Central University of Punjab

Ph.D. in Biotechnology

Session 2026

Department of Biotechnology & Bioinformatics

School of Basic Sciences

Graduate Attributes

Students graduating from the Ph.D. in Biotechnology will contribute to the teaching and research needs in next-generation therapeutics, agricultural biotechnology, industrial bioprocessing, environmental sustainability, and data-driven life sciences in academia, industry, and research institutions at local, regional, national, and international levels. They will be part of the scientific workforce that will transform health, agriculture, environment, and industrial sectors by employing higher-order thinking skills and capabilities. On successful completion of this programme, the students will be able to:

- Design independent research problems and select appropriate methodologies in Biotechnology and allied life sciences
- Investigate real-life biological challenges using advanced biotechnological tools, techniques, and experimental approaches
- Execute cutting-edge research in this multidisciplinary field of science at national and international platforms
- Apply biotechnological interventions to address critical challenges in health, agriculture, environment, and industry
- Integrate knowledge across disciplines such as molecular biology, biochemistry, microbiology, bioprocessing, and bioinformatics to develop innovative solutions
- Communicate research findings effectively through publications, presentations, and scientific writing at peer-reviewed forums
- Demonstrate ethical responsibility, biosafety awareness, and adherence to research integrity standards in all scientific endeavors
- Establish themselves as industrious, independent, and collaborative research personnel in academic or industrial settings
- Continue lifelong learning as autonomous learners and apply critical, creative, and analytical thinking to emerging biotechnological challenges

Course Structure of the Programme in Ph.D. in Biotechnology

S. No.	Course Code	Course Title	Course Type	Hours			
				L	T	P	Cr
1	BIT.701	Research Methodology and Computer Applications	CC	4	0	0	4
2	BIT.751	Research and Publication Ethics	CC	2	0	0	2
3	BIT.752	Teaching Assistantship	CC	0	0	2	1
4	UNI.753	Curriculum, Pedagogy and Evaluation	CC	1	0	0	1
Opt any one of the following courses:							
5	BIT.704	Molecular Structural Biology	DE	4	0	0	4
6	BIT.705	Next-generation Sequencing Data Analysis	DE	4	0	0	4
7	BIT.706	Protein Engineering and Design	DE	4	0	0	4
8	BIT.707	Agricultural Biotechnology	DE	4	0	0	4
9	BIT.708	Biomedical Engineering	DE	4	0	0	4
10	BIT.709	Environmental Biotechnology	DE	4	0	0	4
11	BIT.710	Medical Biotechnology	DE	4	0	0	4
12	BIT.711	Advanced Microbial Technology	DE	4	0	0	4
	Total			**12 Credits**			

CC: Core Course, DE: Discipline Elective, SBE: Skill Based Elective

Mode of Transaction: Lecture, Laboratory based Practical, Seminar, Group discussion, Team teaching, Self-learning, Online tools.

Evaluation Criteria for Theory Courses: End Semester Examination: Based on Subjective Type Test (100 Marks)

Course Title: Research Methodology and Computer Applications
Course Code: BIT.701
Course Type: CC
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):
On completion of this course, students will be able to:

CLO 1: Critically analyse, interpret, and synthesize existing scientific knowledge based on literature review.
CLO2: Identify the knowledge gap and formulate a hypothesis and design experimental/theoretical work.
CLO 3: Apply good laboratory practices and biosafety protocols.
CLO 4: Appreciate the crucial issues in research ethics, like responsibility for research, ethical clearance for experimental studies and scientific misconduct.
CLO 5: Perform hypothesis testing on small and large data samples.
CLO 6: Use correlation and linear regression methods to find a relationship and goodness of fit for the given data.
CLO 7: Retrieve various biological data from the appropriate databases for analysis.
CLO 8: Compare protein structures and perform structure-based drug designing.

Unit/ Hours	Content	Mapping with CLO
I 15 hours	**General Principles of Research:** Meaning and importance of research, Critical thinking, Formulating hypothesis and development of research plan, Review of literature, Interpretation of results and discussion. Bibliographic index **Technical Writing:** Scientific writing, writing synopsis, Research paper, Poster preparation, oral presentations and Dissertations. Reference Management using various softwares such as Endnote, reference manager, Refworks, etc. Communication skills: defining communication; type of communication; techniques of communication, etc.	CLO 1 & CLO 2
II 15 hours	**Introduction and Principles of Good Lab Practices**: Good laboratory practices, Biosafety for human health and environment. Biosafety issues for using cloned genes in medicine, agriculture, industry, and eco-protection, biological containment and physical containment, Biosafety in Clinical laboratories and biohazard management, Physical, Chemical & Biological hazards and their mitigation. Biosafety level/category of pathogens. Biosafety level of laboratories, WHO/CDC/DBT guidelines for biosafety. **Research Ethics:** Ethical theories, Ethical considerations during research, consent. Animal handling/testing, Animal experimental models and animal ethics. Perspectives and methodology & Ethical issues of the human genome project, ICMR guidelines for biomedical and health research. Intellectual property protection (IPP) and intellectual property rights (IPR), WTO (World Trade Organization), WIPO (World Intellectual Property Organization), GATT (General Agreement on Tariff and Trade), TRIPs (Trade Related Intellectual Property Rights), TRIMS (Trade Related Investment Measures) and GATS (General Agreement on Trades in Services). Patents, Technology Development/Transfer Commercialization Related Aspects, Ethics.	CLO3 & CLO4

III 15 hours	**Computer Applications and Biostatistics:** Introduction to spreadsheet, presentation tools. Reference Management software. Role of Cloud computing and HPC in life science research. Introduction to Big data in biology and big data analytics. Data types and sources – variables and types. Descriptive statistics of categorical data and continuous data. Estimation of parameters – hypothesis testing: tests of significance, type I and II errors, z test, t test, analysis of variance (ANOVA), chi-square goodness-of-fit test. Regression and correlation. Statistical packages and their applications.	CLO 5 & CLO 6
IV 15 hours	**Bioinformatics:** Sequence, structure, gene expression, pathway databases. Introduction to Next generation Sequencing. Pair- wise, local and global sequence analysis, BLAST, PHI-BLAST and Multiple sequence alignment. Molecular phylogeny - building phylogenetic trees. Applications of Artificial Intelligence and Machine Learning in genomics, transcriptomics, proteomics and Biomedical Image analysis. Introduction to Protein structure, Structure comparison and visualization, Structure classification of protein: CATH and SCOP. Introduction to molecular modeling and structure-based drug designing. AI-driven approaches for protein structure prediction, biomolecular interaction prediction, functional annotation, and precision medicine.	CLO 7 & CLO 8

Suggested Readings

1. Gupta, S. (2010). *Research Methodology and Statistical Techniques*. Deep and Deep Publications.
2. Kothari, C.R. and Garg, G. (2019). *Research Methodology: Methods and Techniques* (4th ed.). New Age International Publishers.
3. Sahay, V. and Singh, P. (2009). *Encyclopedia of Research Methodology in Life Sciences*. Anmol Publications.
4. Kauda, J. (2012). *Research Methodology: A Project Guide for University Students*. Samfundslitteratur Publications.
5. Dharmapalan, B. (2012). *Scientific Research Methodology*. Narosa Publishing.
6. Norman, G. and Streiner, D. (2014). *Biostatistics: The Bare Essentials* (4th ed.). PMPH-USA.
7. Rao, P.P., Sundar, S. and Richard, J. (2009). *Introduction to Biostatistics and Research Methods*. PHI Learning.
8. Christensen, L. (2007). *Experimental Methodology*. Allyn and Bacon.
9. Fleming, D.O. and Hunt, D.L. (2006). *Biological Safety: Principles and Practices*. American Society for Microbiology Press.
10. Rockman, H.B. (2004). *Intellectual Property Law for Engineers and Scientists*. Wiley-IEEE Press.
11. Shannon, T.A. (2009). *An Introduction to Bioethics*. Paulist Press.
12. Vaughn, L. (2012). *Bioethics: Principles, Issues, and Cases* (2nd ed.). Oxford University Press.
13. Lesk, A.M. (2019). *Introduction to Bioinformatics* (5th ed.). Oxford University Press.
14. Ramsden, J. (2021). *Bioinformatics: An Introduction* (4th ed.). Springer International Publishing.
15. Mount, D.W. (2004). *Bioinformatics: Sequence and Genome Analysis* (2nd ed.). Cold Spring Harbor Laboratory Press.
16. Branden, C. and Tooze, J. (1999). *Introduction to Protein Structure* (2nd ed.). Garland Science

Course Title: Research and Publication Ethics
Course Code: BIT.751
Course Type: CC
Total Hours: 30

L	T	P	Cr
2	0	0	2

Course Learning Outcomes (CLO):
On completion of this course, students will be able to:

CLO1: Describe with the ethics of research.
CLO2: Outline the good practices to be followed in research and publication. CLO3: Describe various aspects of Publication ethics
CLO3: Appreciate the importance of Open access publication CLO5: Identify the misconduct, fraud and plagiarism in research.
CLO4: Utilize various online resources and software to analyze their research output.

Units/ Hours	Contents	Mapping with CLO
I 5 Hours	**Philosophy and Ethics** • Introduction to philosophy: definition, nature and scope, concept, branches • Ethics: definition, moral philosophy, nature of moral judgements and reactions **Learning Activities:** Case studies, Student presentation and group discission.	CLO1
II 5 Hours	**Scientific Conduct** • Ethics with respect to science and research • Intellectual honesty and research integrity • Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP) • Redundant publications: duplicate and overlapping publications, salami slicing • Selective reporting and misrepresentation of database **Learning Activities:** Case studies, Problem based learning, Student presentation and group discission.	CLO2
III 5 Hours	**Publication Ethics** • Publication ethics: definition, introduction and importance • Best practices/standards setting initiatives and guidelines: COPE, WAME, etc. • Conflicts of interest • Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types • Violation of publication ethics, authorship and contributorship • Identification of publication misconduct complaints and appeals • Predatory publishers and journals	CLO3

	Learning Activities: Case studies, Problem based learning, Student presentation and group discission	
IV 5 Hours	**Open Access Publishing** • Open access publication and initiatives • SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies • Software tool to identify predatory publications developed by SPPU • Journal finder/journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester etc. **Learning Activities**: Case studies, Problem based learning, Student presentation and group discission.	CLO4
V 5 Hours	**Publication Misconduct:** **A. Group Discussion:** • Subject specific ethical issues, FFP, authorship • Conflicts of interest • Complaints and appeals: examples and fraud from India and abroad **B. Software Tools:** Use of plagiarism software like Turnitin, Urkund and other open-source software tools **Learning Activities**: Case studies, Problem based learning, Student presentation and group discission.	CLO5
VI 5 Hours	**Databases and Research Metrics** **A. Databases** 1. Indexing databases 2. Citation databases: Web of Science, Scopus, etc. **B. Research Metrics** 1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score 2. Metrics: h-index, g-index, i10 index, altmetrics **Learning Activities**: Concept mapping, Problem based learning, Student presentation and group discission.	CLO6

Transactional Modes: Classroom teaching. guest lecture, group discussion, and practical sessions

Suggested Readings

- Lillie, W. (1967). An Introduction to Ethics. Allied Publishers Pvt. Ltd.; 1 edition.
- MacKenzie, J.S. (2005). A Manual of Ethics. Cosimo Classics.
- Committee on Publication Ethics (COPE). How to handle authorship disputes: a guide for new researchers. 2003. Available at: publicationethics.org/files/2003pdf12.pdf. Accessed on June 17, 2017.
- Elsevier. Publishing Ethics Resource Kit (PERK). (2017) Available at: elsevier.com/editors/perk/plagiarism-complaints.

Course Title: Teaching Assistantship
Course Code: BIT.752
Course Type: CC
Total Hours: 30

L	T	P	Cr
1	0	0	1

Course Learning Outcomes:
On completion of this course, students will be able to:

CLO1: Familiarize themselves with the pedagogical practices of effective classroom delivery and knowledge evaluation system
CLO2: Manage large and small classes using appropriate pedagogical techniques for different types of content

Activities and Evaluation:

- The scholars shall attend master's degree classes of his/her supervisor to observe the various transaction modes that the supervisor follows in the classroom delivery or transaction process one period per week.
- The scholars shall be assigned one period per week under the direct supervision of his/her supervisor to teach the master's degree students adopting appropriate teaching strategy(s).
- The scholars shall be involved in examination and evaluation system of the master's degree students such as preparation of questions, conduct of examination and preparation of results under the direction of the supervisor.
- At the end of the semester, the supervisor shall conduct an examination of teaching skills learned by the scholar as per the following evaluation criteria:
    - The scholars shall be given a topic relevant to the master's degree course of the current semester as his/her specialization to prepare lessons and deliver in the classroom before the master's degree students for one hour (45 minutes teaching + 15 minutes interaction).
    - The scholars shall be evaluated for a total of 50 marks comprising *content knowledge* (10 marks), *explanation and demonstration skills* (10 marks), *communication skills* (10 marks), *teaching techniques employed* (10 marks), and classroom interactions (10).

Course Title: Curriculum, Pedagogy and Evaluation
Course Code: **UNI.753**
Course Type: CC
Total Hours: 15

L	T	P	Cr
1	0	0	1

Course Learning Outcomes (CLO):
On completion of this course, students will be able to:

CLO1: Analyze the principles and bases of curriculum design and development CLO2: Examine the processes involved in curriculum development
CLO2: Develop the skills of adopting innovative pedagogies and conducting students' assessment
CLO3: Develop curriculum of a specific course/programme

Units/ Hours	Contents	Mapping with CLO
I 4 Hours	**Bases and Principles of Curriculum** Curriculum: Concept and Principles of curriculum development, Foundations of Curriculum Development. Types of Curriculum Designs- Subject centered, learner centered, experience centered and core curriculum. Designing local, national, regional and global specific curriculum. Choice Based Credit System and its implementation.	CLO1
II 4 Hours	**Curriculum Development** Process of Curriculum Development: Formulation of graduate attributes, course/learning outcomes, content selection, organization of content and learning experiences, transaction process. Comparison among Interdisciplinary, multidisciplinary and trans-disciplinary approaches to curriculum.	CLO2
III 3 Hours	**Curriculum and Pedagogy** Conceptual understanding of Pedagogy. Pedagogies: Peeragogy, Cybergogy and Heutagogy with special emphasis on Blended learning, Flipped learning, Dialogue, cooperative and collaborative learning Three e- techniques: Moodle, Edmodo, Google classroom	CLO3
IV 4 Hours	**Learners' Assessment** Assessment Preparation: Concept, purpose, and principles of preparing objective and subjective questions. Conducting Assessment: Modes of conducting assessment – offline and online; use of ICT in conducting assessments. Evaluation: Formative and Summative assessments, Outcome based assessment, and scoring criteria	CLO4

Transaction Mode Lecture, dialogue, peer group discussion, workshop

Evaluation criteria: There shall be an end term evaluation of the course for 50 marks for duration of 2 hours. The course coordinator shall conduct the evaluation.

Suggested Readings

1. Allyn, B., Beane, J. A., Conrad, E. P., & Samuel J. A., (1986). *Curriculum Planning and Development*. Boston: Allyn & Bacon.
2. Brady, L. (1995). *Curriculum Development*. Prentice Hall: Delhi. National Council of Educational Research and Training.
3. Deng, Z. (2007). Knowing the subject matter of science curriculum, *Journal of Curriculum Studies*, 39(5), 503-535. https://doi.org/10.1080/00220270701305362
4. Gronlund, N. E. & Linn, R. L. (2003). *Measurement and Assessment in teaching*. Singapore: Pearson Education
5. McNeil, J. D. (1990). *Curriculum: A Comprehensive Introduction*, London: Scott, Foreman/Little
6. Nehru, R. S. S. (2015). *Principles of Curriculum*. New Delhi: APH Publishing Corporation.
7. Oliva, P. F. (2001). *Developing the curriculum* (Fifth Ed.). New York, NY: Longman
8. Stein, J. and Graham, C. (2014). *Essentials for Blended Learning: A Standards-Based Guide*. New York, NY: Routledge.

Web Resources

- https://www.westernsydney.edu.au/ data/assets/pdf_file/0004/467095 /Fundamentals_of_Blended_Learning.pdf
- https://www.uhd.edu/academics/university-college/centers-offices/teaching-learning-excellence/Pages/Principles-of-a-Flipped-Classroom.aspx
- http://leerwegdialoog.nl/wp-content/uploads/2018/06/180621-Article- The-Basic-Principles-of-Dialogue-by-Renate-van-der-Veen-and-Olga- Plokhooij.pdf

Course Title: Molecular Structural Biology
Course Code: BIT.704
Course type: DE
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):
On completion of this course, students will be able to:

CLO1: Describe the structural organization of biological macromolecules, interpret PDB coordinate files, and evaluate structure quality using validation tools and experimental methods.
CLO2: Apply computational tools for protein structure comparison, prediction, and function assignment, and critically assess deep learning approaches including AlphaFold in structural biology.
CLO3: Explain the structural basis of DNA replication, transcription, and translation, and relate macromolecular machinery to mechanistic understanding of these fundamental processes.
CLO4: Analyze the structural basis of cell signalling pathways, macromolecular assemblies, and systems-level organization, connecting molecular architecture to cellular function.

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	**Introduction to protein structures:** Introduction to biological macromolecules, Structural organization of proteins, Factors responsible for Protein folding and stability, Structure determination methods - X-ray crystallography, NMR, Cryo-electron microscopy, SAXS and Neutron scattering. Introduction to PDB Data-file formats, visualizing Structures, reading coordinate files, potential challenges. Structure validation - Ramachandran plot. Software for quality check. Structural Genomics initiatives. **Learning Activities:** Peer discussion, visualization and analysing of protein structures, training on various structural databases and validation, Visit and demonstration of X-ray, NMR and EM facilities.	CLO1
II 15 Hours	**Structure comparison and structure prediction:** Protein structure comparison and alignment, sequence-structure relationship, Structure comparison, multiple structure alignment. Structural domains, Relationship between structure and function, assigning function from structure. Secondary structure prediction methods, Protein- Comparative modeling, Threading, Ab initio modeling, introduction to Deep-learning algorithms in protein structure prediction, Introduction to Membrane Protein Structure Prediction CASP experiments. **Learning Activities:** Hands-on training structure comparison, prediction, Peer group discussion, Student seminars on recent developments	CLO2

III 15 Hours	**Structural perspective of DNA synthesis, transcription and translation:** Replication, mechanism of DNA synthesis, requirements for DNA synthesis in a bacterium, initiation of bacterial DNA replication, unwinding of the DNA – helicase and helicase loader, priming the DNA synthesis, disentanglement of replication products, a glimpse of eukaryotic replication. Bacterial transcription, eukaryotic transcription, prokaryotic regulation, eukaryotic regulation, post- transcription modifications and mRNA processing. RNA – processing, splicing, editing, translation – protein synthesis - the ribosome; initiation of translation – prokaryotic, eukaryotic; translation elongation – Decoding, peptidyl transfer, translocation, translation termination; post- translation modifications. **Learning Activities:** Peer discussion, visualization and analyzing of protein structures.	CLO3
IV 15 Hours	**Structure in cell signaling to systems biology:** Cell signaling, pathway as signal amplifier, signaling by phosphorylation, cAMP signaling pathway; GPCR and Kinase mediated MAPK pathway; structural basis for immune response; structural systems biology; macromolecular assemblies, ATPases, molecular self– assembly - viral capsids, structural assemblies utilized in the study of macromolecular dynamics. **Learning Activities:** Peer discussion, visualization and analyzing of protein structures.	CLO4

Transactional Modes: Lecture, Laboratory based Practical, Seminar, Group discussion, Team teaching, Self-learning, Online tools.

Suggested Readings

1. Branden, C. and Tooze, J. (1999). Introduction to Protein Structure, Garland Publishing Inc., 2e
2. Pal, S. (2020). Fundamentals of Molecular Structural Biology. Academic Press. ISBN: 9780128148556.
3. Gu, J. and Bourne, P. E. (2009) Structural Bioinformatics, John Wiley & Sons, 2e,
4. Liljas, A and L. Liljas, J. Piskur, G. Lindblom, P. Nissen and M. Kjeldgaard. (2009) Textbook of Structural Biology. World Scientific Publishing Co.
5. Rupp, B. (2009) Biomolecular Crystallography: Principles, Practice, and Application to Structural Biology. Garland Science.
6. Gromiha, M.M., (2010) Protein Bioinformatics, From Sequence to Function, Academic Press, USA, 1e.
7. Zhou, Y., Kloczkowski, A., Faraggi, E., and Yang, Y. (2017). Prediction of protein secondary structure. Humana Press. ISBN: 9781493964048, 9781493964048.
8. Kihara, D. (2014). Protein structure prediction. New York, NY, USA: Humana Press.
9. Anderson, W. F. (2014). Structural genomics and drug discovery. Methods and Protocols, 1. Humana Press.

Course Title: Next-generation Sequencing Data Analysis
Course Code: BIT.705
Course type: DE
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):
On completion of this course, students will be able to,

CLO1: Compare NGS platforms and explain the principles underlying genome, transcriptome, and epigenome sequencing technologies including single-cell and long-read approaches.
CLO2: Execute NGS data analysis workflows - quality control, alignment, and variant calling - using standard file formats and bioinformatics tools.
CLO3: Apply NGS data analysis pipelines for DNA-seq, RNA-seq, and ChIP-seq to interpret biological findings from raw sequencing data.
CLO4: Evaluate large-scale NGS applications in genomics, metagenomics, epigenomics, and precision medicine, connecting sequencing data to biological and clinical insights

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	**NGS and its application to Genome, Transcriptome and Epigenome Sequencing.** Introduction to NGS platforms (Roche 454, AB SOLiD, Illumina, Ion Torrent, PacBio, Nanopore sequencing). Total RNA and mRNA seq, targeted RNA-seq and small noncoding RNA-seq, single-cell RNA-sequencing (scRNA-seq); Epigenomics: Methylation sequencing (Methylated DNA immunoprecipitation sequencing (MeDIP-Seq), bisulfite sequencing (BS-seq), ChIP-Seq. **Learning Activities:** Peer discussion, Seminars on application of the techniques, Visit and demonstration of NGS platforms	CLO1
II 15 Hours	NGS data Analysis workflow file formats and tools Primary, secondary and Tertiary analysis; Sequence quality evaluation - Phred Scores; Quality Control and Preprocessing; post alignment quality and bias control; Types of NGS data; File formats - FASTQ, SAM, BAM, VCF; Online NGS databases. Introduction to Galaxy, Bioconductor, velvet. **Learning Activities:** Hands-on training in sequence analysis, Seminars on application of the techniques, Case studies, research paper discussion	CLO2
III 15 Hours	**NGS Data Analysis:** Sequence alignment algorithms-short reads alignment - Suffix tree, indexing, Burrows-Wheeler transformation; Genome Assembly using deBruijn Graphs; Types of NGS data; File formats - FASTQ, SAM, BAM, VCF; Online NGS databases.	CLO3

	DNA Seq data analysis - Sequence mappability, Refined alignment, Quality recalibration, Variant identification, Variant quality recalibration. RNA-Seq data analysis-Differential Expression Analysis Workflow; Aligning Reads to Reference; Transcriptome Assembly; Alignment programs; Spliced alignment Quantitation and Annotation- Based Quality Control; quantitation of gene expression ChIP-Seq - Principle, Experimental workflow; ChIP- Seq data analysis-ChIP-Seq Peak Calling; Software for ChIP-Seq Peak Calling; Peak Annotation; DNA-protein binding site identification; The ENCODE Project. **Learning Activities:** Discussion and seminars on application of the techniques, Case studies, research paper discussion	
IV 15 Hours	**NGS Applications:** Large-scale (Genome 10K project; Tree of life sequencing project); cell and cell compartment applications (Single-cell and Mitochondria genome sequencing); Disease-targeted sequencing (Inherited and complex human diseases); Human gut microbiome and Metagenomic impact on human diseases and health; Precision medicine using personal genome sequencing; animal and plant diversity analysis using whole genome sequencing. Epigenomics, epigenetics of the immune system, epigenomics to improve cancer therapies- case studies **Learning Activities:** Peer discussion, hands-on training in sequence analysis, Seminars on application of the techniques, Case studies, research paper discussion.	CLO4

Transactional Modes: Lecture, Laboratory based Practical, Seminar, Group discussion, Team teaching, Self-learning, Online tools.

Suggested Readings:

1. Brown, S. M. (2013). Next-Generation DNA Sequencing Informatics. Cold Spring Harbor Laboratory Press, 1/e.
2. Xinkun Wang. (2016). Next-Generation Sequencing Data Analysis. Talyor and Francis Group.
3. Low, L., & Tammi, M. (2017). Introduction to next generation sequencing technologies. Bioinformatics: A Practical Handbook Of Next Generation Sequencing And Its Applications.
4. Korpelainen et al (2015). RNA-seq Data Analysis – A Practical Approach, CRC Press, Taylor & Francis Group, 1e.
5. Jianping Xu. (2014). Next-generation sequencing: Current Technologies and Applications. Caister Academic Press, 1/e.

Course Title: Protein Engineering and Design
Course Code: BIT.706
Course type: DE
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):
On completion of this course, students will be able to:

CLO1: Apply principles of protein folding, stability, and mutagenesis to design experimental strategies for engineering proteins with enhanced or altered properties using both canonical and non-canonical approaches.
CLO2: Design protein structures and functional assemblies using rational, combinatorial, and de novo strategies, and evaluate design principles through experimental and computational validation.
CLO3: Implement computational protein design workflows, and deep learning platforms to predict, model, and engineer protein sequences and structures for defined functional outcomes.
CLO4: Evaluate and propose advanced protein engineering applications in biocatalysis, antibody therapeutics, cellular imaging, and AI-guided design, connecting molecular engineering to translational and industrial outcomes.

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	**Protein Folding, Stability and Engineering Methods**: Protein structural hierarchy; folding theory - thermodynamic and kinetic frameworks, Levinthal paradox, folding funnel, and energy landscape. Folding pathways, chaperones, and folding accessory proteins. Conformational diseases - amyloid, prions, and misfolding. Thermostable proteins - structural determinants of stability. Protein expression and purification - *E. coli* and *S. cerevisiae* systems, optimisation strategies. Mutagenesis methods - chemical, oligonucleotide-directed, cassette, PCR-based, saturation mutagenesis. Engineering with non-canonical amino acids - amber suppression, expanded genetic code, backbone and side-chain applications including collagen dissection. **Learning Activities:** Peer discussion, Demonstration using PyMOL and physical folding models, Student seminars, Research paper discussion, Problem-based learning.	CLO1
II 15 Hours	**Strategies for Protein and Assembly Design:** Rational protein design - sequence–structure–function relationships; retrofitting natural proteins with novel functions; incorporating binding sites into existing scaffolds. Design of structural assemblies - self-assembly, ligand-induced assembly, covalent cross-linking, and peptide assembly on synthetic templates. De novo protein design - design of α-helical bundles, β-sheets, and mixed topologies. Membrane protein and ion channel design. Design of catalytically active proteins. Directed evolution - error-prone PCR, DNA shuffling, PACE; high-throughput screening and selection strategies. Allostery engineering - domain insertions, protein fusions, and	CLO2

	combinatorial linker approaches. Design of novel biomaterials and functional nanostructures. **Learning Activities:** Case-based discussion, Research paper discussion, Problem-based learning, Seminar, Peer discussion, Hands-on training on protein design databases and literature.	
III 15 Hours	**Computational Protein Design and AI-Driven Approaches**: Principles of computational protein design - energy functions, rotamer libraries, and sequence optimisation. Rosetta fixed-backbone and de novo design. Protein language models. Protein inverse folding and sequence design. AlphaFold and ESMFold - architecture, training data, accuracy, and use in engineering workflows. Generative models - diffusion-based and flow-matching approaches for protein design. ML-guided directed evolution - fitness landscape navigation, Bayesian optimisation, and active learning. Case studies - computationally designed enzymes, de novo binding proteins, and miniprotein inhibitors. **Learning Activities:** Hands-on training on Rosetta, AlphaFold, ProteinMPNN, RFdiffusion, and ESM platforms, Problem-based learning, Seminar, Research paper discussion, Peer discussion.	CLO3
IV 15 Hours	**Advanced Applications in Protein Engineering**: Engineering artificial metalloenzymes - cofactor incorporation and directed evolution of metal-binding sites. Engineered cytochrome P450s for regio- and stereoselective biocatalysis. Antibody engineering - humanisation, affinity maturation, bispecific antibodies, nanobodies, VHH domains, and antibody–drug conjugates. CAR-T cell engineering and receptor design. **Learning Activities:** Peer discussion, Case-based discussion, Research paper discussion, Seminar, Hands-on training on antibody design tools, docking platforms, and AI drug discovery pipelines, Problem-based learning.	CLO4

Transactional Modes: Lecture, Laboratory based Practical, Seminar, Group discussion, Team teaching, Self-learning, Online tools.

Suggested Readings

1. Zhao, H. (Ed.) (2021). Protein Engineering: Tools and Applications. Wiley-VCH Verlag GmbH & Co., Germany.
2. Lutz, S. and Bornscheuer, U.T. (Eds.) (2012). Protein Engineering Handbook (Vols. 1–3). Wiley-VCH Verlag GmbH & Co., Germany.
3. Park, S.J. and Cochran, J.R. (Eds.) (2010). Protein Engineering and Design (1st ed.). CRC Press / Taylor and Francis, USA.
4. Samish, I. (Ed.) (2017). Computational Protein Design (1st ed.). Humana Press, New York, USA.
5. Branden, C.I. and Tooze, J. (1999). Introduction to Protein Structure (2nd ed.). Garland Science, USA.

6. Carey, P.R. (Ed.) (1996). Protein Engineering and Design (1st ed.). Academic Press, USA.
7. Fersht, A. (1999). Structure and Mechanism in Protein Science: A Guide to Enzyme Catalysis and Protein Folding. W.H. Freeman, USA.
8. Arnold, F.H. and Georgiou, G. (Eds.) (2003). Directed Enzyme Evolution: Screening and Selection Methods. Humana Press, USA.
9. Damborsky, J., Brezovsky, J., and Bednar, D. (Eds.) (2021). Computational Tools for Protein Engineering. Springer, Germany.
10. Lesk, A.M. (2016). Introduction to Protein Science: Architecture, Function and Genomics (3rd ed.). Oxford University Press, UK.

Course Title: Agricultural Biotechnology
Course Code: BIT.707
Course type: DE
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):

On completion of this course, students will be able to,

CLO1: Critically evaluate molecular mechanisms governing plant development, signalling, and adaptive responses to environmental cues
CLO2: Design and assess plant transformation strategies and genome editing approaches for trait improvement.
CLO3: Integrate multi-omics datasets for functional gene characterisation and molecular breeding applications.
CLO4: Analyse regulatory, biosafety, and bioethical frameworks governing GM crops and plant-derived products

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	**Plant Molecular Biology and Developmental Signalling** Molecular basis of meristem identity and organ differentiation; WUSCHEL–CLAVATA signalling axis; floral transition and vernalisation at the chromatin level. Phytohormone signalling networks - auxin, cytokinin, ABA, ethylene, and strigolactones; cross-talk and context-dependent regulation. Light perception and circadian regulation: phytochromes, cryptochromes, phototropins; clock-output pathways controlling growth and development. Nitrogen and carbon sensing; source–sink dynamics; phloem systemic signalling including mobile RNAs and proteins. Plant–microbe molecular dialogue: Nod factor signalling, mycorrhizal symbiosis, and effector-triggered immunity. **Learning Activities:** Journal club, pathway mapping exercise, peer discussion	CLO1
II 15 Hours	**Plant Transformation and Genome Engineering** Agrobacterium biology: VirD2, VirE2, T-strand, and host chromatin targeting — mechanistic depth. Binary vector architecture; promoter selection (tissue-specific, inducible, synthetic); marker elimination strategies. Biolistics, protoplast electroporation, and floral dip — comparative efficiency and species range. Chloroplast transformation: high-expression advantage and transgene biocontainment. CRISPR-Cas9, Cas12a, base editing, and prime editing in crops - delivery as RNP versus DNA; off-target assessment. Transgene silencing - PTGS and TGS mechanisms; strategies for stable expression. Regulatory gene stacking; site-specific recombination (Cre-lox, Flp-FRT). **Learning Activities:** Vector design exercise, case study on recalcitrant crop transformation, group debate	CLO2
III 15 Hours	**Omics, Functional Genomics, and Molecular Breeding** Structural and functional genomics of major crop species; pan-genome concepts and graph-based genome assembly.	CLO3

	Transcriptomics (bulk RNA-Seq, single-cell RNA-Seq), proteomics, and metabolomics - integration strategies for gene function assignment. eQTL mapping; GWAS in polyploid crops; genomic selection models. Marker-assisted backcrossing, foreground and background selection, gene pyramiding for complex traits. Speed breeding and its integration with genomic tools. Epigenomics: DNA methylation, histone modification, and their role in gene regulation and stress memory. Metagenomics of the rhizosphere; microbiome engineering for crop productivity. **Learning Activities:** Hands-on training on bioinformatics tools (Galaxy, KEGG, STRING), research paper analysis, peer discussion on pan-genome concepts	
IV 15 Hours	**Stress Biotechnology, Applied Products, and Regulatory Frameworks** Molecular engineering of drought, salinity, heat, and combined stress tolerance - transcription factor networks (DREB, MYB, NAC), osmolyte pathways, and ROS management. Biotic stress: effector biology, NLR protein function, broad-spectrum resistance strategies, and RNAi-based approaches. Molecular farming: plant-derived vaccines, antibodies (plantibodies), and industrial enzymes - current status and scale-up challenges. Biofortification: Golden Rice, high-lysine maize, iron-rich legumes — metabolic engineering approaches. Biosafety assessment of transgenic and gene-edited crops; Cartagena Protocol; GEAC and national regulatory pathways in India. IPR in plant biotechnology - Plant Variety Protection, UPOV, CBD/Nagoya Protocol; benefit sharing and farmers' rights. **Learning Activities:** Policy document analysis, case studies on GM crop regulation, seminar on biosafety and IPR, peer discussion	CLO4

Transactional Modes: Lecture, Laboratory based Practical, Seminar, Group discussion, Team teaching, Self-learning, Online tools.

Suggested Books

1. Buchanan, B.B., Gruissem, W. and Jones, R.L. (eds.) (2015). Biochemistry and Molecular Biology of Plants (2nd ed.). Wiley-Blackwell, New Jersey, USA.
2. Slater, A., Scott, N. and Fowler, M. (2008). Plant Biotechnology: The Genetic Manipulation of Plants (2nd ed.). Oxford University Press, Oxford, UK.
3. Primrose, S.B. and Twyman, R.M. (2006). Principles of Gene Manipulation and Genomics (7th ed.). Blackwell Publishing, Oxford, UK.
4. Acquaah, G. (2012). Principles of Plant Genetics and Breeding (2nd ed.). Wiley-Blackwell, Oxford, UK.
5. Taiz, L., Zeiger, E., Møller, I.M. and Murphy, A. (2015). Plant Physiology and Development (6th ed.). Sinauer Associates, Massachusetts, USA.
6. Glick, B.R. and Pasternak, J.J. (2003). Molecular Biotechnology: Principles and Applications of Recombinant DNA (3rd ed.). ASM Press, Washington DC, USA.

Course Title: Biomedical Engineering
Course Code: BIT.708
Course type: DE
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):
On completion of this course, students will be able to,

CLO 1: Evaluate the working principles, signal characteristics, and clinical applications of biomedical sensors and bioinstrumentation systems.
CLO 2: Analyse biomechanical behaviour of hard and soft biological tissues and apply biomaterial concepts in implant and tissue engineering contexts.
CLO 3: Interpret image formation physics and reconstruction algorithms across major medical imaging modalities.
CLO 4: Design and critically assess biosensor platforms, point-of-care devices, and AI-integrated diagnostic systems

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	**Bioinstrumentation and Biosignals:** Origin and characteristics of biopotentials - ECG, EEG, EMG, EOG, ERG; signal acquisition, amplification, and noise reduction. Sensor types: resistive, capacitive, inductive, piezoelectric, electrochemical, and optical; signal conditioning circuits. Measurement of physiological parameters - blood pressure, temperature, flow, respiratory function, cardiac output. Operating principles of clinical instruments: pacemaker, defibrillator, ventilator, pulse oximeter, haemodialyser, sphygmomanometer. Electrical safety and isolation in biomedical devices; regulatory standards. **Learning Activities:** Research paper reading, case study on clinical device failure analysis, peer discussion on signal artefact identification	CLO1
II 15 Hours	**Biomechanics and Biomaterials:** Mechanical behaviour of hard tissues - cortical and cancellous bone; stress-strain relationships, viscoelastic models. Soft tissue mechanics - tendon, cartilage, skin; constitutive models and anisotropy. Gait analysis; joint forces and free-body diagram approaches. Biofluid mechanics - blood rheology, non-Newtonian behaviour, Poiseuille and Womersley flow in vessels. Biomaterials - metallic, ceramic, polymeric, and composite; biocompatibility, biodegradation, and surface modification. Characterisation: AFM, SEM, TEM, FTIR, rheology. Basics of drug delivery systems and scaffold design for tissue engineering. **Learning Activities:** Case studies on implant failure and biomaterial selection, hands-on exposure to FTIR/rheology data interpretation, peer discussion	CLO2
III 15 Hours	**Medical Imaging Systems:** X-ray physics - attenuation, contrast, and detector systems. Computed tomography: Hounsfield units, reconstruction algorithms (filtered back projection, iterative methods). MRI - spin physics, pulse	CLO3

	sequences (T1, T2, FLAIR), k-space, functional MRI. PET and SPECT - radiotracers, coincidence detection, quantitative imaging. Ultrasound - piezoelectric transducers, A/B/M-mode, Doppler imaging. Image quality metrics: SNR, CNR, spatial resolution, and artefacts across modalities. Hybrid imaging - PET-CT, PET-MRI; AI-assisted image reconstruction and segmentation. **Learning Activities:** Comparative analysis of imaging modalities, research paper discussion on AI in radiology, case studies on imaging artefacts	
IV 15 Hours	**Biosensors, Point-of-Care Diagnostics, and Emerging Technologies:** Biosensor architecture - recognition elements (antibody, aptamer, enzyme, nucleic acid), transduction mechanisms (electrochemical, optical, piezoelectric, thermal). Immobilisation strategies and surface functionalisation. Microfluidics and lab-on-chip platforms; lateral flow assay design. Wearable and implantable sensors - continuous glucose monitoring, sweat-based diagnostics. Point-of-care device development: from bench to bedside, regulatory pathway (CDSCO, FDA). Organ-on-chip and microphysiological systems. AI and machine learning integration in diagnostic platforms; digital health and remote patient monitoring. **Learning Activities:** Hands-on training on electrochemical biosensor data analysis, seminar on regulatory approval of POC devices, peer discussion on wearable sensor literature	CLO4

Transactional Modes: Lecture, Laboratory-based Practical, Seminar, Group Discussion, Team Teaching, Self-learning, Online Tools.

Suggested Books

1. Webster, J.G. and Nimunkar, A.J. (eds.) (2020). Medical Instrumentation: Application and Design (5th ed.). John Wiley & Sons, New Jersey, USA.
2. Enderle, J.D. and Bronzino, J.D. (eds.) (2012). Introduction to Biomedical Engineering (3rd ed.). Academic Press, Massachusetts, USA.
3. Eggins, B.R. (2008). Chemical Sensors and Biosensors (2nd ed.). John Wiley & Sons, Chichester, UK.
4. Palchetti, I. and Mascini, M. (eds.) (2023). Biosensors and Bioelectronics: Fundamentals and Applications. Springer, Cham, Switzerland.
5. Saltzman, W.M. (2015). Biomedical Engineering: Bridging Medicine and Technology (2nd ed.). Cambridge University Press, Cambridge, UK.
6. Nordin, M. and Frankel, V.H. (eds.) (2022). Basic Biomechanics of the Musculoskeletal System (5th ed.). Lippincott Williams & Wilkins, Philadelphia, USA.
7. Wagner, W.R., Sakiyama-Elbert, S.E., Zhang, G. and Yaszemski, M.J. (eds.) (2020). Biomaterials Science: An Introduction to Materials in Medicine (4th ed.). Academic Press, Massachusetts, USA.
8. Lanza, R., Langer, R., Vacanti, J.P. and Atala, A. (eds.) (2020). Principles of Tissue Engineering (5th ed.). Academic Press, Massachusetts, USA.
9. Bushberg, J.T., Seibert, J.A., Leidholdt, E.M. and Boone, J.M. (2020). *The Essential Physics of Medical Imaging* (4th ed.). Lippincott Williams & Wilkins, Philadelphia, USA.

Course Title: Environmental Biotechnology
Course Code: BIT.709
Course type: DE
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):
On completion of this course, students will be able to,

CLO 1: Critically assess microbial community dynamics, pollutant chemistry, and ecosystem-level responses to anthropogenic stress.
CLO 2: Design and evaluate bioremediation strategies for complex contamination scenarios involving organic, inorganic, and emerging pollutants.
CLO 3: Analyse wastewater treatment systems and industrial effluent management from microbiological, engineering, and regulatory perspectives.
CLO 4: Evaluate biotechnological interventions in waste valorisation, bioenergy production, and environmental monitoring within regulatory and biosafety frameworks

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	**Microbial Ecology, Pollutant Chemistry:** Microbial community structure and ecological succession under pollutant stress; microbial growth kinetics, chemostat theory, biofilm ecology. Biogeochemical cycling - microbial roles and anthropogenic disruption. Chemistry and fate of priority pollutants: PAHs, PCBs, pesticides, heavy metals, pharmaceuticals, and microplastics in soil, water, and air. Environmental monitoring: chemical, biological, molecular approaches, and omics-based detection. Global concerns - greenhouse gases, ozone depletion, and climate–microbiome feedbacks. **Learning Activities:** Research paper analysis, peer discussion, case study on environmental monitoring	CLO1
II 15 Hours	**Bioremediation: Strategies and Applications:** Biodegradation principles: catabolic pathways, co-metabolism, and evolution of degradative pathways. Biostimulation, bioaugmentation - design and field limitations. Bioremediation of heavy metals, radionuclides, xenobiotics, and emerging contaminants. White-rot fungi vs specialised bacteria; phytoremediation strategies. In situ vs ex situ technologies; monitored natural attenuation. Synthetic biology and engineered microbes in bioremediation — regulatory considerations. **Learning Activities:** Case studies, group discussion, seminar on GMO-based remediation regulations	CLO2
III 15 Hours	**Wastewater Treatment and Solid Waste Management:** Aerobic and anaerobic wastewater treatment - activated sludge, biofilm reactors, MBRs, MBBRs, constructed wetlands. Anaerobic digestion - methanogenesis, syntrophic interactions, reactor types. Industrial effluent management: dairy, distillery, sugar, pharmaceutical, tannery. Municipal, biomedical, and agricultural	CLO3

	solid waste - composting, landfill bioreactors, leachate management. Disinfection, effluent disposal, and CPCB/EPA regulatory norms. **Learning Activities:** Case study, BOD/COD data interpretation, peer discussion on biomedical waste protocols	
IV 15 Hours	**Bioenergy, Waste Valorisation, and Biosafety:** Biofuels: biogas, bioethanol, biodiesel, biohydrogen - microbiology, engineering, and optimisation. MEOR, bioleaching, biosurfactants, bioemulsifiers, and bioplastics from waste streams. Biopesticides and biofertilizers - applications, genetic enhancement, and biosafety. Environmental impact assessment; GMO risk assessment; biodiversity conservation and biosafety frameworks. **Learning Activities:** Seminar on bioenergy policy, team discussion on biosafety of engineered microorganisms, self-learning on EIA case studies	CLO4

Transactional Modes: Lecture, Laboratory-based Practical, Seminar, Group Discussion, Team Teaching, Self-learning, Online Tools.

Suggested Books

1. Rittmann, B.E. and McCarty, P.L. (2020). Environmental Biotechnology: Principles and Applications (2nd ed.). McGraw-Hill, New York, USA.
2. Atlas, R.M. and Philp, J. (eds.) (2005). Bioremediation: Applied Microbial Solutions for Real-World Environmental Cleanup. ASM Press, Washington DC, USA.
3. Maier, R.M., Pepper, I.L. and Gerba, C.P. (eds.) (2015). Environmental Microbiology (3rd ed.). Academic Press, Massachusetts, USA.
4. Scragg, A. (2005). Environmental Biotechnology (2nd ed.). Oxford University Press, Oxford, UK.
5. Metcalf and Eddy Inc., Tchobanoglous, G., Stensel, H.D., Tsuchihashi, R. and Burton, F. (2014). Wastewater Engineering: Treatment and Resource Recovery (5th ed.). McGraw-Hill, New York, USA.
6. Singh, S.N. and Tripathi, R.D. (eds.) (2007). Environmental Bioremediation Technologies. Springer, Berlin, Germany.
7. Wackett, L.P. and Hershberger, C.D. (2001). Biocatalysis and Biodegradation: Microbial Transformation of Organic Compounds. ASM Press, Washington DC, USA.

Course Title: Medical Biotechnology
Course Code: BIT.710
Course type: DE
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):
On completion of this course, students will be able to,

CLO 1: Critically evaluate vaccine design strategies, antibody engineering approaches, and immunotechnology platforms for disease intervention.
CLO 2: Analyse molecular and genetic basis of human diseases and apply diagnostic tools for disease detection and genetic counselling.
CLO 3: Assess host–pathogen molecular interactions and apply multi-omics and advanced diagnostic platforms for infectious disease management.
CLO 4: Design and critically evaluate gene therapy, cellular therapy, recombinant biologics, and pharmacogenomics-driven therapeutic strategies

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	**Vaccinology, Immunotechnology, and Cell Imaging:** Vaccine platforms: live attenuated, killed, subunit, conjugate, peptide, plant-based, mRNA, and reverse vaccinology. Adjuvant mechanisms; recombinant and cell-based vaccine design. Antibody engineering: chimeric, humanised, bispecific monoclonal antibodies; phage display; catalytic antibodies. Hybridoma technology; immunoassays — ELISA, RIA, ELISPOT, SPR, biosensor-based assays. Flow cytometry, live cell imaging, immunofluorescence, immunoelectron microscopy, in vivo cell tracking. Cytokine profiling, lymphoproliferation, cytotoxicity, and apoptosis assays. **Learning Activities:** Seminar on mRNA vaccine design, case study on therapeutic antibody development, peer discussion on flow cytometry data interpretation.	CLO1
II 15 Hours	**Medical Genetics, Molecular Pathology, and Genetic Counselling:** Molecular basis of monogenic diseases: cystic fibrosis, DMD, thalassemias, haemophilias, PKU, and inborn errors of metabolism. Neurogenetic disorders: Alzheimer's, trinucleotide repeat expansions, spinal muscular atrophy. Cancer genetics: oncogenes, tumour suppressors, DNA repair deficiency syndromes, haematological malignancies, retinoblastoma. Complex polygenic disorders: diabetes, hyperlipidemia, atherosclerosis; mitochondrial syndromes. Genomic imprinting; prenatal and preimplantation genetic diagnosis. Genetic counselling — pedigree analysis, risk assessment, ethical and legal dimensions. **Learning Activities:** Case studies on genetic counselling scenarios, peer discussion on PGD ethics, research paper on polygenic risk scores.	CLO2
III 15 Hours	**Infectious Disease Biology and Diagnostics:** Host–pathogen molecular interactions in bacterial, viral, and parasitic infections; immune evasion strategies. Infections of GI tract, respiratory	CLO3

	system, CNS, and STDs — molecular pathogenesis and clinical spectrum. DNA-based diagnostics: PCR, sequencing, SNP-based assays, array platforms, CRISPR diagnostics. Antibody-based diagnosis: monoclonal antibodies, ELISA, Western blot for TB, malaria, HIV, and viral infections. Proteomics-based diagnosis: 2D proteomics, mass spectrometry, protein microarrays. Metagenomics in infectious disease surveillance; antimicrobial resistance profiling. **Learning Activities:** Case study on molecular diagnosis, group discussion on CRISPR-based diagnostics, research paper on metagenomic surveillance.	
IV 15 Hours	**Gene and Cell Therapy and Recombinant Biologics:** Gene therapy: viral (retroviral, adenoviral, AAV) and non-viral delivery (lipid nanoparticles, polymeric systems); CRISPR-based gene correction; in vivo vs ex vivo approaches. Gene silencing: antisense oligonucleotides, siRNA, miRNA therapeutics. Stem cell therapy: embryonic, adult, iPSCs; tissue engineering and scaffold design. Recombinant biologics: insulin analogues, erythropoietin, coagulation factors, growth hormone, thrombolytics. Immunotherapy: therapeutic monoclonal antibodies, checkpoint inhibitors, CAR-T cells, cytokine therapy. Pharmacogenomics, pharmacogenetics, and toxicogenomics in personalised medicine; drug target identification and high-throughput screening. **Learning Activities:** Seminar on CAR-T cell therapy, team discussion on gene therapy regulatory landscape, self-learning on pharmacogenomics databases.	CLO4

Transactional Modes: Lecture, Laboratory-based Practical, Seminar, Group Discussion, Team Teaching, Self-learning, Online Tools.

Suggested Books

1. Murphy, K., Weaver, C. and Berg, L.J. (2022). Janeway's Immunobiology (10th ed.). W.W. Norton & Company, New York, USA.
2. Abbas, A.K., Lichtman, A.H. and Pillai, S. (2022). Cellular and Molecular Immunology (10th ed.). Elsevier, Philadelphia, USA.
3. Strachan, T. and Read, A. (2018). Human Molecular Genetics (5th ed.). Garland Science, New York, USA.
4. Nussbaum, R.L., McInnes, R.R. and Willard, H.F. (2016). Thompson and Thompson Genetics in Medicine (8th ed.). Elsevier, Philadelphia, USA.
5. Murray, P.R., Rosenthal, K.S. and Pfaller, M.A. (2025). Medical Microbiology (10th ed.). Elsevier, Philadelphia, USA.
6. Kumar, V., Abbas, A.K. and Aster, J.C. (2020). Robbins and Cotran Pathologic Basis of Disease (10th ed.). Elsevier, Philadelphia, USA.
7. Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H. and Martin, K. (2021). Molecular Cell Biology (9th ed.). W.H. Freeman, New York, USA.
8. Lanza, R., Langer, R., Vacanti, J.P. and Atala, A. (eds.) (2020). Principles of Tissue Engineering (5th ed.). Academic Press, Massachusetts, USA.

Course Title: Advanced Microbial Technology
Course Code: BIT.711
Course type: DE
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Learning Outcomes (CLO):
On completion of this course, students will be able to,

CLO 1: Critically evaluate synthetic biology tools, genome-scale engineering strategies, and regulatory networks governing secondary metabolite biosynthesis in microbial systems.
CLO 2: Integrate multi-omics approaches and systems biology frameworks to decode microbial community function and engineer cellular metabolism for industrial targets.
CLO 3: Design advanced bioprocess configurations and critically assess fermentation economics, scale-up constraints, and downstream processing for commercial microbial products.
CLO 4: Evaluate microbial natural product discovery pipelines, drug target validation strategies, and translational challenges in moving from bench to application

Units/ Hours	Contents	Mapping with CLO
I 15 Hours	**Synthetic Biology and Biosynthetic Pathway Engineering:** Synthetic biology principles: genetic part standardisation, gene circuits, toggle switches, and oscillators. Genome-scale metabolic models (GEMs); flux balance analysis; constraint-based modelling for pathway optimisation. CRISPR interference (CRISPRi), base editing, prime editing, and multiplex genome engineering in industrially relevant hosts. Regulation of biosynthetic gene clusters — pathway-specific regulators, global regulators, and epigenetic control. Heterologous expression of silent and cryptic BGCs; refactoring and combinatorial biosynthesis. Cell-free synthetic biology platforms. **Learning Activities:** Research paper discussion, hands-on training on genome-scale modelling tools, peer discussion, problem-based learning	CLO1
II 15 Hours	**Systems Microbiology and Microbiome:** Integrated omics: metagenomics, metatranscriptomics, metaproteomics, and metabolomics for microbial community characterisation. Microbiome engineering — synthetic microbial consortia design, co-culture systems, and division of metabolic labour. Quorum sensing networks, inter-species signalling, and microbiome-host crosstalk. Single-cell genomics and spatial transcriptomics in microbiology. Phage biology and phage-bacteria coevolution; phage engineering for therapeutic and industrial applications. Computational tools for microbiome data analysis — network inference, machine learning applications. **Learning Activities:** Hands-on training on microbiome bioinformatics pipelines, case-based discussion, seminar, research paper analysis	CLO2

III 15 Hours	**Bioprocess Engineering:** Metabolic engineering strategies: push-pull-block, dynamic regulation, cofactor engineering, and tolerance engineering in *E. coli*, *Bacillus*, *Streptomyces*, *Aspergillus*, and non-conventional yeasts. Fed-batch, continuous, and perfusion bioreactor configurations; process analytical technology (PAT); real-time monitoring and control. Techno-economic analysis and life cycle assessment of microbial bioprocesses. Downstream processing: chromatographic and non-chromatographic purification; integrated bioprocessing concepts. Regulatory considerations: GMP compliance, quality-by-design (QbD) in fermentation-based production. **Learning Activities:** Case study on industrial bioprocess scale-up, team discussion, self-learning on regulatory guidelines (ICH, FDA)	CLO3
IV 15 Hours	**Natural Products, Drug Discovery, and Translational Applications:** Genome mining for novel natural products - antiSMASH, BiG-SCAPE, and GNPS platforms. Biosynthetic logic of polyketides, NRPs, terpenoids, and ribosomally synthesised and post-translationally modified peptides (RiPPs). Antimicrobial resistance - molecular mechanisms, resistome analysis, and strategies to overcome resistance. Microbial therapeutics: live biotherapeutics, engineered probiotics, and bacteriophage therapy. Agricultural applications — biofertilisers, biocontrol agents, and plant microbiome manipulation. IPR landscape; technology transfer, and regulatory pathways for microbial-derived products. **Learning Activities:** Seminar on genome mining case studies, peer discussion on AMR drug discovery, case-based discussion on biotherapeutic regulatory approval	CLO4

Transactional Modes: Lecture, Laboratory-based Practical, Seminar, Group Discussion, Team Teaching, Self-learning, Online Tools.

Suggested Books

1. Glazer, A.N. and Nikaido, H. (2007). Microbial Biotechnology: Fundamentals of Applied Microbiology (2nd ed.). Cambridge University Press, Cambridge, UK.
2. Madigan, M.T., Bender, K.S., Buckley, D.H., Sattley, W.M. and Stahl, D.A. (2021). Brock Biology of Microorganisms (16th ed.). Pearson, New York, USA.
3. Baltz, R.H., Demain, A.L. and Davies, J.E. (eds.) (2010). Manual of Industrial Microbiology and Biotechnology (3rd ed.). John Wiley & Sons, New Jersey, USA.
4. Palsson, B.O (2015). Systems Biology: Constraint-based Reconstruction and Analysis (2nd ed.). Cambridge University Press, Cambridge, UK.
5. Demain, A.L. and Martin, J.F. (eds.) (2010). Industrial Biotechnology of Vitamins, Biopigments, and Antioxidants. Wiley-VCH, Weinheim, Germany.
6. Kayser, O. and M√ºller, R.H. (eds.) (2004). Pharmaceutical Biotechnology: Drug Discovery and Clinical Applications. Wiley-VCH, Weinheim, Germany.
7. Lee, S.Y., Nielsen, J. and Stephanopoulos, G. (eds.) (2021). Metabolic Engineering: Concepts and Applications. Wiley-VCH, Weinheim, Germany.
8. Glick, B.R. and Patten, C.L. (2022). Molecular Biotechnology: Principles and Applications of Recombinant DNA (6th ed.). ASM Press, Washington DC, USA.
9. Wittmann, C. and Lee, S.Y. (eds.) (2012). Systems Metabolic Engineering. Springer, Dordrecht, Netherlands.