Bachelor of Science in Biotechnology (4 Years, 240 ECTS)

> A lab-intensive, industry-aligned biotechnology curriculum bridging molecular & cell biology, chemistry, bioinformatics, bioprocess engineering, and regulatory affairs. Structured across 8 semesters (30 ECTS each) with integrated laboratory courses, research experiences, internship, and a two-semester capstone.

Program Overview

- **Award:** B.Sc. in Biotechnology
- **Duration:** 8 Semesters (4 academic years)
- **Total Credits:** 240 ECTS
- **Delivery:** Lectures (L), Tutorials (T), Laboratories (P), Studio/Project (S), Fieldwork (F)
- **Typical Workload:** 1 ECTS ≈ 25–30 hours
- **Pillars:** Molecular & Cell Biology • Biochemistry • Microbiology & Immunology • Genetics & Genomics • Bioinformatics & Data • Analytical Techniques • Bioprocess & Downstream • Quality & Regulatory • Bioethics & Society • Entrepreneurship.

Graduate Learning Outcomes

Graduates will be able to: 1. **Apply** molecular, cellular, and biochemical principles to design experiments and interpret data.
2. **Operate** core lab techniques (PCR/qPCR, cloning, protein expression/purification, chromatography, spectroscopy, microscopy, flow cytometry) with GLP/GMP awareness.
3. **Model & analyze** biological data using statistics, R/Python, and bioinformatics tools (NGS pipelines, sequence analysis).
4. **Design & run** bioprocesses from bench to pilot scale; perform downstream processing and quality testing.
5. **Assess** biosafety, biosecurity, and ethical/regulatory implications of biotech applications.
6. **Communicate** scientific findings effectively; collaborate in multidisciplinary teams.
7. **Translate** discoveries into products via IP, regulatory strategy, and business planning.

Curriculum Map (By Semester)

Each course lists **ECTS**, **L-T-P-S**, **Pre/Co-requisites**, **Assessment**, **Tools**, and **Detailed Topics** with representative labs/projects.

Semester 1 (30 ECTS)

1. **BT101 General Biology I (Cells & Genetics)** (6 ECTS, 3-1-2-0)
   Assessment: Labs/Reports 35%, Midterm 20%, Final 45%

Topics: Cell structure & function, membranes, organelles, mitosis/meiosis, Mendelian genetics, DNA/RNA/protein overview.
Labs: Microscopy & staining, pipetting & dilution series, DNA extraction from plant/yeast.

2. **BT102 General Chemistry I** (6 ECTS, 3-1-2-0)
   Topics: Stoichiometry, thermochemistry, atomic structure, bonding, solutions, acid-base.
   Labs: Titrations, calorimetry, spectroscopy basics.

3. **BT103 Mathematics & Statistics for Biologists I** (6 ECTS, 2-2-0-0)
   Topics: Functions, limits, derivatives, integrals (applications to kinetics), descriptive statistics, probability, experimental design.
   Tools: R/Python notebooks.

4. **BT104 Scientific Communication & Ethics I** (6 ECTS, 2-1-0-1)
   Topics: Scientific writing, figures/tables, citations, lab notebooks, research integrity, intro to bioethics (consent, data).
   Studio: Short research summaries & peer review.

5. **BT105 Laboratory Foundations & Biosafety** (6 ECTS, 1-0-3-1)
   Topics: GLP, BSL-1/2, aseptic technique, waste management, risk assessments, basic instrumentation (pH, balances, centrifuges).
   Labs: Aseptic streaking, culture maintenance, safety drills.

Semester 2 (30 ECTS)

1. **BT106 General Biology II (Physiology & Microbiology)** (6 ECTS, 3-1-2-0)
   Pre: BT101
   Topics: Microbial diversity, growth & control, metabolism, basics of human/plant physiology.
   Labs: Growth curves, antibiotics susceptibility, enzyme kinetics.

2. **BT107 General Chemistry II (Organic & Bio-Organic)** (6 ECTS, 3-1-2-0)
   Pre: BT102
   Topics: Structure, stereochemistry, reaction mechanisms, functional groups relevant to biochemistry.
   Labs: Synthesis of esters, TLC, NMR/IR interpretation (intro).

3. **BT108 Mathematics & Statistics for Biologists II** (6 ECTS, 2-2-0-0)
   Pre: BT103
   Topics: Linear algebra basics, ANOVA/regression, nonparametric tests, power analysis, intro to ODEs for kinetics.
   Tools: R (tidyverse), Python (pandas, scipy, statsmodels).

4. **BT109 Programming & Data Skills** (6 ECTS, 2-1-2-0)
   Topics: Reproducible analysis (R Markdown/Jupyter), data wrangling, visualization, version control, basics of sequence data formats (FASTA/FASTQ).
   Project: Reproducible mini-paper from open dataset.

5. **BT110 Bioethics, Society & Policy** (6 ECTS, 2-1-0-1)
   Topics: Human subjects, gene editing, privacy, benefit sharing, dual-use, One Health perspectives.
   Assessment: Policy brief + debate.

Semester 3 (30 ECTS)

1. **BT201 Biochemistry I (Macromolecules & Enzymes)** (6 ECTS, 3-0-2-0)
   Pre: BT107
   Topics: Proteins, nucleic acids, lipids, carbohydrates; enzyme kinetics & inhibition; buffers.
   Labs: Protein quantification, Michaelis-Menten kinetics, SDS-PAGE.

2. **BT202 Genetics & Molecular Biology** (6 ECTS, 3-0-2-0)
   Pre: BT101
   Topics: DNA replication/repair, transcription/translation, gene regulation, recombinant DNA.
   Labs: PCR, restriction digests, plasmid ligation & transformation.

3. **BT203 Microbiology & Immunology** (6 ECTS, 3-0-2-0)
   Topics: Bacteria/archaea/eukaryotic microbes, virology intro, host-pathogen, innate/adaptive immunity, vaccines.
   Labs: ELISA, agglutination, biosafety/antisepsis.

4. **BT204 Analytical Techniques I** (6 ECTS, 2-0-3-0)
   Topics: Spectrophotometry, fluorimetry, chromatography (HPLC/GC intro), electrophoresis, microscopy basics.
   Labs: HPLC calibration curves, gel documentation, fluorescence assays.

5. **BT205 Scientific Communication & Ethics II** (6 ECTS, 2-1-0-1)
   Focus: Manuscript structure, peer review, data management, preregistration, open science.

Semester 4 (30 ECTS)

1. **BT206 Biochemistry II (Metabolism & Bioenergetics)** (6 ECTS, 3-0-2-0)
   Pre: BT201
   Topics: Glycolysis/TCA/ETC, photosynthesis, lipid & amino acid metabolism, metabolic control & flux.
   Labs: Metabolic assays, respirometry.

2. **BT207 Cell Biology & Microscopy** (6 ECTS, 3-0-2-0)
   Topics: Membrane trafficking, cytoskeleton, signaling, apoptosis, stem cells; imaging (confocal, live-cell).
   Labs: Immunofluorescence, image analysis.

3. **BT208 Bioinformatics I (Sequences & Genomics)** (6 ECTS, 2-0-3-0)
   Pre: BT109
   Topics: Alignment, BLAST, phylogenetics, NGS pipelines (QC→mapping→variant calling), genome

annotation.
Project: Reproduce an RNA-seq or WGS mini-pipeline.

4. **BT209 Analytical Techniques II (Proteomics & Flow Cytometry)** (6 ECTS, 2-0-3-0)
   Topics: Mass spectrometry basics, LC-MS sample prep, 2D-PAGE, Western blot, flow cytometry & FACS.
   Labs: Western blot optimization; basic flow cytometry panel.

5. **BT2E1 Technical Elective I** (6 ECTS)

Semester 5 (30 ECTS)

1. **BT301 Molecular Genetics & Genome Engineering** (6 ECTS, 2-0-3-0)
   Pre: BT202, BT208
   Topics: CRISPR/Cas systems, base/prime editing, gene drives (ethics), knock-in/knock-out strategies.
   Labs: CRISPR design & validation (safe model organism), genotyping.

2. **BT302 Bioprocess Engineering I (Upstream)** (6 ECTS, 2-0-3-0)
   Pre: BT203, BT206
   Topics: Microbial & mammalian cell culture, media design, kinetics, batch/fed-batch/continuous, oxygen transfer, scale-up criteria.
   Labs: Bench bioreactor operation, DO/pH control, growth modeling.

3. **BT303 Downstream Processing & Purification** (6 ECTS, 2-0-3-0)
   Pre: BT204
   Topics: Cell disruption, filtration, centrifugation, precipitation, chromatography (ion exchange, affinity), ultrafiltration, polishing.
   Labs: Purify a recombinant protein; calculate yield & purity.

4. **BT304 Biostatistics & Experimental Design** (6 ECTS, 2-1-2-0)
   Topics: DOE (factorial, response surface), mixed models, multiple testing, reproducibility, power/sample size.
   Tools: R (tidyverse, lme4), JMP/Design-Expert.
   Project: DOE for expression optimization.

5. **BT3E2 Technical Elective II** (6 ECTS)

Semester 6 (30 ECTS)

1. **BT305 Bioprocess Engineering II (Scale-Up & PAT)** (6 ECTS, 2-0-3-0)
   Pre: BT302, BT303
   Topics: Scale-up/down strategies, mixing/aeration, PAT (Raman/NIR), soft sensors, single-use tech, facility layout.
   Labs: kLa determination; PAT data capture & control loop.

2. **BT306 Regulatory Affairs, GMP & Quality Systems** (6 ECTS, 2-1-2-0)
   Topics: GMP/GLP/GCP, QC/QA, validation, documentation, audits, ICH/EMA/FDA frameworks, biosimilar comparability.
   Activities: Mock audit; batch record authoring.

3. **BT307 Immunotechnology & Biologics** (6 ECTS, 2-0-3-0)
   Topics: Monoclonal antibodies, hybridoma & recombinant platforms, Fc engineering, vaccines, adjuvants, analytics (titer, potency).
   Labs: ELISA/QPCR potency; binding assays.

4. **BT3E3 Technical Elective III** (6 ECTS)

5. **BT398 Summer Internship (0 ECTS recorded, required)**
   Deliverables: Learning plan, supervisor evaluation, reflective report.

Semester 7 (30 ECTS)

1. **BT401 Systems & Synthetic Biology** (6 ECTS, 2-0-3-0)
   Pre: BT301, BT208
   Topics: Gene circuits, metabolic engineering, chassis selection, modeling (ODEs, flux balance), standards (SBOL).
   Project: Design-build-test-learn (DBTL) cycle with bench validation.

2. **BT402 Tissue Engineering & Regenerative Medicine** (6 ECTS, 2-0-3-0)
   Topics: Biomaterials, scaffolds, stem cells, bioprinting basics, organoids, mechanobiology, bioreactors for tissues.
   Labs: Hydrogel scaffolds; viability & differentiation assays.

3. **BT403 Environmental & Industrial Biotechnology** (6 ECTS, 2-0-3-0)
   Topics: Bioremediation, wastewater, biofuels/biochemicals, enzyme technology, circular bioeconomy, LCA.
   Labs: Enzyme immobilization; wastewater treatment bench.

4. **BT4E4 Technical Elective IV** (6 ECTS)

5. **BT490 Capstone I (Proposal, Design & Compliance)** (6 ECTS, 0-1-0-4)
   Activities: Problem framing, literature review, risk & ethics (biosafety/biosecurity), design inputs/outputs, V&V plan, regulatory pathway & QMS integration.

Semester 8 (30 ECTS)

1. **BT491 Capstone II (Implementation, Validation & Tech Transfer)** (12 ECTS, 0-0-2-6)
   Deliverables: Working prototype/process, validation data, batch records/SOPs, tech dossier, poster + public demo, reproducible repo/ELN export.

Examples: Engineered enzyme for plastic degradation; CHO process optimization with PAT; CRISPR diagnostic; microbial consortia for wastewater.

2. **BT404 Bioentrepreneurship & IP Strategy** (6 ECTS, 2-1-2-0)
   Topics: Opportunity assessment, market & reimbursement, IP (patents, FTO), licensing, fund-raising, regulatory milestones.
   Studio: Pitch deck + business/regulatory plan.

3. **BT4E5 Technical Elective V** (6 ECTS)

4. **BT405 Global Health, One Health & Sustainability** (6 ECTS, 2-1-0-1)
   Topics: Zoonoses, AMR, surveillance, equity, sustainability metrics (LCA), policy briefs.

Technical Elective Tracks (Sample Menus)

Choose at least **5 electives**; $\geq$ **2** must be lab/process design focused.

Track A — Biopharmaceuticals & Therapeutics

- **BT451 Advanced Protein Engineering** (6 ECTS) — Directed evolution, rational design, stability, developability.
- **BT452 Cell Culture & ATMPs** (6 ECTS) — CAR-T, gene therapies, viral vectors (AAV/Lenti), closed systems, release testing.
- **BT453 Biophysical Characterization** (6 ECTS) — DSC/DLS/ITC, FTIR/Raman, aggregation & stability.

Track B — Genomics, Bioinformatics & Precision Medicine

- **BT461 NGS Data Analysis** (6 ECTS) — RNA-seq, ChIP-seq, variant calling, pipelines, reproducibility.
- **BT462 Clinical Genomics & Diagnostics** (6 ECTS) — Panels, WES/WGS, interpretation, standards (ACMG), quality & reporting.
- **BT463 Machine Learning for Bioinformatics** (6 ECTS) — Feature engineering, classifiers, model validation, ethics/fairness.

Track C — Industrial & Environmental Biotech

- **BT471 Industrial Enzymes & Biocatalysis** (6 ECTS) — Kinetics, immobilization, reactor design.
- **BT472 Biofuels & Biorefineries** (6 ECTS) — Feedstocks, pretreatment, fermentation, separation, TEA/LCA.
- **BT473 Microbial Ecology & Metagenomics** (6 ECTS) — Community analysis, amplicon/WGS, consortia engineering.

Track D — Biomaterials & Medical Devices

- **BT481 Biomaterials Science** (6 ECTS) — Polymers, ceramics, metals, composites; surface modification; degradation.

- **BT482 Medical Device Development & Regulation** (6 ECTS) — ISO 13485, risk mgmt (ISO 14971), usability & validation.
- **BT483 Biosensors & Diagnostics** (6 ECTS) — Electrochemical/optical sensors, microfluidics, PoC devices.

Track E — Quantitative & Computational Biology

- **BT491 Systems Biology Modeling** (6 ECTS) — ODE/FBA/SSA; parameter estimation, identifiability.
- **BT492 Image Analysis & Bioimage Informatics** (6 ECTS) — Segmentation, tracking, ML pipelines, reproducibility.
- **BT493 Structural Biology & Modeling** (6 ECTS) — Homology modeling, docking, MD basics.

Laboratories & Facilities

- **Core teaching labs:** BSL-1/2 spaces; cell culture suites (biosafety cabinets, CO_2 incubators); microbial labs; analytical rooms.
- **Equipment:** PCR/qPCR, gel systems, spectrophotometers/plate readers, HPLC/UPLC, GC, FPLC/AKTA, centrifuges/ultracentrifuges, fermenters/bioreactors (1–10 L bench + pilot), flow cytometer, confocal microscope, lyophilizer, nanoDrop, balances, pH/conductivity meters.
- **Computational:** Linux workstations, HPC access, R/Python, Galaxy, Git, ELN/LIMS.
- **Quality:** Reference materials, SOPs, clean areas, environmental monitoring tools.

Methods, Practices & Safety

- **GLP/GMP:** Documentation, traceability, change control, deviation/CAPA.
- **Biosafety & Biosecurity:** Risk assessment, PPE, waste, transport, select agents overview, dual-use awareness.
- **Data & Reproducibility:** ELN, version control, preregistration, FAIR data.
- **Statistics & DOE:** Embedded across labs with checkpoints.
- **Responsible Innovation:** Ethics, ELSI, stakeholder engagement.

Capstone Design Sequence (BT490/BT491 Details)

- **Phase 1 — Concept & Compliance (BT490):** Problem definition, URS/requirements, hazard/biorisk analysis, experimental plan, regulatory path (device/drug/IVD), quality plan, IP scan, metrics & milestones.
- **Gate A:** Proposal defense; risk & compliance sign-off.
- **Phase 2 — Build, Test & Translate (BT491):** Prototype/process build, verification/validation per plan, analytics & comparability, tech transfer package (SOPs/batch records), usability or field testing, go/no-go analysis.
- **Gate B:** Public demo & dossier submission; post-mortem & knowledge transfer.

Professional Practice & Experiential Learning

- **Internship (after Sem 6):** 6–10 weeks in pharma/biotech, diagnostics, environmental labs, or research institutes.
- **Co-op (optional):** 20–24 weeks spanning Sem 7–8 with academic substitution.
- **Seminar Series:** Monthly industry & research talks; journal clubs; career panels.

Assessment & Quality Assurance

- **Rubrics:** Emphasize scientific rigor, lab technique, data integrity, safety/compliance, and communication.
- **Authentic assessment:** Open-ended labs, practical exams, project notebooks, oral defenses.
- **Integrity:** Plagiarism checks, data audits; viva for major reports.
- **Program review:** Annual external advisory board & outcomes tracking.

Suggested Texts & Resources (Illustrative)

- **Biochemistry:** Lehninger Principles of Biochemistry
- **Molecular Biology:** Molecular Biology of the Cell (Alberts)
- **Microbiology:** Brock Biology of Microorganisms
- **Immunology:** Janeway’s Immunobiology
- **Bioinformatics:** Bioinformatics Data Skills (Vince Buffalo)
- **Bioprocess:** Bioprocess Engineering (Shuler/Kargi/DeLisa) & Bioprocess Engineering Principles (Doran)
- **Regulatory:** FDA/EMA guidance docs; ICH Q8–Q12

Weekly Syllabi Snapshots (Examples)

BT302 Bioprocess Engineering I (Weeks 1–14):
- W1: Media & sterilization; W2: Growth kinetics; W3: Mass balances; W4: Oxygen transfer & kLa; W5: Batch→Fed-batch; W6: Sensors & control; W7: Scale-up criteria; W8: Mammalian culture; W9: Shear & mixing; W10: Case study clinic; W11: Trouble-shooting; W12: DOE workshop; W13: Project integration; W14: Demo day.
Assessments: Labs 35%, Midterm 20%, Final 25%, Project 20%.

BT208 Bioinformatics I (Weeks 1–14):
- W1: UNIX & file formats; W2: QC & trimming; W3: Aligners; W4: Variant calling; W5: RNA-seq quant; W6: Differential expression; W7: Functional annotation; W8: Phylogenetics; W9: Reproducibility & workflow managers; W10: Visualization; W11: Ethics/privacy; W12: Project clinic; W13: Peer review; W14: Presentations.

BT306 Regulatory & GMP (Weeks 1–14):
- W1: Quality systems; W2: GxP landscape; W3: Documentation; W4: Validation; W5: Audits; W6: Change control; W7: Deviations/CAPA; W8: Data integrity; W9: Comparability; W10: ICH guidelines; W11: Case studies; W12: Mock audit; W13: Inspection readiness; W14: Review.

Accreditation Mapping (Template)

- **Math & Science:** ≥ 60 ECTS (biology, chemistry, physics/maths/stats).
- **Engineering/Process:** ≥ 60 ECTS (bioprocess, analytics, modeling, QA/QC).
- **Laboratory/Design:** ≥ 60 ECTS (labs/projects/capstone).
- **Professional Skills:** ≥ 12 ECTS (communication, ethics, regulatory).
- **Experiential:** Internship + capstone with external review.

Customization & Localization Notes

- Align biosafety & waste with national regulations; map to EMA/FDA/WHO where applicable.
- Tailor electives to local strengths (e.g., fermentation for food biotech, alpine environmental biotech, med-device focus).
- Offer language courses for regulatory landscapes in target markets.
- Provide accessibility and inclusive pedagogy provisions.

This syllabus is a comprehensive template. Institutions should calibrate contact hours, prerequisites, and facilities while preserving lab depth, data rigor, process design, and regulatory competence.