesticides, heavy metals and industrial...
Downstream processing	the sequence of recovery and purification steps that convert fermentation broth into a finished product.

Exam Pointer

Very important for exams: Revise this glossary the night before the paper.

Practice Questions for Exams

Learning Objectives

- Test your preparation with these exam-style questions

Short questions with model answers

Example

Q: Explain: define microbial biotechnology and its scope Model answer: Microbial biotechnology = microbes as factories for useful products. Pasteur, Fleming and recombinant DNA are the three landmark eras.

Example

Q: Explain: describe historical milestones of industrial microbiology Model answer: Microbial biotechnology = microbes as factories for useful products. Pasteur, Fleming and recombinant DNA are the three landmark eras.

Example

Q: Explain: classify industrially important microorganisms Model answer: Match each microbe to its product — examiners love this table. GRAS status is essential for food and pharma microbes.

Example

Q: Explain: state criteria for selecting industrial strains Model answer: Match each microbe to its product — examiners love this table. GRAS status is essential for food and pharma microbes.

Example

Q: Explain: define fermentation and its types Model answer: Aerobic vs anaerobic decides reactor design and products. Sterility and inoculum quality decide success or contamination.

Example

Q: Explain: describe the stages of a fermentation process Model answer: Aerobic vs anaerobic decides reactor design and products. Sterility and inoculum quality decide success or contamination.

Example

Q: Explain: describe bioreactor types and their parts Model answer: Fed-batch avoids catabolite repression; continuous gives steady-state production. Scale-up keeps oxygen transfer and mixing constant, not just volume.

Example

Q: Explain: compare batch, fed-batch and continuous modes Model answer: Fed-batch avoids catabolite repression; continuous gives steady-state production. Scale-up keeps oxygen transfer and mixing constant, not just volume.

Example

Q: Explain: describe mutation, selection and recombinant methods Model answer: Classical mutagenesis = random; rDNA/CRISPR = precise. Metabolic engineering optimizes whole pathways, not single genes.

Example

Q: Explain: explain the role of rDNA in strain development Model answer: Classical mutagenesis = random; rDNA/CRISPR = precise. Metabolic engineering optimizes whole pathways, not single genes.

Example

Q: Explain: list industrially important enzymes and their uses Model answer: Enzymes are the largest-volume microbial products after antibiotics. Immobilization = reuse + continuous processing.

Example

Q: Explain: explain enzyme immobilization and its advantages Model answer: Enzymes are the largest-volume microbial products after antibiotics. Immobilization = reuse + continuous processing.

Example

Q: Explain: describe antibiotic production and its challenges Model answer: Antibiotics = secondary metabolites; resistance is driven by selection pressure. Recombinant microbes produce insulin, vaccines and growth factors.

Example

Q: Explain: list recombinant biopharmaceuticals made by microbes Model answer: Antibiotics = secondary metabolites; resistance is driven by selection pressure. Recombinant microbes produce insulin, vaccines and growth factors.

Example

Q: Explain: describe bioethanol, biodiesel, biogas and biohydrogen production Model answer: Second-generation fuels avoid the food-vs-fuel conflict. Anaerobic digestion gives both fuel and fertilizer (digestate).

Example

Q: Explain: compare fuel generations Model answer: Second-generation fuels avoid the food-vs-fuel conflict. Anaerobic digestion gives both fuel and fertilizer (digestate).

Example

Q: Explain: define probiotics and list selection criteria Model answer: Probiotic = live beneficial microbe; prebiotic = its food. SCP turns waste substrates into protein.

Example

Q: Explain: explain single-cell protein production Model answer: Probiotic = live beneficial microbe; prebiotic = its food. SCP turns waste substrates into protein.

Example

Q: Explain: describe major biofertilizers and their mechanisms Model answer: Biofertilizers add nutrients; biopesticides kill pests — both reduce chemical inputs. Bt toxin is the flagship microbial biopesticide worldwide.

Example

Q: Explain: explain Bt and other biopesticides Model answer: Biofertilizers add nutrients; biopesticides kill pests — both reduce chemical inputs. Bt toxin is the flagship microbial biopesticide worldwide.

Example

Q: Explain: define bioremediation and its strategies Model answer: Bioremediation is cheaper and greener than chemical cleanup but slower. Match pollutant to microbe for exam tables. 

Example

Q: Explain: give examples of pollutant-degrading microbes Model answer: Bioremediation is cheaper and greener than chemical cleanup but slower. Match pollutant to microbe for exam tables.

Example

Q: Explain: list the steps of downstream processing Model answer: Order matters: separate -> disrupt -> concentrate -> purify -> formulate. Downstream cost dominates bioprocess economics.

Example

Q: Explain: explain why it dominates production cost Model answer: Order matters: separate -> disrupt -> concentrate -> purify -> formulate. Downstream cost dominates bioprocess economics.

Example

Q: Explain: define genomics, proteomics, metabolomics Model answer: Omics moves biotechnology from trial-and-error to data-driven design. Future = synthetic biology + waste valorization.

Example

Q: Explain: describe future directions of microbial biotechnology Model answer: Omics moves biotechnology from trial-and-error to data-driven design. Future = synthetic biology + waste valorization.

Long questions

- Write a detailed note on Introduction to Microbial Biotechnology.
- Write a detailed note on Microbial Diversity and Industrial Microorganisms.
- Write a detailed note on Fermentation Technology.
- Write a detailed note on Bioreactors and Fermentation Systems.
- Write a detailed note on Strain Improvement.
- Write a detailed note on Microbial Enzymes.
- Write a detailed note on Antibiotics and Biopharmaceuticals.
- Write a detailed note on Biofuels from Microbes.
- Write a detailed note on Probiotics, Prebiotics and Single-Cell Protein.
- Write a detailed note on Biofertilizers and Biopesticides.

Long questions with model answer outlines

Example

Q: Write a detailed note on Introduction to Microbial Biotechnology. Answer outline: • Traditional applications: bread, cheese, yogurt, beer, wine — fermentation is thousands of years old. • Modern applications: antibiotics, enzymes, biofuels, probiotics, bioremediation, recombinant proteins. • Why microbes: fast growth, easy genetic manipulation, diverse metabolism, cheap substrates. • Louis Pasteur: proved fermentation is caused by microbes; developed pasteurization and vaccines. • Alexander Fleming (1928): discovered penicillin from *Penicillium notatum*.

Example

Q: Write a detailed note on Microbial Diversity and Industrial Microorganisms. Answer outline: • Genetically stable and non-pathogenic (GRAS — generally regarded as safe). • High product yield and fast growth on cheap substrates. • Easy downstream recovery of the product. • Amenable to genetic improvement and scale-up. • Needs: carbon, nitrogen, minerals, water, energy source.

Example

Q: Write a detailed note on Fermentation Technology. Answer outline: • Alcoholic fermentation: yeast converts glucose to ethanol + CO₂ (beer, wine, bioethanol). • Lactic acid fermentation: Lactobacillus converts milk sugar to lactic acid (yogurt, cheese). • Aerobic processes: citric acid, vinegar, antibiotics need oxygen. • Solid-state fermentation: growth on moist solids (tempeh, koji); submerged fermentation: growth in liquid medium (most industry). • 1. Strain selection and inoculum preparation (seed culture).

Example

Q: Write a detailed note on Bioreactors and Fermentation Systems. Answer outline: • Vessel with jacket for heating/cooling; impeller/agitator for mixing. • Sparger for air supply; baffles to improve mixing; foam breaker. • Sensors: pH, dissolved oxygen, temperature probes; sampling and inoculation ports. • Sterilization in place (SIP) systems. • Moist heat (autoclave 121°C), dry heat, filtration for heat-labile fluids.

Example

Q: Write a detailed note on Strain Improvement. Answer outline: • Random mutagenesis: UV or chemical mutagens create mutants; best producers selected (classical, e.g. penicillin yield raised 1000-fold). • Selection and screening: rational screens for desired traits (antibiotic resistance, product tolerance). • Protoplast fusion: combines genomes of two strains without full sexual cycle. • Recombinant DNA: precise — insert genes for heterologous proteins (insulin, growth hormone, vaccines) into E. coli, yeast or CHO cells. • CRISPR-Cas9: targeted genome editing for pathway engineering and removing competing pathways.

Example

Q: Write a detailed note on Microbial Enzymes. Answer outline: • Methods: adsorption, covalent binding, entrapment in gels (alginate), cross-linking. • Advantages: reusability, stability, continuous operation, no enzyme in final product. • Example: immobilized glucose isomerase columns produce high-fructose syrup continuously. • Taq polymerase from hot-spring *Thermus aquaticus* enabled PCR. • Cold-active enzymes for detergents; salt-tolerant enzymes for food.

Example

Q: Write a detailed note on Antibiotics and Biopharmaceuticals. Answer outline: • Antibiotics are secondary metabolites — produced after active growth, in stationary phase. • Penicillin: *Penicillium chrysogenum* in deep-tank aerobic fermentation; recovered by solvent extraction. • Streptomycin, tetracycline, erythromycin from *Streptomyces* species. • Semi-synthetic derivatives (amoxicillin) improve spectrum and stability. • Human insulin (E. coli/yeast) — first recombinant drug, 1982.

Example

Q: Write a detailed note on Biofuels from Microbes. Answer outline: • Bioethanol: yeast ferments sugars/starch (sugarcane, corn); lignocellulosic ethanol uses pretreated straw/wood with cellulases — second generation. • Biodiesel: transesterification of oils; oleaginous microbes (*Yarrowia lipolytica*, microalgae like *Chlorella*) accumulate lipids as feedstock. • Biogas: anaerobic digestion of waste by methanogenic archaea produces methane + CO₂; used for cooking and electricity in rural Pakistan. • Biohydrogen: photosynthetic bacteria and dark fermentation of waste. • Algae yield far more oil per hectare than soy or palm.

Example

Q: Write a detailed note on Probiotics, Prebiotics and Single-Cell Protein. Answer outline: • Safety: non-pathogenic, no transferable antibiotic resistance (GRAS). • Survival: tolerates stomach acid (pH 2-3), bile salts and digestive enzymes. • Adhesion to intestinal cells for temporary colonization. • Antimicrobial activity: produces lactic acid, bacteriocins, hydrogen peroxide. • Technological suitability: survives processing, drying and storage with high viable counts.

Example

Q: Write a detailed note on Biofertilizers and Biopesticides. Answer outline: • Bt (*Bacillus thuringiensis*): produces Cry protein crystals toxic to insect larvae but safe for humans — used as spray and in Bt cotton/maize. • Trichoderma: fungus parasitizing plant-pathogenic fungi. • Beauveria bassiana: insect-killing fungus. • Neem-based and viral (NPV) biopesticides. • Advantages: target-specific, biodegradable, no harmful residues; limitation: slower action, shorter shelf life.

Exam Pointer

Very important for exams: Practice writing answers within the exam time limit.

MCQ Practice Test

Learning Objectives

- Test your recall of the key points from every chapter

Q1. Which of the following was listed as a key point of 'Introduction to Microbial Biotechnology' in this handout?

- A. Aerobic vs anaerobic decides reactor design and products.
- B. Match each microbe to its product — examiners love this table.
- C. Microbial biotechnology = microbes as factories for useful products.
- D. GRAS status is essential for food and pharma microbes.

Q2. Which of the following was listed as a key point of 'Introduction to Microbial Biotechnology' in this handout? 

- A. Aerobic vs anaerobic decides reactor design and products.
- B. Match each microbe to its product — examiners love this table.
- C. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- D. GRAS status is essential for food and pharma microbes.

Q3. Which of the following was listed as a key point of 'Microbial Diversity and Industrial Microorganisms' in this handout?

- A. Aerobic vs anaerobic decides reactor design and products.
- B. Match each microbe to its product — examiners love this table.
- C. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- D. Microbial biotechnology = microbes as factories for useful products.

Q4. Which of the following was listed as a key point of 'Microbial Diversity and Industrial Microorganisms' in this handout?

- A. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- B. Microbial biotechnology = microbes as factories for useful products.
- C. Aerobic vs anaerobic decides reactor design and products.
- D. GRAS status is essential for food and pharma microbes.

Q5. Which of the following was listed as a key point of 'Fermentation Technology' in this handout?

- A. Microbial biotechnology = microbes as factories for useful products.
- B. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- C. Match each microbe to its product — examiners love this table.
- D. Aerobic vs anaerobic decides reactor design and products.

Q6. Which of the following was listed as a key point of 'Fermentation Technology' in this handout?

- A. Match each microbe to its product — examiners love this table.
- B. Microbial biotechnology = microbes as factories for useful products.
- C. Sterility and inoculum quality decide success or contamination.
- D. Pasteur, Fleming and recombinant DNA are the three landmark eras.

Q7. Which of the following was listed as a key point of 'Bioreactors and Fermentation Systems' in this handout?

- A. Fed-batch avoids catabolite repression; continuous gives steady-state production.

B. Microbial biotechnology = microbes as factories for useful products.

C. Match each microbe to its product — examiners love this table.

D. Pasteur, Fleming and recombinant DNA are the three landmark eras.

Q8. Which of the following was listed as a key point of 'Bioreactors and Fermentation Systems' in this handout? 

A. Scale-up keeps oxygen transfer and mixing constant, not just volume.

B. Microbial biotechnology = microbes as factories for useful products.

C. Pasteur, Fleming and recombinant DNA are the three landmark eras.

D. Match each microbe to its product — examiners love this table.

Q9. Which of the following was listed as a key point of 'Strain Improvement' in this handout?

A. Match each microbe to its product — examiners love this table.

B. Classical mutagenesis = random; rDNA/CRISPR = precise.

C. Pasteur, Fleming and recombinant DNA are the three landmark eras.

D. Microbial biotechnology = microbes as factories for useful products.

Q10. Which of the following was listed as a key point of 'Strain Improvement' in this handout?

A. Metabolic engineering optimizes whole pathways, not single genes.

B. Microbial biotechnology = microbes as factories for useful products.

C. Pasteur, Fleming and recombinant DNA are the three landmark eras.

D. Match each microbe to its product — examiners love this table.

Q11. Which of the following was listed as a key point of 'Microbial Enzymes' in this handout?

A. Microbial biotechnology = microbes as factories for useful products.

B. Match each microbe to its product — examiners love this table.

C. Enzymes are the largest-volume microbial products after antibiotics.

D. Pasteur, Fleming and recombinant DNA are the three landmark eras.

Q12. Which of the following was listed as a key point of 'Microbial Enzymes' in this handout?

A. Match each microbe to its product — examiners love this table.

B. Pasteur, Fleming and recombinant DNA are the three landmark eras.

C. Microbial biotechnology = microbes as factories for useful products.

D. Immobilization = reuse + continuous processing.

Q13. Which of the following was listed as a key point of 'Antibiotics and Biopharmaceuticals' in this handout?

A. Match each microbe to its product — examiners love this table.

- B. Microbial biotechnology = microbes as factories for useful products.
- C. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- D. Antibiotics = secondary metabolites; resistance is driven by selection pressure.

Q14. Which of the following was listed as a key point of 'Antibiotics and Biopharmaceuticals' in this handout? 

- A. Recombinant microbes produce insulin, vaccines and growth factors.
- B. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- C. Microbial biotechnology = microbes as factories for useful products.
- D. Match each microbe to its product — examiners love this table.

Q15. Which of the following was listed as a key point of 'Biofuels from Microbes' in this handout?

- A. Second-generation fuels avoid the food-vs-fuel conflict.
- B. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- C. Match each microbe to its product — examiners love this table.
- D. Microbial biotechnology = microbes as factories for useful products.

Q16. Which of the following was listed as a key point of 'Biofuels from Microbes' in this handout?

- A. Microbial biotechnology = microbes as factories for useful products.
- B. Anaerobic digestion gives both fuel and fertilizer (digestate).
- C. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- D. Match each microbe to its product — examiners love this table.

Q17. Which of the following was listed as a key point of 'Probiotics, Prebiotics and Single-Cell Protein' in this handout?

- A. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- B. Probiotic = live beneficial microbe; prebiotic = its food.
- C. Match each microbe to its product — examiners love this table.
- D. Microbial biotechnology = microbes as factories for useful products.

Q18. Which of the following was listed as a key point of 'Probiotics, Prebiotics and Single-Cell Protein' in this handout?

- A. SCP turns waste substrates into protein.
- B. Microbial biotechnology = microbes as factories for useful products.
- C. Match each microbe to its product — examiners love this table.
- D. Pasteur, Fleming and recombinant DNA are the three landmark eras.

Q19. Which of the following was listed as a key point of 'Biofertilizers and Biopesticides' in this handout?

- A. Biofertilizers add nutrients; biopesticides kill pests — both reduce chemical inputs.
- B. Microbial biotechnology = microbes as factories for useful products.
- C. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- D. Match each microbe to its product — examiners love this table.

Q20. Which of the following was listed as a key point of 'Biofertilizers and Biopesticides' in this handout? 

- A. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- B. Bt toxin is the flagship microbial biopesticide worldwide.
- C. Match each microbe to its product — examiners love this table.
- D. Microbial biotechnology = microbes as factories for useful products.

Q21. Which of the following was listed as a key point of 'Bioremediation' in this handout?

- A. Match each microbe to its product — examiners love this table.
- B. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- C. Bioremediation is cheaper and greener than chemical cleanup but slower.
- D. Microbial biotechnology = microbes as factories for useful products.

Q22. Which of the following was listed as a key point of 'Bioremediation' in this handout?

- A. Microbial biotechnology = microbes as factories for useful products.
- B. Match each microbe to its product — examiners love this table.
- C. Match pollutant to microbe for exam tables.
- D. Pasteur, Fleming and recombinant DNA are the three landmark eras.

Q23. Which of the following was listed as a key point of 'Downstream Processing' in this handout?

- A. Order matters: separate -> disrupt -> concentrate -> purify -> formulate.
- B. Match each microbe to its product — examiners love this table.
- C. Microbial biotechnology = microbes as factories for useful products.
- D. Pasteur, Fleming and recombinant DNA are the three landmark eras.

Q24. Which of the following was listed as a key point of 'Downstream Processing' in this handout?

- A. Microbial biotechnology = microbes as factories for useful products.
- B. Downstream cost dominates bioprocess economics.
- C. Pasteur, Fleming and recombinant DNA are the three landmark eras.
- D. Match each microbe to its product — examiners love this table.

Answer Key

1. C 2. C 3. B 4. D 5. D 6. C 7. A 8. A 9. B 10. A 11. C 12. D 13. D 14. A 15. A 16. B 17. B 18. A
19. A 20. B 21. C 22. C 23. A 24. B

Exam Pointer

Very important for exams: Attempt all MCQs without looking back, then check the answer key.

Exam Strategy Guide**Learning Objectives**

- Attempt papers with a winning strategy

Before the exam

- Revise the Key Points boxes and glossary first — they carry the highest marks per minute.
- Practice one past paper under timed conditions; examiners repeat question styles.
- Sleep well the night before — an exhausted brain recalls far less.

Attempting the paper

- Read the whole paper first; start with your strongest question to build momentum.
- Allocate time by marks: a 10-mark question deserves roughly double a 5-mark one.
- Structure long answers: definition, explanation, example/diagram, conclusion.

Presentation matters

- Use headings, underline key terms, and draw labelled diagrams where possible.
- Attempt all questions — partial credit beats a blank page.
- Review your paper in the last 10 minutes for missed parts.

Exam Pointer

Very important for exams: Very important for exams: neat, structured answers consistently score higher than longer messy ones.